THE ISLAMIC REPUBLIC OF PAKISTAN

DETAILED DESIGN STUDY
ON
WEST WHARF
THERMAL POWER PLANT PROJECT

FINAL REPORT-I
VOLUME 1

JANUARY 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Islamic Republic of Pakistan, the Japanese Government decided to conduct a survey on the Detailed Design Study on the West Wharf Thermal Power Plant Project and entrusted the survey to the Japan International Cooperation Agency (JICA).

The JICA sent to Pakistan a survey team headed by Mr. Akio Oiwa, Tokyo Electric Power Services Co., Ltd., from December 1988 to December 1989.

The team exchanged views with the officials concerned of the Government of the Islamic Republic of Pakistan and conducted a field survey. After the team returned to Japan, further studies were made and the present report has been prepared.

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

I wish to express my deep appreciation to the officials concerned of the Government of the Islamic Republic of Pakistan for their close cooperation extended to the team.

January, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

WEST WHARF THERMAL POWER PLANT PROJECT

DETAILED DESIGN STUDY

DRAFT FINAL REPORT - I

VOLUME 1

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WEST WHARF THERMAL POWER PLANT PROJECT

DETAILED DESIGN STUDY

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VOLUME 2

TRANSMISSION LINE AND GRID STATION

WEST WHARF THERMAL POWER PLANT PROJECT

DETAILED DESIGN STUDY

DRAFT FINAL PROJECT - I

VOLUME 3

I-1 PREFACE

This Detailed Design Report was prepared based upon the Detailed Design Study Agreement for the West Wharf Thermal Power Plant Project, and was agreed upon between the Karachi Electric Supply Corporation Ltd. (KESC) and the Japan International Cooperation Agency (JICA).

The Detailed Design Study aims at preparation of the Detailed Design Report (Final Report I) and the Tender Documents (Final Report II) to make possible international procurement of power plant facilities and construction of the West Wharf Thermal Power Plant Project.

This Detailed Design Report (Final Report I) describes all engineering items deemed necessary for implementing two sets of 200 MW oil-fired thermal power generating units for the newly reconstructed West Wharf Thermal Power Plant and related 220 kV transmission and substation facilities.

These engineering items are prepared based upon the results of the Detailed Design which followed the Basic Plan of the Project.

The necessary engineering items have been stipulated in the Tender Documents which will be used for international tendering.

The Detailed Design Report constitutes, the accumulated design results of the West Wharf Thermal Power Plant, and will be used for understanding why and how the design requirements and specifications were derived at and decided upon.

Should any doubts or ambiguous items be found at the time of the implementation stage of this Project, the original intentions of KESC and the Consultant (JICA) will be referred to accordingly.

The report consists of the following three volumes.

Volume 1 General and Power Plant

Volume 2 Transmission Line and Grid Station

Volume 3 Architectural and Civil Work

As the Tender Documents (Final Report II) are divided into four (4) lots in accordance with the wishes of KESC, the Technical Specifications were prepared by carefully selecting the "Scope of Supply" items of each lot, uninterrupted construction work with no omissions, etc.

This carefully prepared Scope of Supply will ensure smooth and effective construction work by each contractor without any unforeseen difficulties.

To clarify each tenderer's proposal, the "Form of Technical Data Sheets", stating the contents of the Technical Specifications, was prepared so as to be filled out by the respective tenderers at the time of tender bidding.

Tender documents have been compiled and contain the Instruction to Tenderers, General Conditions, Schedule of Prices, Technical Specifications, etc.

As the Instruction to Tenderers and General Conditions constitute the main portion of the Tender Documents, these were prepared carefully so as to reflect KESC standards, practices, etc., based on full consultation with KESC.

Tendering will be divided into four (4) tender lots as described below.

Lot I: Power plant facilities
Supply, erection and commissioning of boiler, turbine, generator, electrical control and measurement devices complete with accessories, and architectural/civil work.

Lot IIA: Supply, erection and commissioning of 220/132 kV substation at the West Wharf Thermal Power Station area, extension of the Baldia Grid Station, and related architectural civil works including underground cable tunnel with all necessary facilities.

Lot IIB: Transmission line(s)
Material supply, erection and commissioning of transmission line(s) including related civil work.

Lot III: Dismantling work
Dismantling work of "A", "B" and "BX" Stations.

1. Outline of the Project

Based on the conclusions of the Feasibility Study of the West Wharf Thermal Power Plant Development Project, it is essential to construct large capacity units in the existing West Wharf Power Plant area in view of the present KESC power system operation and the rapidly increasing power demands.

Outline of the project and the scope of the construction work, which is divided into two stages (the first and the second stages) so as to facilitate smooth and effective construction work, is described as follows.

(1) Power plant facilities

Two (2) 200 MW oil-fired thermal power generating units, with auxiliary equipment and other power station facilities including office building, etc., will be constructed at the site of the existing West Wharf Thermal Power Plant.

The existing cooling water intake channels within the premises of the Karachi Port Trust will be utilized. Also, discharge channels will be constructed within the premises of the Karachi Shipyard, crossing a public road in the West Wharf area.

(2) Transmission line and grid station facilities

220 kV transmission line(s) will be constructed between the West Wharf Thermal Power Plant and the Baldia Grid Station.

For this purpose, 220 kV and 132 kV substations will be constructed within the premises of the West Wharf Thermal Power Plant.

In consideration that supply of electric power be continued by the existing 11 kV and 66 kV systems during the period for construction of the new plant, 11 kV distribution facilities will be left as they are, and the 66 kV power transmission and substation facilities will be subsequently dismantled by switching over to the new 132 kV system after completion of the new power transmission and substation facilities.
The new 132 kV system will be planned and constructed by KESC. However, the switchyard within the power plant site will be included in the Scope of Work of this project.

(3) Special considerations deemed necessary for scope of the Project

Because the project is planned to constract a new plant in the existing thermal power plant site with decommissioning and dismantling of the existing facilities, the following items will be constructed during the West Wharf Thermal Power Plant Unit 1 construction period.

(a) To improve the effectiveness of the construction works and to eliminate work difficulties, the discharge channel and outlet of the condenser cooling water for Unit 2, which will be constructed along side that for Unit 1, shall be executed at the time of Unit 1 construction.

(b) Under the same consideration and requirement of plenty of water in Unit 1 construction and test operation, the water treatment system and waste water treatment system for Unit 2 shall be constructed at the time of Unit 1 construction.

(c) Because construction of Unit 2 is scheduled to commence successively to Unit 1, the stack flue for Unit 2 shall be installed simultaneously with Unit 1 construction.

(d) Temporary facilities

Due to the restricted site area and the particulars of the project, e.g. execution of construction work with commissioning of the existing "BX" Station, some temporary facilities should be included in the Scope of Unit 1, such as;

(i) Temporary natural gas fuel supply facilities for the "BX" Station

(ii) Temporary administration facilities for management of Unit 1 operation

(iii) Others

(e) Transmission and distribution facilities

In order to accomplish early decommissioning and dismantling of the existing "BX" Station, the 66 kV switchyard and related facilities, the 220 kV transmission line and 220 kV/132 kV switchyard and associated facilities which are above mentioned, should be implemented as early as possible so as to secure reliable power supply for the West Wharf area and for facilitating construction of the new power plant.

2. Outline of the Scope for the First Stage of the Project (Unit 1 Project)

The project scope for Unit 1, the first unit of the West Wharf Thermal Power Plant to be implemented by KESC, consists of:

(1) One (1) set of oil-firing steam power generating unit of 200 MW capacity and its related accessories to be constructed at the West Wharf Power Plant site as the first unit.

The major facilities are as follows.

(a) Steam generator plant and accessories

(b) Turbine - generator plant and accessories

Including; o Rehabilitation of intake culvert (10 feet square, existing) for cooling water intake way and cooling water discharge way including major part of No. 2 discharge way

(c) Common auxiliary equipment

Including; o Water treatment and waste water treatment system having sufficient capacity for two (2) sets of 200 MW unit

o Oil storage and supply facilities

o Other pertinents

(d) Electrical, measuring and control equipment

(2) 220 kV and 132 kV substations and related accessories constructed inside the West Wharf Power Plant premises, including modification of 11 kV local distribution system

facilities, if required

(3) Double circuit 220 kV transmission lines and their related accessories to be constructed between the West Wharf Power Plant and the Baldia Grid Station via a route along the outer periphery of the Air Force Base, passing near Mauripur Grid Station.

(4) Ancillary facilities
Necessary facilities for operation of No. 1 Unit (including temporary facilities)

(5) Temporary facilities necessary for operation of the "BX" Station

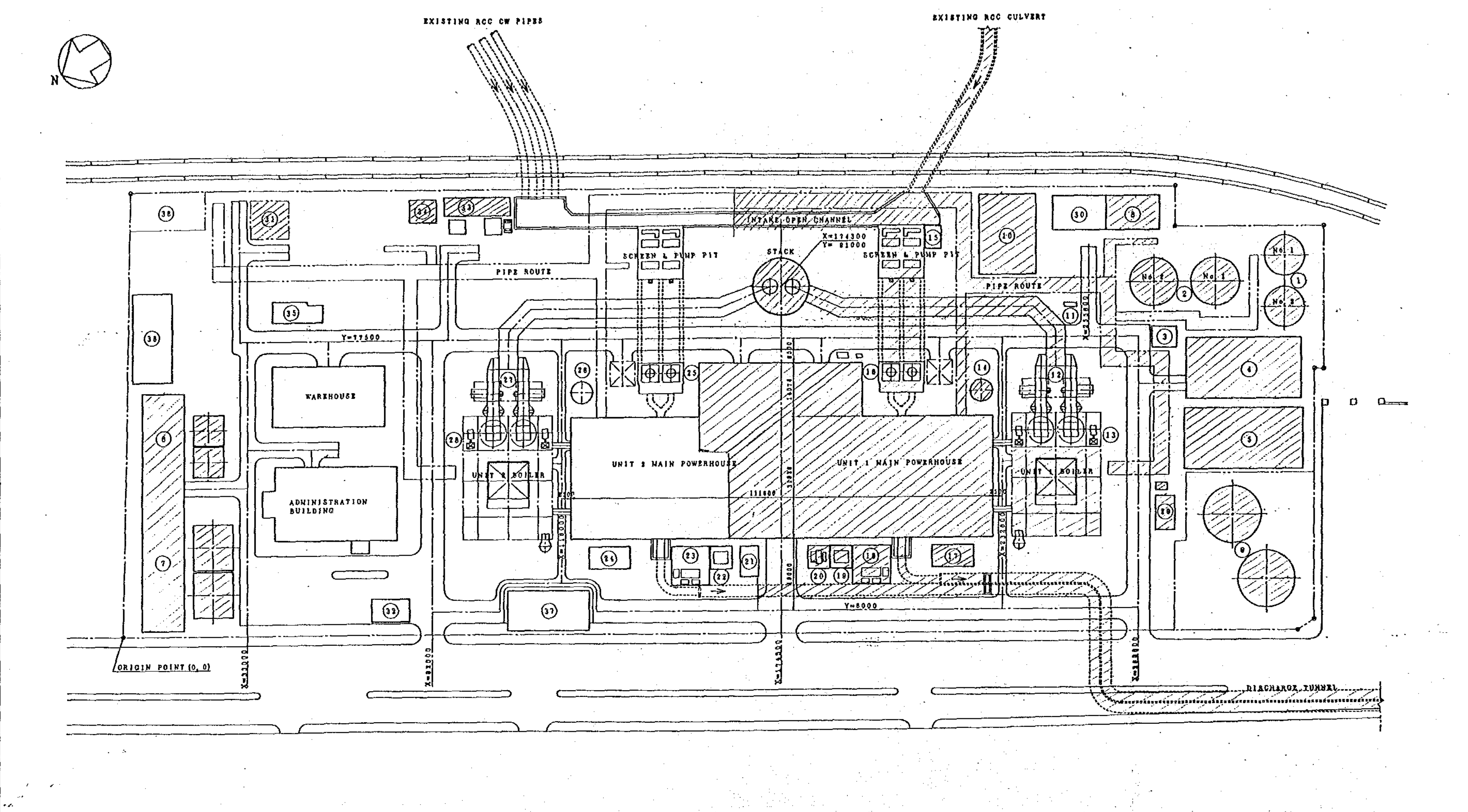
Ex. Temporary natural gas supply facilities and all other temporary facilities required for operation of the "BX" Station

The Scope for Unit 1 is shown by the hatched lines in Fig. 1.2-1.

3. Outline of the Scope of the Second Stage of the Project (Unit 2 Project)

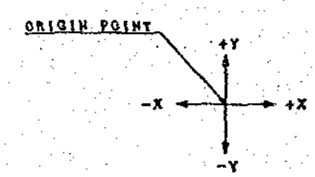
The project scope for Unit 2, the second unit of the West Wharf Power Plant, consists of:

(1) One (1) set of oil-firing steam power generating unit of 200 MW capacity and its related accessories to be constructed at the West Wharf Power Plant site as the second unit. The major facilities are as follows.



No	DESCRIPTION	No	DESCRIPTION	No	DESCRIPTION	No	DESCRIPTION
1	DEMINERALIZED WATER TANK	13	GAS RECIRCULATING FAN	25	CIRCULATING WATER PUMP	37	11KV GRID STATION (EXISTING)
2	RAW WATER TANK	14	MAKE-UP WATER TANK	26	MAKE-UP WATER TANK	38	66KV SWITCHYARD INDOOR (EXISTING)
3	CHEMICAL STORAGE TANK	15	CHLORINATION FEED WATER PUMP PIT	27	FORCED DRAFT FAN		
4	WATER TREATMENT EQUIP. & CONTROL ROOM	16	CIRCULATING WATER PUMP	28	GAS RECIRCULATING FAN		
5	WASTE WATER TREATMENT AREA	17	UNIT NEUTRALIZING PIT	29	FUEL OIL TRANSFER PUMP		
6	132KV SUBSTATION	18	MAIN TRANSFORMER	30	FUEL OIL PUMP & HEATER AREA		
7	220KV SUBSTATION	19	AUXILIARY TRANSFORMER	31	HOUSE BOILER AREA		
8	FUEL OIL PUMP & HEATER AREA	20	STARTING TRANSFORMER	32	GUARD HOUSE		
9	FUEL OIL SERVICE TANK	21	TURBINE OIL STORAGE TANK	33	RAW WATER PRETREATMENT AREA		
10	CHLORINATION EQUIP. AREA & CONTROL ROOM	22	AUXILIARY TRANSFORMER	34	H_2 & GAS GENERATING ROOM		
11	AIR FOAM EQUIPMENT AREA	23	MAIN TRANSFORMER	35	STORAGE BOX FOR STOP LOG		
12	FORCED DRAFT FAN	24	UNIT NEUTRALIZING PIT	36	EXISTING GAS STATION (SUI GAS)		

FIG. 1.2-1
The scope is shown with hatched lines



PAKISTAN
KARACHI ELECTRIC SUPPLY CORPORATION
WEST WHARF THERMAL POWER PLANT PROJECT
UNITS NO. 1 AND NO. 2

SITE LAYOUT PLAN

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO JAPAN

APPROVED BY	REVIEWED BY	CHECKED BY	DRAWN BY
DWG NO. WGTS-1002		SCALE 1:500	DATE

(a) Steam generator plant and accessories

(b) Turbine-generator plant and accessories

Including;

- o Rehabilitation of three (3) existing cooling water intake pipes and extension of open intake culvert for connection to No. 1 culvert
- o Cooling water discharge way
  Outlet part of cooling water discharge way will be connected to the already constructed part of the cooling water discharge way for the No. 2 Unit.

(c) Common auxiliary equipment for No. 2 Unit extending to already constructed facilities.

(d) Electrical, measuring and control equipment

(2) Non-technical and other necessary facilities inside the Power Plant, such as;

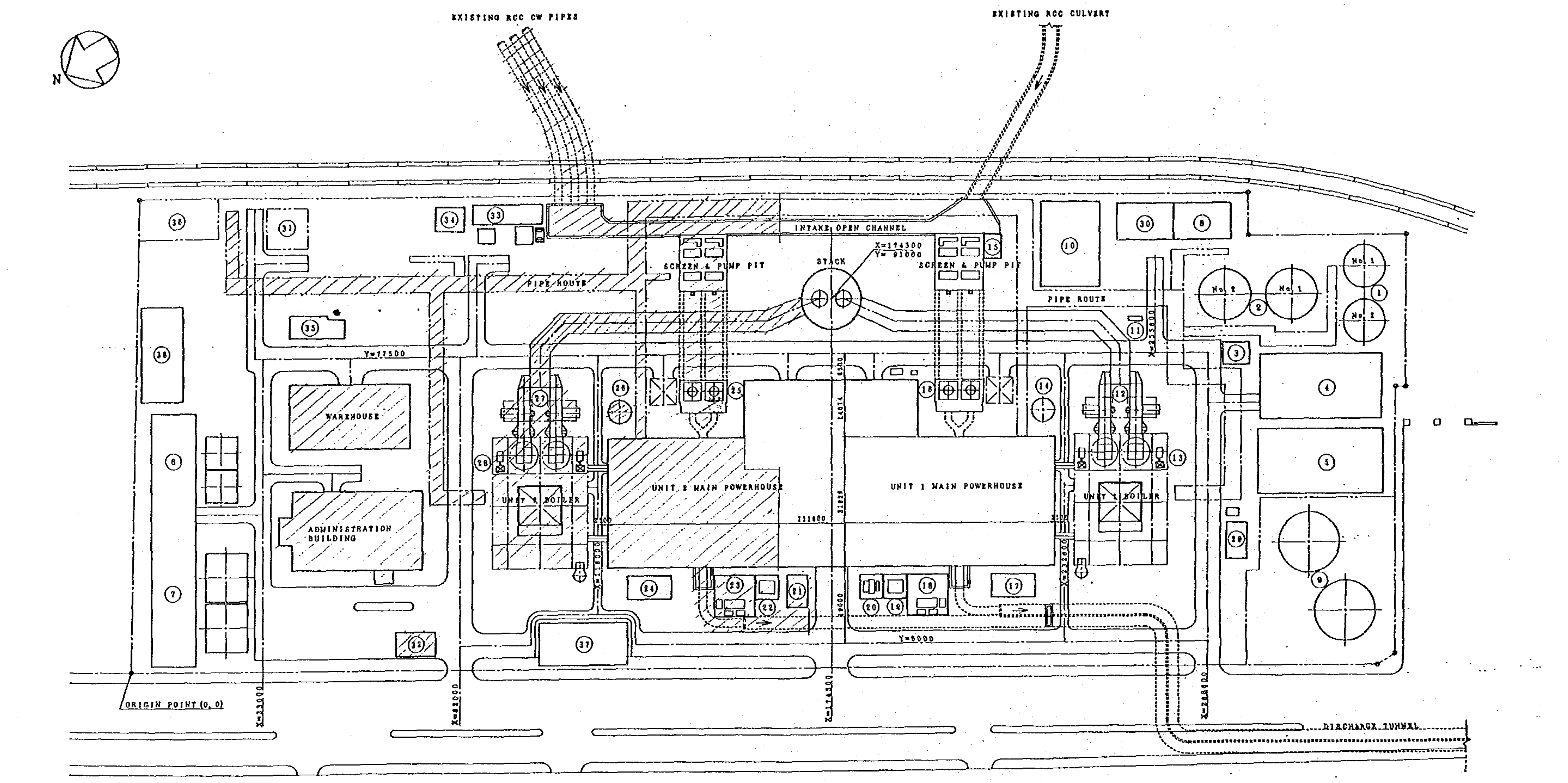
o Administration building

o Warehouse

o Machine shop

o Others

The Scope for Unit 2 is shown by the hatched lenes in Fig. 1.2-2.



No	DESCRIPTION	No	DESCRIPTION	No	DESCRIPTION	No	DESCRIPTION
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3	CHEMICAL STORAGE TANK	15	CHLORINATION FEED WATER PUMP PIT	27	FORCED DRAFT FAN		
4	WATER TREATMENT EQUIP. & CONTROL ROOM	16	CIRCULATING WATER PUMP	28	GAS RECIRCULATING FAN		
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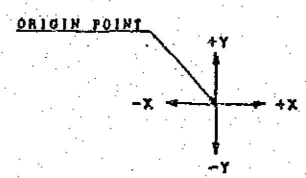
10	CHLORINATION EQUIP. AREA & CONTROL ROOM	22	AUXILIARY TRANSFORMER	34	H_2 & GAS GENERATING ROOM		
11	AIR FOAM EQUIPMENT AREA	23	MAIN TRANSFORMER	35	STORAGE BOX FOR STOP LOG		
12	FORCED DRAFT FAN	24	UNIT NEUTRALIZING PIT	36	EXISTING GAS STATION (SUI GAS)		

Fig. 12-2
The scope is shown with hatched lines



PAKISTAN
KARACHI ELECTRIC SUPPLY CORPORATION

WEST WHARF THERMAL POWER PLANT PROJECT
UNITS NO. 1 AND NO. 2

SITE LAYOUT PLAN

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO JAPAN

APPROVED BY	REVIEWED BY	CHECKED BY	DRAWN BY
DWG NO. WGTS-1002		SCALE 1:800	DATE

I-3 SITE CONDITION AND DESIGN CONDITION

For formulating design of the West Wharf Thermal Power Plant Project, certain natural factors have to be taken into account and certain levels of utility service must be considered so as to ensure suitable detailed design.

The natural factors to be considered for the detailed design are based on existing data collected from KESC at the time of site survey.

Atmospheric Pressures for Karachi

	Mean pressure mb. G.M.T. 0.30	Mean 12.00	
January	1017.0	1015.0	1016.0
February	1014.9	1012.9	1013.9
March	1011.9	1010.0	1010.9
April	1008.4	1006.4	1007.4
May	1004.8	1002.9	1003.9
June	999.6	997.6	998.6
July	998.4	996.7	997.5
August	1000.8	999.3	1000.0
September	1005.6	1003.8	1004.7
October	1011.0	1008.8	1009.9
November	1014.9	1012.6	1013.8
December	1017.2	1015.0	1016.1
Year	1008.7	1006.7	1007.7
No. of Years	50	50	50

Humidity

(Average figures for 1975 - 1984)

Month	Average precipitation (in mm)	Average relative humidity
Jan.	12.1	62 %
Feb.	20.6	69 %
Mar.	13.1	72 %
Apr.	1.1	75 %
May	-	75 %
June	9.8	76 %
July	74.6	80 %
Aug.	100.1	85 %
Sept.	20.0	80 %
Oct.	3.1	75 %
Nov.	2.0	62 %
Dec.	8.7	65 %

Ambient Temperature

(Average Temperatures for the period 1975 - 1987)

Month	Temperature °C Max.	Min.	Mean
Jan.	28.7	6.1	18.2
Feb.	32.3	7.9	20.3
Mar.	35.4	11.5	24.1
Apr.	40.1	18.2	28.4
May	41.2	21.9	30.6
June	42.7	26.2	31.7
July	37.1	25.4	30.4
Aug.	35.5	24.2	28.7
Sept.	37.5	23.0	29.1
Oct.	38.8	15.9	27.2
Nov.	36.2	11.1	23.3
Dec.	30.8	8.3	19.6

TIDAL LEVELS AND DATUMS

(1) DATUMS AT STANDARD AND SECONDARY PORTS

Level of zero of predictions which is chart datum in all cases.

KARACHI	4.31 metres (14.14 ft.) below a Bench Mark about 100 metres (110 yds) south west of the tidal observatory.
MUHAMMAD BIN QASIM PORT (ENTRANCE)	5.57 metres (18.61 ft.) below a Bench Mark on the Bundal Island which is the western bank of Phitti Creek and about 1.2 km (3/4 mile) north of the southern tip of the Island.
MUHAMMAD BIN QASIM PORT (PIPRI)	4.67 metres (15.35 ft.) below a Bench Mark situated close to the H.W. line in Gharo Creek and about 2.4 km (1½ miles) south west of Goth Mahmood Shah.
GWADAR	3.979 metres (13.05 ft.) below a Bench Mark on a top of a Triangulation mark (Pillar of concrete) named G-2, about 500 metres (550 yds) south of Custom House Building on high water line.
PASNI	3.81 metres (12.5 ft.) below a Bench Mark covered in cement at the top of concrete post about 1 metre (3.3 ft.) above ground and 0.49 metre (1.6 ft.) in diameter; erected in the sand near the entrance to the Coast Guard Camp Compund. The camp is near the Mazar at Pasni.

(2) TIDAL LEVELS AT STANDARD AND SECONDARY PORTS

PORTS	L.A.T.	M.L.L.W.	M.H.L.W.	M.S.L.	M.L.H.W.	M.H.H.W.	H.A.T.	Year of tidal Observation
	-430	+430	+1100	+1645	+2190	+2680	+3200	
Karachi	-1.4	+1.4	+3.6	+5.4	+7.2	+8.8	+10.5	1950, 1953
Md.Bin Qasim Ent.	-1.9	+1.8	+4.0	+5.7	+7.4	+9.6	+11.3	1972, 1973
Md.Bin Qasim Pipri	-2.0	+3.2	+4.7	+6.7	+8.7	+11.1	+13.0	1972, 1973
Gwadar	-1.1	+0.7	+3.4	+4.2	+6.3	+6.6	+ 8.4	1982
Pasni	-1.3	+0.8	+3.6	+4.6	+7.1	+7.2	+ 9.5	1985

The above levels, in feet, are referred to CHART DATUM, which is the same as the Zero of the tidal predictions in all cases.

All predictions in this book are calculated by the harmonic method.

NOTE:- The analysis for Pasni is based on one Synodic month.

DEFINITIONS OF TIDAL LEVELS AND DATUMS

Tidal Levels

(a) L.A.T. (Lowest Astronomical Tide). H.A.T. (Highest Astronomical Tide). The lowest and highest levels respectively which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; these levels will not be reached every year. H.A.T. and L.A.T. are not the extreme levels which can be reached, as storm surges may cause considerably higher and lower levels to occur.

(b) M.L.W.S. (Mean Low Water Springs). M.H.W.S. (Mean High Water Springs). The height on mean high water springs is the average, throughout a year when the average maximum declination of the moon is 23½° of the heights, of two successive high waters during those periods of 24 hrs. (approximately once a fortnight) when the range of the tide is greatest. The height of mean low water springs is the average height obtained by the two successive low waters during same periods.

(c) M.H.W.N. (Mean High Water Neaps). M.L.W.N. (Mean Low Water Neaps). The height of mean high water neaps is the average, throughout a year as defined in (b) above, of the heights of two successive high water during those periods (approximately once a fortnight) when the range of the tide is least. The height of mean low water neaps is the average height obtained from the two successive low waters during the same periods.

NOTE. The average value of M.H.W.S. etc., varies from year to year in a cycle of approximately 18.6 years. The tidal levels given in Table III are average values for the whole cycle obtained by computing values of a year or more and correcting the results by the value of f of M_2

M.S.L. (Mean Sea level). Mean sea level is the average level of the sea surface over a long period, preferably 18.6 years, or the average level which would exist in the absence of tides.

M.H.H.W. (Mean Higher High Water). The height of mean higher high water is the mean of the higher of the two daily high waters over a long period of time. When only one high water occurs on a day this is taken as the higher high water.

M.L.H.W. (Mean Lower High Water). The height of mean lower high water is the mean of the lower of the two daily high water over a long period of time.

M.L.L.W. (Mean Lower Low Water). The height of mean lower low water is the mean of the lower of the two daily low waters over a long period of time. When only one low water occurs on a day this is taken as the lower low water.

M.H.L.W. (Mean Higher Low Water). The height of mean higher low water is the mean of the higher of the two daily low waters over a long period of time.

NOTE. The average value of M.H.H.W., etc., varies from year to year in a cycle of approximately 18.6 years. The tidal levels given in Table III are usually computed from a year when the levels are expected to be average that is when f of M_2 is 1.00.

PAKISTAN—KARACHI

Lat. 24° 48' N, Long 66° 58' E

TIME ZONE—0500 TIMES AND HEIGHTS OF HIGH AND LOW WATERS YEAR 1988

JANUARY

	TIME	FT	M		TIME	FT	M
1 F	0250	5.3	1.6	16 SA	0205	5.7	1.7
	0750	7.6	2.3		0649	7.6	2.3
	1456	0.4	0.1		1418	0.4	0.1
	2212	8.6	2.6		2145	8.5	2.6
2 SA	0344	5.1	1.5	17 SU	0307	5.3	1.6
	0841	7.5	2.3		0801	7.8	2.4
	1538	0.3	0.1		1511	-0.2	-0.1
	2250	8.9	2.7		2227	9.2	2.8
3 SU	0429	4.8	1.5	18 M	0359	4.7	1.4
	0928	7.4	2.3		0906	8.2	2.5
	1618	0.3	0.1		1601	-0.6	-0.2
	2324	9.1	2.8		2307	9.8	3.0
4 M	0508	4.6	1.4	19 TU	0446	4.1	1.2
	1013	7.4	2.3		1006	8.5	2.6
	1654	0.4	0.1		1647	-0.8	-0.3
	2356	9.3	2.8		2346	10.2	3.1
5 TU	0545	4.3	1.3	20 W	0532	3.5	1.1
	1056	7.5	2.3		1103	8.7	2.7
	1729	0.7	0.2		1733	-0.8	-0.2
6 W	0027	9.3	2.8	21 TH	0024	10.5	3.2
	0620	4.2	1.3		0618	2.9	0.9
	1135	7.5	2.3		1156	8.8	2.7
	1802	0.9	0.3		1817	-0.3	-0.1
7 TH	0056	9.3	2.8	22 F	0059	10.6	3.2
	0654	4.0	1.2		0703	2.3	0.7
	1211	7.5	2.3		1248	8.6	2.6
	1831	1.3	0.4		1859	0.4	0.1
8 F	0123	9.3	2.8	23 SA	0134	10.5	3.2
	0726	3.8	1.2		0750	1.9	0.6
	1247	7.4	2.2		1340	8.2	2.5
	1859	1.8	0.5		1941	1.4	0.4
9 SA	0148	9.1	2.8	24 SU	0210	10.1	3.1
	0800	3.6	1.1		0836	1.6	0.5
	1326	7.1	2.2		1436	7.6	2.3
	1929	2.4	0.7		2025	2.6	0.8
10 SU	0214	8.9	2.7	25 M	0245	9.5	2.9
	0836	3.4	1.0		0927	1.5	0.5
	1411	6.8	2.1		1541	7.0	2.1
	2000	3.1	0.9		2111	3.9	1.2
11 M	0241	8.7	2.6	26 TU	0321	8.8	2.7
	0917	3.1	1.0		1023	1.5	0.5
	1509	6.4	2.0		1711	6.6	2.0
	2038	3.9	1.2		2209	5.0	1.5
12 TU	0310	8.4	2.6	27 W	0401	8.0	2.5
	1005	2.8	0.8		1129	1.5	0.5
	1625	6.2	1.9		1911	6.8	2.1
	2128	4.8	1.4		2343	5.8	1.8
13 W	0347	8.1	2.5	28 TH	0454	7.4	2.2
	1103	2.3	0.7		1242	1.4	0.4
	1816	6.4	1.9		2033	7.4	2.3
	2241	5.5	1.7				
14 TH	0436	7.8	2.4	29 F	0137	5.8	1.8
	1211	1.8	0.5		0610	6.9	2.1
	1958	7.0	2.1		1347	1.3	0.4
					2126	7.9	2.4
15 F	0028	5.9	1.8	30 SA	0250	5.5	1.7
	0538	7.6	2.3		0729	6.7	2.1
	1319	1.1	0.3		1441	1.1	0.3
	2057	7.8	2.4		2203	8.3	2.5
				31 SU	0340	5.0	1.5
					0832	6.8	2.1
					1524	1.0	0.3
					2234	8.7	2.6

FEBRUARY

	TIME	FT	M		TIME	FT	M
1 M	0418	4.6	1.4	16 TU	0342	4.1	1.2
	0926	7.1	2.2		0906	8.2	2.5
	1603	0.9	0.3		1547	-0.3	-0.1
	2305	8.9	2.7		2240	9.8	3.0
2 TU	0451	4.2	1.3	17 W	0429	3.2	1.0
	1011	7.3	2.2		1006	8.7	2.6
	1640	0.9	0.3		1633	-0.4	-0.1
	2333	9.2	2.8		2317	10.3	3.1
3 W	0524	3.9	1.2	18 TH	0512	2.3	0.7
	1051	7.6	2.3		1101	9.0	2.7
	1712	1.0	0.3		1717	-0.2	-0.1
					2352	10.6	3.2
4 TH	0000	9.4	2.9	19 F	0556	1.5	0.5
	0555	3.5	1.1		1153	9.1	2.8
	1129	7.8	2.4		1759	0.3	0.1
	1742	1.2	.4				
5 F	0026	9.5	2.9	20 SA	0026	10.7	3.3
	0624	3.2	1.0		0638	1.0	0.3
	1204	7.9	2.4		1242	9.0	2.7
	1810	1.5	0.5		1840	1.2	0.4
6 SA	0048	9.4	2.9	21 SU	0058	10.5	3.2
	0652	2.9	0.9		0720	0.6	0.2
	1240	7.8	2.4		1330	8.6	2.6
	1837	2.0	0.6		1920	2.2	0.7
7 SU	0109	9.3	2.8	22 M	0130	9.9	3.0
	0720	2.6	0.8		0803	0.6	0.2
	1316	7.7	2.3		1419	8.0	2.4
	1903	2.6	0.8		2000	3.3	1.0
8 M	0129	9.1	2.8	23 TU	0200	9.2	2.8
	0751	2.3	0.7		0846	0.9	0.3
	1356	7.4	2.2		1517	7.4	2.2
	1932	3.3	1.0		2043	4.4	1.3
9 TU	0150	8.8	2.7	24 W	0229	8.4	2.6
	0828	2.0	0.6		0935	1.3	0.4
	1443	7.0	2.1		1637	6.8	2.1
	2004	4.1	1.3		2140	5.3	1.6
10 W	0215	8.5	2.6	25 TH	0259	7.5	2.3
	0910	1.9	0.6		1039	1.8	0.5
	1545	6.6	2.0		1845	6.8	2.1
	2046	4.9	1.5		2326	5.9	1.8
11 TH	0246	8.1	2.5	26 F	0338	6.7	2.0
	1006	1.8	0.6		1204	2.1	0.6
	1724	6.4	2.0		2012	7.2	2.2
	2152	5.7	1.7				
12 F	0334	7.7	2.3	27 SA	0133	5.7	1.7
	1121	1.7	0.5		0531	6.2	1.9
	1937	6.9	2.1		1323	2.1	0.6
	2359	6.1	1.8		2100	7.7	2.3
13 SA	0448	7.3	2.2	28 SU	0241	5.2	1.6
	1249	1.3	0.4		0726	6.2	1.9
	2041	7.7	2.3		1421	1.9	0.6
					2134	8.1	2.5
14 SU	0150	5.7	1.7	29 M	0321	4.7	1.4
	0628	7.3	2.2		0831	6.6	2.0
	1400	0.7	0.2		1506	1.7	0.5
	2124	8.4	2.6		2203	8.4	2.6
15 M	0253	4.9	1.5				
	0756	7.6	2.3				
	1457	0.1	0.0				
	2203	9.2	2.8				

MARCH

	TIME	FT	M		TIME	FT	M
1 TU	0354	4.1	1.3	16 W	0320	3.1	0.9
	0920	7.1	2.2		0904	8.3	2.5
	1542	1.6	0.5		1526	0.6	0.2
	2230	8.8	2.7		2202	9.8	3.0
2 W	0423	3.7	1.1	17 TH	0405	2.0	0.6
	1002	7.5	2.3		1002	8.9	2.7
	1616	1.5	0.5		1612	0.7	0.2
	2257	9.1	2.8		2239	10.2	3.1
3 TH	0453	3.2	1.0	18 F	0447	1.1	0.3
	1041	7.9	2.4		1056	9.3	2.8
	1647	1.6	0.5		1656	1.0	0.3
	2321	9.2	2.8		2314	10.4	3.2
4 F	0521	2.7	0.8	19 SA	0529	0.4	0.1
	1118	8.1	2.5		1145	9.4	2.9
	1717	1.8	0.6		1738	1.6	0.5
	2345	9.3	2.8		2348	10.3	3.1
5 SA	0548	2.3	0.7	20 SU	0609	-0.1	0.0
	1153	8.3	2.5		1231	9.3	2.8
	1746	2.2	0.7		1820	2.3	0.7
6 SU	0006	9.3	2.8	21 M	0020	10.0	3.0
	0614	1.8	0.6		0648	-0.2	0.0
	1228	8.3	2.5		1316	9.0	2.7
	1813	2.6	0.8		1901	3.1	1.0
7 M	0026	9.2	2.8	22 TU	0051	9.4	2.9
	0642	1.5	0.4		0727	0.1	0.0
	1303	8.2	2.5		1403	8.4	2.6
	1842	3.2	1.0		1941	4.0	1.2
8 TU	0047	9.0	2.7	23 W	0120	8.6	2.6
	0713	1.2	0.4		0808	0.7	0.2
	1341	7.9	2.4		1453	7.8	2.4
	1912	3.8	1.2		2026	4.8	1.4
9 W	0108	8.7	2.7	24 TH	0147	7.8	2.4
	0747	1.2	0.4		0852	1.4	0.4
	1425	7.5	2.3		1601	7.2	2.2
	1944	4.5	1.4		2127	5.4	1.6
10 TH	0132	8.4	2.6	25 F	0214	7.0	2.1
	0831	1.3	0.4		0949	2.2	0.7
	1521	7.0	2.1		1752	6.9	2.1
	2029	5.2	1.6		2317	5.7	1.7
11 F	0205	8.0	2.4	26 SA	0252	6.3	1.9
	0927	1.5	0.5		1118	2.7	0.8
	1654	6.7	2.1		1920	7.2	2.2
	2144	5.8	1.8				
12 SA	0257	7.4	2.3	27 SU	0106	5.4	1.6
	1050	1.8	0.5		0519	5.8	1.8
	1859	7.1	2.2		1245	2.9	0.9
					2010	7.6	2.3
13 SU	0000	5.8	1.8	28 M	0208	4.8	1.5
	0432	7.0	2.1		0719	6.1	1.9
	1226	1.6	0.5		1347	2.7	0.8
	2004	7.8	2.4		2045	8.0	2.4
14 M	0134	5.2	1.6	29 TU	0246	4.2	1.3
	0634	7.1	2.2		0818	6.6	2.0
	1340	1.2	0.4		1432	2.6	0.8
	2048	8.5	2.6		2114	8.3	2.5
15 TU	0232	4.2	1.3	30 W	0318	3.6	1.1
	0800	7.6	2.3		0904	7.2	2.2
	1436	0.8	0.2		1510	2.5	0.8
	2126	9.2	2.8		2142	8.6	2.6
				31 TH	0347	3.0	0.9
					0947	7.7	2.4
					1545	2.5	0.8
					2208	8.9	2.7

PAKISTAN—KARACHI
Lat. 24° 48' N, Long 66° 58' E

TIME ZONE—0500 | TIMES AND HEIGHTS OF HIGH AND LOW WATERS | YEAR 1988

APRIL						MAY						JUNE					
TIME	FT	M	TIME	FT	M	TIME	FT	M	TIME	FT	M	TIME	FT	M	TIME	FT	M
1 0415	2.5	0.7	16 0420	0.1	0.0	1 0403	1.2	0.4	16 0434	-0.5	-0.1	1 0448	-0.1	0.0	16 0536	0.4	0.1
F 1025	8.2	2.5	SA 1047	9.4	2.9	SU 1047	8.8	2.7	M 1125	9.6	2.9	W 1156	9.5	2.9	TH 1235	9.4	2.9
1618	2.6	0.8	1634	2.5	0.8	1625	4.0	1.2	1705	4.2	1.3	1729	4.8	1.5	1824	4.5	1.4
2233	9.0	2.7	2232	9.9	3.0	2206	8.6	2.6	2233	8.9	2.7	2243	8.5	2.6	2335	7.8	2.4
2 0443	1.9	0.6	17 0500	-0.4	-0.1	2 0436	0.7	0.2	17 0515	-0.4	-0.1	2 0531	-0.1	0.0	17 0613	0.9	0.3
SA 1103	8.5	2.6	SU 1135	9.6	2.9	M 1125	9.1	2.8	TU 1209	9.6	2.9	TH 1238	9.6	2.9	F 1311	9.3	2.8
1650	2.8	0.9	1719	3.0	0.9	1701	4.2	1.3	1752	4.3	1.3	1816	4.8	1.4	1905	4.5	1.4
2257	9.0	2.7	2308	9.6	2.9	2236	8.6	2.6	2312	8.5	2.6	2328	8.5	2.6			
3 0511	1.4	0.4	18 0541	-0.5	-0.2	3 0508	0.3	0.1	18 0553	0.0	0.0	3 0614	0.0	0.0	18 0014	7.6	2.3
SU 1139	8.8	2.7	M 1220	9.5	2.9	TU 1204	9.2	2.8	W 1249	9.4	2.9	F 1320	9.5	2.9	SA 0648	1.4	0.4
1722	3.2	1.0	1803	3.5	1.1	1739	4.4	1.3	1837	4.5	1.4	1903	4.7	1.4	1344	9.1	2.8
2321	8.9	2.7	2343	9.2	2.8	2307	8.6	2.6	2349	8.1	2.5				1946	4.4	1.4
4 0539	0.9	0.3	19 0618	-0.3	-0.1	4 0545	0.1	0.0	19 0633	0.5	0.2	4 0016	8.3	2.5	19 0054	7.3	2.2
M 1214	8.8	2.7	TU 1302	9.3	2.8	W 1244	9.2	2.8	TH 1330	9.1	2.8	SA 0702	0.4	0.1	SU 0722	1.9	0.6
1753	3.5	1.1	1847	4.0	1.2	1818	4.6	1.4	1922	4.7	1.4	1404	9.4	2.9	1417	8.9	2.7
2343	8.9	2.7				2339	8.5	2.6				1956	4.5	1.4	2028	4.4	1.3
5 0609	0.6	0.2	20 0016	8.7	2.6	5 0624	0.2	0.1	20 0026	7.7	2.3	5 0108	8.0	2.4	20 0134	7.0	2.1
TU 1251	8.7	2.7	W 0656	0.2	0.1	TH 1326	9.0	2.7	F 0711	1.2	0.4	SU 0751	0.9	0.3	M 0756	2.6	0.8
1826	4.0	1.2	1346	8.8	2.7	1901	4.9	1.5	1411	8.7	2.6	1450	9.3	2.8	1449	8.7	2.6
			1930	4.5	1.4				2010	4.9	1.5	2055	4.3	1.3	2111	4.2	1.3
6 0007	8.7	2.7	21 0047	8.1	2.5	6 0016	8.3	2.5	21 0101	7.3	2.2	6 0211	7.5	2.3	21 0224	6.7	2.0
W 0642	0.5	0.2	TH 0734	0.9	0.3	F 0708	0.5	0.2	SA 0748	1.9	0.6	M 0845	1.7	0.5	TU 0832	3.2	1.0
1330	8.5	2.6	1432	8.2	2.5	1412	8.7	2.6	1455	8.3	2.5	1540	9.1	2.8	1524	8.4	2.6
1901	4.5	1.4	2019	4.9	1.5	1953	5.1	1.5	2102	5.0	1.5	2158	3.9	1.2	2159	4.0	1.2
7 0034	8.5	2.6	22 0118	7.4	2.3	7 0058	8.0	2.4	22 0141	6.8	2.1	7 0330	7.0	2.1	22 0328	6.3	1.9
TH 0720	0.7	0.2	F 0817	1.7	0.5	SA 0758	1.0	0.3	SU 0831	2.6	0.8	TU 0945	2.6	0.8	W 0916	3.9	1.2
1415	8.0	2.4	1528	7.7	2.3	1509	8.4	2.6	1544	8.1	2.5	1633	9.0	2.8	1601	8.2	2.5
1941	4.9	1.5	2121	5.3	1.6	2057	5.2	1.6	2202	4.9	1.5	2304	3.2	1.0	2251	3.6	1.1
8 0105	8.2	2.5	23 0150	6.8	2.1	8 0151	7.5	2.3	23 0236	6.3	1.9	8 0501	6.9	2.1	23 0454	6.2	1.9
F 0807	1.0	0.3	SA 0907	2.5	0.8	SU 0859	1.6	0.5	M 0921	3.3	1.0	W 1051	3.4	1.0	TH 1012	4.6	1.4
1514	7.6	2.3	1646	7.4	2.2	1615	8.3	2.5	1639	7.9	2.4	1725	9.0	2.7	1641	8.0	2.5
2039	5.4	1.6	2247	5.4	1.6	2215	4.9	1.5	2308	4.7	1.4				2348	3.1	0.9
9 0147	7.7	2.4	24 0238	6.2	1.9	9 0314	7.0	2.1	24 0411	6.0	1.8	9 0010	2.4	0.7	24 0635	6.5	2.0
SA 0909	1.5	0.5	SU 1019	3.2	1.0	M 1012	2.2	0.7	TU 1023	3.9	1.2	TH 0634	7.1	2.2	F 1122	5.2	1.6
1639	7.4	2.2	1806	7.4	2.3	1722	8.4	2.6	1732	7.9	2.4	1203	4.1	1.3	1728	7.9	2.4
2209	5.6	1.7				2335	4.3	1.3				1817	8.9	2.7			
10 0252	7.1	2.2	25 0014	5.1	1.5	10 0505	6.8	2.1	25 0010	4.2	1.3	10 0109	1.5	0.5	25 0042	2.4	0.7
SU 1030	2.0	0.6	M 0456	5.8	1.8	TU 1128	2.7	0.8	W 0600	6.1	1.9	F 0753	7.7	2.4	SA 0753	7.1	2.2
1811	7.6	2.3	1142	3.5	1.1	1820	8.7	2.7	1132	4.3	1.3	1315	4.5	1.4	1245	5.5	1.7
2355	5.2	1.6	1901	7.7	2.3				1818	8.0	2.4	1905	8.9	2.7	1816	7.9	2.4
11 0450	6.8	2.1	26 0118	4.5	1.4	11 0042	3.3	1.0	26 0102	3.5	1.1	11 0203	0.7	0.2	26 0133	1.7	0.5
M 1200	2.1	0.6	TU 0651	6.1	1.9	W 0641	7.1	2.2	TH 0720	6.7	2.0	SA 0855	8.3	2.5	SU 0849	7.8	2.4
1913	8.2	2.5	1251	3.6	1.1	1238	3.0	0.9	1240	4.5	1.4	1421	4.7	1.4	1400	5.5	1.7
			1941	8.0	2.4	1909	9.0	2.8	1858	8.1	2.5	1953	8.7	2.7	1906	7.9	2.4
12 0112	4.3	1.3	27 0200	3.9	1.2	12 0140	2.2	0.7	27 0143	2.8	0.8	12 0249	0.2	0.0	27 0219	1.1	0.3
TU 0641	7.1	2.2	W 0754	6.7	2.0	TH 0756	7.8	2.4	F 0818	7.3	2.2	SU 0948	8.8	2.7	M 0937	8.4	2.5
1312	2.0	0.6	1344	3.6	1.1	1341	3.3	1.0	1340	4.7	1.4	1518	4.8	1.5	1457	5.4	1.6
2000	8.8	2.7	2014	8.3	2.5	1951	9.3	2.8	1932	8.2	2.5	2038	8.6	2.6	1958	8.0	2.4
13 0208	3.2	1.0	28 0233	3.2	1.0	13 0228	1.1	0.3	28 0218	2.0	0.6	13 0333	-0.1	0.0	28 0306	0.5	0.1
W 0758	7.7	2.4	TH 0843	7.3	2.2	F 0856	8.5	2.6	SA 0906	7.9	2.4	M 1034	9.2	2.8	TU 1020	8.9	2.7
1410	1.9	0.6	1429	3.6	1.1	1438	3.5	1.1	1432	4.8	1.5	1609	4.8	1.5	1548	5.1	1.6
2039	9.4	2.8	2042	8.5	2.6	2032	9.4	2.9	2007	8.3	2.5	2124	8.4	2.5	2050	8.2	2.5
14 0255	2.0	0.6	29 0304	2.5	0.7	14 0311	0.3	0.1	29 0255	1.3	0.4	14 0415	-0.1	0.0	29 0351	0.0	0.0
TH 0900	8.4	2.6	F 0927	7.9	2.4	SA 0951	9.0	2.7	SU 0951	8.5	2.6	TU 1118	9.4	2.9	W 1104	9.3	2.8
1502	2.0	0.6	1509	3.7	1.1	1530	3.7	1.1	1518	4.8	1.5	1657	4.7	1.4	1634	4.9	1.5
2118	9.7	3.0	2110	8.6	2.6	2113	9.4	2.9	2042	8.3	2.5	2209	8.2	2.5	2144	8.4	2.6
15 0338	1.0	0.3	30 0334	1.8	0.5	15 0354	-0.3	-0.1	30 0330	0.7	0.2	15 0457	0.1	0.0	30 0436	-0.3	-0.1
F 0956	9.0	2.7	SA 1008	8.4	2.6	SU 1040	9.4	2.9	M 1033	8.9	2.7	W 1159	9.4	2.9	TH 1145	9.7	2.9
1549	2.2	0.7	1547	3.8	1.2	1619	4.0	1.2	1603	4.8	1.5	1742	4.6	1.4	1719	4.5	1.4
2155	9.9	3.0	2138	8.6	2.6	2154	9.2	2.8	2120	8.4	2.6	2254	8.0	2.4	2237	8.6	2.6
									31 0408	0.2	0.1						
									TU 1115	9.3	2.8						
									1646	4.8	1.5						
									2201	8.5	2.6						

PAKISTAN—KARACHI

Lat. 24° 48′ N, Long 66° 58′ E

TIME ZONE—0500 TIMES AND HEIGHTS OF HIGH AND LOW WATERS YEAR 1988

JULY

Day	TIME	FT	M	Day	TIME	FT	M
1	0522	-0.4	-0.1	16	0553	1.1	0.3
F	1224	9.9	3.0	SA	1242	9.3	2.8
	1806	4.2	1.3		1838	3.8	1.2
	2329	8.6	2.6				
2	0607	-0.2	-0.1	17	0007	7.7	2.4
SA	1302	10.1	3.1	SU	0626	1.5	0.4
	1854	3.8	1.1		1309	9.3	2.8
					1912	3.6	1.1
3	0023	8.5	2.6	18	0044	7.6	2.3
SU	0652	0.3	0.1	M	0654	2.0	0.6
	1341	10.1	3.1		1334	9.1	2.8
	1943	3.3	1.0		1944	3.5	1.1
4	0118	8.2	2.5	19	0122	7.4	2.3
M	0737	1.0	0.3	TU	0722	2.5	0.8
	1419	9.9	3.0		1358	8.9	2.7
	2033	2.9	0.9		2018	3.3	1.0
5	0217	7.8	2.4	20	0203	7.1	2.2
TU	0824	2.0	0.6	W	0753	3.2	1.0
	1500	9.6	2.9		1424	8.6	2.6
	2128	2.5	0.8		2056	3.0	0.9
6	0324	7.2	2.2	21	0253	6.7	2.0
W	0916	3.1	0.9	TH	0826	4.0	1.2
	1542	9.2	2.8		1450	8.3	2.5
	2227	2.1	0.6		2140	2.8	0.9
7	0447	6.9	2.1	22	0358	6.4	2.0
TH	1015	4.2	1.3	F	0911	4.7	1.4
	1630	8.8	2.7		1524	8.0	2.4
	2332	1.7	0.5		2233	2.5	0.8
8	0627	7.0	2.1	23	0535	6.4	1.9
F	1131	5.0	1.5	SA	1015	5.4	1.7
	1724	8.3	2.5		1609	7.7	2.3
					2339	2.2	0.7
9	0040	1.2	0.4	24	0730	6.8	2.1
SA	0754	7.5	2.3	SU	1155	5.8	1.8
	1259	5.4	1.6		1710	7.5	2.3
	1823	8.0	2.4				
10	0140	0.8	0.2	25	0052	1.7	0.5
SU	0857	8.1	2.5	M	0835	7.5	2.3
	1417	5.3	1.6		1339	5.7	1.8
	1923	7.8	2.4		1823	7.5	2.3
11	0232	0.5	0.2	26	0156	1.1	0.3
M	0947	8.5	2.6	TU	0921	8.2	2.5
	1516	5.1	1.6		1443	5.3	1.6
	2019	7.7	2.3		1936	7.7	2.3
12	0320	0.4	0.1	27	0249	0.4	0.1
TU	1029	8.9	2.7	W	1003	8.8	2.7
	1605	4.8	1.5		1533	4.8	1.5
	2111	7.7	2.3		2041	8.1	2.5
13	0402	0.4	0.1	28	0338	-0.1	0.0
W	1107	9.1	2.8	TH	1043	9.3	2.8
	1647	4.5	1.4		1619	4.2	1.3
	2201	7.7	2.3		2141	8.4	2.6
14	0443	0.5	0.2	29	0425	-0.4	-0.1
TH	1141	9.2	2.8	F	1121	9.8	3.0
	1726	4.3	1.3		1704	3.6	1.1
	2247	7.8	2.4		2237	8.8	2.7
15	0519	0.8	0.2	30	0508	-0.4	-0.1
F	1213	9.3	2.8	SA	1157	10.2	3.1
	1803	4.0	1.2		1748	2.9	0.9
	2328	7.8	2.4		2331	8.9	2.7
				31	0552	-0.1	0.0
				SU	1233	10.4	3.2
					1833	2.3	0.7

AUGUST

Day	TIME	FT	M	Day	TIME	FT	M
1	0023	8.9	2.7	16	0030	8.0	2.4
M	0635	0.5	0.1	TU	0626	2.2	0.7
	1308	10.4	3.2		1249	9.1	2.8
	1918	1.8	0.5		1901	2.3	0.7
2	0115	8.6	2.6	17	0103	7.8	2.4
TU	0718	1.4	0.4	W	0652	2.8	0.8
	1341	10.1	3.1		1309	8.8	2.7
	2004	1.5	0.4		1929	2.1	0.6
3	0208	8.1	2.5	18	0141	7.5	2.3
W	0801	2.4	0.7	TH	0719	3.4	1.0
	1417	9.6	2.9		1330	8.5	2.6
	2053	1.3	0.4		2001	2.0	0.6
4	0309	7.5	2.3	19	0224	7.1	2.2
TH	0848	3.6	1.1	F	0750	4.1	1.3
	1453	8.9	2.7		1353	8.2	2.5
	2147	1.3	0.4		2041	2.0	0.6
5	0426	7.0	2.1	20	0317	6.7	2.0
F	0944	4.7	1.4	SA	0829	4.8	1.5
	1535	8.1	2.5		1422	7.8	2.4
	2251	1.4	0.4		2133	2.0	0.6
6	0618	6.9	2.1	21	0441	6.4	2.0
SA	1110	5.5	1.7	SU	0931	5.5	1.7
	1629	7.4	2.3		1507	7.4	2.2
					2244	2.0	0.6
7	0009	1.5	0.4	22	0705	6.7	2.0
SU	0754	7.3	2.2	M	1128	5.9	1.8
	1302	5.6	1.7		1619	7.0	2.1
	1750	6.9	2.1				
8	0122	1.3	0.4	23	0018	1.8	0.5
M	0853	7.8	2.4	TU	0814	7.3	2.2
	1421	5.2	1.5		1326	5.5	1.7
	1913	6.8	2.1		1803	7.0	2.1
9	0221	1.1	0.3	24	0136	1.2	0.4
TU	0937	8.2	2.5	W	0857	8.0	2.5
	1513	4.8	1.5		1426	4.8	1.5
	2019	7.0	2.1		1933	7.4	2.3
10	0309	1.0	0.3	25	0232	0.6	0.2
W	1012	8.6	2.6	TH	0934	8.7	2.7
	1554	4.3	1.3		1514	4.0	1.2
	2113	7.3	2.2		2042	8.0	2.5
11	0349	0.9	0.3	26	0321	0.2	0.1
TH	1043	8.8	2.7	F	1011	9.4	2.9
	1629	3.9	1.2		1558	3.1	0.9
	2159	7.6	2.3		2141	8.6	2.6
12	0426	1.0	0.3	27	0406	0.0	0.0
F	1112	9.0	2.7	SA	1046	9.9	3.0
	1703	3.5	1.1		1641	2.2	0.7
	2241	7.8	2.4		2236	9.1	2.8
13	0500	1.1	0.3	28	0450	0.1	0.0
SA	1139	9.2	2.8	SU	1121	10.3	3.1
	1735	3.2	1.0		1724	1.3	0.4
	2319	8.0	2.4		2326	9.3	2.8
14	0529	1.4	0.4	29	0532	0.5	0.1
SU	1204	9.2	2.8	M	1156	10.4	3.2
	1804	2.9	0.9		1807	0.7	0.2
	2355	8.0	2.4				
15	0559	1.7	0.5	30	0017	9.3	2.8
M	1228	9.2	2.8	TU	0614	1.2	0.4
	1833	2.6	0.8		1230	10.2	3.1
					1849	0.3	0.1
				31	0105	9.0	2.7
				W	0656	2.1	0.6
					1302	9.8	3.0
					1932	0.2	0.1

SEPTEMBER

Day	TIME	FT	M	Day	TIME	FT	M
1	0154	8.4	2.6	16	0122	8.0	2.5
TH	0739	3.1	0.9	F	0656	3.8	1.2
	1334	9.1	2.8		1244	8.3	2.5
	2015	0.5	0.1		1919	1.1	0.3
2	0249	7.7	2.4	17	0203	7.6	2.3
F	0825	4.1	1.2	SA	0727	4.4	1.3
	1408	8.3	2.5		1306	7.9	2.4
	2106	1.0	0.3		1957	1.3	0.4
3	0401	7.1	2.2	18	0252	7.1	2.2
SA	0924	5.0	1.5	SU	0808	5.0	1.5
	1443	7.4	2.3		1337	7.6	2.3
	2209	1.6	0.5		2050	1.7	0.5
4	0557	6.9	2.1	19	0409	6.7	2.0
SU	1105	5.5	1.7	M	0918	5.6	1.7
	1534	6.6	2.0		1425	7.1	2.2
	2336	2.0	0.6		2208	2.0	0.6
5	0736	7.2	2.2	20	0618	6.8	2.1
M	1306	5.3	1.6	TU	1128	5.7	1.7
	1738	6.0	1.8		1555	6.6	2.0
					2349	2.0	0.6
6	0102	2.1	0.6	21	0733	7.4	2.3
TU	0831	7.6	2.3	W	1308	5.0	1.5
	1415	4.8	1.5		1807	6.7	2.0
	1920	6.2	1.9				
7	0204	1.9	0.6	22	0111	1.7	0.5
W	0907	8.0	2.4	TH	0815	8.1	2.5
	1459	4.2	1.3		1405	4.0	1.2
	2022	6.7	2.0		1936	7.3	2.2
8	0250	1.7	0.5	23	0210	1.2	0.4
TH	0938	8.3	2.5	F	0853	8.8	2.7
	1531	3.6	1.1		1452	2.9	0.9
	2110	7.2	2.2		2041	8.1	2.5
9	0328	1.6	0.5	24	0259	1.0	0.3
F	1005	8.6	2.6	SA	0930	9.4	2.9
	1602	3.1	1.0		1534	1.7	0.5
	2152	7.6	2.3		2137	8.8	2.7
10	0402	1.7	0.5	25	0345	0.9	0.3
SA	1032	8.8	2.7	SU	1005	9.9	3.0
	1632	2.7	0.8		1616	0.7	0.2
	2230	8.0	2.4		2230	9.3	2.8
11	0433	1.8	0.5	26	0429	1.2	0.4
SU	1057	8.9	2.7	M	1041	10.1	3.1
	1700	2.2	0.7		1658	-0.1	0.0
	2305	8.3	2.5		2319	9.6	2.9
12	0503	2.0	0.6	27	0512	1.6	0.5
M	1121	9.0	2.7	TU	1117	10.0	3.1
	1726	1.8	0.6		1739	-0.6	-0.2
	2341	8.4	2.6				
13	0532	2.4	0.7	28	0007	9.6	2.9
TU	1143	8.9	2.7	W	0556	2.2	0.7
	1752	1.5	0.5		1152	9.7	3.0
					1818	-0.7	-0.2
14	0014	8.4	2.6	29	0052	9.3	2.8
W	0559	2.8	0.9	TH	0640	2.9	0.9
	1203	8.7	2.7		1226	9.2	2.8
	1818	1.2	0.4		1859	-0.4	-0.1
15	0047	8.3	2.5	30	0140	8.8	2.7
TH	0627	3.3	1.0	F	0723	3.7	1.1
	1223	8.5	2.6		1258	8.5	2.6
	1847	1.1	0.3		1941	0.2	0.1

PAKISTAN–KARACHI

Lat. 24° 48' N, Long 66° 58' E

TIME ZONE–0500 — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1988

OCTOBER

Day	TIME	FT	M
1 SA	0229	8.1	2.5
	0812	4.4	1.4
	1330	7.7	2.3
	2028	1.0	0.3
2 SU	0334	7.4	2.3
	0917	5.0	1.5
	1404	6.8	2.1
	2127	1.9	0.6
3 M	0511	7.0	2.1
	1058	5.3	1.6
	1452	6.0	1.8
	2253	2.6	0.8
4 TU	0647	7.1	2.2
	1245	4.9	1.5
	1735	5.6	1.7
5 W	0024	2.9	0.9
	0743	7.5	2.3
	1350	4.3	1.3
	1916	6.0	1.8
6 TH	0130	2.8	0.9
	0819	7.8	2.4
	1429	3.7	1.1
	2015	6.6	2.0
7 F	0219	2.7	0.8
	0850	8.1	2.5
	1500	3.0	0.9
	2059	7.2	2.2
8 SA	0257	2.7	0.8
	0917	8.4	2.6
	1528	2.4	0.7
	2138	7.7	2.4
9 SU	0333	2.7	0.8
	0944	8.5	2.6
	1556	1.9	0.6
	2215	8.2	2.5
10 M	0405	2.8	0.9
	1009	8.6	2.6
	1623	1.4	0.4
	2251	8.6	2.6
11 TU	0437	3.0	0.9
	1033	8.6	2.6
	1650	0.9	0.3
	2325	8.8	2.7
12 W	0508	3.3	1.0
	1057	8.5	2.6
	1717	0.6	0.2
13 TH	0000	8.9	2.7
	0539	3.6	1.1
	1119	8.4	2.6
	1745	0.4	0.1
14 F	0034	8.8	2.7
	0611	4.0	1.2
	1143	8.2	2.5
	1816	0.4	0.1
15 SA	0111	8.5	2.6
	0644	4.4	1.3
	1209	8.0	2.5
	1851	0.6	0.2
16 SU	0150	8.1	2.5
	0722	4.8	1.5
	1238	7.8	2.4
	1933	1.0	0.3
17 M	0241	7.7	2.3
	0814	5.1	1.6
	1316	7.4	2.3
	2026	1.5	0.5
18 TU	0351	7.3	2.2
	0933	5.3	1.6
	1414	6.8	2.1
	2142	2.1	0.6
19 W	0522	7.4	2.2
	1117	5.1	1.5
	1603	6.4	1.9
	2315	2.4	0.7
20 TH	0634	7.8	2.4
	1240	4.2	1.3
	1811	6.6	2.0
21 F	0035	2.4	0.7
	0723	8.4	2.6
	1337	3.0	0.9
	1934	7.3	2.2
22 SA	0140	2.3	0.7
	0805	8.9	2.7
	1425	1.8	0.5
	2038	8.2	2.5
23 SU	0233	2.3	0.7
	0845	9.4	2.9
	1510	0.6	0.2
	2133	8.9	2.7
24 M	0323	2.4	0.7
	0923	9.6	2.9
	1551	-0.3	-0.1
	2223	9.4	2.9
25 TU	0411	2.6	0.8
	1001	9.6	2.9
	1633	-0.9	-0.3
	2312	9.7	3.0
26 W	0457	2.9	0.9
	1040	9.5	2.9
	1714	-1.2	-0.4
	2357	9.8	3.0
27 TH	0542	3.3	1.0
	1118	9.1	2.8
	1753	-1.0	-0.3
28 F	0042	9.6	2.9
	0628	3.7	1.1
	1155	8.6	2.6
	1834	-0.5	-0.1
29 SA	0126	9.1	2.8
	0715	4.1	1.3
	1231	7.9	2.4
	1915	0.3	0.1
30 SU	0212	8.6	2.6
	0805	4.5	1.4
	1306	7.3	2.2
	1957	1.3	0.4
31 M	0304	8.0	2.4
	0907	4.8	1.5
	1344	6.6	2.0
	2048	2.2	0.7

NOVEMBER

Day	TIME	FT	M
1 TU	0412	7.5	2.3
	1026	4.9	1.5
	1439	5.9	1.8
	2154	3.0	0.9
2 W	0528	7.4	2.3
	1152	4.6	1.4
	1657	5.5	1.7
	2317	3.6	1.1
3 TH	0630	7.5	2.3
	1259	4.0	1.2
	1849	5.9	1.8
4 F	0031	3.8	1.2
	0715	7.7	2.4
	1346	3.4	1.0
	1954	6.5	2.0
5 SA	0132	3.9	1.2
	0750	7.9	2.4
	1419	2.6	0.8
	2041	7.2	2.2
6 SU	0219	3.9	1.2
	0819	8.1	2.5
	1450	2.0	0.6
	2121	7.8	2.4
7 M	0300	3.9	1.2
	0849	8.2	2.5
	1518	1.4	0.4
	2201	8.3	2.5
8 TU	0338	4.0	1.2
	0917	8.2	2.5
	1548	0.8	0.2
	2237	8.8	2.7
9 W	0416	4.1	1.2
	0945	8.2	2.5
	1618	0.4	0.1
	2314	9.1	2.8
10 TH	0451	4.2	1.3
	1015	8.1	2.5
	1650	0.1	0.0
	2350	9.2	2.8
11 F	0528	4.4	1.3
	1046	8.1	2.5
	1722	0.0	0.0
12 SA	0027	9.2	2.8
	0604	4.5	1.4
	1118	8.1	2.5
	1759	0.0	0.0
13 SU	0105	9.0	2.8
	0644	4.6	1.4
	1153	8.0	2.4
	1840	0.3	0.1
14 M	0146	8.8	2.7
	0729	4.8	1.5
	1233	7.8	2.4
	1923	0.8	0.2
15 TU	0233	8.5	2.6
	0825	4.8	1.5
	1320	7.3	2.2
	2017	1.4	0.4
16 W	0328	8.3	2.5
	0934	4.6	1.4
	1431	6.8	2.1
	2121	2.2	0.7
17 TH	0430	8.2	2.5
	1051	4.1	1.3
	1616	6.4	2.0
	2237	2.8	0.9
18 F	0532	8.4	2.6
	1203	3.2	1.0
	1803	6.6	2.0
	2353	3.3	1.0
19 SA	0626	8.6	2.6
	1305	2.1	0.6
	1929	7.3	2.2
20 SU	0105	3.6	1.1
	0715	8.9	2.7
	1358	0.9	0.3
	2035	8.1	2.5
21 M	0210	3.8	1.2
	0758	9.0	2.8
	1445	0.0	0.0
	2130	8.8	2.7
22 TU	0306	3.9	1.2
	0843	9.1	2.8
	1528	-0.7	-0.2
	2220	9.4	2.9
23 W	0358	3.9	1.2
	0927	8.9	2.7
	1612	-1.0	-0.3
	2307	9.7	3.0
24 TH	0447	4.0	1.2
	1011	8.7	2.7
	1654	-1.0	-0.3
	2350	9.8	3.0
25 F	0535	4.0	1.2
	1054	8.4	2.6
	1735	-0.7	-0.2
26 SA	0033	9.7	2.9
	0621	4.1	1.2
	1136	8.1	2.5
	1816	-0.1	0.0
27 SU	0113	9.4	2.9
	0708	4.2	1.3
	1216	7.6	2.3
	1855	0.6	0.2
28 M	0153	9.0	2.8
	0754	4.3	1.3
	1256	7.2	2.2
	1933	1.4	0.4
29 TU	0232	8.6	2.6
	0845	4.4	1.3
	1339	6.7	2.0
	2012	2.3	0.7
30 W	0314	8.3	2.5
	0940	4.4	1.3
	1432	6.1	1.9
	2056	3.1	0.9

DECEMBER

Day	TIME	FT	M
1 TH	0401	8.0	2.4
	1040	4.2	1.3
	1555	5.7	1.7
	2148	3.9	1.2
2 F	0451	7.8	2.4
	1145	3.8	1.1
	1749	5.8	1.8
	2257	4.5	1.4
3 SA	0541	7.7	2.3
	1242	3.2	1.0
	1920	6.3	1.9
4 SU	0016	4.9	1.5
	0626	7.7	2.3
	1327	2.5	0.8
	2021	7.0	2.1
5 M	0130	5.0	1.5
	0706	7.7	2.3
	1405	1.8	0.5
	2106	7.7	2.3
6 TU	0228	5.0	1.5
	0744	7.7	2.3
	1442	1.2	0.4
	2148	8.3	2.5
7 W	0317	5.0	1.5
	0824	7.7	2.4
	1517	0.6	0.2
	2227	8.8	2.7
8 TH	0359	4.9	1.5
	0903	7.8	2.4
	1554	0.2	0.1
	2305	9.2	2.8
9 F	0440	4.8	1.5
	0944	7.9	2.4
	1632	-0.1	0.0
	2343	9.4	2.9
10 SA	0519	4.7	1.4
	1026	8.0	2.5
	1711	-0.2	-0.1
11 SU	0021	9.6	2.9
	0600	4.5	1.4
	1110	8.1	2.5
	1752	-0.2	-0.1
12 M	0058	9.6	2.9
	0642	4.4	1.3
	1155	8.1	2.5
	1834	0.1	0.0
13 TU	0136	9.6	2.9
	0729	4.1	1.3
	1244	7.9	2.4
	1919	0.7	0.2
14 W	0215	9.4	2.9
	0821	3.9	1.2
	1339	7.5	2.3
	2005	1.4	0.4
15 TH	0257	9.3	2.8
	0917	3.5	1.1
	1448	7.0	2.1
	2057	2.4	0.7
16 F	0342	9.0	2.8
	1018	2.9	0.9
	1612	6.6	2.0
	2158	3.4	1.0
17 SA	0433	8.8	2.7
	1124	2.2	0.7
	1750	6.7	2.0
	2310	4.3	1.3
18 SU	0526	8.7	2.6
	1230	1.4	0.4
	1925	7.2	2.2
19 M	0033	4.8	1.5
	0623	8.5	2.6
	1330	0.6	0.2
	2036	8.0	2.4
20 TU	0153	5.0	1.5
	0718	8.4	2.6
	1424	-0.1	0.0
	2133	8.6	2.6
21 W	0259	4.9	1.5
	0811	8.2	2.5
	1511	-0.5	-0.1
	2220	9.2	2.8
22 TH	0354	4.7	1.4
	0903	8.1	2.5
	1558	-0.6	-0.2
	2304	9.5	2.9
23 F	0443	4.4	1.4
	0955	8.0	2.4
	1640	-0.5	-0.1
	2343	9.6	2.9
24 SA	0529	4.2	1.3
	1043	7.9	2.4
	1722	-0.2	-0.1
25 SU	0020	9.7	3.0
	0611	4.0	1.2
	1128	7.8	2.4
	1800	0.3	0.1
26 M	0055	9.6	2.9
	0652	3.9	1.2
	1210	7.6	2.3
	1837	0.9	0.3
27 TU	0126	9.4	2.9
	0732	3.8	1.1
	1251	7.4	2.2
	1909	1.5	0.5
28 W	0157	9.2	2.8
	0811	3.7	1.1
	1330	7.0	2.1
	1940	2.3	0.7
29 TH	0225	8.9	2.7
	0850	3.6	1.1
	1414	6.6	2.0
	2010	3.0	0.9
30 F	0253	8.6	2.6
	0933	3.4	1.0
	1509	6.2	1.9
	2043	3.8	1.2
31 SA	0323	8.2	2.5
	1019	3.2	1.0
	1626	6.0	1.8
	2128	4.6	1.4

Furnace Oil Analysis

			% by weight	
Conradson carbon	(C)	% wt	20	Max
Hydrogen	(H2)	% wt	11.3	Max
Sulphur	(S)	% wt	3.5	Max
Oxygent + Nitrogen	(O2 + N2)	% wt	2.5	Max
Ash		% wt	0.1	Max
Sediments		% wt	0.25	Max
Kinetic visosity at 50°c		cSt	400	Max
Specific gravity at 15/4°C			0.99	Max
Water volume		% wt	1.00	Max
Flash point		°c	66	Max
Pour point		°c	35	Max
Vanadium		ppm	150	Max
Sodium		ppm	50	Max
Heating value		Kcal/kg	10,000	Min

Test Report

Test Report No.: HDIP/F/85/63 Date: May 5th, 1985

Sample: Furnace Oil Date of Sample:

Sample Recd. on: April 13th 1985

Origin: Karachi Electric Supply Corporation Ltd.
Korangi Thermal Power Station

Test method	Test tittle		Test result
ASTM D - 445	Kinematic viscosity @ 50°c	cSt	137.37
ASTM D - 92	Flash point	COC °c	166
ASTM D - 95	Water by Dean & Stark	Vol.%	0.2
ASTM D - 1298	Specific gravity	@ 60/60°F	0.9444
ASTM D - 96	B.S. & W.	Vol.%	0.4
ASTM D - 482	Total ash	wt.%	0.06
ASTM D - 1548	Vanadium	PPM	30
ASTM D - 240	Calorific value Gross	B tu/lb	18350
	Net	B tu/lb	17515
IP - 63	Sulphur content by Quartz tube method	wt.%	2.32

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Natural Gas Typical Analysis

% by volume

	Use for perf. calculations	Variation
Methane (CH_4)	93.5	90 - 96
Ethane (C_2H_6)	0.9	0.5 - 1.5
Propane (C_3H_6) }		
Butane (C_4H_{10}) }	0.4	0.2 - 1.0
Complex (C_nH_{2n+2}) }		
Carbon dioxide (CO_2)	2.0	0.0 - 5.0
Nitrogen (N_2)	3.2	3.0 - 5.0
Net calorific value kJ/m3 (STP)	34,740	33,000 - 35,000

Light Diesel Oil Analysis

Test	Limit	Value
Color ASTM	Min.	3
Specific Gravity 16/16°c	Max.	0.92
Viscosity at 38°c cSt	Max.	13
Power Point °F	Max.	+ 30
Flash Point PMCC °c	Min.	150
Water % vol	Max.	0.25
Sediment % wt.	Max.	0.25
Strong Acid No. mg KOH/g	–	Mil.
Total Acid No. mg KOH/g	Max.	3.0
Ash %	Max.	0.02
Sulphur Content % wt.	Max.	1.0
Centane Index	Min.	40
Carbon Residue % wt. (Conradson)	Max.	1.5
Net Calorific Value kJ/kg	min.	44190

Raw Water Analysis

Constituent		as	Analysis in ppm	in meq/l
CATIONS:	Calcium	CaCO3	60	1.2
	Magnesium	CaCO3	60	1.2
	Sodium	CaCO3	100	2.0
	Hydrogen	CaCO3	-	-
Total cations		CaCO3	220	4.4
ANIONS:	Bicarbonate	CaCO3	88	1.8
	Carbonate	CaCO3	-	-
	Hydroxide	CaCO3	-	-
	Sulfate	CaCO3	37	0.7
	Chloride	CaCO3	93	1.9
Total anions		CaCO3	220	4.4
Total hardness		CaCO3	220	2.4
Methyl orange alkalinity		CaCO3	88	1.8
Iron, total		Fe	0.3	
Carbon dioxide, free		CO2	4	
			normal maximum	
Total silica		SiO2	4 - 12	
			normal maximum	
Turbidity		Kaolin	4 - 25	
Total dissolved solids		approx.	400	
pH			7.5	
Conductivity at 25°c		MHOS	800	

Chemical Analysis of Sea Water

(Karachi Port)

		SAMPLE 1 ON HIGH TIDE		SAMPLE 2 ON MEDIUM TIDE		SAMPLE 3 ON LOW TIDE	
1.	PH	6.85		6.75		6.82	
2.	CHLORINE	19,915	PPM	19,536	PPM	19,433	PPM
3.	SULPHATE	2,829	"	2,815	"	2,770	"
4.	CALCIUM	357	"	361	"	353	"
5.	MAGNESIUM	1,372	"	1,372	"	1,378	"
6.	SODIUM	9,250	"	9,250	"	9,250	"
7.	POTASSIUM	285	"	285	"	285	"
8.	AMMONIA	0.55	"	0.5	"	0.61	"
9.	IRON	0.04	"	0.04	"	0.05	"
10.	ALUMINIUM	N.D.		N.D.		N.D.	
11.	MANGANESE	0.02	"	0.025	"	0.025	"
12.	CHEMICAL OXYGEN DEMAND AS KMNO 4	1.3	"	1.0	"	1.1	"
13.	HYDROCARBON (OIL)	1.2	"	1.3	"	0.3	"
14.	ORGANIC MATTER IN TDS (CARBON ORANIC DEPOSIT)	2,921	"	2,638	"	2,656	"
15.	FLOURIDES	0.9	"	0.9	"	0.9	"
16.	COBALT	N.D.		N.D.		N.D.	
17.	COPPER	N.D.		N.D.		N.D.	
18.	NICKEL	0.03	"	0.04	"	0.05	"
19.	TOTAL HARDNESS AS CACO 3	6,530	"	6,540	"	6,550	"
20.	TOTAL DISSOLVED SOLIDS (TDS)	39,794	"	39,218	"	38,840	"

N.D. NOT DETECTABLE IN PPM

SEAWATER TEMPERATURES OF KARACHI HARBOUR

(WEST WHARF AREA)

AREA -1

	SURFACE	AVERAGE	3-4 METER	AVERAGE
WINTER	19°C	-	18.5°C	-
SUMMER	31°C	-	31.5°C	-

AREA -2

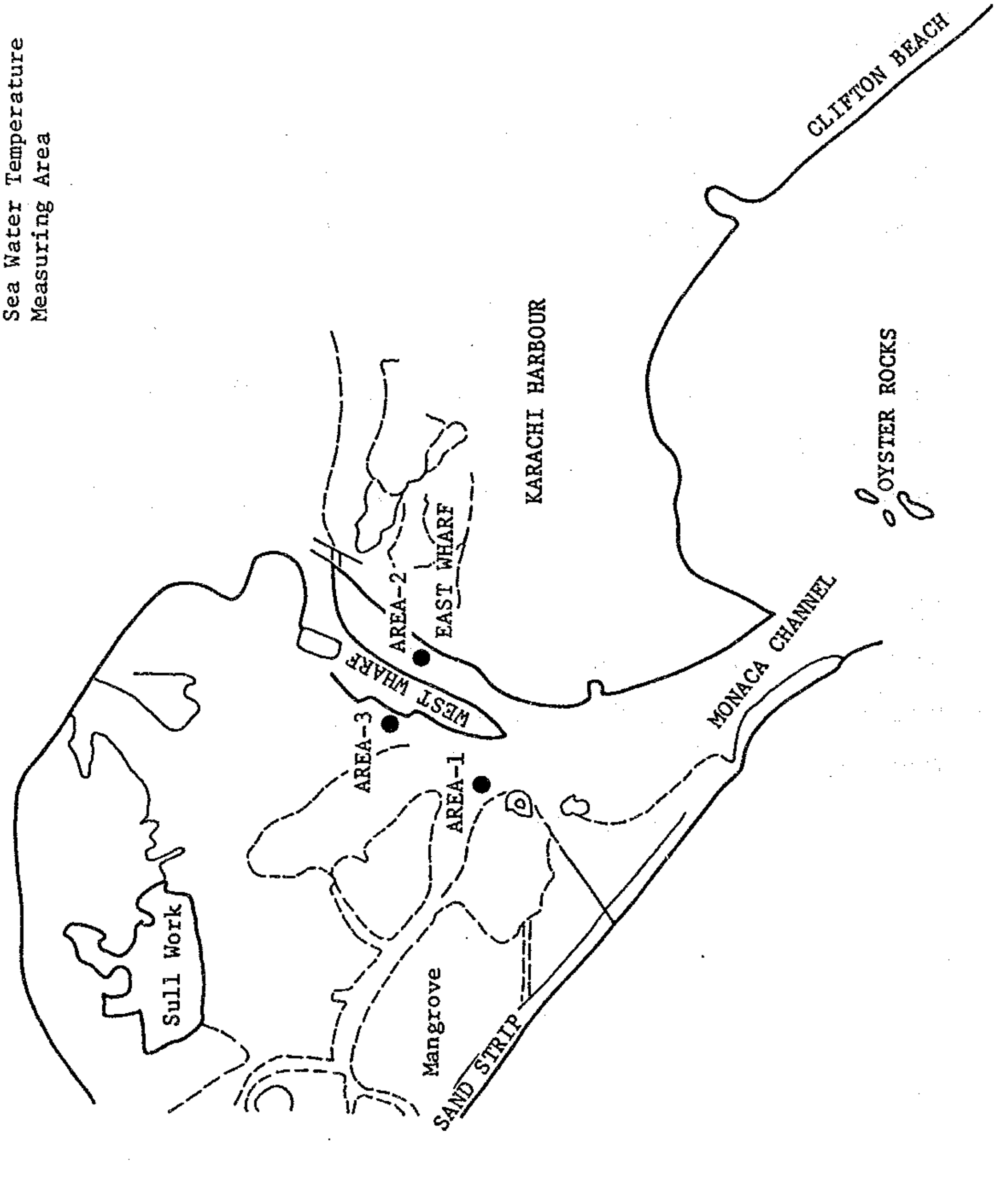
WINTER (DEC.-JAN.)	18-23°C	22.5°C	18.5 - 23.5°C	22.5°C
SUMMER	26-32°C	28°c	25.5 - 32.5°C	28.5°C

AREA -3

SUMMER	26.5-32.5°C	29°C
WINTER (DEC.-JAN.)	18.5-24.0°C	22°C

RANGE 18.5 TO 32.5°C

Sea Water Temperature Measuring Area

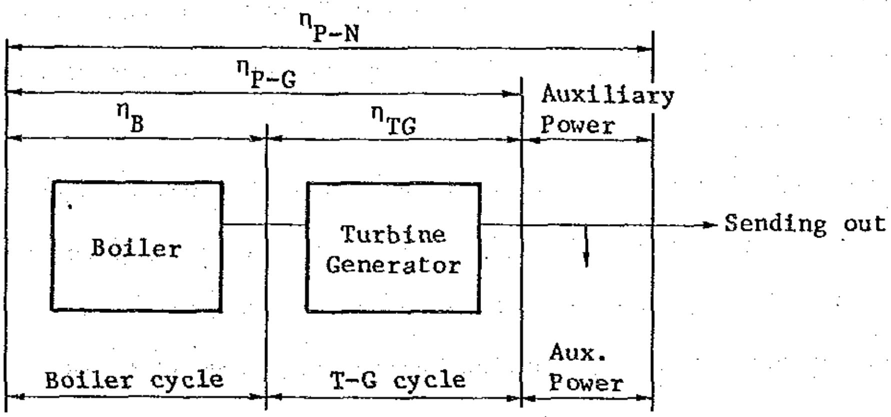


GP-1 PLANT PERFORMANCE

1. Plant Efficiency

1.1 Defination of Power Plant Efficiency

As for the power plant efficiency for the West Wharf Thermal Power Plant, Units 1, 2 the following idea is adopted.



ηB : Boiler cycle efficiency

ηTG : Turbine-Generator cycle efficiency

$\eta P\text{-}G$: Gross plant efficiency

$$\eta P\text{-}G = \eta B \times \eta TG$$

$\eta P\text{-}N$: Net Plant efficiency

$$\eta P\text{-}N = \eta P\text{-}G \times (1 - \text{Aux. power ratio}) \times (1 - C)$$

Where C means a heat loss ratio due to miscellaneous heat losses that cannot be counted within the boiler and turbine cycle boundaries.

1.2 Application of Calculation Method for Efficiency

For the boiler cycle efficiency (ηB), the loss method is applied

for the performance test as usually adopted for these units.
The input/output method will be applied for checking purposes only.
(For these method, refer to ASME Power Test Code PTC 4.1 - 1964 "Steam Generating Units")
For the daily calculation of boiler performance, which will be executed by the plant computer, the input/output method shall be applied.
However, this calculated data shall not be used for the plant performance test during the taking over procedures, but be used for reference only.
The turbine-generator cycle efficiency (η_{TG}) is converted by using the turbine-generator heat rate obtained at the performance test.
(For this method, refer to ASME Power Test Code PTC 6S-1970 "Simplied Procedures for Routine Performance Test of Steam Turbine").

1.3 Outline of Major Equipment for Power Plant

Plant efficiency is usually estimated based upon the experiences of the same type or similar type plants, together with the results of theoretical calculations.
The plant specification for the West Wharf Thermal Power Plant Units 1, 2 is as follows.

1.3.1 Steam Generator

Type	Outdoor, drum type, reheat, pressurized furnace oil fired, top suspended, natural or forced circulation
Capacity	700 t/h (tentative)

Outlet steam condition	174 kg/cm^{2}g (17.17 MPa), 541/541^{o}C (tentative)

1.3.2 Steam Turbine

Type	Reheat-condensing, tandem compound doublt flow turbine (TCDF)
Rated output	200 MW (at 60 mmHg abs. 0% make up)
Steam condition	169 kg/cm^{2}g, 538/538^{o}C (at turbine inlet)
Exhaust pressure	Normal, 60 mmHg abs. Maximum, 90 mmHg abs.
Speed	3,000 rpm
Governing system	Low-pressure type EHC
Extraction	Seven (7) stages

1.3.3 Generator

Type	Horizontal type, H_2 cooled totally enclosed synchronous machine
Rated capacity	250 MVA
Power factor	0.8
Frequency	50 Hz
Speed	3,000 rpm
Connection	Y
Excitation	Static excitation
Short circuit ratio	Not less than 0.58 at rated H_2 pressure
Insulation class	B

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1.4 Estimated Efficiency of Power Plant

1.4.1 Boiler Efficiency (at rated load)

In usual cases, the efficiency of the similar type boiler is in the range of 87.0 - 89.0% (High calorific Heating Value base) The followings are the examples of the power plant in Japan, especially the cases of TEPCO.

Name (rated output)	B (%)	Note
A-SPP (175 MW)	88.85	Oil fired (HHV base)
B-SPP (175 MW)	88.33	ditto
C-SPP (175 MW)	87.52	ditto
D-SPP (265 MW)	88.61	ditto

In this estimation the miscellaneous heat loss C is included in the boiler efficiency.

1.4.2 Turbine-Generator Efficiency (at rated load)

According to the data of the Japanese experiences, η_{TG} is in the range of 43.0 - 45.0% (2,000 - 1,911 kcal/kwh).

The followings are the examples of the power plant in Japan, especially the case of TEPCO.

Same (rated output)	TG (%)	Note
A-SPP (175 MW)	44.75	Condenser vacuum 722mmHg
B-SPP (175 MW)	44.75	ditto
C-SPP (175 MW)	45.06	ditto
D-SPP (265 MW)	45.76	ditto

The turbine-generator efficiency is estimated as 45.3% as described hereinafter for further estimation.

Generator Output (MW)	Condenser Press.(mmHg. abs)	Make-up (%)	Efficiency (%)
200	60	0	45.3 (1,900 kcal/kwh)

1.4.3 Plant Auxiliary Power (at rated load)

Plant auxiliary power ratio is estimated based on the experience by taking into account the following items which will mainly influence.

a. Plant capacity

b. Fuel (oil or gas)

c. Type of BFP (motor driven or steam turbine driven)

In case of the West Wharf of Thermal Power Plant, Plant auxiliary power is estimated to be of 5%.

The typical values of auxiliary power ratio are shown as follows in accordance with the classes of rated output.

(experience in Japanese steam power plant)

Rated output (MW)	Average Auxiliary power ratio	Note
75	6.3%	Oil fired
125	6.8%	ditto
156 - 175	7.2%	ditto
220 - 265	5.0%	ditto

1.5 Conclusion

From the above considerations, the following combination is obtained.

	Boiler cycle Efficiency (%)	T-G cycle Efficiency (%)	Gross Plant Efficiency (%)	Auxiliary Power (%)	Net Plant Efficiency (%)
Probable estimation	88.0	45.3	39.9	5	37.9

1.5.1 Plant Efficiency at Rated Load

As the results of estimation, the following were obtained.

at Generator terminal	39.9% (H.H.V. base)
at Sending end	37.9% (Ditto)

1.5.2 Average Plant Efficiency

The average plant efficiency considering the plant utilization factor during the plant operating life is usually obtained by using the following coefficient.

Plant utilization factor (%)	100	90	80	70	60	50
Coefficient	0.98	0.98	0.97	0.96	0.95	0.95

In case of the West Wharf Thermal Power Plant Units 1, 2, plant utilization factor is assumed to be 75%.

Therefore,

at Generator terminal	38.5% (H.H.V. base)
at Sending end	36.5% (H.H.V. base)

Note:

a. These coefficients are estimated based on the experience of Electric Power Companies in Japan and now are applied widely in these field in Japan for the calculation of power plant efficiency.

b. Plant utilization factor

The annual utilization factor is defined as the following formula.

Annual utilization factor *

$$= \frac{\text{Annual power output quantity (kwh)}}{\text{Unit rated output (KW) x 8,760 (hr)}}$$

In case the utilization factor is high, the unit is playing a role for basic power source.

On the other hand, if the factor is low, the unit is acting as a power source of intermediate load or as a stand-by unit.

* KESC defines this factor as "Average annual plant factor".

2. Guarantee Items

Summary of guarantee items for the power plant is indicated as follows.

	Minimum load	1/2 load 100MW	3/4 load 150MW	ECR 200MW	Capability 200MW	Maximum load
Specified Condition						
Main steam/Reheat steam condition		$169\ kg/cm^2g$, $538/538^oC$				
Condenser press. (mmHg abs.)		60			90	60
Make-up (%)		0			3	0
A. Plant						
A-1 Average net plant heat rate		Weighted average (X)	(X)	(X)		
A-2 Plant maximum load						(X)
A-3 Rated load at worse condition					(X)	
A-4 Plant minimum load	X					
B. Steam generator						
B-1 Steam generator efficiency (ECR)				X		
B-2 Steam generating capacity					X	X
B-3 Steam pressure	X	X	X	X	X	X
B-4 Steam temperature		X	X	X	X	X
C. Turbine-Generator						
C-1 Turbine-generator heat rate (ECR)				X		
C-2 Turbine-generator output 200 MW					X	
D. Transformer						
D-1 Main transformer				(X)		
D-2 Auxiliary transformer				(X)		

Notes: Marked "(X)" and "X" are the guaranteed items, and marked "(X)" are the items to be assessed as liquidated damage.

3. Concept on the Performance Guarantee against Liquidated Damage

In a case that if the performance of the power plant, the boiler or the steam turbine does not meet the guaranteed conditions proposed by the Contractor after the performance test, the items on the following liquidated damage should be applied.

The above concept should also be applied to an evaluation of Bidder's proposals.

3.1 Shortage of Output in Power Plant, Turbine or Boiler

In case of the output capacity of the power plant, when the capacity of turbine or boiler is short, it is necessary to compensate the shortage power with other power source. In this case, there are two methods concerning the calculation of liquidated damage.

a. A method to compensate the power shortage amount based upon the construction cost of the West Wharf of Thermal Power Plant Units 1 & 2.

b. A method to compensate the power shortage amount based upon the construction cost of KESC power system including the West Wharf Thermal Power Plant.

JICA is intending to the latter method in consideration for estimating apply the liquidated damage amount for power plant and the same for main transformer.

a. For power plant, approximately 261,000 ¥ /kW as investment cost of power system is assumed corresponding to annual incremental load demand.

b. The liquidated damage amount for the output shortage of the West Wharf P.P Units 1 & 2 main transformer is assumed as 261,000 ¥ /kW for load loss.

3.2 Thermal Efficiency of Overall Power Plant

Since thermal efficiency of the power plant directly influences the fuel cost, the standard weighted mean net plant heat rate will be calculated by the Engineer in consideration of the utilization factor which satisfies the practical operation of the power plant. And the difference (±) between the above heat rate and the value of Tenderer's proposal will be evaluated.

The liquidated damage for the performance shall be calculated based on the difference (+) between the guaranteed value of the weighted mean net plant heat rate proposed by the Contractor and the value obtained on the occasion of performance test.

3.2.1 Weighted mean net plant heat rate

(1) Net plant heat rate (NPHR)

a. The net plant heat rate shall be tested by the input/ output method, and shall be calculated by fuel consumption, make up water consumption, generator output and auxiliary power.

$$\text{Net Plant Heat Rate} = \frac{FQ \times q + G_{mn} \times h_{mu}}{KW_1 - KW_2} \text{ kcal/kWh}$$

where

FQ : Fuel oil consumption (ℓ)

q : Fuel oil heating value (High heat value) (kcal/ℓ)

G_{mu}: Make up water consumption (kg)

h_{mu}: Make up water enthalpy (kcal/kg)

KW_1: Generator output (kWh)

KW_2: Plant auxiliary power (kWh)

(2) Weighted mean net plant heat rate (Weighted mean NPHR)

Weight-mean net plant heat rate shall be a weighted average of the NPHR, calculated by applying the following formula:

$$\text{Weighted mean NPHR} = \frac{C_1A + C_2B + C_3C}{100}$$

Where:

C_1, C_2, C_3: Coefficients for weited value of each heat rate

A (kcal/kWh): NPHR at generator output 200 MW

B ("): " " " 150 MW

C ("): " " " 100 MW

Assuming A = 2,276.6 kcal/kW/h, C_1 = 60

B = 2,371.0 " , C_2 = 23

C = 2,536.3 " , C_3 = 17,

Then,

$$\text{Weight mean NPHR} = \frac{60 \times 2{,}276.6 + 23 \times 2{,}371.0 + 17 \times 2{,}536.3}{100}$$

$$= 2{,}342.5 \text{ kcal/kWh}$$

3.2.2 Calculation of fuel cost (A subject of evaluation and liquidated damage)

When the actual weighted mean NPHR of power plant exceeds the value of guaranteed by manufacturer, fuel cost will increase for the lifetime.

There are two methods to compensate the increase of fuel oil cost with the liquidated damage as follows;

a. A method to convert the fuel oil cost increase during the power plant lifetime into the initial investment cost.

b. A method to convert the integrated amount of fuel cost increase into the present worth in consideration of fuel price escalation during the lifetime.

Consequently, JICA applied the former method based upon the following reasons.

- o It is difficult to expect and decide the escalation rate of fuel oil price during the lifetime.
- o It is reasonable to compensate the escalation of fuel price with the electric tariff.

Fuel cost (furnace oil):

2,034.05 Rs/M. ton at HHV 10,200 Kcal/kg, or

1.25 Yen/10^3 Kcal = 0.00125 Yen/Kcal

(At conversion rate of 1 Rs = 6.25 ¥

When the weighted mean net plant heat rate proposed by the Contractor exceeds by 1 Kcal/kWh on the occasion of performance test, the exceeding portion becomes a subject of liquidated damage calculated by the following formula:

Increase in fuel cost due to increase in net plant heat rate (In case of 1 Kcal/kWh)

$200{,}000 \text{ kW} \times 8{,}760 \text{ Hr.} \times 0.75 = 1{,}314.0 \times 10^6 \text{ kWh/year}$

.... Annual power generation

$1{,}314.0 \times 10^6 \times 0.00125 \text{ Yen/Kcal} \times 1 \text{ Kcal/kWh}$

$= 1{,}642 \times 10^3 \text{ Yen/year}$

.... Portion for increase in fuel cost

Furthermore, the equivalent initial investment for the increase of fuel cost is calculated by taking the permanent loss for the power plant into account.

The annual interest rate is assumed as follows.

The total construction cost of power plant (for one unit) is assumed as $20{,}159 \times 10^6$ Yen; $17{,}072 \times 10^6$ Yen for foreign currency portion and 494×10^6 Rs ($3{,}087 \times 10^6$ equivalent Yen) for local currency portion, respectively.

The annual interest rates are;

Foreign currency portion	11%
Local currency portion	11%

Therefore, the average rate of annual interest i for the power plant is:

$$i = \frac{17{,}072 \times 10^6 \text{ Yen} \times 0.11 + 3{,}087 \times 10^6 \text{ Yen} \times 0.11}{20{,}159 \times 10^6 \text{ Yen}}$$

$$= 0.11$$

The capital recovery factor R can be obtained as follows by using the total rate of annual expenditure and the lifetime figure of power plant. ($i = 0.11$, plant life $n = 20$, and salvage value of property $\gamma = 10\%$)

$$R = i(1+i)^n/((1+i)^n-1) \times (1-\gamma) + i\gamma = 0.124$$

Annual amount of incremental fuel cost due to the increase of weighted mean NPHR is ¥1,642 x 10^3 as mentioned above.

Therefore, the liquidated damage for the increase of weighted mean NPHR is:

¥1,642 x 10^3/0.124 = 13,242 x 10^3 Yen/Kcal/kWh

This obtained value is recommendable to be a subject amount for the evaluation of the difference (+) between the proposed weight mean NPHR and actually obtained weighted mean NPHR, and to be a subject amount of liquidated damage.

3.3 Main Transformer and Auxiliary Transformer of the Power Plant

As the losses of output (kW) in the main transformer and auxiliary transformer directly or indirectly influence the sent-out loss (kW) of the steam power plant itself, the output loss for these transformers shall be compensated with the liquidated damage.

JICA assumed the efficiency of these transformers as the guide line base upon the similar capacity and type with The West Wharf Units 1 & 2 applied in Japan, and the value is as follows.

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Item	Efficiency at full load (%)
Main transformer	99.28 or above
Auxiliary transformer	99.06 or above

The amount of liquidated damage is based on the assumption previously cited in Clause 3.1.

for transformer losses eq. US$1,800/kW

3.4 Application of Liquidated Damage

a. If it is determined that the power plant is unable to meet the stipulated guarantee values even after the Contractor has taken remedial measures, the Contractor will be assessed for liquidated damage for items A-1, A-2 and A-3 by applying the specified rate indicated in the next table.

b. If the main transformer and/or auxiliary transformer is found unable to meet the guarantee value even after the Contractor has taken remedial measures, the Contractor will be assessed for liquidated damage by the specified rate indicated in the next table.

Notes.

The liquidated damage values indicated in Table 1 are calculated based on certain assumptions. Therefore, it is better to apply higher liquidated damage values for tendering purposes.

The proposed liquidated damage values to be applied are is as follows.

	Liquidated Damage
Average Net Plant Heat -----------	1% of Contract Price for each 0.1% increase in Heat Rate
Plant maximum load ---------------	1% of Contract Price for 0.1% decrease in Plant maximum load
Plant capability -----------------	1% of Contract Price for 0.1% decrease in rated load

Table 1 Items of Liquidated Damage and Guarantee

	Allowable tolerance to guarantee value	Application for liquidated damage (Calculated)
A. Plant		
A-1 Average net plant heat rate	No positive tolerance	13,242 x 10^3 Yen/Kcal/kWh
A-2 Plant maximum load	No minus tolerance allowable	1,800 US$/kW
A-3 Plant capability	ditto	1,800 US$/kW
A-4 Plant minimum load	No positive tolerance allowable	-
3. Steam Generator		
B-1 Steam generator efficiency (ECR)	No minus tolerance	
B-2 Steam generating capacity (MCR)	ditto	
B-3 Steam pressure	$\pm$ 2 kg/cm^{2}g	-
B-4 Steam temperature	$\pm$ 5^{o}C	-
C. Turbine-Generator		
C-1 Turbine-generator heat rate (ECR)	No minus tolerance allowable	-
C-2 Turbine-generator output: 200 MW	No minus tolerance allowable	-
D. Transformer loss		
D-1 P.S. main transformer	No positive tolerance allowable	for no load losses 1,800 US$/kW
D-2 Aux. transformer	ditto	for load losses 1,800 US$/kW

Remarks: Errors of instruments, including reading errors, shall be included in the allowable tolerance to the guarantee value.

GP-2 HEAT BALANCE FOR TURBINE

1. Heat Balance

The following turbine cycle heat balance calculation sheets shall be submitted by the Contractor.

	Case	Generator output (kW)	Heat rate (kcal/kWh)	Steam condition	Turbine exhaust press. (mmHg.abs.)	Make-up water (%)
A	PML	210,000		169 kg/cm^2g 538/538°C	60	0
B	Capability	200,000		ditto	90	3
C	ECR	200,000	1899.4	ditto	60	0
D	75% ECR	150,000		ditto	60	0
E	50% ECR	100,000		ditto	60	0
F	Min. Load			*	60	0

Notes:

PML: Plant Maximum Load

ECR: Economical Continuous Rating

Asterisk (*) marked items shall be proposed by the Contractor.

1.1 Heat Rate

The JICA Study Team has performed heat balance calculation for Economical Continuous Rating.

The results of the Heat Balance Calculation are as shown in attached Drawing No. WMT1101.

1.2 Plant Maximum Load

The Plant Maximum Load shall be decided by the Contractor. The expected output shall be approx. 210,000 kW or over.

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In other words the expected overload output shall be approx. 5% of the rated load.

1.3 Design Condition

To cover the above operating conditions, the capacities and sizing of equipment and pipings, such as the boiler feed pumps, condensate pumps, various heat exchangers and related pipings, shall be decided based upon the heat balance sheets.

2. Investigation

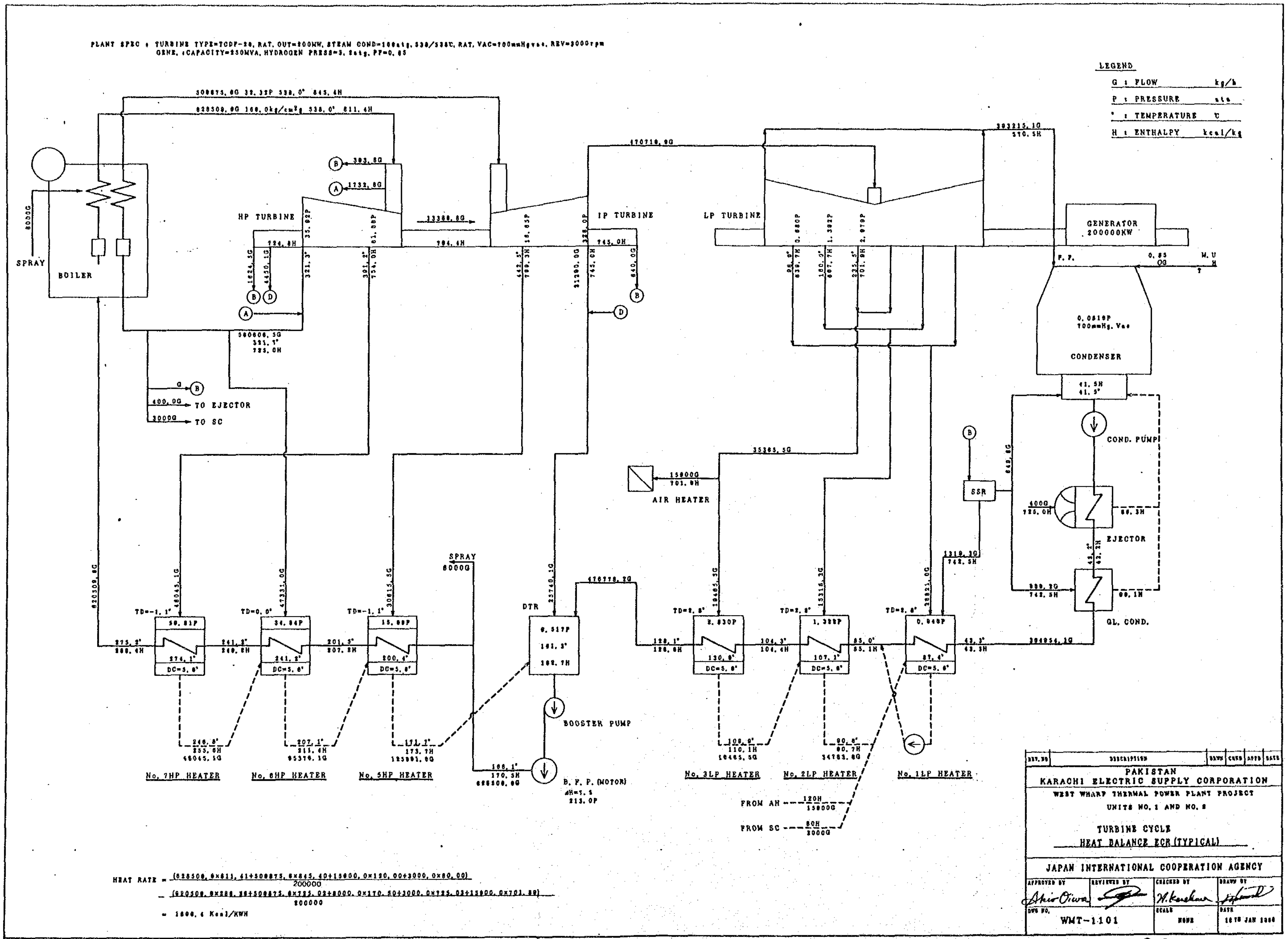
2.1 Data available from Japanese manufacturers shows the heat rate for such type of turbine cycle for ECR is in the range of 1,950 to 1,900 kcal/kWh.

2.2 Plant Maximum Load

In view of the spinning reserve for the power system, it is considered that an overload output of about 5% (10,000 kW) is sufficient.

Note:

Heat balance at Economical Continuous Rating (ECR, Drawing No. WMT1101) is attached for reference. The heat rate obtained from this calculation shows a slightly better performance than the average values described in this report.


PLANT SPEC : TURBINE TYPE=TCDF-26, RAT. OUT=200MW, STEAM COND=166atg, 538/538℃, RAT. VAC=700mmHgvac, REV=3000rpm
GENE. :CAPACITY=230MVA, HYDROGEN PRESS=3. 2atg, PF=0. 85
LEGEND
G : FLOW kg/h
P : PRESSURE ata
° : TEMPERATURE ℃
H : ENTHALPY kcal/kg
SPRAY
BOILER
HP TURBINE
IP TURBINE
LP TURBINE
GENERATOR
200000KW
CONDENSER
COND. PUMP
EJECTOR
GL. COND.
SSR
AIR HEATER
TO EJECTOR
TO SC
DTR
BOOSTER PUMP
B. F. P. (MOTOR)
No. 7HP HEATER
No. 6HP HEATER
No. 5HP HEATER
No. 3LP HEATER
No. 2LP HEATER
No. 1LP HEATER
FROM AH
FROM SC
HEAT RATE
= 1866. 4 Kcal/KWH
PAKISTAN
KARACHI ELECTRIC SUPPLY CORPORATION
WEST WHARF THERMAL POWER PLANT PROJECT
UNITS NO. 1 AND NO. 2
TURBINE CYCLE
HEAT BALANCE ECR (TYPICAL)
JAPAN INTERNATIONAL COOPERATION AGENCY
APPROVED BY
REVIEWED BY
CHECKED BY
DRAWN BY
DWG NO.
WMT-1101
SCALE
NONE
DATE

GP-3 OPTIMUM STEAM CONDITION

The steam conditions of the steam power plant are very important factor for the thermal efficiency, and it should carefully examine to determine the conditions.

1. Technical Evaluation

1.1 The following three conditions are based on the IEC recommendation for the 200 MW-class steam power plants.

Main steam press. (kg/cm^2.g)	(MPa g)	SH temp. (°C)	RH temp. (°C)
127	(12.5)	538	538
169	(16.6)	538	538
169	(16.6)	566	538

1.2 The following steam conditions are adopted at the typical steam power plants in PAKISTAN.

	Main steam press. (kg/cm^2.g)	SH temp. (°C)	RH temp. (°C)
Guddu 210 MW #4	130	535	535
Jamshoro 250 MW #1	169	538	538
Bin Qasim 210 MW #1,2,3,4,5	142.8 (14.0 MP)	525	525

1.3 The following steam conditions are usually adopted at Japanese steam power plants;

125 (MW)	...... 127 (kg/cm^2.g)	538/538 (°C)
175	 169	566/538
220	 169	538/538 or 566/538

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265	 169	566/566
350	 169	566/566

1.4 The turbine heat rate for each steam conditions is assumed based on the experienced data in Japan as follows;

Steam conditions (kg/cm2.g)	(^{o}C)	Heat rate (kcal/kwh)
127	538/538 (case 1)	1,984 (Basis)
169	538/538 (case 2)	1,915 (Approx. -69)
169	566/538 (case 3)	1,900 (Approx. -84)

1.5 The annual amount of fuel oil consumption and of fuel oil cost are calculated as follows for above cases. (Refer to equation (A) and (B) indicated in the Note.)

Case	Fuel oil consumption (kg/year)	(Reduction amount)	Fuel oil cost (¥)	(Reduction amount)
Case 1	290.4×10^6	(Basis)	$3,685 \times 10^6$	(Basis)
Case 2	280.3×10^6	(-10.1×10^6)	$3,556 \times 10^6$	(-128×10^6)
Case 3	278.1×10^6	(-12.3×10^6)	$3,528 \times 10^6$)	(-156×10^6)

1.6 Note

1.6.1 Fuel Oil Consumption; R (kg/year)

$$R = \frac{P \times T \times \frac{U}{100} \times Ht}{\frac{\eta_B}{100} \times Ho} = \frac{P \times T \times U \times Ht}{\eta_B \times Ho} \quad .... \text{(A)}$$

Where;

P : Plant rated output; 200×10^3 (KW)

T : Generating hours per one year; $365^{days} \times 24^{Hr} = 8,760$ (H/year)

Ht: Turbine heat rate (kcal/kwh)

η_B: Boiler efficiency; 88%

H_0: Higher heating value of the residual oil

10,098 (kcal/l) 10,200 (kcal/kg)

(at specific gravity 0.99)

U : Annual utilization factor; 75%

1.6.2 Fuel Oil Cost; C (¥/year)

C = R x u x r ..... (B)

Where;

u : Unit cost of fuel oil = 2,034.05 Rs/M ton = 2.03 Rs/kg

r : Rs conversion rate to Yen = 6.25 (¥/Rs)

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2. Economical Evaluation

The economical evaluation is based on 127 kg/cm^2, 538/538°C unit comparing the operation cost difference and initial investment increase due to grading up of steam conditions to 169 kg/cm^2, 538/538°C and 169 kg/cm^2, 566/538°C.

2.1 Construction Cost (Boiler and turbine equipment)

The construction costs for steam power plant of 127 kg/cm^2, 538/538°C unit (Case 1), 169 kg/cm^2 538/538°C unit (Case 2), and 169 kg/cm^2, 566/538°C unit (Case 3) are shown as follows;

Items Steam conditions	Construction cost (¥)	Remarks	Kilowatt cost (Yen/KW)
127 kg/cm^2 538/538°C (Case 1)	$11,090 \times 10^6$	Basis	55,450
169 kg/cm^2 538/538°C (Case 2)	$11,422 \times 10^6$	+ 3%	57,110
169 kg/cm^2 566/538°C (Case 3)	$11,755 \times 10^6$	+ 6%	58,770

2.2 Power Generation Cost

Power generation cost consists of the fixed cost and the variable cost. In this case, the fixed cost can be thought to be the capital cost. The maintenance cost (which includes salary, wages, and expenditure, etc.) is usually assumed to be the fixed cost by using the average rate for the construction cost in order to simplify the economical evaluation.

2.2.1 Fixed Cost

Prior to estimating the fixed cost, the parameters are usually assumed as follows.

a. Annual interest rate *i:*11% * average of foreign currency portion and local currency portion

b. Operation period n: 20 years

c. Salvage value of property β : 10%

In this case, the capital recovery factor is; $= \frac{i(1+i)^n}{(1+i)^n-1} \cdot (1-\beta) + i\beta$

Applying i = 0.11, n = 20, will be 0.124 based on fixed installment method for depreciation during the operation period of 20 years.

c. Average maintenance cost rate 3%

Therefore, the annual capital cost factor is 0.124 + 0.03 = 0.154.

The annual capital cost is obtained by the following equations and is shown as follows.

(annual capital cost) = (construction cost) x 0.154

Items Case	Construction cost (Yen)	Annual capital cost (Yen)	Remarks
Case 1	11,090 x 10^6	1,707.9 x 10^6	Basis
Case 2	11,422 x 10^6	1,759.0 x 10^6	+ 3%
Case 3	11,755 x 10^6	1,810.3 x 10^6	+ 6%

2.2.2 Fuel Cost (Variable Cost)

The fuel cost for the annual power generation in cases 1, 2 and 3 is as follows.

Items / Case	Fuel* cost (Yen/year)	Remarks
Case 1	$3,684 \times 10^6$	Basis
Case 2	$3,556 \times 10^6$	- 3.5%
Case 3	$3,528 \times 10^6$	- 4.2%

Fuel price

2.03 Rs/kg x 6.25 Yen/Rs

= 12.69 Yen/kg

* Based on the annual fuel consumption (Refer to the item 1.5)

2.2.3 Annual Power Generation Cost

Annual power generation cost can be shown as follows based on the above calculations.

Items / Case	Annual fixed cost (Yen)	Annual variable cost (Yen)	Annual power generation cost (Yen)	Remarks
Case 1	$1,707.9 \times 10^6$	$3,684 \times 10^6$	$5,391.9 \times 10^6$	Basis
Case 2	$1,759.0 \times 10^6$	$3,556 \times 10^6$	$5,315 \times 10^6$	-1.4%
Case 3	$1,810.0 \times 10^6$	$3,528 \times 10^6$	$5,338 \times 10^6$	-1.0%

3. Conclusion

The JICA STUDY TEAM recommends to adopt the steam conditions of 169 kg/cm^2, $538/538^oC$ for the West Wharf Thermal Power Plant Units 1, 2 by taking into consideration of economical evaluation stated in item 2.2.3 as well as operation and maintenance evaluation.

GP-4 OPTIMUM CONDENSER VACUUM

The optimum condenser vacuum, i.e., the optimum turbine back pressure, is decided by deriving the minimum annual cost, calculating corresponding annual costs against various condenser vacuums.

The annual costs are calculated as the summation of annual fuel cost, plant operation/maintenance cost and capital cost.

1. Fuel Cost

   Turbine heat rate will vary corresponding to its back pressure, i.e. condenser vacuum.

   The better heat rate can be expected with lower back pressure and the worse with higher back pressure.

   Therefore, by changing the design back pressure, i.e. the condenser design vacuum, annual fuel consumption will vary and the annual fuel cost will change accordingly.

   Change of heat rates and annual fuel costs corresponding to various condenser vacuums are listed below.

Annual Fuel Cost

Vacuum mmHg	% change in Heat Rate	Annual fuel oil cost	(Difference) x 10^6 YEN
680	1.18	37.78	
685	0.8	25.61	
690	0.4	12.81	
695	0.0 (Base)	0.0 (Base)	
700	-0.37	-11.85	
705	-0.75	-24.01	
710	-1.088	-34.83	

Remarks: Fuel oil rate 2,085 Rs per meteric ton

2. Operation and Maintenance Costs

(1) Circulating pump power consumption

In this survey the circulating water quantity for condenser cooling is assumed to be constant, because the allowable cooling water temperature rise will be specified as not more than 7°C in environmental viewpoint.

Therefore, the power consumption for the circulating water pumps is assumed as a constant, accordingly.

(2) Maintenance cost

The maintenance cost, which includes salary, wages, and expenditure, etc., is usually assumed to be the fixed cost by using the average rate for the construction cost in order to simplify the economical evaluation.

Therefore, in this survey, the maintenance cost is assumed as a fixed cost with 3% of construction cost.

3. Capital Cost

In order to realize lower turbine back pressure with the same quantity of the condenser circulating water and the same inlet temperature, the larger condenser having larger heat transfer area should be installed.

That means to have a better condenser vacuum with the same cooling water conditions, it is necessary to install a larger condenser with higher investment cost, resulting higher annual capital cost.

Prior to estimating the fixed capital cost, the parameters are usually assumed as follows.

a. Annual interest rate (i) — 11% average of foreign currency portion and local currency portion

b. Operation period (n) — 20 years

c. Salvage value of proterty β : 10%

d. Capital recovery factor α :

In this case, the capital recovery factor will be as calculated below, based on the fixed installment method for depreciation during the operation period of 20 years.

$$\alpha = \frac{i(1+i)^n}{(1+i)^n - 1} \times (1 - \beta) + i\beta = 0.124$$

e. Annual capital cost

Therefore, the annual capital cost factor adding maintenance cost is calculated as, 0.124 + 0.03 = 0.154.

Multiplying this factor to the initial investment cost, then, the corresponding capital costs for various condensers are tabulated as follows.

Equivalent Capital Cost ($x10^6$ YEN/year)

Vacuum mmHg	Condenser surface area %	Condenser Cost $X10^6$ YEN	Annual Capital cost $X10^6$ YEN/year	Difference (695 mmHg base)
680	68.90	-93.3	-14.36	
685	75.95	-72.16	-11.11	
690	86.25	-41.25	- 6.35	
695	100.0	Base	Base	
700	122.8	68.4	10.54	
705	160.7	182.1	28.04	
710	261.0	483.0	74.38	

4. Total Annual Expenditures

Summing up the fuel costs and the capital costs, total annual expenditures (differences from 695 mmHg base) corresponding to each assumed condenser vacuums are listed below.

Total Annual Expenditures ($X10^6$ YEN/year) Difference (695 mmHg base)

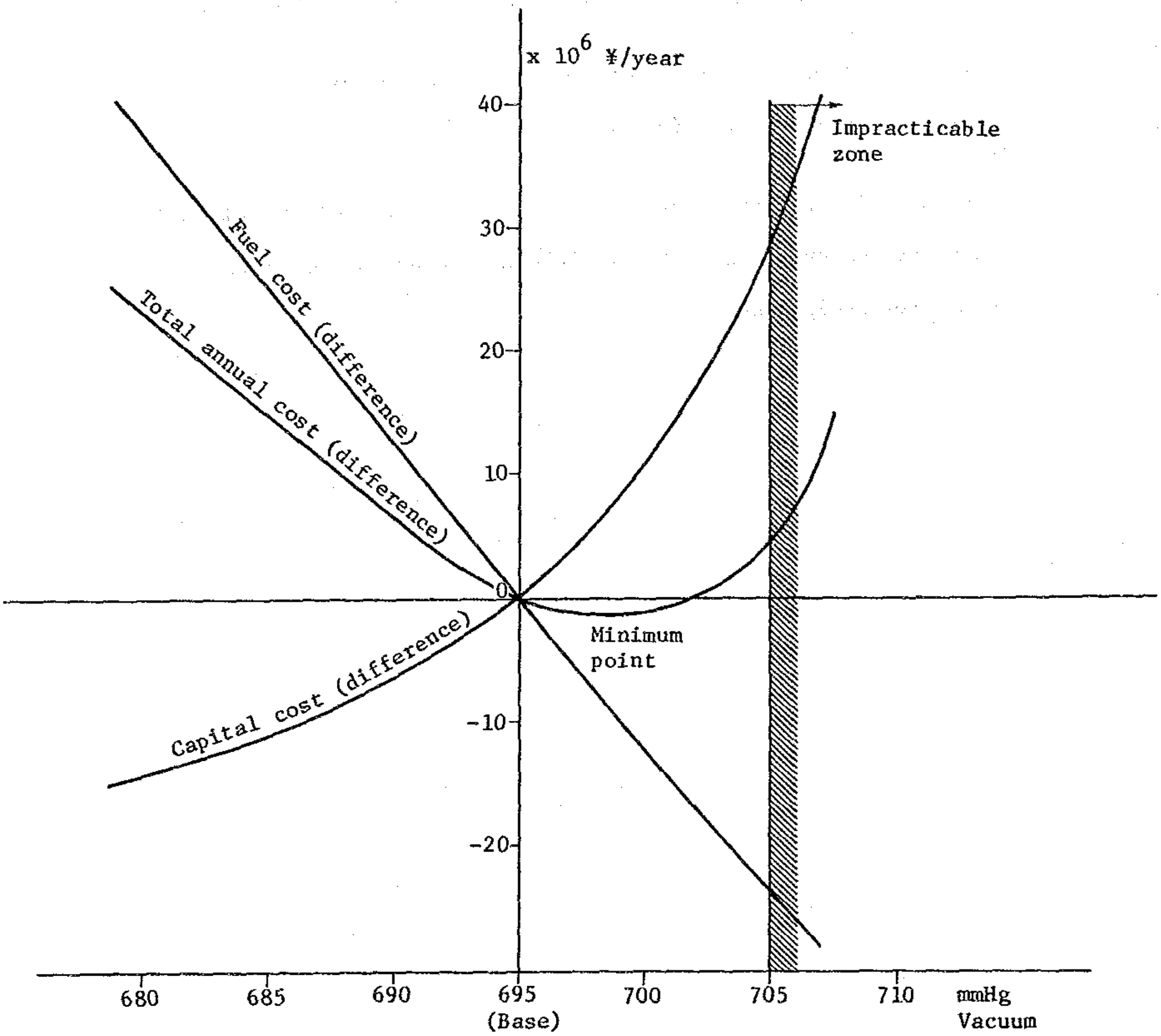
Vacuum mmHg	Fuel cost	Capital cost	Total
680	37.78	-14.36	23.42
685	25.61	-11.11	14.50
690	12.81	- 6.35	6.42
695	Base	Base	Base
700	-11.85	10.54	-1.31
705	-24.01	28.04	4.03
710	-34.83	74.38	39.55

Fig. 1 shows the variation of fuel cost, capital cost and total annual expenditures against a change of selected condenser vacuums. From this figure and the previous table, the most economical condenser vacuum will be in a range between 695 and 700 mmHg.

The above calculation is made with a assumption that the normal condenser cooling water (sea water) is 30°C.

Therefor, in the West Wharf Thermal Power Plant Project, 700 mmHg condenser vacuum is selected at 30°C sea water as the optimum condenser design vacuum.

Fig. 1 Condenser Design Point, Economic Comparison



Based on;
Cooling water inlet temperature 30°C
Cooling water temperature rise 7°C

GP-5 NUMBER OF FEEDWATER HEATERS

For the 200 MW class steam power plant, such as those proposed for the West Wharf Thermal Power Plant Units 1 and 2, three types of feedwater heater system (number of feedwater heaters including deaerator) are selected. These are: eight (8) heater system (top heater above reheat point), seven (7) heater system (top heater above reheat point) and seven (7) heater system (top heater at reheat point). The first one (Case 1) is the prevalent system used in the 200 MW class steam power plant of the Japanese Electric Power Companies. However, the latter systems (Case 2 and Case 3) were adopted for only a few plants of approx. 200 MW units. JICA has carried out a comparative study of the eight (8) heater system and the seven (7) heater system.

1. Technical Evaluation

   The increase of extraction steam from the turbine casing is in proportion to the grading up of steam conditions. As the number of extraction steam points increases, the turbine plant efficiency is theoretically improved, due to use of effective extraction steam. Therefore, an increase in the number of feedwater heaters contributes to improved turbine efficiency.

1.1 The turbine heat rates for the eight (8) heater system and the seven (7) heater systems are assumed as follows; (In these cases, the steam conditions are the same as 169 $kg/cm^2.g$, $538/538^oC$ in each case.

Case	Heat rate (kcal/kWh)	Remarks
Case 1 (8 heater system)	1,909	Basis
Case 2 (7 heater system)	1,912	+ 0.16%
Case 3 (7 heater system)	1,926	+ 0.89%

1.2 The annual fuel oil costs for three (3) cases are obtained as follows.

Case	Heat rate (kcal/kWh)	Annual fuel oil cost (Yen/Year)	Remarks
Case 1	1,909	$3,545.6 \times 10^6$	Basis
Case 2	1,912	$3,551.2 \times 10^6$	+ 0.16%
Case 3	1,926	$3,577.2 \times 10^6$	+ 0.89%

1.2.1 Note;

The annual fuel oil costs are obtained by using the following equations.

(1) Fuel oil consumption; R (kg/year)

$$R = \frac{P \times T \times \frac{U}{100} \times Ht}{\frac{\eta_B}{100} \times Ho} = \frac{P \times T \times U \times Ht}{\eta_B \times Ho} \quad \ldots\ldots (A)$$

Where;

P : Plant rated output; 200×10^3 (kW)

T : Generating hours per one year;

$365^{days} \times 24^{Hr} = 8,760$ (H/year)

Ht : Turbine heat rate (kcal/kWh)

η_B: Boiler efficiency; 88%

Ho : Higher heating value of heavy oil

10,200 (kcal/kg)

U : Annual utilization factor; 75%

(2) Fuel oil cost; C (¥/year)

C = R x u x r ..... (B)

Where;

u : Unit cost of fuel oil = 2,034.05 (Rs/ton) = 2.03 Rs/kg

r : Rs conversion rate 1 Rs = 6.25 ¥

(3) Calculations

for Case 1

$$C = \frac{200 \times 10^3 \times 8,760 \times 0.75 \times 1,909}{0.88 \times 10,200} \times 2.03 \times 6.25$$

$$= 3,545.6 \times 10^6 \text{ (¥/year)}$$

for Case 2

$$C = \frac{200 \times 10^3 \times 8,760 \times 0.75 \times 1,912}{0.88 \times 10,200} \times 2.03 \times 6.25$$

$$= 3,551.2 \times 10^6 \text{ (¥/year)}$$

for Case 3

$$C = \frac{200 \times 10^3 \times 8,760 \times 0.75 \times 1,926}{0.88 \times 10,200} \times 2.03 \times 6.25$$

$$= 3,577.2 \times 10^6 \text{ (¥/year)}$$

2. Economical Evaluation

The economical evaluation is based on the 8 heater system comparing the operation cost difference and the initial investment difference due to the adoption of the 7 heater system.

2.1 Construction Cost (Plant equipment)

The construction cost for steam power plant of 169 kg/cm^2, 538/538^{o}C using 8-heater system (Case 1) and the 7-heater system (Case 2 and Case 3) are shown as follows.

(The difference of construction cost is due to the reduction of 1 (one) heater system equipments including heater body, extraction system pipes, feedwater pipes and their related valves, fittings and laggings, etc.). For Case 2, one low pressure heater is reduced, while in Case 3 one high pressure heater is eliminated).

Items / Case	Construction cost (Yen)	Remarks
Case 1	15,400 x 10^6	Basis
Case 2	15,359 x 10^6	-0.27%
Case 3	15,277 x 10^6	-0.80%

2.2 Power Generation Cost

Power generation cost consists of the fixed cost and the variable cost. The fixed cost can be thought of as the capital cost. The maintenance cost (which includes salary, wages, and expenditures, etc.) is usually assumed to be the fixed cost by using the average rate for the construction cost in order to simplify economical evaluation.

2.2.1 Fixed Cost

Prior to estimating the fixed cost, the parameters are usually assumed as follows.

a. Annual interest i: *11% * average of Yen portion and Rupee portion

b. Operation period n: 20 years

c. Salvage value of property : 10%

In this case, the capital recovery factor, that is

$$\frac{i\,(1+i)^n}{(1+i)^n-1} \times (1-\beta) + i \times \beta$$

(i = 0.11, n = 25, =0.1), will be 0.124 based on fixed installment method for depreciation during the operation period of 20 years.

d. Average maintenance cost rate 3%

Therefore, the annual capital cost factor is 0.124 + 0.03 = 0.154. The annual capital cost is obtained by the following equations and is shown as follows.

(annual capital cost) = (construction cost) x 0.154

Items / Case	Construction cost (Yen)	Annual capital cost (Yen)	Remarks
Case 1	$15,400 \times 10^6$	$2,371.6 \times 10^6$	Basis
Case 2	$15,359 \times 10^6$	$2,365.3 \times 10^6$	-0.27%
Case 3	$15,277 \times 10^6$	$2,352.7 \times 10^6$	-0.80%

2.2.2 Fuel Cost (Variable Cost)

The fuel cost for the annual power generation in Cases 1, 2 and 3 is as follows. (Refer to item 1.2)

Items / Cost	Fuel cost (Yen/Year)
Case 1	$3,545.6 \times 10^6$
Case 2	$3,551.2 \times 10^6$
Case 3	$3,577.2 \times 10^6$

2.2.3 Annual Power Generation Cost

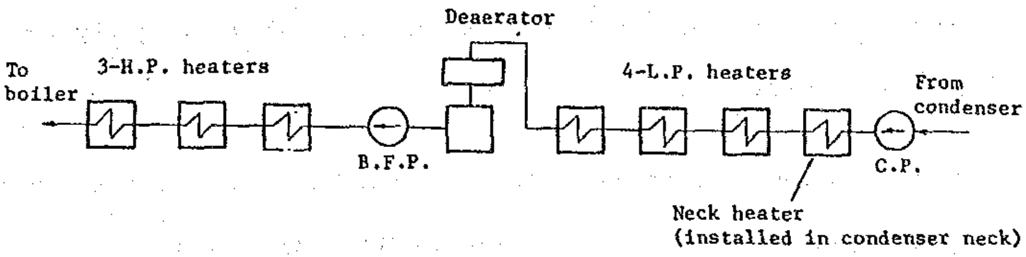
Annual power generation cost is as follows based on the above calculations.

Items / Case	Annual fixed cost (Yen)	Annual variable cost (Yen)	Annual power generation cost (Yen)	Remarks
Case 1	$2,371.6 \times 10^6$	$3,545.6 \times 10^6$	$5,917.2 \times 10^6$	Basis
Case 2	$2,365.3 \times 10^6$	$3,551.2 \times 10^6$	$5,916.5 \times 10^6$	+0.0%
Case 3	$2,352.7 \times 10^6$	$3,577.2 \times 10^6$	$5,929.9 \times 10^6$	+0.2%

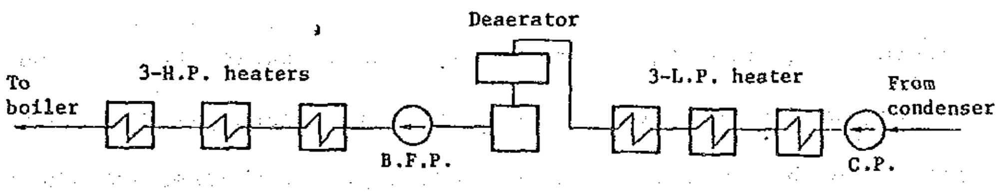
3. Heater Arrangement

The heater arrangement for each case is as shown below.

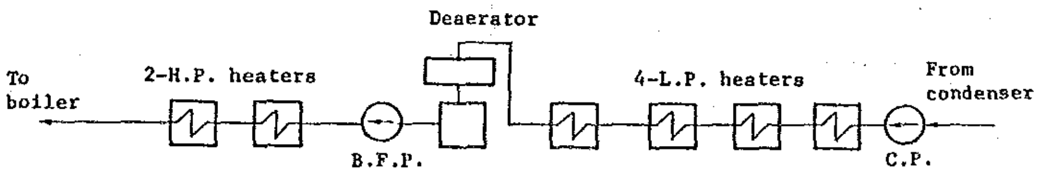
Case 1 8 heater system



Case 2 7 heater system



Case 3 7 heater system



Note that: Case 1 as a newly devised heater arrangement and in Case 2 eliminates the neck heater (the lowest heater installed in the condenser neck); and Case 3 eliminates one high pressure heater.

4. Conclusion

As shown in the evaluations, Case 1 and Case 2 produce similar results and are more economical than Case 3.

However, the efficiency of Case 2 is, theoretically, slightly lower than that of Case 1.

Nevertheless the difference in the theoretical heat rate between the 8 heater system and the 7 heater system (Case 2) is not an appreciable figure, while in economic evaluation, the 8 heater system does not prove justifiable.

Therefore, for the West Wharf Thermal Power Station Units 1 and 2, JICA recommends adoption of the seven (7) heater system as shown in Case 2, which has three high pressure heaters, a deaerator and three low pressure heaters.

M-1 BOILER

1. Selection of Boiler Type

The boiler applied to steam power plant, will be of the drum type (natural circulation or forced circulation boiler) and of once through construction. Both types of boiler are manufactured for a wide range of steam generation capacities.

For a large capacity unit of 400 MW or above, once-through type supercritical pressure boilers are adopted to meet higher steam conditions required for higher thermal efficiency. However, the once-through type boiler requires careful operation and strict water quality control. To maintain high efficiency and to prevent formation of scale and acceleration of corrosion.

In Table-1, comparison between the drum type and once-through type boiler for 200 MW class units is made, showing their merits and demerits.

On the other hand, drum type natural circulation or forced circulation boilers are adopted mostly for 200 MW class units in Japan and in Pakistan. Typical drum type boilers for 200 MW and above units in Pakistan are listed in Table-2.

As such, the drum type boiler will be easier to operate and maintain by KESC engineers. KESC and JICA agreed to adopt a drum type boiler for the West Wharf Thermal Power Plant Units 1 & 2.

Table - 1 Comparison of drum type and Once through type boilers

For 200 MW class

	Drum type boiler	Once through boiler	Remark
1. Generating Capacity	Applicable	Applicable	
2. Steam Conditions 169 Kg/cm^2, 538°C/538°C	Applicable	Applicable	
3. Erection	Applicable	Applicable	
4. Starting Time (Cold Start)	about 8 Hr	about 4 Hr	From initial firing to full load
5. Operation	Easy	More Difficult	
6. Control System	Simple	More Complicated	
7. Water Quality Control	Easy	More Difficult	
8. Maintenance	Easy	More Difficult	

Table - 2 Type of Boiler in Pakistan

Gudd T.P.P. Unit 4 (210 MW)	Jamshoro T.P.P. Unit 1 (250 MW)	Bin Qashim T.P.P. Unit 1,2,3,4,5 (200 MW)	West Wharf T.P.P. Unit 1 & 2 (200 MW)
Outdoor	Outdoor	Outdoor	Outdoor
Top Supported	Top Supported	Top Supported	Top Supported
Natural Circulation	Natural Circulation	Natural Circulation	Natural Circulation
Drum Type	Drum Type	Drum Type	Drum Type
Reheat	Reheat	Reheat	Reheat
Welded Wall	Welded Wall	Welded Wall	Welded Wall
Pressurized Furnace	Pressurized Furnace	Pressurized Furnace	Pressurized Furnace
Natural Gas Firing	Oil Firing	Oil Firing	Oil Firing

2. Type of Boiler

Top suspended

Natural circulation or forced circulation

Drum type

Reheat

Welded wall

Pressurized furnace

Oil firing;

For start-up and low load conditions, natural gas will be used

3. General Technical Description

(1) Furnace

The furnace shall be fully water cooled, using welded walls. Water walls will be arranged so that there is no exposed refractory in the furnace except at the burner throats.

The side walls, front and rear, roof and floor tubes shall be shop assembled into panels of welded construction to minimize field erection work.

The primary objective in furnace design shall be to achieve reliability and long life.

Furnace heat release rate shall be designed under the Tenderer's experience with satisfactory operation records, of at least 5 years.

(2) Superheater and reheater

It is a common practice for boiler designers to select superheaters such as pendant and horizontal types or combinations thereof depending upon the general construction of the boiler. This shall be decided upon based on the design conditions of the boiler and the manufacturer's.

The superheater shall be designed and positioned in the steam generator unit with special attention to protect used materials from high temperature conditions. The steam temperature at outlet of the superheater and reheater shall be automatically controlled for the range specified (for example, above 50% of continuous maximum rating).

The superheater and reheater are of the loop tyre, partly horizontal and partly pendant.

Overall design of the superheater and reheater shall be such that any parts and elements can be removed and replaced with minimum disturbance to other parts.

Headers of the superheater and reheater shall not be located in the gas path.

Sufficient space shall be provided so that additional heating elements can readily be inserted for repair when required.

(3) Economizer

The economizer shall be of approved design and construction.

The economizer shall be designed so that no steam will be generated under any operating condition.

The elements shall be arranged in banks sufficiently shallow to enable the gas passages to be easily cleaned and with ample space for access.

(3) Gas mixing fan and gas recirculation fan

Gas mixing fan (GMF) will be utilized for NOx reduction in boiler flue gas by extracting flue gas from the economizer outlet and mixing it with the combustion air.

Gas recirculation fan (GRF) will be utilized for improvement of temperature control characteristics of the boiler by recirculating flue gas taken from the economizer outlet and returning it to the furnace.

For the West Wharf Thermal Power Plant boiler, the gas recirculation fan, which will be used for the above cited two purposes, shall be provided.

Two half capacity GRF's are preferable. However, due to the narrow site space, one full capacity system may be permissible, provided that it can maintain stable boiler operation even with GRF(s) out of service.

M-2 BOILER AUXILIARIES

The following description shows the Engineer's selection for the types of boiler auxiliaries.

1. Boiler Feed Pump

   (1) Type of Boiler Feed Pump

   Motor driven, a variable speed, horizontal multistage centrifugal barrel type with speed increasing gear and hydro-coupling.

   (2) Number of Boiler Feed Pumps

   Three (3) sets of 50% capacity each

   (One (1) set for standby)

   (3) Approximate Particulars

   350 t/h x 210 kg/cm^2 each (tentative)

   (4) Reasons of the Selection

   Refer to the Detailed Design Sheet, designated as M-8 in this report, titled "Type and number of boiler feed pump".

2. Fuel Oil Pump

   (1) Type of Fuel Oil Pump

   Motor driven, horizontal screw type

   (2) Number of Fuel Oil Pumps

   Two (2) sets each of 100% capacity

(3) Approximate Particulars

60 m^3/h x 30 kg/cm^2 each

(4) Reasons of The Selection

When high viscosity fuel such as crude heavy oil and residual oil is handled, screw or gear pumps are employed for fuel oil pumps.

In general, high speed operation is possible with screw pumps, greater capacity is also available.

In addition, comparing with gear pumps, high pump efficiency, less mechanical losses, low noise and less wear can be expected for screw pumps.

From the above reasons including much experience for similar particulars, screw pump has been selected.

3. Forced Draft Fan

(1) Type of forced draft fan

Inlet vane control, double inlet, constant speed and centrifugal type with backward curved air foil blades.

(2) Number of forced draft fan

Two (2) sets of 50% capacity

(3) Approximate particulars

To be specified by the contractor

(4) Reasons of the selection

a) It is expected that this power station will be operated with high utilization factor as the base load power station. Therefore, a reliable, easy to operate and economical machine is preferable.

b) Many experiences show that this type of fan is the most reliable and durable one.

c) Air control will be achieved readily and accurately.

d) Less maintenance is expectable because the number of parts constructing the fan and damper unit is less.

4. Gas Recirculation Fan

(1) Type of gas recirculation fan

Inlet vane control, double inlet, constant speed and radial type.

(2) Number of recirculation fan

To be decided by the contractor

(3) Approximate particular

To be specified by the contractor

5. Air Preheater

(1) Type of air preheater

Regenerative, rotary counter flow type with horizontal or vertical installation

(2) Number of air preheater

Two (2) sets of 50% capacity

(3) Approximate particulars

Heating surface (gas side) 22,600 m^2 each

Inlet air temperature	88°C
Outlet gas temperature	142°C

(4) Reasons of The Selection

This type of air preheater is widely adopted for steam power plant.

6. Soot Blower for Boiler

(1) Type of soot blower

Long, retractable, electric motor driven and steam blowing type. With automatic sequence control for routine operation, remotely operated individually from central control room.

(2) Number of Soot Blowers

To be decided by the contractor

(3) Approximate Particulars

Operating steam condition	12 to 14 kg/cm^2g

(4) Reasons of The Selection

Any desired steam pressure and steam flow can be obtained from the boiler.

7. Air Compressor

7.1 Instrument Air Compressor

(1) Type of instrument air compressor

Heavy duly, water cooled, oil free with teflon ring, motor driven, with aftercooler and intercooler (if any) air filter and silencer etc.

(2) Number of air compressor

Three (3) sets of 50% capacity each

(3) Particulars

To be specified by the contractor in accordance with air comsumption of the plant

7-2 Air Drier of Instrument Air Compressor

(1) Type of air drier

Refrigerative type

(2) Two (2) sets of 100% air compressor capacity

(3) Particulars

To be specified by the contractor in accordance with air consumption of the plant.

7-3 Service Air Compressor

(1) Type of service air compressor

Motor driven, reciprocating type with aftercooler and intercooler (if any) with air filter.

(2) Number of air compressor

Two (2) sets of 100% capacity each

(3) Particulars

To be specified by Bidder in accordance with air consumption of the plant.

M-3 TURBINE

1. Turbine design conditions

(1) Turbine rated output (Economical Continuous Rating (ECR), design point)

The steam turbine generator should be designed to have a rating output of 200 MW at the generator terminals at normal steam conditions, with a specified back pressure of 60 mmHg abs. This will correspond to the specified design cooling water temperature of 30°C.

(2) The turbine generator shall be able to generate an output of at least 200 MW under exhaust pressure conditions which shall correspond to the maximum specified cooling water temperature 33°C, with 3% make-up water (Capability Rating).

(3) Maximum Continuous Rating (MCR)

A generator output of not less than 210 MW should be guaranteed under the specified steam conditions, at the maximum guaranteed throttle flow and the specified back pressure (Refer to Clause 1 of this section) under normal expected cycle operating conditions.

(4) Initial steam condition

In order to achieve high efficiency in steam turbine design, high pressure and temperature initial steam condition should be adopted. However, considering the unit size and ease of operation and maintenance, a subcritical steam condition has

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been adopted.

Initial	pressure	169 kg/cm^{2}g
	temperature	538^{o}C
Reheat	temperature	538^{o}C

(5) Design back pressure of turbine

The specified back pressure of (60 mm Hg abs.) should be selected in order to achieve the most effective cycle performance throughout annual operation, by referring to the maximum, minimum and yearly average cooling water temperatures as well as the allowable temperature rise of the cooling water (to be set as low as 7K for environmental protection purposes).

2. Type of turbine

The JICA Study Team has considered adoption of a TCDF (Tandem compound double flow) turbine for the KESC West Wharf Thermal Power Plant Units I and II. The reasons are as follows.

The TCDF type turbine is usually adopted for 200 MW class steam power plants similar to the Bin Qasim and Korangi Steam Power Plants of KESC. This turbine is manufactured by several reliable makers and excels in operation performance and maintenance ease.

The main features, pending preference, are as follows.

(1) Number of turbine casing could be two (2) or three (3) casings. Two (2) casing type consists of one casing for HP & IP rotor and the other for LP rotor. The three (3) casing type has independent casings for HP, IP and LP rotor, respectively. For

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the project, two casing type seems preferable due to the limited site space.

(2) The supporting method of the turbine-generator rotor comprises two (2) methods. One is the two (2) bearing support type which provides the bearings before and after each one rotor. The other is single support type which eliminate one side bearing and support the rotor by the adjacent rotor bearing. As past experience of single support type turbines shows unsatisfactory result regarding vibration, this type is not recommended.

M-4 TURBINE AUXILIARIES

The type and number of turbine and turbine auxiliaries in accordance with the Basic Design of the West Wharf Thermal Power Station Units 1 and 2 are selected as follows.

The JICA Study Team proposes the equipment and facilities as shown below from the viewpoints of experiences for domestic and overseas thermal power stations.

1. Reason of Selection for Major Equipments

(1) Steam turbine

Refer to the Detailed Design Sheets Item No. M-2, titled TURBINE in this report.

(2) Main oil tank

One (1) main oil tank is installed on the first floor in the turbine room.

(3) Auxiliary oil pump

One (1) auxiliary oil pump is installed on the main oil tank due to save the space.

(4) Jacking oil pump (if required)

Necessity of jacking oil pump shall be decided by turbine manufacturer based upon their design practice.

Number of pump is one (1) set, if jacking oil pump requires. Because, the jacking oil pump is operated only at the time of start up and after shut down condition of turbine.

(5) Gland steam condenser

One (1) unit

(6) Turbine bypass system

Turbine bypass system will not be provided for economical reasons. Nevertheless, without the turbine bypass system, the units will still be able to change over to house load operation, that is, island operation, in case of sudden load rejection caused by transmission line trouble, etc., by utilizing the FCB (fast cut back) technique.

(7) Surface condenser

(a) The type of surface condenser is one (1) pass, divided water box and horizontal surface type.

(b) The tube material will be decided after studying the water quality inside of Karachi Port and other influencing factors. Titanium tube material has been selected for the final choice.

(c) The condensate oxygen content should be of 0.03 cc/l due to the steam condition of this class.

(8) Circulating water pump

(a) The type of circulating water pump is vertical mixed flow type.

(b) The material of pump should be decided after investigation of the cooling water quality other influencing factors.

Sea water resistant stainless steel is adopted for the main parts.

(9) Condensate pump

(a) The number of condensate pump is three (3) sets due to reliability and easy operation.

(b) The each pump has half capacity at the rated condensate flow. (two pump operation and one standby)

(c) The type of condensate pump is vertical multistage pit can type with suction strainer from the viewpoints of satisfactory experiences.

(d) The kind of material for major parts are as follows:

Impeller : Stainless steel

Casing : Cast iron or cast steel

Shaft : Stainless steel

(10) Feed water heater

(a) The type of feedwater heaters for high pressure and low pressure are horizontal U tube type due to the easy operation and maintenance.

(b) The kind of material for the major parts are the following items from the viewpoints of satisfactory experiences.

Tube material : High pressure heaters

Carbon steel

Low pressure heaters

Stainless steel

Channel and tube sheet: JIS SF50, SB46 or equivalent

(11) Turbine room over head travelling crane

(a) The type of crane is indoor double box girder one trolly type from the viewpoints of satisfactory experience.

(b) The lifting capacity should be selected by maximum weight of turbine and generator parts except the generator stator because of economical design for the turbine room structure.

Therefore, the capacity of crane should be decided at the manufacturing design stage.

M-5 CONDENSER AND CIRCULATING WATER SYSTEM

1. Condenser

1-1 Design Conditions of Condenser

(1)	Type	: One pass, horizontal, surface type, divided water box
(2)	Turbine exhaust pressure	: Rated, 60 mm Hg abs.
(3)	Inlet cooling water temperature (t_1)	: Design, 30°C
(4)	Condenser tube cleanliness factor (Cc)	: 90%
(5)	Turbine exhaust steam flow (at 169 kg/cm^2, 538/538°C)	: 400 ton/hr. (hereinafter the same conditions)
(6)	Turbine exhaust steam enthalpy	: 577.3 Kcal/kg
(7)	Condenser tubes	
	Material	: Titanium
	Size	: 19.05 mm$^{O.D.}$ x 0.5 mm^{T} x 11,000 mm^{L} (effective)
(8)	Number of tube pass (N)	: One (1)
(9)	Velocity of cooling water in tubes (V)	: 2.4 m/sec.
(10)	Condensate water temperature (Pressure of saturated turbine exhaust: 60 mmHg-abs.)	: 41.5°C

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1-2 Condenser Design

1-2-1 Heat duty (H) : 200 MW at 60 mmHg abs. boiler make-up water 3%

(1) Turbine exhaust steam : $(577.3 - 41.5) \times 400,000 = 2.14 \times 10^8$ (Kcal/hr.)

(2) Feedwater heater drain, etc. : 1.35×10^6 (Kcal/hr.)

(3) Total H : 2.16×10^8 (Kcal/hr.)

1-2-2 Heat transfer rate (K)

The heat transfer rate (K) is calculated according to the Standards for Steam Condenser of the Heat Exchange Institute based upon the following formula:

$$K = C \times \sqrt{V} \times Ct \times Cm \times Cc = 3,021.9 \text{ Kcal/m}^2\text{h}^\circ\text{C}$$

where C: Coefficient of basic heat transfer rate. Judging from the outer diameter of tube, C = 2,361

V : Cooling water velocity inside tubes = 2.4 m/sec.

Ct: Correction factor based upon the cooling water temperature (at 30°C) = 1.08

Cm: Correction factor based upon the material and thickness of tubes = 0.85

Cc: Tube cleanliness factor = 0.9

1-2-3 Temperature rise of cooling water (Δt)

$$t = (ts - t_1) \times \left(1 - \frac{1}{e^P}\right) = 6.98^\circ C < 7^\circ C$$

where $ts = 41.5^\circ C$; $t_1 = 30^\circ C$

$$P = \frac{N.K.L.F}{3,600 \times V \times Cp.} = 0.9349; \quad e^P = 2.546$$

N: Number of tube pass = 1

K: 3,021.9 $Kcal/m^2 h^oC$

L: Tube length = 11.0 m

F: Factor based on tube diameter

$$F = \frac{\pi \times O.D}{\pi/4x(O.D-2xT)^2} = 234$$

V: 2.4 m/sec.

Cp.γ: Specific heat x specific gravity = 963 $kcal/m^{3o}C$

1-2-4 Required quantity of cooling water ( )

$$Q = \frac{H}{\Delta t.C_p.\gamma} = 32,134\ m^3/hr. = 8.92\ m^3/sec$$

where $H = 2.16 \times 10^8$ Kcal/hr

$\Delta t = 6.98^oC$

1-2-5 Condenser surface area (F)

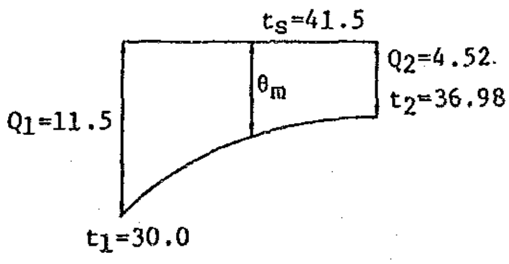
$$F = \frac{H}{K.\ m} = 9,568.7\ m^2$$

where $H = 2.16 \times 10^8$ (Kcal/hr.)

$K = 3,021.9\ (Kcal/m^2\ h^oC)$

$$m = \frac{t_2 - t_1}{l_n \frac{\theta_1}{\theta_2}}$$

$= 7.47\ ^oK$



1-2-6 Number of tubes N_T

$$N_T = \frac{F}{x O.D. x L} = 14,535$$

where $F = 9,568.7\ m^2$

$O.D = 0.01905\ m$

$L = 11.0\ m$

2. Calculation of Circulating Water Pump Head

2-1 Intake Head Loss (CWP Suction Water Level)

(1) + (2)	:	0.616 mAq (EL = -1.046 m)
(1) Intake culvert and open channel head loss	:	0.454 mAq
(2) Screen head loss	:	0.162 mAq

2-2 Discharge Tunnel Head Loss : 1.012 mAq (Unit 1)

For further detail, refer to the Detailed Design Sheets, Item No. CV-3, "Hydrographic Calculation."

2-3 Piping Head Loss

2-3-1 Head loss between CWP and condenser

((a) + (b)) x 1.1 = 1.48 mAq

(1) Pump discharge piping head loss : 0.138 mAq

(a) Piping head loss (Lang's Formula)

$$h = (\alpha + 16\sqrt{\frac{\alpha\nu}{VD}})\ \frac{L}{D}\ \frac{V^2}{2g} = 0.138 \text{ mAq}$$

α	:	Loss coefficient	= 0.019
ν	:	Kinematic viscosity (at 30°C)	= 0.008×10^{-4} m^2/sec
V	:	Velocity	= 3.02 m/sec.
D	:	Piping diameter	= 2.0 m
L	:	Piping length	= 30 m

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Method for deciding the velocity and diameter of the pipe

$$D = \sqrt{\frac{4}{\pi} (Q/V)}$$

$Q = 9.5\ m^3/sec.$

V = Approx. 3 m/sec. ---- $D = 2.01$ m

$D = 2.0$ m $V = 3.02$ m/sec

(b) Valve and fitting head loss = 0.343 mAq.

$$h = \tau \frac{v^2}{2g}$$

45^o elbow: (1.5 m dia. x 2), V = 2.55 m/sec

$h = 0.21 \times 0.332 \times 2 = 0.139$

Y piece: (2 m dia. x 1), V = 3.02 m/sec

$h = 0.5 \times 0.465 \times 1 = 0.233$

Expansion joint: (1.5 m dia. x 2)

$h = 0.05 \times 0.332 \times 2 = 0.033$

Butterfly valve: (1.5 m dia. x 2)

$h = 0.3 \times 0.332 \times 2 = 0.1992$

2-3-2 Condenser outlet piping head loss : 1.643 mAq

((1) + (2)) x 1.1 + (3) + (4)

(1) Piping head loss

$$h = (\alpha + 16\sqrt{\frac{\alpha\nu}{VD}}) \frac{L}{D} \cdot \frac{V^2}{2g} = 0.461 \text{ mAq}$$

$\nu = 0.019$ $= 0.008 \times 10^{-4}$

$V = 3.02$ m/sec. $D = 2.0$ m

$L = 100$ m

(2) Valve and fitting head loss : 0.652 mAq

$$\Delta h = \tau \frac{V^2}{2g} \qquad V = 3.02 \text{ m/sec. (2 m dia.)}$$
$$= 2.55 \text{ m/sec. (1.5 m dia.)}$$

90^o elbow

h = 0.31 x 0.332 x 1 (1.5 m dia.) = 0.103 mAq

0.31 x 0.465 x 3 (2 m dia.) = 0.433 mAq

Expansion joint

h = 0.05 x 0.332 x 1 (1.5 m dia.) = 0.017 mAq

Butterfly valve

h = 0.3 x 0.332 x 1 (1.5 m dia.) = 0.099 mAq

(3) Tube ball-cleaning strainer head loss: 0.15 mAq

(4) Piping discharge head loss : 0.269 mAq

$$h = \tau \frac{V_1{}^2 - V_2{}^2}{2g} = 0.269$$

$\tau = 1.0$ $V_1 = 3.02$ m/sec.

$V_2 = 1.96$

2-4 Condenser Head Loss

2-4-1 Specification of condenser

Tubes

Outer diameter	:	19.05 mm
Thickness	:	0.5 mm
Length	:	11,000 mm
Number of passes	:	One (1)
Velocity	:	2.4 m/sec.

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2-4-2 Head loss (According to the Standards for Steam Surface (Condenser of the Heat Exchange Institute)

(1) Head loss per 1 m of tube length : 0.32 mAq

(2) Tube head loss at 21.1°C (Cooling water temperature)

(1) x tube length x pass = 0.32 x 11.0 x 1 = 3.52 mAq

(3) Water box head loss at 21.1°C : 0.8 mAq

(4) Total head loss

(2) + (3) = 4.32 mAq

(5) Total head loss at 30°C (In case the correction coefficient is 0.98

(4) x 0.98 = 4.23 mAq

4.5 mAq

3. Summary of Circulating Water System

3-1 Summary of Circulating Water Pumps

(1)	Type	: Vertical mixed-flow type
(2)	Number	: Two (2) sets per one unit
(3)	Capacity	: 17,100 m^3/hr./pump
(4)	Total head	: 10.0 mAq
(5)	Driving motor	: 700 kW

3-2 Design Conditions

3-2-1 Capacity (200 MW unit)

(1)	Quantity of condenser cooling water (Refer to ATTACHED SHEET I)	: 32,400 m^3/hr
(2)	Quantity of bearing cooling water for heat exchanger	: 1,700 m^3/hr
(3)	Quantity of water to be used for other purposes	: 100 m^3/hr
	Total	34,200 m^3/hr
(5)	Required capacity of pump $34{,}200 \times \frac{1}{2}$	: 17,100 m^3/hr (4.75 m^3/sec.)

3-2-2 Head (Refer to Fig. 1)

(1) Circulating water pump pit water level : EL -1.046

(2) Discharge tunnel water level : EL +0.582

(3) Piping, fitting and valve head loss

Inlet side 1.48 mAq : 3.12 mAq

Outlet side 1.64 mAq

(4) Condenser head loss : 4.5 mAq

Therefore, the required head loss

= (2) - (1) + (3) + (4) : 9.248 mAq

= 9.5 mAq

3-2-3 Driving motor

(1) Required shaft power

$$\frac{0.163 \times \gamma \times Q \times H}{\eta} = 532.2 \text{ (kW)}$$

where : Specific gravity = 1.025

Q: (4.75 m^3/sec.) = 285 m^3/min.

H: 9.5 m

η: Pump efficiency = 0.85

(2) Motor power

The motor power shall be equivalent to or more than the largest value in the following:

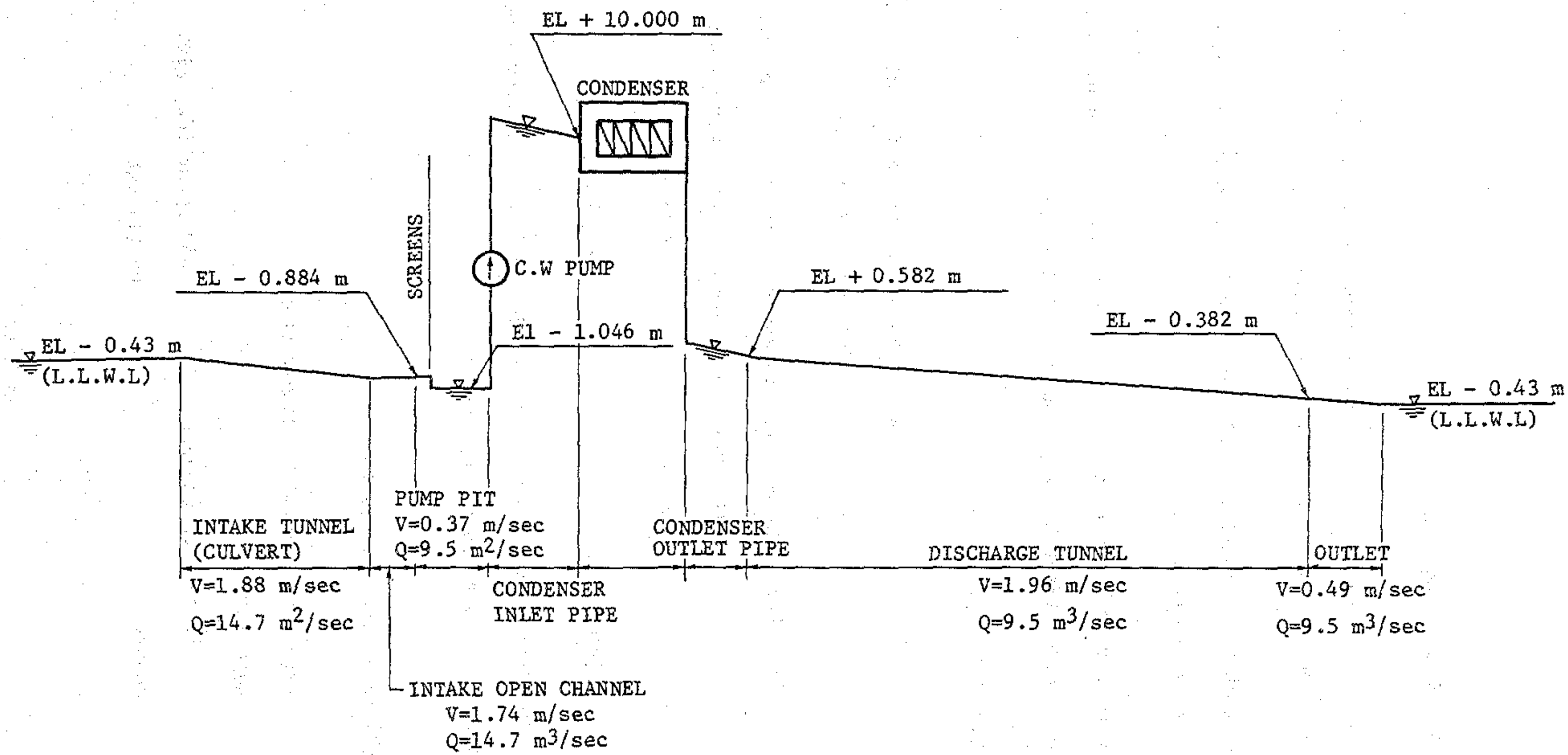
Shaft power at design point x 1.2

Shaft power at shut off point

Therefore, the shaft power shall be 650 kW.

Fig. 1 The Results of Hydrographic Calculation

(UNIT I)



NOTE

V: Water velocity (m/sec)

Q: Quantity of water (m^3/sec)

4. Air Removal Equipment

Removal of air from a steam condenser may be accomplished either by a steam jet air ejector or by a mechanical pump.

For the West Wharf Thermal Power Plant, steam jet air ejectors are planned to be applied.

Capacity and number of equipment are decided according to the H.E.I. Standard. (Heat Exchange Institute, U.S.A.)

(1) Main ejector

Type	Twin element, two stage, steam jet air ejector with common inter and after coolers	
Capacity	Extracting air and vapor mixture with 25.4 mm Hg abs suction pressure and 4.2°F under cool	
	Dry air	25.5 kg/hr
Number		One (1) set

Twin element type means that the ejector has a capacity specified above with one element operation.

(2) Starting air ejector

Type single element, single stage

Capacity

Air suction capacity	1,850 kg/hr (dry air)
Number	One (1) set

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M-6 CONDENSER TUBE MATERIAL

A condenser tube material shall carefully be selected in consideration of various technical, economical factors for actual application.

JICA study team is intending to adopt titanium as the condenser tube material, as the result of our investigation.

The reasons are as follows.

Generally, aluminium brass material has been adopted in many thermal power stations which use sea water for cooling water system, because this material has proper resistance for sea water and having better heat transer coefficient compared with other tube materials.

However, the copper alloy tubes (aluminium-brass, copper-nickel, etc.) are not throughly corrosion resistant for the sea water containing hydrosulfied H_2S, ammonia (NH_4^+), etc. and have a tendency to reveal general corrosion and erosion.

The relative corrosion/erosion/impingement resistivity for various materials is shown in the following table.

Subject	Admiralty brass	Aluminium brass	90-10 Cu-Ni	70-30 Cu-Ni	Stainless steel	Titanium
General Corrosion	2	3	4	4	5	6
Erosion-Corrosion	2	2	4	5	6	6
Pitting (Operation)	4	4	5	5	6[*1] (4)	6
Pitting (Shutdown)	2	2	5	4	5[*1] (1)	6
High Velocity Water	3	3	4	5	6	6
Inlet Attack	2	2	3	4	6	6
Steam/Drain Attack	2	2	3	4	6	6

Stress Corrosion	1	1	6	5	6	6
Cl^- Attack	3	5	6	5	1	6
NH_3 Attack	3	2	4	5	6	6

Note: 1. *1: For seawater use

2. Number shows resistivity 6 (Max) - 1 (Min)

3. For stainless steel and titanium, seamed tubes are applied.

From the above table, the titanium tube shows excellent resistivity compared to the other tube materials. Recently, titanium tube material has been adopted in many thermal power stations not only in Japan but also in many other countries in order to have more reliable condensers, resulting to achieve more increased plant utilization factors.

The Experience list of all-titanium-tube condensers is attached in the following table.

Heat conductivity of titanium is not so high as aluminium brass and cupro-nickel, however, in case of titanium condenser tubes, thinner tube wall thickness can be adopted because of its material reliability and higher cleanliness factor can be applied with its corrosion/erosion resistivity and expected good cleaning result by applying the ball cleaning device and more over higher cooling water velocity can be selected.

Consequently, reasonable and not much different heat transmission coefficient can be obtained for designing the condenser.

(Refer to Fig. 1 attached)

Table 3 All Titanium-Tubed Condenser Experience List

Table 3. All Titanium-Tubed Condenser Experience List (As of April 1988, Major plant)

SW: Seawater, RW: River water, J: Japan, NC: Nuclear
(Saltwater)

Purchaser	Station and Unit No.	Rating (MW)	Outside dia. (mm)	Thickness (mm)	Status	C.W. Type
Tokyo El. Pwr. J	Hirono #1	600	31.75	0.5 (Outside row 0.7)	'80/4	SW
Tokyo El. Pwr. J	Hirono #2	600	31.75	0.5 (Outside row 0.7)	'80/7	SW
Tokyo El. Pwr. J	No. 2 Fukushima #1 (NC)	1,100	25.4	0.5 (Outside row 0.7)	'82/4	SW
Joban Joint Pwr. J	Nakoso #9	600	31.75	0.5 (Outside row 0.7)	'83/12	SW
Tokyo El. Pwr. J	No. 2 Fukushima #3 (NC)	1,100	31.75	0.5 (Outside row 0.7)	'85/6	SW
Tokyo El. Pwr. J	Kashiwazaki Kariwa #1 (NC)	1,100	31.75	0.5 (Outside row 0.7)	'85/9	SW
Tokyo El. Pwr. J	Higashi Ogishima #1	1,000	34.93	0.5 (Outside row 0.7)	'87/9	SW
Tokyo El. Pwr. J	Kashiwazaki Kariwa #2 (NC)	1,100	31.75	0.5 (Outside row 0.7)	('90/10)	SW
Chubu El. Pwr. J	Owase Mita #3	500	28.58	0.5 (Outside row 0.7)	'87/7	SW
Chubu El. Pwr. J	Kawagoe #1	700	28.58	0.5 (Outside row 0.7)	('89/7)	SW
Chubu El. Pwr. J	Kawagoe #2	700	28.58	0.5 (Outside row 0.7)	('90/7)	SW
P.R.N.F.D. J	Monju (FBR) (NC)	280	25.4	0.5 (Outside row 0.7)	('92/7)	SW
China	Baoshan #1, #2	350 each	25.4	0.5 (Outside row 0.7)	'82/11, '83/11	RW/SW
China	Shajiao P/S #1 Shajiao P/S #2	350 350	25.4 25.4	0.5 (Outside row 0.7) 0.5 (Outside row 0.7)	'87/6 '87/6	SW/RW SW/RW
China	Beilungang #1	600	31.75	0.5 (Outside row 0.7)	('90/7)	SW
M.E. & W. Kuwait	Az Zour South #1 - #8	300 each	23.0	0.7	'87/1-'88/1	SW
N.E.B. Malaysia	Paka Combined #1 - #3	300 each	25.4	0.71	'85/10-'86/3	SW

Fig. 1 Heat Transfer Coefficients referring to (1) Tube Material & Wall Thickness (2) Cooling Water Inlet Temperature (3) Tube Cleanliness Factor

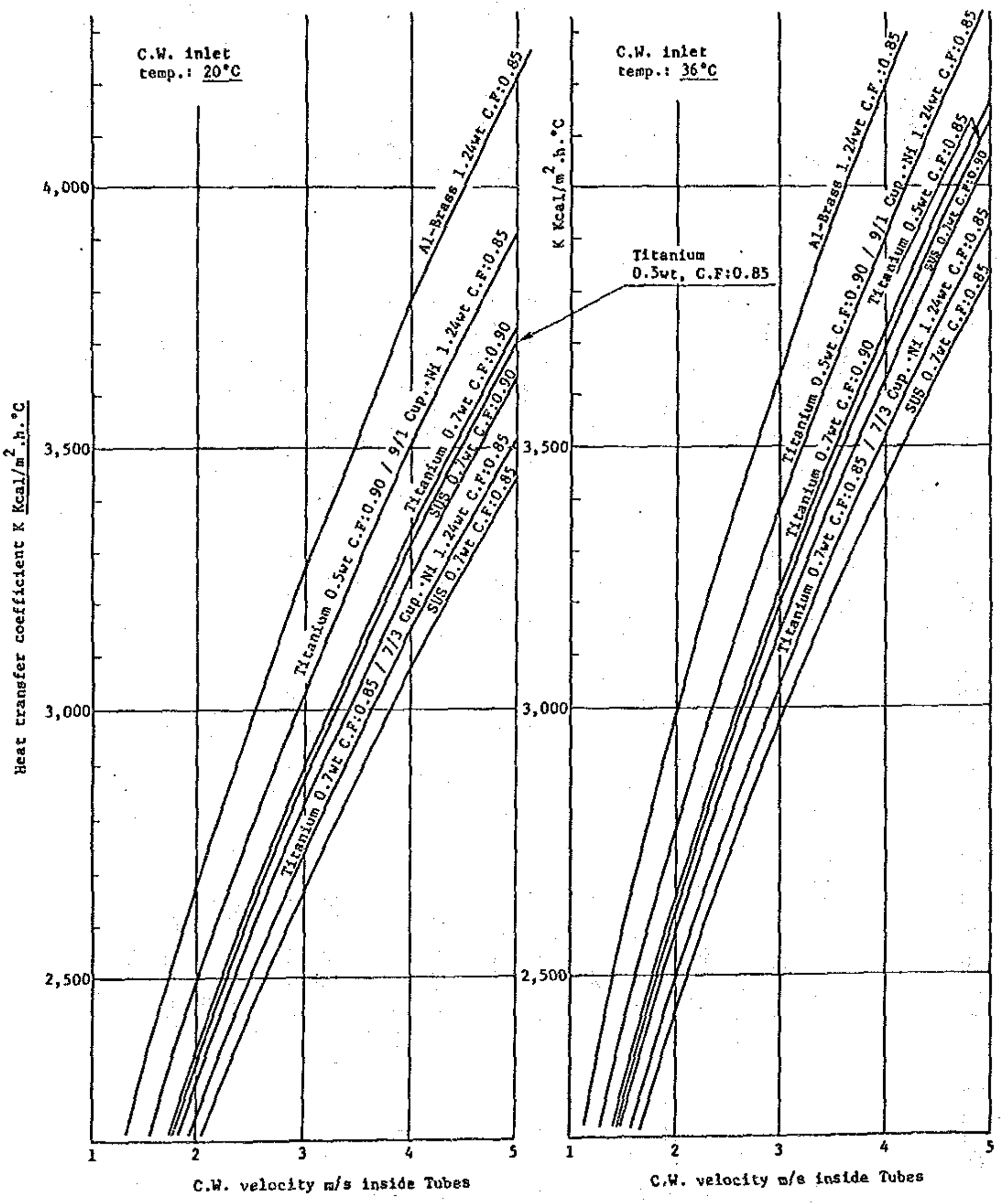

Fig. 1 Heat Transfer Coefficients referring to (1) Tube Material & Wall Thickness (2) Cooling Water Inlet Temperature (3) Tube Cleanliness Factor

Notes:
1. In this comparison, outside diameter of 25.4mmφ is applied for the all cases
2. "wt" means tube wall thickness in mm
3. "C.F" means cleanliness factor
4. "Titanium" shows both of ASTM B338-78 (JIS H4361) Gr.1 (TTH28) and Gr.2 (TTH35)
5. "SUS" shows both of ASTM A249-81 Tp.304 (JIS G3463 SUS304TB) and A269-81 Tp.316 (SUS316TB)

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M-7 FEEDWATER HEATING SYSTEM

1. General

For the West Wharf Thermal Power Plant Units 1 and 2, a seven feedwater heating system (Case 2) is selected due to its superb cost performance, and is as described in item No. G-5, "Number of Feedwater Heaters".

Condensate from the condenser hotwell is pumped up by two 50% vertical, constant speed condensate pumps through three stages of low pressure feedwater heaters arranged in series, to the deaerator, which is installed on the fifth floor of the auxiliary bay of the main power house.

Feedwater from the deaerator storage tank is pumped by two 50% capacity motor-driven feedwater pumps through three high pressure feedwater heaters to the economizer inlet of the steam generator.

Each low pressure feedwater heater is a horizontal shell and U-tube type heat exchanger.

Heating steam is extracted from the turbine and after heating feedwater in each heater, is condensed for drainage and led to the next lower pressure heater, thereby making effectiveness of its heat. It is then accumulated in a drain tank and finally pumped up into condensate line or directly led to the condenser from the lowest pressure heater.

The three low pressure heaters are mounted on the floor of the auxiliary bay.

The horizontal deaerator with a storage tank receives condensate from the low pressure heaters and provides additional heating and deaerating of the condensate by utilizing a extraction steam from the main turbine as heating steam.

Each high pressure feedwater heater is a horizontal shell and U-tube type heat exchanger and utilizes extraction steam from the main turbine as heating steam, similar manner as the low pressure heaters.

The drains from each stage of feedwater heating, with the exception of the deaerator, are cascaded to the next lower pressure heater.

Alternate drain paths should be provided, however, to ensure trouble-free drainage in any operation case, including in an emergency operation.

The last stage high pressure feedwater heaters are mounted on the 4th floor of the auxiliary bay and the other heaters are mounted on the lower floors successively.

2. Tube Materials

Tube materials to be adopted for the feedwater heaters should be carefully selected considering material reliability (resistance against corrosion and erosion, etc.) heat transfer rate (heat conductivity of the material) and their cost.

Tube material of feedwater heaters is highly susceptible to corrosion and erosion due to mechanical and chemical effects imposed on their outer and inner surfaces during operation, if the proper materials are not selected.

The widely used materials for feedwater heaters are shown in the attached list (Standard for Closed Feedwater Heaters, H.E.I)

For units similar to the West Wharf Thermal Power Plant Units 1 and 2, the following tube materials are recommended.

(1) Low pressure heater

Arsenical copper	ASTM B111-80, C14200	
Admiralty	ASTM B111-80, C44300 C44400 C44500	
Carbon steel	ASTM A179-80 A210-80 A556-80	
Stainless steel	ASTM A213-80	TP304

(2) High pressure heater

Monel metal	ASTM B163	
Carbon steel	ASTM A179-80 A210-80 A556-80	
Stainless steel	ASTM A213-80	TP304

Among those materials, mixed use of copper alloys and ferrous alloys is not recommendable, as the feedwater treatment suitable for copper alloys is not necessarily adequate for ferrous alloys, and vice versa.

Boiler feed water and condensate should be strictly controlled to keep their quality within the limits specified by the standards for

Boiler feed water and condensate should be strictly controlled to keep their quality within the limits specified by the standards for feedwater quality control.

For boiler protection, the PH value of boiler feedwater for units of this class should be controled between 8.5 - 9.5, though a higher PH value is preferable for ferrous materials and their alloys.

It is easier to control the feedwater quality suitable for the feedwater heating system having ferrous alloy tubes only than to control the quality for tubes which adopt both copper alloys and ferrous alloys.

Ferrous materials and their alloys which are adoptable for feedwater heater tube material are carbon steel and stainless steel.

For the West Wharf Thermal Power Plant Units 1 and 2 the following material are recommended.

(1) Low pressure feedwater heater

Stainless steel

(2) High pressure feedwater heater

Carbon steel or

The reason why stainless steel is recommendable for low pressure heater is that carbon steel tube is easily susceptible to corrosion and erosion without proper blanketing (N_2 seal/steam seal) in shut down period.

Carbon steel tube for high pressure heaters has a thicker wall thickness and could be covered by protective oxide film formed under the operating conditions with proper design and water treatment.

Nevertheless, carbon steel tubes should be carefully protected by practicing hot blowing, N_2-gas seal or steam blanketing while they are out of operation.

M-8 TYPE AND NUMBER OF BOILER FEED PUMP

1. Outline of Boiler Feed Pump

Since a boiler feed pump is one of the most important auxiliaries in a steam power plant, excellent performance, durability and reliability are highly required for the pump throughout the plant life.

In other words, the pump must have characteristics so as to withstand high pressure and high temperature even in a rapid load change. Moreover, easy operation and less maintenance constitute major factors in selecting an optimum type of the feed water pumps.

2. Prime Mover for Boiler Feed Pump

There are two possibilities for the West Wharf Thermal Power Plant Units 1, 2 to select the prime mover.

One is a motor driven type and another is a turbine driven type. The turbine driven type boiler feed pump will usually be adopted for the unit capacity of larger than 300 MW as shown in Table 1.

2.1 Motor Driven Feed Pumps

For the motor driven feed pump, there are two combinations. One is the direct coupled type with a pump and a motor, and another is the type having a booster pump and a speed increasing gear set between the pump and the motor.

(1) Pump + Motor

(2) Pump + Speed increasing gear + Motor + Booster pump

In general, the boiler feed pump of the combination (1) without booster pump is not suitable for higher operating pressure of boiler, because the pump size becomes large.

In the case where the motor driven boiler feed pumps are adopted for Units 1, 2, the above combination (2) should be selected. The booster pump in the combination (2) is prepared in order to decrease the required NPSH. Thereby, it will be possible to install the deaerator on the proposed level.

2.1.1 Advantage of the Motor Driven Pump

There are the following advantages for the motor driven boiler feed pumps:

(1) Easy to operate the pump

(2) Easy to start up the pump

(3) Easy maintenance

(4) Easy to install the pump.

2.2 Steam Turbine Driven Feed Pumps

In case of turbine driven feed pumps, steam source is taken from main turbine extraction in normal operation. At low load, steam source is taken from main steam pipe and the exhaust steam is led to condenser or feed water heaters depending upon the proposed plant design.

2.2.1 Advantage of the Steam Turbine Driven Pump

(1) It is possible to get high speed revolution easily without speed increasing gear set according to the requirement of the pump characteristics.

(2) Throttling loss

It is expectable to get less throttling loss comparing with the throttling feedwater by a feed water regulating valve.

(3) It is possible to manufacture the boiler feed pump with a large capacity.

(4) Required electric power for auxiliary power supply can be reduced.

2.3 Selection of Prime Mover for Boiler Feed Pump

Table 1 shows the particulars of boiler feed pump in Japanese electric power stations.

In general, the motor driven feed water pumps are adopted for the unit capacity up to 300 MW as shown in Table 1. The step-up gear types have been adopted for the whole motor driven feed pumps. We can expect advantages of steam turbine driven feed pumps mostly in larger units having capacity more than 300 MW.

Therefore, the motor driven boiler feed pump with one set of speed increasing gear and a booster pump has been selected for the Units 1 and 2 from the viewpoints of the general tendency of the feed pump selection and the advantage of the prime mover.

Furthermore, variable speed control pump is preferable, reducing power loss due to throttling of feedwater. For this reason, a variable speed pump with fluid coupling device will be adopted for the West Wharf Units 1 and 2.

3. Number of Boiler Feed Pumps

In the case where the motor driven boiler feed pumps are adopted, the following factors are taken into account in selecting the number

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and capacity of the pumps:

(1) 2 sets with each 100% capacity (One set for standby)

(2) 3 sets with each 1/2 capacity (One set for standby)

(3) 4 sets with each 1/3 capacity (One set for standby)

Generally, three (3) sets of boiler feed pump with each 1/2 capacity are adopted for the pump with a capacity of more than 200 ton/hr.

For West Wharf Units 1 and 2, three sets of boiler feed pumps having 50% capacity each will be adopted.

4. Specification of Boiler Feed Water Pumps

Type:	Motor driven, variable speed, horizontal, multistage centrifugal barrel type with booster pump and water injection seal system
Number:	Three (3) sets (One (1) set for standby)
Capacity:	50% each (350 ton/hr. x 210 kg/cm^2g)
Speed:	Variable speed up to 6,000 rpm with step-up gear (Speed increasing gear set) and fluid coupling

Table 1 Particulars of Boiler Feed Water Pump in Japanese Electric Power Stations

Output MW	Name of Stations	Steam Press. (kg/cm^2)	Boiler Cap. t/h	Rate of Cap.	Feed Pump Cap. t/h	Discharge Press. (kg/cm^2)	Speed (rpm)	Prime Mover (kW)	Number of set
125	A	127	430	1/2	228	177	5,070	1,650	3M.
125	B 1 2	127	435	1/2	228	167 158	1,630 2,975	1,570 1,600	3M 3M
175	C 5 6	190	590	1/2	310	279	3,875	3,750	3M
175	D 5	169	590	1/3	220	203	5,180	1,900	4M
265	E 1 2	169	908	1/3	333	210	6,797	2,600	4M
265	F 1 3	169	900	1/3	320	193	6,797	2,600	4M
350	G 5	169	1,126	27% 1/2	305 610	206 199	7,000 5,850	2,580 4,400	2M 2T
350	H 6	169	1,130	27% 1/2	305 610	210 207	7,100 7,120	2,500 4,250	1M 2T
175	I 1	169	590	1/3	211	197	5,180	1,750	4M
125	J 1 2	127	435	1/2	240 234	168 165	7,840 7,690	1,600 1,600	3M 3M
250	K 3	169	840	1/2	450	221	6,750	2,650 + 2,650 3,900	1M 2T
220	L 1	169	700	1/2	350	243	7,100	3,310	3M
220	M 4 5 6	169	730	1/3	269	216	6,050	2,100	4M
220	N 1 2 3	169	730	40%	300	216	6,000	2,100	4M
250	L 1 6	169	860	1/2	450	204	6,800	3,750 3,500	1M 2T
220	O 1	169	710	1/2	380	193	6,037	2,900	3M

Abbreviation M: Electric Motor
T: Steam Turbine

M-9 BEARING COOLING WATER SYSTEM

(Unit Auxiliaries Cooling Water System)

1. Outline

Bearing cooling water system is one of the most important system for stable operation of the plant.

The system is different from main generating cycle and consists of many different kinds of equipment having respective properties.

JICA Study Team has studied on bearing cooling water system of different kinds and evaluated their systems economically and technically. As the results of the study, closed circuit type is adopted.

2. Comparative Study of Closed Circuit Type and Open Storage Type

Comparative table is attached hereunder.

2-1. Closed circuit type or open storage type

		Closed circuit type	Open storage type
(1)	Volume chamber	. Stand pipe	. Head tank and Underground tank
(2)	Type of BCWP	. Horizontal	. Vertical
(3)	Total head of BCWP	. System head loss	. System head loss plus static head
(4)	Contact area with atmosphere	. Small	. Large

		Closed circuit type	Open storage type
(5)	Emergency case (all A.C. failure)	. Filled up with cooling water with no flow rate Unit should be going to shut down in principle	. Gravity emergency flow of cooling water, depending on storage capacity of the head tank in principle
(6)	Space/loading on structure	. Small	. Large
(7)	System (return) pressure level	. A little bit higher	. Lower

Note. BCWP: Bearing Cooling Water Pump

From the above comparison study, closed circuit type will be recommendable, resulting from following merits.

2-1 Lower running cost

Closed circuit type gives lower running cost resulting from smaller capacity of BCWP motor and less inhibitor consumption due to lower pump total head requirement and smaller contact area with atmosphere.

2-2 Easy maintenance

Maintenance of horizontal pump is easier than that of vertical pump, and there is less tendency of resonance between the critical speed of its structure (especially motor support) and its revoluting speed.

And it is easy for water quality control since contact area with air is limited only in small area of upper water surface of stand pipe.

2-3 Lower capital cost

In open storage type, considerably deep underground tank is necessary and BCWP should provide an appropriate NPSH and both head tank and underground tank shall have considerably large capacity to give large storage water capacity for emergency cooling.

This arrangement induces higher tank cost and civil/architectural cost.

2-4 PH control

PH checking/control of every 1 week will be sufficient for once-through type.

3. Basic Bearing Cooling Water System (BCWS) Arrangement

Following sheets show the BCWS basic arrangements applied in the West Wharf thermal power plant.

Abbreviations:

TCV : Temperature Control Valve

PCV : Pressure Control Valve

LCV : Level Control Valve

TG MOC : T.G. Main Oil Cooler

H_2GC : Hydrogen Gas Cooler

BFP OC : BFP Oil Cooler

BCWC : Bearing Cooling Water Cooler

BCWP : Bearing Cooling Water Pump

Vac.P.SWC: Condenser Vacuum Pump Seal Water Cooler

CPH : Condensing Water Preheater

St. CWC : Stator Cooling Water Cooler

EXC. AC : Exciter Air Cooler

IPB. AC : Isolated Phase Bus Duct Air Cooler

CBP. BRG : Condensate Booster Pump Bearing

GSE. BRG : Gland Steam Exhauster Bearing

HDP. BRG : Heater Drain Pump Bearing

M.BFP.OC : Motor Driven BFP Oil Cooler

GAH : Gas Air Heater (Regenerative air heater)

BCP : Boiler Circulation Pump

P1 : Pressure Indicator

T1 : Temperature Indicator

PTT : Pressure Test Tap

TTT : Temperature Test Tap

TC : Temperature Controller

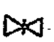
PC : Pressure Controller

LS : Level Switch

PS : Pressure Switch (for stand-by BCWP auto-start)

 : Gate Valve

 : Globe Valve

 : Butterfly Valve

: Parabolic Globe Valve

: Pneumatic Actuator Valve

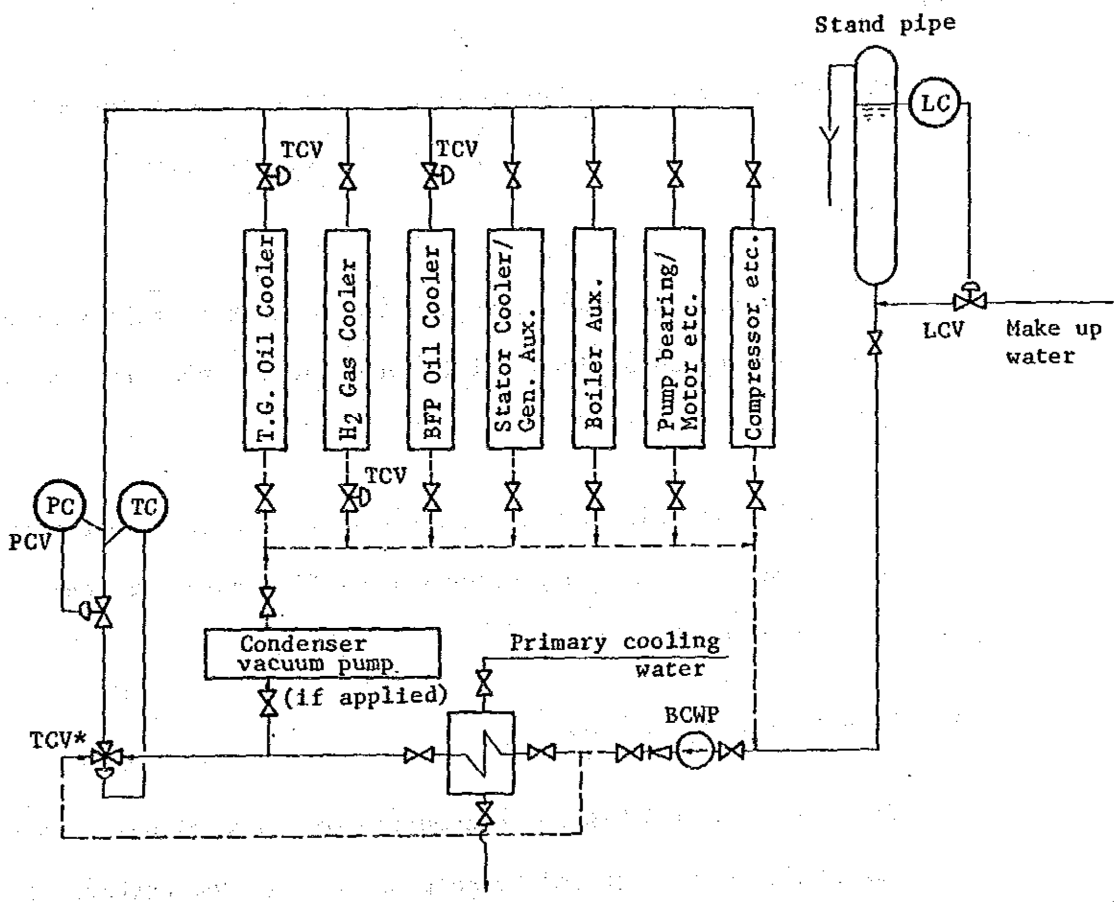
: Electric Motor Valve

: Solenoid Valve

: Non-return Valve

: Flow Sight

: Flange for Flow Balance Adjusting Orifice



* Similar arrangement : 375 MW, 450 MW, 600 MW

* Typical feature : In case of once-through type, NPSH av. for BCWP is given by stand pipe

* Temperature control : On outlet of BCWC

* Pressure control : On outlet of BCWC

* Stator cooling water: Stator cooling water (demineralized water = secondary cooling water of stator cooler) is controlled and primary cooling water (BCW) of the stator cooler isn't controlled.

(1) PCV

The PCV is used in order to keep the flow rate of overall system, however, the PCV can not be used for flow balancing of each line.

It is not necessary to keep the flow rate of overall system in all operating conditions and in this regard, preparation of the PCV is not so worthy.

If PCV is applied, it will be more worthy to provide the PCV on main feed pipe line to prevent excess flow rate for non-controlled equipment.

(2) TCV* (three way valve)

The TCV* is available for prevention of overcooling of non-controlled equipment and to keep the design temperature of all equipment in the system. Design of size and range-ability of each temperature control valves (TCV), other than the TCV*, is performed accordingly.

However, the TCV*s is rather worthless in case there is no possibility of overcooling of non-controlled equipment and primary cooling water of the BCWC is nearly constant all the time.

And it is necessary to adjust setting temperature of the TCV* during the turbine-generator turning operation in some cases.

(3) Stand pipe

The stand pipe is necessary for not only control of the BCWP suction head but also, as surge tank, to avoid water hammer phenomenon accumulating inertia force of water in the system when the BCWP is started/stopped.

From this reason, stand pipe outlet isolating valve will not be necessary.

(4) Water level control for stand pipe

Continuous level controller is applied in this system, however, on-off control (two-position control) by level switches (not continuous control) may be enough since the purposes of the stand pipe are aiming surge tank function and to keep the BCWP suction head within appropriate range.

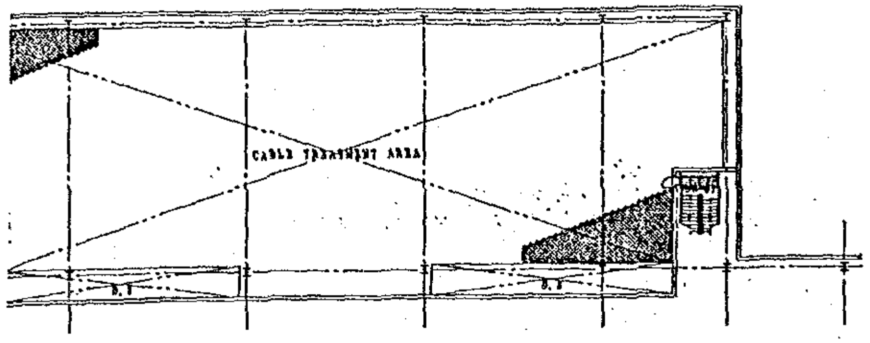
M-10 MAIN STEAM AND REHEAT STEAM PIPELINE ROUTE

The typical main steam and reheat steam pipeline routes are planned as shown in Fig. 1.

This figure shows the plan for the Unit 1.

The routes for the Unit 2 will be arranged as mirror image of this arrangement.

This drawing shows only a typical idea and the actual route of each pipeline will be designed in more detail in the construction design stage considering thermal expansion stress, accessibility for inspection and maintenance, movements of the pipeline under operation, interference with other equipment & structures, etc.



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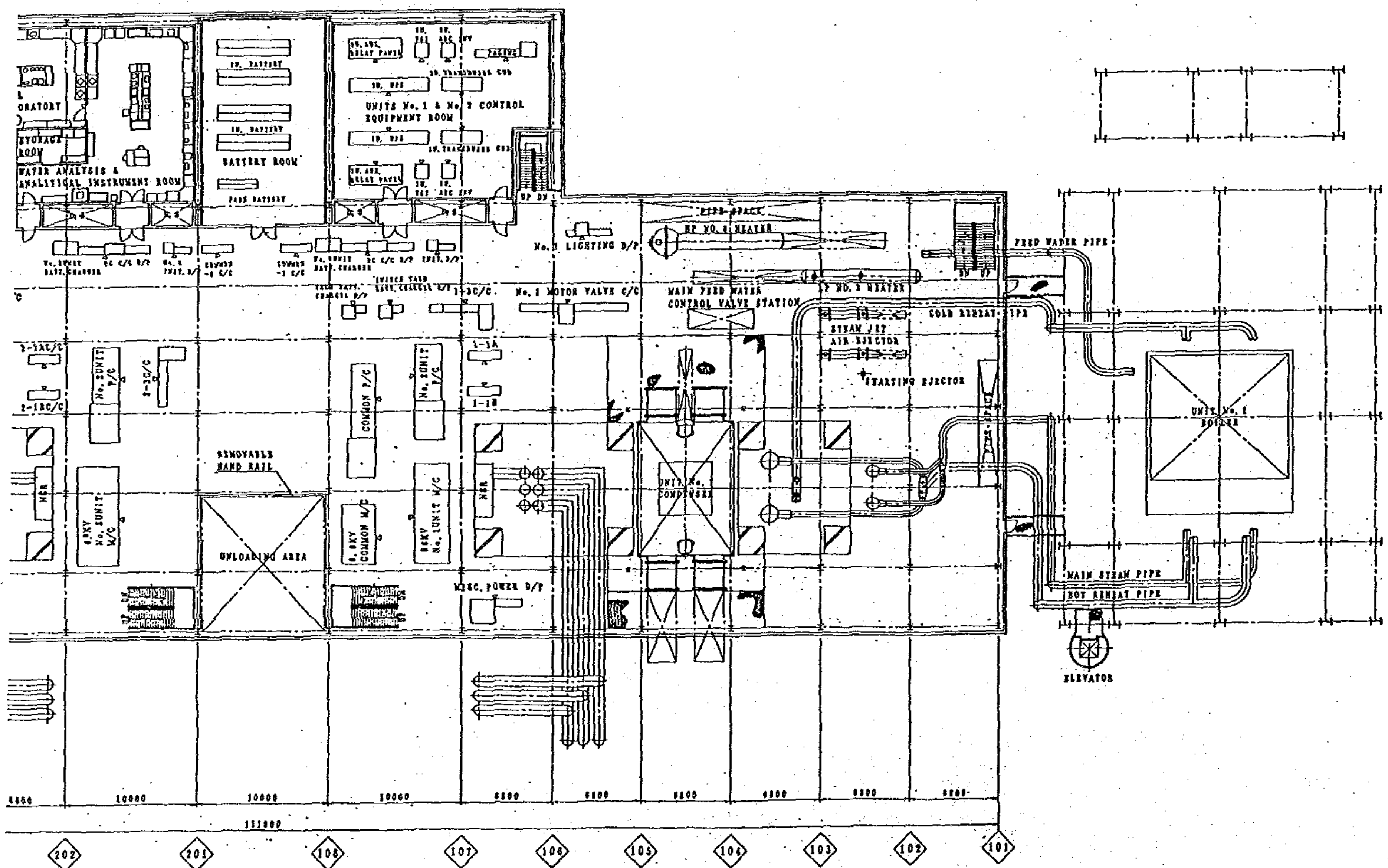

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Fig-1

REV. NO	DESCRIPTION	DATE	CHKD	APPD	DATE

PAKISTAN
KARACHI ELECTRIC SUPPLY CORPORATION
WEST WHARF THERMAL POWER PLANT PROJECT
UNITS NO. 1 and NO. 2

MAIN POWER HOUSE
GENERAL ARRANGEMENT MEZZANINE FLOOR

JAPAN INTERNATIONAL COOPERATION AGENCY

APPROVED BY	REVIEWED BY	CHECKED BY	DRAWN BY

DWG NO.	SCALE	DATE
WGTS-1102	1/200	