ANNUAL REPORT 1983
ON
THE TECHNICAL COOPERATION
FOR THE PROJECT (RESEARCH)
ON
SEA-WATER DESALINATION TECHNOLOGY
IN
THE KINGDOM OF SAUDI ARABIA

MARCH, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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CONTENTS

1. Outline of the Project

1.1 History

The R/D on this project was formally agreed on between SWCC and JICA in Riyadh, January 1982. In March 1982, a Japanese technical survey team visited the Kingdom of Saudi Arabia and had detailed discussions with SWCC officials on project implementation. In the discussions, it was agreed that the project was to get under way in June 1982.

1.2 Objective

This project is intended to establish, through joint efforts of Japan and the Kingdom of Saudi Arabia, the Research Center of Desalination Technology (provisional) that will introduce Japanese desalination technology into the Kingdom, thereby contributing to the stable supply of water resources in the Kingdom and promoting amicable relations between the two countries.

1.3 Scope of Work

The project will span about four years starting on January 12, 1982 and ending on March 31, 1986. During the period, Japan and the Kingdom of Saudi Arabia will jointly set up the Research Center of Desalination Technology in the Kingdom for joint research on seawater desalination. The project plans to implement the following targets:

1) Establishing the Research Center of Desalination Technology (in the first two years)
   (1) Setting up the laboratory building with its related facilities, and installing laboratory equipments
   (2) Setting up a multi-stage flash evaporation process (MSF) test plant (1 unit; 20 m^3/day in capacity)
   (3) Setting up a reverse osmosis (RO) test plant (2 units; 20 m^3/day in capacity)
2) Conducting joint research on seawater desalination (in the latter two years)
   (1) Chemical study
   (2) Study on technology for corrosion prevention and scale deposition control at MSF test plant
   (3) Study on RO module performance test methods at RO test plant
   (4) Others

1.4 Present State

The progress of the project started in 1982 is described in the followings.

1) Laboratory building

With regard to the construction of the laboratory building, SWCC will take charge of all stages raning from basic design to construction, on the basis of the conceptual design to be carried out by JICA. The conceptual design was concluded in October 1982 and was approved by SWCC. However, in view of delays that came about in the implementation schedule, the JICA mission held a meeting with SWCC for consultations about the construction of the building in question. In conformity with this consultations, JICA prepared basic data about the test plant required for construction of the laboratory building as well as laboratory equipments and sent them to SWCC. In connection with the drawing up of these documents, the specifications drawn up in 1982 were revised in view of the necessity of carrying out the detailed design of part of the laboratory building. Furthermore, JICA made preparations to dispatch specialists in architecture in order to explain the contents of the conceputal design of the laboratory building to the consultant

2) Test plant and laboratory equipments

The test plant and the laboratory equipments will be provided by JICA. The relevant specifications were drawn up in 1982, and as things now stand they are only short of being procured. In connection with the procurement of these items it is necessary to take into consideration the epoch of completion of the laboratory building, in view of the requirements related to the place of storage and management, and furthermore the procurement procedure of JICA is involved too. Under the circumstances JICA explained the situation on the occasion of the visit of its mission to Saudi Arabia in August 1983, and SWCC acknowledged.

2. Field Survey

In August 1983 JICA held discussions and consultations with SWCC about the following two subjects.

2.1 Examination of the new Proposals of the SWCC

The new proposals and requests were made in April 1983, on the occasion of the visit of Mr. Najar (then Chief of the Research Division) to Japan. These proposals were examined by a JICA team consisting of experts of various fields, and the pertinent conclusions were informed to SWCC in July, through the attached "REPLY TO THE NEW SWCC PROPOSALS".
Furthermore, on the occasion of the visit of its mission to Saudi Arabia in August 1983, JICA carried out a hearing about some obscure points, explained its basic idea as well as the results of examinations of technical nature and asked for consent of SWCC. On the other hand, SWCC consented that these subjects be themes of future discussions within this project.
In connection to the implementation of the research programs mentioned in the current R/D, JICA explained that it is possible to include part of them in the research themes and to give pertinent advices in order to solve the problems related to the plant in the research center.
Vice-President Jamjoon acknowledged, and it was reconfirmed that the scope of research of this project is that one stipulated in 1-(3),(4) and (4) of the R/D Annex II presently in force.

2.2 Laboratory Building Construction Plan

In connection with the construction of the laboratory building, in the first place the Japanese side explained the procurement system of JICA, and asked for the consent of SWCC. Then, SWCC was asked to disclose the construction schedule of the laboratory building. SWCC gave its consent to the explanation of the Japanese side, and promised to notify the construction schedule to JICA. Furthermore, the mission informed that JICA is ready to dispatch experts in order to explain the conceptual design it drew up to the consultant nominated by SWCC to take charge of the detailed design, and in this connection SWCC promised that it will inform JICA about the schedule for its implementation.

On the other hand, SWCC asked JICA to present as soon as possible the detailed specifications of the test plant to be installed and part of the research equipments, in order to provide facilities for the consultant nominated by SWCC to draw up the special specifications of the foundations and to carry out the detailed design of the interconnections with the utilities. In this connection JICA promised to provide the required information within approximately 3 months.

The contents of the consultations are described in the attached "Minutes of Meeting".

SWCC Requests

The Research Center building in Yambu should be big enough to serve all the Western Region Desalination Plants.

The requests of SWCC are as follows:

A. MSF research for monitoring corrosion and scale information plus efficiency of the plants

B. RO plants for monitoring all kind of membranes, i.e. spiral wound, hollow fiber and plane type water treatment plant

C. To investigate and study the intake sea chemically and bacterologically and pollution

D. To study the affect of potable water of MSF and RO and side affect on human being by helping of hospital laboratory

E. To investigate and monitor corrosion in the boilers, condenser, water pipes, pipeline to cities, corrosion in fuel tank and fuel pipeline

F. To study and investigate fuel contents and efficiency

G. To investigate and study the soot of boiler and the smoke from the stack or chimney and air pollution due to fuel smoke

H. To study and investigate the sulfuric acid and chemicals of low temperatures and high temperatures from chemical corrosion point of view and economical point of view for capital cost and running cost

../-2

I. To study and investigate the brine water of out-fall channel to the seaside and the affect and pollution to the sea water and marine life

The SWCC request that the above mentioned items should be carried out in the Research Center of Yambu. So kindly please consider that the equipment and instrument and experts and technicians and operation and maintenance staff should be scheduled and planned.

Will you please that JICA will consider above mentioned items and to give the help by supporting this study and planning and cooperation from JICA.

The excess cost of the above mentioned items will be paid by SWCC or if you can consider partially the excess cost on your side will be appreciated.

The SWCC will take all necessary excess cost for the above mentioned items. So this Research Center will serve all the Western Coast desalination/power plants.

The SWCC request that to train our fresh graduate engineers and chemists to start on research technology plus the technical operators for Research Center equipment.

Will you please write schedule for giving training for the new fresh graduate engineers and chemists and operators.

The cost will be owned by SWCC and cooperation from your side will be appreciated.

3. Detailed Specifications

We have drawn up the detailed specifications of the test plant and laboratory equipments that accompany the construction of the laboratory building, in compliance with the request of SWCC on the occasion of our visit to Saudi Arabia in August 1983. Concretely, these detailed specifications consist of the drawing up of foundation and load data of the test plant to be installed as well as the drawing up of data related to utilities of all equipments to be provided by the Japanese side, including laboratory equipments.

On the other hand, the design specifications drawn up last year are the basic specifications to be used for issuing the orders to the manufacturers. The basic specifications have been revised and the report drawn up last year is partially rectified, because the work carried out this time extends partially over the detailed design stage.

The contents of the work are described in the followings.

3.1 Reverse Osmosis Process Test Plant

1) Detailed Design

(1) Particular Design Requirements

(a) Pretreatment skid

Size W=2,600 mm, L=2,800 mm, H-3,400 mm

Weight 3.2 tons (Empty), 6.7 tons (Ope.)

(b) Spiral wound type RO skid

Size W=2,000 mm, L=3,000 mm, H=1,700 mm

Weight 2.2 tons (Empty), 2.5 tons (Ope.)

(c) Hollow fiber type RO skid

Size W=2,000 mm, L=3,000 mm, H=1,700 mm

Weight 2.3 tons (Empty), 2.55 tons (Ope.)

(d) Chemical injection skid

Size W=1,250 mm, L=2,780 mm, H=1,350 mm

Weight 0.4 tons (Empty), 1.5 tons (Ope.)

(e) Electric power & instrumentation control panel

Size W=800 mm, L=3,000 mm, H=2,350 mm

Weight 0.4 tons

(f) Fouling index monitor

Weight 100 kg

(g) Raw Seawater tank

Capacity $3m^3$

Size Diameter 1,620 mm, H=2,050 mm

Weight 0.25 tons (Empty), 3.34 tons (Ope.)

(h) Filtered Seawater tank

Capacity $10m^3$

Size Diameter 2,280 mm, H=3,300 mm

Weight 0.65 tons (Empty), 10.95 tons (Ope.)

(i) Feed tank (2 units)

Capacity $1.5m^3$

Size Diameter 1,276 mm, H=1,660 mm

Weight 0.07 tons (Empty), 1.62 tons (Ope.)

(j) Product tank (2 units)

Capacity $1m^3$

Size Diameter 1,106 mm, H=1,450 mm

Weight 0.05 tons (Empty), 1.05 tons (Ope.)

(2) Power consumption

(a) Motor 220 V X 3 ϕ X 60 Hz

Seawater pump	3.7 kW
Back washing water pump	2.2 kW
Back washing air blower	1.5 kW
Waste discharge pump	1.5 kW
Feed pump (2 units)	1.5 kW X 2
Booster pump (2 units)	3.7 kW X 2
High pressure pump (2 units)	15 kW X 2
Chemical injection pump (8 units)	0.03 kW X 8
Air compressor	0.75 kW
Total	50.29 kW

(b) Motor control and instrumentation panel

220/110V X 3/1 ϕ X 60 Hz , 0.5 kW

(c) UV sterilizer 110 V X 1 ϕ X 60 Hz

for Pretreatment 32 VA

for Spiral wound type RO and Hollow fiber type RO 16 VA X 2

(d) Fouling index monitor

110 V X 1 ϕ X 60 Hz , 0.5 kW

2) Rectifications and additions to the specifications

(1) Electricity

(a) Power supply for power equipment

Mains: 480V X 3ϕ X 60Hz

The transformer of the power receiving facilities of the research center steps down the voltage from 480V to 220V and feeds 220V X 3ϕ X 60Hz power to the equipments. Therefore, no substation facilities are required in the laboratory building.

(b) Power supply for ordinary lighting system

220V X 1ϕ X 60Hz and 110V X 1ϕ X 60Hz

NOTE: Primary-side power wiring up to the power control panel of this system will be provided by SWCC.

(2) The heater of the hot-water supply system is changed from electric heater to steam heater in view of the high-temperature operation. Steam is expected to contribute positively to cut down the cost by considerable extent compared with the conventional system, because it is supplied by the boiler used in the MSF test plant.

(3) The pre-treatment equipment aimed at preventing troubles of mechanical nature caused by damages due to salt it changed to indoor type.

(4) The indicator-type thermometers, pH meters and dissolved oxygen meters are changed to recorder-type instruments. In this case the cost becomes slightly more expensive, but it is desirable to record data because this plant will be used for research purposes.

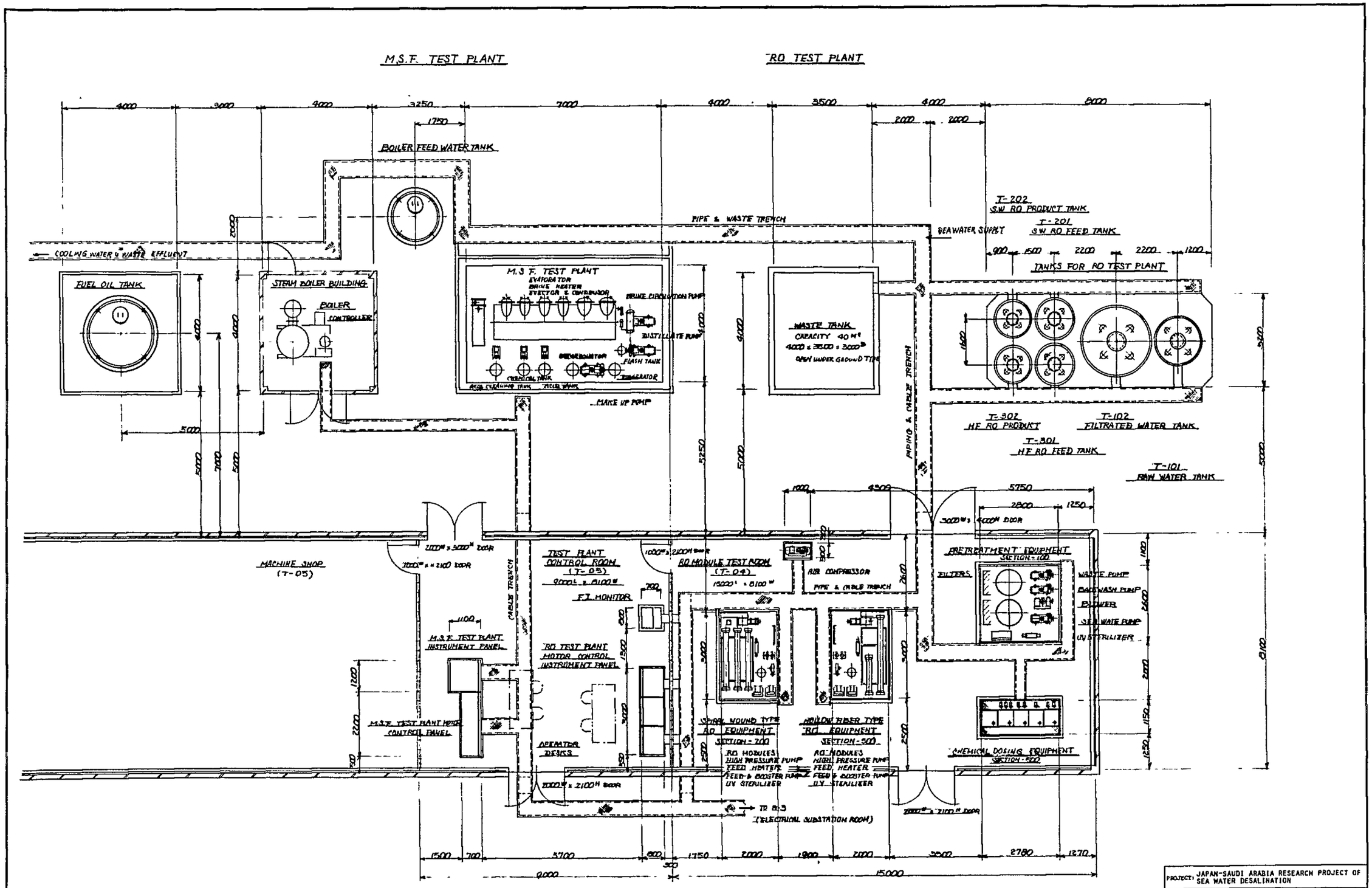
(5) The size of the skid is slightly changed as a result of the detailed design.

(6) Change of power

(a) Backwashing pump 1.5kW → 2.2kW

(b) Filter backwashing blower 2.2kW → 1.5kW

The specifications of the equipment are shown in the Appendix 3.



PROJECT:	JAPAN-SAUDI ARABIA RESEARCH PROJECT OF SEA WATER DESALINATION
TITLE:	PLOT PLAN OF M S F & RO TEST PLANTS
DATE: 30-OCT-1983	SCALE: 1/60
DRAWING NO :	SAJ-R1001
	JAPAN INTERNATIONAL COOPERATION AGENCY

CHEMICAL DOSING EQUIPMENT
SECTION 500

CHLORINE FEEDER
CHEMICAL TANK T-501
DOSING PUMP P-501 A,B

COAGULANT FEEDER
CHEMICAL TANK T-502
DOSING PUMP P-502

ACID FEEDER
CHEMICAL TANK T-503
DOSING PUMP P-503 A,B

DEOXIDANT FEEDER
CHEMICAL TANK T-504
DOSING PUMP P-504 A,B,C

STEAM
FROM BOILER B.P. 32A

STRAINER

SBS DOSING (1ST STAGE)

AIR COMPRESSORE
P-104

COMPRESSED AIR
TO AUTOMATIC VALVES
INSTRUMENT & CONTROL VALVE

CHEMICAL DOSING

GAS SEAL

STERILE NON-FILTERED SEAWATER
(BYE-PASS)

STATIC MIXER

B.P 25A

COOLED CONCENTRATE (RO-201)

BALL TAP

FEED HEATER
HE-202

FEED PUMP
P-201

FEED PREHEATER
HE-201

(BYE-PASS)

DIVER FLOW

Blow

RAW SEA WATER SUPPLY

D.P 50# F.F
CONN. OF SW SUPPLY

AUTOMATIC FOULING INDEX METER

TREATED SEA WATER

BACKWASHING AIR

NOTE F-101 A AUTOMATIC DEVICE BACKWASHING BY TIMER PROGRAM.

BYE-PASS

BACKWASHING WATER

RAW S/W BYE-PASS

OVER FLOW

CONCENTRATE

COOLED CONCENTRATE (RO-301)

FEED PUMP
P-301

FEED HEATER
HE-302

FEED PREHEATER
HE-301

WASTE PIPING TRENCH

WASTE & PRODUCT DISCHARGE TO WASTE TANK

RO CONCENTRATE DISCHARGE TO WASTE TRENCH

B.P

ESP 65# F.F

RAW SEA WATER TANK
T-101

ULTRA VIOLET RAY STERILIZER
UV-101

DUAL MEDIA FILTERS
F-101 A,B

BACKWASHING AIR BLOWER
P-103

BACKWASHING PUMP
P-102

FILTERED SEA WATE TANK
T-102

SEA WATER PUMP
P-101

PRETREATMENT EQUIPMENT
SECTION 100

SPIRAL WOUND TYPE RO EQUIPMENT
SECTION - 200

STEAM
FROM BOILER
B.P. 32A
STRAINER
PI
PIC 106
PASV

SBS SHOCK TREATMENT
SBS DOSING (2ND STAGE)
SBS DOSING (1ST STAGE)
ACID DOSING

B.P. 25A
COOLED CONCENTRATE (RO-201)
PI 206
TC 201
TR 201
TI 201
TI 202
PI 201
TI 204
(BYE-PASS)
STATIC MIXER
BALL TAP
LSA 201
LI 201
BLENDING CONCENTRATE
FAT
FEED HEATER HE-202
FEED PUMP P-201
FEED PREHEATER HE-201
TI 203
OVER FLOW
Blow
FEED TANK WITH SEAL BALL T-201
TR 201
PI 202
BOOSTE PUMP P 202
STERILIZER UV-201
SAFETY FILTERS F-201. A,B
PI 203
TA 201
DPRA 201
PSA 201
FLX. HOSE
R.V
ACC
M.F.V
PI 204
PI 205
CR 201
FI 201
HIGH PRESSURE PUMP P-203
FI 202
S.W. RO MODULE RO-201
SV
MIN. FLOW (P-203)
BLENDING PRODUCT (RO-201)
CONCENTRATE (RO-201)
PURGING PRODUCT

B.P. 25A
COOLED CONCENTRATE (RO-301)
PI 306
TC 301
TR 301
TI 302
TI 301
MAT
PI 301
TI 304
TI 101
(BYE-PASS)
FEED PUMP P-301
FAT
TI 305
(BYE-PASS)
FEED HEATER HE-302
FEED PREHEATER HE-301
WASTE PIPING TRENCH
CONCENTRATE
FILTERED SEA WATE TANK T-102
FEED TANK WITH SEAL BALL T-301
BOOSTER PUMP P-302
ACID DOSING
NAOH DOSING
NOZZLES SPACE
STERILIZER UV-301
SAFETY FILTERS F-301 A,B
PI 303
TA 301
DPRA 301
PSA 301
FLX HOSE
R.V
ACC
M.F.V
PI 304
PI 305
CR 301
FI 301
HIGH PRESSURE PUMP P-303
FI 302
H.F MODULE RO-301
SUCK BAC
BLOW
RO FEED
RO FEED BLOW
PUMP COOLING
PUMP COOLING
MIN. FLOW (P-303)
BLENDING PRODUCT (RO-301)
CONCENTRATE (RO-301)
PRODUCT
PURGING PRODUCT

HOLLOW FIBER TYPE RO EQUIPME
RO-300

SBS SHOCK TREATMENT
SBS DOSING (2ND STAGE)
ACID DOSING

SPIRAL WOUND TYPE RO EQUIPMENT
SECTION -200

MEMBRANE / ELEMENT CLEANING EQUIPMENT
SECTION 600

CLEANING TANK
WITH POTABLE FLEXIBLE HOSES
T-601

PI 202 · STATIC MIXER · BOOSTE PUMP P 202 · STERILIZER UV-201 · SAFETY FILTERS F-201. A.B · PI 203 · TA 201 · DORA 201 · PSA 201 · FLX. HOSE · R.V · ACC · HIGH PRESSURE PUMP P-203 · M.S.V · PI 204 · PI 205 · CR 201 · FI 201 · S.W. RO MODULE RO-201 · FI 202 · PRODUCT (PERMEATE) (RO-201) · S.W RO PRODUCT TANK WITH BALL SEAL T-202 · L I 202 · OVER FLOW · BP 32A · BLOW

MIN. FLOW (P-203)
BLENDING PRODUCT (RO-201)
CONCENTRATE (RO-201)
PURGING PRODUCT (FLUSHING RO-201)

ACID DOSING
NAOH DOSING
NOZZLES SPACE
PI 302 · STATIC MIXER · STERILIZER UV-301 · SAFETY FILTERS F-301. A.B · PI 303 · TA 301 · PHRA 301 · PSA 301 · FLX HOSE · R.V · ACC · PI 304 · PI 305 · CR 301 · FI 301 · PRODUCT (PERMEATE) (RO-301) · HIGH PRESSURE PUMP P303 · M.S.V · FI 302 · H.F MODULE RO-301 · L I 302 · OVER FLOW · SUCK BACK · BP 32A · BLOW · H.F PRODUCT TANK T-302

FLOW · RO FEED · BLOW · PUMP COOLING · PUMP COOLING

MIN. FLOW (P-303)
BLENDING PRODUCT (RO-301)
CONCENTRATE (RO-301)
PURGING PRODUCT (FLUSHING RO-301)

BOOSTER PUMP P-302

HOLLOW FIBER TYPE RO EQUIPMENT
RO-300

PRODUCT TO LABORATORY

SYMBOL MARKS

- BALL VALVE
- GLOBE OR GATE VALVE
- NONRETURN VALVE
- NEEDLE VALVE
- AV — AUTOMATIC ON/OFF VALVE
- RV — REGULATING VALVE
- PRV — PRESSURE REGULATING VALVE
- SV — RELIEF OR SAFTY VALVE
- SP — SAMPLE VALVE OR COCK
- ASDV — AUTOMATIC SHUT DOWN VALVE
- STEAM OR DRAIN TRAP

- PI — PRESSURE INDICATOR
- LI — LEVEL INDICATOR
- FI — FLOW INDICATOR
- TI — THERMOMETER
- LSA — LEVEL SWITCH WITH ALARM
- PSA — PRESSURE SWITCH WITH ALARM
- TR — TEMPERATURE RECORDER
- TC — TEMPERATURE CONTROLLER
- TA — TEMPERATUR SWITCH WITH ALARM
- PHRA — PH RECORDOR WITH ALARM
- DORA — DISSOLVED OXYGEN RECODER WITH ALARM
- CR — CONDUCTIVITY RECORDER
- LOCAL MOUNT TYPE INSTRUMENT
- PANEL MOUNT TYPE INSTRUMENT
- BP-*-FF — BATTERY LIMIT POINT, CONNECTING SIZE

PROJECT: JAPAN-SAUDI ARABIA RESEARCH PROJECT OF SEA WATER DESALINATION

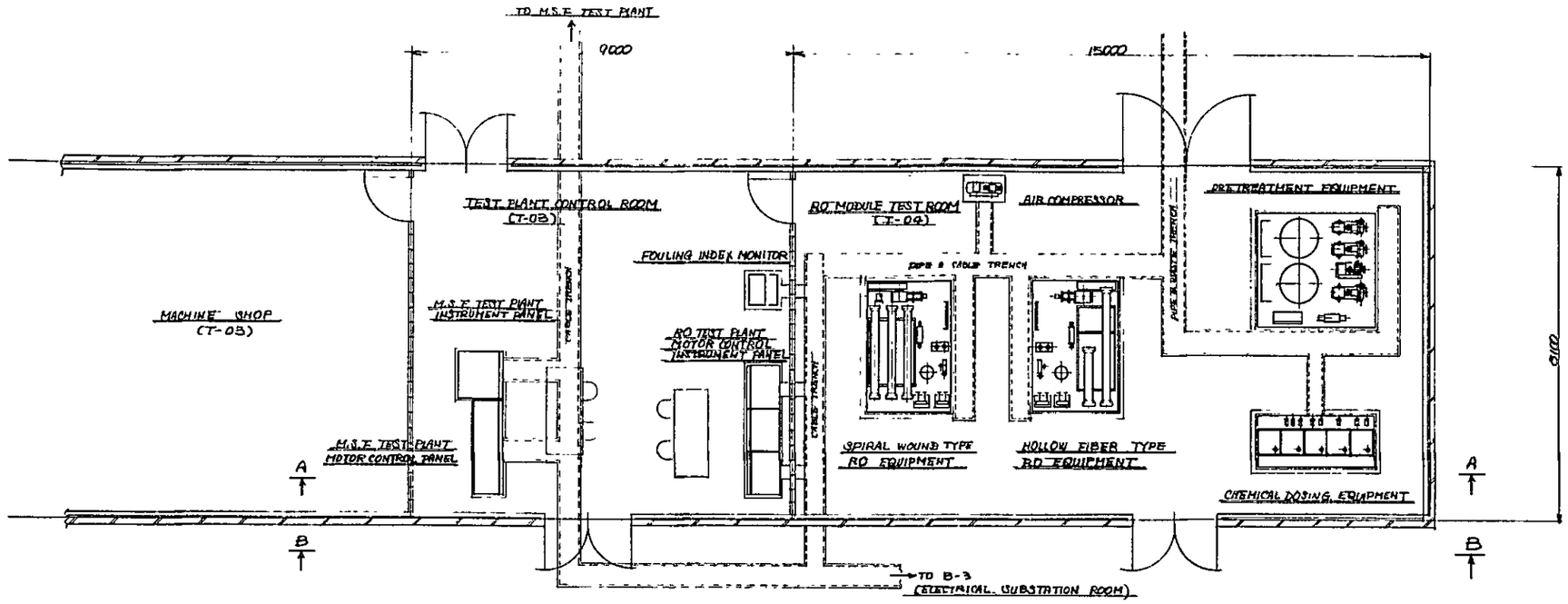
REVERSE OSMOSIS TEST PLANT FACILITY

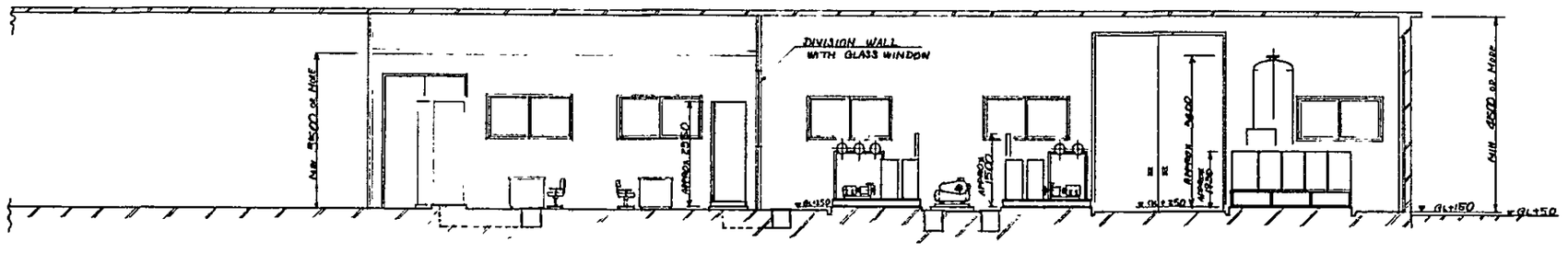
TITLE: PIPING & INSTRUMENT DIAGRAM

DATE: 30-OCT-1983 | SCALE: NON

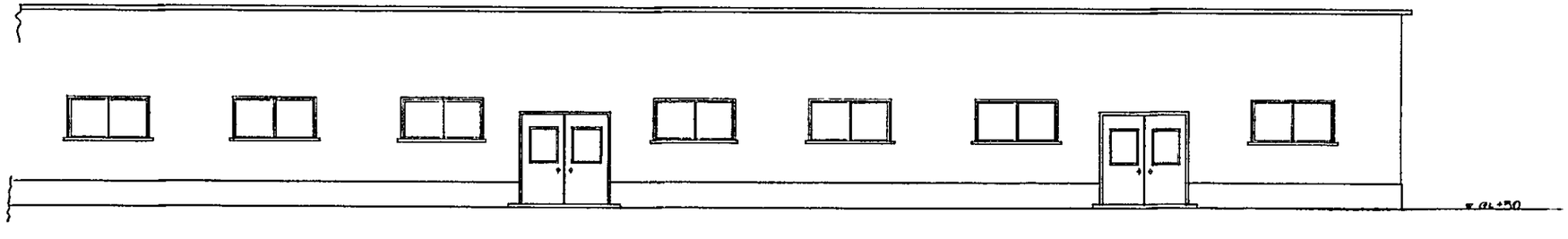
DRAWING NO.: SAJ-R4001

JAPAN INTERNATIONAL COOPERATION AGENCY





A ~ A VIEW



B ~ B VIEW

PROJECT:	JAPAN-SAUDI ARABIA RESEARCH PROJECT OF SEA WATER DESALINATION
TITLE:	PLOT PLAN OF INDOOR & SIDE VIEW
DATE 30-OCT-1983	SCALE: 1/60
DRAWING NO :	SAJ-R4003
	JAPAN INTERNATIONAL COOPERATION AGENCY

3.2 Multi Stage Flash Distillation Test Plant

1) Detailed Design

(1) Particular Design Requirements

(a) Control Panel

Size	W=1,000mm,	H=2,000mm.	D=1,000mm
Weight	200 kg		
Foundation	W=1,200mm,	L=1,200mm,	H=GL+100mm

(b) Motor Panel

Size	W=2,000mm,	H=2,400mm,	D=600mm
Weight	300 kg		
Foundation	W=800mm,	L=2,200mm,	H=GL+100mm

(c) MSF Plant skid

Size	W=4,000mm,	L=7,000mm	
Weight	25 tons (Empty), 30 tons (Ope.) 40 tons (Filled with water)		
Foundation	W=4,500mm,	L=7,500mm,	H=GL+150mm

(d) Feed tank

Capacity	$3m^3$		
Weight	1 ton (Empty), 4 tons(Filled with water)		
Foundation	Diameter 1,950mm,		H=GL+150mm

(e) Boiler

Boiler capacity	1,000 kg/h		
Weight	1.8 tons (Empty), 2.5 tons (Ope.)		
Foundation	W=4,000mm,	L=4,000mm,	H=GL+150mm

(f) Oil tank

Capacity	$10m^3$		
Weight	4 tons (Empty), 14 tons (Ope.)		
Foundation diameter	2,000mm,		H=GL+150mm

(2) Power consumption

(a) Motor 220V X 3 ϕ X 60 Hz

Brine recirc. pump	7.5 kW
Make-up pump	7.5 kW
Distillate water pump	3.7 kW
Acid injection pump	0.4 kW
Acid cleaning pump	0.75 kW
Total	20.25 kW

(b) Control panel

110V X 1ϕ X 60Hz, 1 kW

(c) Boiler

220V X 3ϕ X 60Hz, 11.3 kW (Include feed water pump)

2) Rectifications and additions to the specifications

(1) Electricity

Same as reverse osmosis test plant.

(2) So far it was possible to supply replenishment water up to the last stage, but in the modified specification it is directly supplied to the circulating brine line.
The sampling pump becomes unnecessary as a result of this modification.

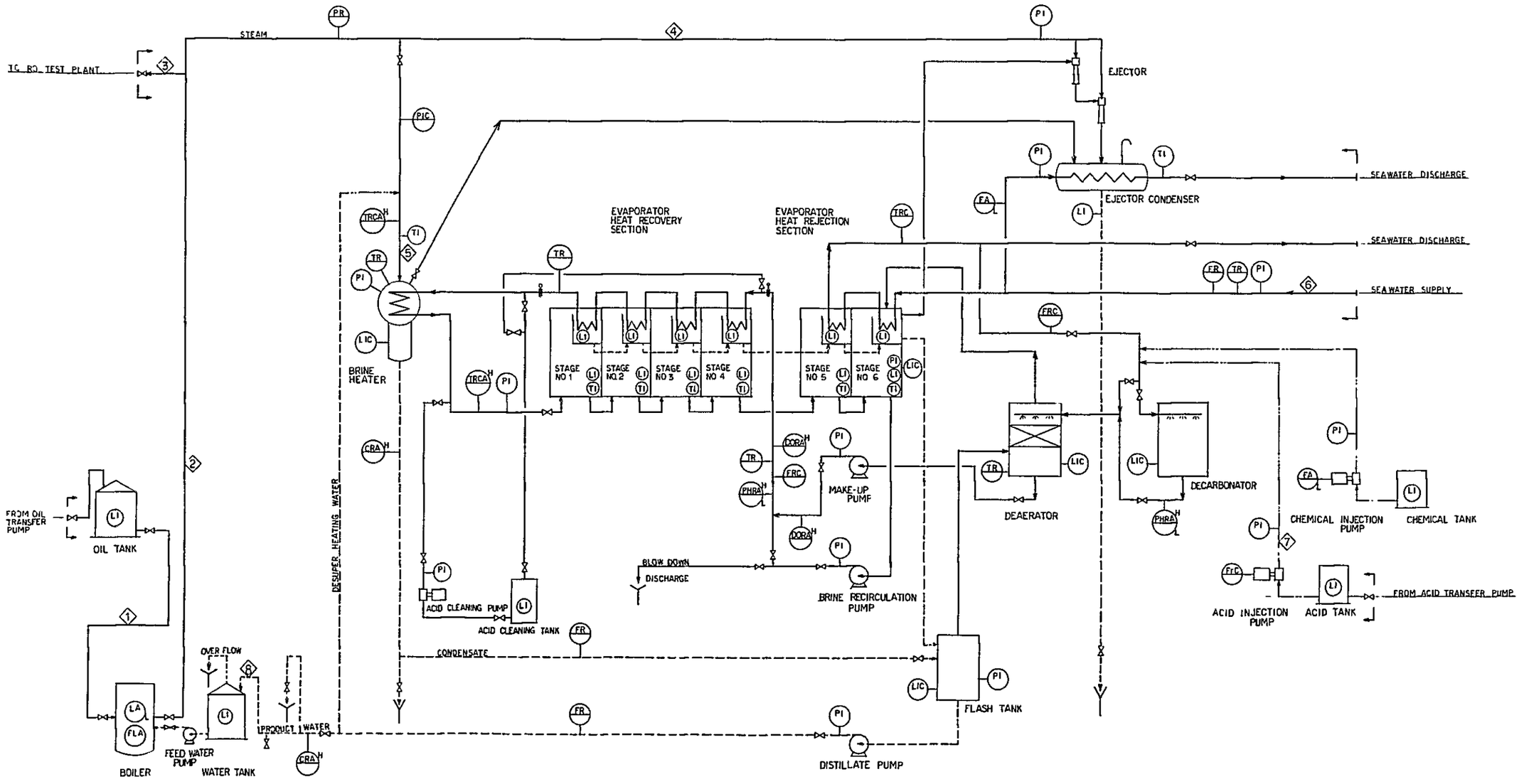
(3) Spare units of each pump and motor will be supplied one each, but they will be warehouse spare units.

(4) At first the piping of the skid borderline of the boiler and test plant was to be provided by SWCC, but in reality it will be provided by JICA in order to prevent the risk of inconveniences at the connection point.

(5) The flow diagram is rectified by adding the boiler facilities.

Refer to the Appendix 4 for the required measuring instruments and specifications of the equipment.

NO	REVISIONS DESCRIPTION	DRN'D	CHK'D	APPR'D
◇				
◇				
◇				
◇				



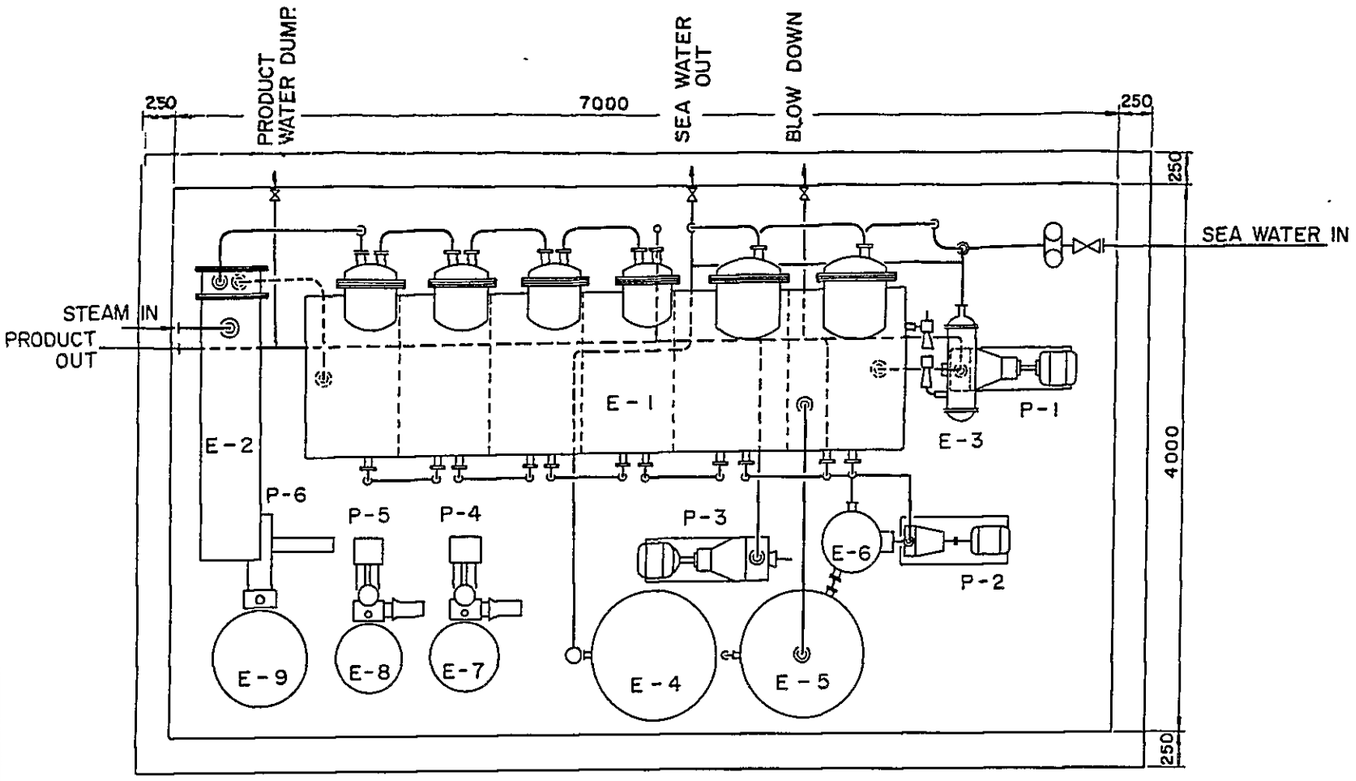
NOTE :

1 THERE IS A BALL CLEANING SYSTEM FOR THE HEAT RECOVERY SECTION AND THE BRINE HEATER.

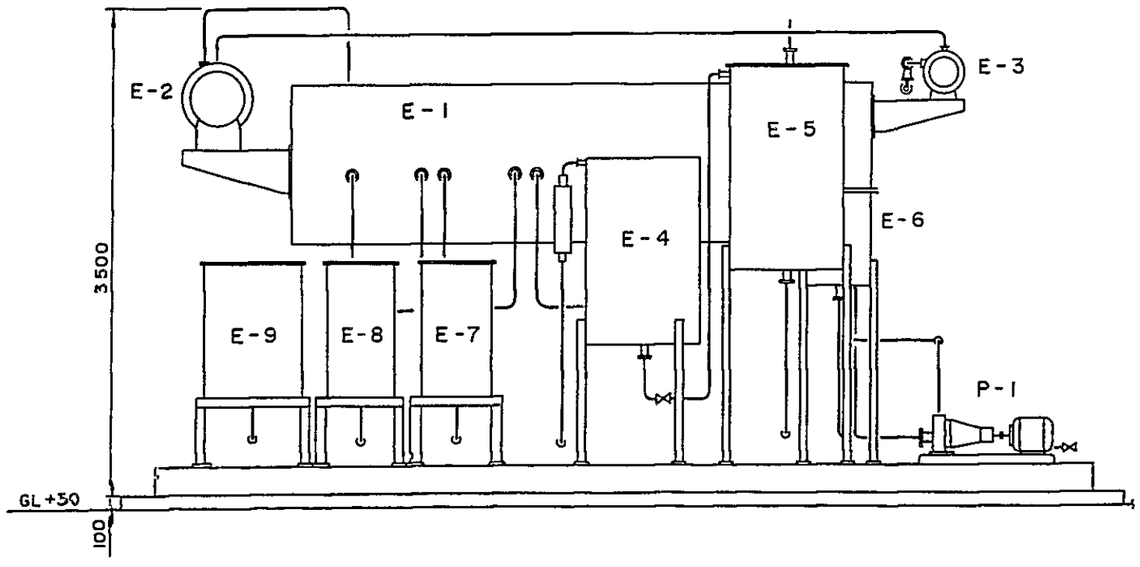
MASS BALANCE TABLE (pH CONTROL)

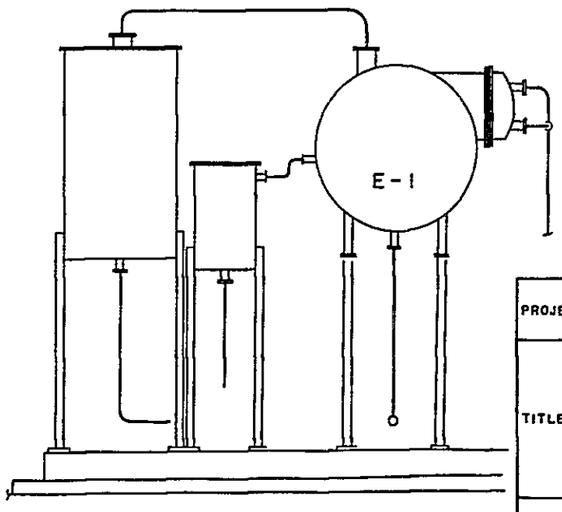
NO	①	②	③	④	⑤	⑥	⑦	⑧
LIQUID	HEAVY OIL BUNKER A	STEAM	→	→	→	SEAWATER	H_2SO_4 (98 wt%)	DISTILLATE
TEMP					127 ℃ sat.	OVER23		
PRESS		8 KG/cm²G sat				KG/cm²G		
FLOW	48 ℓ/H	555 KG/H	180 KG/H	50 KG/H	333 KG/H	24100 KG/H	0 52 KG/H	1100 KG/H

PROJECT:	JAPAN-SAUDI ARABIA RESEARCH PROJECT OF SEA WATER DESALINATION
TITLE:	M.S.F TEST PLANT FLOW DIAGRAM
DATE	SCALE NONE
DRAWING NO	SAJ – R3001 ⓪
	JAPAN INTERNATIONAL COOPERATION AGENCY



TAG No	EQUIPMENT NAME	No. REQ.
E-1	EVAPORATOR	1
E-2	BRINE HEATER	1
E-3	EJECTOR CONDENSER	1
E-4	DECARBONATOR	1
E-5	DEAERATOR	1
E-6	FLASH TANK	1
E-7	ACID TAND	1
E-8	CHEMICAL TANK	1
E-9	ACID CLEANING TANK	1
P-1	BRINE RECIRCURATION PUMP	1
P-2	DISTILLATE PUMP	1
P-3	MAKE UP PUMP	1
P-4	ACID PUMP	1
P-5	CHEMICAL PUMP	1
P-6	ACID CLEANING PUMP	1





PROJECT: JAPAN-SAUDI ARABIA RESEARCH PROJECT OF SEA WATER DESALINATION

20 T/D MSF TEST PLANT

TITLE: GENERAL ARRANGEMENT

DATE: | SCALE.

DRAWING NO.: SAJ – R3002 ◇0

JAPAN INTERNATIONAL COOPERATION AGENCY

3.3 Laboratory Equipments

JICA was asked by SWCC to provide information about the test plant and part of the laboratory equipments regarded as necessary in advance before setting about the design, but no problem was found in particular in connection with the laboratory equipments prior to setting about the design.

However, the equipments are to be provided by the Japanese side, and in designing the laboratory building SWCC is required to pay special attention to the wiring and joints of the utilities, in order to make possible the convenient use of the equipments to be provided by JICA, free of any obstacle.

In this paper the information related to the utilities are reported on the basis of the conceptual design presented by JICA in August 1982 (Document No. SAJ-303). It must be borne in mind however, that this is merely an idea JICA is proposing in connection with the facilities of the research center, and therefore it is subject to changes concurrently with the future progress of the basic design and detailed design. Such being the case, we point out that careful discussions by JICA and SWCC will be required prior to coming to the final decision.

As for the laboratory equipments requiring utilities, their consumptions are shown in the Table 3-1, and as for the points of connection they are shown in the laboratory equipments layout (SAJ-R5001~3). The list of the laboratory equipments is shown in the Appendix 5.

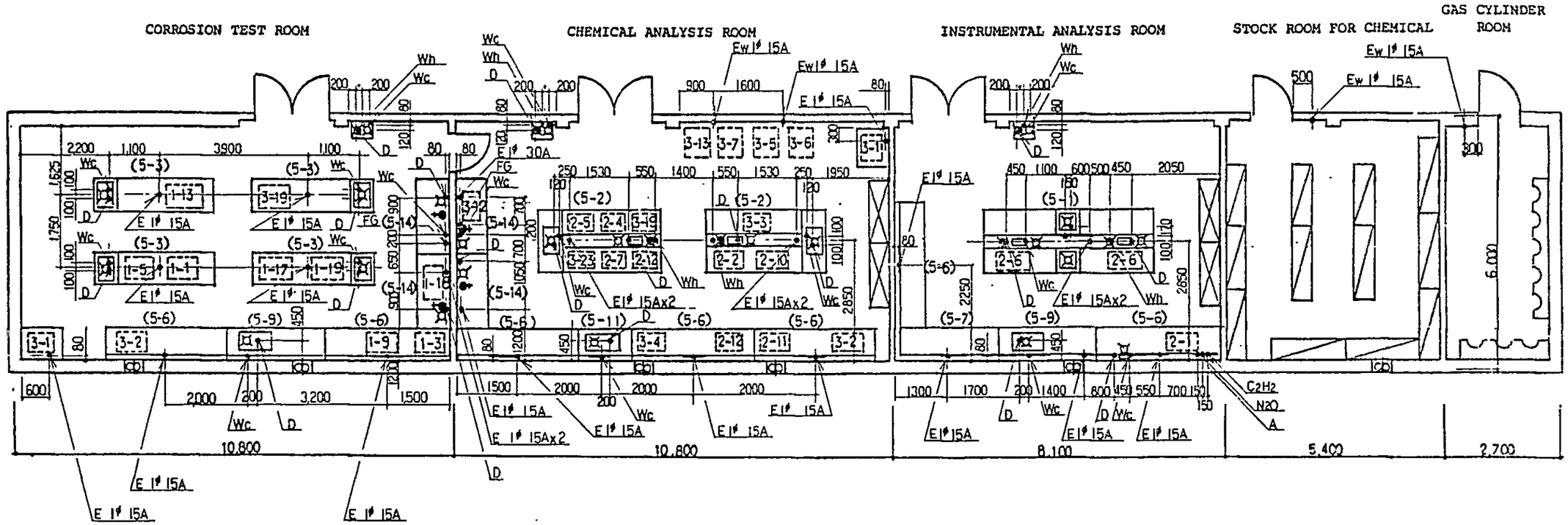
Table 3-1 Utilities Consumption

Item No.	Description	Q'ty	Electricity (kW) 220V/1φ	Electricity (kW) 380V/3φ	Water (ℓ/min.)	Remarks
1-1	Corrosometer	1	0.15			
1-2	Corrator	1	0.05			
1-3	Electrometer	1	0.005			
1-4	Tester	2	BATT. UM-3x2			
1-5	Recorder	2	0.19x2			
1-6	Camera					
	(1) Body	1	BATT. MR.(H-D) x1			
	(2) Illuminator	1	1.0			
1-7	Photographic enlarger	1	0.15			
1-8	Metallurgical microscope	1	0.03			
1-9	Roughness meter	1	0.05			
1-10	Mounting Press	1	1.01		6.0 (1 kg/cm^{2}G)	Chilled water (below 30°C)
1-11	Wet grinder and polisher					
	(1) Wet manual grinder	1	-		1.5 (1 kg/cm^{2}G)	Chilled water (below 30°C)
	(2) Wet auto polisher	1	0.19		4.5 (1 kg/cm^{2}G)	Chilled water (below 30°C)
1-12	Spot welder	1	0.2			
1-13	Electropolishing equipment	1	0.2			
1-14	Dryer	1	0.82			
1-15	Precision cutter	1		1.9	6.0 (1 kg/cm^{2}G)	Chilled water (below 30°C)
1-16	Plastic desiccator	4	0.008			
1-17	Potentionstat/ galvanostat					
	(1) Potentionstat/ galvanostat	1	0.05			
	(2) Function generator	1	0.008			

Item No.	Description	Q'ty	Electricity (kW) 220V/1φ	Electricity (kW) 380V/3φ	Water (ℓ/min.)	Remarks
	(3) Logarithmic converter	1	0.008			
	(4) X-Y recorder	1	0.035			
1-18	Immersion corrosion testing equipment	2	1.0			
1-19	Zero shut ammeter	1	0.005			
1-20	DOS tester	1	BATT. 12 V			
2-1	Atomic absorption spectrophotometer					Chilled water (below 30°C) C_2H_2: 3ℓ/min. (1 kg/cm^2) 15ℓ/min. (3 kg/cm^2) N_2O :10ℓ/min (3 kg/cm^2)
	(1) Atomic absorption spectrophotometer	1	0.35	"	0.5	
	(2) Air compressor	1	0.4			
	(3) Recorder	1	0.03			
2-2	Spectrophotometer					
	(1) Laboratory type	1	0.35			
	(2) Portable type	1	0.165			
2-3	X-ray diffractometer with x-y Plotter	1	4.0	1.0	4 (3.5kg/cm^{2}G)	
2-4	Electrical conductivity meter	2	0.024			
2-5	pH meter					
	(1) Laboratory type	2	0.05			
	(2) Portable type	1	BATT. SUM3x6			
2-6	Automatic titrater	1	0.05			

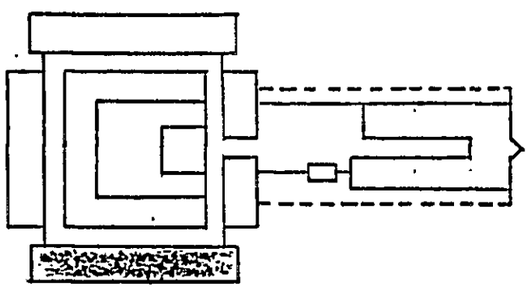
Item No.	Description	Q'ty	Electricity (kW)		Water (ℓ/min.)	Remarks
			220V/1φ	380V/3φ		
2-8	Portable water analysis kit	1	DC SUM3 x 4 AC 0.005			
2-9	Scale deposition testing equipment	2	2.0			
2-10	Turbidity meter	1	0.75			
2-11	oil content determination app.	1	0.1			
2-12	DO meter	1	BATT. Ni-Cd			
2-13	ORP meter	1	0.001			
2-15	X-ray fluorescence analyser	1	0.36		15	
3-1	Analytical balance	2	1.0			
3-2	Chemical balance	2	0.3			
3-4	Water purification app.	2	2.0		2	
3-5	Drying oven for Glassware	2	1.5			
3-6	Drying oven for chemical	1	0.5			
3-7	Muffle furnace	1	1.0			
3-8	Vacuum pump	2	1.72			
3-9	Air compressor	1	0.4			
3-10	Magnetic stirrer	2	0.06			
3-11	Magnetic stirrer	1	0.15			
3-12	Water bath	1	12			
3-13	Refrigerator	1	0.102			
3-14	Water circulating pump (handy type)	2	0.44			
3-16	Hot plate	1	0.4			
3-17	Air pump (handy type)	2	1.3			
3-19	Constant temperature bath	2	0.5			

Item No.	Description	Q'ty	Electricity (kW)		Water (ℓ/min.)	Remarks
			220V/1φ	380V/3φ		
3-20	Calculator	3	BATT. LR44x3			
3-21	Digital thermometer	2	BATT. UM-2x2			
3-23	Vacuum evaporator	1	0.3			
5-1	Precision lathe	1		6.5		
5-2	Bench drilling	1		0.4		
5-3	Electric bench grinder	1		1.8		
5-4	Cutter	1		2.2		
5-5	Electric drill	2		1.0		
5-7	Hack sawing machine	1		1.5		
5-8	Band sawing machine	1		0.75		
5-19	Electric soldering iron	5		0.31		
5-36	Expander	1		2.7		
6-1	Dissolved oxygen meter	1	0.012			

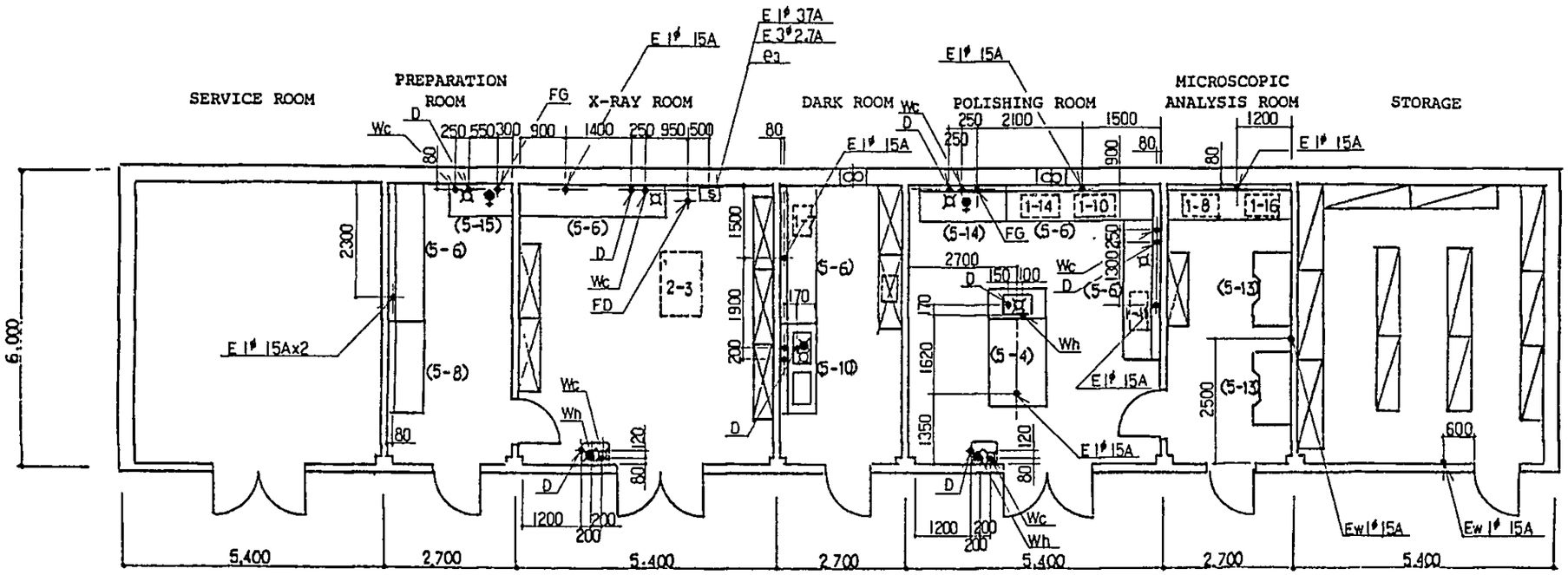


:OPEN TYPE SHELF
:LOCKED TYPE SHELF
:EXHAUST FAN
:COLD, WATER FAUCET
:HOT, WATER FAUCET
:FUEL GAS COCK
Wc :WATER SUPPLY (COLD WATER)
Wh :WATER SUPPLY (HOT WATER)
D :DRAIN
FD :FLOOR DRAIN

FG :FUEL GAS
C2H2 :ACETHYLENE GAS
N2O :NITORUS OXIDE GAS
A :AIR
E :POWER SUPPLY
Ew :POWER SUPPLY (FOR WALL MOUNTED TYPE RECEPTACLE)
1φ15A :SINGLE PHASE(AC220V) 15AMP.
3φ :THREE PHASE(AC380V)
S :SWITCH BOX



PROJECT:	JAPAN-SAUDI ARABIA RESEARCH PROJECT OF SEA WATER DESALINATION
	LABORATORY BUILDING
TITLE:	LABORATORY EQUIPMENT LAYOUT (1)
DATE:	SCALE: NONE
DRAWING NO.:	SAJ-R5001
	JAPAN INTERNATIONAL COOPERATION AGENCY



:OPEN TYPE SHELP
:LOCKED TYPE SHELP
:EXHAUST FAN
:COLD, WATER FAUCET
:HOT, WATER FAUCET
:FUEL GAS COCK
Wc :WATER SUPPLY (COLD WATER)
Wh :WATER SUPPLY (HOT WATER)
D :DRAIN
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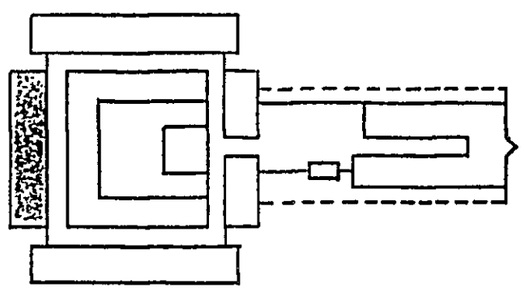
PG :FUEL GAS
C2H2 :ACETHYLENE GAS
N2O :NITORUS OXIDE GAS
A :AIR
E :POWER SUPPLY
Ew :POWER SUPPLY (FOR WALL MOUNTED TYPE RECEPTACLE)
1φ 15A :SINGLE PHASE(AC220V) 15AMP.
3φ :THREE PHASE(AC380V)
S :SWITCH BOX



PROJECT:	JAPAN-SAUDI ARABIA RESEARCH PROJECT OF SEA WATER DESALINATION
	LABORATORY BUILDING
TITLE:	LABORATORY EQUIPMENT LAYOUT (2)
DATE:	SCALE: NONE
DRAWING NO.:	SAJ-R5002
	JAPAN INTERNATIONAL COOPERATION AGENCY

OIL TANK

WATER TANK

BOILER HOUSE

MSF TEST PLANT

4,000

4,000 2,000 7,000

R.O TEST PLANT TANKS

PRETREAT-MENT EQUIPMENT

3,100

8,300 2,000 2,300

13,500 8,100 16,200

250 E 3φ 1.2A E 3φ 5.0A

2300 E 3φ 6.0A E 3φ 18.0A

Ew 1φ 15A

3,000 3,000

6-2 6-3 6-4 6-1

2000

CHEMICAL DOSING

450W X 400D

5-4 5-25

6,000

SUPPLIED BY SWCC

SPIRAL-WOUND TYPE R.O TEST EQUIPMENT

FOLLOW FINE FIBER TYPE R.O TEST EQUIPMENT

CONTROL INSTRUMEN-TATION

6-8 6-7 6-6

E3φ 4.0A

D Wc Wh 120 80 1000 200 200

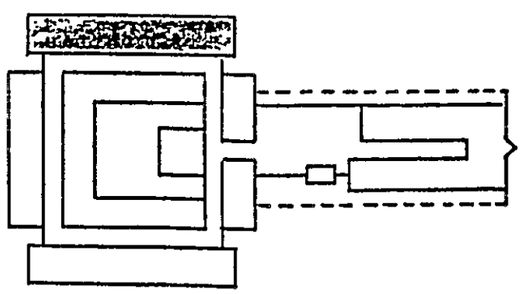
MACHINE SHOP

MSF CONTROL ROOM

R.O MODULE TEST ROOM

:OPEN TYPE SHELP
:LOCKED TYPE SHELP
:EXHAUST FAN
:COLD, WATER FAUCET
:HOT, WATER FAUCET
:FUEL GAS COCK
Wc :WATER SUPPLY (COLD WATER)
Wh :WATER SUPPLY (HOT WATER)
D :DRAIN
FD :FLOOR DRAIN

PG :PUEL GAS
C2H2 :ACETHYLENE GAS
N2O :NITORUS OXIDE GAS
A :AIR
E :POWER SUPPLY
Ew :POWER SUPPLY (POR WALL MOUNTED TYPE RECEPTACLE)
1φ 15A :SINGLE PHASE(AC220V) 15AMP.
3φ :THREE PHASE(AC380V)
S :SWITCH BOX



PROJECT: JAPAN-SAUDI ARABIA RESEARCH PROJECT OF SEA WATER DESALINATION

LABORATORY BUILDING

TITLE: MSF AND RO TEST PLANT LAYOUT

DATE:

SCALE: NONE

DRAWING NO.: SAJ-R 5003

JAPAN INTERNATIONAL COOPERATION AGENCY

4. Technical Survey

4.1 Present State

As can be seen from the Table 4-1, the sea water desalination plants in operation all over the world have daily capacity of 7.28 million tons as of 1980. By process, the evaporation process accounts for 75.9%, the reverse osmosis process 20.3% and the electrodialysis process 3.8%.

Table 4-1 Sea water desalination plants in operation all over the world (Unit: 1,000 m^3/d)

	Late 1974	Late 1976	Late June 1980
Distillation process	1,697 (85.2%)	2,879 (77.7%)	5,526 (75.9%)
Reverse osmosis process	169 (8.5%)	632 (17.0%)	1,478 (20.3%)
Electrodialysis process	124 (6.2%)	195 (5.3%)	274 (3.8%)
Freezing process	1 (0.1%)	1 (-)	- (-)
Total	1,991 (100.0%)	3,707 (100.0%)	7,278 (100.0%)

Note: 1. Figures enclosed with parenthesis indicate percentage by type in each year.

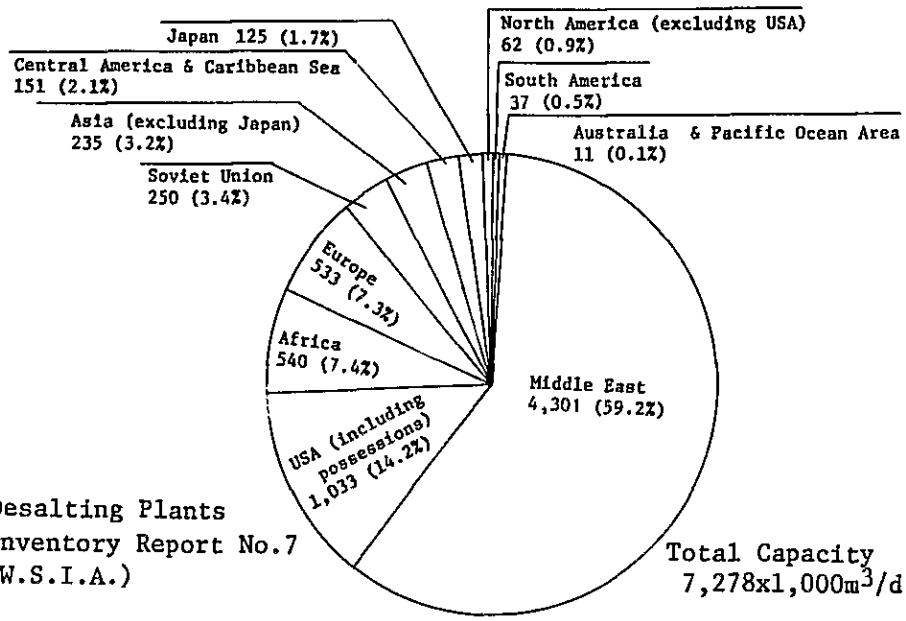
2. This table is the compilation of data of plants with 95 m^3/d or more capacity.

3. Source: Desalting Plants Inventory Report (O.W.R.T. and W.S.I.A.)

Figure 4-1 Sea water desalination plants in operation by area

Unit: 1,000 m^3/d

(As of late June 1980)



Source: Desalting Plants Inventory Report No.7 (W.S.I.A.)

The evaporation process consists mostly of large-sized plants, and accounts for more than 2/3 of the total. As for the scale of the equipment, the largest plant operating on commercial basis has capacity of approximately 36,000 m^3/d in the case of MSF and 8,500 m^3/d in the case of the multi-effect distillation process (hereinafter referred to as ME). Both MSF and ME have many units in operation their reliability is high. MSF with addition of scale inhibitor has particularly high reliability.

RO is a new sea water desalination process becoming increasing popular of late. The maximum scale of each sea water desalination unit using RO that are in practical operation at the present time is of the order of 2,000 m^3/d in the case of treating sea water and 5,000-6,000 m^3/d in the case of treating brackish water. In reality however, it is possible to construct sea water desalination equipment with capacities ranging from ten to scores of thousand m^3/d with the existing technology, and as a matter of fact large-scale plants have been constructed and tendered of late.

As for the areas where sea water desalination plants are located, the majority is concentrated in the Middle East, as can be seen from the Figure 4-1.

As can be seen, it is nowadays possible to construct sea water desalination plants of considerable scale, and it may safely said that the

reliability has been practically consolidated from the technical standpoint. On the other hand however, it must be borne in mind that there are many issues requiring improvement and development in order to improve further the reliability. For example, in the case of the evaporation process careful countermeasures are required in order to cope with scale and corrosion and in the case of the reverse osmosis process it is necessary to collaborate the performance and durability of the module exposed to high temperature and high concentration sea water. The troubles that break out commonly in the existing plants using MSF and RO as well as the countermeasures to cope with them are shown in the Table 4-2 and Table 4-3.

Table 4-2 Troubleshooting in MSF plants

Name of trouble	Results	Causes	Corrective measures
1. Unsatisfactory quality of product water	. Rise of TDS of product water	. Unstable operation . Shortage of anti-foam agent . Leak of tube	. Keep the operation stable . Adjust the injected volume . Search for tube with leak and take the appropriate countermeasures
2. Unsatisfactory decarbonation	. Deposition of scale . Insufficient quantity of product water	. Insufficient injection of sulfuric acid, insufficient mixing. . Clogging of spray nozzle . Insufficient volume of air blower	. Repair pH meter and sulfuric acid injection pump . Repair sulfuric acid mixer and blower . Clean spray nozzle
3. Unsatisfactory deaeration performance	. Accelerated corrosion	. Clogging of spray nozzle . Shortage of stripping steam . Incorrect level, air leak . Unsatisfactory injection of reducing agent	. Inspect and clean spray nozzle . Regularization of stripping steam . Regularization of level and repair of leaking part . Inspect and repair of injection pump
4. Insufficient desalination capacity	. Insufficient quantity of product water	. Generation of scale . Increase of leakage . Abnormal venting . Unstable operation	. Eliminate scale (acid cleaning, ball cleaning) . Check and repair leak . Inspect and repair ejector . Keep the operation stable

Name of trouble	Results	Causes	Corrective measures
5. Trouble in pump and/or motor	. Vibration of pump and/or motor, rise of bearing temperature . Occurrence of abnormal current . Unsatisfactory seal	. Abrasion or seizure of bearing . Abrasion of packing and mechanical seal	. Check and replenish oil and grease . Replace bearing . Replace packing and mechanical seal
6. Trouble of measuring instrument	. Difficulty to the correct operation and maintenance management of the facilities	. Pressure gauge: Deterioration of the Bourdon tube . Conductivity meter: Soiling and damage of sensor . pH meter: Soiling and damage of sensor	. Periodic inspection, repair and replacement
7. Malfunction of piping and valve	. Leak of sea water . Difficulty to carry out the correct operation and maintenance management due to the abrasion of the valve body and valve seat of control valve	. Corrosion and erosion due to sea water, concentrate, chemicals, etc.	. Selection of correct material and type . Periodic inspection and repair . Stock of spare parts
8. Corrosion during stoppage of operation	. Accelerated corrosion	. Intensification of corrosive ambient	. Corrosion prevention countermeasures
9. Oil contamination of sea water	. Adhesion of scale	. Oil contamination of sea water	. Prevention of mixture of oil at the intake . Elimination of oil from sea water

Table 4-3 Troubleshooting in RO plants

Name of trouble	Result	Causes	Corrective measures
1. Deterioration of quality of pretreated water a) Rise of FI and turbidity	. Rise of differential pressure of RO module or cartridge . Reduction of volume of permeate from RO membrane	. Abnormality in the backwashing of filter . Leak of floc . Abnormal injection of flocculating agent	. Periodic inspection of the interior of the filter . Check or change the injected quantity of flocculating agent . Shorten time between successive backwashing
b) Fluctuation of pH	. Reduction of volume of permeate due to deposition of calcium salt on membrane surface . Deterioration of performance due to hydrolisis of CA membrane (this deterioration is not pronounced)	. Malfunction of sulfuric acid pump . Malfunction of pH meter and adjusting meter	. Check injected volume . Inspect and repair pumps and instruments
c) Imperfect elimination of Cl_2 and O_2	. Deterioration of performance due to acid decomposition of synthetic membrane . The desalination: performance declines because the reaction speed of the membrane with chlorine is particularly high.	. Unsatisfactory injection of reduction agent ($NaHSO_3$, etc.) . Malfunction of ORP meter, O_2 meter, etc. . The liquid level of deaeration tower is not correctly controlled.	. Check injected volume of chemicals . Periodic inspection and repair of pumps and measuring instruments

Name of trouble	Result	Causes	Corrective measures
2. Mechanical trouble of pretreatment equipment	. The effect on the membrane and module is negligible because the equipment is automatically shut down . Noise and vibration of pump	. Malfunction of automatic valve due to damage caused by salt . Abrasion and seizure of pump bearing	. Avoid outdoor installation . Check and replenish lubricating oil . Replace bearing
3. Trouble of high-pressure pump and motor	. Vibration and rise of bearing temperature of motor and pump . Operation of circuit breaker due to abnormal current . Leak of water from gland seal	. Abrasion and seizure of bearing . Abrasion of gland packing	. Periodic inspection of oil and grease . Replacement of bearing . Replacement of gland packing
4. Clogging of RO module	. Reduction of volume of permeate due to rise of differential pressure	. Feed water FI is above design value . Frequent sedimentation principally of iron	. Circulating washing with citric acid solution (1-2%) brings about the most effective results.
5. Deterioration of RO module performance	. Reduction of volume of permeate . Deterioration of permeate water quality, water conditions . Mechanical damage of O-ring	. Contamination of membrane occurrence of scaling . Compaction of membrane . Chemical deterioration of membrane due to change in feed	. Raise operation pressure . Clean module . Check water quality of each module . Replace module with deterioration of performance

Name of trouble	Result	Causes	Corrective measures
6. Trouble of measuring instruments	. Difficulty to carry out the correct operation and maintenance management of the equipment	. Pressure gauge: Deterioration of Bourdon tube . Conductivity meter: Soiling and abrasion of sensor . pH meter: Soiling and damage of sensor . Flow meter: Corrosion of D/P cell, damage of rotor meter	. Periodic inspection (cleaning, calibration of pressure gauge, etc.) . Repair or replacement
7. Malfunction of high-pressure piping and valve	. Leak of sea water . Difficulty to keep correct operation conditions due to abrasion of valve body and valve seat of control valve	. Corrosion and erosion due to sea water, concentrate, chemicals, etc. . Abnormality in compressed air, malfunction of converter	. Periodic inspection and repair . Stock of spare parts . Selection of correct material and type

It goes without saying that all of the aforementioned troubles can be prevented before they occur through correct operation and maintenance management of the plant. In other words, for correct operation management it is indispensable to establish clear operation standards, including starting and stopping procedures. For this purpose it is indispensable to provide complete instruction manuals for quick reference by the operators of the plant. The foundation of the maintenance management is the correct execution of the monitoring, inspection, adjustment and maintenance for the functions of the existing facilities to be given full play and to guarantee the stable operation of the facilities for long time by taking appropriate measures such as replacement of parts and components at the appropriate epoch. In this connection it is indispensable to provide complete manuals and other documents related to maintenance management for quick reference by the maintenance personnel.

Table 4-4 shows the results of statistical analysis of the causes of troubles in chemical plants. As can be seen, misoperation accounts for a considerable percentage (45%) of the causes of troubles. This fact illustrates the importance of mastering correct operation and maintenance management.

Table 4-4 Causes of troubles
(Source: MITI statistics)

Misoperation	(45%)
Damage of equipment	(17%)
Faulty structure	(17%)
Deterioration/ corrosion of equipment	(13%)
Inadequate design	(8%)

In this connection we have prepared data aimed at extending the knowledge of technical personnel engaged with sea water desalination plants. These data will be described in the following sections. The corrosion of metals of various kinds used in sea water desalination plants and the corrective measures to cope with the problem are described in the section 4.2. The results of investigations about the inspection during operation as well as periodic inspection and maintenance of reverse osmosis process plants and distillation process plants are described in the section 4.3.

4.2 Corrosion and its Prevention in Sea Water

1) Iron and low alloy steel

Seam pipe is used very frequently in ordinary piping in view of its cheaper cost compared with seamless pipe. However, when it is used in sea water piping and in industrial water piping the seam suffers selective corrosion, resulting into grooved corrosion in some cases. Under the circumstances, case studies have been carried out with the purpose of examining the causes and the state of things of the corrosion. Changes take place in the metallographic structure of the seam due to the local heating when the pipe is manufactured. As a consequence a practically continuous and uniform corrosion takes place along the seam due to galvanic effect when the pipe is exposed to sea water and other kinds of liquid with high conductivity. The base metal suffers a relatively uniform corrosion too, and a pronounced reduction of wall thickness is observed in many cases.

2) Stainless steel

According to the cases examined so far, the forms of corrosion that occurs frequently in stainless steel are those ones shown in Figure 4-2. Stress corrosion cracking (hereinafter called SCC) is the most frequent form of corrosion in stainless steel, followed by pitting (including crevice corrosion). Pitting and SCC together share 3/4 of all cases of corrosion in stainless steel. When the pH is not so high, the pressure of chlorides brings about the shift of the pit corrosion to general corrosion. When the crevice is exposed to sea water its pH drops and the concentration of chlorides increases concurrently with the progress of the corrosion. As a consequence the pH in the interior of the crevice is activated, the passive state is broken and the corrosion is activated. On the other hand, the examination of cases of SCC from the standpoint of form of corrosion indicates that it is frequently accompanied with pit corrosion as shown in Table 4-5. Therefore, the resistance to SCC is improved by improving the resistance to pit corrosion.

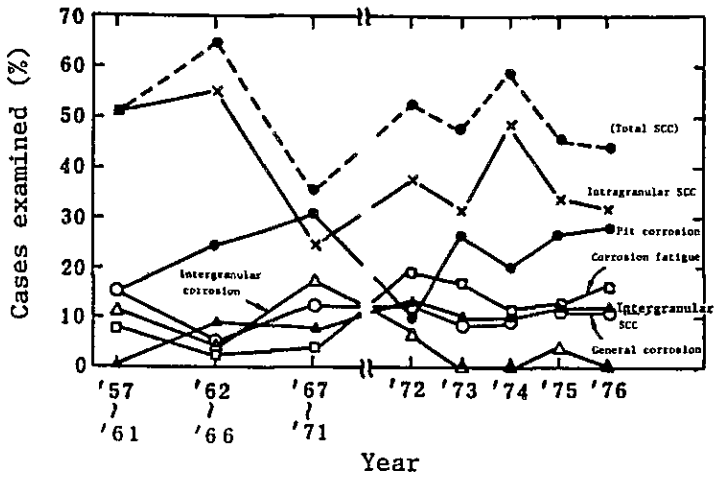


Figure 4-2 Evolution of the percentages of the various forms of corrosion in the case of wet corrosion of stainless steel (Source: Survey carried out by Japan Metallurgical Industry)

Table 4-5 Other forms of corrosion observed at the periphery of stress corrosion cracking

Form of peripheral corrosion	No. of cases	%
General corrosion	8	12.5
Intergranular corrosion	3	4.7
Pit corrosion	31	48.4
Crevice corrosion	3	4.7
No corrosion (?)	19	29.7
Total	64	100.0

Crevice corrosion of stainless steel is caused by the presence of metallic or non-metallic foreign matter on the surface and other similar causes, and has the following characteristics.

° Active dissolution progresses only in the interior of the crevice, while its exterior keeps a completely inactive state.

° The properties of the solution in the interior of the crevice are changed to low pH and high Cl^- concentration and contribute to accelerate the corrosion process.

Troubles caused by external stress corrosion cracking are observed in austenite-type stainless steel lined with heat insulator. This kind of corrosion occurs because Cl^- ion contained in the heat insulator is eluted due to the infiltration of rain water, etc., resulting into a high concentration on the surface of stainless steel. Cracks are frequent at the vicinity of 90°C in cases reported

in foreign countries. The following kinds of countermeasures are required in order to prevent this kind of trouble:

° Means to prevent the infiltration of water
° Elimination of Cl^- ion from the heat insulator
° Use of corrosion inhibitor
° Means to avoid the risky temperature range
° Modification of the quality of the material
° Means to cope with the residual stress

According to the results of the study carried out in 1977 about the use of heat exchangers in Japan, the frequency of SCC of longitudinal type is 61.2% and surpasses the frequency of transversal type SCC. By type of material, this kind of trouble occurs most frequently in SUS304 with 50.6%, followed by SUS316L with 15.3% and SUS316 with 11.8%. In terms of rate of occurrence, 52.9% of the cases are concentrated within 1 to 3 years, evidencing high frequency of occurrence of troubles of this kind in an early epoch. The causes of this kind of trouble and the applicable countermeasures are shown in Tables 4-6 and 4-7.

Table 4-6 Classification of the causes of SCC

Cause*	No. of Cases	%
Existence of gaseous phase	32	34.4
Inadequate working	12	12.9
Inadequate material quality	10	10.8
Inadequate water quality	8	8.6
"Force majeure"	7	7.5
Misoperation at the process side	6	6.5
Rise of cooling water temperature	3	3.2
Tube fixing method	3	3.3
Defect in the material	2	2.2
Others	10	10.8
TOTAL	93	100

* Cases with 2 or more attributable causes are counted as one event in this table. Questionnaires without reply are excluded.

Table 4-7 Classification of countermeasures to cope with SCC

Countermeasure*	No. of cases	%
Modification in the quality of material	25	30.9
Water treatment	9	11.1
Modification in the structure	8	9.9
Change of the method of operation	7	8.6
"Keep watching"	7	8.6
Modification in water passage route	6	7.4
"No countermeasure"	6	7.4
Heat treatment	2	2.5
Others	11	13.5
TOTAL	81	100

* Cases with 2 or more countermeasures are counted as one event in this table. Questionnaires without reply are excluded.

SCC corresponds to 30-40% of all cases of corrosion occurring in the chemical industry. The occurrence of cracking is very difficult to forecast and to detect, and once occurred its repair is also very difficult.

In reality the countermeasures to cope with SCC consist principally of change to high-grade material and change to low-grade material. In many cases SCC occurring in real environment is triggered by pit corrosion. Therefore, the advantageousness of pit-corrosion-resistant steel becomes evident. Even SCC-resistance of ferrite-type stainless steel becomes a weakpoint if there is absorption of C and N during welding. Therefore, the welding technique becomes a key point in this regard. Welding exerts important influence on the occurrence of SCC, because it is not only source of residual stress, but also contributes to the sensitization due to the thermal influence. In one of the cases we examined, crack occurred within one week in the new weld when the part in question was used without annealing after being repaired by weld. However, the part in question was annealed at 650°C after being welded once again, and then it has been used for 5 years with no trouble at all. From the standpoint of the shop floor it is necessary to pay attention to the

tensile residual stress caused by surface grinding. It causes local heating and plastic deformation and therefore it is a residual stress that can by no means neglected.

From the environmental and structural standpoints, electric protection, inhibition of temperature and cracking chemical seet, lining and cladding with strong metallic material, rubber lining and plastic coating are effective countermeasures to cope with SCC.

3) Bronze alloy

The superior corrosion resistance of bronze is attributable to the presence of SnO_2, which is a material with good protective properties, within the passive film formed on the surface of bronze. Bronze is reported to be particularly resistant to sea water. Bronze alloy castings containing lead are used very popularly in cocks, valves, etc., in view of their improved pressure resistance and machinability. On the other hand however, the presence of Pb is reported to exert noxious influence on the corrosion resistance of the alloy.

Aluminum-brass alloys have consolidated a solid position as corrosion-resistant materials since their use as heat-transfer tube in condensers of power plants using sea water for cooling purposes. The self-restoring film alone is insufficient to guarantee sufficient corrosion resistance, and in reality the corrosion resistance of this kind of material relies on the formation of protective film consisting of ferrous components on the inner surface of the pipe, which is attained through the injection of ferrous ion in the sea water used for cooling purposes, in accordance with the idea proposed by Bostwick. The protective film is required to be uniform with an appropriate thickness, and even a single point of absence will surely result in trouble. The adhesion of ferrous compound is spoiled when there is formation of a white film consisting mostly of $MgAl_2CO_3(OH)_{16}\cdot 4H_2O$ (hydrotalsite) on the surface of aluminum-brass, and as a consequence erosion takes place at the places where this film is peeled off. Therefore, an effective injection of ferrous ion at the beginning of the passage of water through the pipe is very important as corrosion prevention measure.

4) Titanium

Of the two cases of MSF desalination equipment using titanium tube,

no corrosion at all occurred for 7 years in that one where the titanium tube are joined with the titanium tube sheets by shielded-arc welding, while violent crevice corrosion occurred within 4 months in that one using expanding joint. On the other hand, there are also cases where there is no corrosion in the titanium tube, but violent crevice corrosion occurs in the titanium tube sheet and on the packing surface of titanium lining of the water box. Next, the examination of the conditions of occurrence of crevice corrosion in the expansion joint between tube and tube sheet, in terms of relationship with concentration of NaCl and temperature, evidences that crevice corrosion occurs at temperatures above 60°C and that no crevice corrosion occurs in Ti-0.15Pd alloy tube in the same solution even at temperatures of the order of 85-125°C. The values of the pH and tube expansion rates within practical limits exert negligible influence, and crevice corrosion can be prevented by using either copper alloy tube sheet or putting metallic copper in contact with titanium inside the crevice.

As for absorption of hydrogen by titanium, this metal has high affinity with hydrogen, and as a consequence embrittlement takes place due to the deposition of hydrogen compounds. The kinds of environment that cause absorption of hydrogen are broadly classified into non-oxide acid solution with pH below 3, neutral solution containing hydrogen sulfide, strong alkaline solution, etc. In desalination equipment hydrogen absorption is experienced at high-temperature ranges above 80°C, titanium in salt water medium is prone to acquire potentials below hydrogen absorption limits when it is in contact with steel, and hydrogen absorption is enhanced even in fresh water at temperatures of the order of 100°C. The countermeasures to cope with corrosion of titanium are prevention of contamination by iron, adoption of working methods free of contact with steel, means for upkeep of acidity of the environment, electric protection, etc.

5) Prevention of corrosion

(1) Electrochemical corrosion protection

With regard to the polarities of zinc and steel, their inversion is frequently observed in aerated water with temperature above 60°C. Not only the temperature, but also the presence of hydrogencarbonate ions contained in the water play a decisive part in this inversion. Nitrate ions

contribute to accelerate the inversion, but on the other hand sulfate ions and chlorine ions contribute to inhibit it and furthermore no inversion takes place if there is no dissolved oxygen in the solution.

(2) Corrosion inhibitors

In connection with corrosion inhibitors for protection of copper and copper alloys, the method consisting of the formation of piping systems was used very popularly in conventional cases. Anodic type corrosion inhibitors consisting of nitrites were used in these cases, but local corrosion was very frequent due to insufficient quantity of inhibitor added. In the case of pipings consisting of iron and copper it is necessary to mix benzotriazol (BTA) with the corrosion inhibitor because amines tend to accelerate the corrosion in some cases.

6) Plants

With regard to tubes for boilers, data collected so far evidence that SUS316 used at places with temperatures of 90°C or more suffers SCC within approximately 1 year, while 70/30 Cu-Ni can be used at places with temperatures of 90-110°C for 5 years with no problem at all. Tube made of SUS316L used at places with temperature of 75-100°C suffered SCC within approximately 4 years, and therefore they were replaced with Alblack pipes. No SCC has been observed yet at temperatures of 50-60°C. In view of the aforesaid results, SCC of stainless steel tube is presumed to be strongly influenced by the concentration of chlorides. Clad steel made of SUS316 is used in the body of evaporators, but no leak accident has been observed in approximately 10 years of operation. Pumps made of SCS13 have short life, while pumps made of SCS14 can be used for 5-6 years.

The test results with small-sized boilers using stainless steel tube, with liquid temperature of 105°C at the tube side, are as follows after 2 years.

° In SUS316L there is liquid leak due to crevice corrosion at the tube sheet side.

° In 25Cr-27Ni-Ti-type stainless steel the pit corrosion pierced the tube wall.

° In the case of Inconel 800, crevice corrosion occurred in the tube sheet.

After 4 years of test the corrosion progressed slightly in Inconel 800 but did not result in leak. On the other hand, no abnormality was observed in cladded stainless steel and in 23Cr-26Ni-5Mo-type stainless steel.

7) Corrosion protection control

Periodic overhaul is carried out as corrosion protection control at the time of operation suspension. Thickness measurement by means of ultrasonic thickness gauge, X-ray inspection to examine the state of local erosion and corrosion at the welds, etc., are used as methods of inspection. The visual inspection is used only for qualitative judgement, and the measurement of the surface roughness is an effective means for early detection of abnormality, because it is used for estimation of the extent of corrosion as well as for measurement of minute parts. The eddy-current method is used to detect SCC progressing from outside, such as tubes of heat exchangers, and it is possible to identify the faulty parts and to estimate the epoch of occurrence of leak.

4.3 Inspection and Maintenance

The inspection during the operation is carried out with the following purposes.

(1) To compare the state of operation of each equipment of the plant with the operation standards for any abnormality.

(2) To observe the evolution of the state of operation to estimate the epoch of replacement and repair of parts and components, in order to prevent accidents and troubles before they occur.

Part of the periodic inspection such as observation and inspection of sea water intake and discharge opening, measurement of the vibration of pumps and motors, inspection of the permeate water quality of the module, etc., are carried out with the plant in operation, but in general it consists of the overhaul of the equipment, replacement of parts, repair, coating, etc., carried out with suspension of operation.

1) Intake and drainage facilities

The inspection and maintenance of the sea water intake and drainage oepnings require special attention because they are prone to suffer damages caused by salt. Particularly the intake, outlet, intake channel, outlet channel, control tank, intake pump, etc., installed on the bottom of the sea are subject to troubles caused by the adhesion of sea life, floating and sedimentation of sand

and mud, damages caused by waves, etc., and adequate countermeasures are required in order to cope with them.

As for the equipment and apparatuses installed on the ground, it is indispensable to carry out the routine inspection related to their operation and maintenance and to record the state of operation for any abnormality.

(1) Chlorine facilities

The most important aspect in connection with the maintenance of the sea water intake facilities is to prevent the adhesion of sea life. As present now stand the most economical measure to prevent the adhesion of sea life is the injection of chlorine through the intake.

In the case of sea water desalination facilities the injection of chlorine in the form of hypochlorites through the electrolysis of sea water is the most popular method, but it can be injected in the form of chlorine gas as well.

In the chlorine injection method the amount of residual chlorine in the control tank or in the raw water tank is determined in the first place by examining the sea water life, water quality, quantity of water intake and other conditions of use at the intake area. Then, the volume of chlorine to be injected is decided on the basis of above mentioned residual amount. Therefore, it is indispensable to measure every day the amount of residual chlorine in the control tank or in the raw water tank.

(2) Intake opening, outlet opening and intake/outlet channels

With regard to the intake opening, intake channel and outlet channel installed in the sea and on the bottom of the sea, it is recommendable to submit to inspection by divers the state of things of the bottom of sea at the installation site, the state of installation of the facilities in question, the state of adhesion of sea life, etc., approximately once a year. In particular, the state of things related to the injection of chlorine at the intake, ejection of chlorine by the nozzles, adhesion of life in the intake channel, sedimentation of sand and mud, ejection of water at the outlet, etc., should be submitted to careful inspection and maintenance.

It is recommendable to measure the loss of head of the outlet channel approximately once a year, because the expected volume of intake can not be obtained when there are too many obstacles in the intake channel.

It must be borne in mind that chlorine injection has no effect at all on the outer surface of the intake point hood and drainage nozzle in the case of sea water intake facilities consisting of intake channel and drainage facilities consisting of subaquatic outlet system, and shells grow up with ease on these parts. Therefore, in some cases it is necessary to inspect by submersion the hood at the extremity of the intake and the drainage nozzle at annual intervals and to remove them for cleaning and coating at three-year intervals.

(3) Control tank, depurator and intake pump

The interior of the control tank should be inspected every two months for adhesion of life and state of sedimentation of grit. Approximately once every three years it should be emptied to remove deposits and dead shells. Depurating equipment such as travelling screen, etc., installed with the purpose of removing suspended solits, sea life, etc., should be operated intermittently in the case of sea with few suspended matter, but anyway it should be operated at least twice a day for more than 20 minutes in order to prevent these suspended solids from sticking on these equipment. Furthermore, the cleaning water pump and nozzles should be inspected in the same way.

As for the overhaul of the intake pump and depurator, it is recommendable to carry out approximately once every 3 years. As for the parts submitted to electric protection, they should be inspected approximately once every two years by measuring the protection potential.

2) Inspection and maintenance of the pretreatment facilities

(1) Reverse osmosis pretreatment facilities

(a) Operation control

The volume of chemicals to be injected, the floc surface of the flocculator and clarifier and the cleaning cycle of the filter should be adequately controlled in accordance with the quality of the raw water in order to keep the quality of the treated water in conformity with

the target values. It is recommendable to draw up the daily operation record and chart in order to facilitate the control of the operation state.

① Daily operation control

The state of operation of the plant should be recorded every day. Furthermore, the pertinent record should be taken every time the conditions of operation are changed. In particular, when the turbidity of the raw water changes violently or is very high, it is indispensable to carry out the measurement of the turbidity of the raw water and the FI (fouling index) of the treated water.

② Weekly operation control

It is recommendable to calculate the unit consumption of chemicals approximately once a week. Should excess or shortage occur for 2 or 3 successive weeks, it is necessary to check the possible causes. In the same way, it is recommendable to calculate the unit consumption of power too.

③ Monthly operation control

The unit consumption of chemicals and power should be calculated every month. Furthermore, it is also necessary to analyze the quality of raw water and pretreatmented water.

(b) Inspection and maintenance

① Routine inspection, maintenance and control

The routine inspection and maintenance of equipment of the plant should consist of patrolling inspection of rotary machines such as pumps, motors, etc., for vibration, noise, leak, etc. The calibration of the pH meters, replacement of lubricant oil, etc., should be carried out in accordance with the cycles specified in the instruction manual.

② Periodic inspection and repair

The contents of the periodic inspection consists of the emptying inspection of the flocculator & clarifier, opening inspection of the filter, overhaul of the rotary equipment, calibration of the measuring instruments, etc. The inspection of the flocculator

& clarifier consists of the inspection of the internal coating for possible defects and the corresponding repairs, overhaul of the rotary parts, replacement of grease, etc., which should be carried out after draining water contained therein. The inspection of the filter consists of checking the filter material for soiling and shortage, replacement of the soiled and damaged filter materials and replenishment of the filter materials in shortage, which should be carried out by opening the filter. In the case of abnormal shortage of filter materials, the possible causes should be investigated in order to consider the pertinent countermeasures.

(2) Pretreatment equipment of evaporation process

The correct maintenance and control of the pretreatment equipment is very important in order to secure the stable operation of the plant for a long time.

(a) pH control process

In connection with the pH control process, particular attention should be paid to the following points.

① Handling of sulfuric acid, which is a dangerous material, in the case of using it.

② Control of the electrode used to detect the pH.

③ Drainage in the case of prolonged stoppage.

(b) Control of the scale inhibitor addition process

In the case of polymer phosphate as scale inhibitor, it is particularly important to carry out the correct control of the solution. The solution should be used as much as possible within 48 hours after the dissolution of the chemicals. Care should be taken not to use solutions with more than one week elapsed.

(c) Control of the ball cleaning process

The ball cleaning process is changed in accordance with the scale prevention process used concurrently, as well as the conditions of operation and the properties of the sea water. The appropriate cleaning cycle should be determined and controlled in conformity with the state of each plant.

(d) Control of acid cleaning process

The detailed description of the means to control the acid cleaning process is omitted here, because in many cases the acid cleaning facilities are installed in provisional. However, attention should be paid to the following aspects related to the acid cleaning process.

① Control by means of test pieces

A test piece made of the same material as tube should be hanged in the interior of the acid solution circulation tank in order to measure the weight reduction due to corrosion. The obtained data should be used for the purpose of evaluating the effect exerted on the equipment.

② Control of the elution of components of the materials of the equipment

The circulating acid solution should be sampled one or more times per hour during the acid cleaning process, and the sample should be analyzed to check the elution of components of materials composing the equipment being submitted to acid cleaning.
At the beginning of the circulation of acid solution the elution of scale components is conspicuous in the first place. In the case of alkaline scale the total hardness and the pH of the solution tend to rise. On the other hand, the total concentration of Fe ion tends to rise in the case of sludge. Next, components of tube material (e.g. Cu^{2+}) commences to elute after the complete removal of the scale. The judgement about the completion of the acid cleaning process should be made by identifying the change in the concentration of these components.

③ Opening inspection and maintenance of the equipment

After the completion of the acid cleaning process the equipment in question should be opened to check the cleaning effect. Should residual scale be present in the interior of the equipment, it should be removed by means of the water jet process. Next, the equipment in question should be restored to their

original state, submitted to hydrostatic leak test and flushing with passage of water.

(e) Control of the alkaline cleaning process

The alkaline cleaning process consists of the alternative cleaning with alkali and acid. Therefore, in principle the above considerations referring to the control of the acid cleaning process are applicable to this case as well.

(f) Control of the low pH operation process

This operation process is identical with the ordinary operation of the equipment in most aspects, with exception of the pH of the circulation line which is kept at low level. Attention should be paid to the following points in the case of low pH operation.

① Control of pH

Continuous monitoring of the pH at as much places as possible is required in the process of the equipment, in order to control the progress of corrosion in the material of tube. If the normally equipped pH meters are insufficient, portable pH meters should be provided in order to carry out a sufficiently accurate pH control. In particular, it is indispensable to calibrate the pH meters prior to starting the low pH operation.

② Control of scale

The frequency of sampling and analysis of the Ca^{2+} and Mg^{2+} components of the scale should be increased, and the plant should be returned as soon as possible to operation with normal pH when the elution of scale components is saturated. The duration of the low pH operation time depends on the state of deposition of scale and the setting of the pH value, but 3 hours should be taken as a reference, and even in the case of extending the low pH operation due to incomplete removal of scale, the additional time should not exceed 1 hour.

3) Main facilities

(1) Main facilities of the reverse osmosis process

(a) Maintenance and control during the operation

The main facilities of the reverse osmosis process that require routine control of the state of operation are the module stack, high-pressure pump and power recovery turbine. It is necessary to inspect the water quality, discharge, operating pressure and pressure loss. The recovery rate and the rejection rate are the parameters used to indicate the overall performance, and their numerical values are calculated to carry out the overall control. Particular attention should be paid to the following points during the operation.

① Rise of pressure loss due to contamination.

② Abnormality in the quality of the permeate due to damage in the O-ring and brine seal.

③ Abnormality in the quality of permeate and reduction in the volume of permeate due to the deterioration of the membrane.

④ Changes in the quality and volume of permeate due to the temperature of the supplied water.

The water quality, discharge and pressure loss of the module stack changes gradually with the operation time. However, in the case of violent change it is necessary to measure the water quality of each module in order to check possible troubles in the modules. In the case of deterioration in the performance of the module due to the bad quality of the supplied water, it is possible to recover the module in question by washing if the trouble is minor. Sudden deterioration in the performance of individual modules is often caused by leak of concentrated water from the joint of the element.
In the case of any abnormality it is necessary to replace the module, but in the case of trouble it is recommendable to ask for the technical judgement of the manufacturer in charge of the design and construction of the equipment in question prior to taking the required countermeasures. It is recommendable to include the following alarm and automatic stoppage sequence circuits

in order to guarantee the safety of the maintenance and control of the module stack.

- o Abnormal operating pressure
- o Abnormal quality of feed water
- o Abnormal instrumentation air pressure
- o Abnormality in the motors
- o Abnormality in the quality of the permeate
- o Abnormality in the permeate discharge

The routine inspection and operation of high pressure pumps has no difference compared with ordinary pumps, but a strict control are required because they are important equipment of the reverse osmosis system. In the case of facilities with automatic control of the pressure and discharge, particular care is required in connection with the selection of the materials and routine inspection of the automatic control valves, because the corrosion of their materials exerts important influence on the equipment.

(b) Maintenance during the stoppage and periodic inspection

In the case of short-term operation stoppage of the order of one week, it may be sufficient to remove the brine from the module stacks and piping by carrying out the flushing with feed water. If possible however, it is recommendable to replace the brine with permeate. In the case of prolonged stoppage it is necessary to flush with permeate or the like the interior of the reverse osmosis equipment including the high-pressure pump. Furthermore, depending on the type of the module or use of the product water, it is necessary to enclose either formaldehyde solution of the order of 0.2% or sodium bisulfite solution (SBS) of the order of 500 mg/liter for the sake of sterilization and preservation against putrefaction. Anyway, it is necessary to maintain the osmosis membrane in wet state and to protect it against the ploriferation of bacteria and microorganisms.

(c) Overhaul

① Module stack

The routine inspection and overhaul of the module carried out during the operation of the desalination

plant are not required in this case. Particularly in the case of modules with abnormality of any kind, it is necessary to take out the element and to examine the O-ring of the element connector and the brine seal for damages, the surface of the element as well as the interior of the pressure container for contamination, and if necessary to replace the element, O-ring and other parts and components.

② High-pressure pump and motor

The overhaul of the high-pressure pump consists of the following steps of procedure.

- Replacement of parts and components such as gland packing, mechanical seal, etc.
- Inspection of the abrasion and replacement of the bearing sleeve.
- Inspection of the abrasion and replacement of the check valve.
- Careful inspection of the impeller and casing for corrosion, damage and abrasion and applicable repair.

Furthermore, special attention should be paid to the corrosion and abrasion of the pressure and discharge control valve, and the automatic control valves should be sumitted to overhaul in the same way as the pumps. The motors require practically no overhaul, but it is recommendable to replace periodically the bearings, coupling between pump and motor, etc. In the case of disassembly and assembly of the high-pressure pump, it should be submitted to performance test and the relevant data should be recorded for the sake of reference during the operation. The same considerations referring to the overhaul of the high-pressure pump are applicable to the overhaul of the power recovery turbine.

(2) Main facilities of the evaporation process

(a) Control procedure in the case of starting/stopping the plant

① Preparations for operation

The following points should be checked prior to starting the operation.

- Make sure that the accessory equipment are filled with the required quantity of lubricating oil and grease.
- Make sure that compressed air for control purposes has the prescribed pressure and is free of humidity.
- Make sure that the control valves operate correctly.
- Make sure that the rotary equipment rotate smoothly by manual operation.
- Set the opening of the valves at the prescribed positions.

② Management in the case of stopping the plant (stopping operation)

The operation of the equipment should be stopped in accordance with the operating instructions. The corrosion protection measures require special attention in the case of prolonged stoppage. These measures are described in a separate section.

(b) Management during the operation

Appropriate monitoring and countermeasures to cope with abnormalities are required in order to realize the prolonged continuous operation without stopping the equipment. Should an appropriate monitoring be carried out without interruption, it will be possible to discover with ease any deviation from the steady state and furthermore it will be possible to restore the normal conditions of operation with slight corrections. The points requiring management during the operation are as follows.

① Collection of data.

② Inspection of measurement instruments such as pH meter, dissolved oxygen meter, etc., for correctness of the readings.

③ It is recommendable to clean the strainer and to check the operation of the drain trap at fixed periods.

④ Replenish each pump, motor, etc., with the required quantity of grease, lubricating oil, etc.

⑤ Check the liquid level of each tank.

⑥ Take measures for early discovery of abnormal sounds.

(c) Prolonged custody

It is recommendable to take the following measures for corrosion protection of the equipment.

① Remove completely the drain of the equipment in the case of stopping the operation.

② Flush the interior of the equipment by circulating fresh water.

③ Dry the interior of the equipment after flushing them.

④ Put desiccant in the interior of the equipment and seal them after drying.

In addition to the aforementioned measures, the interior of the equipment can be filled with inert gas such as N_2 in order to provide the required protection.

4) Piping and pump

(1) Piping

Troubles that could obstruct the operation of the plant are very rare in the piping, because they have no movable parts. However, troubles such as leak caused by the progress of corrosion, increasing resistance of the piping due to the adherence of scale, may bring about the impoverishment of the efficiency of the facilities after long time of operation. The piping should be flushed periodically or adequate measures should be taken in order to prevent the adherence of scale. Should the occurrence of corrosion be suspected, it is recommendable to provide adequate management by carrying out wall thickness inspection and other applicable measures.

(2) Pump

Any trouble or accident in the pump has a wide range of

influence, and the operation of the desalination plant as a whole may become impossible in the worst case. Therefore, the pump should be handled with sufficient care and the routine maintenance and management should be carried out without fail.

(a) Handling the pump

① Precautions prior to starting the pump

- Make sure that the bearings are filled with the prescribed quantity of grease or lubricating oil. In the case of forced lubrication, make sure that the lubricating oil has the prescribed pressure. Check the rotary parts of the equipment for smooth manual operation.
- Open completely the valves of the small pipings such as liquid injection pipes and balance pipes of cooling water systems and mechanical seals, lubricating water pipe of bearings, etc., and make sure that the required quantity of cooling water and lubricating water are supplied with the required pressure.
- Open completely the valve located at the suction side pipeline.
- Prepare the pump for operation by priming it.
- Preheat the high-temperature pumps by gradually pouring high-temperature liquid.
- The centrifugal pump and the mixed-flow pump are normally started with the discharge valve completely closed. Submersible pump is started with the discharge valve slightly open.
- In the case of the centrifugal and mixed-flow pump the discharge side valve should be opened after the rise of pressure at the rated revolution speed. It is necessary to take care not to operate the pump for a long time with the discharge valve closed, because otherwise the temperature of the liquid contained in the pump rises, resulting in its evaporation which brings about its idle running and troubles such as seizing, etc.

② Precautions during the operation

- Inspection of the bearing

  In the case of oil-ring type lubricating system, it is necessary to check the oil ring for normal operation. In the case of bearings requiring cooling water, the temperature and quantity of cooling water, in order to prevent the bearing temperature from rising 40°C or more above the normal room temperature.

- Attention should be paid to the temperature and leak at the gland

  In the case of excessive leak, the packing holder should be gradually tightened, by taking care to prevent uneven tightening. On the other hand, when the temperature is abnormally high, the packing holder should be loosened in order to allow a rather large leak. The pump should be operated for a period of time under the said conditions, and then the packing holder should be tightened again after the packing getting fit.

- Check the pump for abnormal sound.
- Check the pump for excessive vibration.
- Check the operation for abnormalities in the discharge pressure, suction pressure, discharge and current.

③ Precautions in the case of stopping the operation

- Normally, the centrifugal pump is stopped after completely closing the discharge valve, Refrain from closing the suction valve prior to stopping the pump.

  In the case of the axial flow pump, the motor is normally stopped after draining water by opening the vacuum breaker, because this kind of pump is normally installed in siphon-type pattern.

- In the case of machines not equipped with foot valve, water contained in the pump is returned to the suction tank by opening the vacuum breaker simultaneous with the stoppage of the operation.

- In the case of pumps using cooling water the cooling water valve should be closed after stopping the operation.
- It is recommendable not to stop sealing liquid of the shaft seal part while there is liquid in the interior of the pump.
- In the case of power stoppage during the operation of the pump, the power switch should be turned OFF in the first place, and the discharge valve should be manually closed at the same time. In the case of the axial flow pump the vacuum breaker should be opened prior to closing the discharge valve.

④ Other precautions

- The liquid contained in the pump should be discharged in the case of stopping the operation for long time. Furthermore, the finished surfaces of the bearing, shaft, packing stopper, shaft joint, etc., should be coated with oil or any other anticorrosive.
- The reserve pump should be maintained ready to operate at any time. When the reserve pump is left still for long time its interior may be rusted, becoming unable to operate. Therefore, it should be operated approximately once a week in order to maintain it ready to function at any time.
- The pump should not run idle even for a short time. In the case of the axial pump however, it can be run idle if the underwater shaft part and the gland part are sufficiently lubricated, because it has no underwater friction part.

(3) Valve

The manual valves should be checked for leak from the gland packing. In the case of any leak the packing stopper should be tightened further. The automatic valves should be operated and inspected periodically for correct and reliable operation. After using the valves for long time it is recommendable to disassemble and check them for abrasion, corrosion and leak.

5) Maintenance and management of electrical equipment and instrumentation

(1) Electrical equipment

When the maintenance of the electrical equipment is imperfect, any partial accident or trouble exert influence not only on the parts they are occurring, but also on other sound systems, with risk of total power stoppage which could result into serious troubles in the desalination plant itself. Therefore, the maintenance of the electrical system should cover all equipment, without neglecting even the smallest unit or apparatus, by taking utmost care with every detail.

Therefore, the mechanism and peculiarities of the electric equipment should be perfectly known, and the operation should be carried out accordingly. Furthermore, the routine patrolling inspection, periodic inspection, accurate internal inspection should be carried out without fail, in order to guarantee perfect inspection and maintenance in accordance with the check list.

As for the equipment in operation, it is necessary to carry out the diagnosis and measurement of abnormalities of mechanical and electrical nature by means of appropriate instruments such as vibration meter, hot-line temperature detector, E-I detector, etc.

(2) Instrumentation

The mechanism and characteristics of the equipment and apparatuses of the desalination plants should be perfectly known and they should be operated accordingly in order to give full play to the functions of the instrumentation. Furthermore, instrumentation should be submitted to perfect maintenance management through the careful execution of routine inspection and calibration, periodic inspection, etc. The term "maintenance management" means to compensate drops in the functions of the instrumentation, and to maintain their original functions, and is carried out with the purpose of minimizing the effects of troubles, if any. For this purpose it is necessary to establish an adequate process of operation and maintenance, and to pay special attention to the development of the capacity, improvement of

comprehension, acquisition of legal qualification, training, etc., of the required personnel. In particular, attention should be paid to the following points of the maintenance management in order to maintain the functions of the equipment in conformity with the purposes of the instrumentation.

① To minimize troubles of the equipment

② To reduce as much as possible the duration of idle time due to troubles

The reduction of troubles of the equipment, i.e., improvement of its reliability requires special care. The equipment should allow an easy inspection in order to shorten as much as possible the duration of idle time due to trouble. Furthermore, it is necessary to upgrade the global ease of maintenance, i.e., maintainability, including subsidiary aspects such as complete stock of spare parts and repair tools.

6) Posttreatment facilities

Posttreatment facilities require no routine attention in particular, with exception of the management of chemicals in the chemical injection equipment and maintenance management of rotary equipment such as pumps, blowers, etc. In the case of replenishing chemicals, care should be taken in connection with the control of the concentration, in addition to the replenishing quantity itself. Limestone used for the purpose of adjusting hardness is a kind of filler, but it must be replenished periodically because it is consumed concurrently with the passage of water.

7) Accessory facilities

Accessory facilities of a desalination plant consist principally of water quality analysis facilities, buildings, corridors, stands and heat-insulation/coating. Generally speaking these facilities require the same kind of maintenance management as those ones of ordinary water treatment facilities. Therefore, the same maintenance measures are applicable, with exception of the protective measures to cope with damages caused by salt in the case of facilities located at the vicinity of the seashore.

(1) Water quality analysis facilities

The maintenance management of water quality analysis facilities is classified in 2 types, i.e., the maintenance

of an appropriate stock of reagents, chemicals and other articles of consumption, and the management of the measurement instruments.

(2) Maintenance management of the coating

Most of the desalination facilities are located at the vicinity of the seashore, and therefore they are prone to accelerate the corrosion, because they are exposed to corrosive environment containing salt. Furthermore, they are exposed to the risk of oxidation of piping and surface of equipment due to the leak of salt water from seals of valves and pumps. Therefore, the importance of the coating should be always borne in mind and renewed whenever occasion calls. The epoch of renewing the coating depends on the place where the facilities in question are installed. Generally speaking however, in the case of steel material the painting cost can be saved by renewing the coating when rust appears on approximately 20% of the painted surface.

(3) Maintenance control of heat insulation

Generally speaking, the smaller the bulk specific gravity of the material, the better its heat insulating capacity and as a consequence in most of the cases the strength is far lower compared with structural materials. They are often used in form of composite materials consisting of heat insulator material and lining material because the strength is not sufficient when used individually. Heat insulator of synthetic plastic type is used frequently when the temperature is relatively low of the order of 120-130°C. Inorganic heat insulators such as glass wool, rock wool, calcium silicate, etc., are used in the case of higher temperatures.

The maintenance of heat insulator requires different precautions in accordance with its properties. For example, the heat insulating effect is intensely impoverished by water in the case of materials with high water absorption. Therefore, when materials of this kind are moistened due to leak of piping, infiltration of rain water etc., it is necessary to remove the cause of the moisture or to replace the moistened part with water resistant heat insulator.

Depending on the equipment it is necessary to remove the heat

insulator in the case of overhaul and replacement of parts. In these cases the heat insulator which was perfect when the equipment was constructed anew is gradually damaged as a consequence of the repeated disassembly and inspection. These facts bring about the functional impoverishment of the equipment, and therefore the heat insulator should be restored to its best state.

In the case of plastic-type materials it is necessary to check approximately once every 2-3 years, because it tends to shrink after prolonged use. Furthermore, attention is required in the case of plastic-type materials, because in presence of water they may elute matters that could cause the corrosion of steel materials.

APPENDIX

1. Reply to the New SWCC Proposals

2. Minutes of Meeting

3. List of Equipments for RO Test Plant

4. Table of Instrument and List of Equipments for MSF Test Plant

5. List of Laboratory Equipments

1. Reply to the New SWCC Proposals

THE TECHNICAL COOPERATION
FOR
THE PROJECT (RESEARCH)
ON
SEA WATER DESALINATION TECHNOLOGY
IN
THE KINGDOM OF SAUDI ARABIA

REPLY TO THE NEW SWCC PROPOSALS

JULY 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

Reply to the New SWCC Proposals

1. The new SWCC proposal showed us that they are now intending to broaden the scope of activities of the Research Center to be established as part of the agreed bilateral cooperation project. The Center is thus expected to be a central research institution of the Western Region's sea water desalination as well as power generation. The proposals includes such new subjects of research as boilers, air pollution, sea water pollution, medical sciences, etc.

2. In formulating the current project of cooperation, both Saudi Arabian and Japanese sides have agreed that the focal point of cooperation would be the training of researchers, the number of which is still small at present. Thus, the project intends to provide the persons concerend with the opportunities to acquire the methodology and techniques of research through basic experiments and studies. Then, the following stages would be to foster the capabilities to manage technical problems that occur in the actual operation of the plants.

   However, in order to implement the new SWCC proposal, it is likely that many qualified researchers would be required. Such a program is not basically viable until the researchers are properly trained. From the viewpoint of bilateral cooperation, the consistency of the proposal with the project's framework remains unclarified.

3. With respect to the facilities of the Research Center, however, it may be reasonalble, as Mr. Najjar has suggested, to include in its design the spaces and structures which the future scope of the Center's activities will require.

   However, since no specific research has been conducted, it is difficult, at present, to determine the depth or methods of respective fields of research activities, as mentioned in the new proposal. Also, even if their determination is possible, there is the possibility that the present project

may result, beyond our expectations, in certain alterations to the use of the Research Center.

Since the scope of the proposed research activities needs to be materialized further, we should jointly make an in-depth study on the background and necessity of the new activities. After the consensus is obtained as to such proposed activities, concrete ideas about the outline of each research work, staffing, spacing and so on will be determined in the form of JICA's recommendation.

# # #

Item	Applicable Area	Contents of Request	Ambiguous Points in the Contents of Request	Results of Review
A	MSF	1. MSF research on monitoring corrosion	The meaning of the term "monitoring"	(1) If "monitoring" means the centralized management in Yambu of the West Coast desalination plants, it would not be possible for the following reasons: 1) The study of corrosion is usually conducted at each plant by attaching a probe in a water box and so on to "monitor" and measure current density or by attaching a metal specimen to the evaprator, which is checked for corrosion at regular shut down times. 2) Corrosion and scale formation can be detected by any abnormal signs (for example, an unusual rise in temperature or decrease in product water) and then immediately the necessary measures are taken at each plant.
		2. MSF research for monitoring scale formation	1) The meaning of the term "monitoring"	(1) Since plant specifications vary from one unit to another and data required would be enormous, requiring a very much time for analysis, it may not practicable to attempt centralized "monitoring". (2) In order to prevent scale formation, in general, each plant operates within the critical points in consideration of the relationship between the solubility product and the operating temperature on the basis of previous data. (3) Centralized "monitoring" is not possible for the same reasons as stated in 1.(1).2).

		3. MSF research for monitoring the efficiency of plants		(1) Centralized "monitoring" is not practicable for the same reason as stated in 2.(1). (2) In general, data is recorded at respective plant. Counter-measures should be taken immediately at the site. (3) Operation and research using a pilot plant for the Center would provide information that would identify those factors influencing the optimum operating conditions and desalination efficiency. As for the above 1., 2. and 3., it is possible for the Research Center to analyse the results and data recorded at respective plants.
B	RO	1. RO plants for monitoring all types of membranes, i.e. spiral wound, hollow fiber and tubular-type water treatment plant	The meaning of "RO plants for monitoring..."	(1) Centralized "monitoring" is not practicable for the same reason as stated in A.2.(1). (2) "Monitoring" at respective plants is possible, however, if it is to be conducted in existing plants, equipment costs would be extremely high.
C	MSF, RO	1. To investigate and study the intake of sea water both chemically and bacterologically, as well as in terms of pollution	How the research conducted be reflected in the operation of the plant.	(1) Generally, the problem of water quality in normal sea water can be solved by employing the pretreatment techniques. (2) There has been little research conducted on polluted sea water (e.g. oil spills). (3) With respect to bacterological research, the Japanese side had not considered this topic to be included in the subjects of joint research so far. Therefore, the Japanese support group for the current project does not include specialists, and is thus incapable of making any comments. This research should be considered as another project by SWCC.

D	MSF, RO	1. To study the affect of potable water of MSF and RO and its effects on human beings by assisting hospital laboratories		(1) If research in this area is conducted, it would require large-scale facilities using experimental animals, and specialists in the field of medicine. This research should be considered as another project by SWCC.
E	MSF	1. To investigate and monitor corrosion in boilers, condensers, water pipes, pipelines to cities, and corrosion in fuel tanks and fuel pipelines		(1) Centralized "monitoring" is not possible for the same reasons as stated in A.(1). (2) In Japan, it is obligatory to conduct regular inspections to check the state of corrosion. (3) Electrolytic protection provided at the time of construction is the only measure taken against corrosion.
F	MSF	1. To study and investigate fuel content and efficiency		(1) This would require a specialist on boiler technology.
G	MSF	1. To investigate and study boiler soot and the smoke from the stack or chimney and air pollution caused by fuel smoke		(1) Many research activities in this field have already been conducted in Japan, and the emission standard has been set. (Information will be supplied separately.) It seems unnecessary to repeat the same process of research.

H	MSF	1. To study and investigate sulfuric acid and chemicals of low temperatures and high temperature from the chemical corrosion point of view as well as the economical point of view for capital costs and running costs		(1) Since an incorrect amount of the chemicals injected could be hazardous, the amount of injection and the types of chemicals are determined in consideration of previous experiences, research results as well as economy, at the time of design. Therefore, it is preferred that this type of research be conducted in a pilot plant, similar to the test plant of the current project, rather than in an existing plant.
I	MSF, RO	1. To study and investigate the brine water of the out-flow channel to the coast, and the effects on and pollution of the sea water and marine life		(1) Waste water discharged from plants is treated so as not to affect and pollute the sea water and marine life. (2) The research for the diffusion of waste water is conducted by chemical research laboratories and power generation plants in Japan.

2. Minutes of Meeting

Minutes of Meeting

A meeting was held between the delegation of JICA and SWCC from August 27-29, 1983. A list of members attending the meeting is attached as appendix (1).

The Japanese side presented an agenda for the meeting which was discussed in detail. The Agenda is attached as appendix (2).

The Japanese side explained about the financial matters concerning the procurement of the test plants and the laboratory equipment. According to the Japanese Govt. rules,

1. All the procurement and shipping work for which JICA budgets in one fiscal year should be completed within the same fiscal year of Japan. (April - next year March.)

2. Test plants and a part of laboratory equipments will take around nine months to procure in Japan and about three months for transportation to the Kingdom.

3. It is necessary for JICA to begin the procedure to procure them at the beginning of Japanese fiscal year. (It would be April 1984 at the earliest)

4. The procurement of test plants and equipments will take about two fiscal years.

SWCC emphasized that the test plants will have priority in procurement.

The Japanese side enquired about the schedule of construction such as the award of contract for detailed design and its duration and award of contract for construction and its duration. SWCC informed the Japanese side that JICA will be informed in the near future about the schedule of construction and again emphasized the importance of awarding a single contract for the Research and Training facility for both detail design and construction.

JICA is ready to dispatch Japanese architect/engineer at the time of SWCC's

implementing detailed design in order to explain the conceptual design to the consultant which will be soon selected by SWCC. JICA will be informed of the selection of the consultant when they are invited to bid on this project.

SWCC mentioned that the details of the test plants and the equipment to be installed should be provided at the earliest so that the consultant can design accordingly the connections for utilities and also any special design for foundations. The JICA will provide the details about the equipment in about three months.

As for the SWCC's new requests submitted by Mr. Najjar in Tokyo on April 27, 1983, the mission explained JICA opinion to SWCC on a basis of the "Reply to the SWCC proposals (requests)" submitted to SWCC by JICA in July 1983. This center should accomodate for:

1. Prevention Study of Corrosion and Scale Deposition.
   Examination of typical corrosion phenomena and scale deposition mechanism in the various desalination environment, and confirmation of preventing methods for corrosion and scale deposition by long term operation of MSF Test Plant using both brine recirculation and once through.

2. R.O. Study
   Examination of durability and performance of R.O. module available in the market in the natural conditions of the Kingdom of Saudi Arabia, and standardization of selecting procedure of suitable modules.

3. Chemical Study
   Study on chemical analysis of corrosion products, scale deposition and water quality.

SWCC emphasized the importance of having a person nominated from JICA to be a co-ordinator who will attend all meetings either in Japan or in Saudi Arabia in order to have some one who knows about the progress taking place under the R/D and to have continuity.

Isam M.R. Jamjoom
Deputy Governor
for Projects & Technical Affairs

Yoshio Murayama
Leader
Japanese Mission
for Research Project

Appendix (I)

Member List of JICA Mission (for Research)

MURAYAMA Yoshio	Leader
MATSUSHIMA Tomoo	Sub-Leader
TOGANO Hideo	Corrosion Specialist
KIJIMA Jiro	Process Engineer (RO)
HARADA Toshio	Civil & Architectual Engineer
KOJITANI Toshio	Civil & Architectual Engineer
MIURA Michio	Process Engineer (MSF)
TSUJI Norio	Chemical Engineer & General Affairs
HIRANO Masaki	Technical Official Technical Cooperation Division MITI
NAGATA Kuniaki	Coordinator Mining & Industrial Planning and Survey Department JICA

Member List of SWCC

Mr. Saeed M.N. Najjar	Director of Research, Western Region
Mr. Hassan Al-Dow	Western Region
Mr. Habeeb Mohammed	Chemical Engineer, Dept. of Research
Mr. Syed A. Hawary	" " " " "

Appendix (2)

1. Purpose of the Mission (Research)

a. To discuss on the construction schedule of Research Center including the installation of test plants, laboratory equipment and other facilities, and to confirm the outline of the schedules.

b. To discuss on the suitable time of dispatching Japanese specialists to assist SWCC in selecting architect engineers and construction contractor, and to confirm the schedule outline.

c. To explain the results of our technical study and examination concerning the SWCC's new proposals.

2. Agenda

August 27

9:30-10:00	Meeting with SWCC Vice Governor, Issam Jamjoom (Training and Research)	
10:00-14:00	Discussion : construction schedule and SWCC's new proposals etc.	

August 28

9:00-14:00	Discussion : ditto	(Research)

August 29

9:00-14:00	Discussion : ditto	(Research)

August 30

9:00-12:00	Preparation for Minutes	(Research)

August 31

9:30	Signature on Minutes (signed by Mr. Jamjoom and Mr. Murayama)	(Research)

3. List of Equipments for RO Test Plant

List of Equipments for RO Test Plant

1. Sea Water Pretreatment Equipment Section-100			
Item	Equipment Name	Specification	Q'ty
T-101	Seawater intake tank	Vertical, cylindrical, and closed type	1 set
	Material	Polyethylene	
	Capacity	3 m^3	
	Accessories	Level indicator, overflow pipe, drain valve, ladder, man-holes, anchor bolts, etc.	
T-102	Filtered sea water tank	Same as T-101	1 set
	Capacity	10 m^3	
F-101AB	Filter	Pressured dual media layer filter	2 sets
	Material	Steel inside of filter lining with rubber sheet	
	Media	Gravel-Sand-Anthracite	
	Accessories	Manhole, nozzles, piping, sight glass, etc.	
P-101	Sea water pump	Volute centrifugal pump	1 set
	Material	SCS14/SUS316	
	Motor	Outside 220V x 3ϕ x 60Hz x 3.7kW, TEFC, insulation class JIS E	
	Accessories	Common bed, coupling etc.	
P-102	Back washing pump	Pumps type and material is same as P-101.	1 set
	Motor	Outside, 220V x 3ϕ x 60Hz x 2.2kW, TEFC, insulation class JIS E	
P-103	Back washing air blower	Roots blower, three blade helical	1 set
	Material	Cast iron	
	Motor	Outside 200V x 3ϕ x 60 Hz x 1.5kW, TEFC, insulation class JIS E	
	Accessories	Common bed, V belt/pulley, silent cleaner, relief valve etc.	

Item	Equipment Name	Specification	Q'ty
P-105	Waste pump	Volute centrifugal pump	1 set
	Material	Stainless steel SCS-14 (SUS-316)	
	Motor	Outside, 220V x 3ϕ x 60Hz x 1.5kW TEFC, insulation class JIS E	
UV-101	UV sterilizer	Ultra violet ray type	1 set
	Capacity	7.5 m^3/h	
	Material	Hard glass, SUS 316	
	Accessories	Setting bed, controller, etc.	
FI-101 - 103	Flow indicator	Rotor-meter type For sea water feed, back washing, back washing air	3 sets
	Material	SUS 316 or plastic	
PI-101 - 106	Pressure indicater	Bourdon tube type	8 sets
	Material	SUS 316, plastic	
	Piping & valve	Class JIS 10K type	1 set
	Material	Plastic pipe & fitting	
	Valve	JIS 10K type gate, ball valve plastic made	
	Automatic valve	JIS 10K air torque cylinder type diaphragm valve	
		Steam pressure regulating valve (PVC)	
		Heated steam automatic shut down valve (TASV)	
		Cast iron line with rubber made Sample valve, etc.	
		Strainer, Steam trap, etc.	
	Indicator board	Pressure & flow indicators setting	1 set
	Material	Steel	
	Skid	Shape steel made	1 set
	Accessories	Anchor bolt, others	
		Note: Instruments such as LSA-101, 102, 103 AB etc. are listed in Section 700.	

Item	Equipment Name.	Specification	Q'ty
P-104	Air compressor	Oilless baby compressor	1 set
	Discharge pressure	7 kg/cm^2, automatic pressure control	
	Motor	Outside, 220V x 3ϕ x 60Hz x 4P x 2.2 kW, TEFC, insulation Class JIS E	
	Accessories	Bed, V belt/pulley, air receiver, safety valve, etc.	
2. Fouling Index Automatic Indicating Recorder			
FIR-101	FI meter	Automatic sampling, measuring, indicating and recorder for filtered seawater fouling index	1 set
	Sampling & measuring part	Automatic operation	
	Controlling part	Digital printer, sequence controller	
	Power source	100V x 1ϕ x 60Hz x 0.5kW	
3. Chemical Feeder Section-500			
T-501	Sodium hypochlorite solution tank (NaHClO)	Square type 200 l capacity	1 set
	Material	Plastic	
	Accessories	Level indicator, etc.	
T-502	Ferric chloride solution tank ($FeCl_3$)	Same as T-501	1 set
T-503	Sulfuric acid solution tank (H_2SO_4)	Same as T-501.	1 set
T-504	Sodium bisulfate solution tank	Same as T-501.	1 set
P-501AB	Sodium hypochlorite injection pump	Constant flow injection diaphragm pump	2 sets
	Accessories	Pump bed, pump cover, etc.	
	Motor	220V x 3ϕ x 60Hz x 0.03kW, Tropical insulation treated	

Item	Equipment Name	Specification	Q'ty
P-502	Ferric chloride injection pump	Same as P-501.	1 set
P-503AB	Sulphuric acid	Same as P-501. Note: P-503B pump operation (ON-OFF) is controlled by PHRA-301.	2 sets
P-504ABC	Sodium bisulfate injection pump	Same as P-501. Note: 1) P-504B pump operation is controlled by DORA-201 and timer program. 2) P-504AC pumps inject 40 ppm SBS for normal operation, P-504B inject 500 ppm SBS for shock treatment.	3 sets
	Piping & valve	Pump suction valve (non-return with strainer) Pump delivery valve (non-return with siphon protector) Braid hose, hose band, etc.	1 set
	Mixing bar Material	For chemical tank PVC	4 sets
	Skid Accessories	Shape steel made Anchor Bolts, others Note: 5 tanks (one is S/P tank) and 8 pumps shall be installed and mounted on the same skid.	1 set
4. Spiral wound type Reverse Osmosis Equipment Section-200			
T-201	Feed tank Material Capacity Accessories	Vertical, cylindrical, closed type Polyethylene 1.5 m^3 Level indicator, nozzles, overflow pipe, drain valve, manhole, bolt-tap, anchor bolt, etc.	1 set

Item	Equipment Name	Specification	Q'ty
T-202	Permeate tank	Vertical cylindrical, closed type, and polyethylene make.	1 set
	Capacity	1.0 m^3	
	Accessories	Level indicator, nozzles, overflow pipe, drain valve, anchor bolt, etc.	
P-201	Feed water supply pump	Centrifugal pump	1 set
	Material	SCS-14	
	Motor	Outside 220V x 3ϕ x 60Hz x 1.5kW, TEFC, insulation class E	
	Accessories	Common bed, coupling, etc.	
P-202	Booster pump	Centrifugal pump	1 set
	Material	SCS-14	
	Motor	220V x 3ϕ x 60Hz x 3.7kW	
	Accessories	Common bed, coupling, etc.	
P-203	High pressure pump	Variable flow 20 - 100%, triplex plunger pump	1 set
	Material	SCS-14/SUS-316	
		Plunger: Ceramic coating	
	Motor	220V x 3ϕ x 60Hz x 300 - 1,375rpm x 15kW, VS motor, TEFC, insulation class E	
	Accessories	Common bed, driving system, relief valve, accumulator, etc.	
HE-201	Feed preheater	Plate type heat exchanger	1 set
	Capacity	45,000 Kcal/h	
	Design pressure	5 kg/cm^2	
	Material	Heating surface; titanium or equivalent equal	
HE-202	Feed heater	Plate type	1 set
	Capacity	Steam supply : max. 90 kg/hr : saturated steam of 8 $kg/cm^2/g$	
		Supply water temperature is to be automatic-controlled up to max. 50°C	
	Material	Titanium or equivalent equal	
	Design pressure	5 kg/cm^2	

Item	Equipment Name	Specification	Q'ty
UV-201	UV sterilizer	Ultra violet ray type	1 set
	Capacity	3.5 m^3/h	
	Material	Hard glass, SUS 316	
	Design pressure	5 kg/cm^2	
	Accessories	Setting bed, controller, etc.	
F-201AB	Safety filter	Cartridge filter type	2 sets
	Capacity	3.5 m^3/h x 20 micron	
	Material	Filter element: polypropylene	
		Housing: Polycarbonate	
	Design pressure	5 kg/cm^2	
RO-201ABC	RO membrane moduel		1 set
	RO membrane element	Spiral wound type 8"ϕ x 6 elements	
	RO vessel	FRP made 2 elements x 3 vessels	
		Max. applied pressure x temperature 70 kg/cm^2 x 50°C	
	Accessories	RO element/Vessel parts	
FI-201 - 202	Flow indicator for permeate, brine	Rotor meter type panel mounted	2 sets
	Material	Taper tube-hard glass	
		Other: SUS 316 or plastic	
PI-201 - 206	Pressure indicator	Bourdon tube type panel mounted D model	6 sets
	Material	SUS 316/plastic case	
		Note: PI-204, 205 are vibro-isolating type	
TI-201 - 204	Thermometer	Local mounted scale 0 - 100°C with protecting tube, SUS 316 made	4 sets
PSA-201	Pressure switch	Bellows or bourdon tube type	1 set
	Material	SUS 316	
	Setting pressure	0 - 3 kg/cm^2	1 set
	Indicator board	Steel plate is stainless steel.	1 set
		Mount pressure, flow indicators, pressure switch and name plate, etc.	

Item	Equipment Name	Specification	Q'ty
	Piping & valve	High pressure side Stainless steel pipe SUS-316 TP, high pressure rubber hose, victaulic coupling, flange and fitting, valve Valve: 600 Lbs type stainless steel made Low pressure side Plastic pipe, rubber, plastic hose, JIS 10K flange and fitting, valve: JIS 10K plastic made ball, globe, gate valve, etc. Sampling valve: stainless steel, plastic made Automatic control valve, Diaphragm valve, drain trap, etc.	1 set
	Skid Accessories	Shape steel made Anchor bolt, others Note: Instrument such as TC-201, TR-201, DORA-201, CR-201, LSA-201, TA-201 etc. are listed in SECT-700.	1 set
	Special parts	Setting parts for other foreign spiral wound RO module Note: Other module (RO element) is U.S.A. UOP Fluid System model TFC-1501 PA	1 set
5. Hollow fiber type Reverse Osmosis Equipment Section-300			
T-301	Feed tank Material Capacity Accessories	Vertical, cylindrical closed type Polyethylene 1.5 m^3 Level indicator, nozzles, Overflow pipe, drain valve, manhole, ladder, ball-tap, anchor bolt, etc.	1 set
T-302	Permeate tank	Same as T-202 Note: Without ball-tap	1 set

Item	Equipment Name	Specification	Q'ty
P-301	Feed water supply pump	Centrifugal pump	1 set
	Material	Stainless steel casting SCS-14	
	Motor	Outside 220V x 3ϕ x 60Hz x 1.5kW, TEFC, insulation class E	
	Accessories	Common bed, coupling, etc.	
P-302	Booster pump	Centrifugal pump	1 set
	Material	SCS-14	
	Motor	220V x 3ϕ x 60Hz x 3.7kW	
	Accessories	Common bed, coupling, etc.	
P-303	High pressure pump	Variable flow 20 - 100%, triplex plunger pump	1 set
	Material	SCS-14/SUS-316	
		Plunger: ceramic coating	
	Motor	220V x 3ϕ x 60Hz x 300 - 1,375 rpm x 15kW, VS motor, TEFC, insulation class E	
	Accessories	Common bed, driving system relief valve, accumulator, etc.	
HE-301	Feed preheater	Same with HE-201	1 set
HE-302	Feed heater	Same with HE-202	1 set
UV-301	UV Sterilizer	Ultra violet ray type	1 set
	Capacity	3.5 m^3/hr	
	Material	Hard glass and stainless steel	
	Deisgn pressure	5 kg/cm^2	
	Accessories	Setting bed, controller etc.	
F-301AB	Safety filter	Cartridge filter type	2 sets
	Capacity	3.5 m^3/h x 10 micron meter	
	Material	Filter element: polypropylene	
		Housing: Polycarbonate	
	Design pressure	5 kg/cm^2	
RO-301AB	RO membrane module	RO membrane module: Hollow fiber type	1 set
		2 elements (8" ϕ) x 1 module	
		1 element (8" ϕ) x 1 module	
		Max. applied pressure x temperature 65 kg/cm x 50°C	

Item	Equipment Name	Specification	Q'ty
F1-301 - 302	Flow indicator	Rotor meter type panel mounted For permeate, brine	2 sets
	Material	Taper tube: Hard glass	
		Other: Stainless steel or plastic	
PI-301 - 306	Pressure indicator	Bourdon tube type panel mounted model D	6 sets
	Material	Stainless steel/plastic case	
		Note: PI-304 - 305 are vibro-isolating type	
TI-301 - 304	Thermometer	Local mounted scale 0 - 100°C with protecting tube SUS-316 made	4 sets
PSA-301	Pressure switch	Bellows or bourdon tube type	2 sets
	Material	Stainless steel	
	Setting pressure	0 - 3 kg/cm^2	
	Indicator board	Steel plate or stainless steel.	1 set
		Mounted pressure, flow inciators pressure switch, and name plate etc.	
	Piping & valve	High pressure side	1 set
		SUS-316 TP, high pressure rubber hose, victaulic coupling, flange and fitting	
		Valve: 600 Lbs type stainless steel made	
		Low pressure side	
		Plastic pipe, rubber and plastic hose, JIS 10K flange and fitting	
		Valve: JIS 10K type plastic made ball, glove, gate valve, etc.	
		Automatic control valve (CV), diaphragm valve, drain trap etc.	

Item	Equipment Name	Specification	Q'ty
	Skid	Shape steel made	1 set
	Size	Approx. 3,000 L x 2,000 W mm	
	Accessories	Anchor bolt, others	
		Note: Instruments such as TC-301, TR-301, PHRA-301, CR-301, LSA-301, TA-301 are listed in SECT. 700.	
	Special parts	Setting parts for other foreign hollow fiber type RO module.	1 set
		Note: Other module is U.S.A. DuPont Permasep B-10 model 6840-060 x 1 module.	
6. Cleaning Equipment for RO Membrane Module Sectin-600			
T-601	Cleaning tank	Portable cylindrical, vertical, closed type	1 set
	Capacity	500 l	
	Material	Polyethylene	
	Accessories	Level indicator, nozzles, manholes, etc.	
	Piping & valve	Portable type	1 set
	Material	Plastic hose, JIS 10K type, valve plastic made	
7. Electrical Equipment and Instrumentation Section-700			
MCP-701	Motor control panel	Self-supporting indoor use type	1 set
	Size	Approx. 3,000W x 2,350H x 800D mm	
		Attached apparatus	
		Main molded case circuit breaker, distribution molded case circuit breaker, pilot lamp, magnetic contactor, thermal relay, VS controler, VS operator, VS system module etc., pilot pilot lamp (running), annunciator lamp for operation switch, (change over switch, push button switch), auxiliary relay, auxiliary timer,	

Item	Equipment Name	Specification	Q'ty
		float less switch, flicker relay, off delay relay, announciator relay, buzzer, power control switch, hour meter for transformer 220/110V, panel inner lighting, name plate, terminal plate, inner wiring material.	
		Attached instrument	
		Feed pH recorder with alarm, temperature recorder, conductivity recorder, dissolved oxygen recorder with alarm (only mounted S.W. RO skid)	
MVP-701	Solenoid valve panel	Self-supporting indoor use type	1 set
		(attached in MCP-701 panel)	
		Back washing automatic valve for filter (F-101A)	
		Operating control panel	
		Attached apparatus	
		Solenoid valve, annunciator lamp, pilot lamp for valve (open-close), changeover switch (auto-manu), auxiliary relay, timer relay, off delay relay, etc.	
	Instrument		1 set
TR-201 301	Temperature recorder	2-pen recorder (range 0 - 110°C)	1 set
TC-201 301	Temperature controller	Temperature indicating-controlling instrument using air pressure	2 sets
DORA-201	Dissolved oxygen recorder with alarm	Electrode type recorder with alarm	1 set
		(range 0 - 5 mg/l DO_2)	
		Sensor, electrode holder,	1 each
		Special cable	1 set
PHIA-301	pH recorder with alarm	Glass electrode type recorder with alarm (range 0 - 14 pH)	1 set
		Electrode, electrode holder	1 each
		Special cable	1 set

Item	Equipment Name	Specification	Q'ty
CR-201 301	Conductivity recorder	2-pen conductivity recorder (range 0 - 1,000 uS/cm)	1 set
		Electrode	2 sets
		Special cable	1 set
LSA-101 201 301 103AB	Level switch	Conductivity type level switch	6 sets
TA-201 301	Temperature switch		
8. Piping and Wiring Materials			
	Scope of Supply for piping and wiring materials inside of battery limit shown in flow sheet and plot plan of this test plant.		
	Piping materials	Sea water intake pipe	1 set
		Waste, steam and concentrate discharge pipe, sea water, filtered water, product concentrate, etc. Pipes between each equipment and tank.	
		Chemical injection pipe	
	Material	10 - 80 mmø plastic pipe (PVC) and fitting JIS 10K class plastic flange.	
		15 - 25 mmø SGP & SUS-316 pipe & fitting, JIS 10K class	
		8 mmø plastic braid hose, vinyl hose, hose hand, pipe fitting, etc.	
	Valve	JIS 10K class, BC or FC, PVC	1 set
		Globe, ball, check valves,	
		Sampling valve, etc.	
	Other	Drain trap, strainer, etc.	
	Wiring material	Wiring material between control panel and electrical equipments and instruments.	1 set

Item	Equipment Name	Specification	Q'ty
	Power cable	CV cable type	
	Control cable	CVV cable type	
	Instrument cable	CVV cable type and special type	
	Wiring pipe	Steel pipe for wiring	
	Flexible wiring pipe	Flexible wiring pipe covered with vinyl	
	Supporting materials etc.		
	Pnumatic pipe air set	Hard vinyl pipe & fitting	
9. Apparatus and tool for Operation and Maintenance			
	Apparatus	Portable measuring instruments and mess cylinder, sampling bottle, etc. for daily operation and maintenance.	1 set
	Portable fouling index meter	Pressure water vessel, FI filter, baby compressor etc.	1 set
		Portable pH meter	1 set
		Portable conductivity meter	1 set
		Portable dissolved oxygen meter	1 set
		Portable residual chlorine meter	1 set
		Thermometer 0 - 100°C	2 sets
		Mess-cylinder, bottle, filter paper, etc.	1 set
	Tools	Tools for daily operation and maintenance	1 set
	Ordinary tool	Spanner, pench, hammer, driver, metal saw etc. and tool box.	
		Waste cloth, fitting material for piping, glue, seal gasket, maintenance paint etc.	
		Buckets	
	Special tool	Special tool for overhaul and fabrication of pump and RO module.	
	Spare parts and reagent	For one year operation.	1 set

Item	Equipment Name	Specification	Q'ty
10. Chemical for Operation and Maintenance			
	Chemicals for one year operation and maintenance		1 set
		Note: Not include chemicals (Sulfuric acid, sodium hypochlorite)	
	Ferric chloride	34% conc. $FeCl_3$ drum can	800 kg
	Sodium bisulfate	95% more conc. S.B.S. vinyl bag	2,400 kg
	Sodium hexameta-phosphate	98% more conc. S.H.MP. vinyl bag	200 kg
	Citric acid	98% citric acid vinyl bag	120 kg
	Ammonia	25% ammonia 20 l plastic bottle	60 l
	Formaline	34% Formaldehyde 20 l plastic bottle	100 kg
	Membrane treatment agent		1 set

4. Table of Instrument and List of Equipments for MSF Test Plant

Table of Instrument for MSF Test Plant

Measurement Place & Item \ Working Item	Local Indicator	Recorder	Control	Alarm	Emergency Working
1. Flow Measurement					
(1) Raw Seawater	o	o			
(2) Make-up Water		o	o		
(3) Recirculation Brine		o	o		
(4) Distillate Water		o			
(5) Condensate Water		o			
2. Flow Confirmation					
(1) Cooling Seawater to Ejector Condenser			o	o	Ejector driven steam stop, Annunciator
(2) Sulfuric Acid			o		
(3) Chemicals				o	Annunciator
3. Temperature Measurement					
(1) Raw Seawater		o			
(2) Heat Rej. Outlet Cooling Seawater		o	o		
(3) Ejector Condenser Outlet Cooling Seawater	o				
(4) Final Stage Inlet Make-up Water		o			
(5) Heat Rej. Inlet Recirculation Brine		o			
(6) B/H Inlet Recirculation Brine		o			
(7) B/H Outlet Recirculation Brine		o	o	o	Heating steam stop, Annunciator
(8) B/H Inlet Steam	o	o	o	o	Annunciator
(9) B/H Shell Steam		o			
4. Boss for Tempeature Measurement					
(1) Each Stage Brine	o				
5. Pressure Measurement					
(1) Raw Seawater	o				
(2) Each Pump Outlet	o				
(3) 1st Stage Inlet Brine	o				

Measurement Place & Item \ Working Item	Local Indicator	Recorder	Control	Alarm	Emergency Working
(4) 1st Stage Steam Chamber	o				
(5) 6th Stage Steam Chamber	o				
(6) Ejector Condenser Inlet Seawater	o				
(7) Ejector Driving Steam	o				
(8) B/H Heating Steam	o		o		
(9) B/H Shell Steam	o				
(10) Flash Tank	o				
(11) Boiler Steam	o	o			
(12) Flameless of Boiler				o	Annunciator
6. Level Measurement					
(1) Each Stage Brine	o				
(2) 6th Stage Brine	o		o		
(3) Each Stage Distillate	o				
(4) Brine Heater	o		o		
(5) Decarbonator	o		o		
(6) Deaerator	o		o		
(7) Ejector Condenser	o				
(8) Flash Tank	o		o		
(9) Sulfuric Acid Tank	o				
(10) Chemical Tank	o				
(11) Water Tank	o				
(12) Oil Tank	o				
7. pH Measurement					
(1) Make-up Water		o		o	Annunciator
(2) Recirculation Brine		o		o	Annunciator
8. Concentration Measurement					
(1) Product Water		o	o	o	Annunciator
(2) Condensate		o		o	Annunciator
(3) DO for Brine and Make-up Water		o		o	Annunciator

List of Equipments for MSF Test Plant

Item	Equipment Name	Specification	Q'ty
1	Evaporator		1 set
	Type	Cross tube type multi stage distillation	
	Capacity	20 m^3/D (in operation under pH control rated output)	
	No. of stage	Heat recovery section: 4 stages Heat rejection section: 2 stages	
	Operating system	Brine recirculation system (also operative as once-through system)	
	Scale control system	pH control system (also operable as chemical injection system)	
	Performance ratio	2.5 (rated output, pH control operation)	
	Material	Plate & partition : 90/10 Cu-Ni Tube 16 mmϕ x 1t : 90/10 Cu-Ni Tube sheet : 90/10 Cu-Ni Internal parts : 90/10 Cu-Ni Demister : SUS 316 Connection pipe between water-box : 90/10 Cu-Ni Pipe for brine loopseal : 90/10 Cu-Ni Pipe for distillate loopseal : 90/10 Cu-Ni	
2	Brine Heater		1 set
	Type	Shell & tube	
	Material	Shell : Carbon steel Tube 16 mmϕ x 0.5t : Titanium Tube sheet : 90/10 Cu-Ni Water box (with Anode): 90/10 Cu-Ni	

Item	Equipment Name	Specification		Q'ty
3.	Vacuum System			1 set
3-1	Ejector			1 set
	Type	Two stage jet steam ejectors		
	Material	Mixing chamber	: Cast iron	
		Nozzle	: SUS 304	
		Diffuser	: Cast Bronze	
3-2	Ejector Condenser			1 set
	Type	Shell & Tube		
	Material	Shell	: SUS 316	
		Tube 16 mmϕ x 0.4 t	: Titanium	
		Tube sheet	: Titanium	
		Water-box	: C.S + Neoprene Rubber Linning (3t)	
		Tube Support	: SUS 316	
4.	Deaerator & Decarbonator			
4-1	Deaerator			1 set
	Type	Vertical cylinder		
	Performance	DO concentration	: 20 ppb or less	
	Capability	8 m^3/h		
	Material	Shell	: C.S + Neoprene Rubber Linning (3t)	
		Internal parts	: SUS 316	
4-2	Decarbonator			1 set
	Type	Spray tray type		
	Performance	Decarbonation efficiency: 80% or more		
	Capability	8 m^3/h		
	Material	Shell	: C.S + Neoprene Rubber Lining (3t)	
		Internal parts	: SUS 316	

Item	Equipment Name	Specification	Q'ty
5	Pump & Motor		
5-1	Brine recirc. pump		2 sets (1 set is spare of warehouse)
	Type	Horizontal centrifugal	
	Capacity	Surplus 10% or more determined by Mf'R	
	Head		
	NPSH	0.5 m (NPSHav - NPSHreq)	
	Material	Casing, impeller : SCS 14	
		Shaft : SUS 316	
5-2	Make-up pump		2 sets (1set is spare of warehouse)
	Type	Horizontal centrifugal	
	Capacity	Surplus 10% or more determined by Mf'R	
	Head		
	NPSH	0.5 m (NPSHav - NPSHreq)	
	Material	Casing, Impeller : SCS 14	
		Shaft : SUS 316	
5-3	Distillate pump		2 sets (1 set is spare of warehouse)
	Type	Horizontal centrigual	
	Capacity	Surplus 10% or more determined by Mf'R	
	Head		
	NPSH	0.5 m (NPSHav - NPSHreq)	
	Material	Casing, impeller : SCS 13	
		Shaft : SUS 304	
5-4	Acid injection pump		2 sets (1 set is spare of warehouse)
	Type	Controlled volume, diaphragm	
	Capacity	10 mℓ/min	
	Head	50 mAq	
	Material	Diaphragm : Teflon	
		Body : SCS 14	
5-5	Chemical injection pump		2 sets (1 set is spare of warehouse)
	Type	Controlled volume, diaphragm	
	Capacity	10 mℓ/min	
	Head	50 mAq	
	Material	Mf'R St'd,(Liquid end nonmetallic)	

Item	Equipment Name	Specification	Q'ty
5-6	Acid cleaning pump		1 set
	Type	Controlled volume, Mf'R St'd.	
	Capacity	10 ℓ/min	
	Head	20 mAq	
	Material	Mf'R St'd. (Liquid end nonmetallic)	
5-7	Motor for recirc. brine pump	TEFC, insulation class JIS B AC 220V X 3ϕ X 60Hz	2 sets (1set is spare of warehouse)
5-8	Motor for make-up pump	TEFC, outdoor type, insulation class JIS B, AC 220V X 3 X 60Hz	2 sets (1set is spare of warehouse)
5-9	Motor for distillate pump	TEFC, outdoor type, insulation class JIS B, AC 220V X 3ϕ X 60Hz	2 sets (1set is spare of warehouse)
5-10	Motor for acid injection pump	Insulation class JIS B	2 sets (1set is spare of warehouse)
5-11	Motor for chemical injection pump		2 sets (1set is spare of warehouse)
5-12	Motor for acid cleaning pump	Insulation class JIS B	1 set
6	Electric Instrumentation		
6-1	Motor control panel	Indoor type, self-standing Power supply: AC 480V X 3ϕ X 60Hz AC 110V X 1ϕ X 60Hz (for Control) Breaker : NFB Start method: Direct online Spare parts Overcurrent circuit: 3 elements Earth : Earth trip Stop lamp : Supply instrument panel Control switch : Supply on central panel & local	

Item	Equipment Name	Specification	Q'ty
6-2	Instrument panel	Indoor type, self-standing Size: 1000(W)x2000(H)x1000(D) Power supply: AC 110V X 1φ X 60Hz Design condition: temperature : 40°C relative humidity : 60%	1 set
	Recorder Adjuster Annunciator Push button Lamp	Same as 6-4	
6-3	Electric instrumentation work materials	Wiring materials shall be provided for use in the test plant site: between the plant and instrument panel, motor control panel.	1 set
6-4	Panel instruments	The instruments complying with the requirements shown in "Table of Instrument" shall be provided.	1 set
	6 point type recorder	4 ∿ 20 mA DC or resistance thermometer input 2 sets	
	2 pen type recorder	4 ∿ 20 mA DC input 3 sets	
	Indicator	4 ∿ 20 mA DC input 5 sets	
	Ratio bias setter	4 ∿ 20 mA DC input 1 set	
	2 point process alarm	4 ∿ 20 mA DC input 2 sets (Upper & lower set point)	
	1 point process alarm	4 ∿ 20 mA DC input 10 sets (Upper or lower alarm)	
	Annunciator	Abnormal on light, test push button, acknowledge push button, reset push button, push button lamp	

Item	Equipment Name	Specification	Q'ty
6-5	Local transmitters	The transmitters complying with the requirements shown in "Table of Instrument" shall be provided.	1 set
	Differential pressure transmitter	4 ∿ 20 mA DC output 5 sets	
	Pneumatic pressure controller	0.2 ∿ 1.0 kg/cm^2 1 set	
	Pneumatic level controller	0.2 ∿ 1.0 kg/cm^2, displacement type 5 sets	
	Conductivity meter	4 ∿ 20 mA DC output, direct mounted 2 sets	
	pH meter	4 ∿ 20 mA DC 2 sets	
	Differential pressure switch	Diaphragm or bellows type 1 set	
	Orifice plate	Flange tap or ring tap, SUS 316 5 sets	
	Thermal resistance	Pt 100 Ω, 3 wire type 8 sets	
	Rotor meter	Orifice + rotor 1 set	
	Local pressure gauge	Dial type 100 ϕ, bourdon tube 13 sets	
	Local thermometer	Glass type, attached thermowell 8 sets	
	Level gauge	Glass type 17 sets	
	Differential pressure transmitter	1 set	
	Dissolved oxygen meter	Range 0 ∿ 200 ppb 2 sets	
6-6	Control valve		1 set
	Flow C/V for desuperheater Pressure C/V for B/H steam Temperature C/V for brine	Globe valve, serial each 1 set control, attached positioner, SCPH/SUS 316	
	Level C/V for brine	Globe valve, serial control, attached positioner, SCS 14/SUS 316 1 set	

Item	Equipment Name	Specification	Q'ty
	ON-OFF valve for distillate online ON-OFF valve for distillate damp	Ball valve, ON-OFF control, electro-magnetic valve, SCS 14/SUS 316 each 1 set	
	Flow C/V for seawater Level C/V for deaerator	Batterfly valve, serial control, attached positioner, FC20+Rubber Lining/SCS 14 each 1 set	
	ON-OFF valve for ejector steam	Glove valve, ON-OFF control, electromagnetic valve, SCPH 1 set	
	Flow C/V for brine	Butterfly valve, serial control, attached positioner, FC20+Rubber Lining/SCS 14 1 set	
	Level C/V for B/H condensate	Globe valve, serial control, attached positioner, SCPH/SUS 316 1 set	
	Flow C/V for make-up	Butterfly valve, serial control, attached positioner, FC20+Rubber Lining/SCS 14 1 set	
	Level C/V for flash tank	Globe valve, serial control, attached positioner, FC20+Rubber Lining/SCS 14 1 set	
	Level C/V for decarbonator	Butterfly valve, serial control, attached positioner, FC20+Rubber Lining/SCS 14 1 set	
	Pressure C/V for acid injection	1 set	
	Pressure C/V for chemical dosing	1 set	
7	Piping	◦ Intra-skid piping shall be provided for MSF test plant. ◦ Assembled products or sub-assemblies shall be provided as the interconnecting piping among the boiler, feedwater tank, fuel tank and MSF test plant skid.	

Item	Equipment Name	Specification	Q'ty
	Material	Seawater & brine line : Cu-Ni, FRP, Rubber Lining Distillate line : SUS Vent line : SUS Others : Mf'R St'd. Note: PVC piping shall not be furnished.	
8	Tanks and Sulfuric Acid Mixer		
8-1	Sulfuric acid tank	Capacity, 100 ℓ, material:SUS 316	1 set
8-2	Chemical tank	Capacity:100 ℓ, material: polyethylene, attached mixer	1 set
8-3	Flash tank	Capacity:150 ℓ, material:SUS 304	1 set
8-4	Acid cleaning tank	Capacity:300 ℓ, material:polyethylene, attached mixer	1 set
8-5	Hydrochloric acid tank	Capacity:10 ℓ, material: polyethylene	1 set
8-6	Sulfuric acid mixer	Material: SUS 316	1 set
8-7	Seawater strainer	Material: SUS 316	1 set
8-8	Frames, platforms and baseplates	∘ Appropriate frames, platforms and baseplates shall be provided to facilitate operation. ∘ A lifting device shall be installed to take out the brine heater and evaporator tube bundle.	1 set
8-9	Ball cleaning system	The tube of the brine heater and the heat recovery section shall be cleaned with sponge balls during operation.	1 set
9	Boiler system	Indoor type	
9-1	Boiler		1 set
	Type	Once-through, water tube type	
	Equivalent evaporation	1,000 kg/h	
	Max. steam press.	10 kg/cm^2	
	Efficiency	85% or more	
	Oil consumption	73.1 ℓ/h (A heavy oil bunker A)	
9-2	Fuel tank	Capacity: 10 m^3, material: CS	1 set
9-3	Boiler feed tank	Capacity: 3 m^3, material CS Resin coating	1 set

Item	Equipment Name	Specification	Q'ty
9-4	Boiler feed water Pump		
	Type	Horizontal centrifugal	1 set
	Capacity	2.4 m^3/h	
	Head	Surplus 10% or more determined by Mf'R	
	NPSH	0.5 m(NPSHav - NPSHreq)	
	Materials	Mf'R St'd.	
9-5	Accessories	Chemical injection system etc.	1 set
10	Spare Parts	For one year	1 set

5. List of Laboratory Equipments

List of Laboratory Equipments

1. Equipments for Corrosion Test

Item No.	Description	Q'ty	Remarks
1-1	Corrosometer	1 set	For laboratory use; measures the corrosion rates of the test pieces of heat transfer tubes for the MSF test plant. Probe material: Cu-Ni, BsTF, Steels
	(1) Probe	(4)	
	(2) Corrosometer (6 channels)	(1)	
1-2	Corrator	1 set	For process use; measures the corrosion rates of Probe metals mounted in the water box of the MSF test plant, and evaluates the corrosion of the metals by hot brine. Probe material; Cu-Ni, BsTF
	(1) Probe	(6)	
	(2) Controlling corrater (4 channels)	(1)	
1-3	Electrometer	1 set	Measures the electrode potential to determine the corrosion behaviors of metals.
	(1) Body	(1)	
	(2) Electrode	(10)	
1-4	Tester (volt-ohm meter)	2 sets	For electric test purposes
1-5	Recorder (include charts)		For multi-purpose applications using multi-point recording and wide range functions.
1-6	Camera	1 set	Photographs the status of corrosion on specimens
	(1) Camera	(1)	
	(2) Illuminator with stand	(1)	
1-7	Photographic enlarger	1 set	For enlargement of photographs
	(1) Enlarger	(1)	
	(2) Colour analyzer	(1)	
	(3) Lens for enlarger	(4)	
	(4) Negative carrier (holder)	(1)	
	(5) Developing kit	(1)	
1-8	Metallurgical microscope	1 set	Observes microstructures and corroded portions of metallic specimens and let them be photographed.
	(1) Metallurgical microscope	(1)	
	(2) Polaroide camera	(1)	
1-9	Roughness meter	1 set	Analyzes the roughness of specimen surfaces before and after corrosion testing, and evaluate the status of corrosion.

Item No.	Description	Q'ty	Remarks
1-10	Mounting press	1 set	A small heating press for embedding metalic materials into plastic resin for the purpose of microscopic observation
1-11	Wet grinder and polisher	2 sets	For metal griding in preparation for observation by the melallurgical microscope
	(1) Wet manual grinder	(1)	
	(2) Wet auto polisher	(1)	
1-12	Spot welder	1 set	Electric spot welder for use in the laboratory
1-13	Electropolishing equipment	1 set	For electrotic polishing of metalic materials for microscopic observation
	(1) Power supply unit	(1)	
	(2) Electropolishing unit	(1)	
	(3) Transcopy	(1)	
1-14	Dryer	1 set	For hot air drying of metal specimens
1-15	Precision cutter	1 set	Cuts metallic materials for microscopic observation and corrosion testing.
1-16	Plastic desiccator	4 sets	Stores the camera, metallurgical microscope parts and metallic specimens.
1-17	Potentiostat/galvanostat	1 set	Analyzes corrosion, passivity and other behaviors of metal surfaces.
	(1) Potentiostat/ galvanostat	(1)	
	(2) Function generator	(1)	
	(3) Logarithmic converter	(1)	
	(4) Rack	(1)	
	(5) Electrolytic cell	(1)	
	(6) X-Y recorder	(1)	
1-18	Immersion corrosion testing equipment	2 sets	For corrosion tests in the laboratory in compliance with ASTM G-31
1-19	Zero shunt ammeter	1 set	Measures short-circuit currents between different metals in electrolytic solutions.
1-20	DOS tester (Degree of sensitization)	1 set	Measures the sensitivity to inter-granular corrosion of austenite stainless steels in laboratory and field.

2. Equipments for Water and Chemical Analysis

Item No.	Description	Q'ty	Remarks
2-1	Atomic absorption spectrophotometer	1 set	Microchemical analysis of the seawater ingredients scale and corrosion products (Ca, Mg, Fe, Cu, etc.)
	(1) Air compressor	(1)	
	(2) Hollow cathode lamp Fe, Cr, Ni, Ti, Na, Ca, K, Mg, Co, V, Cu, Mo, Al, Mn, Si	(1 each)	
	(3) Fuel Gas with regulator N_2O	(1)	
	(4) Recorder	(1)	
2-2	Spectrophotometer	2 sets	Colorimetric analysis of the seawater ingredients, scale and corrosion products (Fe, Cu, SiO_2, SO_4^{2-}, Cl^-, etc.)
	(1) Laboratory type	(1)	
	(2) Portable type	(1)	
2-3	X-ray diffractometer with x-y plotter	1 set	Analyzes the crystal structure of various scale and corrosion products.
2-4	Electrical conductivity meter	1 set	Measures electrical conductivity of seawater and product water.
2-5	pH meter	2 sets	Measures pH values of seawater and product water.
	(1) Laboratory type	(1)	
	(2) Portable type	(1)	
2-6	Automatic titrater	1 set	Automatic titration equipment capable of controlling titration process with recorder.
2-7	Residual chlorine meter	1 set	Measures residual chlorine in seawater and product water.
2-8	Portable water analysis kit	1 set	Capable of making simplified chemical analyses of seawater and product water for 25 test items.
2-9	Scale deposition testing equipment	2 sets	Reactor for scale deposition test in the laboratory
2-10	Turbidity meter	1 set	Checks the amount of colloids, microbes, scale deposits and corrosion products in seawater.
2-11	Oil content determination app.	1 set	Measures oil content in seawater.

Item No.	Description	Q'ty	Remarks
2-12	DO meter	1 set	Measures the dissolved oxygen level in the pretreated and concentrated sea water in the RO test plant.
2-13	ORP meter	1 set	Measures the redox potential of seawater and and product water.
2-14	Micro biological examination kit	1 set	Tests seawater and product water for colibacilli and other bacterial contamination.
2-15	X-ray fluorescence analyser	1 set	Elementaly analysis of the scale inside heat transfer tubes and corrosion products.

3. General Equipments

Item No.	Description	Q'ty	Remarks
3-1	Analytical balance max. 162 g.	2 sets	Electronic precision balance for chemical analysis and corrosion study. Increment 0.1 mg
3-2	Chemical balance direct reading, max. 2.1kg	2 sets	Balance for chemical analysis, Increment 0.01g
3-3	Balance, max. 20 kg	1 set	Rough balance for chemical analysis Increment 1 g
3-4	Water purification app.	2 sets	Products purified water for test use at 1.8 ℓ/h
3-5	Drying oven for glass-ware, 45 x 40 x 40 cm	2 sets	Constant temperature blast drver, Operating temp. 40~200°C, Accuracy ± 2°C
3-6	Drying oven for chemical, 45 x 30 x 30 cm	1 set	Operates on a forced draft system, Operating max. temp. 20°C, Accuracy ± 0.75°C
3-7	Muffle furnace, max. 1,150°C, 14 x 14 x 25 cm	1 set	Electric furance, Operating max. temp. 1200°C
3-8	Vacuum pump	2 sets	
	(1) For high vacuum environment	(1)	For laboratory use; Discharge rate 13 ℓ/min, Vacuum degree 10^{-4} mmHg.
	(2) For low vacuum environment	(1)	For laboratory use; Discharge rate 13 ℓ/min, Vacuum degree 350 mmHg.
3-9	Air compressor, tank capacity 16 ℓ	1 set	Exclusive use of the atomic absorption spectrophotometer, Max. rated pressure 6 kg/cm^2
3-10	Magnetic stirrer	2 sets	Stirrer for titration, Capacity 50~5000 mℓ
3-11	Magnetic stirrer, with hot plate	1 set	
3-12	Water bath, general type	1 set	Constant temperature bath using water.
3-13	Refrigerator	1 set	For laboratory use, Capacity 205 ℓ, Store chemicals that must be kept at low tempeature.
3-14	Water circulating pump (handy type)	2 sets	Displacement 6 ℓ/min.
3-15	Stop watch	2 sets	Digital indication, double scales.
3-16	Hot plate	1 set	Operating temp. 50 ~ 200°C
3-17	Air pump (handy type)	2 sets	Covers both the domains of pressure and reduced pressure. Applicable to pressure reduction filtration, pressurized filtration, air sampling and spectrophotometer.

Item No.	Description	Q'ty	Remarks
3-18	Gas flow meter	3 sets	Precision portable gas flow meter.
3-19	Constant temperature bath	2 sets	Precision constant temperature water bath
3-20	Calculator	3 sets	Hand-held type
3-21	Digital thermometer	2 sets	Operating range: 0 ~ 150/140 ~ 300°C
3-22	Pressure regulator (1) for N_2 (2) for H_2	5 sets (3) (2)	Pressure reducing mechanism consists of two stages.
3-23	Vacuum evaporator	1 set	Capacity 1,000 mℓ, cooling device is an upright and dual-hose type.

4. Glassware and Others

Item No.	Description	Q'ty	Remarks
4-1	Beakers		Implements for water and chemical analysis
	(1) Beaker, hard glass, standard type		
	Capacity: 50, 100, 200, 300 mℓ	24 each	
	Capacity: 500, 1000, 2000 mℓ	12 each	
	(2) Beaker, hard glass, tall type		
	Capacity: 500 mℓ	12	
	(3) Beaker, hard glass, conical type		
	Capacity: 300 mℓ	12	
	(4) Beaker, silicate glass		
	Capacity: 500 mℓ	6	
	(5) Beaker, stainless steel with handle		
	Capacity: 2,000 mℓ	3	
	(6) Beaker, poly-ethylene with handle		
	Capacity: 500, 1000mℓ	3 each	
4-2	Flasks		
	(1) Flask, erlenmeyer, unstoppered		
	Capacity: 25, 50 1000 mℓ	12 each	
	Capacity: 100, 500 mℓ	24 each	
	Capacity: 300 mℓ	48	
	(2) Flask with inter-changeable stopper		
	Capacity: 50, 100 300, 500 mℓ	12 each	

Item No.	Description	Q'ty	Remarks
	(3) Flask, iodine		Implements for water and chemical analysis
	Capacity: 300 mℓ	3	
	(4) Flask, volumetric		
	Capacity: 10, 25, 50, 100, 250, 500, 1000mℓ	12 each	
	(5) Flask, volumetric, amber		
	Capacity: 10, 25, 50, 100, 250, 500, 1000 mℓ	6 each	
4-3	Pipets		
	(1) Pipet, volumetric		
	Capacity: 0.5, 1, 2, 20, 25, 50 mℓ	12 each	
	Capacity: 5, 10 mℓ	24 each	
	(2) Pipet, graduated		
	Capacity: 1, 2, 5, 10, 25 mℓ	12 each	
	(3) Pipet, automatic		
	minimum graduation 0.05 mℓ Capacity: 5 mℓ	3	
	minimum graduation 0.05 mℓ Capacity: 10 mℓ	3	
4-4	Burets		
	(1) Buret, plain, teflon plug		
	minimum graduation 0.05 mℓ Capacity: 5 mℓ	6	
	minimum graduation 0.05 mℓ Capacity: 10 mℓ	6	
	minimum graduation 0.1 mℓ Capacity: 25 mℓ	3	
	minimum graduation 0.1 mℓ Capacity: 50 mℓ	3	
	(2) Buret, blue line, teflon plug		
	minimum graduation 0.1 mℓ Capacity: 50 mℓ	3	

Item No.	Description	Q'ty	Remarks
	(3) Buret, amber, teflon plug		Implements for water and chemical analysis
	minimum graduation 0.1 mℓ Capacity: 50 mℓ	3	
	(4) Buret, micro, plain, teflon plug with stand		
	Capacity: 1, 2 mℓ	3 each	
	Capacity: 5, 10 mℓ	2 each	
	(5) Buret, automatic, plain, teflon plug with bulb and reservoir		
	minimum graduation 0.1 mℓ Capacity: 10 mℓ	3	
	minimum graduation 0.1 mℓ Capacity: 25 mℓ	6	
	minimum graduation 0.1 mℓ Capacity: 50 mℓ	6	
	(6) Buret, automatic, amber, teflon plug with bulb and reservoir		
	minimum graduation 0.1 mℓ Capacity: 25 mℓ	6	
	minimum graduation 0.1 mℓ Capacity: 50 mℓ	6	
4-5	Bottles		
	(1) Bottle, plastic with screw cap		
	Capacity: 250, 500, 1000 mℓ	36 each	
	(2) Bottle , for reagent, narrow mouth with stopper		
	Capacity: 250, 500, 1000 mℓ	48 each	
	(3) Bottle, for reagent, amber, narrow mouth with stopper		
	Capacity: 250, 500, 1000 mℓ	24 each	

Item No.	Description	Q'ty	Remarks
	(4) Bottle, for reagent, wide mouth with stopper		Implements for water and chemical analysis
	Capacity: 100 - 120 mℓ	12	
	(5) Bottle, for reagent, amber, wide mouth with stopper		
	Capacity: 100 - 120 mℓ	12	
	Capacity: 250, 500 mℓ	6 each	
	(6) Bottle, dripping type		
	Capacity: 100 - 120 mℓ	12	
	(7) Bottle, dripping type, amber,		
	Capacity: 100 - 120 mℓ	12	
	(8) Bottle, filtering, Buchner type		
	Capacity: 250, 500, 1000 mℓ	12 each	
	(9) Bottle, washing, polyethylene		
	Capacity: 500 mℓ	24	
	(10) Bottle, polyethylene with stopcock		
	Capacity: 10 mℓ	3	
	(11) Bottle, gas washing		
	(a) Dressel type		
	Capacity: 250 mℓ	12	
	(b) Fritted disc type		
	Capacity: 250 mℓ	12	

Item No.	Description	Q'ty	Remarks
	(12) Bottle, weighing		Implements for water and chemical analysis
	40 mm (high) x 20 mm (diameter)	12	
	60 mm (high) x 30 mm (diameter)	12	
4-6	Cylinders		
	(1) Cylinder, glass, graduated, stopper		
	Capacity: 25, 50, 100, 250, 500, 1000 mℓ	24 each	
	Capacity: 2000 mℓ	6	
	(2) Cylinder, glass, graduated, un-stoppered		
	Capacity: 5, 10, 10 (cone type), 100, 250, 500, 1000 mℓ	12 each	
	Capacity: 2000 mℓ	6	
4-7	Condensers		
	(1) Condenser, Liebig type		
	Length: 300 - 350 mm	3	
	(2) Condenser, Dimroth type		
	Length: 300 - 350 mm	3	
	(3) Condenser, Graham type		
	Length: 300 - 350 mm	3	
4-8	Crucibles and dishes		
	(1) Crucible, porcelain with cover (B-type)		
	Capacity: 30 mℓ	12	

Item No.	Description	Q'ty	Remarks
	(2) Crucible, porcelain, Gooch type 40 mm diameter with 24 mm inlet board		Implements for water and chemical analysis
	Capacity: 35 mℓ	12	
	(3) Dish, evaporating		
	Diameter: 85 mm, capacity: 100 mℓ	12	
	Diameter: 120 mm, Capacity: 260 mℓ	12	
	(4) Crucible, platinum		
	Capacity: 30 mℓ	2	
4-9	Funnels		
	(1) Funnel, separatory, with teflon plug		
	Capacity: 100, 250, 500, 1000 mℓ	12 each	
	(2) Funnel, filtering		
	ID at top 75 mm	24	
	ID at top 100 mm	12	
	ID at top 200 mm	6	
	ID at top 75 mm (long stem)	6	
	(3) Funnel, Buchner type, porcelain		
	ID at top 100 - 120 mm	6	
	(4) Funnel, Buchner type, fritted glass disc		
	ID at top 60 - 70 mm	6	
	(5) Funnel with fritted disc		
	JIS No.1, capacity: 30 mℓ	6	
	JIS No.2, Capacity: 30 mℓ	6	
	JIS No.3, Capacity: 30 mℓ	6	

Item No.	Description	Q'ty	Remarks
	JIS No.4, Capacity: 30 mℓ	6	Implements for water and chemical analysis
	Stem for above	6	
4-10	Desiccators with perforated porcelain plate		
	(1) Desiccator, Scheibler type with perforated, porcelain plate		
	Diameter, inside 150 mm	6	
	Diameter, inside 300 mm	2	
	(2) Desiccator, vacuum type with stopcock		
	Diameter, inside 300 mm	2	
	(3) Desiccator, Scheibler type, amber		
	Diameter, inside 150 mm	2	
4-11	Test tubes		
	Hard glass 200(L)x21(D) mm	100	
	Hard glass 150(L)x12(D) mm	100	
4-12	Watch glasses		
	Diameter: 75, 120 mm	36 each	
4-13	Glass tubings		
	(1) 1,500 mm length, 6-7mm OD, glass rod	10	
	(2) 1,500 mm length, 1 mm ID capillary, hard glass	5	
	(3) 1,500 mm length, 2 mm ID 6 - 7 mm OD, hard glass	5	

Item No.	Description	Q'ty	Remarks
	(4) 1,500 mm length, 4 mm ID medium wall, hard glass	30	Implements for water and chemical analysis
	(5) 1,500 mm length, 6 mm ID medium wall, hard glass	30	
	(6) 1,500 mm length, 8 mm ID medium wall, hard glass	30	
	(7) 1,500 mm length, 12 mm ID medium wall, hard glass	10	
	(8) 1,500 mm length, 16 mm ID medium wall, hard glass	5	
	(9) 1,500 mm length, 19 mm ID medium wall, hard glass	5	
	(10) 1,500 mm length, 26 mm ID medium wall, hard glass	3	
4-14	Glass stopcocks, interchangeable plug for liquid		
	(1) Straight type, arms 5 - 6 mm OD	12	
	(2) Straight type, arms 7 - 8 mm OD	12	
	(3) Three way type, arms 7 - 8 mm OD	12	
4-15	Tubes, connecting, T-shaped, glass		
	Arms 7 - 8 mm OD	12	
4-16	Tubes, connecting, Y-shaped, glass		
	Arms 7 - 8 mm OD	12	
4-17	Filter pumps (aspirator)		
	Length: 300 - 350 mm	12	
4-18	Glass stopcock for gas		
	(1) Stopcocks, high vacuum oblique bore		
	Arms 7 - 8 mm OD	6	

Item No.	Description	Q'ty	Remarks
	Arms 10 - 12 mm OD	6	Implements for water and chemical analysis
	Arms 13 - 15 mm OD	6	
	(2) Stopcock, high vacuum, three way bore		
	Arms 7 - 8 mm OD	3	
	Arms 10 - 12mm OD	3	
4-19	Drying tubes, U-shape with side arms and stoppers		
	Height of tube, 100 - 150 mm	6	
4-20	Stoppers, cork		
	Size No. / Top Diameter mm/ Bottom Diameter mm		
	1 — 15/12	100	
	2 — 16.5/13.5	100	
	3 — 18/15	100	
	4 — 19.5/16.5	100	
	6 — 22.5/19.5	100	
	8 — 25.5/22.5	50	
	10 — 30/27	50	
	12 — 36/33	50	
	14 — 42/39	50	
	16 — 48/45	50	
	18 — 54/51	50	
4-21	Stoppers, rubber		
	Size No. / Top Diameter mm/ Bottom Diameter mm		
	03 — 11/ 9	20	
	01 — 14/10	20	
	0 — 15/12	20	
	1 — 16/12	20	
	2 — 18/14	20	
	3 — 19/15	20	
	4 — 20/16	20	
	5 — 22/19	20	

Item No.	Description	Q'ty	Remarks
	Size No. / Top Diameter mm/ Bottom Diameter mm		Implements for water and chemical analysis
	6 — 23/20	20	
	7 — 25/21	20	
	8 — 28/23	20	
	9 — 30/25	20	
	10 — 32/28	20	
	12 — 37/32	10	
	14 — 41/37	10	
	16 — 46/40	10	
	18 — 52/46	10	
	20 — 58/51	10	
	25 — 74/63	10	
	30 — 90/84	10	
4-22	Stoppers, silicone		
	Size No. / Top Diameter mm/ Bottom Diameter mm		
	3 — 19/15	20	
	8 — 28/23	10	
4-23	Tubings		
	(1) Tubing, rubber, red		
	3mm(ID)x4.6mm(OD)	10 m	
	5mm(ID)x7mm(OD)	20 m	
	8mm(ID)x11.6mm(OD)	50 m	
	12mm(ID)x17.0mm (OD)	50 m	
	(2) Tubing, rubber for gas burner		
	8mm(ID)x12mm(OD)	30 m	
	(3) Tubing, rubber for vacuum		
	4.5mm(ID)x15mm(OD)	10 m	
	6mm(ID)x21mm(OD)	10 m	
	9mm(ID)x24mm(OD)	10 m	
	(4) Tubing, rubber for high pressure		
	8mm(ID)x18mm(OD)	10 m	

Item No.	Description	Q'ty	Remarks
	(5) Tubing, synthetic rubber		Implements for water and chemical analysis
	5mm(ID)x7mm(OD)	10 m	
	7mm(ID)x10mm(OD)	10 m	
	10mm(ID)x14.5mm (OD)	10 m	
	(6) Tubing, silicone		
	6mm(ID)x8mm(OD)	10 m	
	8mm(ID)x11mm(OD)	10 m	
	12mm(ID)x16mm(OD)	10 m	
	(7) Tubing, polyvinyl chloride		
	3mm(ID)x5mm(OD)	10 m	
	6mm(ID)x8mm(OD)	50 m	
	8mm(ID)x11mm(OD)	30 m	
	10mm(ID)x13mm(OD)	30 m	
	15mm(ID)x19mm(OD)	20 m	
	18mm(ID)x22mm(OD)	10 m	
	25mm(ID)x29mm(OD)	10 m	
4-24	Bucket, polyethylene		
	Capacity: 10 ℓ	12	
4-25	Siphone, polyethylene, middle type	6	
4-26	Thermometers, general use		
	Temperature range: 0 - 100°C	12	
	Temperature range: 0 - 250°C	6	
	Temperature range: 0 - 360°C	6	
4-27	Transformer, variable, total capacity: 1 KW	3	
4-28	Boring apparatus		
	(1) Borer, for cork, set	3	
	(2) Borer, for rubber, set	3	

Item No.	Description	Q'ty	Remarks
	(3) Cork borer sharpener	2	Implements for water and chemical analysis
4-29	Cork press, rotary	1	
4-30	Tripod, iron, 20 - 22 cm high, 10 - 12 cm OD	12	
4-31	Triangle, with clay pipe stem	24	
4-32	Asbestos wire gauze, 18 cm x 18 cm square	100	
4-33	Asbestos		
	(1) Asbestos, band, 3 cm width, high quality (AAA)	60 m	
	(2) Asbestos, band, 5 cm width, high quality (AAA)	60 m	
	(3) Asbestos, yarn, 3 mm high quality (AAA)	50 m	
4-34	Pinch cock, middle type	24	
4-35	Screw cocks		
	(1) Large type (5 cm)	24	
	(2) Middle type (3 cm)	24	
4-36	Mortars		
	(1) Mortar and pestle, porcelain, 150 mm OD	3	
	(2) Mortar and pestle, agate, 150 mm OD	2	
4-37	Tongs		
	(1) Tongs, for crucible, 150 - 180 mm long	6	
	(2) Tongs, for crucible, 220 - 250 mm long	2	
	(3) Tongs, for crucible, 500 - 600 mm long	2	

Item No.	Description	Q'ty	Remarks
	(4) Tongs,for breaker, 300 mm long	2	Implements for water and chemical analysis
	(5) Tongs,for platinum crucible,with platinum shoes, 200-250 mm long	2	
4-38	Forceps		
	(1) Forceps, general use, 120 mm long	12	
	(2) Forceps, general use, 180 mm long	12	
	(3) Forceps, general use, 300 mm long	6	
	(4) Forceps, teflon coating, 180 mm long	3	
4-39	Spoons		
	(1) Spoon, general use, 150 mm long	12	
	(2) Spoon, general use, 180 mm long	12	
	(3) Spoon, with spatula, 150 mm long	6	
	(4) Spoon, with spatula, 180 mm long	6	
4-40	Spatula, stainless steel, 150 mm long	6	
4-41	Clamps		
	(1) Clamp, versatile, small size	12	
	(2) Clamp, versatile, medium size	12	
	(3) Clamp, versatile, large size	24	
	(4) Clamp holder, regular type	48	

Item No.	Description	Q'ty	Remarks
4-42	Supports		Implements for water and chemical analysis
	(1) Support stand, tripod base, 50 cm high	6	
	(2) Support stand, tripod base, 90 cm high	6	
	(3) Support, for two funnel	2	
	(4) Support, with buret holder, porcelain base	6	
	(5) Support, test tube	2	
	(6) Support, pipet	3	
4-43	Rings		
	(1) Ring support, cast iron with clamp, small size	6	
	(2) Ring support, cast iron with clamp, medium size	12	
	(3) Ring support, cast iron with clamp, large size	6	
4-44	Gas burners		
	(1) Gas burner, standard type	12	
	(2) Gas burner, Meker type	3	
4-45	Blower, rubber (spray)	12	
4-46	Pipet filler, rubber	6	
4-47	Papers		
	(1) Paper, filtering, qualitative No.1 12.5 cm (diameter)	600	
	(2) Paper, filtering, qualitative No.1 18.5cm (diameter)	600	
	(3) Paper, filtering, qualitative No.2 12.5cm (diameter)	600	

Item No.	Description	Q'ty	Remarks
	(4) Paper, filtering, qualitative No.5A 12.5cm (diameter)	600	Implements for water and chemical analysis
	(5) Paper, filtering, qualitative No.5B 12.5cm (diameter)	600	
	(6) Paper, filtering, qualitative No.5C 12.5cm (diameter)	200	
	(7) Paper, filtering, oil, 800x300mm square	200	
	(8) Paper, paraffin, pack of 50 sheets	6 packs	
	(9) Paper, for pH test, pH range 0.4 - 13.6	6 sets	
4-48	Emery papers		
	(1) Fine	24 sheets	
	(2) Medium	24 sheets	
	(3) Coarse	24 sheets	
4-49	Brushes		
	(1) Brush, for test tube	12	
	(2) Brush, for burette	12	
	(3) Brush, for flask, middle type	12	
	(4) Brush, for flask, large type	12	
	(5) Brush, for pipette	12	
	(6) Brush, for beaker	6	
4-50	Vessel, evacuated with case capacity 1 ℓ	6	
4-51	Platinum dish 120-150mℓ	2	
4-52	Bottle, DO measuring, Winkler type	10	
4-53	Electric tool set	3	

5. Machines and Tools

Item No.	Description	Q'ty	Remarks
5-1	Precision lathe	1 set	High-speed processing, Floor area 1100L x 2800W, Net weight 2,150 kg
5-2	Bench drilling	1 set	Max. drilling 23mm
5-3	Electric bench grinder	1 set	Grindstone diameter 305mm
5-4	Cutter	1 set	Grindstone diameter 405mm
5-5	Electric drill	2 sets	Max. drilling 20mm
5-6	Hand lever shear	1 set	Processing thickness 16mm, Processing length 1m
5-7	Hack sawing machine	1 set	Max. cutting 250mmø, Machine size 1040L x 430W
5-8	Band sawing machine	1 set	Max. cutting 260mm, Processing length 400mm
5-9	Universal swivelling branch vice	1 set	Max. opening 165mm, Depth of jaws 83mm
5-10	Cast anvil	1 set	Size 560L x 140W x 280H
5-11	Hack-saw frame	1 set	Saw blade 250mm
5-12	File each size	1 set	Type: Flat, Half-round, Round, Square, Three square Size: 150, 250mm
5-13	Calipers	1 set	Size: 150, 200, 250, 300, 350mm
5-14	Steel tape measure	1 set	Size: 2, 3.5, 5, 30m
5-15	Steel rule	1 set	Size: 150, 300, 600mm
5-16	Vernier calipers	1 set	Size: 150, 300, 600mm
5-17	Micrometer (All kinds)	1 set	For external micrometer: 0∿25, 25∿50, 50∿75, 75∿100mm For inside micrometer: 5∿25, 25∿50, 50∿75, 75∿100mm
5-18	Adjustable tap wrench	1 set	Size: 1∿5, 1∿6, 2∿10, 5∿13, 10∿25mm
5-19	Electric soldering iron	1 set	Rating: 30, 40, 60, 80, 100W
5-20	Spanner	1 set	B type, ISO type
5-21	Adjustable angle wrench	1 set	Size: 150, 200, 250, 300, 375mm
5-22	Water pump pliers	1 set	Size: 250, 300mm
5-23	Side cutting pliers	1 set	Size: 150, 175, 200mm
5-24	Radio pliers	1 set	Size: 120, 150mm
5-25	Diagonal cutting nippers	1 set	Size: 120, 150mm

Item No.	Description	Q'ty	Remarks
5-26	Figure and letter punch	1 set	The figure punch set includes 9 punches and the alphabet set consist of 26 punches Size: 2, 3, 5, 6, 8mm
5-27	Wire stripper	1 set	A type, B type
5-28	Hammer	1 set	Size: 0.225, 0.45, 0.9, 1.3, 1.8, 2.2, 2.7, 3.6kg
5-29	Plastic hammer	1 set	Size: 0.2, 0.3, 0.5, 0.8, 1.0 kg
5-30	Tinners scissors	1 set	Size: 210, 240, 300mm
5-31	Oil gun	1 set	Size: 160, 540 mℓ
5-32	Screw drivers (All kinds)	1 set	With wood handles type: 100, 150, 200, 250mm With plastic handles type: 100, 150, 200mm
5-33	Box spanner	1 set	A type, B type, ISO type
5-34	Gas cutter	1 set	Portable gas cutter kit
5-35	Tube puller	1 set	For MSF test plant
5-36	Expander	1 set	For MSF test plant
6.	Process Analyzer		
6-1	Dissolved oxygen meter	1 set	Range: 0∿50/0∿100/0∿200ppb
7.	Standards		
7-1	Standard data booklet	1 set	