FINAL REPORT
FOR
STUDY ON MEASURES TO PREVENT OIL POLLUTION
OF
THERMAL ELECTRIC POWER STATIONS
AND
SEA WATER DESALINATION PLANTS
IN
UMM AL NAR, ABU DHABI
THE UNITED ARAB EMIRATES

OCTOBER 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the United Arab Emirates, the Government of Japan decided to conduct a Study on Measures to Prevent Oil Pollution of Thermal Electric Power Stations and Sea Water Desalination Plants in Umm Al Nar, Abu Dhabi and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Abu Dhabi a study team headed by Mr. Yoshio Murayama, Technical Advisor of Water Re-Use Promotion Center, from March 1988 to September 1989.

The team held discussions on the Study with the officials concerned of the Government of the Abu Dahbi Emirate and conducted field surveys at the plant site as well as in the relevant waters in Abu Dhabi. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the development of the project and to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Abu Dhabi Emirate for their close cooperation extended to the team.

October 1989

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

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Chapter 1

Introduction

by
Yoshio Murayama
Kunio Kikuchi
Toshikazu Ishii

Chapter 1 Introduction

1.1 Background of Study

The entire potable water in Abu Dhabi, the United Arab Emirates (UAE), is supplied by sea water desalination plants, which also supply a part of the water supply to Al Ain through pipelines. Also, large quantity of sea water is used as cooling water in the thermal power plants.

In recent years, apprehension has been deepened about the oil contamination of intake sea water caused by the effusion of oil from tanker, oil fields and oil refineries, and the establishment of measures to prevent oil contamination has become a matter of urgency.

If the present conditions are left to continue as it is, not only the efficiency of the sea water desalination plants will fall due to contamination of the facilities, but also the product water itself will be polluted, causing the complete stop of the potable water supply and a lower efficiency rate of generation of the thermal power stations.

Therefore, the need has arisen to establish effective countermeasures to prevent such oil contamination in order to keep a stable electric power supply.

In particular, Umm Al Nar power and desalination plants located in the east of Abu Dhabi City are the key plants bearing about 3/4 of the water production load and about 2/3 of all electric power generation for the whole of Abu Dhabi, and there is a fear also that the plants may be polluted by oil effused from oil refinery located adjacent to the south east.

Therefore, studies on measures to prevent oil contamination are urgently required, taking Umm Al Nar plants as the subject site.

With these as background, the UAE requested the Japanese Government in March 1987 to offer technical cooperation in making study on these matters. In reply to this request, Japan International Cooperation Agency (JICA) dispatched pre-study team, consisting of six members headed by Dr. M. Sato, and after consultation about the study methods, signed an agreement on fundamental items necessary for the study on October 31, 1987.

1.2 Purpose of Study

The purpose is to study the influence of oil contamination of sea water and to work out a plan to set up necessary countermeasure, taking as the subject site power and desalination plants owned by the Abu Dhabi Water and Electricity Department (WED) in Umm Al Nar district in the suburbs of Abu Dhabi City. Also aimed for is the transfer of technology related to the subject field to the counterpart engineers of WED through this study.

1.3 Procedure of Study

The principal procedure of the study is as shown in Fig. 1.3.1.

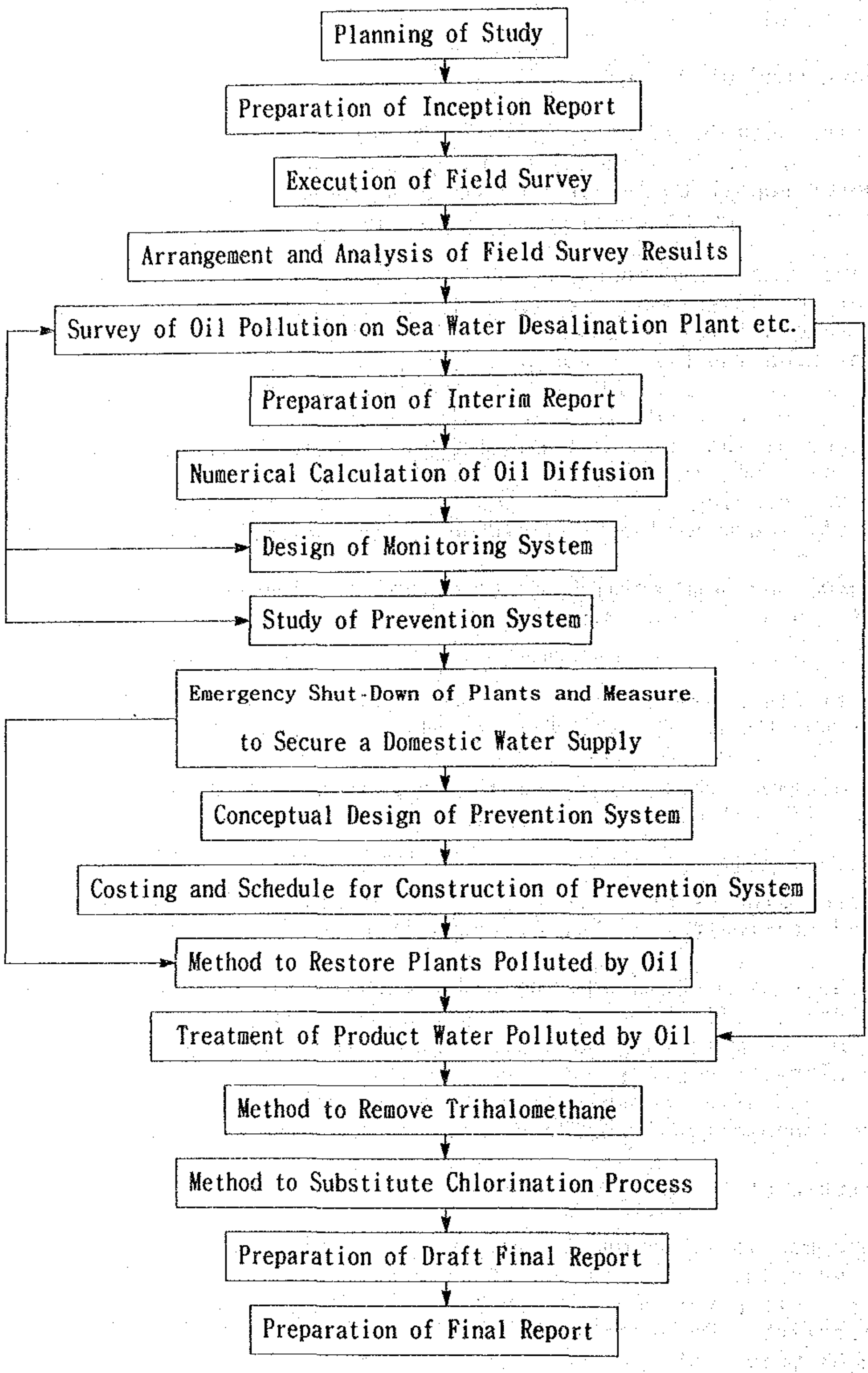


Fig. 1.3.1: Principal Procedure of Study

1.4 Details of Study

The subjects of this study are Umm Al Nar West No. 1 to No. 6 Power and Desalination Plants and East No. 1 to No. 3 Desalination Plants, including the coastal areas surrounding these plants.

The study consists of the following four fields:

1.4.1 Marine Field Survey

In order to predict the influence of oil contamination and to study the required countermeasures, it is necessary to get a solid grasp of marine characteristics and to assess accurately the present state of oil contamination near Abu Dhabi Island.

Since the area around Abu Dhabi Island is dotted by many islands, and tidal currents seem to be fairly complicated, a detailed survey of marine characteristics around the area where sea water intake facilities for Umm Al Nar Plants exist, including the more outlying sea areas, is necessary.

The marine field survey will be conducted over a long period in summer and in winter, centered around the following items;

(1) Tidal current
(2) Tidal level
(3) Water temperature
(4) Salinity
(5) Water quality
(6) Bottom sediment
(7) Marine organism

A study will be made to find out the effect of oil contamination on the performance and efficiency of the desalination and thermal power plants, when the plants are operated with sea water polluted by oil.

Also, a study will be made on the contamination of product water, and on the possible production of harmful substances in the chlorination process.

In addition, the influence of pollution on the corrosion of the plant equipment and materials will be investigated.

1.4.2 Study on Influence of Oil Pollution on Desalination and Thermal Power Plants

A study will be made to find out the effect of oil contamination on the performance and efficiency of the desalination and thermal power plants, when the plants are operated with sea water polluted by oil. Also, a study will be made on the contamination of product water, and on the possible production of harmful substances in the chlorination process. In addition, the influence of pollution on the corrosion of the plant equipment and materials will be investigated.

1.4.3 Practical Measures to Prevent Oil Contamination and their Evaluation

Based on the results obtained from the survey of marine characteristics, a numerical calculation on the diffusion of effused oil will be conducted, and the main conditions will be predicted.

With these results, a monitoring system and an oil pollution preventive system will be studied and a conceptual design of the preventive system will be carried out.

Furthermore, emergency shut-down of the plants and shut-down procedures, as well as measures to secure a domestic water supply during the shut-down period, will be studied.

1.4.4 Countermeasures against Oil Contamination

A study will be made on possible countermeasures in cases where oil contamination cannot be avoided even by the above mentioned preventive systems.

Firstly, methods to separate the oil component from the oil-contaminated product water by appropriate treatments, to remove harmful chlorinated organic compounds, and to sterilize both the raw sea water and the product water without chlorine, will be investigated and studied.

Then, methods and procedures to restore the oil-contaminated plant to normal, and to resume operation will be established.

1.5 Execution of Study

JICA dispatched a study team to the site three times, in March 1988, September 1988 and January 1989, and made field surveys as described below.

Subsequent to the field surveys, all works including analysis, design and evaluation were carried out in Japan, based on which this report has been prepared.

1.5.1 Field Survey

The first filed survey was conducted for 15 days in March 1988. After obtaining WED's agreement to the study plan, a preliminary survey of marine characteristics was conducted with a boat, for the preparation and planning of the second and subsequent full-scale surveys of marine characteristics. Also, the actual conditions of the subject plants and other related matters were surveyed.
The second field survey was conducted for 59 days in September through November 1988. Two boats were used for the survey of marine characteristics during summer, and a lot of data of many samples were collected.

The survey was jointly conducted with the local counterparts at the site, for the additional purpose of effecting technology transfer. In addition, the actual conditions of the desalination plants and related facilities were also surveyed.

The third field survey was conducted for 45 days in January through March 1989. At the beginning, the contents of the interim report, into which the preceding survey results were compiled, were explained and discussed.

The marine characteristics during winter was surveyed in the same way as during summer, and various data and samples were collected.

A joint survey with the local counterparts at the site was conducted in this time too, to effect technology transfer. In addition, the actual conditions of the power plants, monitoring systems and other related facilities and equipment were surveyed.

1.5.2 Study in Japan

A study of the field survey data, analyses of the collected samples and the collection of related information and data in Japan were carried out. Based on these results, studies were made on the influence of oil contamination on thermal power and desalination plants, the execution of oil contamination preventive measures and their evaluation, and countermeasures to oil contamination. This report has been prepared with these results.

Furthermore, two of the local counterpart engineers were dispatched to Japan from WED as trainees, each for six weeks from March through May 1989. The attended lectures and training on related technology and visited related facilities.

1.5.3 Persons engaged in Study

List of Japanese study team members and their assignments is as shown in Table 1.5.1. List of WED staff participated in the study is as shown in Table 1.5.2

Table 1.5.1: List of Japanese Study Team Members and Their Assignments

Name	Function	Assignment
Yoshio Murayama	Team Leader	Overall management Field work & home office work
Kunio Kikuchi	Deputy Leader	Control of technical works Home office work
Toshikazu Ishii	Engineer	Study on countermeasure of oil pollution Field work & home loffice work
Yuzuru Naito	Engineer	Study on countermeasure of oil pollution Field work & home office work
Keiichi Ohta	Engineer	Study on water quality Home office work
Masaji Kanayama	Engineer	Study on desalination plant Home office work
Shizuo Hashimoto	Engineer	Study on oceanography Home office work
Masaru Sakai	Engineer	Study on oceanography Home office work
Isamu Kondou	Engineer	Study on Hydrology Home office work
Shigeru Suizu	Engineer	Study on Hydrology Field work & home office work
Hiroshi Kuboki	Engineer	Study on oceanography Field work & home office work
Akira Watanabe	Engineer	Study on oceanography Field work & home office work
Hisayoshi Taira	Engineer	Study on oceanography Field work
Shingo Itonaga	Engineer	Study on oceanography Field work
Shin-ichiro Nagai	Engineer	Study on oceanography Field work
Masafumi Okudaira	Engineer	Study on oceanography Field work

Table 1.5.1: Continued

Name	Function	Assignment
Hiroji Takahashi	Engineer	Study on monitoring system Home office work
Kenshiro Matsuzaki	Engineer	Study on monitoring system Field work & home office work
Tooru Nakao	Engineer	Study on monitoring system Home office work
Masanori Higashino	Engineer	Study on monitoring system Home office work
Noboru Kioka	Engineer	Study on power plant Field work & home office work

Table 1.5.2: List of WED Staff

Name	Function
Dr. A. M. Shams El Din Director Material Testing Laboratory	Team Leader
Mr. I. Money General Superintendent Umm Al Nar Station	Plant Engineer
Dr. Rasheed A. Arain	Plant Engineer
Mr. Samih Ammari	Plant Engineer
Mr. A. H. Hammoud	Plant Engineer
Mr. Showky Aziz	Plant Engineer
Mr. McGreger	Plant Engineer
Mr. Rizk A. Mohammed	Oceanographic Engineer
Mr. Tag El Din	Oceanographic Engineer
Dr. W. Falldorf	Oceanographic Engineer
Dr. R. Wundes	Oceanographic Engineer
Dr. R. Walker	Oceanographic Engineer

Chapter 2

Present Status of Subject Plants and Environmental Conditions
(Fundamental Principles and Conditions for this Study)

by
Yuzuru Naito
Noboru Kioka
Shigeru Suizu
Akira Watanabe

Chapter 2 The Present Status of Subject Plants and Environmental Conditions (Fundamental Principles and Conditions for this Study)

The fundamental principles and conditions used in the implementation of this study such as the current status of the power plants, desalination plants and ancillary systems, current natural environmental conditions, properties of UAE. crude oil in an oil spill, etc., are described in this chapter.

2.1 Power and Sea Water Desalination Plants

Umm Al Nar power and desalination plants have 14 units which consist of five groups: West Nos. 1 - 6, West Nos. 7, and 8, West Nos. 9 and 10, East Nos. 1 - 3 and East Nos. 4 - 6.

West Nos. 1 - 6 is a conventional power/desalination plant of six independent units, each of which consists of a 365 t/h boiler and a 60 MW turbine generator, with passout steam to an adjacent distiller of 4 MGD each.

West Nos. 7 and 8 contains two 660 t/h boilers and two 160 MW turbine generators with passout steam to four distillers of 5 MGD each but increasing to 6 MGD with high temperature addition. West Nos. 9 and 10 are *two boilers of 316 t/h each, supplying two 75 MW turbine generators without distillers.*

East First Phase consists of 2 gas turbines rated at 61.6 MW each with their recovery boilers and 4 gas/oil fired boilers to provide steam with three distillers of 5 MGD each. East Second Phase consists of 2 gas turbines of 65 MW each with their recovery boilers and two auxiliary boilers to generate steam for three distillers of 6 MGD each.

The plant layout is shown in Fig. 2.1.1.

The present study was confined to the West Nos. 1 - 6 and the East Nos. 1 - 3 units of the enclosed with thick line in Fig. 2.1.1. These units are supplied with sea water from the No. 1 sea water intake system.

The outline of the plants is given in Table 2.1.1.

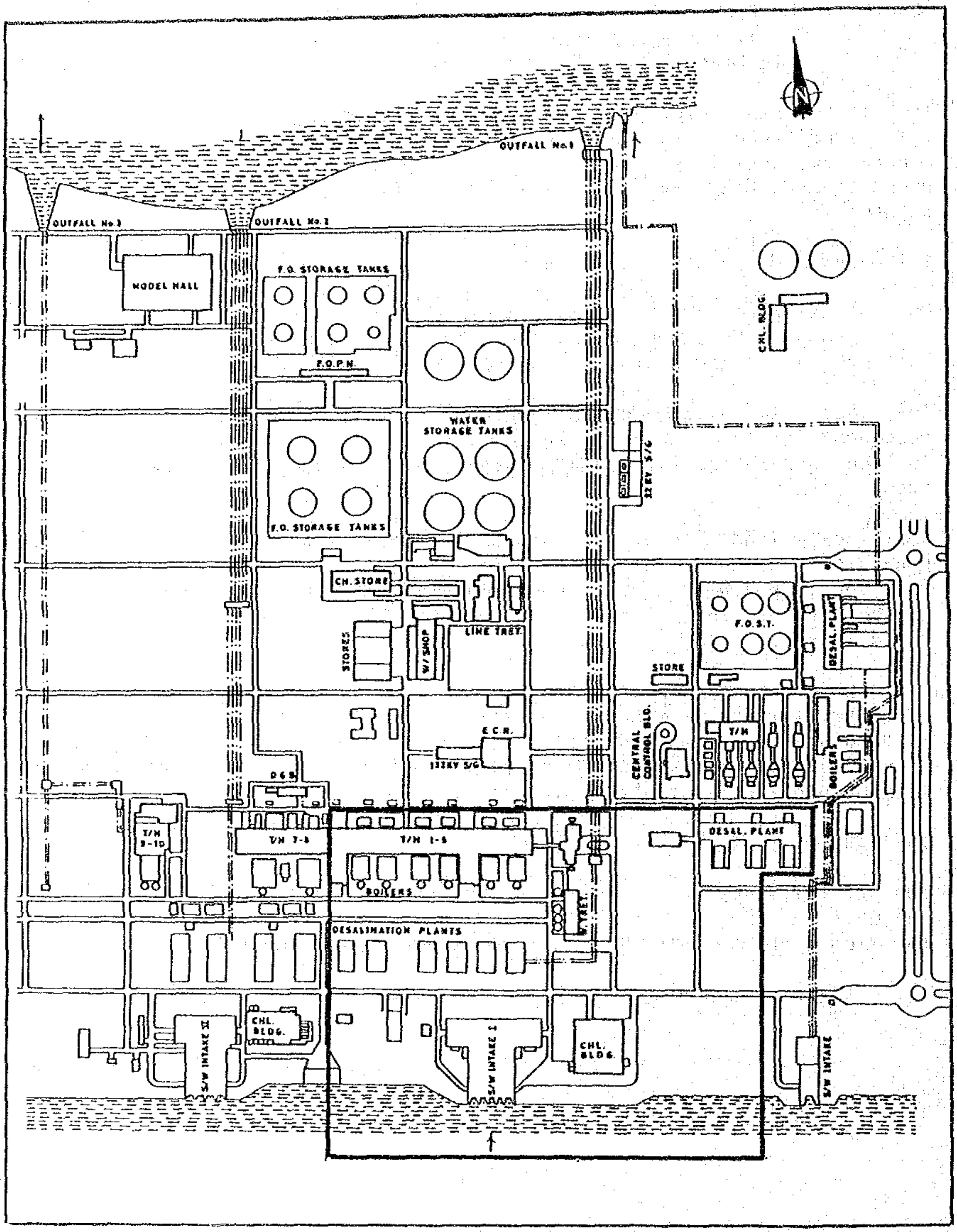


Fig. 2.1.1: General Arrangement of Power and Sea Water Desalination Plants in Umm Al Nar

Table 2.1.1: Outline of Thermal Electric Power Stations and Sea Water Desalination Plants

Items	West Nos. 1 - 6	East First Phase
Thermal Power Station		
1. Consultant	Lahmeyer Int.	Preece Cardew R & Ali El-Saie
2. General Contractor	Deutsche Babcock	BBC
3. Completion Date	1979 - 1980	1979
Turbine Generator		
1. Type	Steam	Gas
2. Contractor	SKODA	BBC
3. Capacity x Unit	60 MW x 6	61.6 x 2
Boiler		
1. Contractor	Deutsche Babcock	Waagner BIRO Voist Alpine
2. Capacity x Unit	365 t/h x 6	136 t/h x 4
3. Fuel (Main)	Natural Gas	Natural Gas
Waste Heat Boiler		
1. Contractor		BORSIG
2. Capacity x Unit		185 t/h x 2
Desalination Plant		
1. Consultant	Ali El-Ssie	Ali El-Ssie
2. Contractor	IHI	SIDEM
3. Capacity	4 MGD x 6	MGD x 3
4. Completion Date	1979 - 1981	1979 - 1980

2.1.1 Sea Water Desalination Plants

(1) West Nos. 1 - 6 Units

Each unit is a multi-stage flash evaporator which has an 18-stage flash chamber, a 15-stage heat recovery section and a 3-stage heat rejection section.

As described above, the evaporator is a double deck model so as to reduce the size of the installation area and the deaerator, which prevents corrosion, is included in the evaporator. This plant uses a cooling water recirculation system to keep the cooling water at a fixed temperature for the purpose of preventing a decline in the performance ratio (G.O.R.) during winter when the sea water has a low temperature.

Hage Vap and Belgard EV 2000 are used to inhibit scale and to maintain the maximum allowable brine temperatures at 90 °C and 100 °C.

For the removal of scale, an acid cleaning system and a sponge ball cleaning system are used to clean the inside of the brine heater and the heat recovery section tubing.

The main technical data and schematic flow are shown in Fig. 2.1.2, Fig. 2.1.5 and Table 2.1.2, and the heat/mass balance sheets are shown in Fig. 2.1.3 and Fig. 2.1.4. This plant is the most reliable plant in Abu Dhabi and its operation load was always more than 90% (93.6%: 1986).

(2) East Nos. 1 - 3 Units

This unit employs a multi-stage flash evaporator which has a 16 stage flash chamber, consisting of a section for 13 stages of heat recovery and a section for the 3 stages of heat rejection.

The process is basically the same as that used in the West Nos. 1 - 6 units. In this plant, high purity distillate is taken from the 7th stage to use as boiler feed water for the waste heat recovery boiler.

The main technical data and schematic flow are shown in Table 2.1.2 and Fig. 2.1.6 and the heat/mass balance sheets are shown in Fig. 2.1.7 to 2.1.10. The operation load of this plant in 1986 was 76.8%.

Table 2.1.2: Main Technical Data of Sea Water Desalination Plants

Description	WEST No1-No6	EAST No1-No3
Type	MSF	MSF
Arrangement	Cross Tube 2-Deck	Cross Tube 2-Deck
Nominal Capacity (MGD)	4	5/6
Chemical Dosing	Poly-phosphate	Poly-phosphate
Performance Ratio (GOR)	6	6
Nos of Stage Heat Recovery Section Heat Rejection Section	 15 3	 13 3
Guaranteed Purity of Distillate (ppm)	25	25
TDS of Blow Down (ppm)	66,000	65,000
Max.Brine Temperature (℃)	90	90
Blow Down Temperature (℃)	42	42
Flash Range (℃)	48	48
Seawater Temperature (℃) Max. Min.	 35 18	 35 18
On Load Cleaning Sections Cleaning	Sponge Ball (Taproge) Heat Input Section Heat Recovery Setion	Sponge Ball (Taproge) Heat Input Section Heat Recovery Section
High Purity Distillate Quality (ppm) Temperature (℃) Source	none	 1 60(after Cooler) Stage 7
Specific Heat Consumption (kcal/kg)	95.3	91.7

continued

Table 2.1.2: (Continued)

Description	WEST No1-No6	EAST No1-No3
Material		
Main Shell	Carbon Steel	Carbon Steel
Protective Coating	Epoxy	Epoxy
Special Protection	Stage 1.2 Cu.Ni Clad	Dearator 316 ss
Water Boxes	Carbon Steel + Cu.Ni Clad	Cu.Al A20
Heat Transfer Tubes		
Heat Input Section	70/30 Cu.Ni	70/30 Cu.Ni
Heat Recovery Section		
High Temperature	70/30 Cu.Ni	70/30 Cu.Ni
Low Temperature	Al Brass	Al Brass
Heat Rejection Section	70/30 Cu.Ni	70/30 Cu.Ni
Ejector Condenser	Ti	Ti
Demister	Stainles Steel	Stainles Steel
Pipings		
Seawater Supply	Bonna	Bonna
Brine Recycle		
High Temperature	Carbon Steel + 90/10 Cu.Ni Clad	Cu.Al A20
Low Temperature	Carbon Steel + Epoxy Coat	Carbon Steel + Epoxy Coat
Distillate	304 SS	316L SS
Vent	304 SS	304 SS

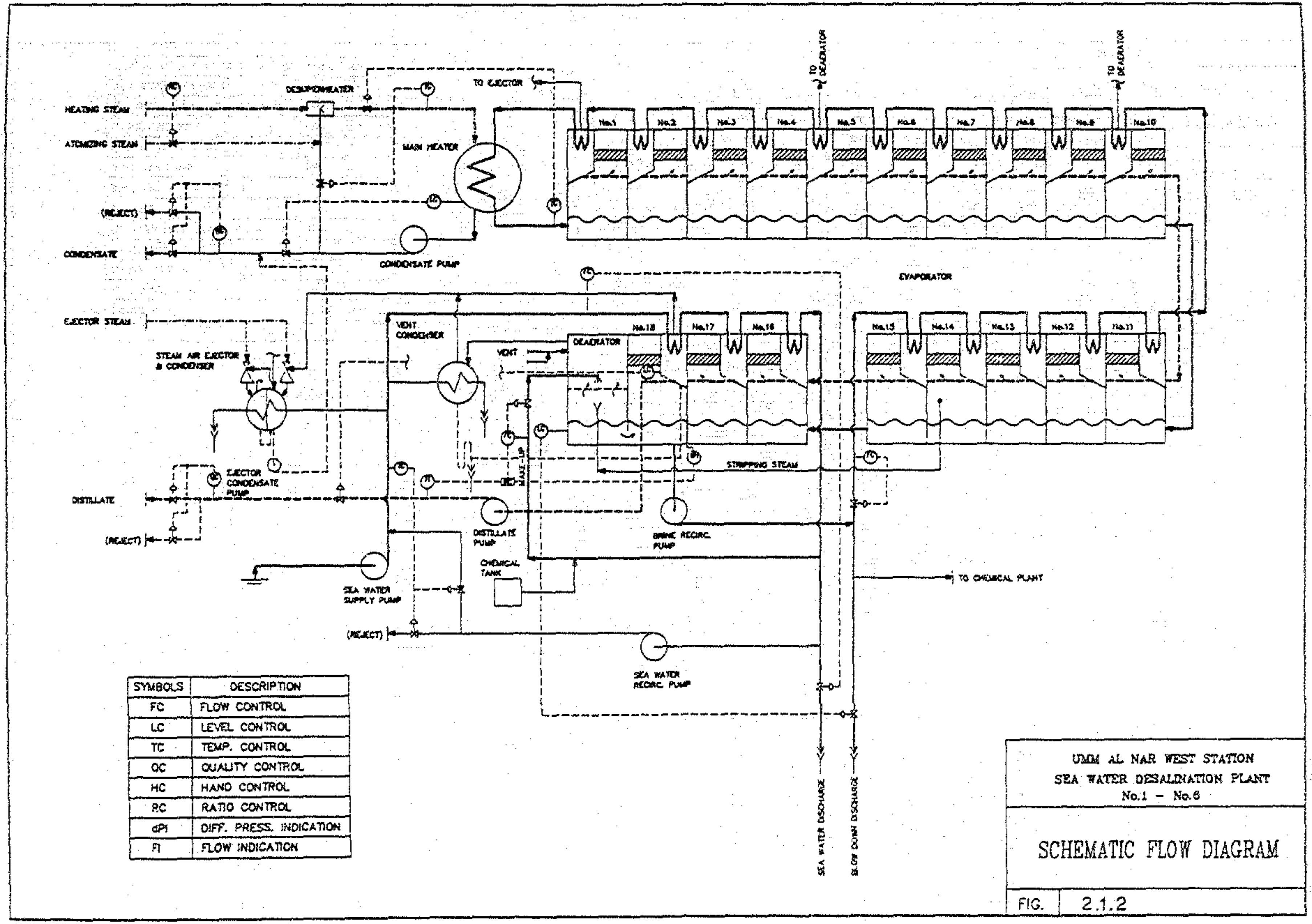
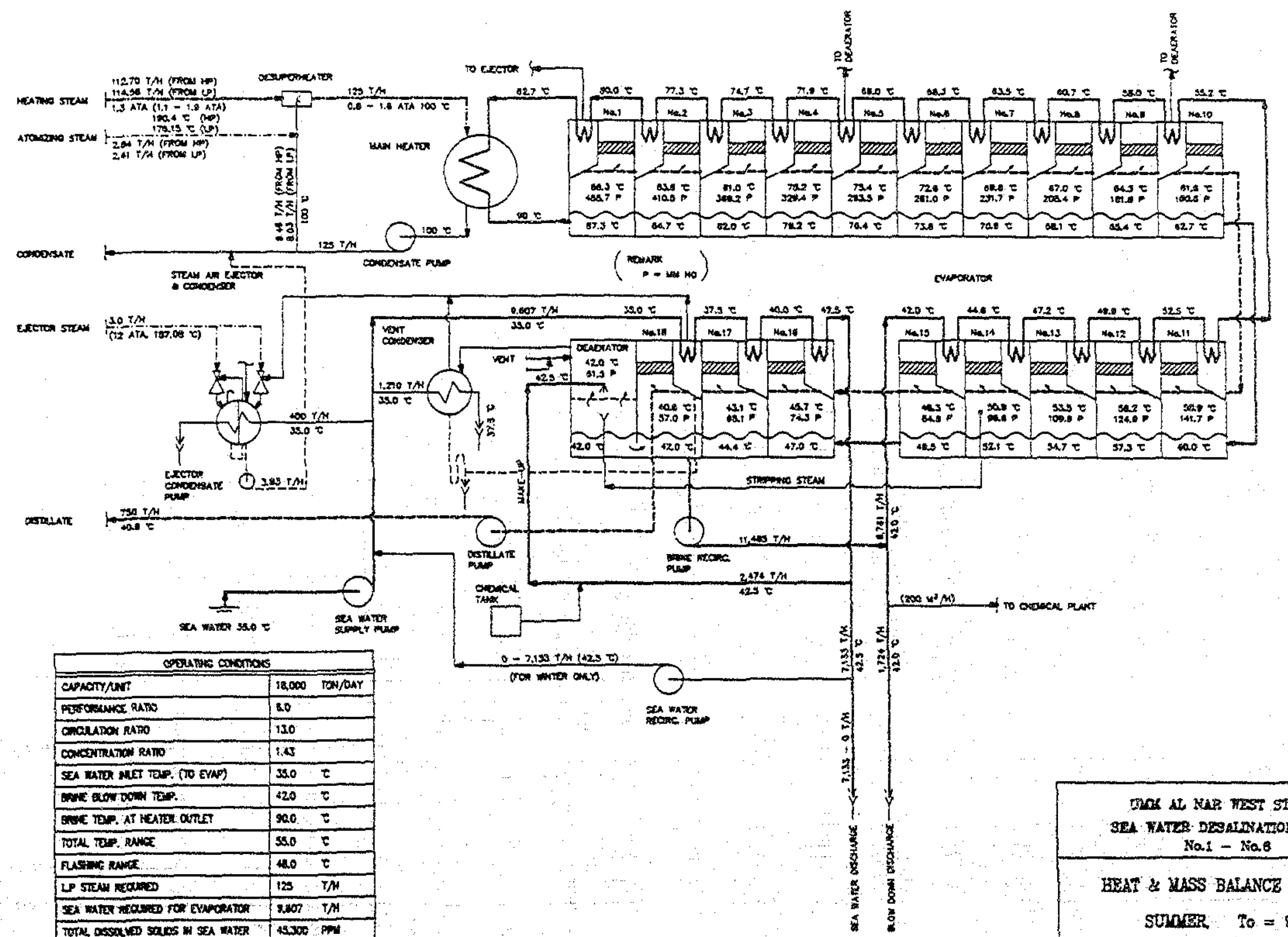


Fig. 2.1.2: Schematic Flow Diagram of Umm Al Nar West No.1 - No.6 Desalination Plant



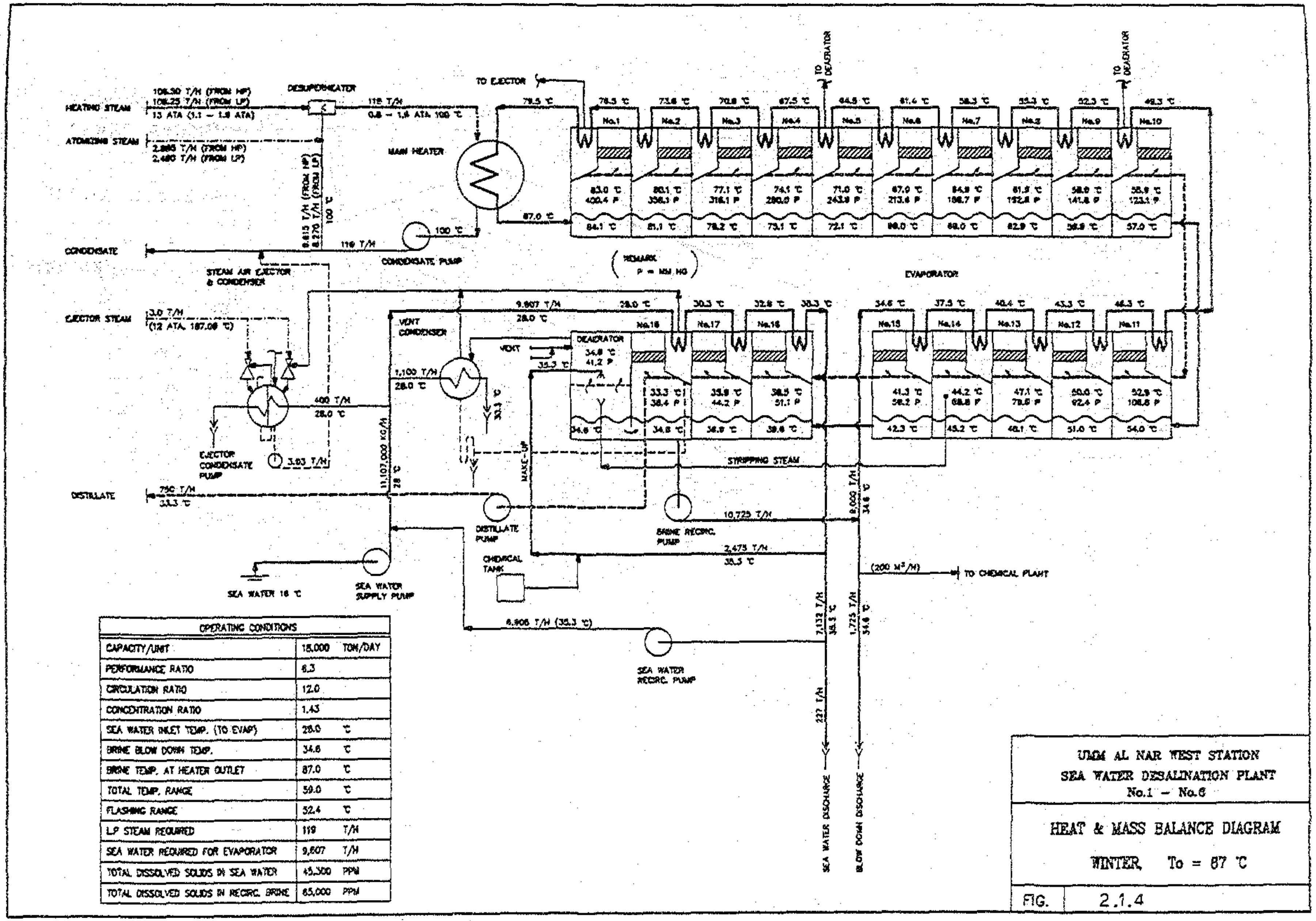
OPERATING CONDITIONS		
CAPACITY/UNIT	18,000	TON/DAY
PERFORMANCE RATIO	8.0	
CIRCULATION RATIO	13.0	
CONCENTRATION RATIO	1.43	
SEA WATER INLET TEMP. (TO EVAP)	35.0	℃
BRINE BLOW DOWN TEMP.	42.0	℃
BRINE TEMP. AT HEATER OUTLET	90.0	℃
TOTAL TEMP. RANGE	55.0	℃
FLASHING RANGE	48.0	℃
LP STEAM REQUIRED	125	T/H
SEA WATER REQUIRED FOR EVAPORATOR	9,807	T/H
TOTAL DISSOLVED SOLIDS IN SEA WATER	45,300	PPM
TOTAL DISSOLVED SOLIDS IN RECIRC. BRINE	65,000	PPM

UMM AL NAR WEST STATION
SEA WATER DESALINATION PLANT
No.1 – No.6

HEAT & MASS BALANCE DIAGRAM
SUMMER To = 90 ℃

FIG. 2.1.3

Fig. 2.1.3: Heat and Mass Balance Diagram of Umm Al Nar West No.1 - No.6 Desalination Plant, Summer To = 90 °C



OPERATING CONDITIONS		
CAPACITY/UNIT	15,000	TON/DAY
PERFORMANCE RATIO	8.3	
CIRCULATION RATIO	12.0	
CONCENTRATION RATIO	1.43	
SEA WATER INLET TEMP. (TO EVAP)	28.0	°C
BRINE BLOW DOWN TEMP.	34.6	°C
BRINE TEMP. AT HEATER OUTLET	87.0	°C
TOTAL TEMP. RANGE	59.0	°C
FLASHING RANGE	52.4	°C
LP STEAM REQUIRED	119	T/H
SEA WATER REQUIRED FOR EVAPORATOR	9,607	T/H
TOTAL DISSOLVED SOLIDS IN SEA WATER	45,300	PPM
TOTAL DISSOLVED SOLIDS IN RECIRC. BRINE	65,000	PPM

UMM AL NAR WEST STATION
SEA WATER DESALINATION PLANT
No.1 - No.6

HEAT & MASS BALANCE DIAGRAM

WINTER, To = 87 °C

FIG. 2.1.4

Fig. 2.1.4: Heat and Mass Balance Diagram of Umm Al Nar West No.1 - No.6 Desalination Plant, Winter To = 87 °C

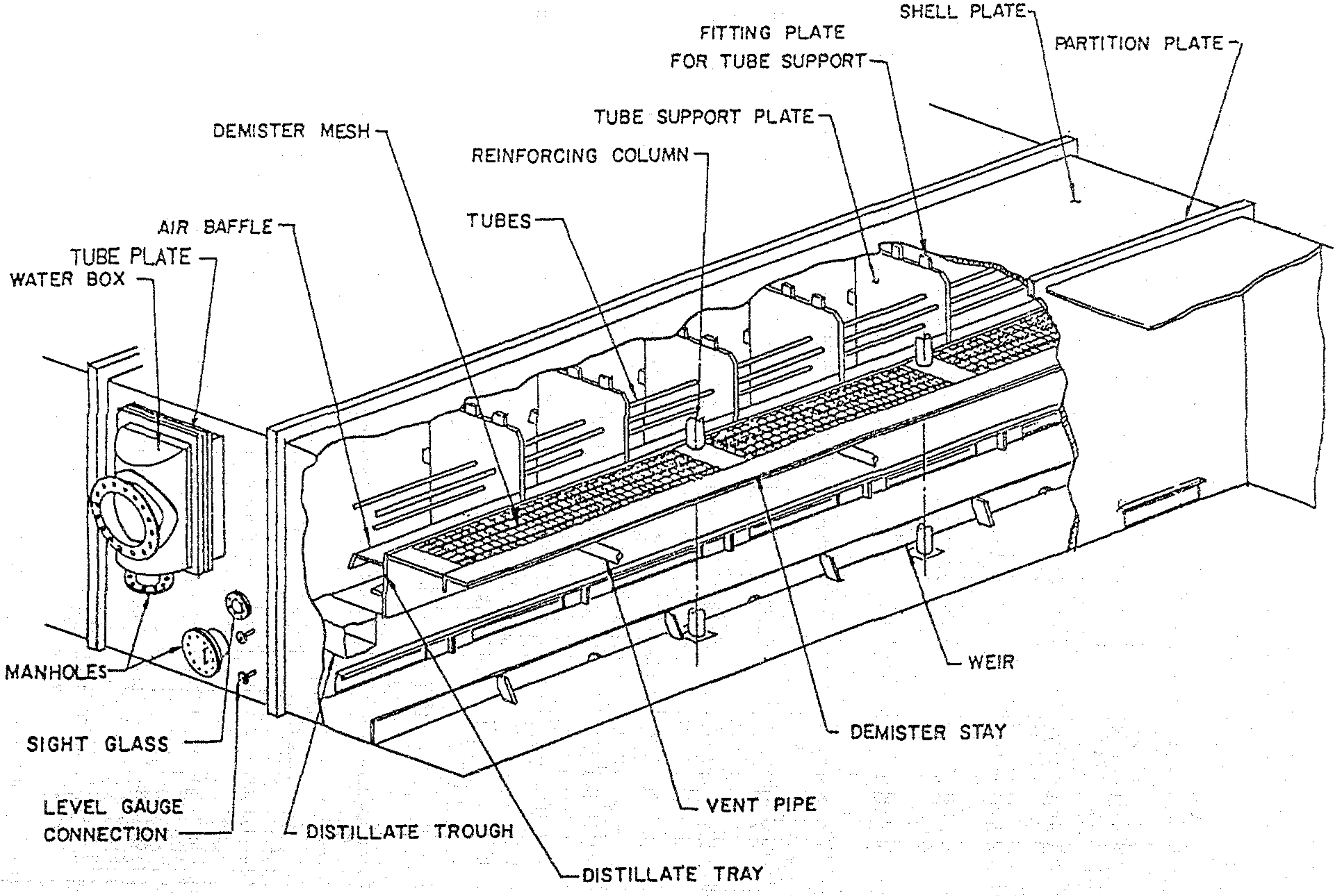


Fig. 2.1.5: Typical Evaporator Stage

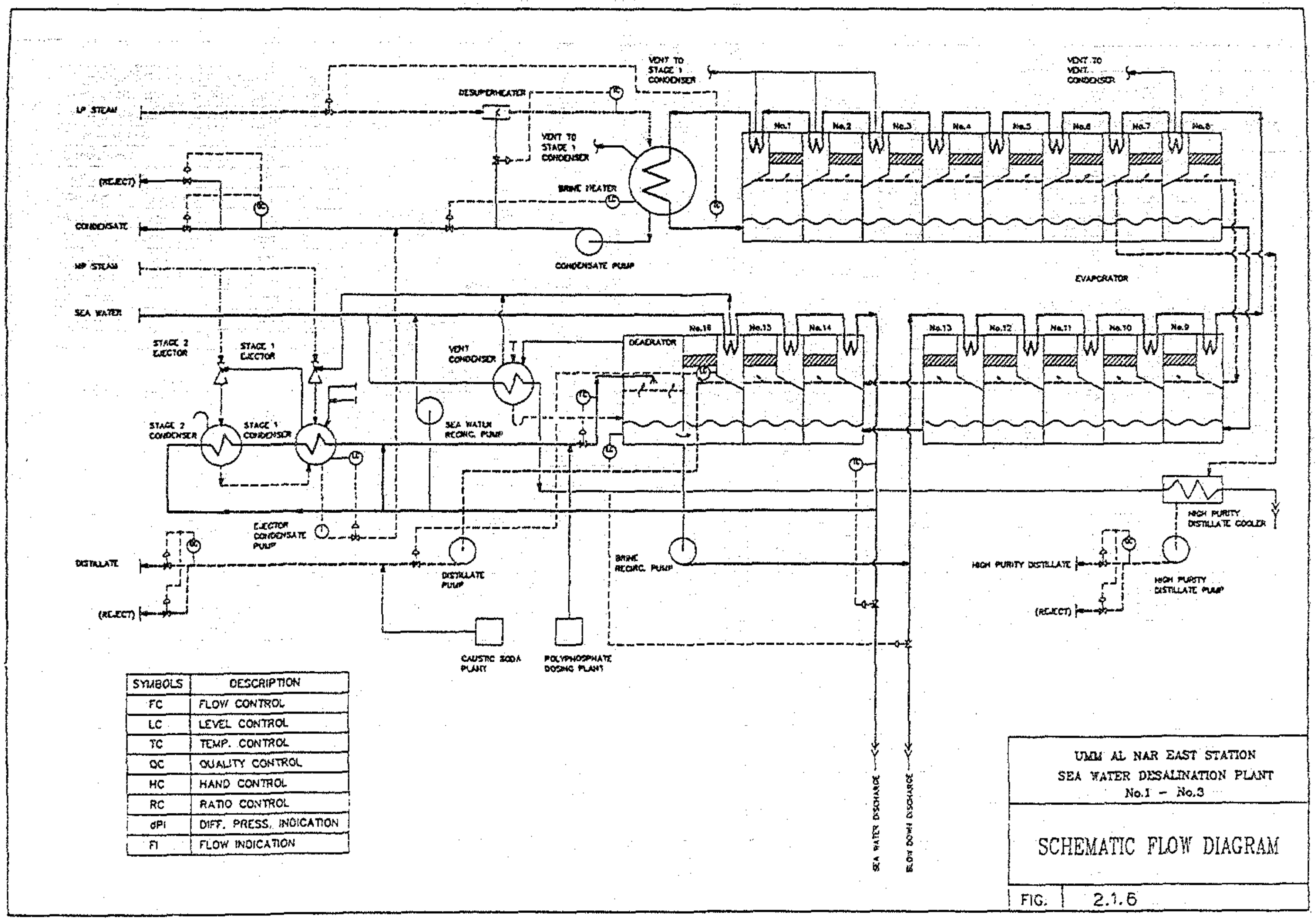
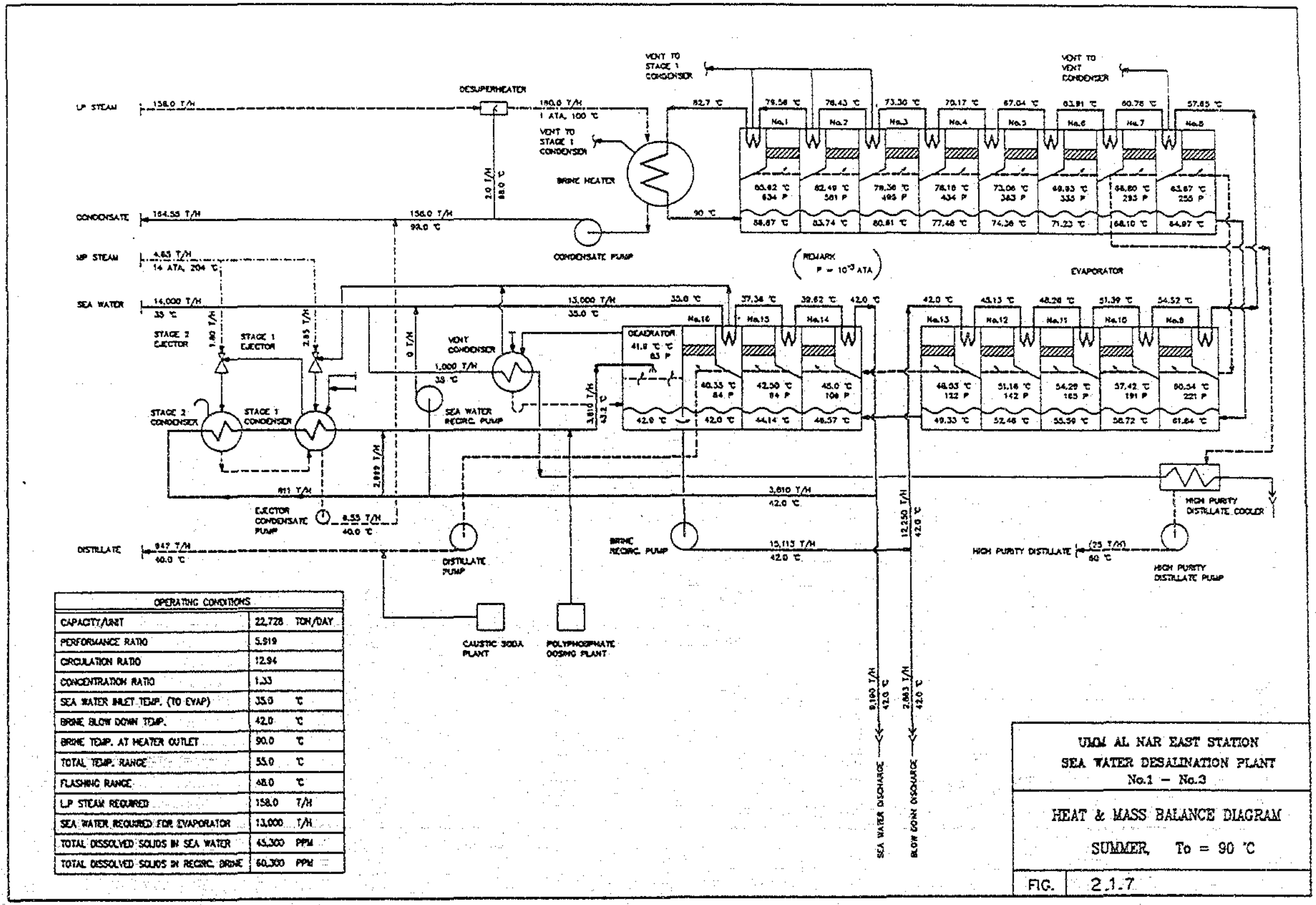
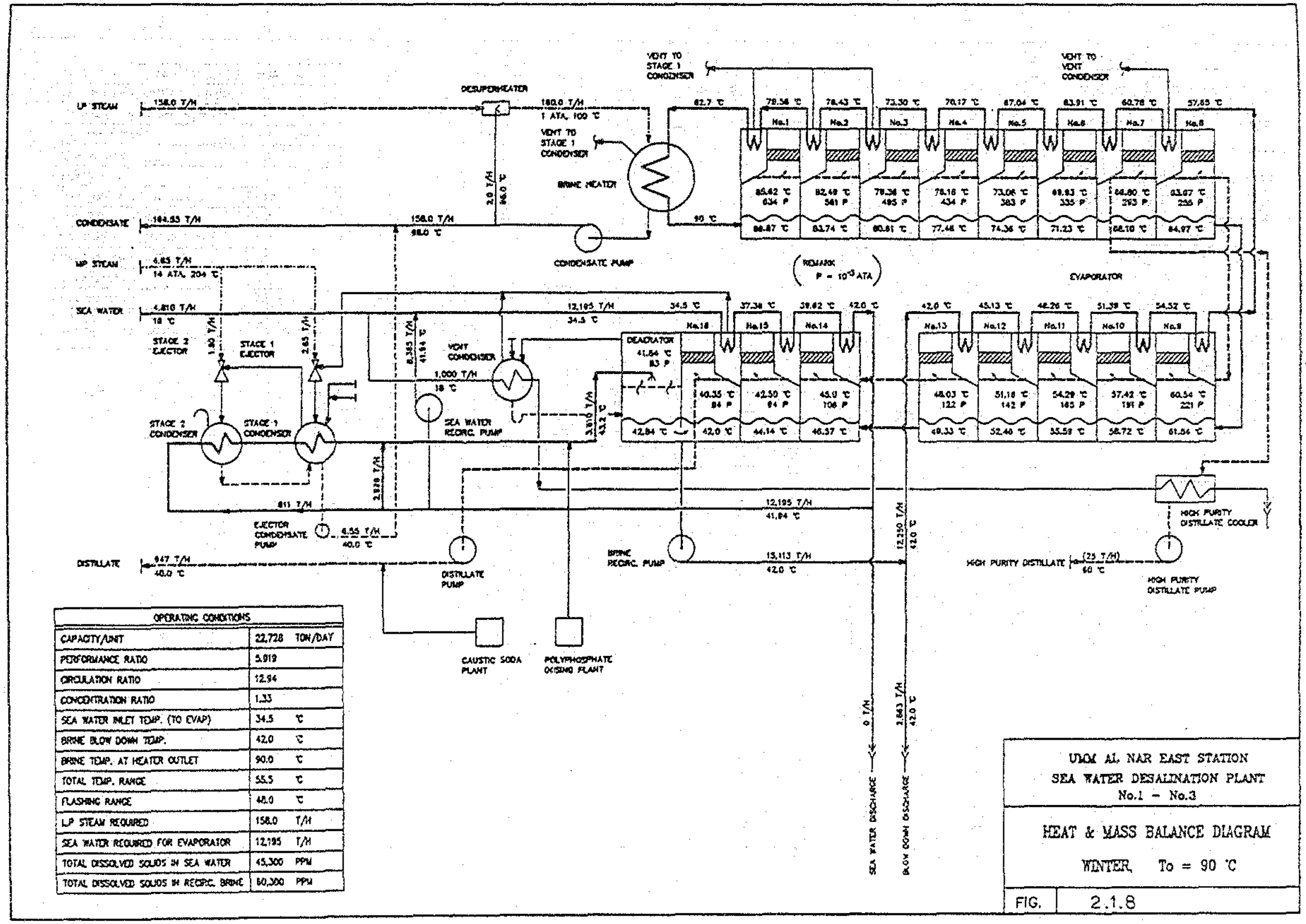


Fig. 2.1.6: Schematic Flow Diagram of Umm Al Nar East No.1 - No.3 Desalination Plant



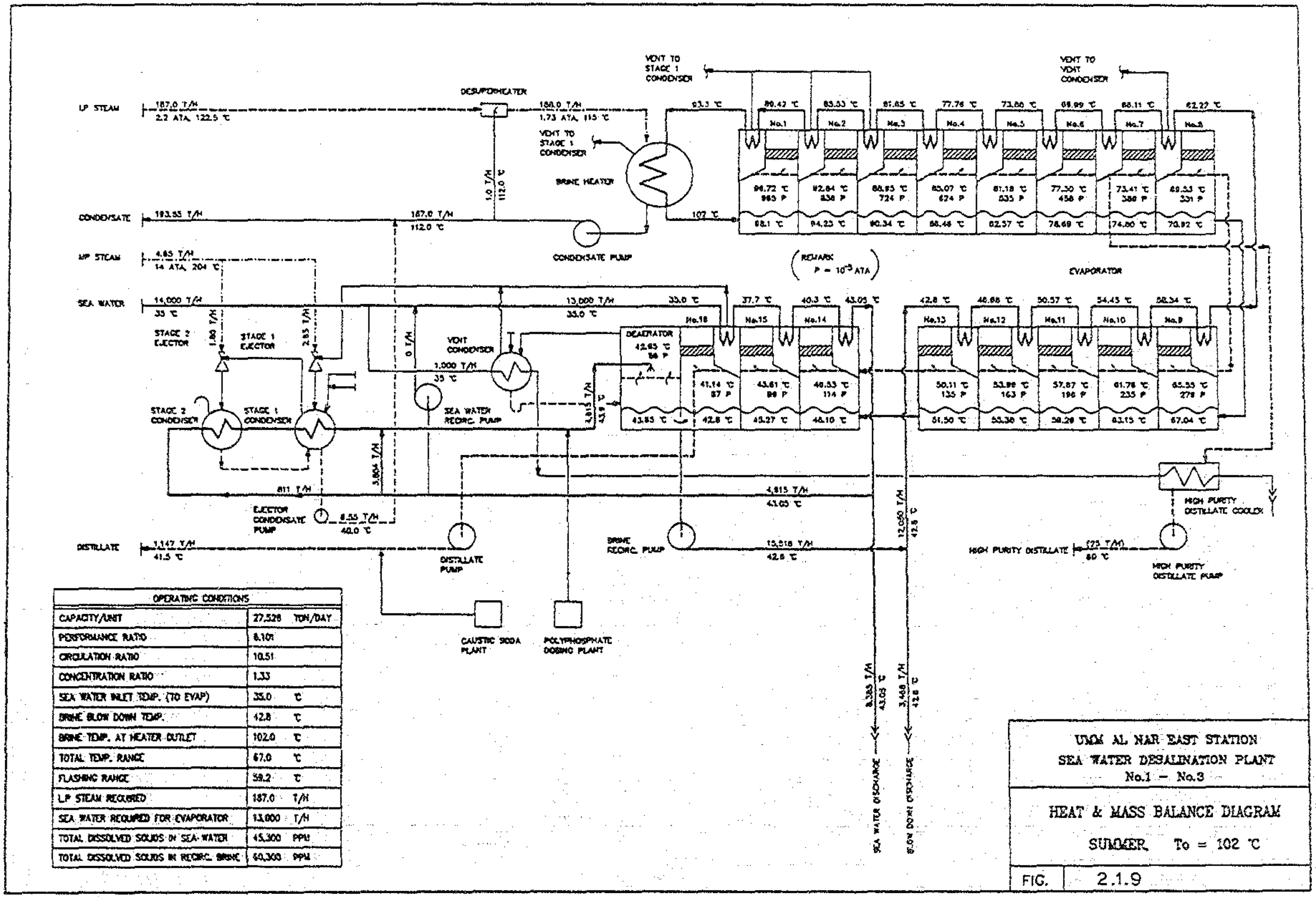
OPERATING CONDITIONS		
CAPACITY/UNIT	22,728	TON/DAY
PERFORMANCE RATIO	5.919	
CIRCULATION RATIO	12.94	
CONCENTRATION RATIO	1.33	
SEA WATER INLET TEMP. (TO EVAP)	33.0	°C
BRINE BLOW DOWN TEMP.	42.0	°C
BRINE TEMP. AT HEATER OUTLET	90.0	°C
TOTAL TEMP. RANGE	55.0	°C
FLASHING RANGE	48.0	°C
LP STEAM REQUIRED	158.0	T/H
SEA WATER REQUIRED FOR EVAPORATOR	13,000	T/H
TOTAL DISSOLVED SOLIDS IN SEA WATER	45,300	PPM
TOTAL DISSOLVED SOLIDS IN RECIRC. BRINE	60,300	PPM

Fig. 2.1.7: Heat and Mass Balance Diagram of Umm Al Nar East No.1 - No.3 Desalination Plant, Summer To = 90 °C



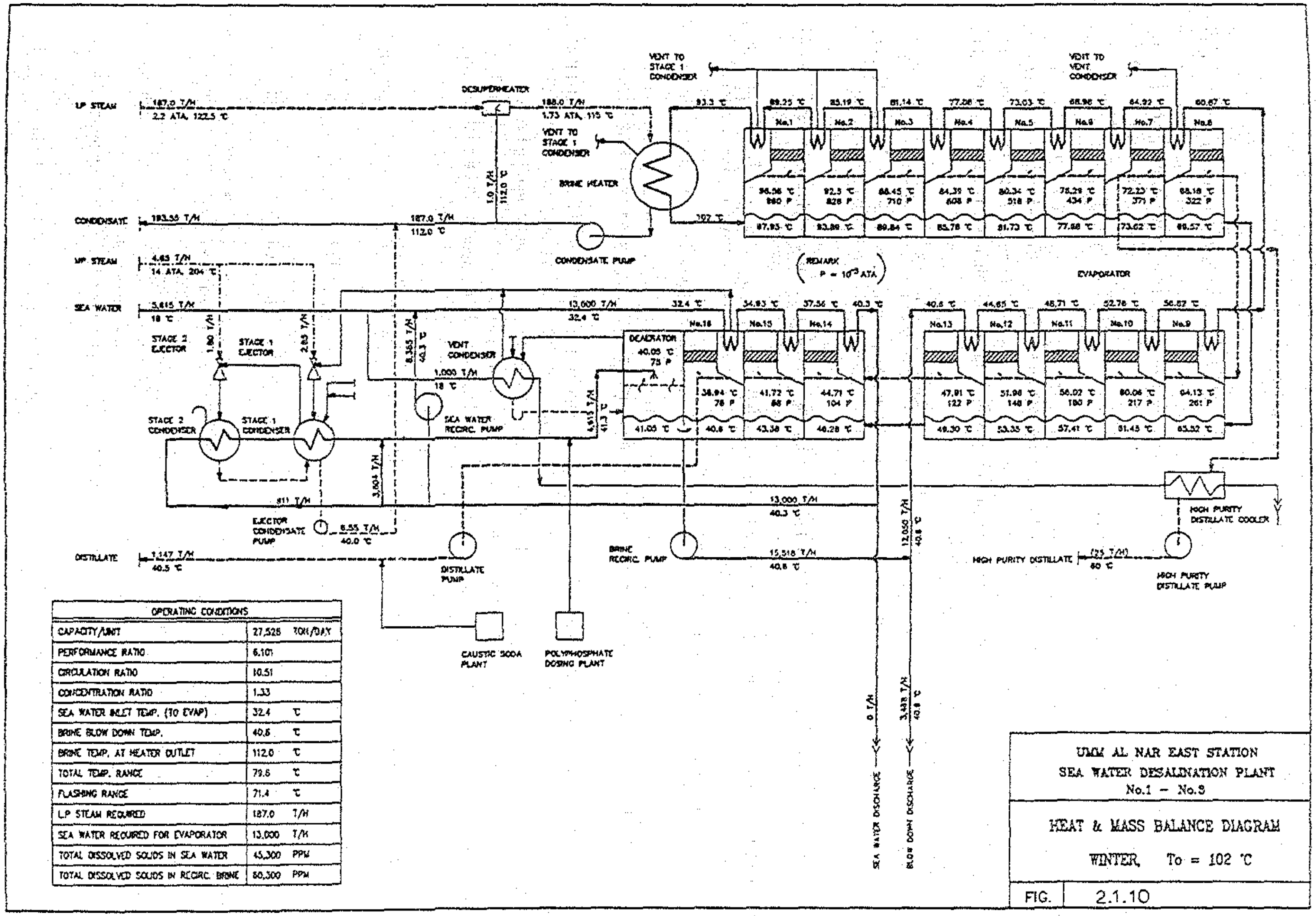
OPERATING CONDITIONS		
CAPACITY/UNIT	22,728	TON/DAY
PERFORMANCE RATIO	5.919	
CIRCULATION RATIO	12.94	
CONCENTRATION RATIO	1.33	
SEA WATER INLET TEMP. (TO EVAP)	34.5	℃
BRINE BLOW DOWN TEMP.	42.0	℃
BRINE TEMP. AT HEATER OUTLET	90.0	℃
TOTAL TEMP. RANGE	55.5	℃
FLASHING RANGE	48.0	℃
LP STEAM REQUIRED	158.0	T/H
SEA WATER REQUIRED FOR EVAPORATOR	12,195	T/H
TOTAL DISSOLVED SOLIDS IN SEA WATER	45,300	PPM
TOTAL DISSOLVED SOLIDS IN RECIRC. BRINE	60,300	PPM

Fig. 2.1.8: Heat and Mass Balance Diagram of Umm Al Nar East No.1 - No.3 Desalination Plant, Winter To = 90 °C



OPERATING CONDITIONS		
CAPACITY/UNIT	27,526	TON/DAY
PERFORMANCE RATIO	8.101	
CIRCULATION RATIO	10.51	
CONCENTRATION RATIO	1.33	
SEA WATER INLET TEMP. (TO EVAP)	35.0	℃
BRINE BLOW DOWN TEMP.	42.8	℃
BRINE TEMP. AT HEATER OUTLET	102.0	℃
TOTAL TEMP. RANGE	67.0	℃
FLASHING RANGE	59.2	℃
LP STEAM REQUIRED	187.0	T/H
SEA WATER REQUIRED FOR EVAPORATOR	13,000	T/H
TOTAL DISSOLVED SOLIDS IN SEA WATER	45,300	PPM
TOTAL DISSOLVED SOLIDS IN RECIRC. BRINE	60,300	PPM

Fig. 2.1.9: Heat and Mass Balance Diagram of Umm Al Nar East No.1 - No.3 Desalination Plant, Summer To = 102 °C



OPERATING CONDITIONS		
CAPACITY/UNIT	27,528	TON/DAY
PERFORMANCE RATIO	6.101	
CIRCULATION RATIO	10.51	
CONCENTRATION RATIO	1.33	
SEA WATER INLET TEMP. (TO EVAP)	32.4	°C
BRINE BLOW DOWN TEMP.	40.6	°C
BRINE TEMP. AT HEATER OUTLET	112.0	°C
TOTAL TEMP. RANGE	79.6	°C
FLASHING RANGE	71.4	°C
LP STEAM REQUIRED	187.0	T/H
SEA WATER REQUIRED FOR EVAPORATOR	13,000	T/H
TOTAL DISSOLVED SOLIDS IN SEA WATER	45,300	PPM
TOTAL DISSOLVED SOLIDS IN RECIRC. BRINE	60,300	PPM

Fig. 2.1.10: Heat and Mass Balance Diagram of Umm Al Nar East No.1 - No.3 Desalination Plant, Winter To = 102 °C

2.1.2 Thermal Electric Power Stations

(1) WEST No. 1 - No. 6 Units

6 boilers and 6 steam turbine-generators are installed, each as a unit system, in the Power Station. The boilers, normally natural gas fired and as standby crude oil fired, generate steam of 365 t/h each at 67 bar and 490 °C. Each turbine-generator is rated output of 60 MW and reduced pass-out steam is supplied to the desalination plant.

The sea water cooled surface condensers can accept the full steam capacity of the boilers if the desalination plants are shut down. Alternatively, a pressure reducing system and a bypass system allow the desalination plants to operate on full output when the steam turbine-generator is shut down or on reduced load.

The main technical data of the principal equipment is shown in Table 2.1.3, the heat balance diagram in Fig. 2.1.11, and the main flow diagram in Fig. 2.1.12.

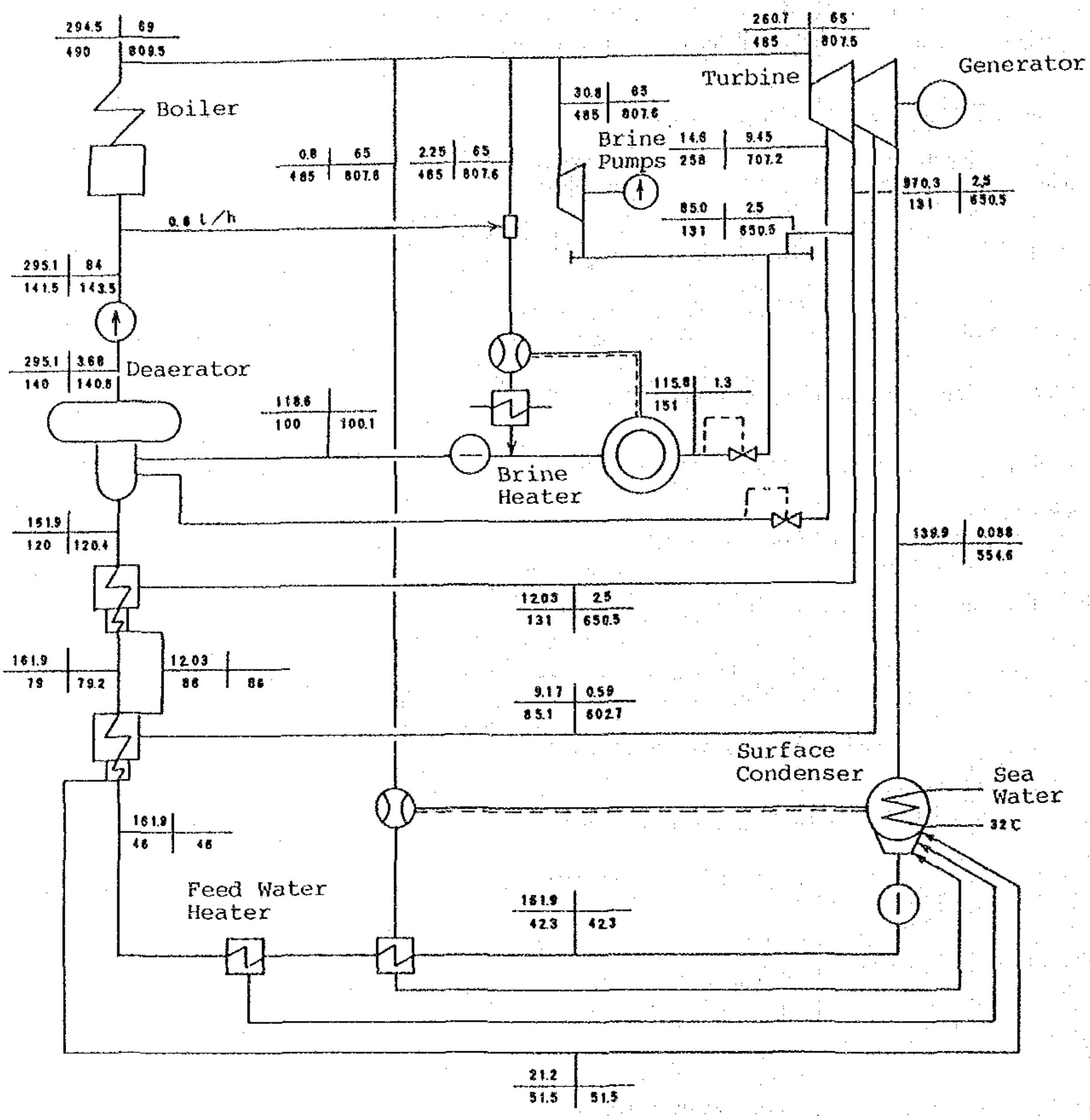
The output capacity, thermal efficiency and operation rate of the Power Station are all dependent on the performance of the principal heat cycle equipment. In the Umm Al Nar West No. 1 - No. 6 units, the surface condensers only use sea water directly in the heat cycle system and would be subject to sea water oil contamination.

In addition, service water coolers, turbine oil coolers and generator air coolers also use sea water as a cooling medium in the power station.

The cooling sea water flow diagram is shown in Fig. 2.1.13. As indicated in the diagram, in the West No. 1 - No. 6 units the cooling sea water flow system is independent of the heat cycle, namely, being completely separated from the heat cycle system, oil polluted sea water accordingly does not cause any essential operational troubles in the power stations.

Table 2.1.3: Main Technical Data of Thermal Electric Power Station, West No.1 - No.6

Description		Technical Data
Equipment	Particulars	
Steam Turbine	Type	Condensing
	Rated Output (Generator terminal) kW	60,000/64,500
	Inlet Steam Temperature (Rated) °C	485
	Inlet Steam Pressure (Rated) Bar	60.8
	Passout steam, Flow t/h	85.0
	Temperature °C	131
	Pressure Bar, abs	2.5
	Exhaust pressure (Sea water: 32 °C) Bar, abs	0.115
	Rated revolution rpm	3,000
	Extraction stages No.	3
	Manufacturer	SKODA (Czech.)
Condensing System	Cooling Area m²	3.715
	Design condensate flow t/h	216,261
	Design sea water temperature °C	32 (max. 35)
	Design sea water flow at 35 t/h	13,600
	Cooling tube, out/in mm	23.0/20.0
	Length (between plates) mm	7.975
	Material	70/30 CuNi
	Quantity	6.446
	Tube plate material	70/30 CuNi
	On load cleaning	Sponge ball (Taproge)
	Manufacturer	Bulcke-Durr (W.G.)
Steam Boiler	Type	Single drum Radiant natural Circul.
	Design pressure Bar	86.4
	Steam pressure at Superheater Outlet Bar	66.7
	Steam temperature, ditto	490
	Steam production (max.) t/h	365
	Inlet feed water temperature	140
	Draft System	Forced draft
	Fuel	Natural gas Crude oil
	Burner for natural gas	Multi-spud
	Manufacturer	Babcox (W.G.)
Generator	Rated Capacity kVA	80,625
	Power factor	0.85
	Rated voltage kV	11
	Rated frequency cycle	50
	Rated revolution	3,000
	Manufacturer	SKODA (Czech.)



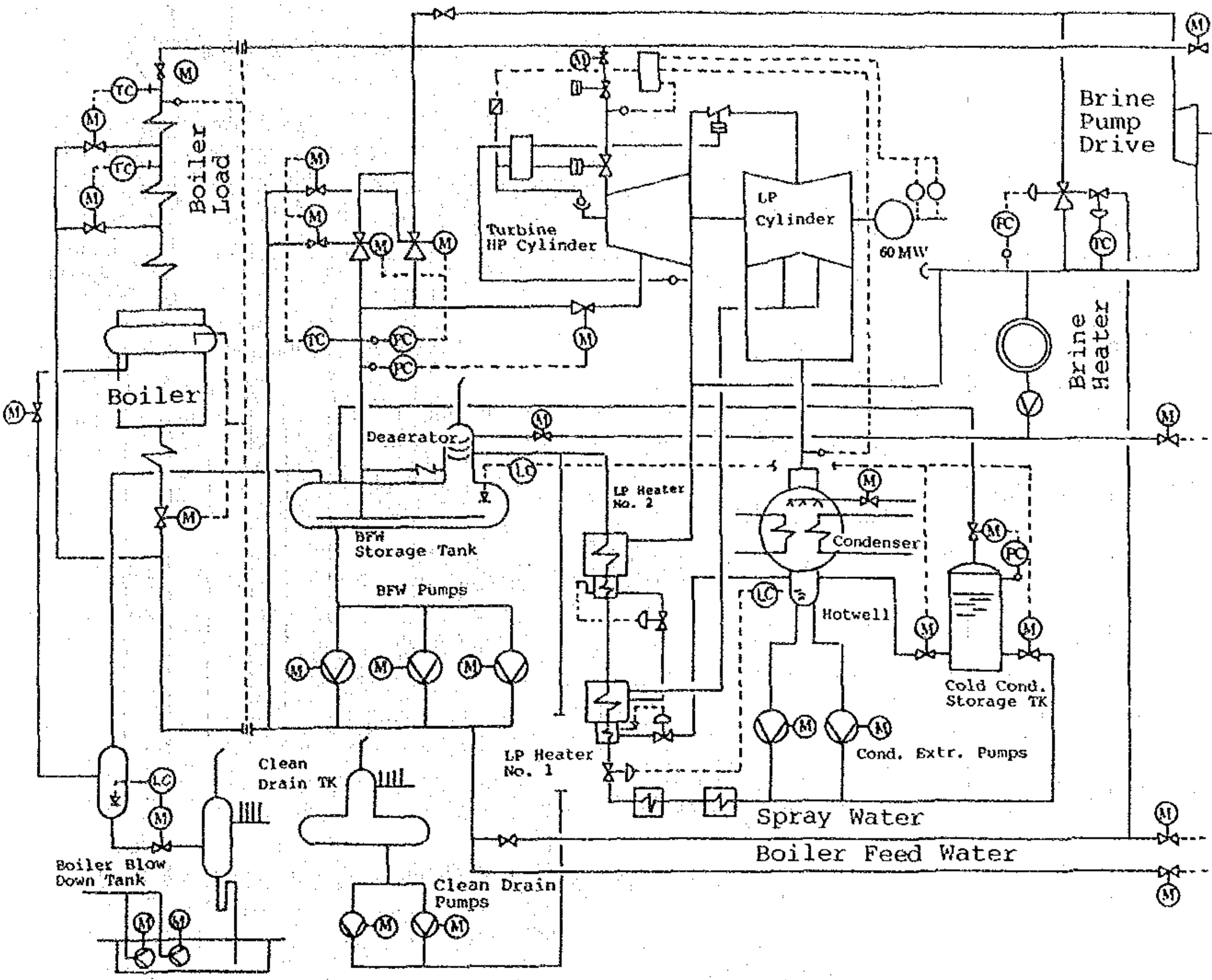
Generator Output: 60 MW, Passout Steam: 85 t/h

Source: WED Drawing 3980.412.004

Indicating Unit:

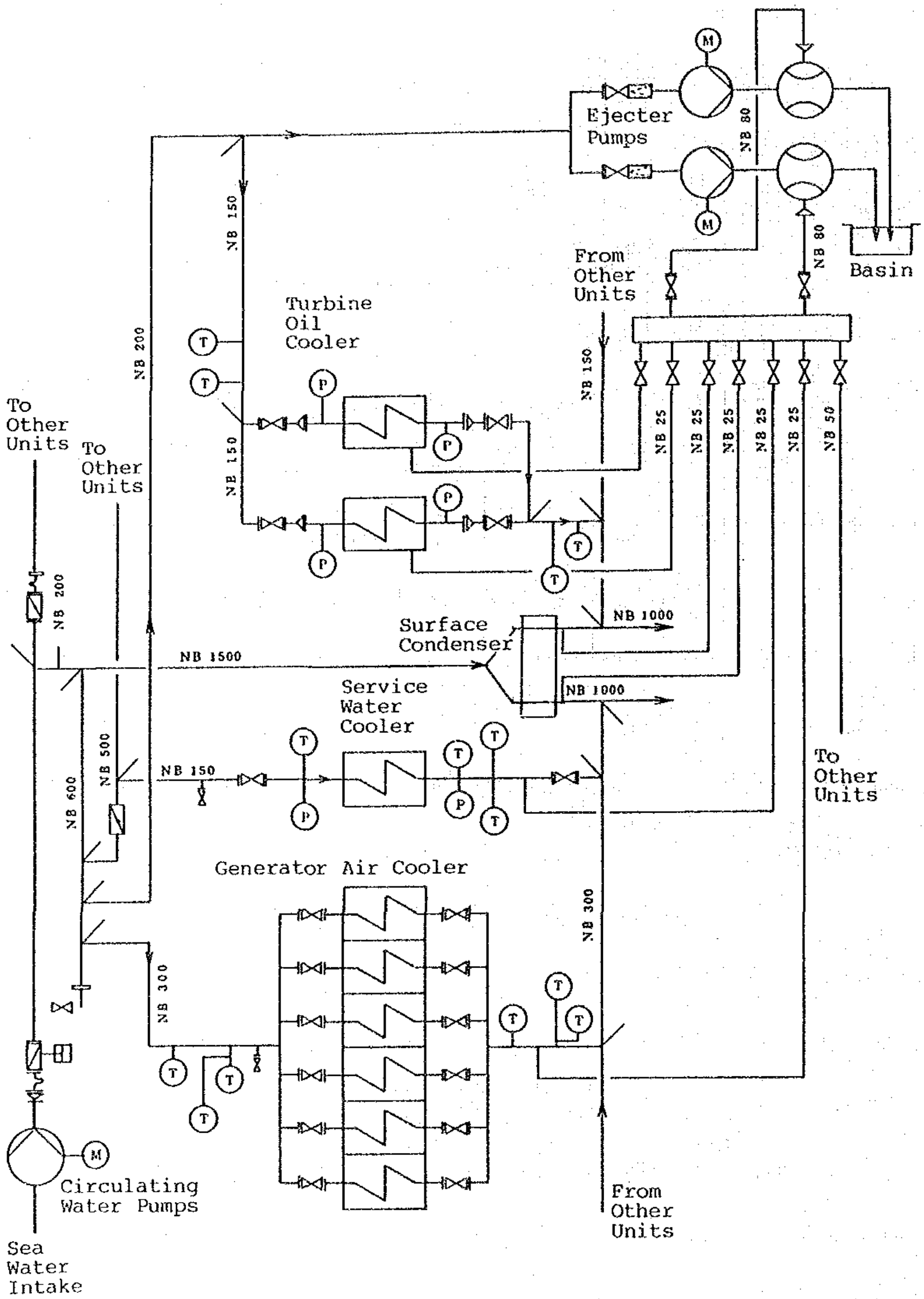
t/h	kg/cm^2 abs
°C	kcal/kg

Fig. 2.1.11: Heat Balance Diagram of Umm Al Nar West No.1 - No.6 Power Station



Source: WED Drawing 3980. 412. 001

Fig. 2. 1. 12: Main Flow Diagram of Umm Al Nar West No. 1 - No. 6 Power Station



Source: WED Drawing A2.2-5 230

Fig. 2.1.13: Cooling Sea Water Flow Diagram of Umm Al Nar West No.1 - No.6 Power Station

(2) Equipment Subject to Oil Contamination

1) Surface Condenser

This equipment is used to condense the steam exhausted from the steam turbine, using sea water as its cooling medium. The outline of the surface condenser is shown in Fig. 2.1.14. Its function is to raise the turbine thermal efficiency by reducing the back pressure of the turbine, to less than atmospheric pressure, under which steam is cooled to be condensed by sea water.

The surface condenser has horizontally installed cooling tubes (quantity 6,446) through which the sea water passes, and around the tube bundle steam passes downwards. The sea water temperature thus rises several degrees, while steam is cooled to be condensed, passing in the tube bundle. Inside the tubes the heat is transferred to sea water through turbulent flow from the tube wall, while outside the tubes the heat is transferred from steam through laminar flow film formed by condensation. The flow films at the surface of lower tubes are disturbed by condensed droplets from the upper tubes.

Design Data of Surface Condenser

Exhaust steam rate	58.4	kg/s
Enthalpy of exhaust steam	2,350.5	kJ/kg
Condensation pressure	0.115	bar abs
Cooling sea water rate	3,778	kg/s
Cooling sea water temperature (inlet)	32.0	°C
Cooling sea water temperature (outlet)	39.9	°C
Cooling sea water velocity (inside tubes)	1.87	m/s

2) Service Water Cooler

The service water is used to cool the rotating machines in the power station. The service water is recirculated and reutilized as cooling water through the service water cooler (U-tube, shell and tube type heat exchanger) in the system. The outline of the service water cooler is as shown in Fig. 2.1.15.

Design Data of Service Water Cooler

Service water rate	63	m^3/h
Cooling sea water rate	126	m^3/h
Service water temperature (inlet/outlet)	50/40	°C
Cooling sea water temperature (inlet/outlet)	35/40	°C
Service water velocity (inside tubes)	0.55	m^3/h
Cooling sea water velocity (outside tubes)	1.73	m^3/h

The service water is cooled inside the tubes which are horizontally arranged in a U-shaped bundle, while the cooling sea water absorbs the heat of the service water from the outside of tubes changing its flow directions up and down between the baffle plates equipped outside the tube bundle. The sea water passing through the cooler is accordingly in a very violent, turbulent condition.

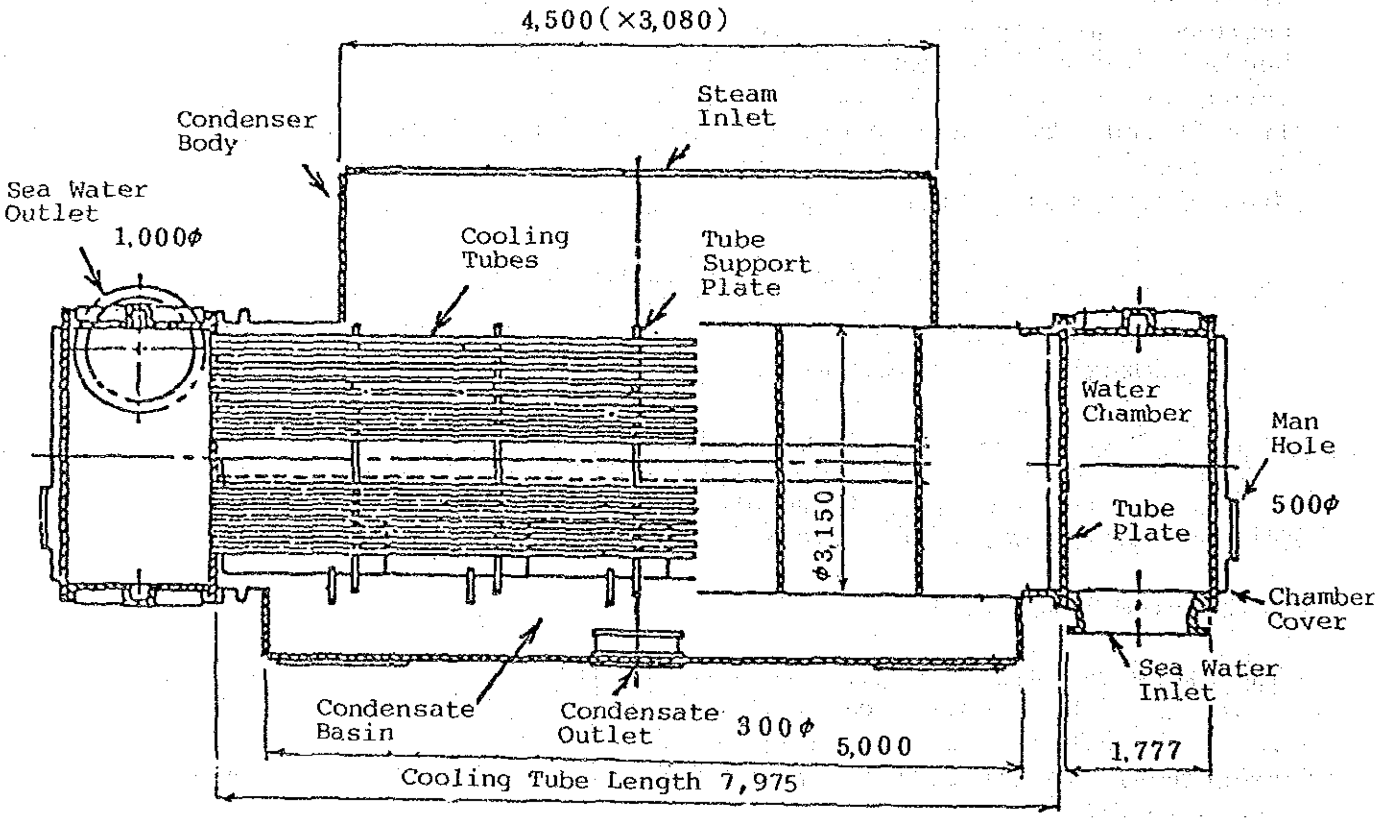
3) Steam Turbine Oil Cooler

This is for cooling the lubricating oil for the steam turbine using sea water. The oil is then re-used in a closed system. The structure is the same as the service water cooler's.

4) Generator Air Cooler

This is for cooling down the cooling air for the generator using sea water. Sea water passes through the cooler tubes, which are arranged horizontally under the generator, and air passes around the outside.

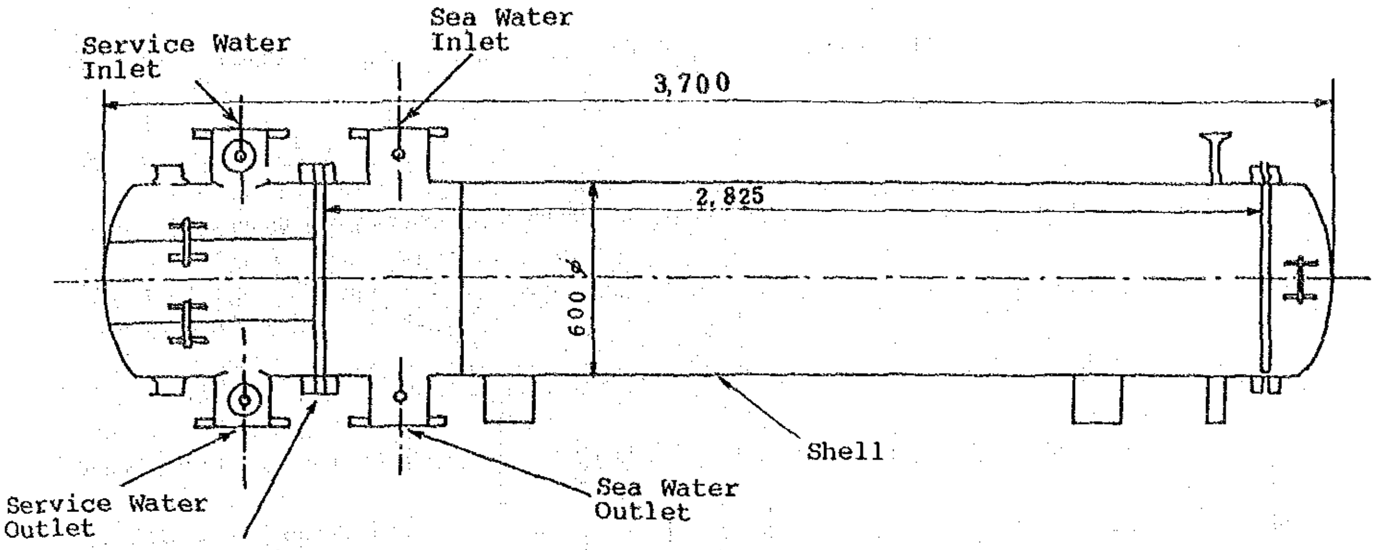
The outline of the generator air cooler is shown in Fig. 2.1.16.



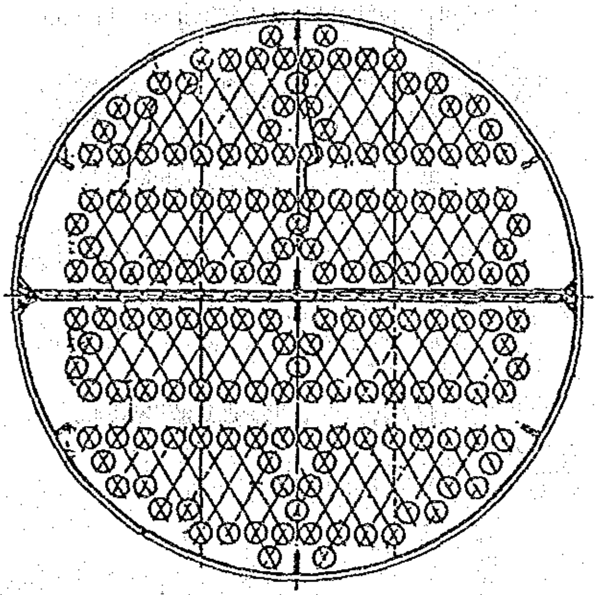
Main Technical Data		Shell	Thick Material	19 mm H-II (DIN)
Type	Horizontal			
Cooling Tube No. O.D I.D L Material	6,446 23 mm 20 mm 7,975 mm CuNi 30Fe	Tube plate	Thick Material	48 mm H-II
		Manufacturer		BALCKEDURR
Shell O.D	3.150 mm	Completion date of built up drawing		26 Jul 84

Source WED Drawing: 3980.428.014J

Fig. 2.1.14: Surface Condenser Outline of Umm Al Nar West No.1 - No.6 Power Station



Cooler Outline

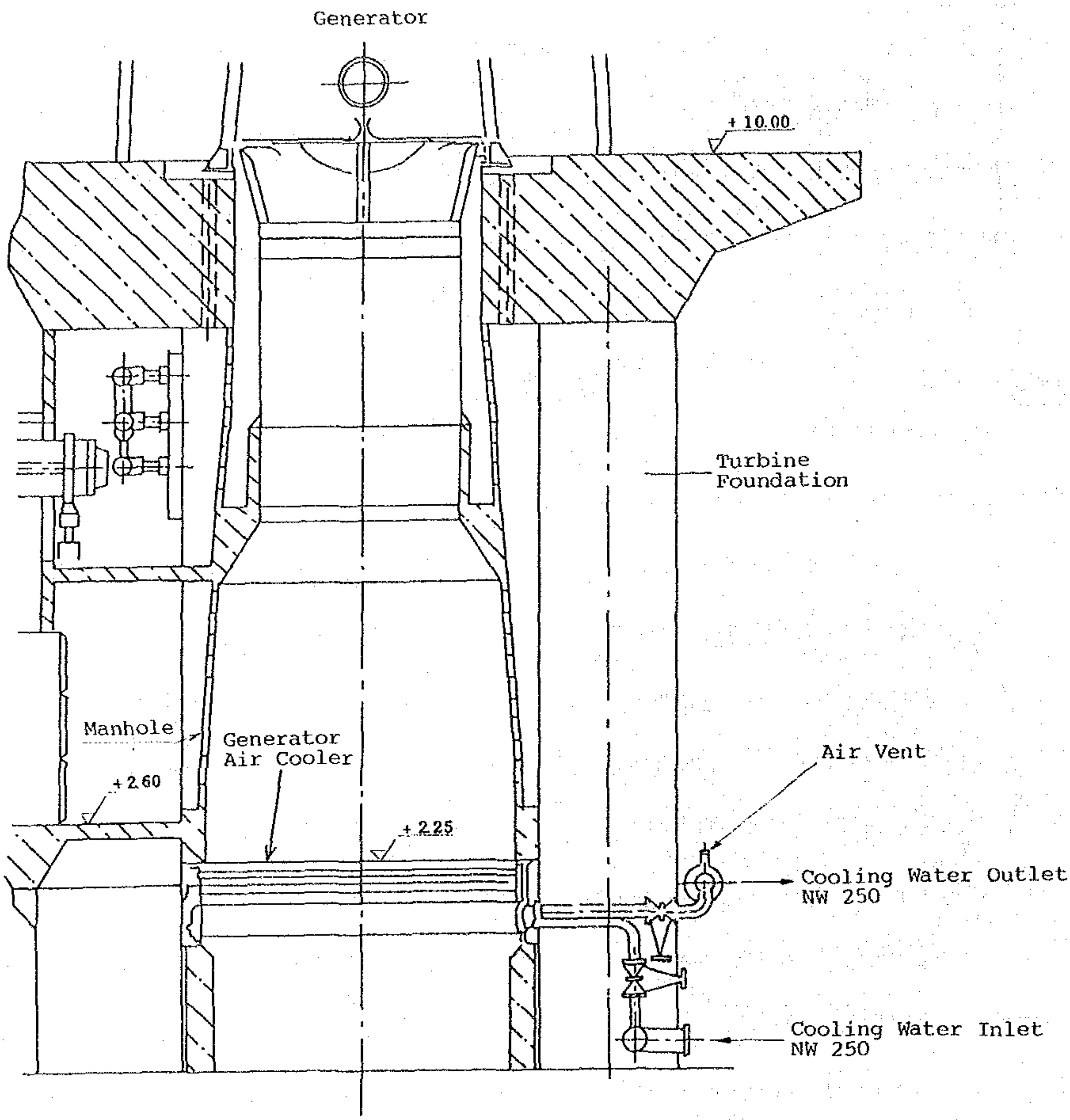


Cooling Tube Arrangment

Main Technical Data	
Type	Horizontal
Cooling Tube No. O.D I.D L Material	260 23 mm 20 mm 2,825 mm CuNi 30Fe
Shell O.D Thick Material	600 mm 6 mm H-II (DIN)
Tube plate O.D Material	36 mm CuNi 30Fe
Manufacturer	BALCKDURR
Completion date of built up drawing	26 Jul 84

Source WED Drawing: 3980.428.014J

Fig. 2.1.15: Service Water Cooler Outline of Umm Al Nar West No.1 - No.6 Power Station



Max. Operating Pressure: 10 bar
Test Pressure : 15 bar

Source WED Document A1. 3. 5 Page 21

Fig. 2. 1. 16: Generator Air Cooler Outline of Umm Al Nar West No. 1 - No. 6 Power Station

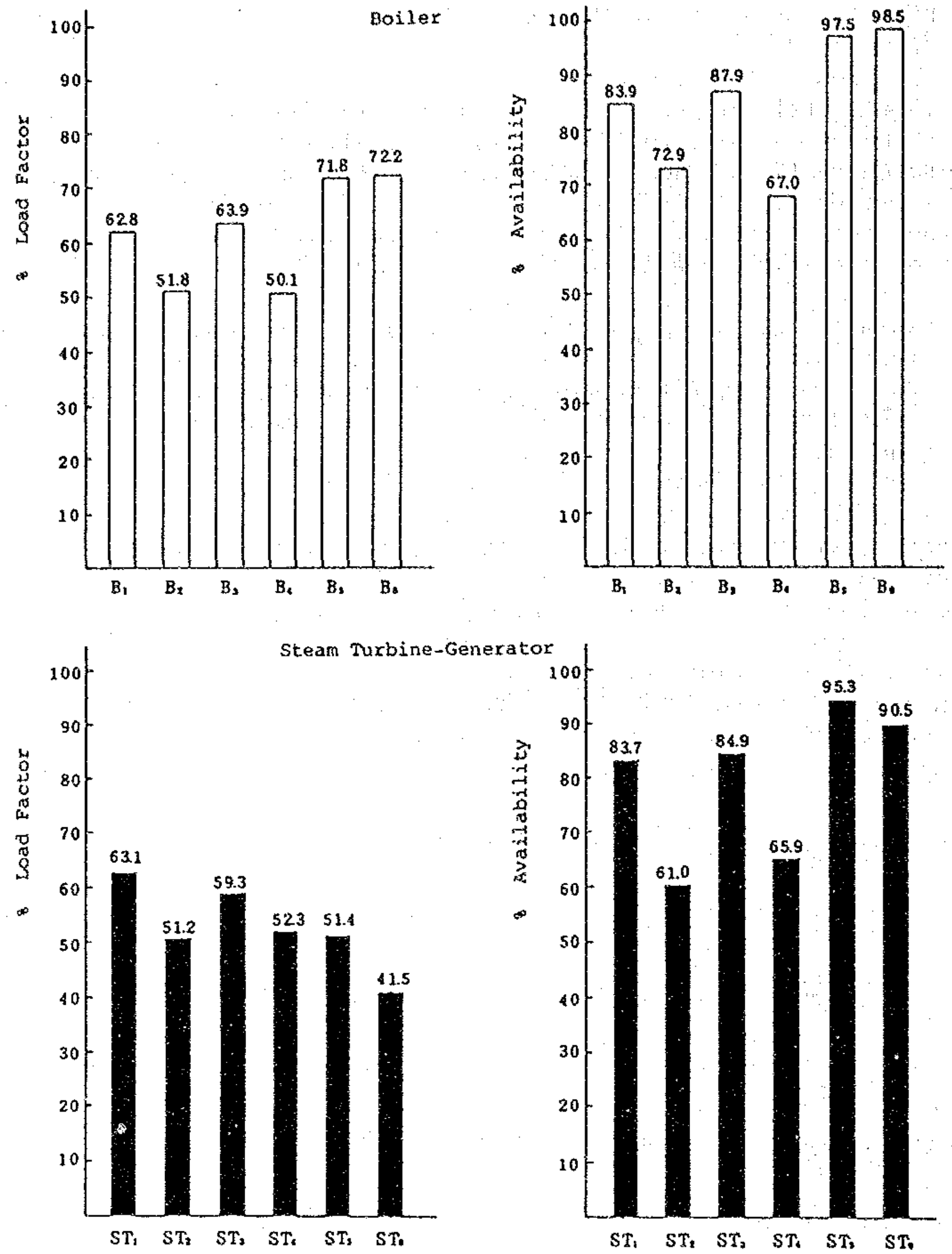
(3) Operational Conditions of the Power Station (WEST No. 1 - No. 6 Units)

As is clear from Fig. 2.1.17, the load factor of the power station kept up high levels such as 50 to 70% for the boiler, and 41 to 63% for the steam turbine generators in 1986. This means that the power station had been operated on base load. This was also backed up by the high availability factor of the Power Station i.e. 67 to 99% for boilers and 61 to 95% for the steam turbine-generators. It is presumed that such high load operation of the station will continue also into the future.

The power station is designed to use cooling sea water at a temperature of 32 °C ideally, and at a maximum of 35 °C. The actual sea water temperatures, according to WED measurement values, are estimated at 20 to 34 °C, which, due to the temperature difference, do not demonstrate an ample margin for operation.

In addition, the steam turbine and surface condenser are being operated under severe temperature conditions because the actual sea water maximum temperature period, from June to October, falls on the power station's peak load period, as is clarified in WED operational data.

The operational conditions of the station show that it should be kept in operation even if hindered slightly by a reduction in the cooling efficiency, which would be caused by oil polluted sea water.



$$\text{Load Factor} = \frac{\text{Total Generated Load}}{\text{Rated Load} \times \text{Operating Hours}} \times 100$$

$$\text{Availability} = \frac{\text{Open Hours} + \text{Standby Hours}}{\text{Total Hours}} \times 100$$

Source WED Report CA/87/09

Fig. 2.1.17: Load Factor and Availability in 1986 of Umm Al Nar West No. 1 - No. 6 Power Station

2.2 Auxiliary Facilities of the Power and Desalination Plant

2.2.1 Facilities for Sea Water Intake and Chlorination

Sea water supplied to Umm Al Nar Station is taken from the south coast of the plant and is discharged from the north coast of the plant. 3 sea water intake facilities and 4 discharge facilities are installed at the station.

The designed capacity for each of the intake and the discharge facilities is as follows:

Intake facilities	No. 1	220,000 m^3/h
	No. 2	180,000 m^3/h
	No. 3	55,000 m^3/h

Discharge facilities	No. 1	143,000 m^3/h
	No. 2	178,000 m^3/h
	No. 3	72,000 m^3/h
	No. 4	51,000 m^3/h

Sea water intake supplied from intake facilities No. 1 is as follows:

To W1 - W6 Power Plants	13,000 m^3/h x 6 =	78,000 m^3/h
To W1 - W6 Desalination Plant	12,000 m^3/h x 6 =	72,000 m^3/h
To E1 - E3 Desalination Plants	15,000 m^3/h x 3 =	45,000 m^3/h
To ADNOC		5,000 m^3/h
Total		200,000 m^3/h

Horizontal and vertical profile sections of sea water intake facilities No. 1 are shown in Figs. 2.2.1 and 2.2.2 respectively.

Sea water intake facilities No. 1 consists of 5 submerged ferro-concrete intakes, Bar screen, traveling screens and sedimentation basins are connected to the intakes. Furthermore there are common channels at which the sea water from each of the intakes meets. Sea water which passes through the band screen is supplied to each of the units through vertical pumps.

Data on each of the installations is as follows:

Intake	: 5 sets cross section to take sea water -4.5 m (W) x EL-4.30 - 9.00m (H)
Bar Screen	: 5 sets gap of 7 cm
Traveling Screen	: 5 sets
Sedimentation Basin	: 10 sets 4.75 m (W) x 37 m (L) x 9.00 m (D)
Band Screen	: 7 sets mesh size of 1.5 mm x 1.5 mm

Remarks, EL (at Umm Al Nar)
EL = ACD + 3.55 m

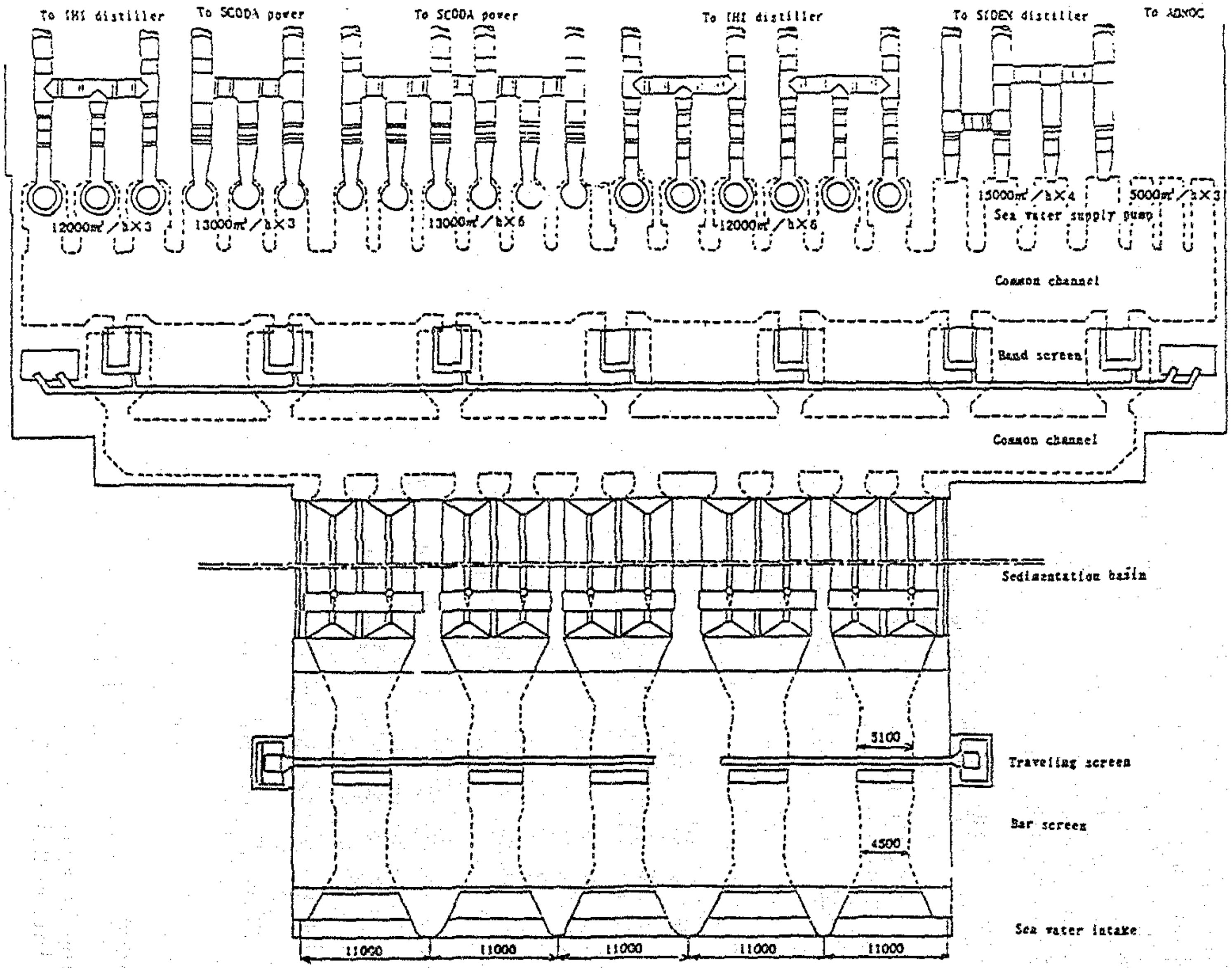


Fig. 2.2.1: Horizontal Profile Sections of Sea Water Intake Facilities No.1

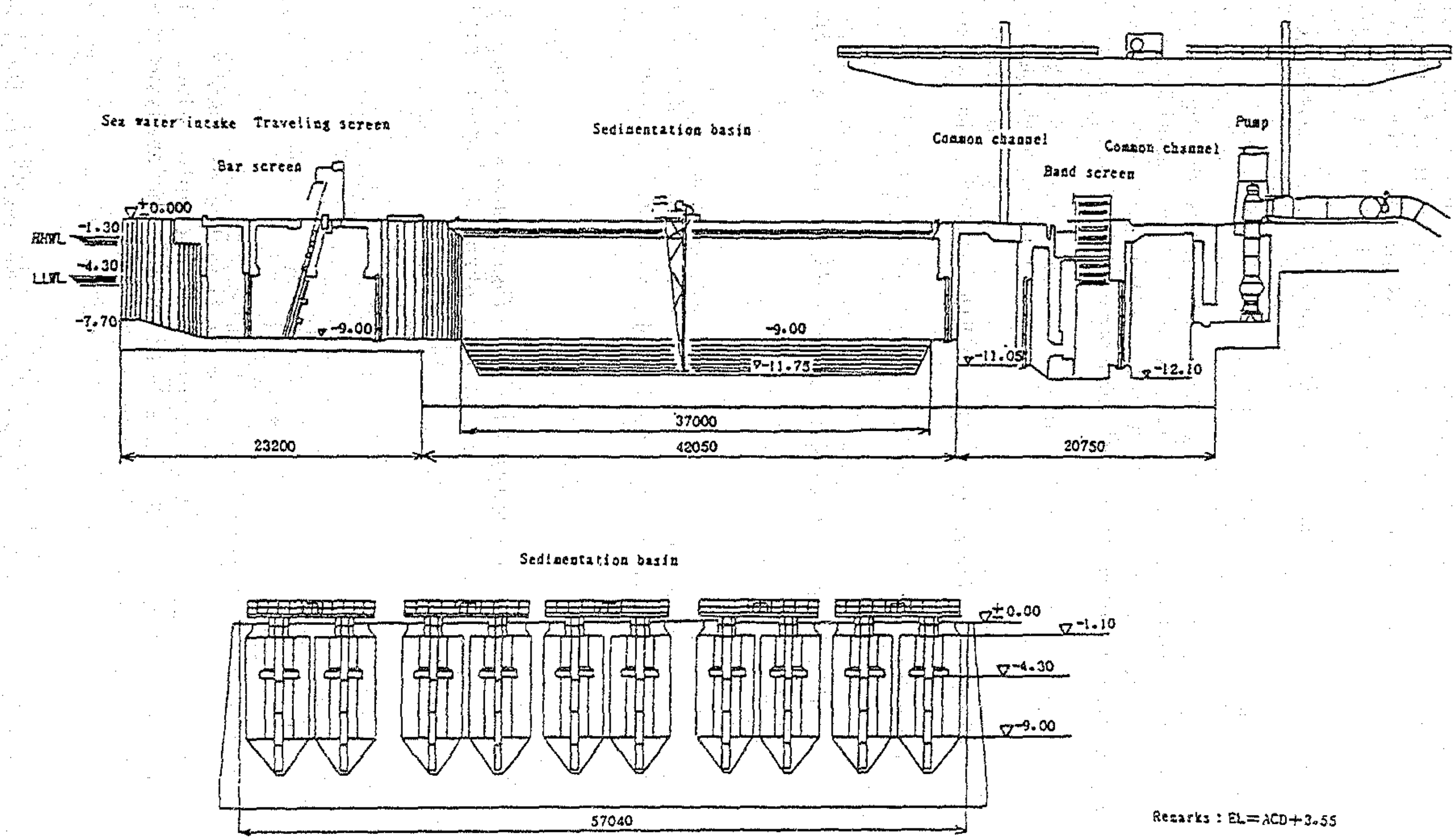


Fig. 2.2.2: Vertical Profile Section of
Sea Water Intake Facilities No.1

Sea water (with a dissolved chlorine content of about 2,000 mg/l) which is manufactured by ADNOC adjacent to Umm Al Nar, is injected into the sea water intake and the sea water pump inlet to prevent plants from fouling.

The chlorination system is designed to feed continuously into the sea water intake as well as into the suction inlet of each water pump at a rate of 1 mg/l as Cl_2, which gives a rate of 0.1 to 0.3 mg/l as Cl_2 at the heat exchanger discharge.

Shock chlorination at a rate of 2 mg/l as Cl_2 a few times during a one day period is also required to avoid the growth of marine organisms. The residual chlorine is measured directly at the sea water outlets of each of the desalination plants and of the turbine condensers.

2.2.2 Existing Oil Preventive Facilities

An oil preventive facilities consisting of a monitoring system, an air bubbling system and an oil fence, as shown in Fig. 2.2.3, is already installed outside the No.1 intake.

(1) Monitoring System

This system consists of a buoy, oil sensor, power supply unit, analyzer, transmitter and receiver.

1) Buoy

The floating buoy is used as a mount for an oil sensor, solar battery and beacon light, and as a housing for the power supply unit, analyzer and transmitter.

2) Oil Sensor

The oil sensor detects oil in sea water by measuring changes in the conductivity of sea water. It is comprised of 2 separated copper plates immersed in sea water.

3) Power Supply Unit

Power is supplied by a 6 V DC battery and a solar battery.

4) Analyzer

The analyzer receives the measured conductivity from the oil sensor and compares this measured value with a predetermined threshold value. When the measured conductivity exceeds the threshold value, the analyzer sends alarm signals to the receiver via the transmitter.

5) Transmitter

The transmitter transforms the alarm signal from the analyzer to radio signal and to the receiver.

6) Receiver

The receiver is located in the control room of the station. An alarm bell rings when the transmitter begins sending radio signals to the receiver.

(2) Oil Preventive Facilities

An air bubbling system is installed as the first line of defense. This system prevents oil infiltration of the intake by the use of minute bubbles produced at and jetted from the vicinity of the sea bottom. Oil film is rejected by the horizontal water flow grown out near the sea surface by the air bubbles and the oil emulsion in sea is also prevented by the rising water flow produced by the air bubbles.

Air for the air bubbles is supplied by 3 compressors (pressure: 8 bar, delivery volume: 2,225 cfm = 62.3 m^3/min) in the compressor room located ashore.

As a second barrier, an oil fence is stretched out at the inner side of the air bubbling system, having a depth of about 1 m under the sea surface and about 10 cm above the water.

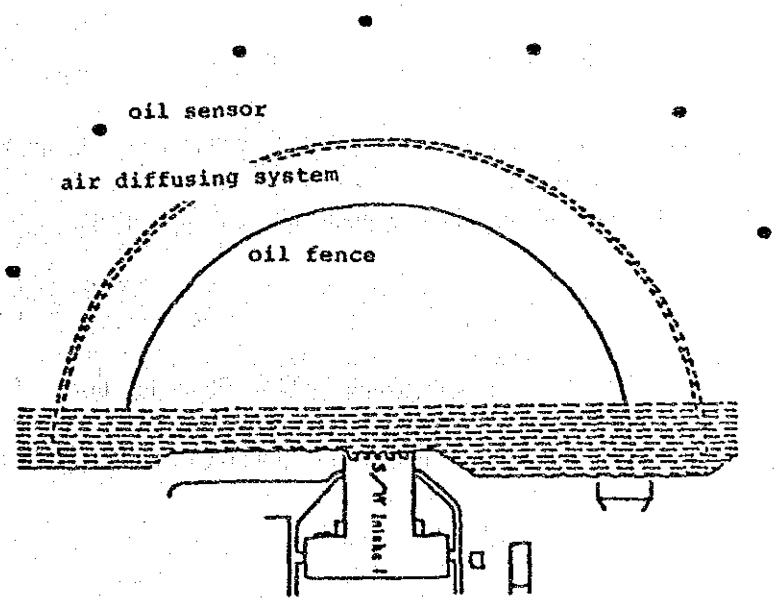


Fig. 2.2.3: Existing Oil Spill Protection Facilities

2.3 Natural Environment

Based on the existing data and information collected, an outline of the natural environment is given below. The observation sites hereinafter described are shown in Fig. 2.3.1.

2.3.1 Climatic Conditions

(1) Atmospheric Temperature

Abu Dhabi is located in a desert climate region. In summer (April to October), high temperature and humidity are experienced. The average temperature is in the range of 25 to 35 °C, and the maximum temperature sometimes reaches 45 °C.

In winter (November to March), the north wind, "Shamir", is strong and the climate is rather warm with an average temperature of about 20 °C. At night, the temperature sometimes falls to 10 °C. The monthly average temperatures in Abu Dhabi city are shown in Fig. 2.3.2.

As shown in Fig. 2.3.3, "Average Variation in Temperature", the annual average maximum temperature was approximately 35 °C over the 3 years from 1977 to 1979, but was about 40 °C over the years 1980 to 1982.

As shown in Figs. 2.3.4 and 2.3.5 respectively, the diurnal variations in temperature and humidity show that the minimum temperature and maximum humidity occur in the early morning at approximately 7 o'clock, and the maximum temperature and minimum humidity occur at around 1 o'clock in the afternoon. The diurnal variation in temperature and humidity are 10 to 15 °C and 40% respectively.

(2) Rainfall

The annual variation in rainfall is shown in Fig. 2.3.6. In Abu Dhabi, more than 50 mm of rainfall was recorded in 1975, 1976, 1977, 1982 and 1983. The annual rainfall varies greatly in Abu Dhabi.

As shown in Fig. 2.3.7, "Variations in Monthly Rainfall in Abu Dhabi", a little rainfall was observed in winter from January to March, and no rainfall was observed in summer from June to September. Because 30 mm of rainfall was observed only in August 1975 during the 14 year period from 1975 to 1984, the average rainfall in Abu Dhabi is recorded as approximately 2 mm. The variation in monthly rainfall in Abu Dhabi is shown in Fig. 2.3.8.

(3) Wind Direction and Velocity

The wind velocity frequency distributions recorded at Abu Dhabi International Airport and Bateen Airport in 1984 are shown in Fig. 2.3.9. The north-westerly wind prevails at both locations. The prevailing direction at Bateen Airport is a little northward of the prevailing direction at Abu Dhabi International Airport.

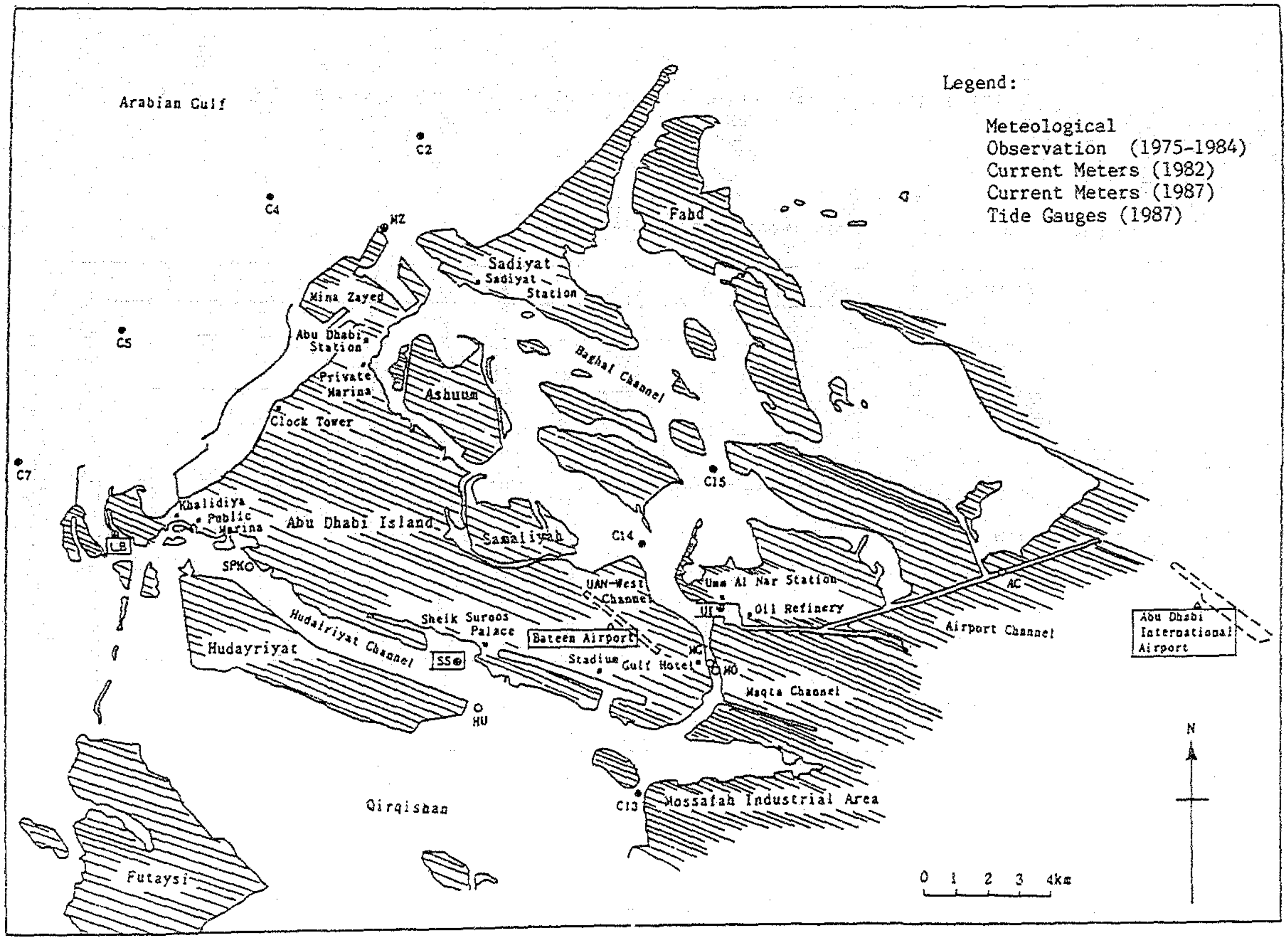
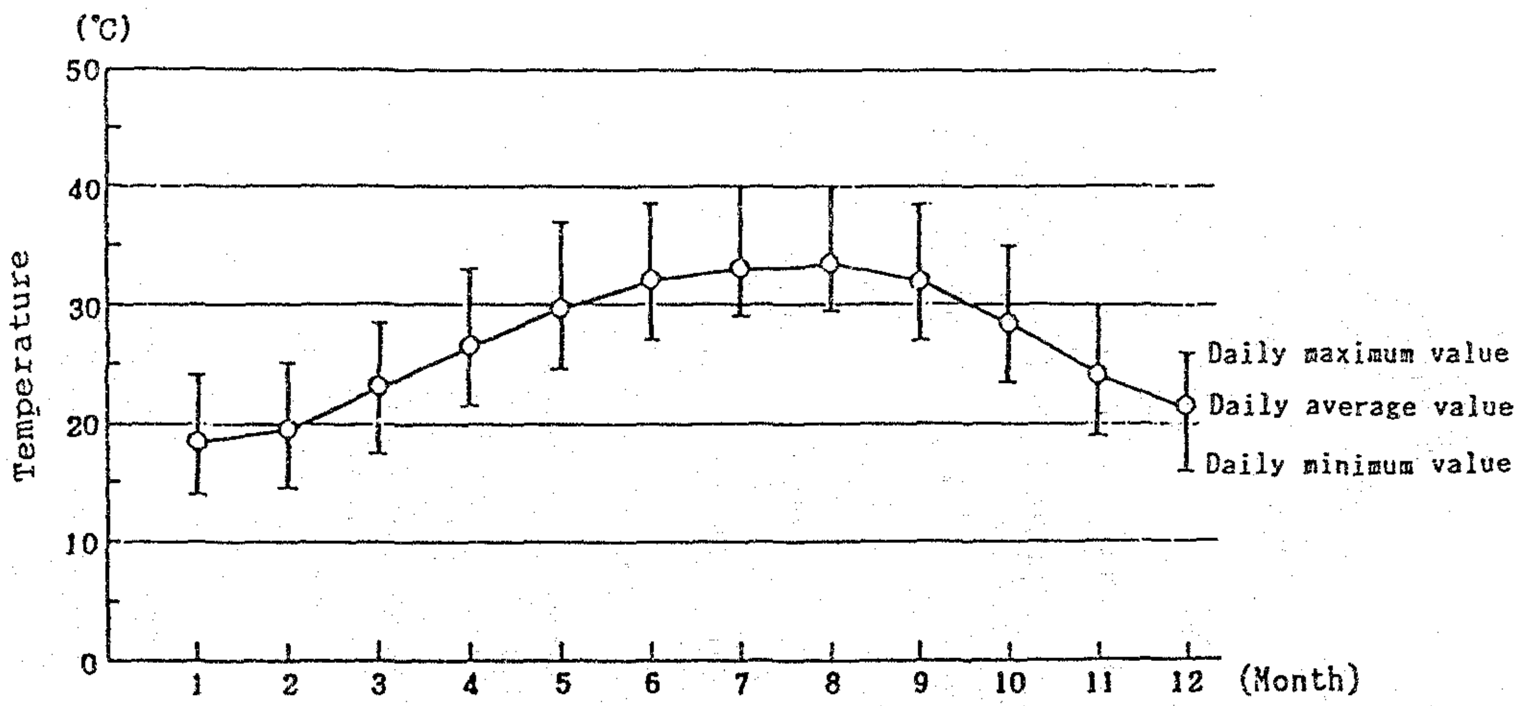
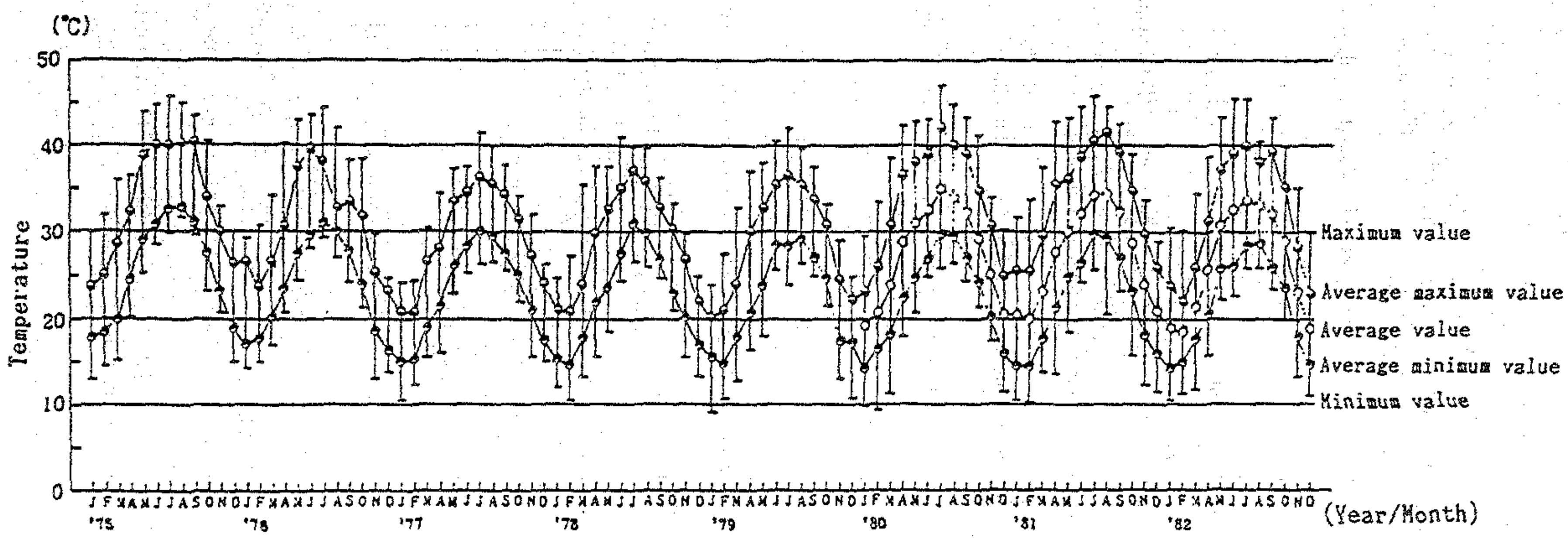


Fig. 2.3.1: Observation Sites (Recorded Information)



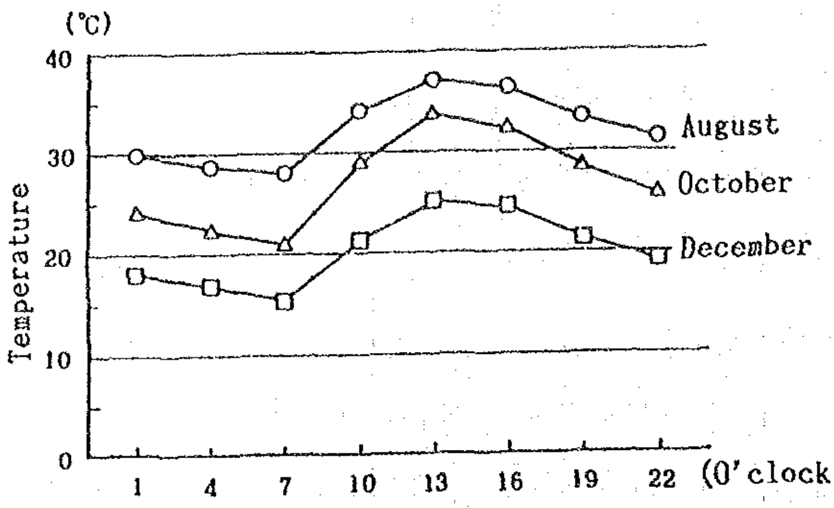
Remarks:Tabulated from Information Supplied by W.E.D.

Fig. 2.3.2: Monthly Average Temperature at Bateen Airport (1971-1984)



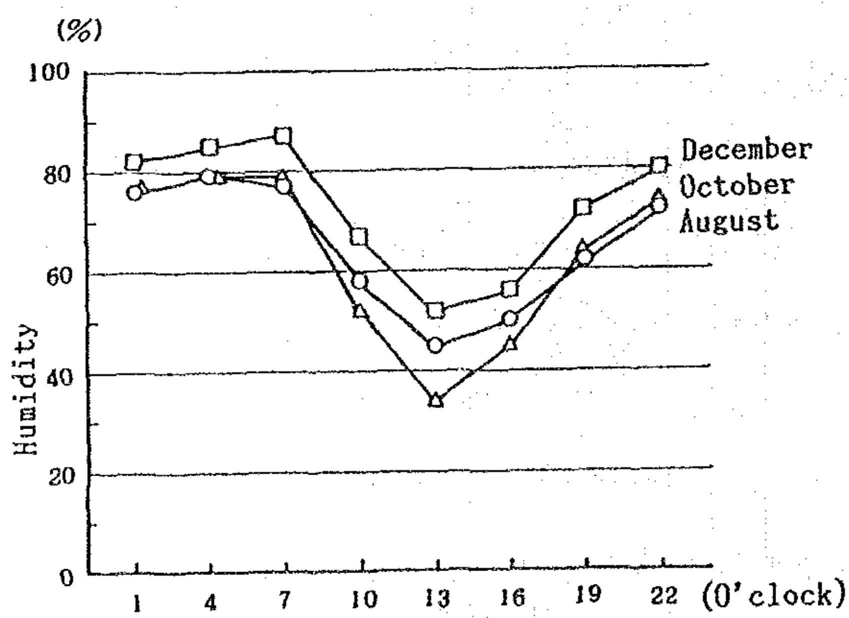
Remarks:Tabulated from Information Supplied by W.E.D.

Fig. 2.3.3: Variations in Monthly Temperature at Bateen Airport



Remarks:Tabulated from Information Supplied by W.E.D.

Fig. 2.3.4: Diurnal Variations in Monthly Average Temperature at Bateen Airport (1984)



Remarks:Tabulated from Information Supplied by W.E.D.

Fig. 2.3.5: Diurnal Variations in Monthly Average Humidity at Bateen Airport (1984)

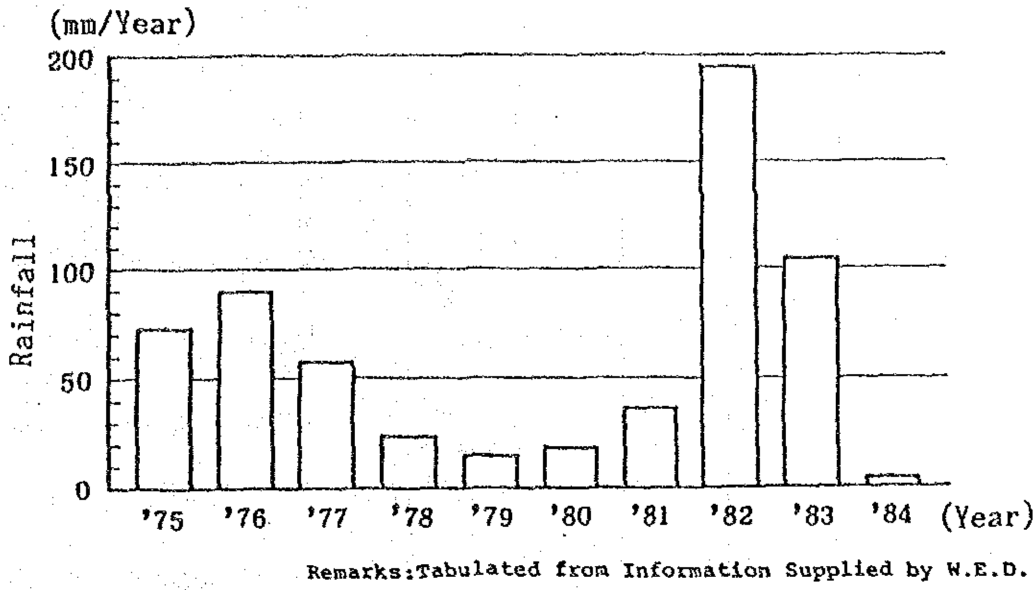


Fig. 2.3.6: Variations in Annual Rainfall at Bateen Airport

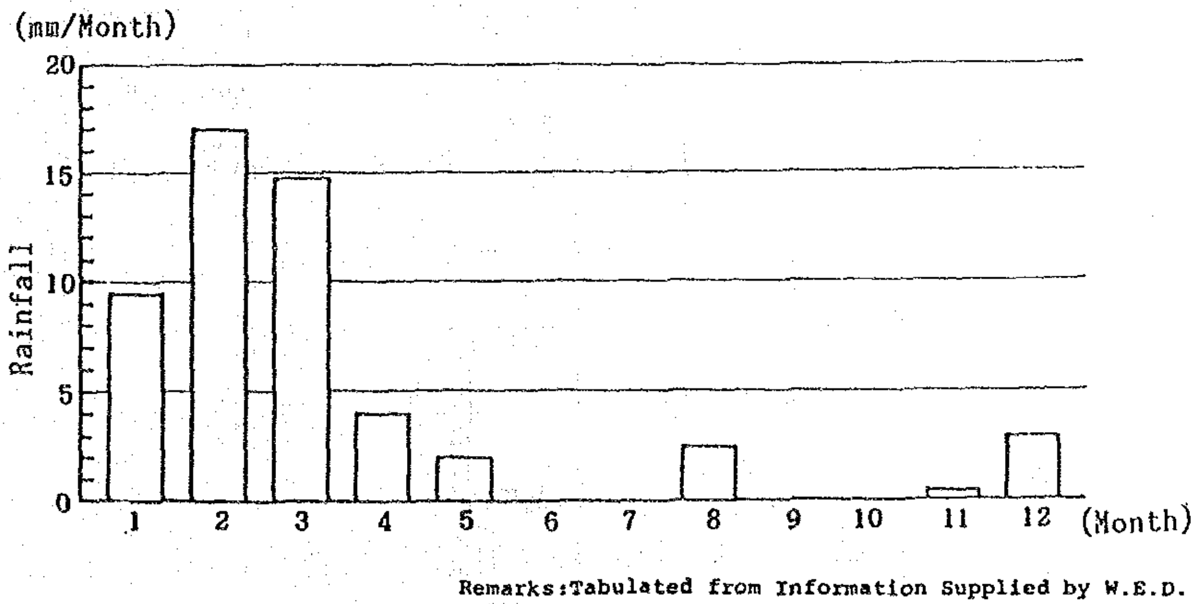
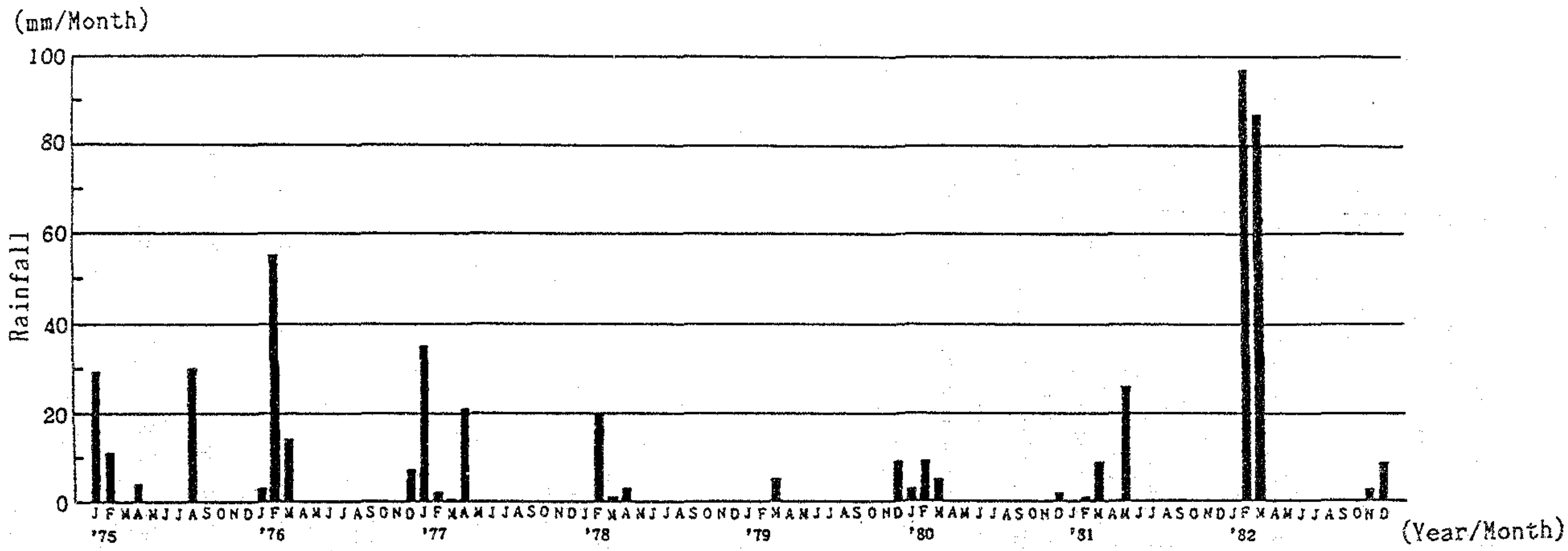
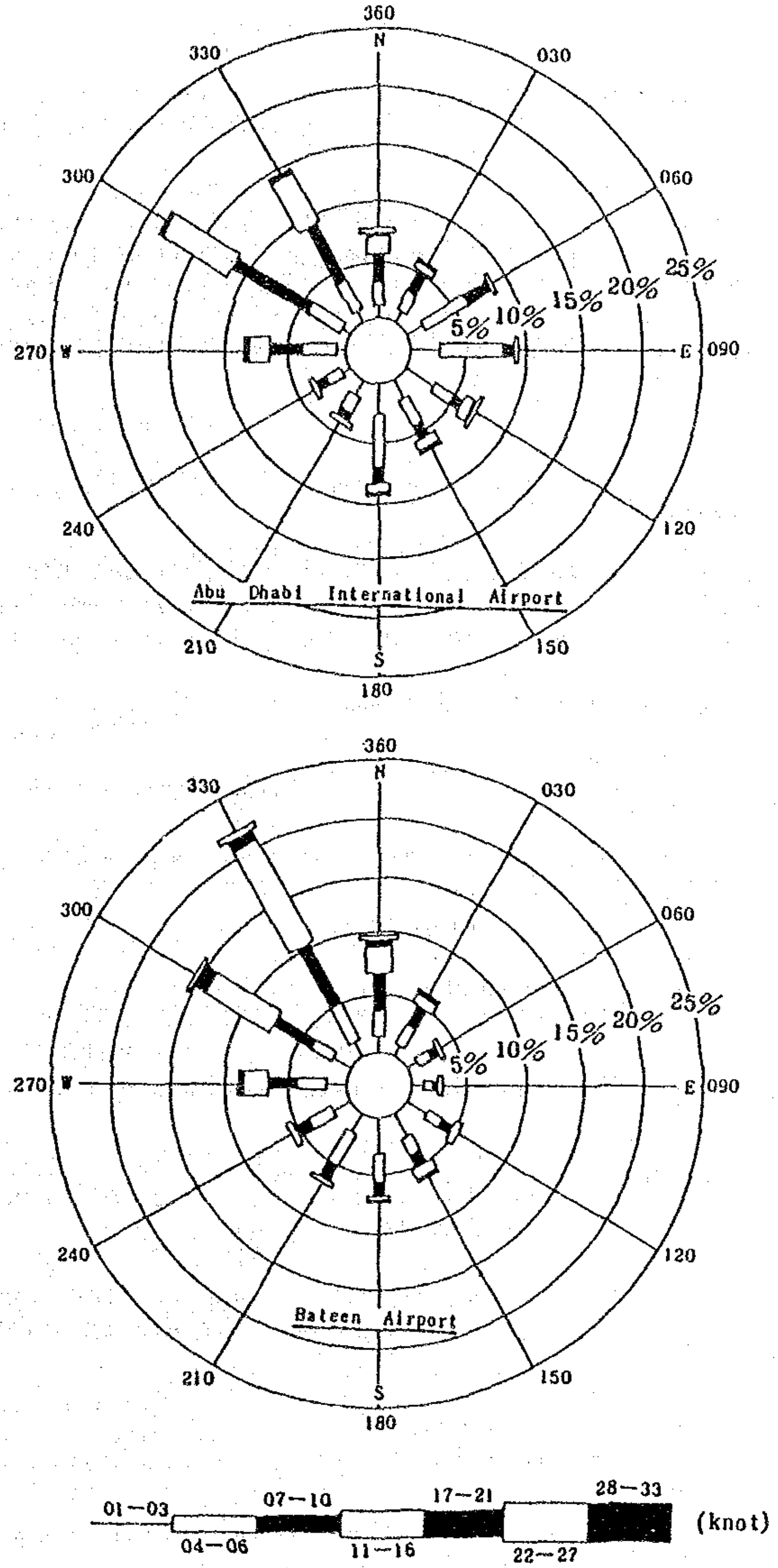


Fig. 2.3.7: Monthly Average Rainfall at Bateen Airport (1971-1984)



Remarks:Tabulated from Information Supplied by W.E.D.

Fig. 2.3.8: Variations in Monthly Rainfall at Bateen Airport



Remarks: Tabulated from Information Supplied by W.E.D.

Fig. 2.3.9: Comparison Between Annual Wind Velocity Frequency Distributions at Abu Dhabi International Airport and Bateen Airport (1984)

2.3.2 Marine Conditions

(1) Tidal Level

The observations of tidal level which the Hydraulic Laboratory carried out in the sea area around the Abu Dhabi Island from June 8 to 25, 1987, were subjected to short-term harmonic analysis and the characteristics of the tides were examined. The observation sites were 4 locations, Ladies Beach (LB), Mina Zayed (MZ), Sheik Suroors Palace (SS) and the Umm Al Nar Intake (UI) as shown in Fig. 2.3.1.

Remarks : Harmonic Analysis

The tidal level h(t) at a particular site at a particular time (t) is able to be developed in the cosine series with fixed amplitudes and fixed periods.

That is, h(t) is expressed as follows:

$$h(t) = h_0 + \Sigma h_k \cos(\omega_k t - \psi_k)$$

where,

h_0: average tidal level
h_k: amplitude of component k
ω_k: angular velocity of component k
ψ_k: phase of component k
h_k: $\cos(\omega_k\ t - \omega_k)$ is called component k. ψ_k

The constant h_k and ψ_k are peculiar to each site, being the so-called harmonic constants. The constant ω_k is also common to all sites and is fixed for each component.

Harmonic analysis means that the harmonic constants of each component are calculated from the recordings of tidal level.

Tides are caused by the astronomic motions and so many components have been fixed already. The following 4 components are important in practical application.

M_2 (main lunar semi-diurnal component)
angular velocity: 28.98410 deg/h
period: 12.42 h

S_2 (main solar semi-diurnal component)
angular velocity: 30.00000 deg/h
period: 12.00 h

K_1 (solar and lunar compound diurnal component)
angular velocity: 15.04107 deg/h
period: 23.93 h

O_1 (main lunar diurnal component)
angular velocity: 13.94304 deg/h
period: 25.82 h

Harmonic analysis can also be applied in respect to tidal currents.

---

1) Outline of Tidal Level Variation

As shown in the tide curve of Fig. 2.3.10, the variations in tidal level at each site shows, apparently, diurnal tides and semi-diurnal tides. The largest variations during the period of observation was observed on the June 14 during the spring tide period. The largest variations at LB and MZ near the channel entrances and UI the inner part of the channel were approximately 2 m, but the variation at SS near the middle of the channel was approximately 1.5 m.

2) Tidal Harmonic Constants

The harmonic constants at each site are shown in Table 2.3.1. The features of the tides at each site are as follows:

(a) Type of Tides

The tides are usually classified into the following 3 types;

a) Semi-Diurnal Type $F < 0.25$

2 high tides and 2 low tides are observed every day. M_2 (main lunar semi-diurnal component) and S_2 (main solar semi-diurnal component) generally cause the tides.

b) Mixed Type $0.25 < F < 1.25$

The tides are of the semi-diurnal type when the moon and the observation site are in the same section of the equatorial plane in a lunar month. Contrary to the former case, the tides are of the diurnal type when the moon and the observation site are in different sections of the equatorial plane in a lunar month.

c) Diurnal Type $F > 1.25$

Only one high tide and only one low tide are observed in a day. K_1 (solar and lunar compound diurnal component) and O_1 (main lunar compound diurnal component) generally cause the tides.

Remark: F

According to the French method of classification of tidal types, F is expressed in agreement of the following equation:

$$F = (K_1 + O_1) / (M_2 + S_2)$$

where,

K_1: amplitude of component K_1
O_1: amplitude of component O_1
M_2: amplitude of component M_2
S_2: amplitude of component S_2

According to the equation, F value are 1.13 at MZ, 1.20 at LB, 1.16 at SS and 1.10 at UI. Therefore, the tidal types at each site is classified as a mixed type.

(b) Range of Tide

The variation ranges in the spring tide and the neap tide at each site are as follows:

* MZ: Range of the spring tide is 120 cm
  Range of the neap tide is 71 cm

* LB: Range of the spring tide is 105 cm
  Range of the neap tide is 64 cm

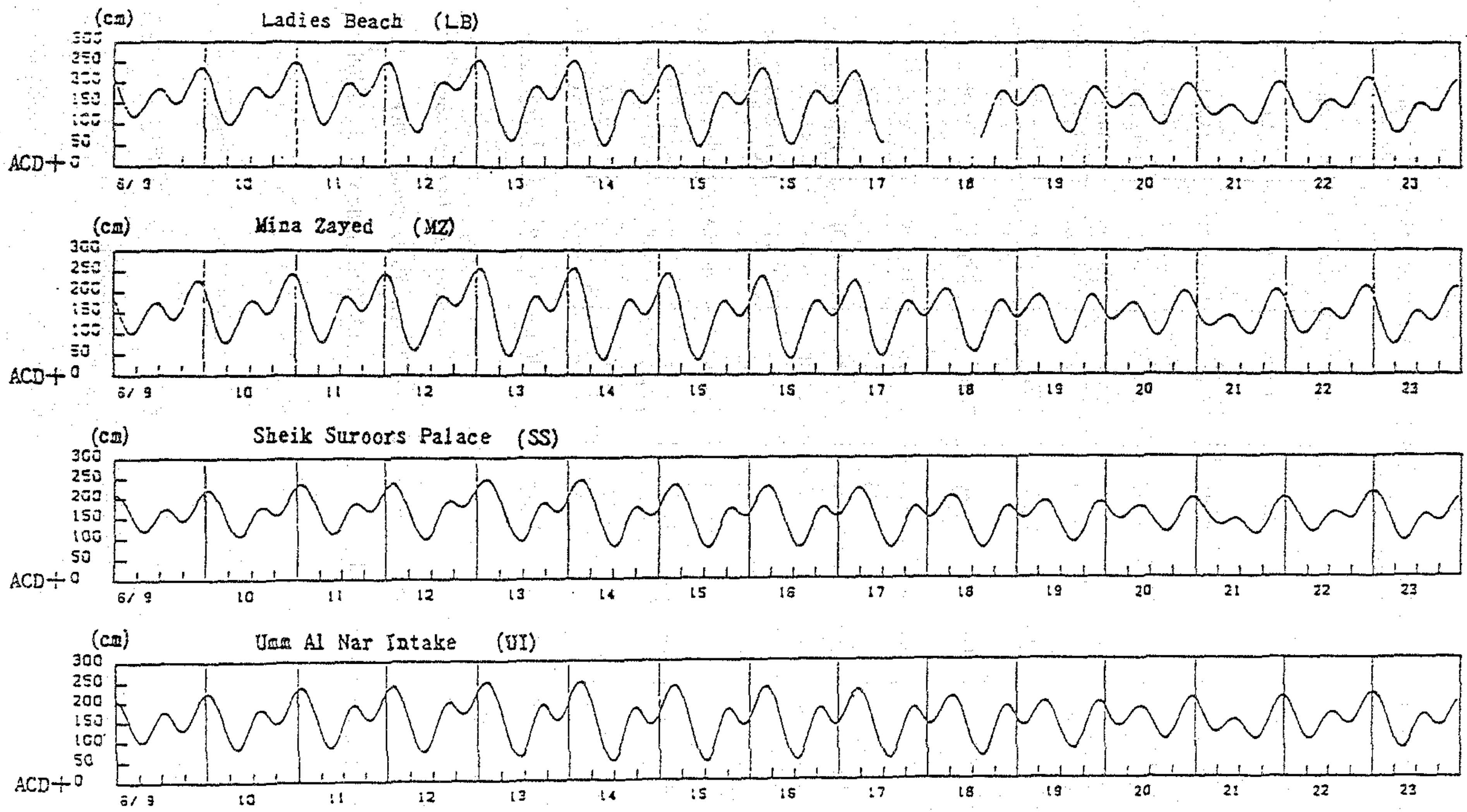
* SS: Range of the spring tide is 95 cm
  Range of the neap tide is 53 cm

* UI: Range of the spring tide is 113 cm
  Range of the neap tide is 60 cm

The range of the spring tide is the difference between the high water level and the low water level during the spring tide period. The range of the neap tide is the difference between the high and low water levels during the neap tide period. The range recorded as SS are the smallest values of all sites regarding both the spring and neap tides.

(c) Phase Shift

The phase shift between MZ near the channel entrance and every other site is 18 min at LB, 76 min at UI, and 120 min at SS respectively.



Remarks : Calculated from Observations by the Hydraulic Laboratory

ACD : Admiralty Chart Datum

Fig. 2.3.10: Tidal Level in Typical Sea Areas around Abu Dhabi Island (June, 1987)

Table 2.3.1: Tidal Level Harmonic Constants in Typical Sea Areas around Abu Dhabi Island

Component	Item	Unit	MZ	LB	SS	UI
M2	Amplitude	cm	47.56	42.40	37.04	43.24
	Phase	deg	25.17	33.81	83.13	61.78
S2	Amplitude	cm	12.22	10.25	10.52	13.10
	Phase	deg	154.27	139.24	207.96	164.36
K2	Amplitude	cm	3.32	2.79	2.86	3.56
	Phase	deg	154.27	139.24	207.96	164.36
N2	Amplitude	cm	8.07	3.56	3.42	7.89
	Phase	deg	272.76	304.81	306.14	73.10
K1	Amplitude	cm	37.45	36.34	32.61	35.42
	Phase	deg	162.10	170.18	199.77	192.04
O1	Amplitude	cm	30.36	27.04	22.67	26.68
	Phase	deg	99.81	102.89	137.07	125.01
P1	Amplitude	cm	12.47	12.10	10.86	11.80
	Phase	deg	162.10	170.18	199.77	192.04
Q1	Amplitude	cm	7.43	6.96	5.19	6.59
	Phase	deg	118.08	114.91	134.98	134.52
M4	Amplitude	cm	1.10	0.92	0.63	0.58
	Phase	deg	115.96	128.37	175.63	153.97
MS4	Amplitude	cm	0.45	0.53	0.32	0.43
	Phase	deg	132.23	158.56	226.86	188.24
Average Water Level ACD+		cm	149.08	157.36	158.07	149.91

Remarks :

* Observer : Hydraulic Laboratory
* Duration of Observation : 8th-25th June 1987
* Commenced : 0h 00min 9th June 1987

3) Tidal Level at Mina Zayed

According to the results of the tidal observation which were carried out at Mina Zayed from February to December, 1987 by the Hydraulic Laboratory, the characteristics of the tidal level at Mina Zayed are as follows.

(a) Average Water Level

The average water level during the whole observation period is ACD + 118 cm, which was recorded in February, as shown in Fig. 2.3.11.

Remarks: ACD

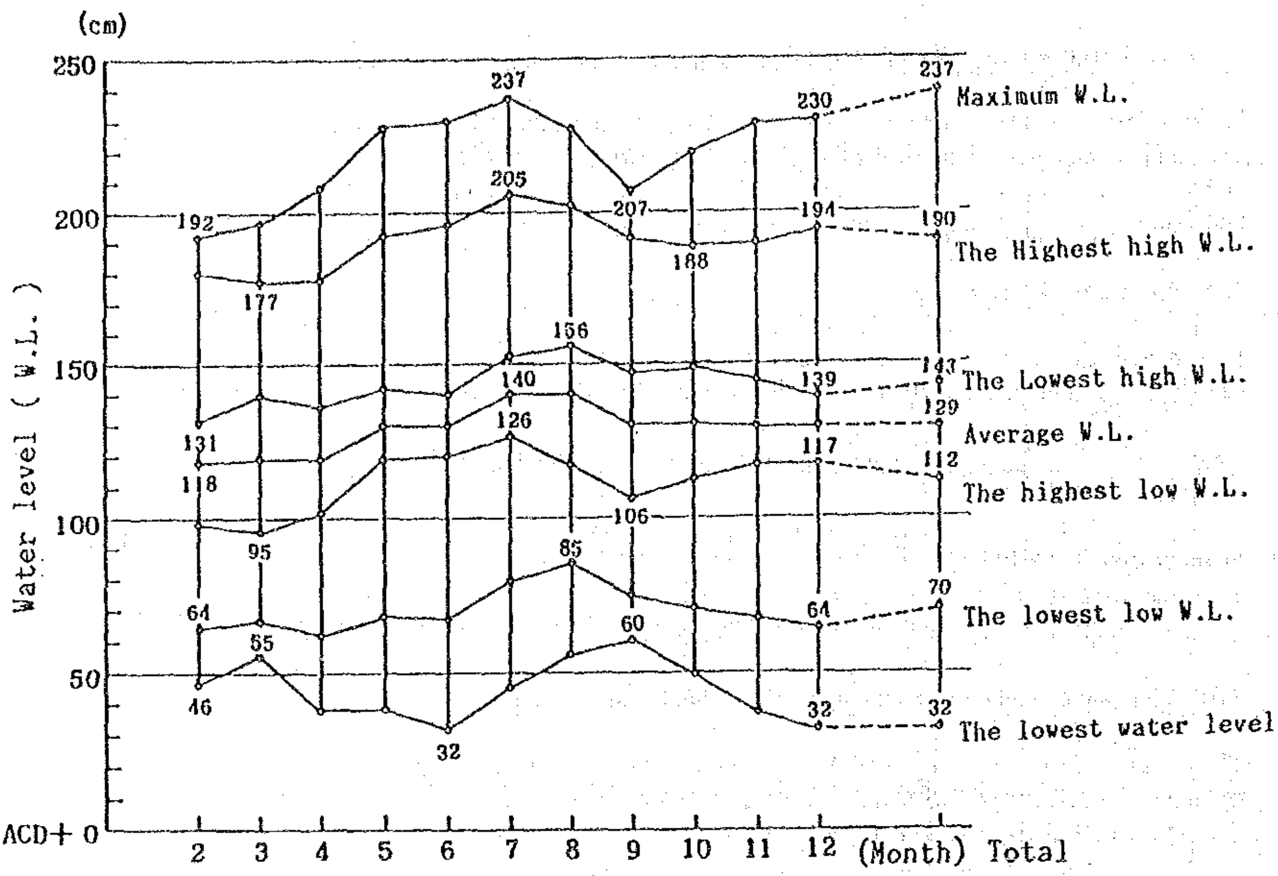
ACD means : Admiralty Chart Data, and is equivalent to the water level of 129 cm below the long-term average water level at Mina Zayed.

(b) Maximum Water Level and Minimum Water Level

The maximum water level and the minimum water level during the whole observation period are respectively ACD + 237 cm (which was recorded in July), and ACD + 32 cm (which was recorded in June and December).

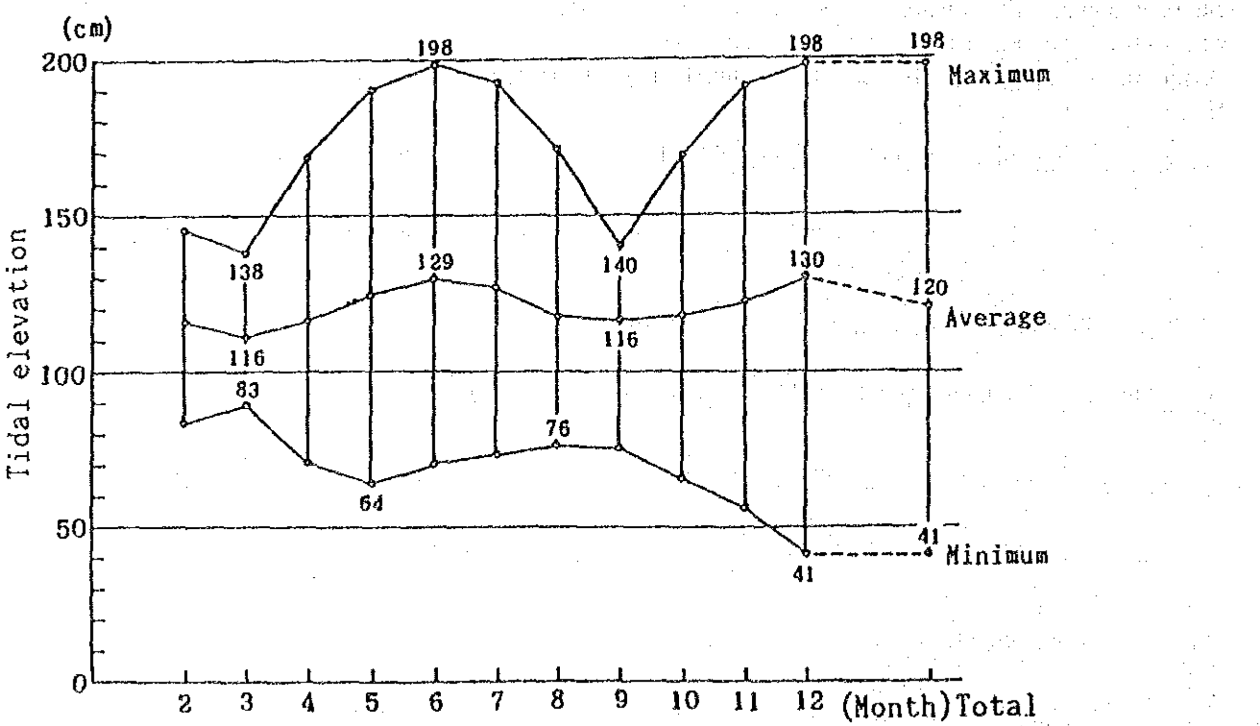
(c) Range of Water Level

The monthly water levels during the whole observation period are shown in Fig. 2.3.12. The monthly maximum range is relatively smaller in March and September, and larger in June and December. The variation in the monthly maximum range shows an inverse tendency to the variation in the monthly maximum range. The highest monthly minimum variation was recorded in March.



Remarks : Figured from Observations by Hydraulic Laboratory

Fig. 2.3.11: Monthly Tidal Level at Mina Zayed (1987)



Remarks : Figured from Observation by Hydraulic Laboratory

Fig. 2.3.12: Monthly Variations in Tidal Level at Mina Zayed (1987)

Table 2.3.2: Harmonic Constants Table at Mina Zayed (1987)

NO.	Component	Angular Velocity(deg/h)	Harmonic Constants	
			Amplitude (cm)	Phase (deg)
1	SA	0.0410686	8.99	123.0
2	SSA	0.0821373	2.97	202.8
3	MM	0.5443747	4.96	94.1
4	MSF	1.0158958	1.79	186.0
5	MF	1.0980331	0.07	60.7
6	S1	15.0000000	0.05	335.9
7	K1	15.0410686	25.64	170.9
8	P1	14.9589314	8.52	172.2
9	PAI1	14.9178647	0.05	176.6
10	PUSHII1	15.0821353	0.13	323.4
11	PHAI1	15.1232059	0.08	143.9
12	M1	14.4920521	0.13	52.7
13	SITA1	15.5125897	0.00	175.6
14	J1	15.5854433	2.14	166.4
15	KAI1	14.5695476	0.12	146.5
16	O1	13.9430356	20.05	111.8
17	MP1	14.0251729	0.07	281.9
18	SO1	16.0569644	0.05	35.6
19	OO1	16.1391017	1.54	240.5
20	ROU1	13.4715145	0.13	323.6
21	Q1	13.3986609	3.08	102.5
22	SIGMA1	12.9271398	0.02	343.7
23	2Q1	12.8542862	0.03	22.1
24	S2	30.0000000	15.42	83.8
25	T2	29.9589333	0.03	60.0
26	R2	30.0410667	0.03	266.1
27	K2	30.0821373	4.17	81.5
28	L2	29.5284789	1.49	38.8
29	RAMDA2	29.4556253	0.06	299.8
30	MSN2	30.5443747	0.03	273.1
31	KJ2	30.6265120	0.03	248.4
32	M2	28.9841042	40.53	26.8
33	2SM2	31.0158958	0.04	270.6
34	OP2	28.9019669	0.08	50.0
35	MKS2	29.0662415	0.04	18.4
36	N2	28.4397295	8.74	4.0
37	NU2	28.5125831	1.67	3.0
38	MIU2	27.9682084	1.26	166.8
39	2N2	27.8953548	0.10	200.6
40	MNS2	27.4231337	0.02	220.3
41	OQ2	27.3416964	0.03	188.7
42	SK3	45.0410686	0.03	60.8
43	MK3	44.0251729	0.06	184.6
44	SO3	43.9430356	0.06	304.7
45	M3	43.4761563	0.73	251.5
46	MO3	42.9271398	0.05	242.1
47	S4	60.0000000	0.08	53.4
48	SK4	60.0821373	0.03	234.1
49	MS4	58.9841042	0.06	205.0
50	MK4	59.0662415	0.01	160.4
51	SN4	58.4397295	0.12	129.6
52	M4	57.9682084	0.45	182.0
53	MN4	57.4238337	0.08	51.5
54	2SM6	88.9841042	0.08	162.3
55	MSK6	89.0662415	0.01	39.1
56	2MS6	87.9682084	0.08	71.2
57	2MK6	88.0503457	0.02	57.9
58	MSN6	87.4238337	0.09	178.9
59	M6	86.9523127	0.03	222.9
60	2MN6	86.4079380	0.09	179.2
61	S0	0.0000000	128.93	0.0

Remarks : * Commenced : 0h 00min 1st February 1987

(2) Tidal Currents

According to the results of the continuous observations made during the 15 day period from June 9 to 24 by the Hydraulic Laboratory in the ocean region around the Abu Dhabi Island, the special characteristics of the tidal currents are as follows:

1) Tidal Frequency

According to Fig. 2.3.13 which shows the frequency distribution of tidal direction and speed, a WNW to NW current and an ESE to SE returning current parallel to the channel, were recorded at Khalidiya (SPK) near the channel inlet area. In the inner areas of the channel, at both the Maqta Channel - Gulf Hotel (MG) and the Maqta Channel- Opposite (MO) sites, a NNW to N current and a SSE to S returning current were recorded.

2) Tidal Current Vector

The variation in the tidal current vector at each site is shown in Fig. 2.3.14.

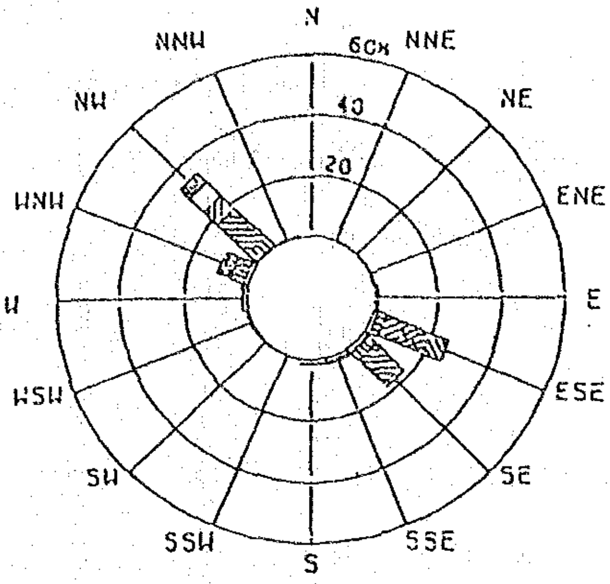
3) Long-Period Current

The average movement over 25 hours of the tidal current vector at each site is shown in Fig. 2.3.15. The noticeable features of the long-period current are that of a diurnal returning current of a N to W and S - E direction at SPK, and of a northerly and southerly direction at HU. At MG inside the channel, a diurnal returning current toward Umm Al Nar increases or decreases repeatedly according to the diurnal period.

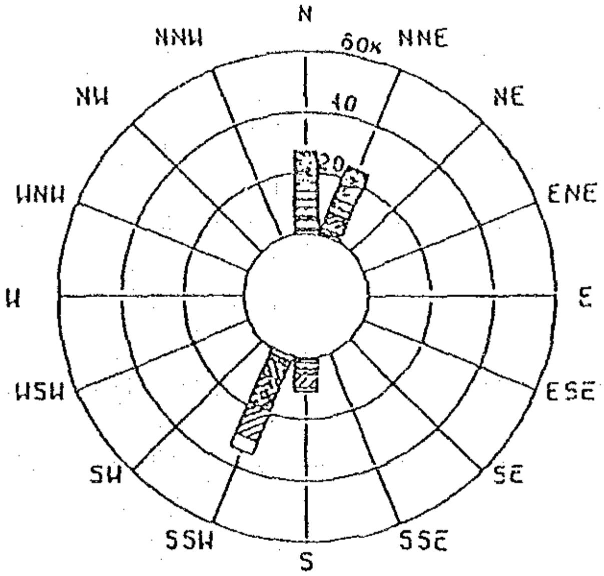
4) Harmonic Analysis of Tidal Current

According to the harmonic constants table of tidal currents which is shown in Table 2.3.3, the principle component currents at each site are M_2 (main lunar semi-diurnal component), S_2 (main solar semi-diurnal component), K_1 (solar and lunar compound diurnal component), and O_1 (main lunar diurnal component).

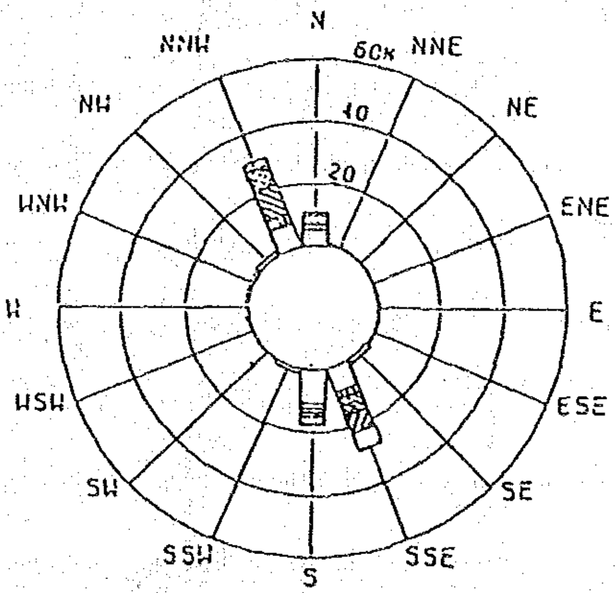
The ratios of the diurnal component to the semi-diurnal component, namely, $(K_1 + O_1)/(M_2 + S_2)$, are 0.75 at SPK, 1.29 at HU, 0.67 at MG, and 0.82 at MO. Therefore, the type of tidal current at HU is diurnal and of the mixed type at SPK, MG and MO.



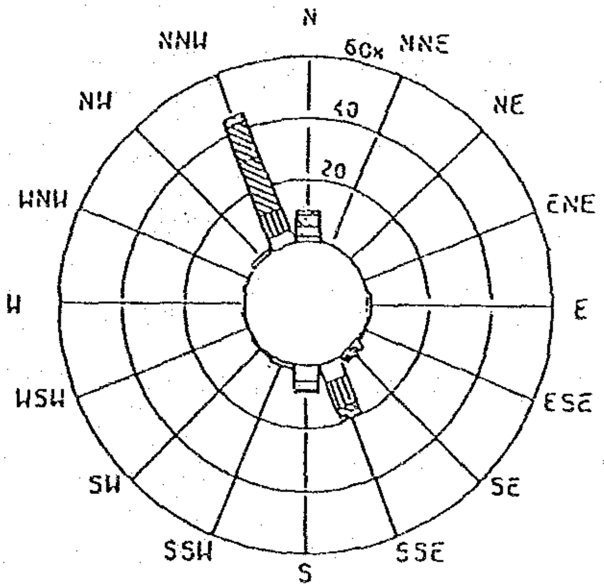
Khalidiya (SPK)



Hudairiyat Channel (HU)



Maqta Channel, Gulf Hotel (MG)



Maqta Channel, Opposite (MO)

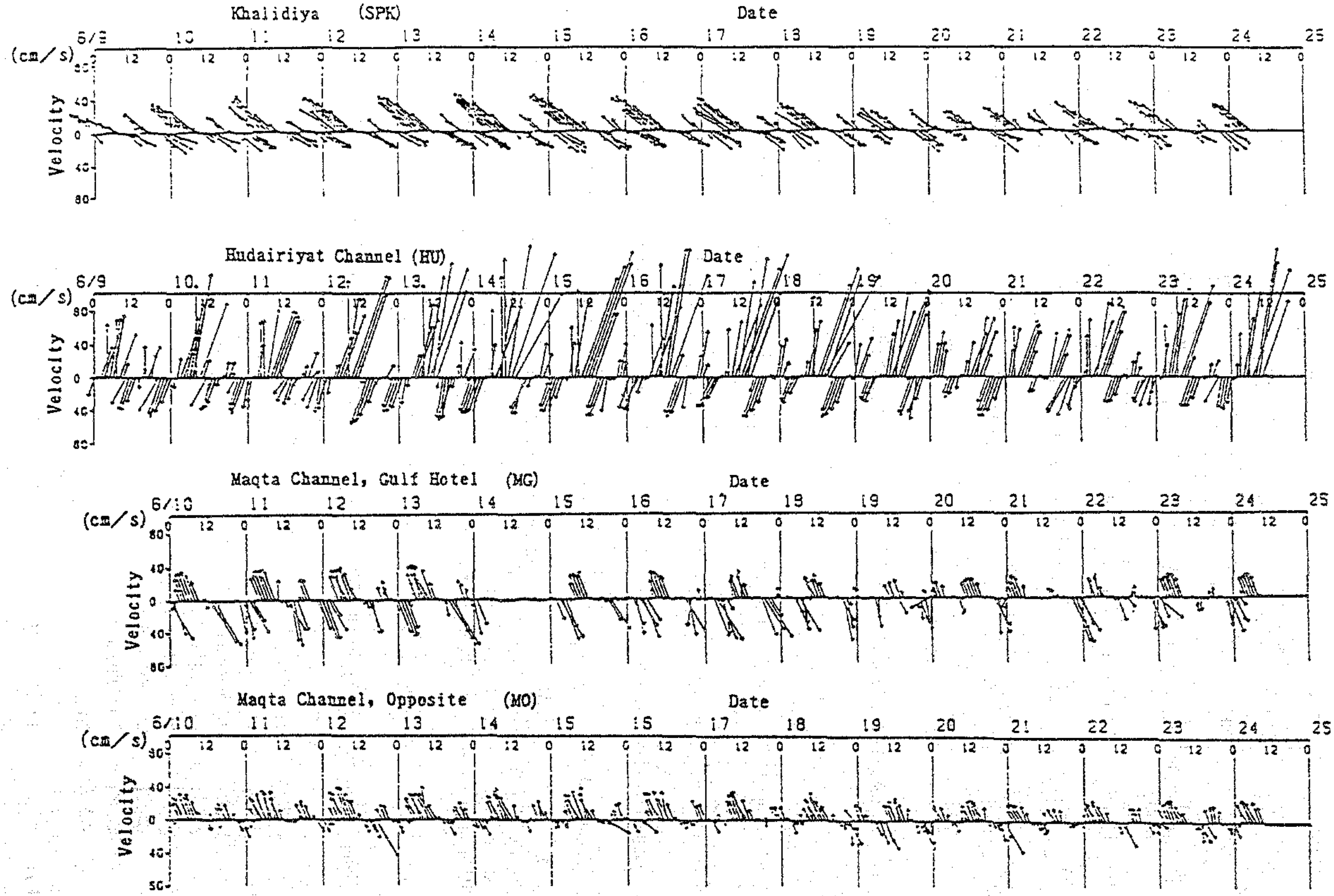
Notes :
- 0～10cm／s
- 10～20cm／s
- 20～30cm／s
- 30～40cm／s
- 40～50cm／s
- 50～60cm／s
- 60～70cm／s
- 70～80cm／s
- 80cm／s～

Remarks :

Observer : Hydraulic Laboratory

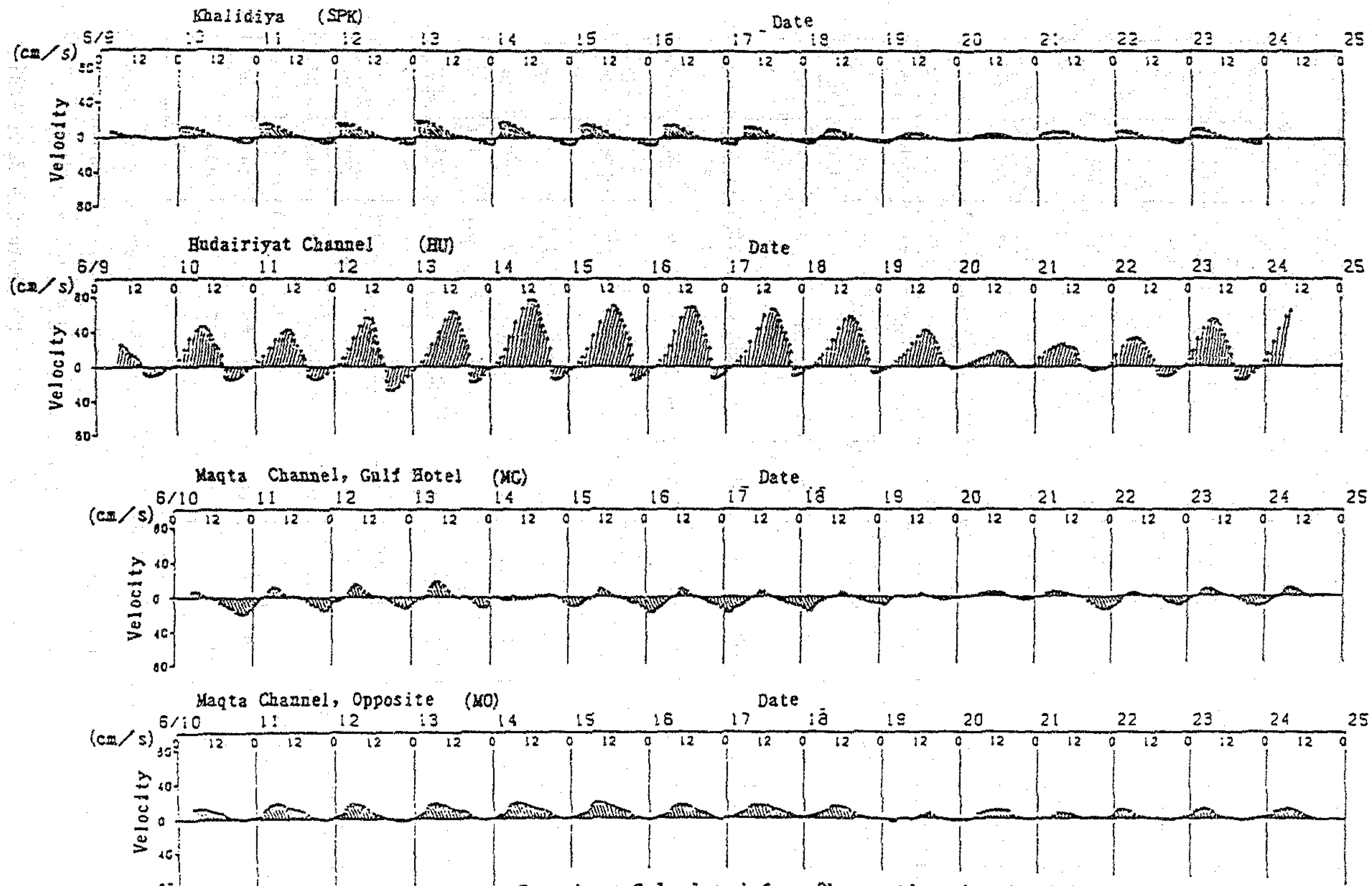
Observed
Duration : 9th～24th June 1987

Fig. 2.3.13: Tidal Current Vector Frequency in Typical Sea Areas



Remarks : Calculated from Observations by the Hydraulic Laboratory

Fig. 2. 3. 14: Observations of Tidal Currents for 15 Days in Typical Sea Areas (June, 1987)



Remarks : Calculated from Observations by the Hydraulic Laboratory

Fig. 2.3.15: Average Movement of Tidal Currents over 25-Hour Period in Typical Sea Areas (June, 1987)

Table 2.3.3: Tidal Current Harmonic Constants in Typical Sea Area

Comp.	Item	Unit	SPK L. A.	SPK S. A.	HU L. A.	HU S. A.	MG L. A.	MG S. A.	MO L. A.	MO S. A.
M2	Dir.	deg	306	36	14	104	340	70	338	68
	Speed	cm/s	36.3	0.6	51.6	0.7	25.3	0.3	18.3	0.5
	Phase	deg	153	243	179	269	159	249	155	245
S2	Dir.	deg	300	30	8	98	337	67	335	65
	Speed	cm/s	8.0	0.1	7.0	1.6	5.3	0.6	3.5	0.0
	Phase	deg	234	324	300	30	236	146	232	142
K2	Dir.	deg	300	30	8	98	337	67	335	65
	Speed	cm/s	2.2	0.0	1.9	0.4	1.5	0.2	1.0	0.0
	Phase	deg	234	324	300	30	238	148	234	144
N2	Dir.	deg	54	144	13	103	340	70	22	112
	Speed	cm/s	7.0	0.6	10.0	1.1	4.9	0.4	3.6	0.1
	Phase	deg	118	208	114	24	118	208	115	205
K1	Dir.	deg	309	39	14	104	339	69	336	66
	Speed	cm/s	18.9	0.1	39.2	1.0	12.8	0.3	9.4	0.4
	Phase	deg	302	32	320	50	326	236	320	50
O1	Dir.	deg	310	40	14	104	341	71	336	66
	Speed	cm/s	14.4	0.4	36.5	0.2	7.7	0.6	8.5	0.5
	Phase	deg	236	146	254	344	249	159	227	137
P1	Dir.	deg	309	39	14	104	339	69	336	66
	Speed	cm/s	6.3	0.0	13.0	0.3	4.3	0.1	3.1	0.1
	Phase	deg	302	32	320	80	324	234	318	48
Q1	Dir.	deg	310	40	14	104	341	71	337	67
	Speed	cm/s	2.8	0.1	7.1	0.0	1.5	0.2	1.6	0.2
	Phase	deg	203	113	221	131	224	134	194	104
M4	Dir.	deg	17	107	24	114	341	71	340	70
	Speed	cm/s	1.7	0.5	5.5	0.0	2.5	0.5	1.5	0.1
	Phase	deg	324	234	120	30	193	283	281	11
MS4	Dir.	deg	297	27	22	112	342	72	346	75
	Speed	cm/s	1.8	0.5	5.3	0.9	0.9	0.0	0.5	0.2
	Phase	deg	170	80	200	290	56	326	141	51
U0	Dir.	deg	321		9		157		339	
	Speed	cm/s	3.8		18.9		2.6		8.2	

Remarks :

* Observer : Hydraulic Laboratory
* Duration of Observation : 9th-24th June 1987
* Commenced : 0h 00min 9th June 1987

2.3.3 Water Quality

The range of chloride in the intake sea water at Umm Al Nar West is between 25,690 and 28,250 ppm. This value is approximately 1.4 times that of the value in Fleming standard sea water.

The analysis results of sea water at Umm Al Nar Station intake are shown in Table 2.3.4.

The results of analysis carried out in 1984 on intake sea water at Abu Dhabi Power Station intake and Umm Al Nar Station intake are shown in Table 2.3.5. There is much more chloride at Umm Al Nar Station than at Abu Dhabi Power Station, and a similar tendency is also found in other analysis items.

The ranges of annual water temperatures is between 25 and 38 °C at Umm Al Nar Station and between 18 and 35 °C at Abu Dhabi Power Station. From these results it is reckoned that at Abu Dhabi Station, facing Arabian Gulf, exchange of sea water between the site and offing is comparatively easy. On the other hand, at Umm Al Nar Station, located at inner part of the channel, exchange of sea water between the site and offing is not easy. Therefore, sea water near Umm Al Nar Station is apt to be influenced by operating conditions of the plants and climatic conditions.

Hydrogen sulfide which seems to be a factor causing corrosion of plant materials was not detected in the sea water at Umm Al Nar Station, but was detected at 0.3 to 1.0 ppm in the sea water at the Abu Dhabi Power Station. As shown in Table 2.3.6, the oil content in the sea water was approximately 0.2 ppm, but a very high value of 480 ppm was observed on October 19, 1983, due to the dumping of a ship's waste.

2.4 Crude Oil Produced in Abu Dhabi

In this investigation, the assumption has been made that the spilled oil originates from oil produced in Abu Dhabi and the surrounding areas.

Table 2.4.1 shows the properties of the principal types of crude oil. The components of the spilled oil are also assumed in Table 2.4.2.

Table 2.3.4: Monthly Analysis of Sea Water Supply to Umm Al Nar West Station

Item (Year / Month)		1985 Jun.	1986 Jan.	1987 Jan.	1987 Mar.	1987 Apr.	1987 May.	1987 Jun.	1987 Jul.	1987 Aug.	1987 Sep.
pH		7.95	8.00	8.00	7.95	8.05	8.05	8.00	8.05	8.00	8.05
Conductivity at 20℃ (μS/cm)		63,300	67,900	59,780	62,000	63,000	64,900	67,500	68,000	70,000	68,300
T.D.S. at 180℃ (ppm)		49,870	48,720	46,390	48,420	47,220	49,920	49,100	49,560	49,600	48,400
	Ratio to Cl	1.77	1.79	1.81	1.78	1.73	1.75	1.78	1.78	1.72	1.78
T.D.S. at 600℃ (ppm)		43,950	43,800			43,850	44,940	45,390	45,890	45,920	44,250
	Ratio to Cl	1.56	1.61			1.60	1.60	1.64	1.65	1.59	1.63
Total Hardness (ppm as $CaCO_3$)		8,850	8,800	8,800	8,600	8,800	8,900	8,850	8,900	8,860	9,000
	Ratio to Cl	0.31	0.32	0.34	0.32	0.32	0.32	0.32	0.32	0.31	0.33
Alkali Hardness (ppm as $CaCO_3$)		118	126	118	120	123	124	118	116	118	120
	Ratio to Cl	0.0042	0.0046	0.0046	0.0044	0.0045	0.0044	0.0043	0.0042	0.0041	0.0044
Chloride (ppm)		28,250	27,250	25,690	27,222	27,335	28,160	27,600	27,790	28,800	27,200
Sulphate (ppm)		3,700	3,756	3,690	3,720	3,680	3,750	3,760	3,780	3,820	3,750
	Ratio to Cl	0.131	0.138	0.144	0.137	0.135	0.133	0.136	0.136	0.133	0.138
Sodium (ppm)		14,120	14,610	13,920	14,480	13,050	14,200	14,490	14,700	14,725	14,400
	Ratio to Cl	0.50	0.54	0.54	0.53	0.48	0.50	0.53	0.53	0.51	0.53
Potassium (ppm)		660	570	580	590	600	620	625	610	620	620
	Ratio to Cl	0.023	0.021	0.023	0.022	0.022	0.022	0.023	0.022	0.022	0.023
Calcium (ppm)		600	590	580	600	540	580	580	540	588	600
	Ratio to Cl	0.021	0.022	0.023	0.022	0.020	0.021	0.021	0.019	0.020	0.022
Magnesium (ppm)		1,786	1,780	1,785	1,725	1,810	1,810	1,798	1,835	1,795	1,822
	Ratio to Cl	0.063	0.065	0.069	0.064	0.066	0.064	0.065	0.066	0.062	0.067

Remarks: Tabulated from Analysis by W.E.D.

Table 2. 3. 4: (Continued)

Item / Year / Month	1987 Oct.	1987 Nov.	1987 Dec.	1988 Jan.	1988 Feb.	1988 Mar.	Average	※Fleming (1940)		
pH	8.00	8.05	8.00	8.05	8.05	8.05	8.02			
Conductivity at 20℃ (μS/cm)	64,200	58,900	59,200	59,200	58,500	58,000	63,290			
T.D.S. at 180℃ (ppm)	47,550	46,900	47,800	47,800	46,700	45,850	48,070			
Ratio to Cl	1.76	1.73	1.75	1.72	1.80	1.77	1.762			
T.D.S. at 600℃ (ppm)	43,690	43,650		43,620	42,590	41,920	44,110			
Ratio to Cl	1.62	1.61		1.57	1.64	1.62	1.618			
Total Hardness (ppm as $CaCO_3$)	8,950	8,350	8,200	8,200	8,200	8,200	8,650			
Ratio to Cl	0.33	0.31	0.30	0.29	0.32	0.32	0.317			
Alkali Hardness (ppm as $CaCO_3$)	121	122	130	130	120	121	122			
Ratio to Cl	0.0045	0.0045	0.0048	0.0047	0.0046	0.0047	0.00447			
Chloride (ppm)	26,980	27,120	27,245	27,850	25,900	25,920	27,270	18,980		
Sulphate (ppm)	3,770	3,600	3,590	3,776	3,400	3,340	3,680	2,649		
Ratio to Cl	0.140	0.133	0.132	0.136	0.131	0.129	0.1349	0.1395		
Sodium (ppm)	13,690	13,150	13,900	13,800	13,700	13,580	14,030	10,556		
Ratio to Cl	0.51	0.48	0.51	0.50	0.53	0.52	0.514	0.556		
Potassium (ppm)	620	650	560	570	565	560	600	380		
Ratio to Cl	0.023	0.024	0.021	0.020	0.022	0.022	0.0220	0.0200		
Calcium (ppm)	592	520	570	570	560	540	570	400		
Ratio to Cl	0.022	0.019	0.021	0.020	0.022	0.021	0.0209	0.0211		
Magnesium (ppm)	1,815	1,700	1,646	1,646	1,652	1,665	1,754	1,272		
Ratio to Cl	0.067	0.063	0.060	0.059	0.064	0.064	0.0643	0.0670		

Remarks : Tabulated from Analysis by W.E.D.

Table 2.3.5: Comparison between Sea Water Supply to Abu Dhabi Power Station and Umm Al Nar Power Station (1984)

Station / Item	Abu Dhabi Power Station	Umm Al Nar Power Station
pH	8.0～8.3	8.05～8.10
Conductivity at 20℃, μS/cm	53,000～55,000	60,200～68,000
Total Dissolved Solids at 180℃ ppm	45,355～47,070	47,620～
Total Hardness, ppm as $CaCO_3$	8,400～8,500	8,750～9,050
Calcium Hardness, ppm as $CaCO_3$	1,000～1,250	1,475～1,550
Magnesium Hardness, ppm as $CaCO_3$	7,250～7,400	7,275～7,530
Total Alkalinity, ppm as $CaCO_3$	120～125	120～125
Chloride, ppm	25,000～26,000	26,640～28,560
Sulphate, ppm	3,400～3,600	3,690～3,968
Iron, ppm	0.05～0.05	
Dissolved Silica, ppm	0.35～0.40	
Hydrogen Sulphide, ppm	0.3～1.0	Nil
Copper, ppm	Trace～0.005	0.01
Suspended Matter, ppm	1.0～10.0	3～10
Phosphate, ppm	Nil～Trace	Nil
Nitrate, ppm		Nil
Water Temperature, ℃	18～35	25～38

Remarks : Tabulated from Analysis by W.E.D.

Table 2.3.6: Oil Content in Sea Water Intake

Date	ppm	Analysed by	Remarks
1983.06.20	0.25	ADNOC	
1983.06.22	0.20	ADNOC	
1983.06.26	0.56	ADNOC	Abnormal
1983.06.29	0.20	ADNOC	
1983.07.03	0.20	ADNOC	
1983.07.06	0.22	ADNOC	
1983.07.17	0.10	ADNOC	
1983.08.03	0.30	ADNOC	
1983.08.10	0.10	ADNOC	
1983.09.14	0.40	ADNOC	
1983.10.02	0.30	ADNOC	
1983.10.12	0.14	ADNOC	
1983.10.19	4.80	ADNOC	Very high due to ships waste
1983.11.02	NIL	ADNOC	
1983.11.09	0.45	ADNOC	
1983.11.16	0.10	ADNOC	
1983.11.29	0.48	ADNOC	
1984.01.04	0.13	ADNOC	
1984.01.29	0.20	ADNOC	
1984.03.03	0.20	ADNOC	
1984.03.27	0.20	ADNOC	
1984.04.21	NIL	W.E.D.	
1984.04.28	0.23	W.E.D.	
1984.05.06	0.35	W.E.D.	
1984.05.19	0.28	W.E.D.	
1984.05.31	0.18	W.E.D.	
1984.06.16	0.18	W.E.D.	
1984.07.07	0.33	W.E.D.	
1984.07.15	0.135	W.E.D.	
1984.07.23	0.200	W.E.D.	
1984.07.29	0.166	W.E.D.	
1984.08.05	NIL	W.E.D.	
1984.08.12	0.13	W.E.D.	
1984.08.19	NIL	W.E.D.	

Remarks : Tabulated from Information Supplied by W.E.D.

Table 2.4.1: Properties of Principal Crude Oil Produced in Abu Dhabi
(Data from Petroleum Association of Japan)

	Crude Oil	Murban	Umm Ash Shaif	Zakum	Mubarraz	Dubai
General Properties of Crude Oil	Specific gravity (15/4 ℃)	0.828	0.840	0.827	0.834	0.864
	Gravity (° API)	39.3	36.9	39.5	38.1	32.2
	Vapor Pressure (kg/cm² @37.8℃)	0.33	-	0.49	-	0.50
	Viscocity (50 ℃) (cSt)	2.5	3.8(37.8℃)	2.4	4.7(30℃)	4.85
	Viscocity (50 ℃) (R.W.)	32.1	-	-	-	-
	Pour Point (℃)	-30.0	-15	-33 below	-30 below	-25 below
	Wax Content (W %)	7.1	7.0	4.4	6.2	2.96
	Sulfur Content (W %)	0.80	1.38	1.06	0.93	1.51
	Carbon Residue (W %)	1.40	2.2	1.7	2.5	3.7
	Ash Content (W %)	0.01 below	0.004	0.01	-	-
	Water and Sediment (W %)	0.1 below	-	0.1	-	0.05
	Water (W %)	0.1 below	-	0.1 below	0.9	Trace
	Salt Content (W %)	0.0035	0.0005	0.0005	0.080	0.0017
Properties of Distillate	Gasolines					
	Cut Points (℃)	40~179	IBP~175	IBP~181	IBP~190	IBP~180
	Yield (W %)	24.3	27.1	26	29.0	21.1
	Octane Number (Research Method) Clear	60.0(Debutanized Gasline)	65	60.8(Debutanized Gasline)	-	66(Debutanized Gasline)
	Octane Number (Research Method) TEL (1cc/gallon)	69.1(〃)	-	71.7(〃)	-	-
	Kerosenes					
	Cut Point (℃)	179~234	175~232	181~240	190~250	181~240
	Yield (W %)	14.3	11.2	13.0	13.3	12.5
	Gas Oil					
	Cut Point (℃)	234~325	232~343	240~335	250~275	240~300
	Yield (W %)	17.6	20.7	16.4	5.7	10.2
	Atmospheric Residue					
	Yield (W %)	35.2	38.5	39.2	-50.5	51.1
	Pour Point (℃)	+30	+27	+27.5	+10	+12.5
	Sulfur Content (W %)	1.6	2.60	2.17	1.49	2.33
	Kinematic Viscocity (50 ℃ cSt)	25	62.7	46.5	-	112.9
	Carbon Residue (W %)	3.6	5.2	4.5	5.0	6.2
	Distillation Loss (W %)	-	-	-	1.5	-

Table 2. 4. 2: Assumed Spilled Oil Composition

n-paraffins	10 %	Volatile matter & Resin	30%
iso-paraffins	3 %	Asphaltene	1.5 %
Cyclo-paraffins	20 %	(Sulphur	2.5 %)
Alkyibenzens	10 %	(Nitrogen	0.1 %)
2~3Cyclic Aromatics	25 %	(Nickel	8mg/kg)
Policyclic Aromatics	0.5 %	(Vanadium	30mg/kg)

Paraffins

Hexanes
- n-Hexane
  - 2-Methylpentane
  - 3-Methylpentane
  - 2,2-Dimethylbutane
  - 2,3-Dimethylbutane

Heptanes
- n-Heptane
  - 3-Methylhexane
  - 3-Ethylpentane
  - 2-Methylhexane
  - 2,[illegible]-Dimethylpentane
  - 2,4-Dimethylpentane

Octanes
- n-Octane
  - 2-Methylheptane
  - 2,2-Dimethylhexane
  - 2,3-Dimethylhexane
  - 2,4-Dimethylhexane
  - 2,5-Dimethylhexane
  - 3,3-Dimethylhexane
  - 2-Methyl-3-ethylpentane
  - 2,2,3-Trimethylpentane
  - 2,3,3-Trimethylpentane
  - 2,3,4-Trimethylpentane

Nonanes
- n-Nonane
  - 2-Methyloctane
  - 3-Methyloctane
  - 4-Methyloctane
  - 2,3-Dimethylheptane
  - 2,6-Dimethylheptane

Higher Paraffins
- n-Decane
- n-Undecane
- n-Dodecane

Cycloparaffins (Naphthenes)

- Cyclopentane
- Methylcyclopentane
- Cyclohexane
- Ethylcyclopentane
- Methylcyclohexane
- 1,1-Dimethylcyclopentane
- 1-Trans-2-dimethylcyclopentane
- 1-Cis-3-dimethylcyclopentane
- 1-Trans-3-dimethylcyclopentane
- Propylcyclopentane
- Ethylcyclohexane
- 1-Trans-2-dimethylcyclohexane
- 1-Cis-3-dimethylcyclohexane
- 1,1,3-Trimethylcyclopentane
- 1-Trans-2-cis-3-trimethylcyclopentane
- 1-Trans-2-cis-4-trimethylcyclopentane
- 1,1,2-Trimethylcyclopentane
- 1,1,3-Trimethylcyclohexane
- 1-Trans-2-trans-4-trimethylcyclohexane

Aromatics

- Benzene
- Toluene
- Ethylbenzene
- o-Xylene
- m-Xylene
- p-Xylene
- N-propylbenzene
- Isopropylbenzene

- 1-Methyl-2-ethylbenzene
- 1-Methyl-3-ethylbenzene
- 1-Methyl-4-ethylbenzene
- 1,2,3-Trimethylbenzene
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- Tert. butylbenzene
- 1,2,3,4-Tetramethylbenzene
- Tetrahydronaphthalene
- Naphthalene
- 1-Methylnaphthalene
- 2-Methylnaphthalene
- 5-Methyltetrahydronaphthalene
- 6-Methyltetrahydronaphthalene

2.5 References of Chapter 2

1. WED (1985): Climatic Information of Abu Dhabi 1975 - 1984

2. Umm Al Nar Hydraulic Laboratory (1987): Observation of Hydraulic Field Survey

3. Lahmayer (1988): Tides at Mina Zayed

4. Umm Al Nar West Station (1988): Observation of Water Quality. Monthly Analysis of Sea Water

5. WED: Typical Analysis of Sea Water Supply to Umm Al Nar Power Station

6. WED: Typical Analysis of Sea Water Supply to Abu Dhabi Power Station

7. WED: Oil Content in Sea Water at Umm Al Nar Intake