JICA

FEASIBILITY STUDY
ON
SMALL-SCALE POWER PLANTS REHABILITATION PROJECT
IN
THE REPUBLIC OF COLOMBIA

F/S REPORTS
OF
EACH POWER PLANT

(VOL.1/2)

MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

FEASIBILITY STUDY
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REHABILITATION PROJECT
IN
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TERMOPAIPA THERMAL POWER PLANT

20952

MARCH 1990

Japan International Cooperation Agency

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1. INTRODUCTION

In February of 1987, the Republic of Colombia, in line with its policies, requested the Government of Japan to conduct a study for establishing a rehabilitation and feasibility study plan for the 82 power stations (3 thermal, 62 hydroelectric, and 17 diesel engine power plants) that are owned by the 13 public electric companies that are under the jurisdiction of the Institute of Colombiana de Enegergia Electrica (hereinafter referred to as ICEL).

In response to the request, the Government of Japan decided to conduct a pre-feasibility study (hereinafter referred to as Pre-F/S) and a feasibility study (hereinafter referred to as F/S) in two steps. The thermal power pre-feasibility study was conducted for Termopaipa in Boyaca Department, Termopalenque (in Santander Department), and Termobarranca (in Santander Department) plants over a period of eight months (November 1987 through June 1988). Based on the pre-feasibility study, the Termopaipa plant was selected as the site for the feasibility study and, in July of 1988, the Scope of Work for the study was agreed upon and signed by JICA and ICEL.

This is the Final Report of the feasibility study.

2. SUMMARY OF THE FEASIBILITY STUDY RESULTS

Detailed examination results for the improvement plan made based on information and data obtained during pre-feasibility and feasibility study periods and on data confirmed by the field study are described in Chapters 6 through 8. An outline of each improvement item is described hereunder:

2.1 Power Output Increase Plan for Unit No. 2 (from 66 MW to 74 MW)

The turbine output is increased from 66 MW to 74 MW by replacing existing turbine units parts (turbine rotator, blades, nozzles, and diaphragms) and feedwater heaters (No. 1 LP, No. 2 LP, and No. 4 HP) with new units.

The estimated rehabilitation cost is US$ 6.3 million based on the exchange rate of 140 Yen/US$. The modification cost per 1 kW is estimated to be US$ 790 and the generating cost is estimated to be US$ 20 mills/kWh.

2.2 Modification Plan for Unit No. 2's Instrumentation System

The purpose of the modification plan is to convert some of the air type instrument units into electronically operated types in order to increase their reliability by facilitating operations and maintenance work, and for introducing a computerized system.

The estimated modification cost is US$ 5.8 million. By assuming that the future operation cost will be the same as the present value, an additional US$1.9 mill/kWh will be required to the generating cost.

2.3 Cooling System Modification Plan

The existing cooling system's efficiency will be increased by installing cooling towers and changing it into the type where water circulates through the towers.

Design conditions for the circulating cooling water system are as follows:

- Cooling Tower Capacities:

No. 1 Unit:	7,000 m^3/H
No. 2 Unit:	13,000 m^3/H
No. 3 Unit:	13,000 m^3/H

- Cooling Water Temperatures:

At cooling tower inlet:	35°C
At cooling tower outlet:	27°C

- Air Temperature (wet bulb temperature): 13°C

- Rough Features of Cooling Water Booster Pumps:

	(Capacity)	(Lift)
No. 1 Unit:	7,000 m^3/H x	20 m
No. 2 Unit:	13,000 m^3/H x	20 m
No. 3 Unit:	13,000 m^3/H x	20 m

- Chemical injection units will be installed to improve the quality of the circulating cooling water.

The estimated costs for the cooling system modification are as follows:

Total modification costs: US$ 14.8 million, and an additional US$ 4.9 mill/kWh to the generating cost will be required.

2.4 Recommendations on operation and Maintenance

(1) Introduction of a Computer System

During the field survey period, examination of adoption of a computer system was requested. In this report, introduction of a general type computer was examined. However, the adoption of central control system including data logger was considered based on the ICEL's long-term plan, including the No. 4 Unit that is presently in the planning stage.

(2) Improvement of Preventive Maintenance Technology

It is evident from the data obtained during the field surveys. That frequent emergency shutdowns occur in this power plant. When items as the prevention of the frequent emergency shutdown, a stable power supply, overall economic improvement, and the deterioration of power supply equipment are considered together, it can be expected that preventive maintenance technology will become a very important issue. Since preventive maintenance is expected to be very effective in prolonging the service life of equipment by preventing possible accidents and improving maintenance effects, it is advisable to stress that preventive maintenance be included in the improvement plan.

(3) Environmental Effects

The adverse environmental effects that are presently caused by the power plant are soot problems (no soot treatment unit is installed for No.1 unit) and ash inflow problems into the Chicamocha River.
Since the ash inflow causes serious problems in the downstream cities, overall measures for the problems including the construction of retaining wall for the ash disposal yard and a new ash disposal yard should be urgently established.

Without solving these environmental problems, it will be impossible to install the #4 Turbine generator unit in the future. The following measures can be considered for solving the problems:

1) Anti-soot Measures

Since the #1 unit is not equipped with an electrostatic precipitator, one should be installed. To install the electrostatic precipitator, however, the following additional work would be required:

(i) The space between the existing boiler and stack is very small. Furthermore, in the vicinity there are such facilities as a coal conveyor, boiler water treatment unit, etc. that are commonly used by units #1, #2, and #3. To install a new electrostatic precipitator for the #1 unit, extensive work, such as demolishing the existing stack and constructing a new stack, would be necessary.

(ii) For the installation of an electrostatic precipitator, it would be necessary to increase the boost pressure of the forced draft fan thereby necessitating the replacement of the existing forced draft fan with a new one. It would also be necessary to install a new air duct through the forced draft fan, boiler, electostatic precipitator, and stack.

2) Ash Flow Preventive Measures

(i) Ash flow preventive walls should be built on both banks of the Chicamocha River.

(ii) A filteration chamber and a settling chamber should be built for the ash disposal yard. Rainwater in the ash disposal yard should be treated in the filtaration chamber and the settling chamber before it is discharged into the Chicamocha River.

(iii) In order to handle the storm water coming from the mountain, a drainage channel should be constructed along the boundary between unit No.2's ash disposal yard and the mountain.

(iv) To prevent ashes from being scattered by the wind, ash deposits should be covered by dirt or sand on which a lawn and trees should be planted.

2.5 Project Implementation Recommendations

(1) For Unit #2 turbine Output Increase:

1) For the improvement of unit #2, E. Boyaca and the turbine manufacturer, should maintain very close communications in order to ensure that the improvement plan is based on up-to-data turbine unit records, such as operations and maintenance data.

2) The steam generating capacity of the existing #2 boiler unit is 300 tons/hr at peak operation and 284 tons/hr during continuous maximum operation.

It will require 285.85 tons/hr of steam to increase the output of the #2 turbine unit an additional 8 MW. The existing #2 boiler unit can therefore supply the required amount of steam within the limits of its peak capacity. Under continuous maximum operating conditions, however, the steam output will be 1.85 tons/hr short.

To solve the steam shortage problem prior to commencing the turbine unit modification work, E. Boyaca must consult with the boiler manufacturer showing all the up-to-date operation and maintenance records of the boiler unit and its associated facilities.

(2) Conversion of Instrumentation Method

1) For selecting a manufacturer for the #2 unit instrumentation units, it is necessary to consider whether the same manufacturer for #3 unit instrumentation unitis should be selected or not by taking into account the of their spare parts, reliablitites, and operation and maintenance methods.

2) For #2 units, it is necessary to develop and keep an instrumentation system gaging position diagram, in its vicinity, clearly indicating each.

(3) Conversion of Cooling System

1) The cooling tower installation site is located in a vicinity close to the Chicamocha River. It is not known whether the ground has a sufficient bearing capacity to support the construction of a cooling tower. For this reason, a detailed geological survey, a boring survey, should be conducted to confirm the ground condition.

2) The existence of underground wiring and pipes should be investigated and, if found, their locations should be confirmed prior to commencing cooling tower construction work. Any existing wiring or piping that would interfere with the construction should be rerouted either by making appropriate modifications or by replacement with a new installation.

3. OUTLINE OF TERMOPAIPA THERMAL POWER PLANT

The Termopaipa Thermal Power Plant, owned by E. Boyaca Public Electric Company, is located approximately 6 km west of Paipa City, Boyaca Department. It is a coal fired power station that produces 173 MW of electricity. The plant consists of the 33 MW capacity No. 1 unit that was installed in 1958, the 66 MW capacity No. 2 unit that was installed in 1974, and the 74 MW capacity No. 3 unit that was installed in 1983. The No. 3 unit is owned by ICEL.

ISA uses this thermal power plant to supply electricity nationwide.

3.1 Power Conditions

The power plants owned by E.Boyaca Public Electric Company consists of Termopaipa Thermal Power Plant and the small scale hydroelectric plants.
The electric power demand and supply balance is classified in accordance with the present power condition and the power plant equipment as follows:

3.1.1 Present Condition of Power Demand and Supply

The power demand and supply balance during the five year period from 1983 through 1987 is as shown in Table 3.1.1. As for the power demand and supply balance of 1987, the maximum power demand was 161 MW while the installed capacity was 173 MW (108% of the maximum demand). The total power demand was 617 GWh while the total generated energy was 693 GWh (about 112% of the total power demand). The surplus electricity was transmitted to the nearby departments.

The 1987 power demand breakdown shows 24% for domestic use, 3% for commercial use, 53% for industrial use, and 20% for other sector use -- the percentage for industrial use was high while it was low for commercial use.

The annual increase rate of domestic, commercial, and industrial power use was 7%, a very high value.

The average annual increase rate of the power demand during the period from 1983 through 1987 was 3.3%. Conversely, the generated energy during the same period decreased by 9.0% annually.

Table 3.1.1 Power Demand and Supply Condition (1983 - 1987)

Item \ Year	1983	1984	1985	1986	1987	Average Annual Increase Rate (%)
Demand						
1. Maximum Power Demand (MW)	120	128	128	148	161	7.6
2. Power Demand (GWh)						
1) Domestic Use	107	122	134	140	145	7.9
2) Commercial Use	15	17	18	19	20	7.5
3) Industrial Use	236	246	246	268	327	8.5
4) Others	184	265	156	165	125	-9.2
TOTAL	542	650	554	592	617	3.3
Supply (including ICEL)						
1. Installed Capacity (MW)	173	173	173	173	173	0
2. Generated Energy (GWh)	1,010	1,134	989	757	693	-9.0
3. Loss	88	65	114	125	167	17.4

(SOURCE: INFORME ESTADISTICO: RESUMEN 1983-1987)

3.1.2 Existing Power Facility Conditions

(1) Power Plants

The total installed capacity of the E. Boyaca Public Electric Company is shown in Table 3.1.2. Most of the capacity is generated by thermal power plants.

Table 3.1.2 Power Plant Conditions (1983 through 1987)

(Unit in MW)

Item \ Year	1983	1984	1985	1986	1987	Average Annual Increase Rate (%)
Total Installed Capacity						
1. Thermal Power	99	99	99	99	99	0
2. Hydropower	1.6	1.6	1.6	1.6	1.6	0
TOTAL	100.6	100.6	100.6	100.6	100.6	0

(SOURCE: INFORME ESTADISTICO: RESUMEN 1983-1987)

The conditions of Termopaipa Power Plant, the concerned power plant for the Feasibility Study, is as shown in Table 3.1.3.

Table 3.1.3 Condition of Termopaipa Power Plan (1983 through 1988)

Item \ Year	1983	1984	1985	1986	1987	1988
Installed Capacity (MW)	173	173	173	173	173	173
Present Output (MW)	170	170	170	170	170	170
Generated Energy (GWh)						
1) No. 1 & No. 2 Units	549	708	584	492	452	371
2) No. 3 Unit	361	426	405	265	240	390
TOTAL	1,100	1,134	989	757	693	761

(SOURCE: E. BOYACA PUBLIC ELECTRIC COMPANY)

A future expansion plan has been made for installing Termopaipa No. 4 Unit (150 MW), Cooling tower type.

(2) Transmission Facilities

The existing transmission facilities have 230 kV (maximum) transmission line. The lines connected to the Termopaipa Power Plant are as follows:

- 230 kV system: 3 lines
- 115 kV system: 3 lines

It is planned to install two additional 115 kV lines in the future.

3.1.3 Generating Cost and Electric Fee

Changes in the annual average generating cost and electric fee during the five years period of 1983 through 1987 are as shown in Table 3.1.4.

Table 3.1.4 Generating Cost and Tariff

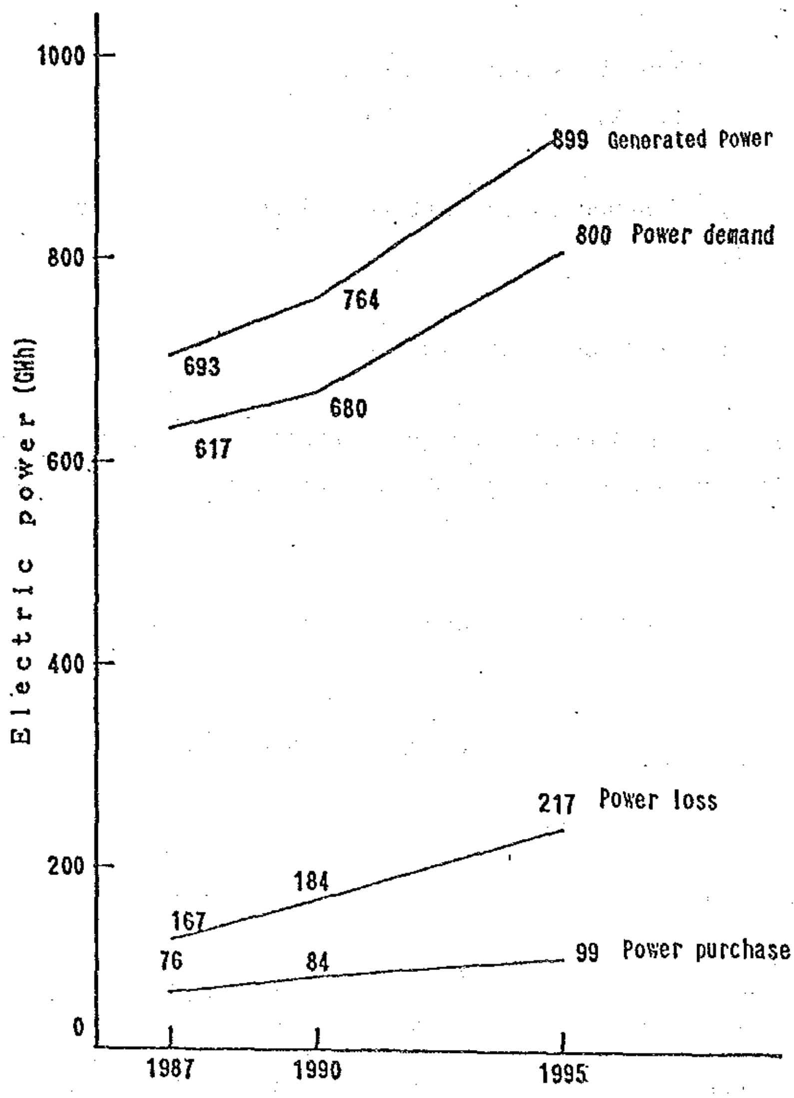
(Unit: Col$)

Item \ Year	1983	1984	1985	1986	1987	Average Annual Increase Rate (%)
Generating Cost	2.84	2.95	4.16	5.32	6.97	25.2
Electric Fee						
1. Domestic Use	2.70	3.29	3.63	5.32	7.75	30.1
2. Commercial Use	5.00	5.81	6.85	9.45	12.50	25.6
3. Industrial Use	4.44	4.96	6.31	8.49	10.41	20.6
4. Public Use	3.13	3.85	4.96	6.99	9.01	30.2
5. Total Average	3.23	3.51	4.78	6.55	8.94	29.0
Diffusion of Electric Use						
1. Number of Households (x1,000)	323	396	434	493	533	13.3
2. Total Users (x1,000)	1,080	1,080	1,098	1,107	1,116	0.8
3. Diffusion Rate (%)	30	36	39	45	48	12.5

(SOURCE: INFORME ESTADISTICO: RESUMEN 1983-1987)

3.1.4 Power Demand Forecast

Estimating the average annual increase rate as 3.3%, based on the figures in Table 3.1.1 the power demand and supply balance for 1990 and 1995 was forecasted to be as shown in Fig. 3.1.1.



NOTES:
1. An average annual increase rate of 3.3% (the same as the power demand average annual increase rate) was used for power purchase, power loss, and generated power forecasting.
2. In accordance with the Proyecciones De Demanda 1986-2006 prepared by ISA, the average annual increase rate was forecasted as 5.9%. The average annual increase rate of the ICEL group was forecasted 6.6%.

Fig. 3.1.1 Forecasted Power Demand and Supply Balance

3.2 Present Features of the Termopaipa Power Plant

The survey results of the Termopaipa Power Plant were classified into the following groups: mechanical, electrical, and other facilities (see Appendix I). An outline of the units is as follows:

Unit No.	Installation Year	Installed Capacity (MW)		Present Output (MW)	Rehabilitation or Improvement Plan
		Turbine	Generator		
No.1	1958	33	33	30	1) Improvement of cooling method
No.2	1974	66	74	66	1) Improvement of cooling method 2) Increase of turbine output 3) Modification of instrumentation method
No.3	1982	74	74	74	1) Improvement of cooling

Steam Condition

Unit	Boiler					At Turbine Inlet	
	*1	Volume of Evaporator (Max. t/h)	Steam Pressure (Max.kg/cm2)	At outlet of Superheater Press. kg/cm2	At outlet of Superheater Temp. °C	Press. kg/cm2	Temp. °C
#1	234	136	79	68	505	65	505
#2	220	284	107	92	510	88	510
#3	220	300	107	93	515	88	510

*1 Feed water temperature at outlet of Economizer.

4. CONTENTS OF THE STUDY

4.1 Objectives of the Study

4.1.1 Increase of Turbine Output

The mechanical specifications of the existing No. 2 Unit boiler, generator, and transformer are 74 MW; however, the turbine output is 66 MW. To effectively utilize the existing facilities, the turbine will be modified to have an output of 74 MW.

4.1.2 Modification of the Instrumentation System

(1) The instruments and automatic control units are either insufficient or are not functioning. Improvements should be made to the instrumentation system.

(2) Some of the instruments are obsolete and the manufacturers no longer produce the same types. Due to the difficulty of obtaining parts, the instrumentation system should be modified.

4.1.3 Modification of the Cooling System

(1) Water cooling the condensers and the bearings of auxiliary equipment is discharged at the upstream point of the cooling water intake in the Chicamocha River. For this reason, cooling efficiency is poor and weather conditions affect the system. Furthermore, the system fosters the growth of such water grass as buchon in the cooling pond. This grass interferes with the water flow and, as a result, causes insufficient water quantity.

These problems, including water grass removal work, should be solved.

(2) In addition to solving the above problems, the existing cooling pond may be utilized as an ash disposal yard.

This yard may also be utilized by the presently planned No. 4 unit. Thus, the problem of land acquisition will be solved.

4.2 Formation of the Study Team

4.2.1 Members of the JICA Feasibility Study Team

JICA's feasibility study team was made up of the team leader and members who were engaged in the pre-feasibility study. The members are listed below:

Duty	Field	Name
Team Leader	General (Civil Engineer)	Masami Ono
Member	Thermal Power Plant Facilities (Mechanical Engineer)	Eiji Shimomura
Member	Thermal Power Plant Facilities (Electrical Engineer)	Hirohito Seto

ICEL was the counterpart agency of JICA for the feasibility study team.

Participating ICEL members were as follows:

Name	Major	Division
Juvenal Penaloza Rosas	Ing. Civil	Jefe Div. De Centrales
Mario Guiterrez Ospina	Ing. Civil	Ing. Div. Centrales
Augusto Sanabira Diaz	Ing. Mecanico	Ing. Div. Centrales
Ramiro Velasco		Div. Centrales

4.2.3 Supporting Engineering Staff Members from E. Boyaca Public Electric Company

The E. Boyaca Public Electric Company provided the following engineering personnel to assist the JICA study team with the Termopaipa Power Plant field survey and data collection:

Name	Division
Edgar Duarte Ryes	Gerente
Francisco Duque	Subgerente
Enuck Guerrero	Jefe Div. De Planeacion
Hector Pulido	Jefe Planta Termopaipa
Jorge Hernan Ramirez S.	Jefe Depto. Serv. Tecnico
Pedro Lesmez	Ing. Depto. Serv. Tecnico
Avelno Cely	Ing. Depto. Serv. Tecnico
Ferndo Cruz F.	Jefe Mant. Electrico
Jose Cardenas	Ing. Mant. Electrico
Aluaro Delgado O.	Ing. Production
Fabio Abril G.	Ing. Mecanico
Reinaldo Avelia	Ing. Operation

4.3 Study Schedule

The contents and schedule of the Study are as shown in Table 4.3.1. As of September 1989 the Study was conducted in the following three steps:

(1) Examination and Analysis of Previous Data

(2) Field Reconnaissance -- field surveys of the following items:

1) Operations of existing power plant facilities
2) Confirmation of each facility's specifications and the possibility of using existing facilities
3) Preparation of Rehabilitation Plan and Basic Design, Construction Cost Estimate, and Economic Analysis in Japan

The field surveys were conducted as follows:

- First Field Survey: November 26 through December 23, 1988
- Second Field Survey: January 14 through February 25, 1989
- Interim Reporting : September 16 through October 1, 1989

Field survey schedules are shown in Table 4.3.2.

Table 4.3.1 Tentative Time Schedule of F.S.

	Year	1988		1989												1990			
	Month	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
	Project month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Working Item	1. Review of existing data	▒ ▨	▒ ▨	▒ ▨	▒ ▨														
	2. Site reconnaissance	▒ ▨	▒ ▨	▒ ▨	▒ ▨														
	3. Power survey								□	□									
	4. Optimum plan								□	□	□								
	5. Feasibility design								□	□	□	□							
	6. Construction method										□	□							
	7. Cost estimation										□	□							
	8. Economic and financial analyses										□	□							
	9. Maintenance manual										□								
Report	1. Inception report	△																	
	2. Progress report				① △										② △				
	3. Interim report											△△							
	4. Draft final report															△	△		
	5. Final report																	△	

Legend: ▒ JICA Field Work ▨ ICEL Field Work □ JICA Work in Japan △―△ Report submission

Table 4.3.2 Itinerary of Field Reconnaissance

	DATE	ROUTE	VISIT	MEMBER	PARTICIPANT
First Field Survey	1988 Dec.5	Bogata ↓ Tunja ↓ Paipa	Head office of E.Boyaca Termopaipa P/S	ICEL:Juvenal Penaloza JICA:E.Shimomura :(I.Sato)	Gerente:Dr.Edgar Duarte Reyes Subgerente:Dr.Francisco Duque Jefe Planta Termopaipa: Hector Pulido
	6.		Termopaipa P/S		Jefe Depto.Serv.Tecnico :Jorge Hernan Ramirez S
	7.		Termopaipa P/S	ICEL:Mario Gutierrezo JICA:E.Shimomura :(I.Sato)	Jefe MTO.Electrico:Fernando Cruz F Producion :Ing.Aluaro Delgado O. MTO.Mecanico :Ing. Fabio Abril G.
	8.		Termopaipa P/S		
	9.	Paipa→Tunja →Bogota	Termopaipa P/S Head office of E.Boyaca		
Second Field Survey	1989 Feb.7	Bogota →Tunja	Head office of E. Boyaca	ICEL:Ramiro Velasco JICA:H.Seto :(N.Nakamura)	Head office E.boyaca Subgerente :Francisco Duque Jefe Div.de planeacion :Enuck Guerrero Jefe PLANTA Termopaipa :Hector Pulido
		→ Paipa	Termopaipa P/S		
	8		Termopaipa P/S		
	9	Paipa →Tunja	Termopaipa P/S		Jefe Depto.Serv.Tecnico :Jorge Hernan Ramirez S. :Pedro Lesmes :Avelino Ceiy Jefe Mant.Electrico :Jose Cardenas Operacion :Reinaldo Avelia
	10	→ Bogota	Head office of E.Boyaca		

5. REHABILITATION AND IMPROVEMENT PLAN

5.1 Rehabilitation and Improvement Items

Among the various rehabilitation and improvement items pointed out during the pre-feasibility study period, the following three were selected as the Feasibility Study Items by the JICA Study Team in agreement with ICEL:

(1) Increase of No. 2 Turbine Output:

The generator output capacity is 74 MW, but the turbine output capacity is only 66 MW -- an 8 MW capacity gap. By replacing the turbine, turbine output shall be increased.

(2) Replacement of No. 2 Unit's Instrumentation System:

Obtaining spare parts for the existing air type instrumentation system is difficult. Furthermore, the supervisory meters and the automatic control units are either inadequate or inoperative. The existing system should be replaced with one similar to that for unit No. 3.

(3) Replacement of Cooling System:

The possibility of replacing the present pond cooling system with a circulating type using a cooling tower should be studied.

5.2 Basic Conditions of the Rehabilitation Plan

For the preparation of the rehabilitation plan, each rehabilitation or improvement item will be examined separately. For the plan's basic conditions, the following should be taken into consideration:

(1) Easy operation and maintenance
(2) Compatibility of parts
(3) Justification of supporting operation and maintenance

For preparing the rehabilitation plan's feasibility study, the following basic conditions should be established.

(1) Basic Conditions of the Plan

1) Except for the turbine unit, all existing No. 2 Unit facilities can be utilized in their present state even after increasing the turbine's output to 74 MW.

2) The soil data obtained for No. 3 installation will be utilized in the preparation of the rehabilitation plan.

3) The remaining service life of power plant units are as follows:

Unit No.	Installed Capacity (MW)	Installation Year	Remaining Service Life (years)
No. 1	33	1958	12 (by year 2001)
No. 2	66	1975	22 (by year 2011)
No. 3	74	1982	25 (by year 2014)

4) The future installation of the No. 4 Unit should be taken into consideration when determining the scale of the cooling system improvement work. Additionally, consideration should be given to solving the problems related to the insufficient capacity of the existing ash disposal yard.

5) Governor Unit Improvement

The importance of the power plant will increase as a result of the increased output of the No.2 unit. As the power plant must be highly reliable, the existing governor unit should be converted to an electrical type unit.

(2) Construction Work Conditions

The Feasibility Study is related to rehabilitation or improvement work; thus, there are no special problems involved concerning equipment and material transportation, and construction work.

The principal conditions for the construction work are as follows:

1) Local contractors will be used for work related to civil engineering and equipment.
2) It may be possible to proceed simultaneously with No. 2 Unit's turbine output increase work and the instrumentation improvement work in order to minimize the shutdown period. In the Feasibility Study, however plans were made to implement these two tasks independently.
3) The manufacturers will provide instructors for the new equipment.

(3) Basic Conditions for Preparing Cost Estimates

Cost estimate items are classified based on ISA's standardization data as follows:

1) Portion to be Covered by Foreign Currency (US$):

		Ratio to FOB Price (%)	Ratio to Civil Engineering Work Cost (%)
a)	Machinery and Material Cost	100	-
b)	Shipping and Insurance Fee	12	-
c)	Contingencies for Mechanical Facilities	17	-

2) Portion to be Covered by Domestic Currency (Col $):

		Ratio to FOB Price (%)	Ratio to Civil Engineering Work Cost (%)
a)	Tax	3.5	-
b)	Value Added Tax	13.4	-
c)	Law 68	2.2	-
d)	Law 50	8.8	-
e)	Proexpo	5.5	-
f)	Nationalization	2.2	-
g)	Inland Transportation and Insurance Fee	6	-
h)	Installation and Testing	16	-
i)	Civil Engineering Work	-	100
j)	Contingencies for Civil Engineering Work	-	15
k)	Engineering Fee		
	- Civil Engineering Work	-	11.5
	- Mechanical Facilities	15	-

3) Exchange Rate: US$ = 369.4 Col $ = ¥140

4) Generating Cost (same figure of 1987): 6.97 Col $/kWh

5.3 Study Procedure

For conducting the rehabilitation plan's Feasibility Study, the major work contents and items to be examined were indicated in flow charts Figs. 5.3.1 thru 5.3.3.

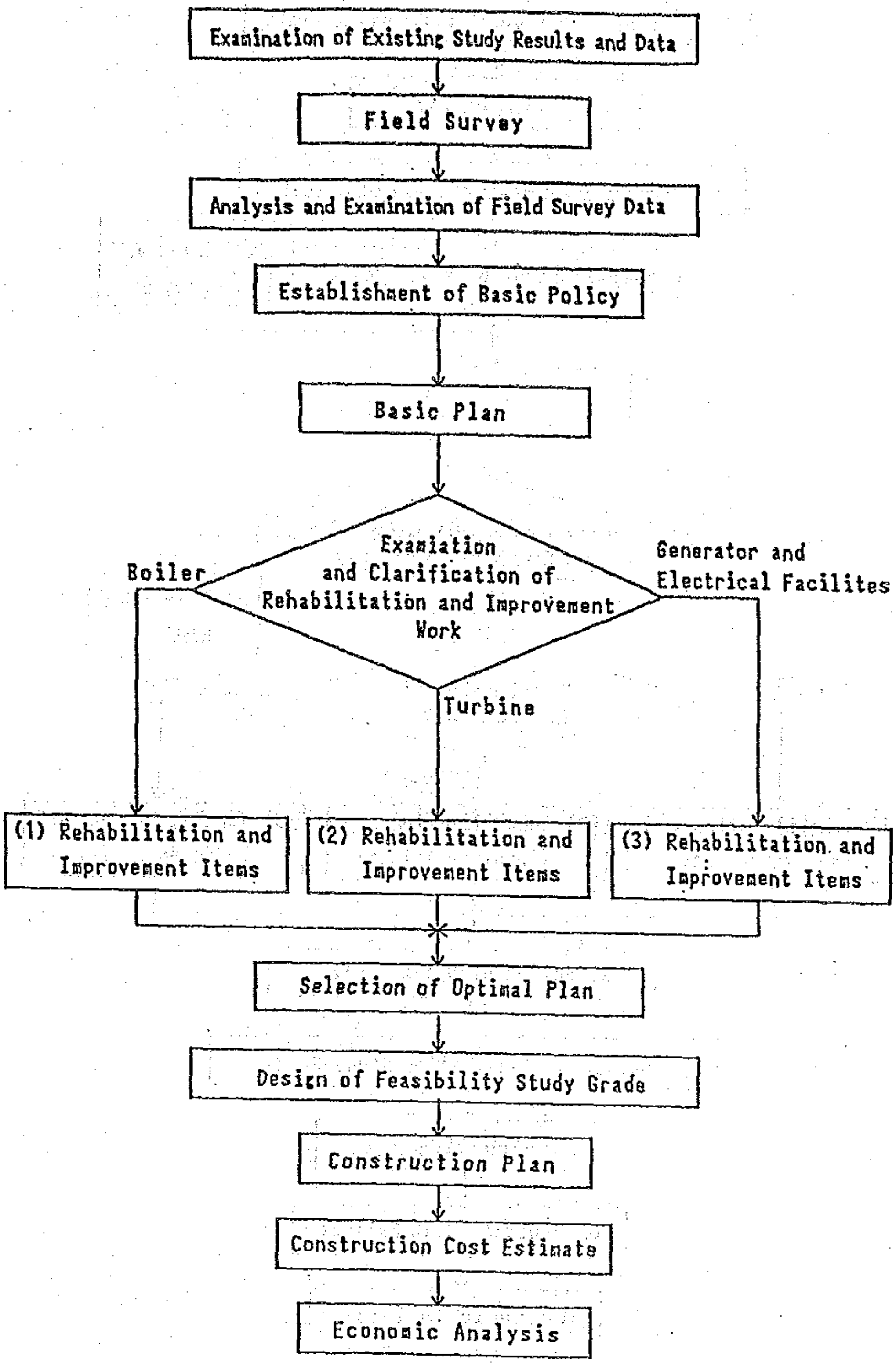


Fig. 5.3.1 Work Procedure Flow Chart for No. 2 Unit Turbine Output Increase Plan

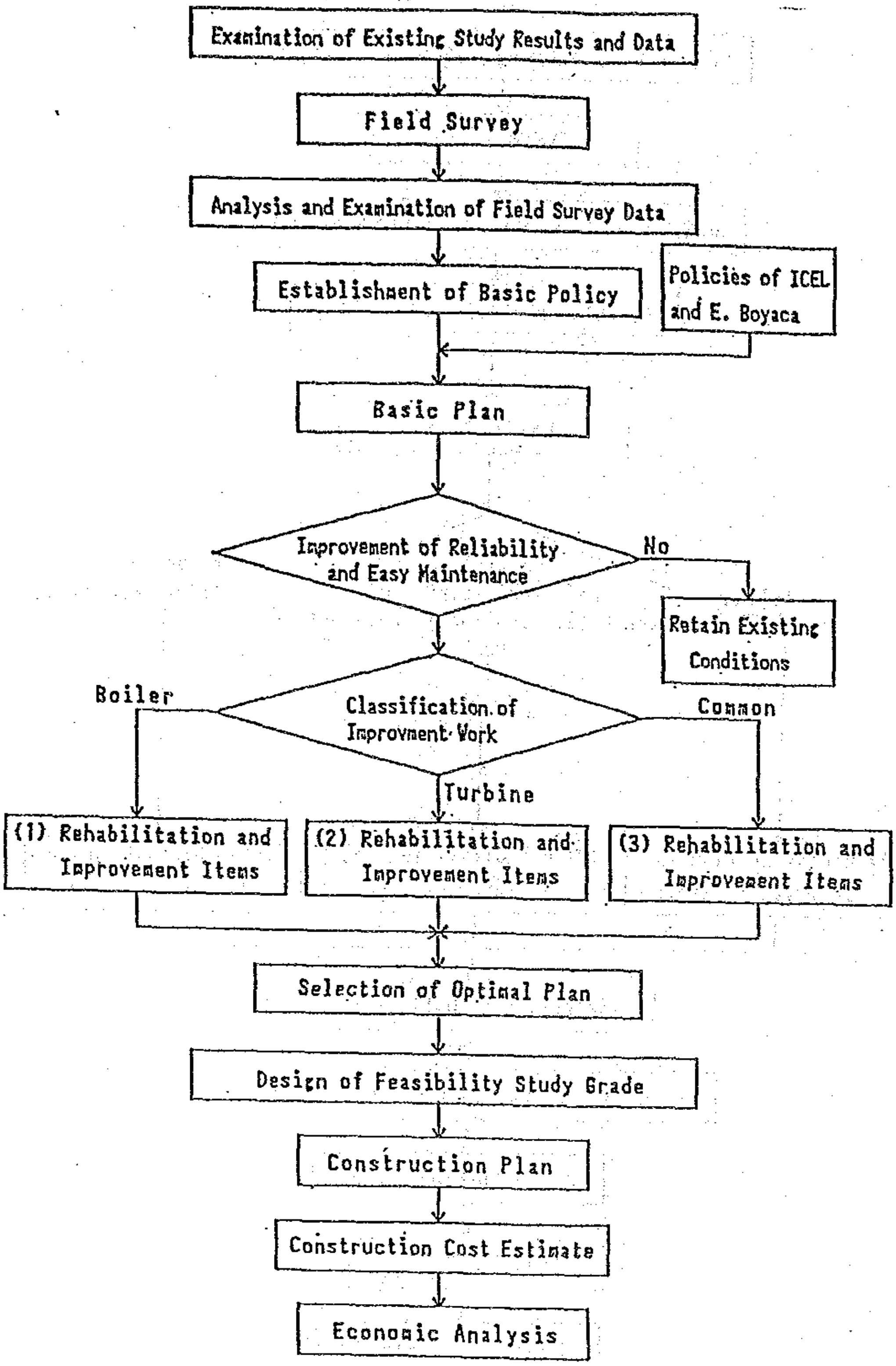


Fig. 5.3.2 Work Procedure Flow Chart for Instrumentation System Modification Plan

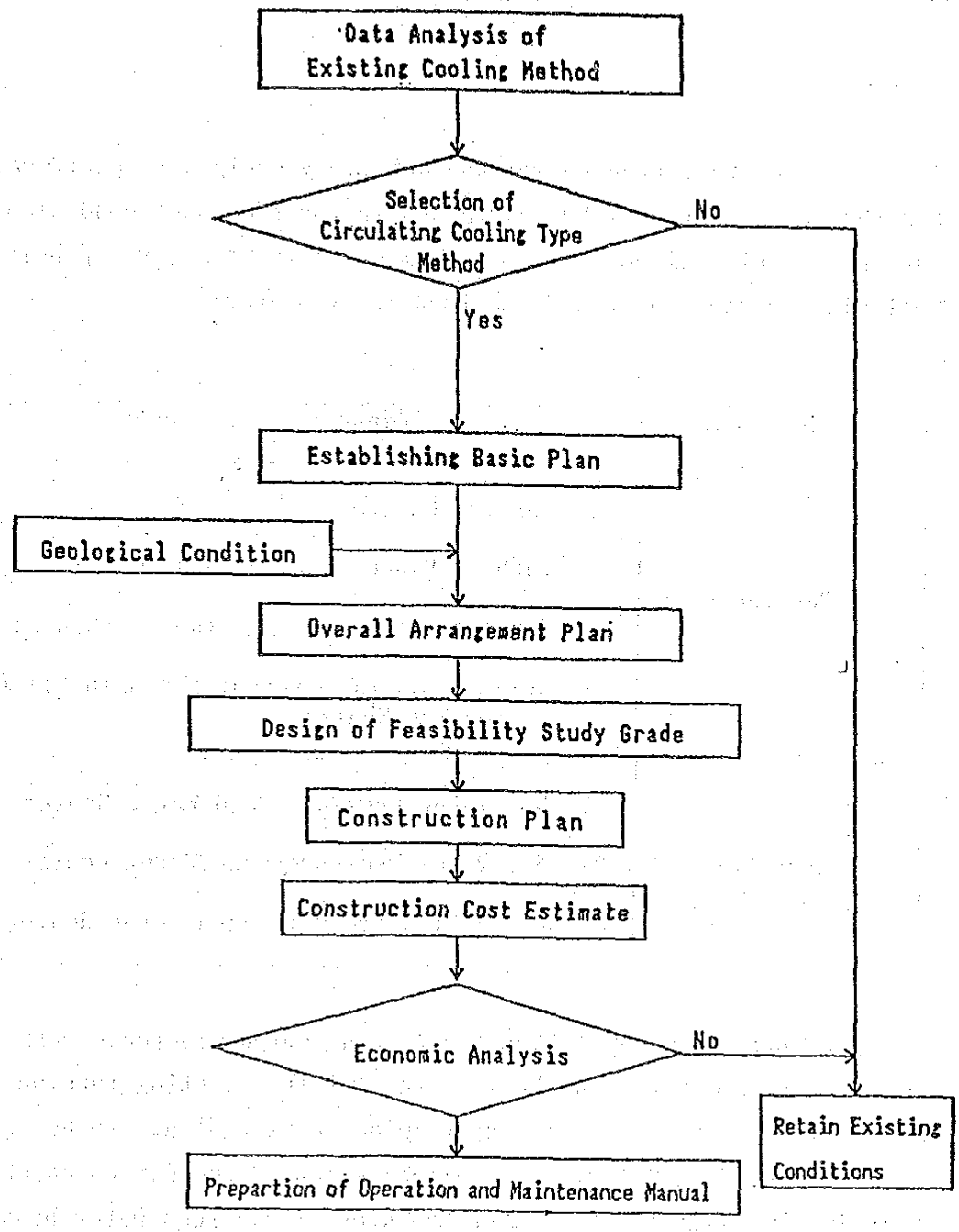


Fig. 5.3.3 Work Procedure Flow Chart for Cooling System Modification Plan

6. NO. 2 UNIT TURBINE OUTPUT INCREASE PLAN

6.1 Design

Boiler, generator, transformer and auxiliary equipment specifications for the No. 2 Unit will be maintained in their present conditions. Turbine output will be increased from 66 MW to 74 MW by replacing the following turbine parts and the feed water heater:

No.	Unit Name	Parts to be Replaced
1	Turbine Unit	1) Turbine Rotator 2) Turbine Blades (No. 1 thru No. 16) 3) Nozzles and Diaphragms (No. 1 thru No. 16) 4) Drive Shaft of Governor and Main Oil Pump (Extension Shaft)
2	Feed Water Heater	1) No. 1 Low Pressure Feed Water Heater 2) No. 2 Low Pressure Feed Water Heater 3) No. 4 High Pressure Feed Water Heater

Heat balance after completing the turbine output increase work is shown in Fig. 6.1.1. The heat balance of the existing turbine is shown in ANNEX-III.1. Existing turbine parts that are to be replaced are shown in Fig. 6.1.2. A detailed sketch of the extension shaft is included in ANNEX-III.2. Major features of the feed water heater are shown in ANNEX-III.3. Detail technical data of #2 boiler is given in ANNEX-III.5.

6.2 Implementation Plan

1) Work Plan

For implementing turbine output improvement work, a thorough examination of replacement work procedures for each unit is essential. This is especially true for the replacement of the feed water heater because of space limitations. Other data related to the output increase plan are listed in ANNEX-III.4.

(1) Optimal Capital Investment

The No. 2 Unit's power generating facilities have 22 service life years remaining. Even after completing the turbine output increase work, the capacities of the boiler, generator, and other related facilities will be fully utilized without any modifications.

Considering that the effective use of power generating facilities are related to the nation's power condition, it is desirable that the turbine output increase work be implemented as soon as possible.

(2) Construction Time

No. 2's shutdown period for the turbine output increase work is approximately two months; thus, if there is a power shortage during this period, it will be necessary to purchase electricity from ISA to meet the demand.

2) Construction Schedule (Tentative Plan)

Since this plan is for the rehabilitation work of the existing power plant, the work should be undertaken by the original plant installation contractor. The contractor may take approximately 14 months for the manufacture of machinery and about 2 months to accomplish the installation work. The construction schedule was prepared as shown in Table 6.2.1.

6.3 Construction Cost Estimate

The construction cost is estimated to be US$ 6.3 million. The cost breakdown follows:

(1) Portion to be Covered by Foreign Currency: (million US$)

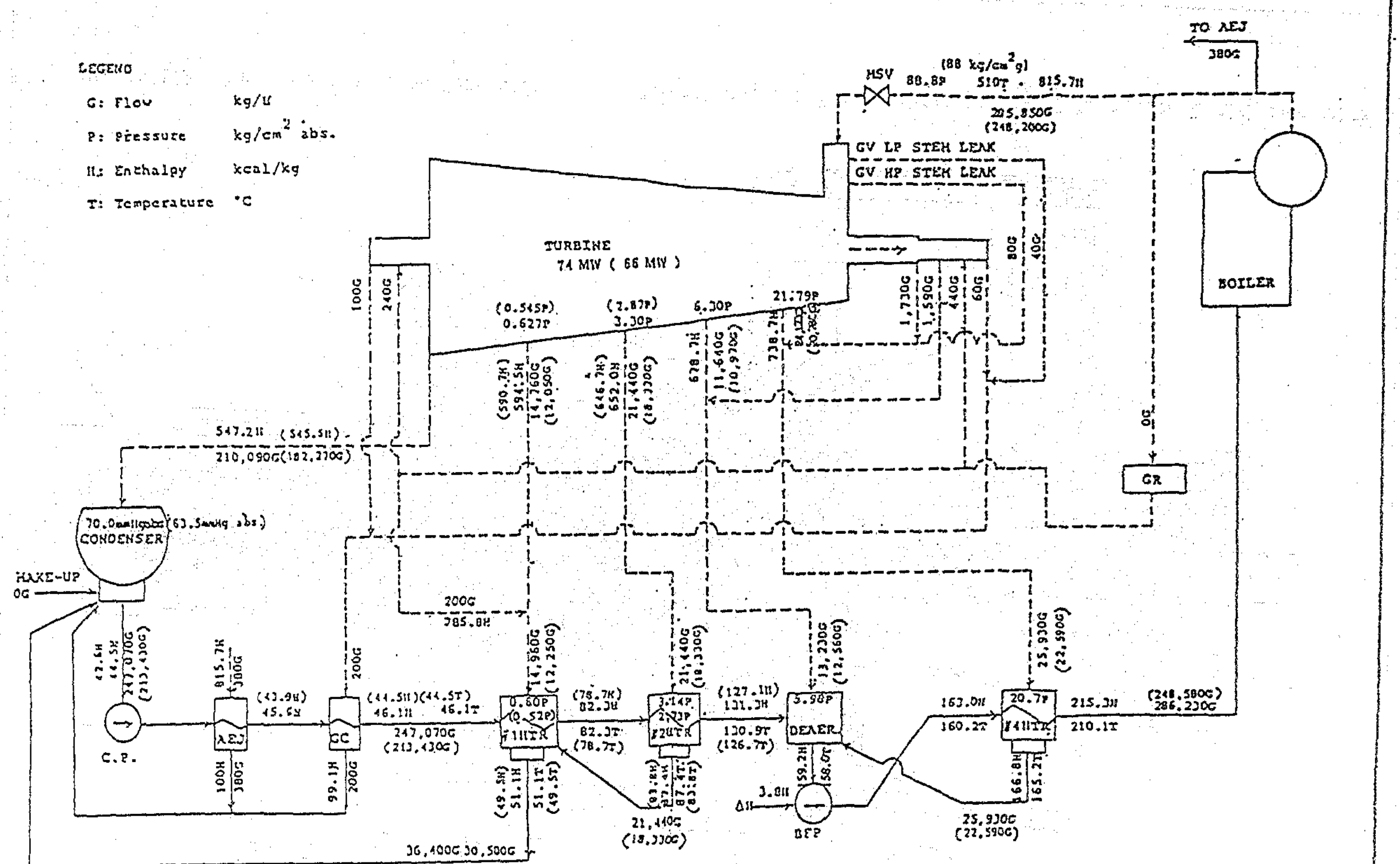
a)	Machinery and material cost	3.14
b)	Shipping and insurance fees	0.38
c)	Contingencies for mechanical facilities	0.54
	SUBTOTAL	4.06

(2) Portion to be Covered by Domestic Currency

a)	Tax	0.11
b)	Value added tax	0.42
c)	Law 68	0.07
d)	Law 50	0.28
e)	Proexpo	0.17
f)	Nationalization	0.07
g)	Inland transportation and insurance fee	0.19
h)	Installation and testing	0.50
i)	Engineering fees (Mechanical facilities)	0.47
	SUBTOTAL	2.28
	TOTAL	6.34

6.4 Economic Effects

The estimated unit construction cost is US$ 793/kW. By assuming the plant operation rate as being 52% (the 1988 value) and having the present number of personnel, the generating cost per unit electricity will be US$ 20 mill/kWh.



Note 1: Figures shown in parentheses indicate the values of existing unit (66 MW)

2: Independent figures without parentheses indicate values that will not change.

Fig. 6.1.1 Heat Balance Diagram

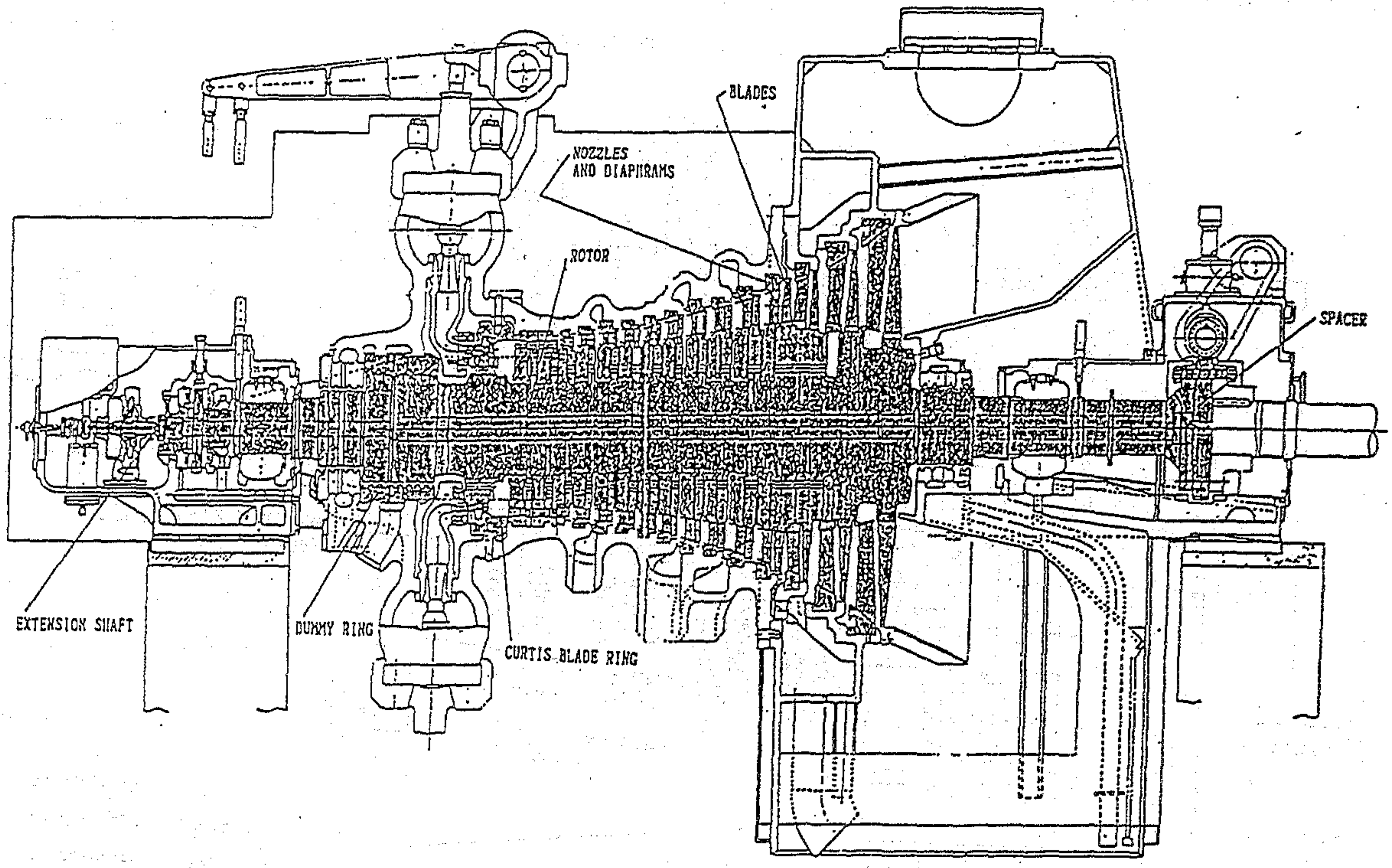
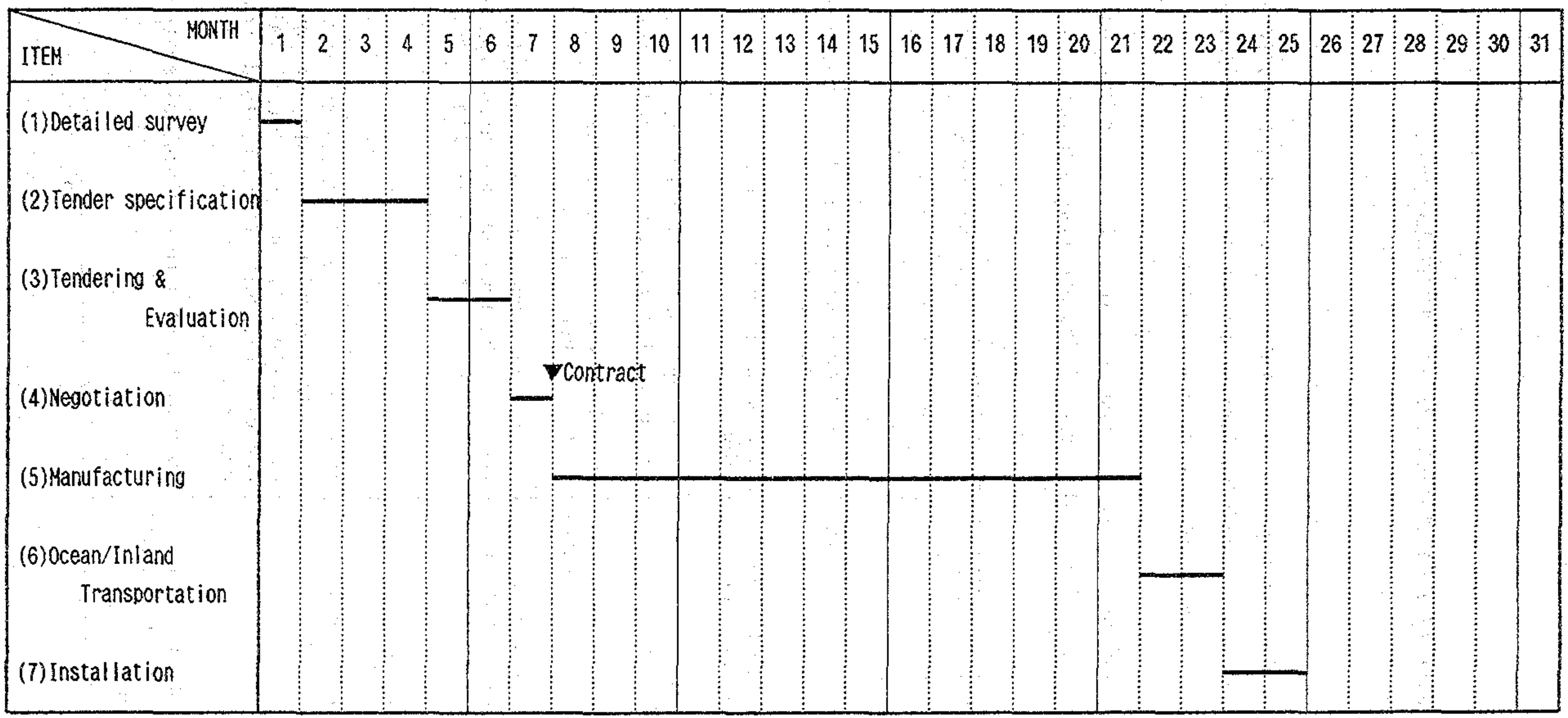


Fig. 6.1.2 Turbine Parts to be Replaced

Colored parts indicate those that will be replaced with new units.

Fig. 6.2.1 TENTATIVE IMPLEMENTATION SCHEDULE



7. NO. 2 UNIT INSTRUMENTATION SYSTEM IMPROVEMENT PLAN

7.1 Design

The existing air type instrumentation system will be modified to an electric type in order to improve reliability, secure accurate operations, and provide easy maintenance.

The supervisory meters and control units at the central control board are to be modified. The major items are listed below:

No.	Control Unit	Planned Work
1	Boiler Unit:	
	1) Automatic Boiler Control	To replace with a Digital automatic boiler control unit (DBC)
	2) Automatic Boiler Master Control	To feed back the coal feeder speed as a coal flow
	3) Heavy Oil Control	To set up a new boiler master circuit in DBC by installing a heavy oil flow meter
	4) Main Steam Pressure Control	To set up a new outlet steam temperature cascade control in DBC
	5) Starting Feed Water Control	To install a DBC control circuit for allowing the starting feed water control valve to control drum level at starting time.
2	Turbine Unit:	
	1) Mechanical Governor	To convert to a digital electric/hydraulic governor control unit in order to automate the acceleration, frequency, stress, valve opening and closing, self run back, load, governor controls
	2) Condenser and Evaporator Level Control	To convert to a remote control system by DBC

For replacing the existing boiler control unit with a digital automatic boiler control unit (DDC), it is necessary to modify the existing feed water flow control system. An example of the modified feed water flow control diagram is shown in Fig. 7.1.1.

In order to conduct overall plant instrumentation and control operations, the existing instrumentation and control systems should be replaced by the following computer operated systems:

(1) Digital Automatic Boiler Control System
(2) Digital Electric/Hydraulic Governor Control System
(3) Data Acquisition System

The installation of these systems will have the following effects:

Planned System	Effects
1. Digital Automatic Boiler Control	- More reliable control - Easy maintenance - Higher performance
2. Digital Electric/ Hydraulic Governor	- Automatic load control - Frequency control - Automatic starting and stopping
3. Data Acquisition System	- Easy instrumentation - Various data collection

7.2 Implementation Plan

(1) Work Plan

It is necessary to prepare the instrumentation improvement work plan that will make plant shutdown as short as possible.

Plant shutdown will last about 3 months. The effects of the plant shutdown can be minimized by scheduling it to coincide with No. 2 Unit's turbine output increase work.

An outline of improvement work specifications is shown in ANNEX-IV.1, and the data related to the existing instrumentation units are shown in ANNEX IV.3.

(2) Implementation Schedule

It is considered that it will take approximately 12 months to manufacture the machinery units and procure materials. About 3 months will be needed for constructing the facilities and installing the machinery. The improvement work implementation schedule was prepared as shown in Table 7.2.1.

7.3 Cost Estimate

The estimated cost for the improvement work is US$ 5.8 million. A breakdown of the estimated costs are as follows:

	(million US$)
(1) Portion to be covered by Foreign Currency:	
a) Machinery and Materials	2.85
b) Shipping and Insurance Fees	0.34
c) Contingencies for Mechanical Facilities	0.49
SUBTOTAL	3.68
(2) Portion to be Covered by Domestic Currency	
a) Tax	0.10
b) Value added tax	0.38
c) Law 68	0.06
d) Law 50	0.25
e) Proexpo	0.16
f) Nationalization	0.06
g) Inland transportation and insurance fee	0.17
h) Installation and testing	0.46
i) Engineering fees (Mechanical facilities)	0.43
SUBTOTAL	2.07
TOTAL	5.75

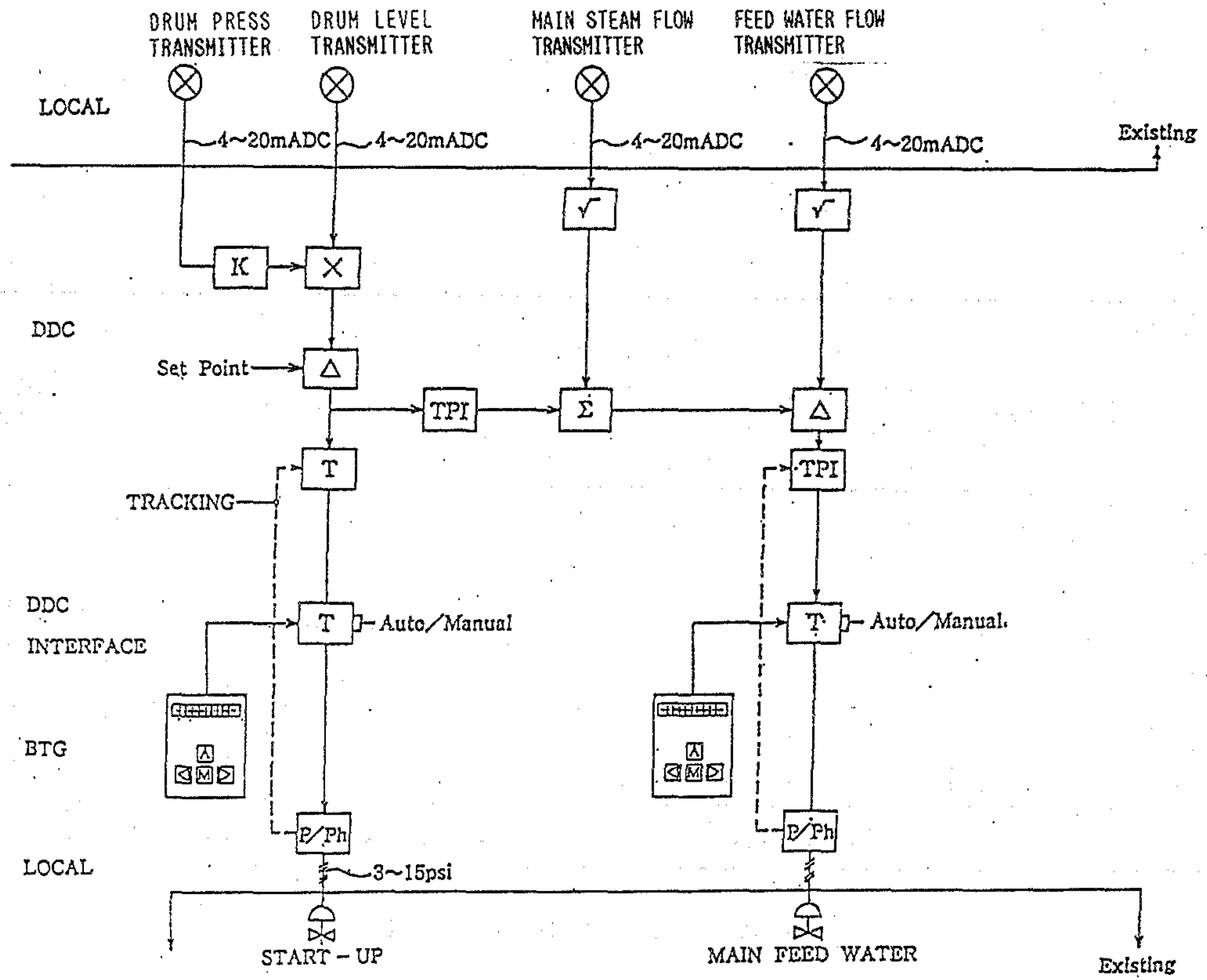
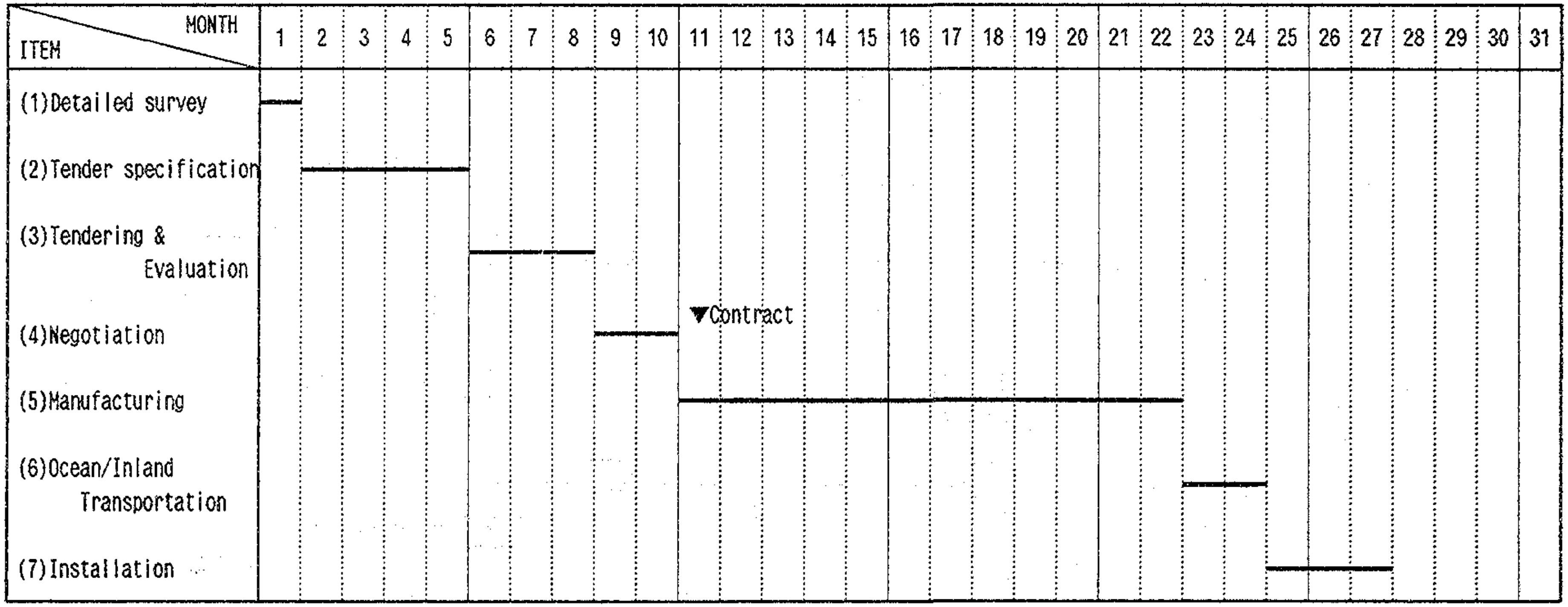


Fig. 7.1.1 Feed water control system

Fig. 7.2.1 TENTATIVE IMPLEMENTATION SCHEDULE



7.4 Economic Effects

As a result of the introduction of the automatic instrumentation and control systems, plant operation work during starting and shutdown times will be greatly reduced making planned maintenance work possible, thereby minimizing overall plant work.

The estimated cost per unit installed capacity is US$ 87/kW. By assuming the operating cost to be the same as the present value, an additional US$ 1.9 mill/kWh to the generating cost will be required.

8. COOLING METHOD IMPROVEMENT PLAN

8.1 Data Analysis of Existing Cooling Water System

(1) Present Condition of the Cooling Water System

As shown in Drawing No. TP-C1, the pumps for condenser cooling water and the shaft bearing cooling water for the auxiliary units are installed in the same water tank.

The warm water from the condenser and auxiliary units is discharged into the Chicamocha River through the same duct. The discharged water mixes with the river water then flows into the cooling water pond. After the water in the pond is cooled by the ambient temperature, it is pumped to the condenser and auxiliary units.

(2) Weather Data

No weather data (temperature and humidity) is kept. During the field survey periods, the Study Team were unable to obtain recorded weather data.

(3) Present Problems

Warm water from the condenser and auxiliary units is discharged at the upstream point of the cooling water intake in the Chicamocha River, therefore, the following problems exist:

1) A large cooling water pond is required.

2) Since the intake water temperature is higher than the original river water's and it must be cooled by ambient temperature in the cooling pond, the cooling efficiency of the existing system is low.

As a result of No. 2 turbine's output increase work, the discharged cooling water temperature will be higher than at present and the cooling efficiency will decrease even further.

3) Since intake water is cooled by ambient temperature, the cooling efficiency is completely controlled by weather conditions.

4) Warm water flowing into the cooling water pond fosters the growth of such water grass as Buchon which interfere with the water flow. Furthermore, labor work is required for grass removal.

8.2 Layout Plan

The existing cooling water system will be modified into the type equipped with cooling towers. Based on data collected by the field survey and the pre-feasibility study, the data analysis for the existing cooling water system was conducted. Analysis results are as follows:

8.2.1 Selection of Cooling Method

There are several types of cooling methods as shown in Table 8.2.1. After comparing their overall features, the forced draft cooling tower method was selected for the Project based on the following reasons.

1. Available space for the cooling facility installation is limited.

2. Effects caused by weather conditions are negligible.

3. Stable performance.

Table 8.2.1 Cooling Method Comparison

Cooling Method		Installation Space	Effects by Weather	Cooling Efficiency	Power	Economy	Performance	Remarks
Cooling Pond		Large	Large	Low	Not required	Poor	Unstable	
Spray Pond		Large	Large	Low	Not required	Poor	Unstable	
Cooling Tower	Spray Type	Small	Small	Medium	Not required	Good	Stable	Only applicable when large water temperature difference is availab
	Natural Ventilation Type	Medium	Medium	Medium	Not required	Fair	Slightly unstable	
	Forced Draft Type	Small	Small	High	Required (large)	Good	Stable	

The existing cooling pond method should be changed to the forced draft cooling tower method.

Based on data obtained during the filed survey period and from the information described in the pre-feasibility study report, the exsiting cooling system was analyzed. The results of the analysis are described below:

8.2.2 Cooling Water System

The existing warm water discharge route is mainly provided by an open channel. Water pressure cannot be applied to the underground culvert sections. It is not sufficient to only replace the existing condenser units' circulating water pumps; therefore, they will be retained in their present conditions and booster pumps will be installed to pump the discharged warm water into new cooling towers before the discharged warm water flows in the Chicamocha River. This cooling water system is shown in Drawing No. TP-C1.

8.2.3 Cooling Tower Layout Plan

The installation of the Termopaipa No. 4 Unit is presently in the planning stage. The circulating water cooling method with a cooling tower will be adopted for the No. 4 Unit. The cooling tower layout plan is shown in Drawing No. TP-C2.

It is assumed that the ground at No. 1, 2 and 3 Units' cooling tower sites along the Chicamocha River is soft; thus, cooling tower foundations are to be designed as piled foundation types.

For the detailed design, it is necessary to analyze and examine the geological data.

8.3 Design

8.3.1 Cooling Tower (Forced Draft Type)

(1) Capacity

The cooling tower capacity should be decided based on the cooling water quantity necessary for the condensers and for the cooling of the auxiliary machinery shaft bearings.

Table 8.3.1 Cooling Tower Capacities

Unit: m^3/Hr

Item \ Unit No.		No. 1	No. 2	No. 3	Remarks
Required Cooling Water	a) Condenser Cooling	6,500	11,600	12,200	
	b) Shaft Bearing Cooling	-	114	60	
	c) Subtotal	6,500	11,714	12,260	a) + b)
Cooling Tower Capacity		7,000	13,000	13,000	c) x 5-10%

(2) Number of Cooling Tower Units

No. 1 and No. 2 Units presently share a single cooling water system. No. 3 Unit uses one independent cooling water system.

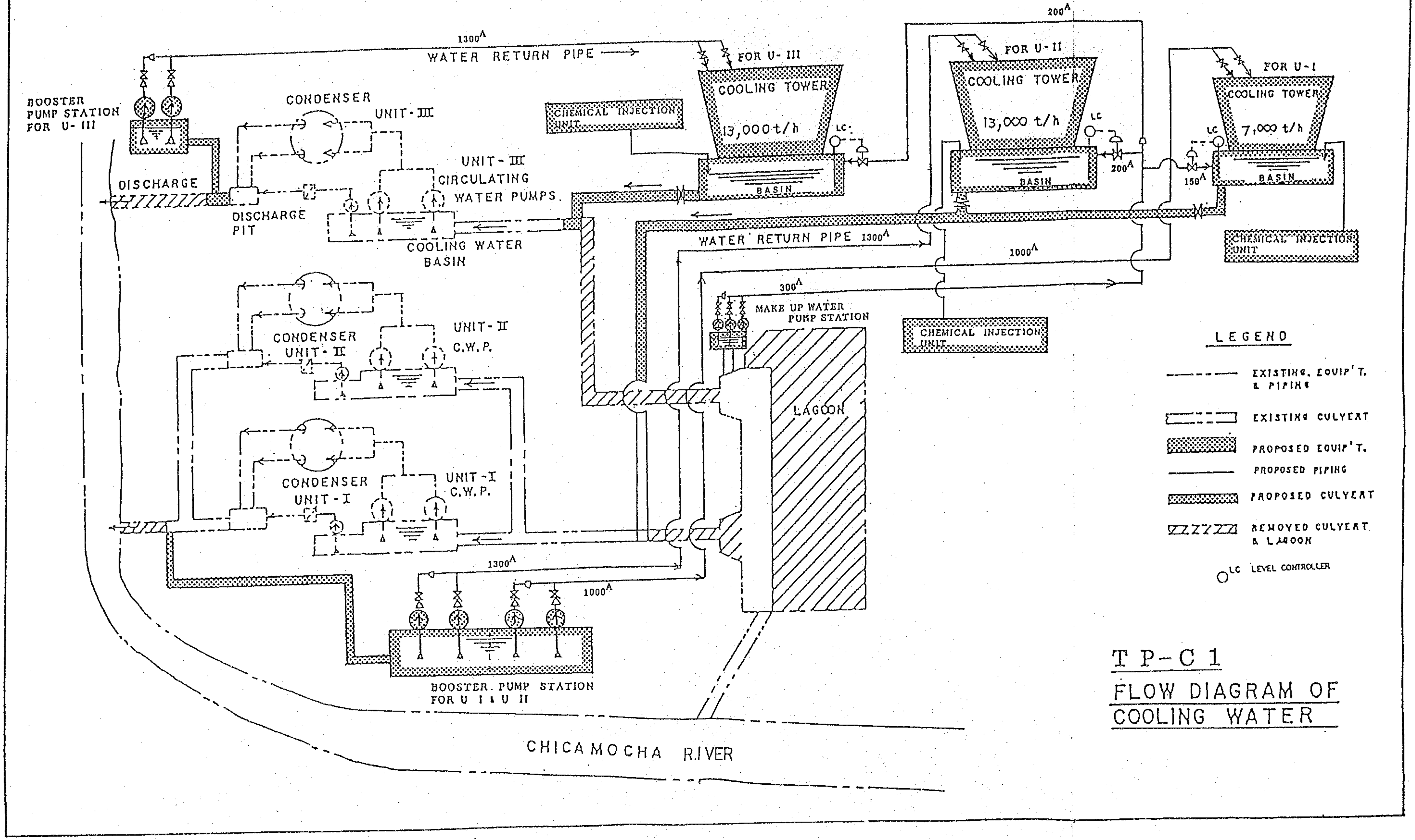
The No. 1 Unit has been in operation for 31 years; No. 2 for 15 years.

A single cooling tower may be able to handle units No. 1 and 2, but to achieve that, a large capacity tower will be required.

As the remaining service life of the No. 1 Unit is very short in comparison to No. 2's, it can be concluded that it would be uneconomical to install one cooling tower for the two units. Also, there is the problem of locating a large cooling tower in the power station. With this reasoning in mind, it was planned to install one small capacity cooling tower for each unit.

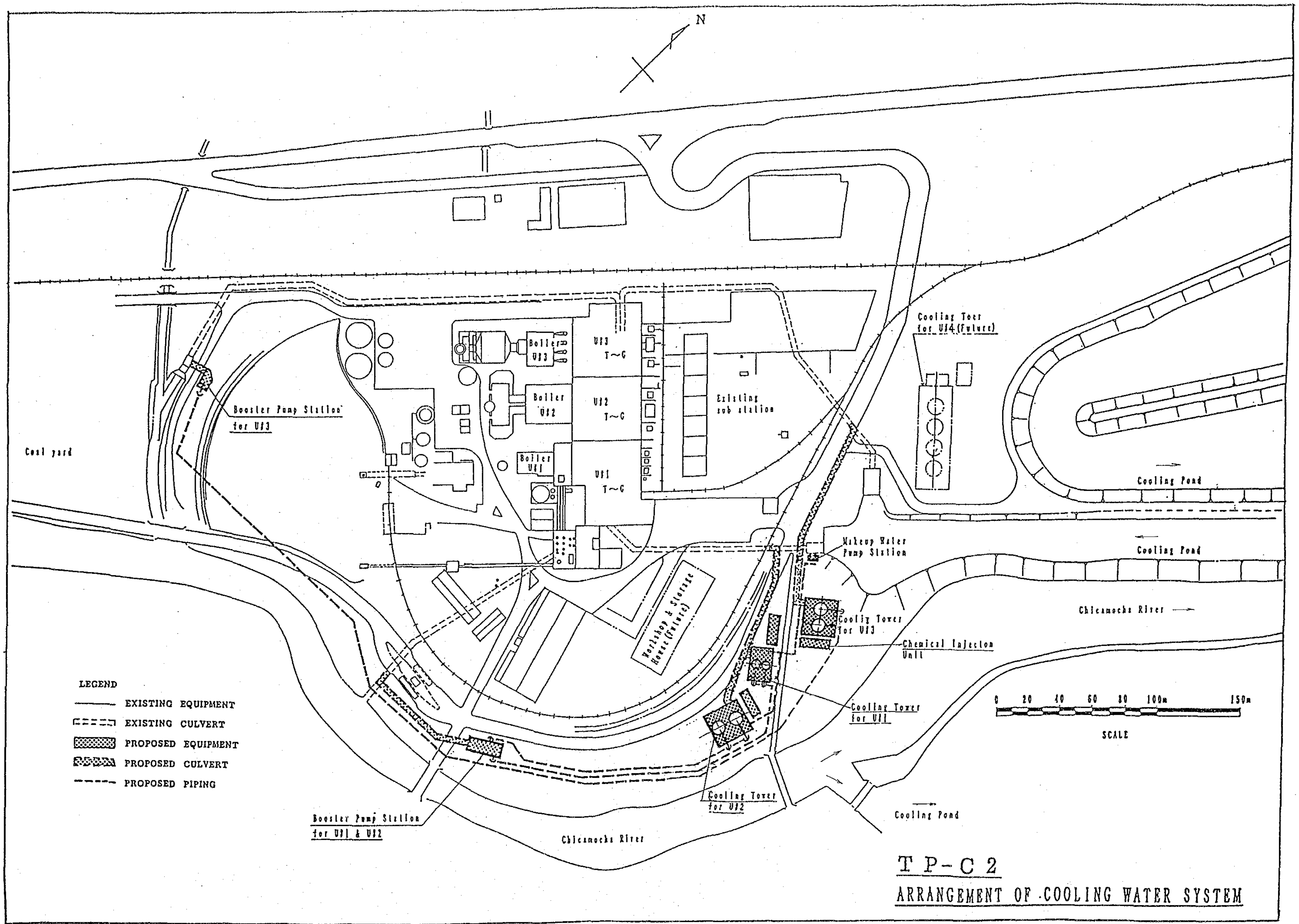
(3) Cooling Tower Data Sheet

The data sheet for the cooling towers is attached in ANNEX-V.1.



TP-C1

FLOW DIAGRAM OF COOLING WATER



T P - C 2

ARRANGEMENT OF COOLING WATER SYSTEM

8.3.2 Booster Pump for Circulating Water

A new pump station will be built along the warm water discharge channels to pump water to the cooling towers.

(1) Number of Pumps and their Capacities

Booster pump capacities should be sufficient for cooling off the existing condensers and shaft bearings of auxiliary machinery. It was planned to install the same number of booster pump units as there are existing cooling water circulating pumps (one for normal use and one for standby use at each plant unit).

Booster pump specifications are as follows:

Unit No.	Capacity x Lift (m^3/hr) x (m)	Motor Output (kW)	Number of Pumps
No.1	7,000 x 20	520	2 (one for normal use and one for standby)
No.2	13,000 x 20	950	2 (one for normal use and one for standby)
No.3	13,000 x 20	950	2 (one for normal use and one for standby)

(2) Selection of Pump Type

There are horizontal axis and vertical axis type pumps. Both types were examined and the vertical axis type was selected for the following reasons:

1) The available pump installation area is small due to the arrangement of the existing power plant
2) Automatic operations can be easily conducted
3) Motors can be easily protected during a flood

Table 8.3.2 Pump Type Comparison List

	Horizontal Axis Type	Vertical Axis Type
MERITS	(1) Since most of the pump body is in air, the pump doesn't suffer severe corrosion. (2) Maintenance and inspection of major pump parts is easy to perform. (3) Disassembling and assembling work is easy. It is not necessary to remove the motor for disassembling the pump unit of a horizontal split-casing pump. (4) Easy to connect to a horizontal shaft motor. Common standard type motors can be used. (5) In general, this type of pump is quite inexpensive.	(1) A small area is required for pump installation (2) No cavitation problems exist because the pump impeller is submerged. (3) Pump starting is easy. This type of pump is suitable for automatic operations. No priming is required -- a vacuum pump is not required. (4) The motor can be mounted at any elevation and can therefore be kept safe during a flood. (5) It is easy to provide this type of pump with watertight protection. It is suitable for outdoor installation.
DE-MERITS	(1) Large installation space is required. (2) Pump suction height is limited. If the pump is installed too high, cavitation may result. (3) Priming is required for starting the pump. Pump operations are complex. A vacuum or air-tight pump is required. Automatic pump operations are complicated. (4) Motor protection should be provided for protection against flood waters.	(1) Since most part of the pump body is submerged, it is subject to corrosion. (2) Inspection work of the pump's major parts is difficult. (3) Pump disassembling and repair work is quite difficult. It is necessary to remove the motor and reduction gear in order to disassemble the pump. (4) In general, the price for this type of pump is expensive.

8.3.3 Makeup Water Pump

A new makeup water pump station will be built near the existing cooling water pond in order to pump makeup water into the cooling towers.

(1) Makeup Water Quantity

Water loss in the cooling towers due to evaporation, spillage, and boiler blowdown operations must be replenished by adding water to the cooling water system. The detailed breakdown of the required water quantity to be replenished is shown in the data sheet in ANNEX-V.1. A summary of the required water replenishment quantity for each plant unit is as follows:

1) No. 1 Unit:	117.6 m^3/hr
2) No. 2 Unit:	218.4 m^3/hr
3) No. 3 Unit:	218.4 m^3/hr
TOTAL	554.4 m^3/hr

(2) Number of Pumps and their Capacities

If one makeup water pump has to be provided for each cooling tower, a large pump installation space would be required. Also, if a number of pumps need to be installed, the required construction and operating costs would be high. For these reasons, it was planned to install three makeup water pumps for the three cooling towers (two units for normal operations and one for standby use).

Pump capacities should be 554.4/2 = 277.2, say 280 m^3/hr.
Pump lift: 10 m.
Motor Output: 11 kW.

(3) Selection of Pump Type

For the same reasons the circulating water booster pumps were selected, the vertical type pumps were selected by taking into account installation space limitations and automatic operation requirements.

8.3.4 Cooling Water Piping System

The warm water booster pumps and cooling towers will be connected by piping systems (these systems are shown in Drawing No. TP-C2). In order not to interfere with existing ground structures, the pipes will be installed underground.

(1) Pipe Sizes

Main pipe sizes should be as follows:

For No. 1 Unit:	Diameter =	1,000 mm (1,016 mm O.D. x 10.3 mm thick)
For No. 2 Unit:	Diameter =	1,300 mm (1,320 mm O.D. x 11.1 mm thick)
For No. 3 Unit:	Diameter =	1,300 mm (1,320 mm O.D. x 11.1 mm thick)

(2) Pipe Material

Pipe material should be carbon steel (STPY 41, JIS G3457, or ASTM A139, GR A equivalent). The pipes should be coated on the outside with polyethylene.

(3) Corrosion Protection Measures

The piping systems will be buried underground and therefore should be provided with cathodic protection to prevent them from electrolytic corrosion (pipe wall boring) caused by electric current leakage into ground.

Cathodic protection methods:

1) Current Anode Protection Method
2) External Electrical Power Source Method
3) Enforced Current Removal Method

A comparison of these three methods are shown in Table 8.3.3.

Item \ Method	Galvanic Anode Method	External Electric Power Source method	Forced Drainage Method
Power Source	Not required	Required	Required
Power Source Voltage	Influenced mainly by earth resistance of electrode	Influenced mainly by earth resistance of electrode	Influenced mainly by earth resistance of electrode
Electrode	Required	Required	Not required
Current Adjustment	Impossible	Possible	Possible
Cost	Inexpensive	Expensive	Medium
Effect on Other Underground Pipes:			
- Cathode Action	Yes	Yes	Yes
- Anode Action	No	No	No

As a result of the above comparison, the current anode protection method was selected for economical reasons. The specifications for cathodic protection of piping system facilities using the current anode protection method are shown in ANNEX-V.2.

8.3.5 Chemical Injection Unit

The water cooled in cooling towers gradually becomes concentrated when it circulates through the system and thereby changes the water quality. The concentrated water may corrode the circulation system's equipment and piping. To prevent possible damage, the cooling water quality should be maintained within a certain level by chemical injection.

Features of the chemical injection unit are summarized in ANNEX-V.3.

8.4 Implementation Plan for Cooling Method Improvement Work

For the preparation of the implementation plan for cooling method improvement work, no special problems are expected to be encountered when transporting and installing the machinery units. However, the following aspects were taken into consideration for the plan's preparation:

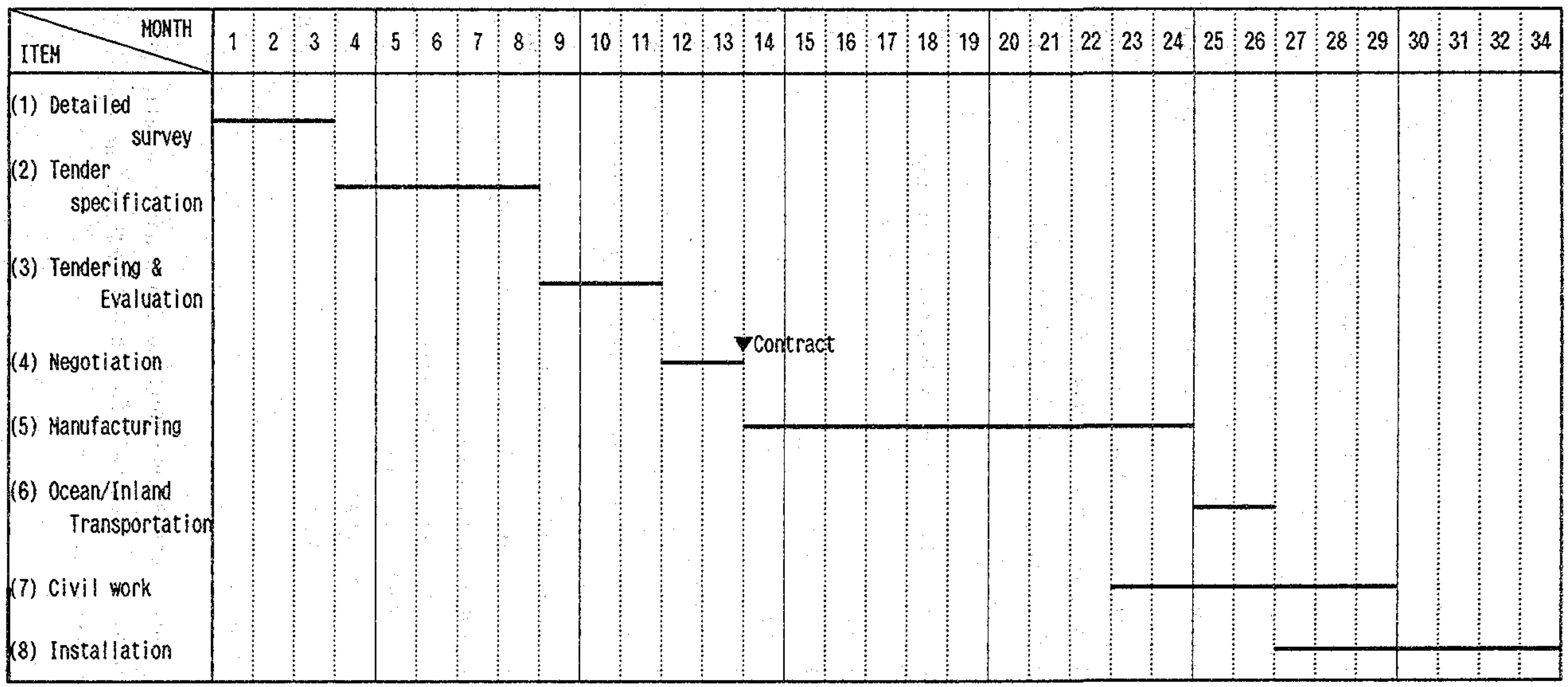
(1) For the cooling tower foundation work, no geological data of the site has been forthcoming; thus, the foundations were planned as pile type having pile depth of 10 m.

(2) It was assumed that an approximately 10 month period would be required to manufacture the cooling towers and 2 months time to ship them.

(3) Implementation of the cooling method improvement work should take place without considering the possibility of using the existing cooling water pond for an ash disposal yard.

The tentative implementation schedule is shown in Table 8.4.1.

Fig. 8.4.1 TENTATIVE IMPLEMENTATION SCHEDULE



8.5 Cost Estimate

The estimated cost of the improvement work is US$ 14.8 million.

A breakdown of the estimated cost is as follows:

(1) Portion to be Covered by Foreign Currency: (million US$)

a)	Machinery and Materials	6.79
b)	Shipping and Insurance Fees	0.81
c)	Contingencies for Mechanical Facilities	1.16
	SUBTOTAL	8.76

(2) Portion to be Covered by Domestic Currency

a)	Tax	0.24
b)	Value added tax	0.91
c)	Law 68	0.15
d)	Law 50	0.60
e)	Proexpo	0.37
f)	Nationalization	0.15
g)	Inland transportation and insurance fee	0.41
h)	Installation and testing	1.09
i)	Civil engineering work	0.91
j)	Contingencies for civil engineering work	0.14
k)	Engineering fees:	
	- Civil engineering work	0.12
	- Mechanical facilities	1.02
	SUBTOTAL	6.11
	TOTAL	14.87

8.6 Economic Effects

The estimated improvement work cost per unit installed capacity is US$85.7/kW. An additional US$ 4.9 mill/kWh to the generating cost will be required.

ANNEX-I FACILITY REGISTER

CONTENTS

1. Mechanical equipment (1/7)

No.	Description	Unit	#I	#II	#III
1	Turbine				
	(1) Type		Impulse-single flow-condensing turbine		
	(2) Rated output (at generator terminal)	kW	30,000	66,000	74,000
	(3) Steam pressure	kg/cm2	65	88	88
	(4) Steam temperature (at inlet of main stop valve)	°C	505	510	510
	(5) Vacuum	mmHg		63.5	63.5
	(6) Revolving speed	rpm	3,600	3,600	3,600
	(7) Quantity of extracted steam		5	4	4
	(8) Pressure of extracted steam	kg/cm2 abs	17.7,8.4, 1.6,-0.4	23.7,2.2,3 -0.35	34,14.6, 1.2,-0.4
	(9) Manufacturer		ALSTHOM	MHI	MHI
2	Condensing equipment				
	2-1 Condenser				
	(1) Type		Surface condense, horizontal, two water boxes		
	(2) Condenser surface and Q'ty	m2	2,300	4,100	4,683
	(3) Volume of steam	t/h	125	260	285
	(4) Material of condenser tube				
	(5) Rated temp. of cooling water	°C	20-32	20-32	20-32
	(6) Manufacturer		ALSTHOM	MHI	MHI
	2-2 Cooling water pump				
	(1) Type		Vertical, mixed flow		
	(2) Rated capacity and Q'ty	m2	6,500x2	11,600x2	12,200x2
	(3) Discharge head	mm	920	1200	1220
	(4) Design temperature	°C	26	28	28
	(5) Manufacturer		SULZER	EBARA	MHI
	(6) Motor 1) Type		NYP86/52	MKB-R	FZKB-R
	2) Capacity and Q'ty	kW	258x2	390x2	420x2
	3) Manufacturer		ALSTHOM	MHI	MHI
	2-3 Air ejector				
	(1) Type		Jet steam		
	(2) Steam volume and Q'ty	kg/h	1	380.1	380.1
	(3) Steam pressure	kg/cm2	50	20	20
	(4) Steam temperature	°C	505	510	510
	(5) Manufacturer		ALSTHOM	MHI	MHI
	2-4 Condensate pump				
	(1) Type		----- Centrifugal -----	--- vertical ---	
	(2) Rated capacity and Q'ty	t/h	160x2	300x2	285x2
	(3) Manufacturer		ALSTHOM	EBARA	MHI
	(4) Motor 1) Type		NP747	MKB-V	SB-FV
	2) Capacity and Q'ty	kW	70x2	210x2	420x2
	3) Manufacturer		ALSTHOM	------ MHI ------	
3	Boiler				
	3-1 The true form				
	(1) Type		1-drum, natural	2-drums, natural	2-drums, natural
			----- circulation -----		

1. Mechanical equipment (2/7)

No.	Description	Unit	#I	#II	#III
	(2) Steam pressure				
	1) Maximum allowable working	kg/cm2	79	107	107
	2) At outlet of superheater	kg/cm2	68	92	93
	3) Reheater		-	-	-
	(3) Steam temparature				
	1) At outlet of superheater	˚C	505	510	515
	2) At outlet of reheater	˚C	-	-	-
	(4) Volume of evaporator				
	1) Maximum rating	t/h	136	284	300
	2) Economical rating	t/h	122	264	280
	(5) Heating surface area				
	1) Radiation	m2		826	872
	2) Touch	m2		2,889	2,836
	3) Total	m2		3,715	3,708
	(6) Super heater				
	1) Type		PENDANT	PENDANT	PENDANT
	2) Surface area	m2		1,333	2,274
	(7) Economizer				
	1) Surface area	m2	1,254	2,889	2,836
	2) Temp. of feed water (at inlet/outlet)	˚C	170/234	220	220
	(8) Furnace				
	1) Volume	m2		1,430	1,442
	2) Wall structure (type)		----- Vertical, Pendant -----		
	(9) Manufacturer		ALSTHOM	DISTRAL	DISTRAL
	3-2 Air heater				
	(1) Type		TUBES	TUBES	LJUNSTROM
	(2) Surface area	m2	5,200	25,709	13,088
	(3) Air temp.(inlet/outlet)	˚C	77/271	27/325	27/376
	(4) Manufacturer		STAIN & ROURAIX	DISTRAL	LJUNSTROM
4	Soot blower				
	(1) Type		Steam jet, rotative anrevroctable		
	(2) Manufacturer		FOREST	DIAMOND	POWER
5	Automatic boiler control				
	(1) Combustion				
	1) Type		Pneumatic	---- Pneumatic ----	
	2) Manufacturer		BAILEY-FRANCE	-- BAILEY - USA --	
	(2) Temperature				
	1) Type		Pneumatic	---- Pneumatic ----	
	2) Manufacturer		BAILEY-FRANCE	-- BAILEY - USA --	
	(3) Feed water				
	1) Type		Pneumatic	---- Pneumatic ----	
	2) Manufacturer		BAILEY-FRANCE	-- BAILEY - USA --	
6	Fuel combustion equipment				
	6-1 Coal bunker				
	(1) Structure				
	(2) Capacity and Q'ty	ton	270x3	304x3	304x3

1. Mechanical equipment (3/7)

No.	Description	Unit	#I	#II	#III
	6-2 Pulverized coal combustion equipment				
	(1) Coal scale				
	1) Type		-	-	-
	2)Capacity and Q'ty	t/h	-	-	-
	3) Manufacturer		-	-	-
	(2) Coal feeder				
	1) Type		Rotative	Belt-Conveyor	Belt
	2) Capacity and Q'ty	t/h	10x3	24x4	24x4
	3) Manufacturer				
	4) Motor				
	a. Type				
	b. Capacity and Q'ty	kW	3x3	1.7x4	1.2x4
	c. Manufacturer		ALSTHOM	--- LOWIS ALLIS ----	
	(3) Mill				
	1) type		Bowl-mill 613	EL-76 (vert)	EL-76 (vert)
	2) Capacity and Q'ty	t/h	12x3	15x4	15x4
	3) Manufacturer		RAYMOND	---- BABCOCK&W -----	
	4) Motor				
	a. Type		NP7'87	P	P
	b. Capacity and Q'ty	kW	225x3	149x4	186x4
	c. Manufacturer		ALSTHOM	RELIANCE	RELIANCE
	(4) Mill exhauster				
	1) Type		Exhauster fan	-- Primary AF --	
	2) Capacity and Q'ty	m3/min	0.3x3	0.53x4	0.53x4
	3) Manufacturer		RAYMOND STAIN&ROUB	B&W	B&W
	4) Motor				
	a. Type		-	P/AP	P/BF
	b. Capacity and Q'ty	kW	-	298x4	298x4
	c. Manufacturer		-		
	(5) Burner				
	1) Type		Tangential	---- Frontal -----	
	2) Capacity and Q'ty	kg/h	2500x12	---- 5500x12 -----	
	3) Manufacturer				
	6-3 Oil combustion equipment				
	(1) Heavy oil service tank				
	1) Type				
	2) Capacity and Q'ty	kl	50x1		50x1
	3) Manufacturer				
	(2) Heavy oil burner				
	1) Type				
	2) Capacity and Q'ty	kg/h	190x4	----- 412x12 -----	
	3) Manufacturer		STAIN&ROUB	---- PEABODY -----	
	(3) Light oil torch				
	1) Type		Air atmizing		
	2) Capacity and Q'ty	kg/h	146x4	---- 165x12 -----	
	3) Manufacturer		STAIN&ROUB	---- PEABODY ----	
	(4) Heavy oil pump				
	1) Type		H323D	3	AK-195
	2) Pressure(inlet/outlet)	kg/cm2			
	3) Capacity and Q'ty	t/h	x2	x2	x2
	4) Manufacturer		IMO SCAM	ROPER	VIKING

1. Mechanical equipment (4/7)

No.	Description	Unit	#I	#II	#III
	5) Motor				
	a. Type		VWH1006	------ P --------	
	b. Capacity and Q'ty	kW	2.2x2	---- 7.46x2 ----	
	c. Manufacturer		ALSTHOM	--- RELIANCE ---	
	(5) Light oil pump				
	1) Type		H153D	3	AK4195
	2) Pressure	kg/cm2			
	3) Capacity and Q'ty	t/h	5x2	5x2	5x2
	4) Manufacturer		SCAMIMO	ROPER	VIKING
	5) Motor				
	a. Type		R075BTPS	1LA277-6 -AA/P	P
	b. Capacity and Q'ty	kW	0.36x2	4.92x2	7.46x2
	c. Manufacturer		ALSTHOM	RELIANCE	RELIANCE
	(6) Heavy oil heater				
	1) Type		Surface (steam)	---- Surface ----- ---- (steam) -----	
	2) Capacity and Q'ty	t/h	Tubesx1	----- Tubesx2 -----	
	3) Manufacturer		STAIN&ROUB	----- DISTRAL -----	
7	Boiler feed water pump				
	(1) Type			HBD6x10	HBD
	(2) Capacity and Q'ty	t/h	70x3	175x3	175x3
	(3) Discharge head	m	80	110	110
	(4) Revolving speed	rpm	3550	3560	3560
	(5) Manufacturer			EBARA B.J.	MHI
	(6) Motor				
	1) Type		NTP93	FKB-H	F2KB-H2
	2) Capacity and Q'ty	kW	662x2	1100x3	880x3
	3) Manufacturer		ALSTHOM	MHI	MHI
8	Boiler feed water heating equipment				
	8-1 Feed water heater				
	(1) No.1 L.P.heater				
	1) Type		Surface tubes U	---- Surface ---- ---- tubes U ----	
	2) Heating surface area	m2	135	------ 260 ------	
	3) Material of heater tube		Cooper	Cu-Ni	Cu-Ni
	4) Temperature of F/water (inlet/outlet)	°C	42/	44/78	44/82
	(2) No.2 L.P.heater				
	1) Type		Surface tubes U	---- Surface ----- ---- tubes U -----	
	2) Heating surface area	m2	150	------ 200 ------	
	3) Material of heater tube		Cooper	Cu-Ni 78/126	Cu-Ni 82/116
	4) Temparature of F/water (inlet/outlet)	°C			
	(3) No.4 H.P.heater				
	1) Type		Surface-tubes		
	2) Heating surface area	m2	5	260	370
	3) Material of heater tube		Steel	Cu-Ni	Cu-Ni
	4) Temperature of F/water (inlet/outlet)	°C		160/210	158/187

1. Mechanical equipment (5/7)

No.	Description	Unit	#I	#II	#III
	(4) No.5 H.P.heater				
	1) Type		Surface tubes U	-	Surface tubes U
	2) Heating surface area			-	270
	3) Material of heater tube			-	Cu-Ni
	4) Temperature of F/water (inlet/outlet)			-	187/230
	(5) Manufacturer		ALSTHOM	-	MHI
	8-2 Deaerator				
	(1) Type		- Conventional, counter flow, sheets		
	(2) Capacity of disposal feed water	t/h	140	290	295
	(3) Allowable volume of oxygen	cc/l	0.005	0.005	0.005
	(4) Pressure in deaerating chamber	kg/cm2G	4	5	7
	(5) Manufacturer		ALSTHOM	MHI	MHI
9	Draft fan & stack				
	9-1 Forced draft fan				
	(1) Type		------- Centrifugal --------		
	(2) Rated capacity and Q'ty	m3/min	912 x 2	5550 x 2	4245 x 2
	(3) Pressure	mmAg	280	460	324
	(4) Revolving speed	rpm	1200	1200	1161
	(5) Manufacturer				
	(6) Motor				
	1) Type		NR400B	------- P ------	
	2) Capacity and Q'ty	kW	147 x 2	---- 522 x 2 ----	
	3) Manufacturer		ALSTHOM	--- RELIANCE ----	
	9-2 Induced draft fan				
	(1) Type		-------- Centrifugal --------		
	(2) Rated capacity and Q'ty	m3/min	2408 x 1	8411 x 2	6262 x 2
	(3) Pressure	mmAg	250	447	400
	(4) Revoluving speed	rpm	890	890	900
	(5) Manufacturer		SOCIETE	BAFFALO	CHICAGO
	(6) Motor				
	1) Type			P	P/BY
	2) Capacity and Q'ty	kW	425 x 420	932 x 2	932 x 2
	3) Manufacturer		ASEA/ ALSTHOM	RELIANCE	RELIANCE
	9-3 Stack				
	(1) Kind of structure		Concrete	Steel	Steel
	(2) Diameter of top	m	3.35	4.29	4.25
	(3) Height	m	50	50	75
	(4) Quantity		1	1	1
	(5) Manufacturer		ALSTHOM	DISTRAL	DISTRAL
10	Dust collector				
	10-1 Mechanical				
	(1) Type		Cyclone separator		-
	(2) Capacity (gas volume) and Q'ty	Nm3/h	175	-	-
	(3) Manufacturer			-	-

1. Mechanical equipment (6/7)

No.	Description	Unit	#I	#II	#III
	10-2 Electrical				
	(1) Type		Non	Cold electrostatic precipitator	
	(2) Capacity (gas volume) and Q'ty	Nm3/h	Non	136859x2	273700x1
	(3) Manufacturer		Non	MHI	MHI
11	Ash handling equipment				
	11-1 Clinker				
	(1) Type		Drag link conveyer		
	(2) Capacity and Q'ty	t/h	~5	~10	
	(3) Manufacturer		STAIN&ROUB.	DISTRAL	U.C.C.
	11-2 Pyrite				
	(1) Type		Non	Non	Non
	(2) Capacity and Q'ty	t/h			
	(3) Manufacturer				
	11-3 Fly ash				
	(1) Type				
	(2) Capacity	t/h	~50	~120	~120
	(3) Q'ty	set			
	(4) Manufacturer		F.U.M. Leuausis	U.C.C.	U.C.C.
	11-4 Ash disposal (pump)				
	(1) Type				G.T.E.
	(2) Capacity, (discharge head)	t/h, (m)			1500G.P.M.
	(3) Q'ty	set			2
	(4) Manufacturer				
	(5) Motor				
	1) Type		Non	-	P
	2) Capacity	kW	Non	-	149
	3) Q'ty	set			3
	4) Manufacturer		Non	-	RELIANCE
12	Coal storage area				
	(1) Area	m2	1 coal yard=10,000		
	(2) Storage capacity	t	120,000		
13	Coal handling equipment				
	13-1 Coal unloader				
	(1) Type		Non	Non	Non
	(2) Capacity and Q'ty	t/h			
	(3) Manufacturer				
	13-2 Truck hopper				
	(1) Capacity	t	120		
	(2) Q'ty	set	1		
	13-3 Main belt conveyer				
	(1) Type		Belt conveyer (rolls)		
	(2) Capacity	t/h	90	-	90
	(2) Capacity and Q'ty				
	(3) Manufacturer		DISTRAL		DISTRAL
	13-4 Bulldozer				
	(1) Type		D85A18		
	(2) Weight of equipment	t	25x1		
	(3) Q'ty				
	(4) Maximum tractive force	t	4.73		
	(5) Horsepower of prime mover and Q'ty	HP	220		
	(6) Manufacturer		KOMATSU		

1. **Mechanical equipment (7/7)**

No.	Description	Unit	#I	#II	#III
	13-5 Scraper				
	(1) Type		Non		
	(2) Capacity	m3			
	(3) Q'ty	set			
	(4) Horsepower of prime mover and Q'ty	HP			
	(5) Manufacturer				
14	Oil storage tank				
	14-1 Heavy oil				
	(1) Capacity	kℓ			
	(2) Q'ty				
	(3) Manufacturer				
	14-2 Light oil				
	(1) Capacity	Gℓ	22,740		
	(2) Q'ty				
	(3) Manufacturer		DISTRAL		
15	Oil transportation equipment				
	15-1 heavy oil transp. pump				
	(1) Type		Non		
	(2) Capacity	t/h			
	(3) Q'ty				
	(4) Manufacturer				
	(5) Motor				
	1) Type				
	2) Capacity	kW			
	3) Q'ty				
	4) Manufacturer				
	15-2 Pipeline (nominal diameter)	mm			
16	Ash disposal				
	(1) Method of type		Conveyer	Conveyer	
	(2) Place of ash disposal		Ash yard	Ash yard	Ash yard
	(3) Volume of disposal area	m3	3,000,000		
17	Aux. cooling water pump for bearing cooling				
	(1) Capacity	m3/h	-	114	60
	(2) Discharge head	m	50	50	45
	(3) Q'ty	set	3	2	3
	(4) Design temperature	°C	26	28	28
	(5) Design temperature of cooling water	°C			
	1) at condenser inlet		28	28	28
	2) at condenser outlet		41	41	41

2. Electrical equipment (1/3)

NO.	Description	Unit	#I	#II	#III
1	Generating equipment				
	1-1 Generator				
	(1) Type		T188-210 ALSTHOM	MBH MITSUBISHI	MBH MITSUBISHI
	(2) Rated capacity	kVA	41,250	87,836	87,836
	(3) Power factor	%	80	85	85
	(4) Voltage	v	13,800	13,800	13,800
	(5) Frequency	Hz	60	60	60
	(6) Revolving speed	rpm	3,600	3,600	3,600
	(7) Cooling method		H2	H2	H2
	(8) Pressure of hydrogen	kg/cm2	1.9	2.11	2.11
	(9) Winding method		Y	Y	Y
	(10) Exciting method		AMPLIGING		
	(11) Short circuit ratio			0.48	0.48
	(12) Manufacturer		ALSTHOM	M.H.I.	M.H.I.
	1-2 Exciter (main)				
	(1) Type		ET 17.5/27	Brushless	Brushless
	(2) Capacity	kW	130	470	370
	(3) Voltage	v	215	250	250
	(4) Revolving speed	rpm	3,600	3,600	3,600
	(5) Exciting method		AMPLIDINS	IMANES PERMANENTES	
	(6) Quantity		1	1	1
	(7) Kind of driving machine		Manual	Automatic voltage regulator	
	(8) Manufacturer		ALSTHOM	MHI	MHI
	1-3 Sub exciter				
	(1) Type		ET7,25/6.8		
	(2) Capacity	kW	3		
	(3) Voltage	V	115		
	(4) Revolving speed	rpm	3,600		
	(5) Exciting method				
	(6) Quantity		1		
	(7) Kind of driving machine		Manual		
	(8) Manufacturer		ALSTHOM		
2	Transformers				
	2-1 Main transformer				
	(1) Type		MHGE	NUCLEO/CUB	NUCLEO/CUB
	(2) Capacity	kVA	13,800	88,000	88,000
	(3) Primary voltage	V	13,800	13,200	13,200
	(4) Secondary voltage	V		115,000	115,000
	(5) Phase		1	3	3
	(6) Winding method		Y/D	Y/D	Y/D
	(7) Cooling method			Oil	Oil
	(8) Quantity		3	1	1
	(9) Manufacturer			MHI	MHI
	2-2 Other (if any) auto-ransformer				
	(1) Type		TH6E 170/11000		Nucleo/ cub-mrm
	(2) Capacity	kVA	30,000	90,000	90,000
	(3) Primary voltage	V	125,000	220,000	220,000
	(4) Secondary voltage	V	69000/ 4228	115000/ 13800	115000/ 13800
	(5) Phase		3	3	3

2. Electrical equipment (2/3)

NO.	Description	Unit	#I	#II	#III
	(6) Winding method				
	(7) Cooling method		OFAF	OFAF	OFAF
	(8) Quantity		1	1	1
	(9) Manufacturer			HAWKER	MHI
	2-3 Station transformer				
	(1) Capacity	kVA	3,500	10000/ 12000	12,000
	(2) Primary voltage	V	13,800	13,800	13,800
	(3) Secondary voltage	V	4,160	4,160	4,160
	(4) Phase		3	3	3
	(5) Winding method				
	(6) Cooling method		Forced oil	Forced oil	Forced oil
	(7) Quantity		1	1	1
	(8) Manufacturer		ALSTHOM	MHI	MHI
	2-4 Starting transformer				
	(1) Capacity	kVA	Non	12,000	12,000
	(2) Primary voltage	V	Non	13,800	13,800
	(3) Secondary voltage	V	Non	4,160	4,160
	(4) Phase		Non	3	3
	(5) Winding method		Non	D/D	D/D
	(6) Cooling method		Non	Forced oil	Forced oil
	(7) Quantity		Non	1	1
	(8) Manufacturer			MHI	MHI
	2-5 Low voltage transformer				
	(1) Capacity	kVA	400	1,200	2,000
	(2) Primary voltage	V	4,160	4,160	4,160
	(3) Secondary voltage	V	440	460/265	460/265
	(4) Quantity		3	3	3
	(5) Winding method				
	(6) Cooling method		Oil	Oil	Oil
	(7) Quantity		2	2	2
	(8) Manufacturer		ALSTHOM	MHI	MHI
3	Substation				
	3-1 Circuit breaker				
	(1) Type				
	(2) Voltage	V			
	(3) Current	A			
	(4) Rupturing capacity	MVA			
	(5) Manufacturer			2CM96/ 2LHCM10	
	3-2 Lightning arrester				
	(1) Type			2CM96/ 2LHCM10	Metal oxide
	(2) Voltage	V		115000/ 220000	97000/ 196000
	(3) Maximum allowable voltage	V		650000/ 550000	212000/ 424000
	(4) Discharge current	A		10,000	10,000
	(5) Manufacturer		ASEA	EMP	MELCO

2. Electrical equipment (3/3)

NO.	Description	Unit	#I	#II	#III
	3-3 High voltage switch gear for station				
	(1) Type		HP6E/11-15	SJ2/5J4	SF6-120
	(2) Voltage	V	170000/ 123000	123000/ 245000	123000 (245000)
	(3) Current	A	600/1250	1600/1600	1200
	(4) Rupturing capacity	MVA	3200/3500	5300/10600	
	(5) Quantity		4/1	4/3	2(1)
	(6) Manufacturer		DELLE	GEC	MHI
	3-4 Battery				
	(1) Type		Non	ISF-900	EA-15
	(2) Capacity and Q'ty	AH		900x1	880x2
	(3) Voltage	V		120	125
	(4) Manufacturer			G.S.JAPAN STORAGE	EXIDE
	3-5 Battery charger				
	(1) Type		Non	S6F3-180 -125CA	US-130-3- 150 U.P.S.
	(2) Capacity and Q'ty	A		35x2	48.9x2
	(3) Voltage	V		440	460
	(4) Manufacturer			G.S.JAPAN STORAGE	EXIDE P.

3. Other facilities (1/2)

No.	Description	Unit	#I	#II	#III
1	Over head travelling crane				
	(1) Capacity (main/aux)	t	70	-	-
	(2) Span	m	100	-	-
	(3) Lift (main/aux)	m	16	-	-
	(4) Quantity		1		
	(5) Manufacturer		APPLEVAGE		
2	Emergency generating equipment				
	2-1 Generator				
	(1) Type		Non	SRCR	20,332
	(2) Rated capacity and Q'ty	kVA		256x1	312.5x1
	(3) Voltage	V		230/460	277/480
	(4) Manufacturer			--- CATERPILLAR ---	
	2-2 Prime Mover				
	(1) Type		Non	D334	D353
	(2) Capacity and Q'ty	kW		205x1	361.8x1
	(3) No. of Revolving speed	rpm		1,800	1,200
	(4) Manufacturer			--- CATERPILLAR ---	
3	Water treatment equipment				
	3-1 Raw water				
	(1) Kind of water (or name of river)		Chicamocha River		
	(2) Hardness (CaCo3)	ppm		12.5	
	(3) PH value			7.4	
	(4) Silica	ppm		5.3	
	(5) Turbidity			19.0	
	3-2 Raw water tank				
	(1) Type		Cylindrical	Non (channel)	Non (channel)
	(2) Capacity and Q'ty	m3	80		
	(3) Manufacturer		COPEF		
	3-3 Clarifier				
	(1) Type		----- Coagulator -----		
	(2) Capacity and Q'ty		25m3/hrx1	24m3/hrx1	24m3/hrx1
	(3) Manufacturer		COREF	KURITA	RAMFE
	3-4 Filter				
	(1) Type		Sand, charcoll U-II & III Only sand U-I		
	(2) Capacity and Q'ty	t/day	25m3/hrx2	25m3xhrx4	25m3/hrx4
	(3) Manufacturer		COREF	KURITA	RAMFE
	3-5 Feed water treatment				
	(1) Method of W/treatment				
	1) Method		Ionic -exchange		
	2) Type		Open circuit;clarificattion, filtration		
	3) Kind of treatment material and Q'ty	kg/piece	Ionic exchange		
	4) Type of decarbonater and capacity	t/h	Non		
	(2) Capacity	t/cycle	1,400	200	450
	(3) Quantity of series		1	2	2
	(4) Manufacturer		COREF	KURITA	DEGREMONT

3. Other facilities (2/2)

No.	Description	Unit	#1	#II	#III
	3-6 Demineralized water tank				
	(1) Type		-	--- Cilyndrical ---	
	(2) Capacity and Q'ty	m3		258	260
	(3) Manufacturer			MHI	MHI
	3-7 Make-up water for boiler feed water treatment plant				
	(1) Capacity	m3/h	7	10(t/h)	20
4	Chemical injection equipment				
	4-1 Feed water				
	(1) Name of chemicals		N2H4	N2H4	N2H4
	(2) Pump capacity and Q'ty		41.5l/hr	40l/hr	40l/hr
	(3) Tank capacity and Q'ty	l	500	1,000	1,000
	(4) Manufacturer			-- HILTON ROYAL --	
	4-2 Boiler water				
	(1) Name of chemicals		Na2PO4+Na2HPO4 [coordinated phosphate]		
	(2) Pump capacity and Q'ty		8x2	11.5x2	11.5x2
	(3) Tank capacity and Q'ty		4,000	1,000	1,000
	(4) Manufacturer		COREF	HILTON-ROYAL	HILTON-ROYAL
5	Air compressor				
	5-1 Control air compressor				
	(1) Service				
	(2) Type		RADIAL 2HA2S	RADIAL WN114F	RADIAL WN114F
	(3) Capacity and Q'ty	m3/min	x1	43.9x2	43.9x2
	(4) Compressed pressure	kg/cm2	8	8	8
	(5) Revolving speed	rpm		586	585
	(6) Capacity of air reciever and Q'ty	m3	5x1	14x1	14x1
	(7) Manufacturer		CREPEUE	--- ISH.JAR.JOY ---	
	(8) Motor				
	1) Type		NP3.37	FKT	FZKT
	2) Capacity and Q'ty	kW	47x1	220x2	220x2
	3) Manufacturer		ALSTHOM	MHI	MHI
	5-2 Plant air compressor				
	(1) Service				
	(2) Type		RADIAL 2HA2S	RADIAL WN114F	RADIAL WN114F
	(3) Capacity and Q'ty	m3/min	1	43.9x1	43.9x1
	(4) Compressed pressure	kg/cm2	8	8	8
	(5) Revolving speed	rpm		586	585
	(6) Capacity of air reciever	m3	5x1	14x1	15x1
	(7) Manufacturer				
	(8) Motor				
	1) Type		NP3.37	FKT	F2KT
	2) Capacity and Q'ty	kW	47x1	220x1	220x1
	3) Manufacturer		ALSTHOM	MHI	MHI

ANNEX-Ⅱ PLANT DATA

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II.1 Operation data

No.	Description	unit	1983	1984	1985	1986	1987	1988
A	No. 1 unit							
1	Installed capacity	(MW)	33	33	33	33	33	33
2	Generated energy	(GWh)	177	185	175	179	109	73
3	Running hour	(Hr)	6,224	7,169	6,857	6,066	4,043	2,728
4	No. of starting time	(Time)	21	15	17	24	19	43
5	Cause of trip	(Time)						
	a) Boiler		0	0	1	4	1	6
	b) Turbine		1	4	2	3	6	6
	c) Generator		6	1	0	0	0	4
	d) Cooling system		1	1	1	1	3	0
	e) Other		0	0	1	0	0	5
	Sub total		8	6	5	8	10	21
6	Operation factor	(%)	71	82	78	69	46	31
7	Utilization factor	(%)	61	64	60	62	38	25
B	No. 2 unit							
1	Installed capacity	(MW)	66	66	66	66	66	66
2	Generated energy	(GWh)	372	523	409	313	343	298
3	Running hour	(Hr)	6,223	8,141	6,605	4,791	6,372	5,817
4	No. of starting time	(Time)	25	14	14	14	8	
5	Cause of trip	(Time)						
	a) Boiler		9	4	2	3	2	0
	b) Turbine		2	1	1	2	0	0
	c) Generator		2	1	2	1	2	0
	d) Cooling system		1	0	0	1	0	0
	e) Other		1	1	0	0	0	0
	Sub total		15	7	5	7	4	0
6	Operation factor	(%)	71	93	75	55	73	66
7	Utilization factor	(%)	64	90	71	54	59	52
C	No. 3 unit							
1	Installed capacity	(MW)	74	74	74	74	74	74
2	Generated energy	(GWh)	461	426	405	265	240	390
3	Running hour	(Hr)	6,307	6,225	7,310	5,636	4,674	7297
4	No. of starting time	(Time)	42	26	24	10	7	
5	Cause of trip	(Time)						
	a) Boiler		16	10	10	2	3	6
	b) Turbine		14	4	5	2	2	1
	c) Generator		2	2	4	2	1	9
	d) Cooling system		0	1	3	0	0	0
	e) Other		2	1	1	0	0	4
	Sub total		34	18	23	6	6	20
6	Operation factor	(%)	72	71	83	64	53	83
7	Utilization factor	(%)	71	66	63	41	37	60
D	Plant total							
1	Installed capacity	(MW)	173	173	173	173	173	173
2	Generated energy	(GWh)	1,010	1,134	989	757	693	761
3	Running hour	(Hr)	18,754	21,535	20,772	16,493	15,089	15,842
4	No. of starting time	(Time)	88	55	55	48	34	43
5	Cause of trip	(Time)						
	a) Boiler		25	14	13	9	6	12
	b) Turbine		17	9	8	7	8	7
	c) Generator		10	4	6	3	3	13
	d) Cooling system		2	2	4	2	3	0
	e) Other		3	2	2	0	0	9
	Sub total		57	31	33	21	20	41
6	Operation factor	(%)	71	82	79	63	57	60
7	Utilization factor	(%)	67	75	65	50	46	50

界

II.2 Consumption of coal and production of ash

Year	Coal consumption (ton/MWh)			Coal ash (ton)			Total Coal ash (ton)
	Unit No.			Unit No.			
	I	II	III	I	II	III	
1983	0.56	0.42	0.42	17,565	31,234	38,876	87,675
1984	0.55	0.43	0.38	15,790	40,889	30,420	87,099
1985	0.54	0.41	0.40	15,999	30,627	27,976	74,602
1986	0.53	0.41	0.41	16,342	27,323	19,573	63,238
1987	0.53	0.44	0.42	11,426	31,719	17,976	61,121
1988							
Jan.	0.52	0.45	0.41	1,002	2,235	1,915	5,152
Feb.	0.56	0.42	0.46	1,789	2,991	3,395	8,175
Mar.	0.53	0.42	0.42	1,579	3,613	3,810	9,002
Apr.	0.53	0.41	0.42	1,585	3,268	3,786	8,639
May	0.55	0.42	0.43	777	2,716	2,579	6,072
Jun	0	0.42	0.41	0	1,860	2,317	4,177
Jul.	0	0	0.40	0	0	3,121	3,121
Aug.	0	0.45	0.41	0	2,099	2,526	4,625
Sep.	0	0.45	0.42	0	2,247	474	2,721
Oct.	0.55	0.45	0.44	84	1,253	1,054	2,391
Nov.	0	0	0.42	119	0	2,367	2,486
Dec.	0	0.45	0.42	0	1,001	2,577	3,578
	Sub total			6,935	23,283	29,921	60,139

II.3 Cooling water analysis (Circulating water)

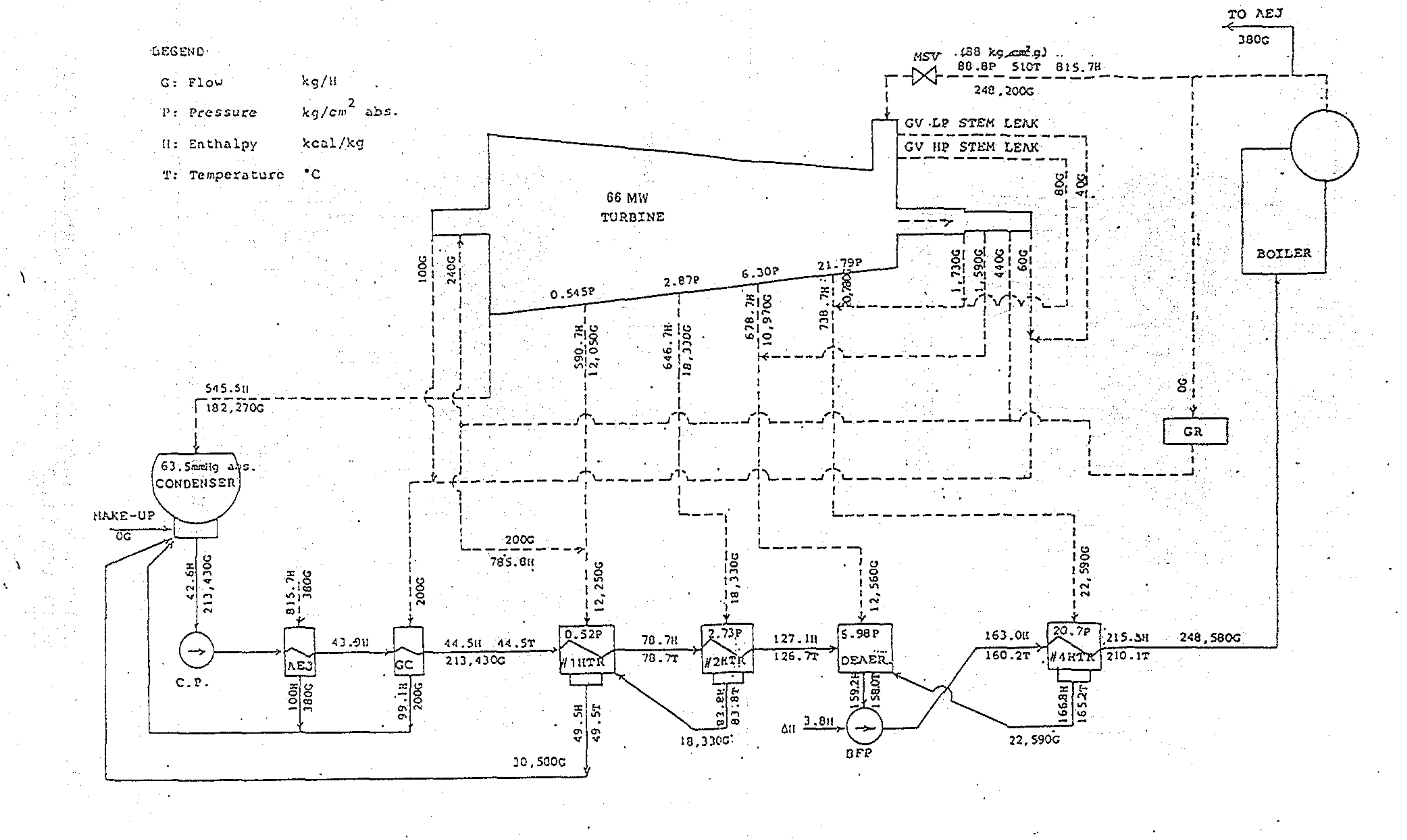
No.	Description	Unit	Data	Remarks
1	Hydrogen concentration	ph	7.1	
2	Dissolved oxygen concentration	mg/l	7.9	
3	Electric conductivity	uS/cm	110	
4	Oxidant-reduction potential	mV	-	
5	Cyanogen ion concentration	mg/l	-	
6	Chlorine ion concentration	mg/l	8	
7	Ammonia concentration	mg/l	0.41	
8	Turbidity		66	
9	Total hardness	mg/l	39	
10	Total dissolved solids	mg/l	77	

II.4 Technical data of coal and ash

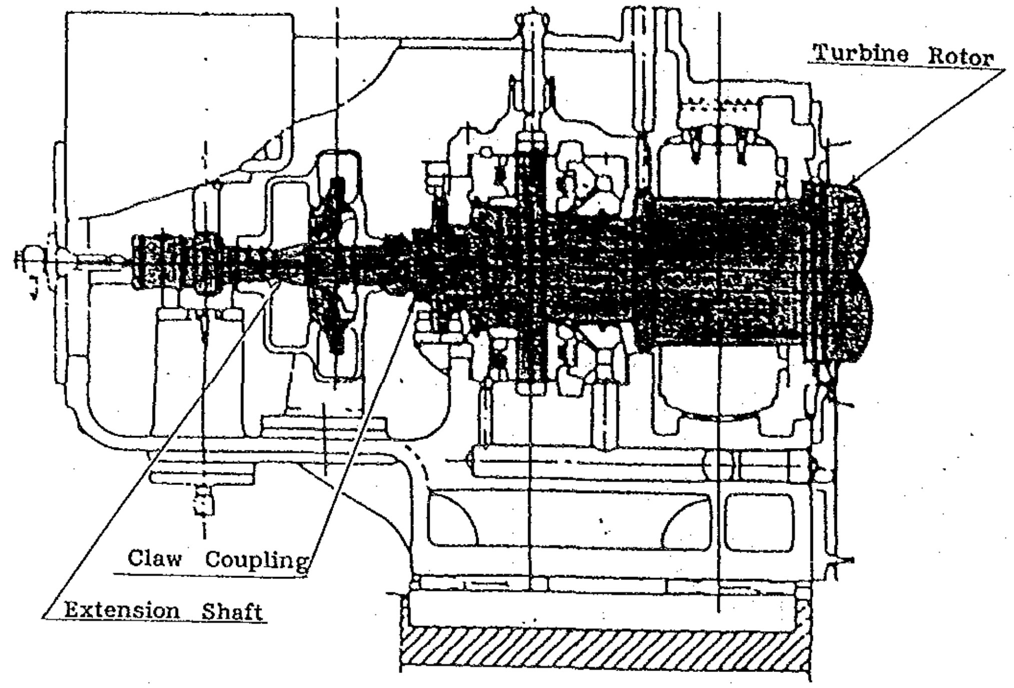
No.	Description	Unit	Specification	Remarks
1	Analysis of coal			
	1) Chemical analysis			
	a) Calorific value	kcal/kg	6547	
	b) Water content	%	3.25	
	c) Ash content	%	15.00	
	d) Valotile	%	40.40	
	e) Carbon	%	32.06	
	f) Sulfur	%	1.37	
	g) Melting point	℃	------	
	2) Physical analysis of ash			
	a) Shape		Round	
	b) Specific gravity	g/cm3	2.00	
	c) Specific gravity at ash storage yard		------	
	d) Diameter			
	- Fly ash	μm	125	
	- Clinker	mm	------	
	e) Carbon	max.%	12	
	3) Composition of coal ash			
	a) SiO_2	%	66.18	
	b) AL_2O_3	%	19.05	
	c) Fe_2O_3	%	7.93	
	d) CaO	%	1.59	
	e) MgO	%	0.71	
	f) K_2O	%	1.58	
	g) Na_2O	%	0.32	
	h) SO_3	%	0.07	

ANNEX-Ⅲ DATA OF POWER-UP FOR #2 TURBINE

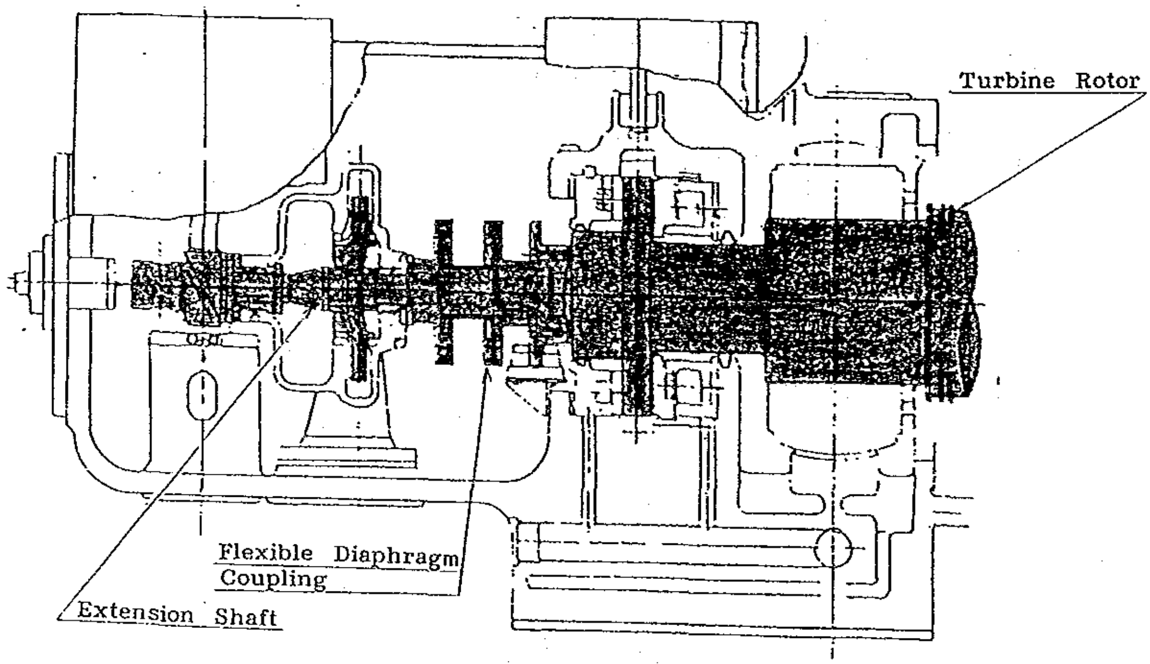
CONTENTS



III - 1 HEAT BALANCE DIAGRAM BEFORE TURBINE MODIFICATION



BEFORE MODIFICATION



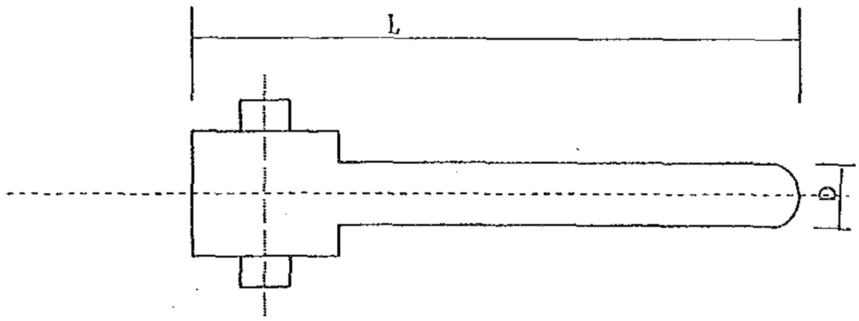
AFTER MODIFICATION

EXCHANGING PART

III - 2 EXTENSION SHAFT FOR DRIVING GOVERNOR AND MAIN OIL PUMP

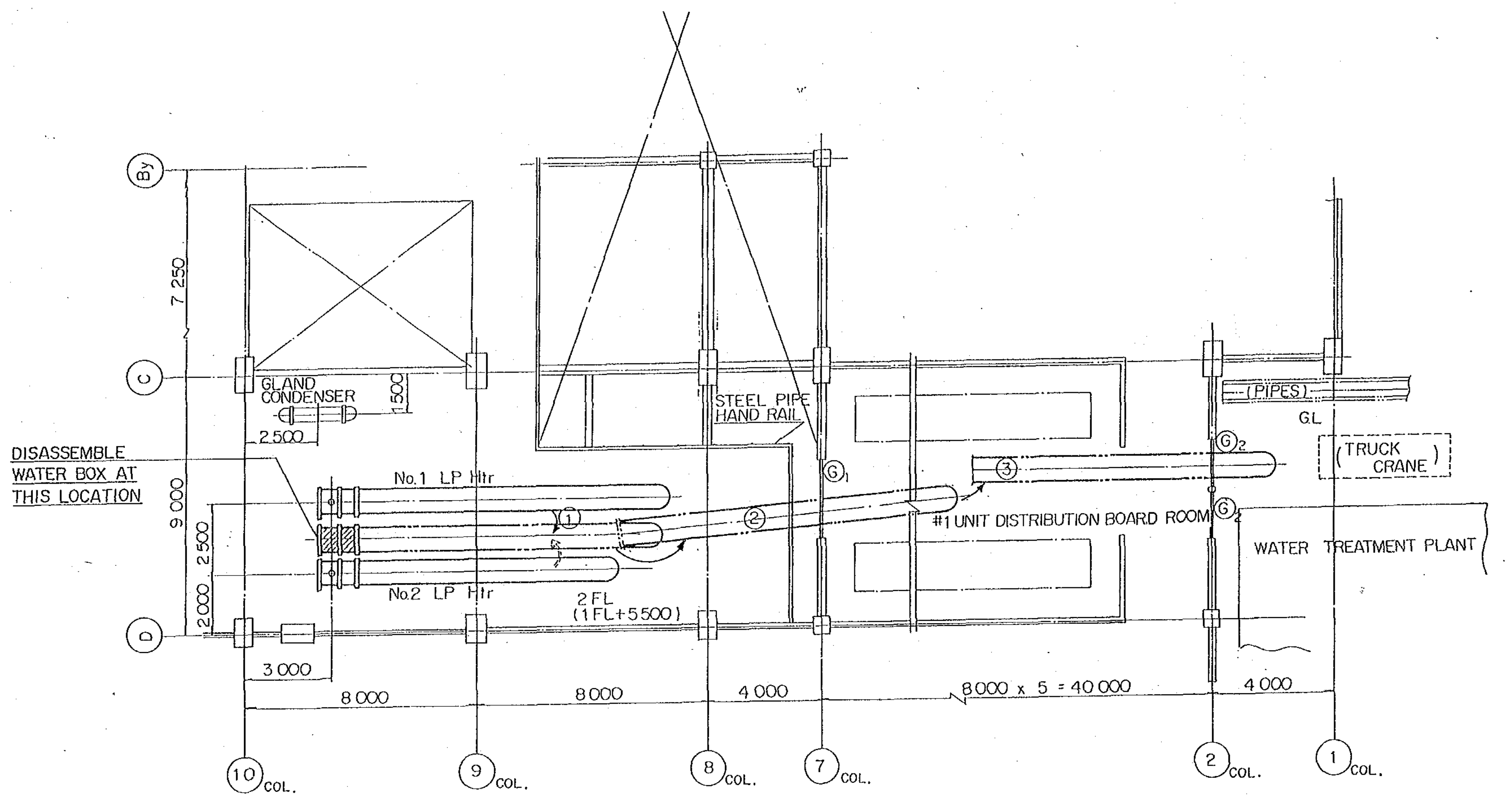
III.3 TECHNICAL DATA OF FEEDWATER HEATER

HTR. NO.	ITEMS	UNIT	66000 kW	74000 kW
LP No. 1 HEATER	Heating surface area	m²	240	281
	Number of tubes		U-230	U-265
	Shell I.D.	mm	750	800
	Channel I.D.	mm	750	800
	Total length	mm	11800	12100
LP No. 2 HEATER	Heating surface area	m²	200	221
	Number of tubes		U-230	U-265
	Shell I.D.	mm	750	800
	Channel I.D.	mm	750	800
	Total length	mm	10000	9750
HP No. 4 HEATER	Heating surface area	m²	260	300
	Number of tubes		U-342	U-394
	Shell I.D.	mm	860	1140
	Channel I.D.	mm	750	1030
	Total length	mm	8920	9020



(Unit:mm)

Description	66000 KW	74000 KW
LP No. 1 HEATER		
D	750	800
L	11800	12100
LP No. 2 HEATER		
D	710	800
L	10000	9750
HP No. 4 HEATER		
D	860	1140
L	8920	9020



Notes:

1) G_1 and G_2 indicate glass windows
Dimensions of glass windows:

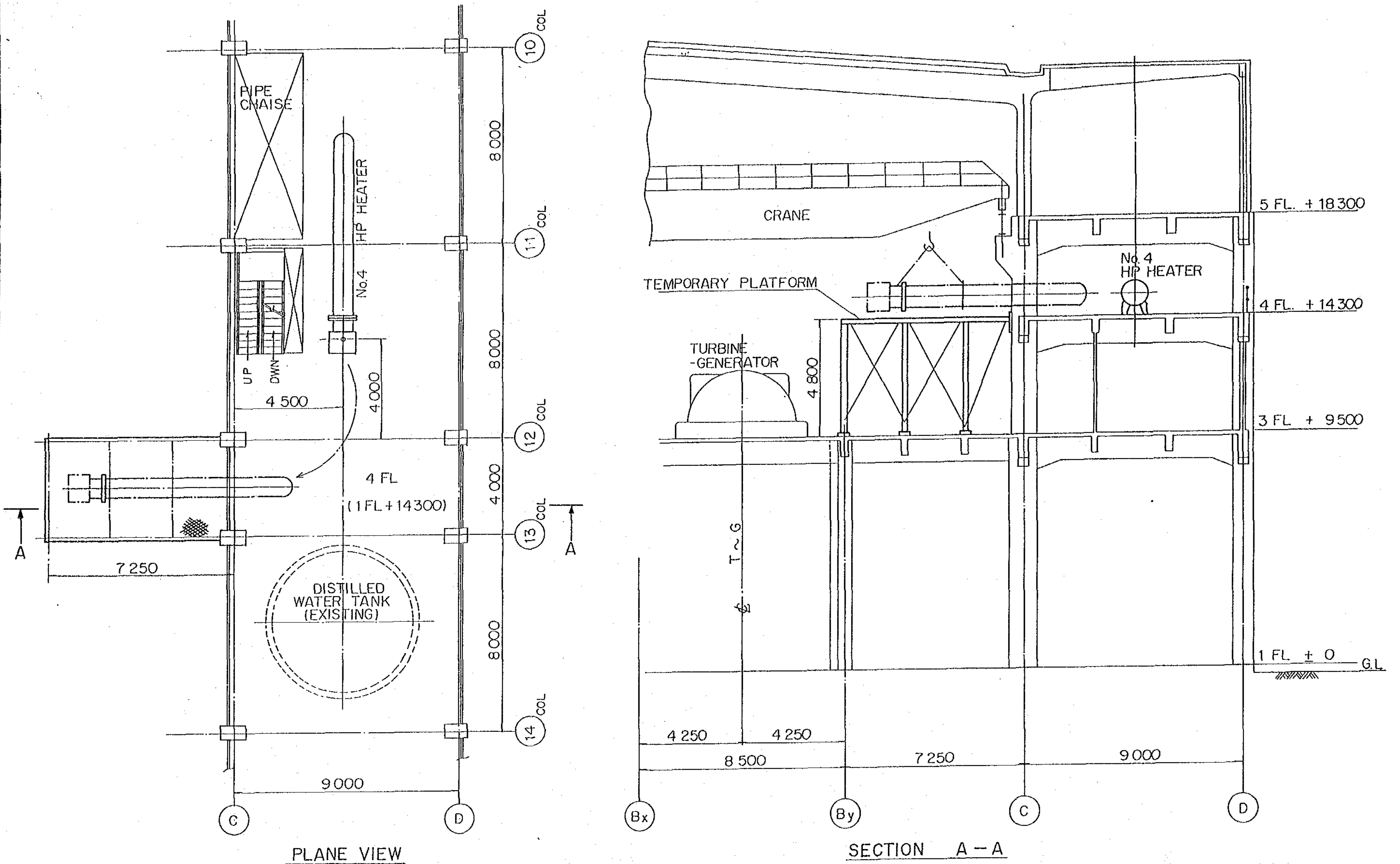
	Width (mm) X Height (mm)
G_1:	2,800 X 1,300
G_2:	1,900 X 1,300

2) The G_1 and G_2 glass windows should be temporarily removed before taking out the existing heater units. After installing new heater units, reinstall the windows.

3) The No.1 LP heater unit should be taken out first followed by the No.2 unit.

4) The heater units should be moved out according to the following route:
① → ② → ③
In the No.1 Unit Distribution Room, place a heater unit on rollers (heaters are to be moved one at a time) and move it along column No. ② towards the window side.
Lift the heater unit by using a truck mounted crane and take it out off the powerhouse.

III. 4.1 REPLACEMENT PROCEDURE FOR LP. No.1 & LP. 2 HEATERS



III. 4. 2 REPLACEMENT PROCEDURE FOR HP. No. 4 HEATER

III. 5 Performance sheet of #2 Boiler

Design Pressure	1500 PSIG		
Fuel		COAL	COAL
Boiler Load	%	PEAK	MCR
Main Steam	M lb/hr	661.5	626.22
Saturated Auxiliary Steam	M lb/hr	8	8
At temp. Water Flow	M lb/hr	11.5	10.7
Pressure Airheater outlet	Psig	1308	1308
Steam Temp. Prim SH outlet	F	814	815
Steam Temp. Second SH inlet	F	789	785
Steam Temp. Final SH outlet	F	960	960
Pressure boiler drum	Psig	1437	1425
Excess air leaving	%	22	22
Gas leaving boiler	M lb/hr	870.87	834.41
Air entering boiler	M lb/hr	812.36	778.36
TEMPERATURES			
Feed ent. unit	F	470	410
Attemp. water temp.	F	420	410
Air ent. unit	F	57	57
Air Lvg. air heater	F	658	653
Gas Lvg. furnace	F	1982	1959
Gas Lvg. prim. S.H.	F	1368	1348
Gas Lvg. boiler	F	736	729
Gas Lvg. air heater	F	287	283
GAS DRAFT LOSS			
Draft in furnace	in H20	0.10	0.10
Boiler	in H20	1.45	1.33
Superheater	in H20	0.17	0.16
Air heater	in H20	6.60	6.06
Flues	in H20	1.13	1.04
Dust collector	in H20	2.82	2.59
Total gas side loss	in H20	12.27	11.28
AIR PRESSURE LOSS			
Air heater	in H20	3.14	2.88
Ducts	in H20	1.34	1.23
Burners	in H20	7.39	6.78
Steam Coil	in H20	1.22	1.12
Total Air side	in H20	13.09	12.01
Total Air & Gas Loss	in H20	25.35	23.29
Primary S.H. pressure drop	Psi	27	24
Secondary S.H. pressure drop	Psi	102	93
Fuel Burned	Lb/hr	68706	65824
Furnace Liberation	BTU/cu.ft.hr	16483	15792
Net heat Release	BTU/sq.ft.hr	72680	69593
Boiler efficiency	H.M.V %	87.00	87.09
Boiler efficiency	L.H.V %	91.06	91.15

HEAT LOSSES

Dry gas	%	5.54	5.45
H2 and H20 in fuel	%	4.99	4.98
Moisture in air	%	0.08	0.08
Unburned combustible	%	0.66	0.65
Radiation	%	0.23	0.25
Manufacturers margin.	%	1.50	1.50
Total losses	%	13.00	12.91
Efficiency H.H.V.	%	87.00	87.09
Efficiency L.H.V.	%	91.06	91.15

Performance based on fuel apecified below

ULTIMATE ANALYSIS	COAL		
Percent by	WEIGHT	ASH ANALYSIS	
Ash	14.38	Si02	61.54
S	1.04	AL203	31.42
H2	5.38	Ti02	0.70
C	69.42	Fe203	3.87
H20	3.55	Ca0	0.07
N2	1.46	Mg0	0.38
02	4.77	Na20	0.44
Btu/Lb fired	12049		

PROXIMATE ANALYSIS

Per cent by	WEIGHT
H20	3.55
Ash	14.38
Volatile matter	34.87
Fixed Carbon	47.20
Hardgrove Grindability	39.8

ANNEX-IV DATA OF INSTRUMENTATION FOR #2 GENERATING FACILITY

CONTENTS

IV.1 OUTLINE OF REPLACED SYSTEM

1. Digital - ABC system

1.1 Computer system hardware — 1 set

(1) CPU with 512 KB memory (i80286)		2 sets	
(2) Data network interface (ETHERNET)		2 sets	
(3) Serial communication interface (RS232C)		2 sets	
(4) Process input/output system		2 sets	
- Analog input	96		
- Analog output	48		
- Digital input	128		
- Digital output	128		
(5) RAS unit		1 set	
(6) Signal interface module (include signal isolator, DISTRIBUTOR)		1 set	
(7) Power distribution		1 set	
(8) System cabinet including above all (W 700 mm x D 800 mm x H 2300 mm/1 cabinet)		5 cabinets	

1.2 Operator console desk — 1 set

(1) 20 inch color CRT (DP810)	3 sets	
(2) Communication interface (ETHERNET)	3 sets	
(3) Functional P.B. panel (3 types)	3 sets	

1.3 AUTO/HAND station — 22 sets

(1) fitted on operator console desk

1.4 Maintenance system hardware (using IDOL) — 1 set

(1) 16 bit personal computer with 14 inch color CRT
(2) 20MB HARD DISK
(3) 1MB FLP DISK

1.5 Software of D-ABC system — 1 set

(1) Basic operating system
(2) Control execution software
(3) CRT operation
(4) IDOL maintenance software

2. Digital - E/H governor

2.1 Computer system hardware — 1 set

(1) CPU with 512kB memory (i80286)		2 sets
(2) Data network interface (ETHERNET)		2 sets
(3) Serial communication interface (RS232C)		2 sets
(4) Process input/output system		2 sets
- Analog input	32	
- Analog output	24	
- Digital input	128	
- Digital output	128	

(5) RAS unit 1 set

(6) Signal interface module 1 set
(include signal isolator, DISTRIBUTOR)

(7) Power distributuion 1 set

(8) System cabinet including above all 1 set
(W 700 mm x D 800 mm x H 2300 mm/1 cabinet)

2.2 Operator Control Panel
(W 600 mm x D500 mm)

2.3 AUTO/HAND station

(1) Fitted on operator console desk

2.4 Software of D-E/H system

(1) Basic operating system
(2) Control execution software
(3) IDOL maintenance software

3. Data acquisition system

3.1 DAS hardware

(1) 32 bit CPU with 8MB memory (Micro VAX)		1
(2) Communication Interface (ETHERNET)		1
(3) Magnetic disk 159MB		1
(4) Remote I/O system		1
- AI (4 - 20 mA)	100	
- T/C (Thermo couple)	100	
- DI	100	

(5) CRT of D-BCE are commonly used with DAS operation. 3

3.2 DAS software

4. Other instrumentation

(1) Air flow elements
(Double ventury and differential pressure transmitter)
(2) Primary air flow elements
(Slant orifice and differential pressure transmitter)
(3) Heavy fuel oil flow elements
(Orifice and differential pressure transmitter)
(4) Coal feeder speed transmitter
(5) DSH outlet temperature thermo couple
(6) Pneumatic/electric converter
(7) Electric/pneumatic converter

IV.2 Specification of Tarbine governor system modification

The exisiting mechanical governor is changed to Digital Electro-Hydraulic (DEH) governor Table-1 and Fig-1 show the comparison between mechanical governor and DEH governor. Appendix-1 shows the advantages which will be expected by this modification.

1. Outline of the work

(1) Parts of Supply

(a)	EH Converter of Governing Valve	1 set
(b)	Pilot Relay Ass'y of Governing Valve Servomoter	1 set
(c)	Remote Reset Device - Air Cylinder 1 pc - Solenoid Valve 1 pc	1 set
(d)	Vacuum Trip Device - Pressure Switch 3 pcs	
(e)	Lube. Oil Emerg. Device - Pressure Switch 2 pcs	
(f)	Oil Piping Material	1 set
(g)	Welding Rod	1 set
(h)	Motor Valves	4 pcs
(i)	Foremore Valves for Motor Valves	2 pcs

(2) Removed Device

(a) Mechanical Governor

(b) Speed Changer

(c) Load Limiter

(d) Pilot Valve of Governing Valve Servomotor

(e) Vacuum Trip Device

(f) Lube. Oil Emerg. Device

2. Recommendation

Following Valves are also exchanged to motor valves for the operation from the control room.

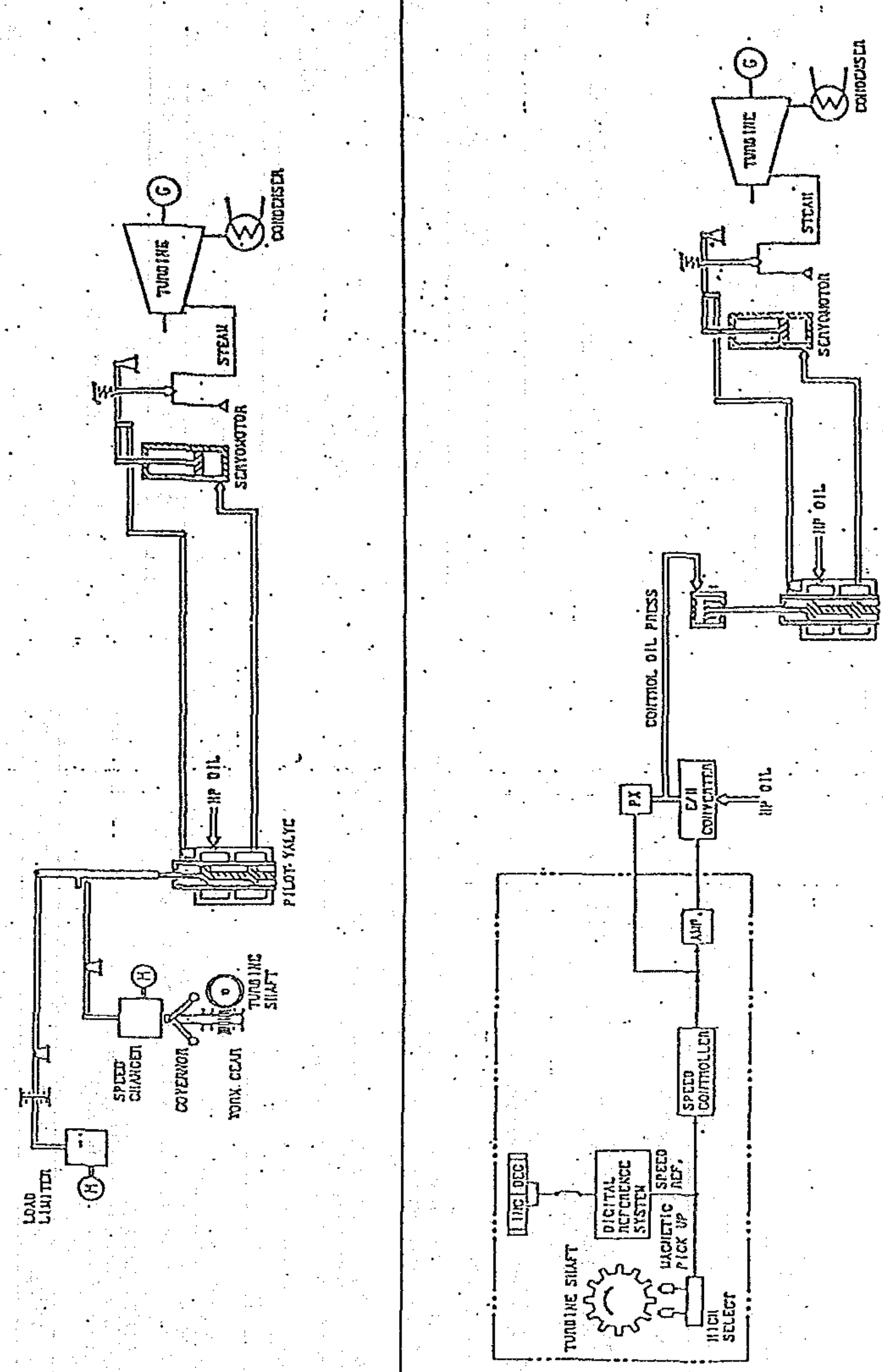
- MSV Stem Leak Valve (TV-5)
- MSV Steam pipe drain Valve (TV-2)
- 1st Stage Exit drain Valve (TV-5)
- LP Gland Steam drain Valve (TV-5)

Table 1 COMPARISON OF TURBINE GOVERNOR SYSTEM

	MECHANICAL GOVERNOR SYSTEM	DEH GOVERNOR SYSTEM
Speed Detection	T/G shaft → Main Oil Pump Shaft → Worm Gear → Flexible Shaft → Governor	T/G shaft → Magnetic Pick Up → Pulse Counter → Electrical Speed Control Circuit
Governor	Displacement of governor spindle due to centrifugal force	Electrical speed control circuit
Speed Changer	Amplifier of displacement of governor spindle to displacement of speed changer lever Displacement of governor spindle → Change of Hydraulic pressure → Change of position of Differential Piston → Displacement of speed changer lever Relation between displacement of governor spindle and speed changer lever can be changed by speed changer handle or governor motor	Electrical speed control circuit
Non-Interference Control	Control Lever Mechanism (Non-Interference condition is not variable)	Electrical Circuit (Non-Interference condition is variable)

Fig. 1 COMPARISON OF TURBINE GOVERNOR SYSTEM

DIGITAL ELECTRO-HYDRAULIC GOVERNOR	MECHANICAL GOVERNOR



ANNEX- 1

DEH GOVERNOR SYSTEM

ADVANTAGES

1. FLEXIBLE AND AUTOMATIC OPERATION

- Droop can be changed during operation in order to match the net work condition. This is very suitable for the requirement of the TERMOPAIPA POWER STATION.

- Operator can choose the speed change rates which are set in stops (COLD START/ HOT START etc) and can change the speed automatically from turning speed to rated speed by setting the target speed.

  DEH governor system adopts electrical speed control circuit, so that the speed can be controlled correctly from low speed to rated speed.

- After synchronizing, load can be controlled according to the load demand.

- Load can be changed aytinatucally be setting target loads and load change rates. And it is also equiped with the load limiter function and the auto follow function (target load will follow the load limiter) where setting can be changed at random.

- Synchronizing operation can be done automatically by the combination of the automatic synchronizing system. (option) And other functions can be added by connecting external computers.

2. HIGHER RELIABILITY

- SELF-DIAGNOSTIC FUNCTION
  If some trouble happens in control circuit, the operation mode is changed to "MANUAL" mode automatically and the operation can be continued.

- ON-LINE MAINTENANCE
  Logic and parameter in control system can be modified easily during operation by the maintenance tool (personal computer).

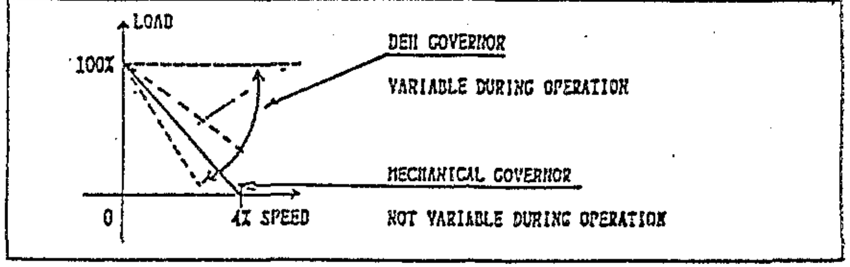
3. NO DETERIORATION DUE TO MECHANICAL WEAR

- GOVERNOR DRIVING GEAR IS NOT NECESSARY
  No governor hunting occurs oven if there is uneven sinking of the T/G foundation.

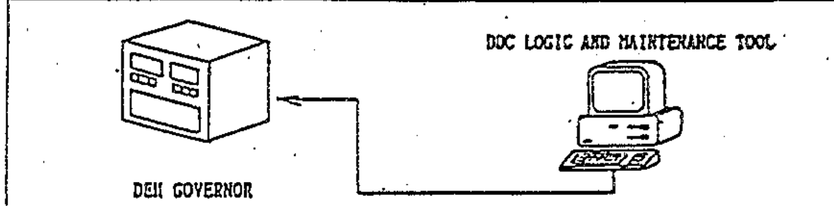
4. LOW MAINTENANCE COST

- FREE FROM MAINTENANCE OF MECHANICAL GOVERNOR DEVICES
  DEH governor system does not consist of many mechanical parts, so that the maintenance is simple, easy and at low cost.

VARIABLE DROOP SETTING

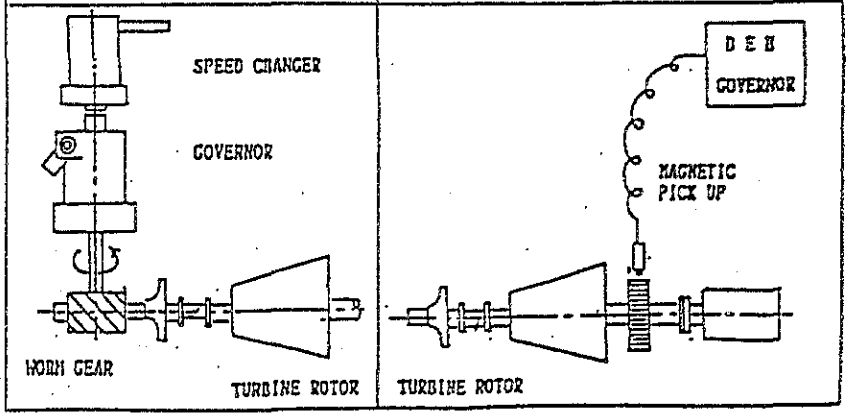


ON-LINE MAINTENANCE



SPEED DETECTION

MECHANICAL GOV.	DEH GOV.



IV.3 Indicator for boiler (1/2)

No.	Description	Instrument Range	Unit	Remarks
1	Presion aire atemperacion	0 → 400	mmH2O	
2	Precion aire de sellos	0 → 200	mmH2O	
3	Presion Plenum	0 → 200	mmH2O	
4	Presion Hogar	-50 → 0 → 50	mmH2O	
5	Succion Tiro Inducido 1.A	0 → -500	mmH2O	
6	Succion Tiro Inducido 1.B	0 → -500	mmH2O	
7	Succion Tiro Inducido 2.A	0 → -500	mmH2O	
8	Succion Tiro Inducido 2.B	0 → -500	mmH2O	
9	Descarga Tiro Inducido 1	0 → 60	mmH2O	
10	Descarga Tiro Inducido 2	0 → 60	mmH2O	
11	Descarga Tiro Forzado 1	0 → 500	mmH2O	
12	Descarga Tiro Forzado 2	0 → 500	mmH2O	
13	Entrada Gas calentador Aire 1	0 → -100	mmH2O	
14	Entrada Gas Calentador Aire 2	0 → -100	mmH2O	
15	Salida Gas Calentador Aire 1	0 → -300	mmH2O	
16	Salida Gas Calentador Aire 2	0 → -300	mmH2O	
17	Salida Aire Calentador Aire 1	0 → 300	mmH2O	
18	Salida Aire Calentador Aire 2	0 → 300	mmH2O	
19	Presion Tambor	0 → 150	kg/cm2	
20	Presion Vapor Atomizacion	0 → 10	kg/cm2	
21	Presion Fuel Oil Quemador	0 → 10	kg/cm2	
22	Presion ACPM Pilotos	0 → 6	kg/cm2	
23	Presion aire de sellos pulverizadores 1	0 → 200	mmH2O	
24	Presion aire de sellos pulverizadores 3	0 → 200	mmH2O	
25	Presion aire de sellos pulverizadores 2	0 → 200	mmH2O	
26	Presion Aire de Sellos Fulverizadores 4	0 → 200	mmH2O	
27	Presion Descarga Pulverizador 3	0 → 400	mmH2O	
28	Prusion Diferencial Molino 3	0 → 600	mmH2O	
29	Presion diferencial Aire Primario 3	0 → 125	mmH2O	
30	Temperatura Mezcla Pulverizador 3	0 → 100	°C	
31	Presion Aire Primario Pulverizador 3	0 → 1000	mmH2O	
32	Temperature Aire Primario 3	0 → 400	°C	
33	Presion Descarga Pulverizador 1	0 → 400	mmH2O	
34	Presion Diferencial Molino 1	0 → 600	mmH2O	
35	Presion Diferencial Aire Primario 1	0 → 125	mmH2O	
36	Temperatura Mezcla Pulverizador 1	0 → 100	°C	
37	Presion Aire Primario 1	0 → 1000	mmH2O	
38	Temperature Aire Primario 1	0 → 400	°C	
39	Presion Descarga Pulverlzador 4	0 → 400	mmH2O	
40	Presion Diferencial Molino 4	0 → 600	mmH2O	
41	Presion Diferencial Aire Primario 4	0 → 125	mmH2O	
42	Temperature Mezcla Pulv. 4	0 → 100	°C	
43	Presion Aire Primario 4	0 → 1000	mmH2O	
44	Temperature Aire Primario 4	0 → 400	°C	
45	Presion Descarga Pulverlzador 3	0 → 400	mmH2O	
46	Presion Diferencial Molino 3	0 → 600	mmH2O	
47	Presion Diferencial Aire Primario 3	0 → 125	mmH2O	
48	Temperature Mezcla Pulv. 3	0 → 100	°C	
49	Presion Aire Primario 3	0 → 1000	mmH2O	
50	Temperature Aire Primario 3	0 → 400	°C	
51	Temperatura Vapor Sabre calentado	200 → 600	°C	
52	Temperatura Vapor Antes Atemperador	200 → 600	°C	

IV.3 Indicator for boiler (2/2)

No.	Description	Instrument Range	Unit	Remarks
53	Temperatura Vapor Despues Atemperador	200 → 600	°C	
54	Temperatura Gas Salida Caldera	0 → 500	°C	
55	Flujo Vapor Sobre calentado	0 → 300	ton/Hr	
56	Presion Vapor Sobre calentado	0 → 150	Kg/cm2	
57	Presion Agua Alimentacion	0 → 150	Kg/cm2	
58	Temperatura Agua Alimentacion	0 → 250	°C	
59	Flujo Agua Alimentacion	0 → 35	ton/Hr	
60	Presiones Aire de Servicio Bloqueo	0 → 8	Kg/cm2	
61	Presiones Aire de Servicio Instrumentos	0 → 8	Kg/cm2	

III-B Meter for Boiler (input signal : 0-1 mA)

1	Amperimetro		
	(1) Ventilador Tiro Inducido 1	0 → 450	Amp
	(2) Ventilador Tiro Inducido 2	0 → 450	Amp
	(3) Ventilador Tiro Forzado 1	0 → 225	Amp
	(4) Ventilador Tiro Forzado 2	0 → 225	Amp
2	Posicionador		
	(1) Registro Aire/Quemador 1I	0 → 90	%
	(2) Registro Aire/Quemador 1C	0 → 90	%
	(3) Registro Aire/Quemador 1D	0 → 90	%
3	Amperimetro		
	(1) Puluerizador 1	0 → 75	Amp
	(2) Ventilador Aire Primario 1	0 → 150	Amp
4	Posicionador		
	(1) Registro Aire/Quemador 2I	0 → 90	%
	(2) Registro Aire/Quemador 2C	0 → 90	%
	(3) Registro Aire/Quemador 2D	0 → 90	%
5	Amperimetro Posicionador		
	(1) Puluerizadoe 3	0 → 75	Amp
	(2) Ventilador Aire Primario 3	0 → 150	Amp
6	Posicionador		
	(1) Registro Aire/Quemador 3I	0 → 90	%
	(2) Registro Aire/Quemador 3C	0 → 90	%
	(3) Registro Aire/Quemador 3D	0 → 90	%
7	Amperimetro		
	(1) Puluerizador 4	0 → 75	Amp
	(2) Ventilador Aire Primario 4	0 → 150	Amp
8	Posicionador		
	(1) Registro Aire Quemador 4I	0 → 90	%
	(2) Registro Aire Quemador 4C	0 → 90	%
	(3) Registro Aire Quemador 4D	0 → 90	%
9	Amperimetro		
	(1) Puluerizador 2	0 → 75	Amp
	(2) Ventilador Aire Primario 2	0 → 150	Amp
	(3) Ventilador Aire de Sellos 1	0 → 50	Amp
	Ventilador Aire de Sellos 2	0 → 50	Amp

IV.3.3 Recorder for Boiler

No.	Description	Range	Unit	Recorder Type	Input Signal
R-1	(1) Flujo Vapor	0 - 300	ton/Hr		
	(2) Flujo Aire	0 - 100	%	Bailey	3-15 psi
	(3) Presion Vapor	0 - 150	Kg/cm2		
R-2	(1) CO	0 - 5	%		
	(2) Humo	0 - 100	%	Bailey	4-20 mA
	(3) Oxigeno	0 - 10	%		
R-3	(1) Flujo Carbon	0 - 100	%		
	(2) Temp Vapor Sobre Calga	200 - 600	°C	Bailey	3-15 psi
	(3) Spare				
R-4	(1) Flujo Agua Alim	0 - 350	ton/Hr		
	(2) Flujo Agua Atemp	0 - 30	ton/Hr	Bailey	3-15 psi
	(3) Nivel Domo	-300 - 400	mm		
R-5	(1) Temp Hogar	0 - 1000	°C		
	(2) Temp Hogar	0 - 1000	°C	FOXBORO-1	
R-6	(1) Temp Despues Atemp	0 - 1000	°C		
	(2) Temp Antes Atemp	0 - 1000	°C	FOXBORO-2	
R-7	(1) Temp Gas Entrada AH-1				
	(2) Temp Gas Entrada AH-2				
	(3) Temp Gas Salida AH-1				
	(4) Temp Gas Salida AH-2			L/N	TYPE-J (IC)
	(5) Temp Aire Entrada AH-1				
	(6) Temp Aire Entrada AH-2				
	(7) Temp Aire Salida AH-1				
	(8) Temp Aire Salida AH-2				
R-8	Temp Metal Primary SH-1～18			L/N	TYPE-K (CA)
R-9	Temp Metal Secondary SH-1～13			L/N	

IV.3.4 Boiler Alarm (1/2)

No.	Description	Remarks
1	Disparo Nivel Tambor	
2	Rele Corte Combustible Disparo	
3	Ventilador Tiro Forzado 1 Parado	
4	Ventilador Tiro Forzado 2 Parado	
5	Ventilador Tiro Inducido 1 Parado	
6	Ventilador tiro Inducido 2 Parado	
7	Ventilador Aire de Sello 1 Parado	
8	Ventilador Aire de Sello 2 Parado	
9	Llama apaeada Pilotos	
10	Peligro Bajo Porcentaje Oxigeno	
11	Hogar Alta Presion Disparo	
12	Hogar Alto Vacio Disparo	
13	Alimentador de Carbon No.3 Parado	
14	Ventilador Primario 3 Parado	
15	Puluerizador 3 Parado	
16	Alimentador de Carbon No.1 Parado	
17	Ventilador Primariol Parado	
18	Puluerizadorl Parado	
19	Alimentador de Carbon No.4 Parado	
20	Ventilador Primario 4 Parado	
21	Puluerizador 4 de Parado	
22	Alimentador de Carbon No.2 Parado	
23	Ventilador Primario 2 Parado	
24	Puluerizador 2 Parado	
25	Nivel Tambor Alto	
26	Presion Tambor Alta	
27	Nivel Tambor Bajo	
28	Presion Vapor Bajo	
29	Presion Vapor Alta	
30	Temperatura Vapor Alta	
31	Vacio Hogar Alto	
32	Presion Hogar Alta	
33	Relacion Combustible/Aire Insuficiente	
34	Presion Aire de Sello Baja	
35	Flujo de aire Bajo Minimo	
36	Gas Salida de Calentador Temperatura Alta	
37	Gas Salida de Calentador Temperatura Alta	
38	Ventilador Tiro Inducido 1 Sobre Carga Motor	
39	Ventilador Tiro Inducido 2 Sobre Carga Motor	
40	Ventilador Tiro Forzado 1 Sobre Carga Motor	
41	Ventilador Tiro Forzado 2 Sobre Carga Motor	
42	Puluerizador 3 Aviso Alta Carga Motor	
43	Puluerizador 3 Sobre carga Motor	
44	Puluerizador 3 Temperatura Alta	
45	Alimentador 3 Falta Flujo Salida	
46	Puluerizador 1 Aviso Alta Carga Motor	
47	Puluerizador 1 Subre Carga Motor	
48	Puluerizador 1 Temperatura Alta	
49	Alimentador 1 Falta Flujo Salida	
50	Puluerizador 4 Aviso Alta Carga Motor	
51	Puluerizador 4 Sobre Carga Motor	
52	Puluerizador 4 Temperatura Alta	
53	Alimentador 4 Falta Flujo Salida	
54	Puluerizador 2 Auiso Alta Carga Motor	
55	Puluerizador 2 Sobre Carga Motor	

IV.3.4 Boiler Alarm (2/2)

No.	Description	Remarks
56	Pulverizador 2 Pulverizazdor 1 Temperatura Alta	
57	Alimentador 3 Falta Flujo Entrada	
58	Alimentador 1 Falta Flujo Entrada	
59	Alimentador 4 Falta Flujo Entrada	
60	Alimentador 2 Falta Flujo Entrada	
61	Falla Sistema Deshollinadores	
62	Aire Instrumentos Cerrado	
63	Falla Llama Carbon	
64	Presion Baja Aire Instrumentos	
65	Baja Presion Atonizacion Pilotos	
66	Baja Presion ACPM Pilotos	
67	Baja Presion Diferencial Vapor Quemadores F.O.	
68	Quemador 31 Presion Baja F.O.	
69	F.O. Quemador 1I Presion Baja	
70	F.O. Quemador 3C Presion Baja	
71	F.O. Quemador 1C Presion Baja	
72	F.O. Quemador 3D Presion Baja	
73	F.O. Quemador 1D Presion Baja	
74	Ceniza Vacio Alto Reserva	
75	Ceniza Vacio Bajo Reserva	
76	F.O. Qnemador 4I Presion Baja	
77	F.O. Qnemador 2I Presion Baja	
78	F.O. Quemador 4C Presion Baja	
79	F.O. Quemador 2C Presion Baja	
80	F.O. Quemador 2C Presion Baja	
81	F.O. Quemador 4D Presion Baja	
82	F.O. Quemador 2D Presion Baja	

IV.3.5 Lamp Indicator (1/2)

No.	Description	Data Logging System Design Input
1	Fila 1 de Quemadores Izquierda	Sin Llama y Encendido
2	Fila 1 de Quemadores Centro	Sin Llama y Encendido
4	Fila 2 de Quemadores Izquierda	Sin Llama y Encendido
5	Fila 2 de Quemadores Centro	Sin Llama y Encendido
6	Fila 2 de Quemadores Derecha	Sin Llama y Encendido
7	Fila 3 de Quemadores Izquierda	Sin Llama y Encendido
8	Fila 3 de Quemadores Centro	Sin Llama y Encendido
9	Fila 3 de Quemadores Dercha	Sin Llama y Encendido
10	Fila 4 de Quemadores Izquierda	Sin Llama y Encendido
11	Fila 4 de Quemadores Centro	Sin Llama y Encendido
12	Fila 4 de Quemadores Derecha	Sin Llama y Encendido
13	Piloto 1 izquierda	Energizado-Llama Apagada-Listo Para Operar-En operacion
14	Piloto 1 centro	Energizado-Llama Apagada-Listo Para Operar-En operacion
15	Piloto 1 derecha	Energizado-Llama Apagada-Listo Para Operar-En operacion
16	Piloto 2 izquierda	Energizado-Llama Apagada-Listo Para Operar-En operacion
17	Piloto 2 centro	Energizado-Llama Apagada-Listo Para Operar-En operacion
18	Piloto 2 derecha	Energizado-Llama Apagada-Listo Para Operar-En operacion
19	Piloto 3 izquierda	Energizado-Llama Apagada-Listo Para Operar-En operacion
20	Piloto 3 centro	Energizado-Llama Apagada-Listo Para Operar-En operacion
21	Piloto 3 derecha	Energizado-Llama Apagada-Listo Para Operar-En operacion
22	Piloto 4 izquierda	Energizado-Llama Apagada-Listo Para Operar-En operacion
23	Piloto 4 centro	Energizado-Llama Apagada-Listo Para Operar-En operacion
24	Piloto 4 derecha	Energizado-Llama Apagada-Listo Para Operar-En operacion
25	Ventilador Tiro Inducido No.1	Parado 1 En Marcha
26	Ventilador Tiro Inducido No.2	Parado 2 En Marcha
27	Ventilador Tiro Forzado No.1	Parado - En Marcha
28	Ventilador Tiro Forzado No.2	Parado - En Marcha
29	Ventilador Aire de Sello No.1	Parado - En Marcha
30	Ventilador Aire de Sello No.2	Parado - En Marcha
31	Puzen chldern	
32	Compuerta Descarga Aire de Sello 1	Abierto y Cerrado
33	Compuerta Descarga Aire de Sello 2	Abierto y Cerrado
34	Compuerta Entrada Aire atemperacion	Abierto y Cerrado
35	Compuerta Salida Aire Calentador 1	Abierto y Cerrado
36	Compuerta Salida Aire Calentador 2	Abierto y Cerrado
37	Compuerta Entrada Gas A Calentador 1	Abierto y Cerrado
38	Compuerta Entrada Gas A Calentador 2	Abierto y Cerrado
39	Compuerta Ducto Interconexion Gases	Abierto y Cerrado
40	Cierre Emergencia ACPM-Pilotos	Reposicionador
41	Cierre Emergencia Fuel oil Quemadores	Reposicionador
42	Cierre Maestro Combustiable	Cerrado y Adierto
43	Valvula Principal de Vapor	Cerrado y Adierto
44	Valvula de Alivio Motarizada	Cerraba - Abierto - Automatico
45	Bomba Fuel Oil # 1	Parado - En Marcha - Sobre Carga
46	Valvula de carbon 1 Derecha	Abierto - Cerrado
47	Valvula de carbon 1 Centro	Abierto - Cerrado
48	Valvula de carbon 1 Derecha	Abierto - Cerrado
49	Valvula de carbon 2 Izquierda	Abierto - Cerrado
50	Valvula de carbon 2 Centro	Abierto - Cerrado
51	Valvula de carbon 2 Derecha	Abierto - Cerrado
52	Valvula de carbon 3 Izquierda	Abierto - Cerrado
53	Valvula de carbon 3 Ceatro	Abierto - Cerrado
54	Valvula de carbon 3 Derecha	Abierto - Cerrado
55	Valvula de carbon 4 Izguierda	Abierto - Cerrado

IV.3.5 Lamp Indicator (2/2)

No.	Description	Data Logging System Design Input
56	Valvula de carbon 4 Centro	Abierto - Cerrado
57	Valvula de carbon 4	Abierto - Cerrado
58	Bomba Fuel Oil #2	Parada - En Marcha - Sobre Carga
59	Control Puluerizader 1	Parada - En Marcha
60	Control Puluerizader 2	Parada - En Marcha
61	Control Puluerizader 3	Parada - En Marcha
62	Control Puluerizader 4	Parada - En Marcha
63	Control Ventilador Aire Primario 1	Parado - En marcha
64	Control Ventilador Aire Primario 2	Parado - En marcha
65	Control Ventilador Aire Primario 3	Parado - En marcha
66	Control Ventilador Aire Primario 4	Parado - En marcha
67	Bomba ACPM #1	Parado - En marcha - Sobre Carga
68	Bomba ACPM #2	Parado - En marcha - Sobre Carga
69	Alimentador de carbon #1	Parado - En marcha
70	Alimentador de carbon #2	Parado - En marcha
71	Alimentador de carbon #3	
72	Alimentador de carbon #4	Parado - En marcha
73	Valvula Bloqueo agua Alimentacion	Cerrado - Abierto
74	Valvula Bloqueo agua Alimentacion Arranque	Cerrado - Abierto
75	Valvula Bloqueo By-pass Agua Alimentacion	Cerrado - Abierto
76	Valvula de corte, Agua Atemperacion	Cerrado - Abierto
77	Control By-pass Agua Atemperacion	Cerrado - Abierto
78	Anunciador Alarmas	Falla CC - Falla CA
79	Anunciador Disparo	Falla CC - Falla CA
80	Flujo Minimo Bomba Alimentacion 1	Abierto - Cerrado
81	Flujo Minimo Bamba Alimentacion 2	Abierto - Cerrado
82	Flujo Minimo Bamba Alimentacion 3	Abierto - Cerrado
83	Bomba Alimentacion 1	Parada - En Marcha
84	Bomba Alimentacion 2	Parada - En Marcha
85	Bomba Alimentacion 3	Parada - En Marcha
86	Bomba Circulacion 1	Parada - En Marcha
87	Bomba Circulacion 2	Parada - En Marcha
88	Bomba Circulacion 3	Parada - En Marcha
89	Bomba Circulacion 1	Cedo - Abito
90	Bomba Circulacion 2	Cedo - Abito
91	Governador	
92	Limitador	
93	Bomba Enfriamiento intercambiadores 1	
94	Bomba Enfriamiento intercambiadores 2	
95	Valvuladescarga Bomba Circulacion 1	Abierto - Cerrado
96	Valvuladescarga Bomba Circulacion 2	Abierto - Cerrado
97	Valvula Control rebose Tanque Agua Alimentacion	Abierto - Cerrado
98	Valvula Cerada Principioz	Abierto - Cerrado
99	ALR	En Servicio
100	Rompe Vacio	Abierto - Cerrado - Sobre Carga
101	Valvula Entrada Eyector de Aire 1	Abierto - Cerrado - Sobre Carga
102	Valvula Entrada Eyector de Aire 2	Abierto - Cerrado - Sobre Carga
103	Valvula de Retencion de Extracciones	1-2-3
104	Bomba Transferencia Agua Tratada 1	Parada - En Marcha
105	Bomba Transferencia Agua Tratada 2	Parada - En Marcha
106	Bomba Incendio Diesel	Parada - En Marcha
107	Valvula Cierre Agua Potable	Abierto - Cerrada
108	Compresor Aire Instrumentos 1	Parada - En Marcha
109	Compresor Aire Instrumentos 2	Parada - En Marcha
110	Compresor Aire Servicio	Parada - En Marcha
111	Bomba Incendios Motor	Parada - En Marcha

ANNEX-V DATA OF COOLING WATER SYSTEM

CONTENTS

V・1 DATA SHEET OF COOLING TOWER

1. GENERAL

Description	UNIT 1	UNIT 2 & 3
1. Circulating Water FLOW:	7,000m³/H	13,000m³/H
2. Hot Water Temp.;	38℃	38℃
3. Cold Water Temp.;	30℃	30℃
4. Wet Bulb Temp.;	13℃	13℃
5. Wind Load;	$60\sqrt{H}$	
6. Seismic load;	0.30G	
7. Water Loss		
1) Evaporation Loss;	98.0m³/H	182.0 m³/H
2) Drift Loss;	7.0 〃	13.0 〃
3) Blow Down;	12.6 〃	23.4 〃
(Total)	(117.6m³/H)	(218.4 m³/H)

2. SPECIFICATION OF COOLING TOWER FOR UNIT 1 : 7,000㎥/H

Item	Description
1. Type:	Mechanical Induced Draft Cross Flow
2. Number of Units	One unit (2 Cells/Unit)
3. Structural Details;	
(1) Overall Tower Dimension;	
a;Tower Length;	14,840㎜
b;Tower Width;	21,970㎜
c;Height;	10,930㎜ (From top of basin curb)
d;Total Height	16,430㎜
(2) Inside Basin Dimension	
a;Total Length;	14,940㎜
b;Total Width;	17,230㎜
c;Depth;	2,500㎜
4. Mechanical Equipment;	
(1) Fan	
a;Type;	Axial Flow Propeller Fan
b;NO. of Fan and Diameter	2 sets, 6700mm
c;Blade Materials;	FRP
d;Brake HP/Fan;	65 BKW/FAN
(2) Driver	
a;Type;	Outdoor use, Induction Motor
b;Rated HP;	75 KW, 4 Poles
c;Electric Charact.;	380V, 50Hz
d;No. Required ;	2 sets
(3) Speedreducer	
a;Type;	Sprial bevel/Helical gear
b;No. Required;	2 sets

3. SPECIFICATION OF COOLING TOWER FOR UNIT 2 & 3: 13,000㎥/H

Item	Description
1. Type	Mechanical Induced Draft Cross Flow
2. Number of Units	2 Units (2 Cells/Unit)
3. Structural Details; (Per One Unit)	
(1) Overall Tower Dimension;	
a;Tower Length;	22,160mm
b;Tower Width;	21,970mm
c;Height;	10,930mm (From top of basin curb)
d;Total Height	16,430mm
(2) Inside Basin Dimension	
a;Total Length;	22,260mm
b;Total Width;	17,230mm
c;Depth;	2,500mm
4. Mechanical Equipment;	
(1) Fan	
a;Type;	Axial Flow Propeller Fan
b;NO. of Fan and Diameter	2 sets/Unit, 8,535mm
c;Blade Materials;	FRP
d;BRAKE HP/Fan;	140 BKW/FAN
(2) Driver	
a;Type;	Outdoor use, Induction Motor
b;Rated HP;	150KW, 4 Poles
c;Electric Charact.;	380V, 50Hz
d;No. Required ;	3 sets
(3) Speed reducer	
a;Type;	Sprial bevel/Helical gear
b;No. Required;	3 sets/Unit

4. MATERIALS OF CONSTRUCTION FOR COOLING TOWER

Item	Description
(1) Framework Members;	Douglas fir (Treated wood)
(2) Casing;	FRP or Asbestos Coment Boards
(3) Filling;	Polypropylene (Splash type)
(4) Filling Support	Douglas fir (Treated wood)
(5) Draft Eliminator;	Rigid PVC
(6) Eliminator Spacer;	Ployypropylene
(7) Fan stack;	FRP (Velocity recovery type)
(8) Fan Deck;	FRP or Asbestos Cement Boards
(9) Fan Deck;	Douglas fir (Treated wood)
(10) Water Distribution;	Douglas fir (Treated wood)
(11) Splash Nozzles;	Polypropylene
(12) Stairway & Handrail;	Douglas fir (Treated wood)
(13) Structural Connector;	Hot dip galv. carbon steel
(14) Ring Joint Connector;	FRP
(15) Bolts, Nuts, Washers;	Hot dip galv. carbon steel
(16) Anchor Connectors;	Hot dip galv. carbon iron
(17) Nails;	Stainless steel (SUS.304)
(18) Mech.Equip.Support;	Hot dip galv. carbon steel

5. COLD WATER BASIN

Item	Description
(1) Construction;	Reinforced concrete
(2) Depth;	2,500 mm
(3) Level of Basin Curb;	G.L +500mm

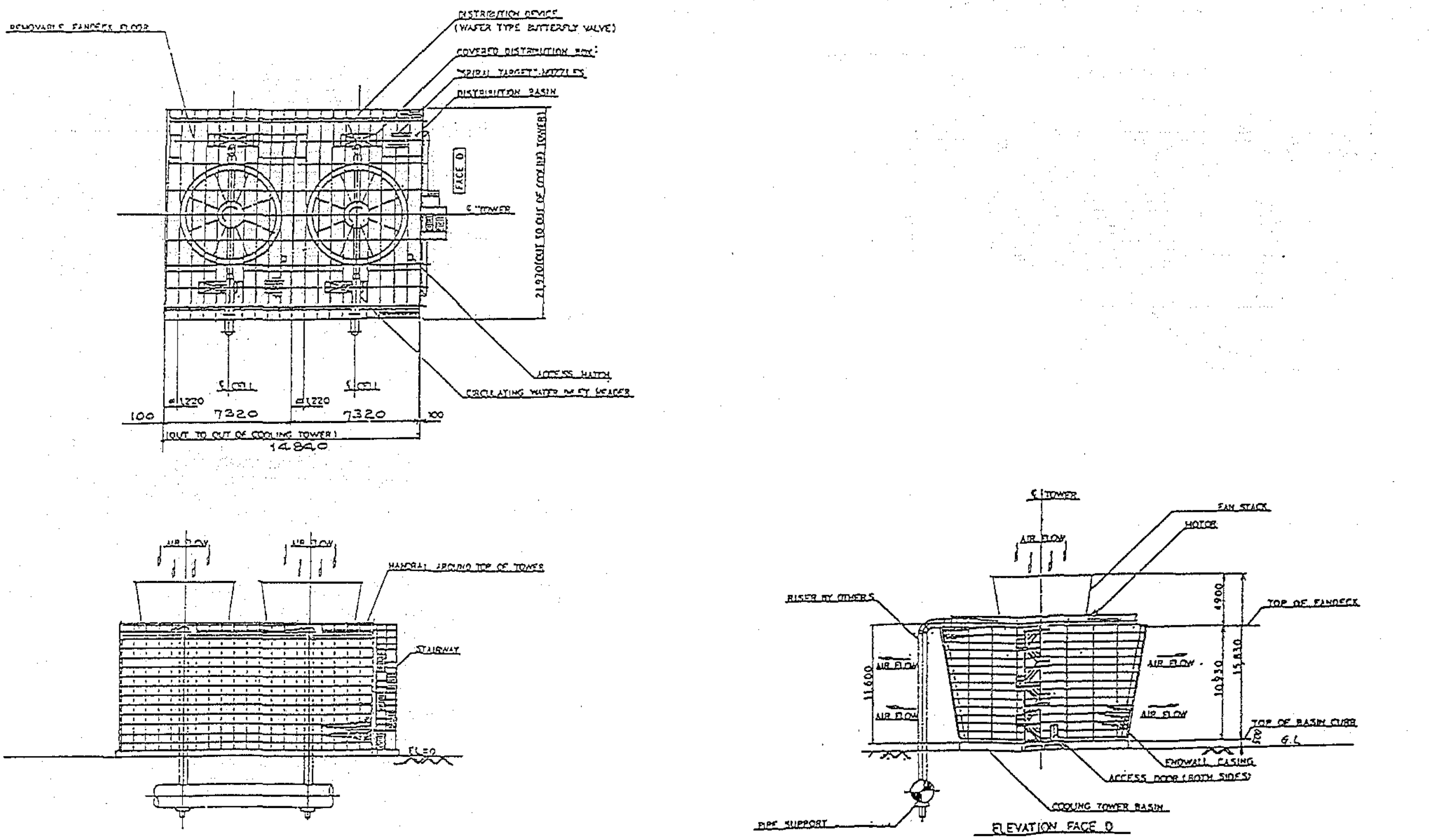


Fig. V.1.1 OUTLINE DRAWING OF COOLING TOWER FOR U #1

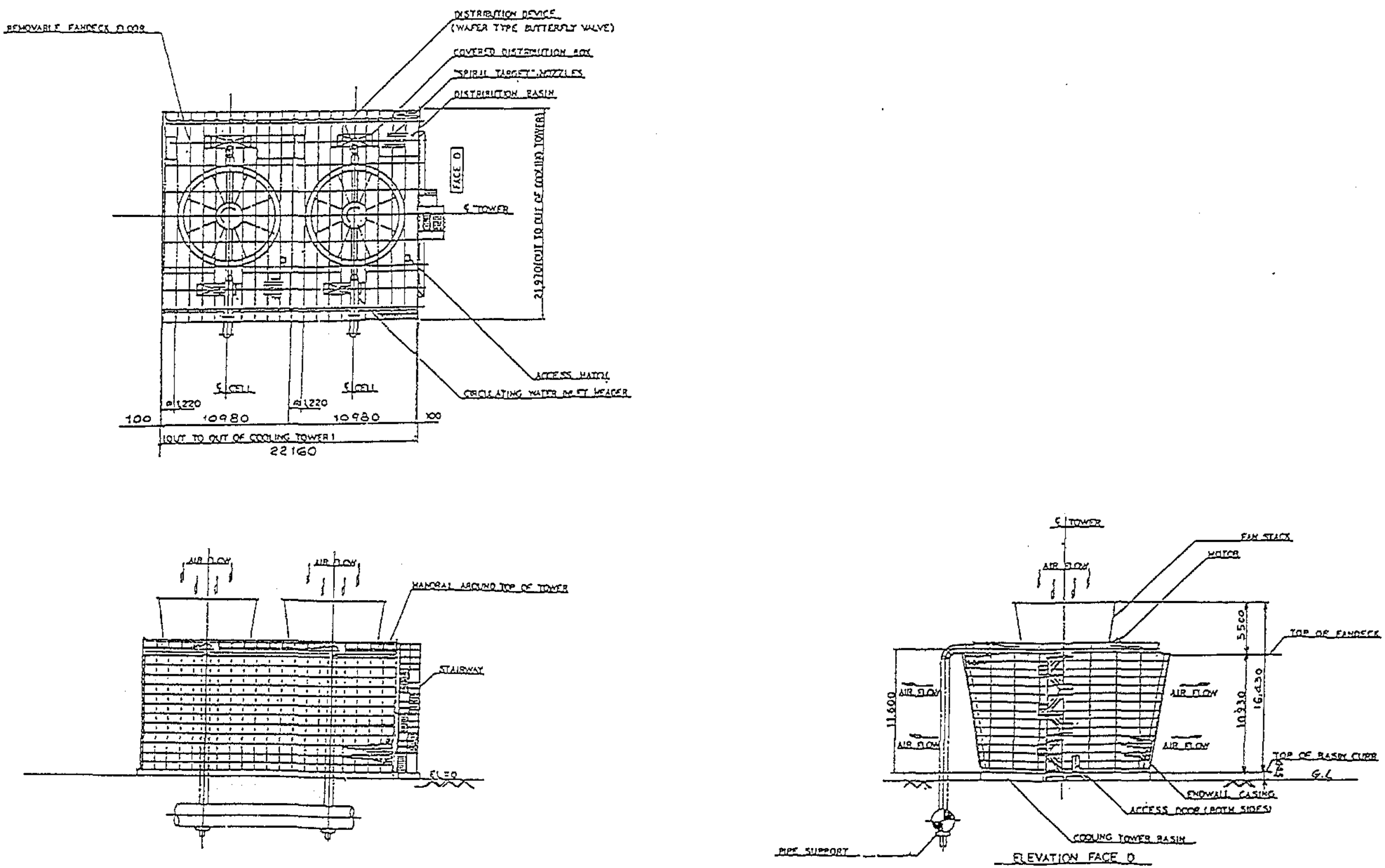


Fig. V.1.2 OUTLINE DRAWING OF COOLING TOWER FOR U #2 & #3

V.2 Design Specification of Cathodic Protection System for Cooling Water Pipe

1. General

This specification covers the design of the cathodic protection system for the pipes in power plant.

2. Codes and Standards

The following codes and standards shall be used for partial guidance for the design and selection of materials for cathodic protection system.

National Association of Corrosion Engineers (NACE) Standard RP-01-69, Control of External Corrosion on Underground or Submerged Metallic Piping Systems

3. Basic Requirement

3.1 Protection Method

The galvanic anode method is applied for the protection of pipes.

3.2 Electrical Insulation

To prevent electrical connection with foreign metallic structure,- such as concrete reinforcing steel bar, earthing, casing, cable rack, other underground piping and existing pipeline-a unit of insulating flanges with insulating bolts and a gasket, is installed at each rising point of underground protected pipe.

The structures to be protected should be electrically insulated from existing pipelines and structures.

Inner surface of insulation joint installed in pipe conveying electric conductive fluid should be coated with tar epoxy of 300 micron thick or equivalent for the length shown in the following table.

Fluid	Length to be coated
Sea water	20 times of inside dia.
Fresh water(approx. 80℃)	5 times of inside dia.
Water(normal temp.)	2 times of inside dia.

Also, instrument cable conduit shall be electrically insulated from the pipe to be protected.

3.3 Bonding

To reduce excessive resistance of valves, bonding cables are used.

4. Structures to be protected

4.1 Pipe Descrition

Fluid conveyed	Pipe O.D. (mm)	Length (m)	Wall thickness (mm)	Protective area (m^2)
CW	1000 1300 1300	240 170 640	- - -	4334

4.2 Pipe Service Condition

Material	Operation temp. (℃)	Pipe coating
Carbon steel	40	Asphalt Jute

5. Design Conditions

5.1 Soil Resistivity of Anode Groundbed Design

10000 ohm-cm (estimated) to be confirmed by site survey

5.2 Protective Current Density

2.0 mA/m^2

5.3 Anode Design Life

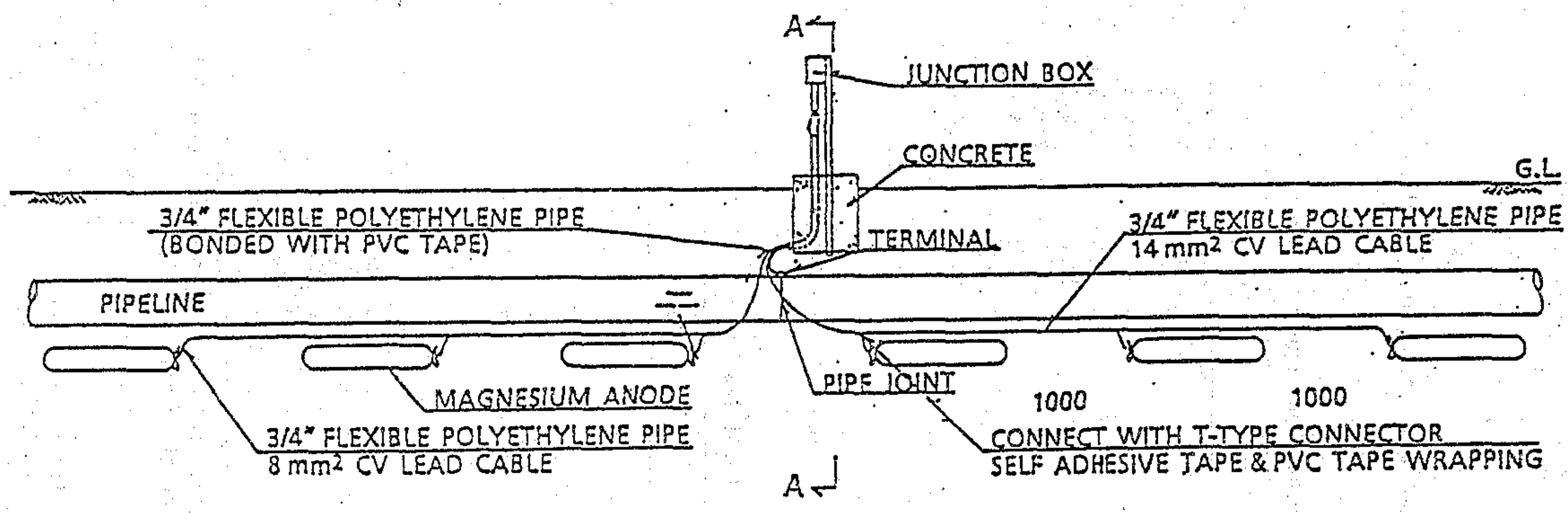
20 years

6. Design Calculation

6.1 Design Calculation Results

Structure	Protective current requirement (A)	Quantity of anode (pcs)
U/G pipe	8.7	580

U/G : Underground



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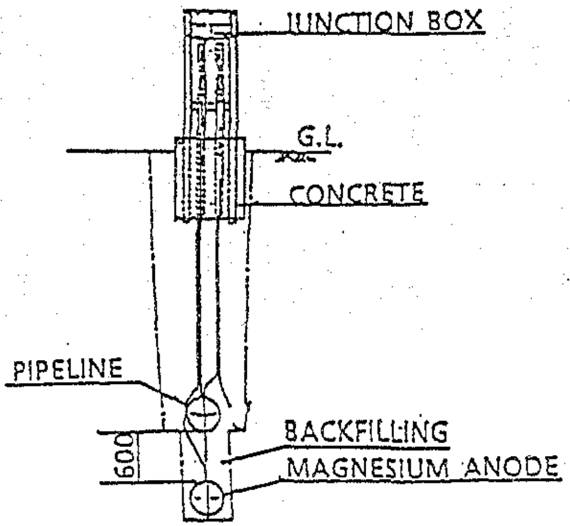
REFERENCE DRAWING



NOTE : THIS IS TYPICAL DRAWING FOR INSTALLING FIVE OR OVER ANODES BY ONE LOCATION.

1. ANODES SHALL BE INSTALLED ON BOTH SIDES OF THE TERMINAL ALONG THE PIPELINE.
2. ANODES SHALL BE BACKFILLED WITH THE EXCAVATED SOIL.
3. WHEN IT IS IMPOSSIBLE TO DIG JUST UNDER THE PIPELINE ANODES CAN BE PUT AT OTHER POSITIONS 0.6 METER AWEY FROM THE PIPELINE.

INSTALLATION OF MAGNESIUM ANODE

V.3 Technical Specification of Chemical Injection Unit for Cooling Water System

1. Conditions of cooling water system

1-1. Water Balance

Table-1 shows the water balance of the open recirculating cooling water system at cycle number of 6.

Table-1 Water Balance and Operating Conditions

Description	UNIT-1	UNIT-2	UNIT-3
Circulating water quantitiy(m3/hr)	7,000	13,000	13,000
Water temperature difference (°C)	8	8	8
Evaporation loss (m3/hr)	98.0	182.0	182.0
Drift loss (m3/hr)	7.0	13.0	13.0
Blowdown quantity (m3/hr)	12.6	23.4	23.4
Make-up water quantity (m3/hr)	117.6	218.4	218.4
Cycles of concentration	6.0	6.0	6.0
Holding water volume (m3)	1,750	3,250	3,250
Retention time (hr)	90.0	90.0	90.0

1-2. Make-up Water Quality

Table-2 shows Make-up water quality for the cooling water system.

Table-2 Make-up Water Qualities

Description	Values
PH	7.1
Electrical conductivity (us/cm)	110
Dissolved solids (ppm)	77
Total hardness (CaCO3 ppm)	39
Calcium hardness (CaCO3 ppm)	-
Magnesium hardness (CaCO3 ppm)	-
M-alkalinity (CaCO3 ppm)	-
Chloride ion (Cl ppm)	8
Silica (SiO2 ppm)	-
Sulfate ion (So4 2- ppm)	-
Iron (Fe ppm)	-
Turbidity (Sio2 ppm)	66
Ammonia (NH3 ppm)	0.41

Note : Suspended solids, turbidity shall be removed by pre-treatment for make-up water or side filteration for circulating water.

Aimed value

Suspended solid : below 20 ppm in circulating water
Turbidity : below 20 ppm in circulating water

Note: Calcium hardness, M-alkalinity and silica in make-up water quality should be confirmed to determine the final technical proposal of chemical treatement program.

2. Recommended Chemical Treatment Program

2-1. Corrosion and Scale Control

2-1-1 Initial Treatment

Polyphosphate and Polymer are recommended as a corrosion inhibitor and a scale inhibitor for initial treatment.
The dosage of the chemicals and the conditions of initial treatment are shown in Table-3.

Table-3 Initial Treatment Condition

Description	Values
Dosage of chemicals *1	
Polyphosphate	400 ppm
Polymer	200 ppm
Initial pH of cooling water	6.0 - 7.0
Period of initial treatment	Longer than 24 hours

*The dosage against holding water volume

Initial treatment shall be generally carried out without heat load.

2-1-2 Maintenance Treatment

The inhibitors based treatment program by phosphates and polymer is recommended for cooling water treatment.
Its concept is to control both corrosion and scale under weak alkaline cooling water by combination use of synthetic polymer and phosphate.
Phosphates and polymer shall be injected into cooling tower basin or cooling water line by using a quantitative pump for maintaining the specified concentration in cooling water.
The control range of cooling water quality is shown in Table-4.

Table-4 Standard Cooling Water Control Range

Description	Values
PH (at 25°C)	7.0 - 8.5 *1
M-alkalinity (CaCO3 ppm)	below 200
Ca-hardness (CaCo3 ppm)	50 - 150
Silica (Sio2 ppm)	below 130
Turbidity (degree)	below 20
Total dissolved solids (ppm)	below 1,500
Chloride ion (Cl-) + Sulfate ion (So| 2) (ppm)	below 1,000
KURITA S-3300 (ppm)	80 - 60

Table-5 Application Method of KURITA S-3300

Description	Values
Dosage (ppm against blowdown)	60 - 80
Dosing frequency	Continuous dosing
Dosing point	Cooling tower basin

2-2. Bio-fouling Control

2-2-1 Chlorination

Chlorination is recommended for sterilization and reducing the bacteria number in cooling water. The recommended condition of chlorination is shown in Table-6.

Table-6 Application Method of Chlorination

Description	Specification
Residual chlorine (Cl2 ppm)	0.5 - 1.0 in the cooling water
Dosing frequency	Continuously for 3-5 hrs per day
Dosing point	Cooling tower basin

2-2-2 Slime Control Agent

The application of slime control agent, Nitrogenous compounds and organic polyer is recommended together with chlorination. The combined treatment can minimize the corrosive chlorine concentration in water and demonstrates excellent biofouling control.
The proposed application method of Nitrogenous compounds and organic polymer is shown in Table-7.

Table-7 Application Method of Nitrogenous compounds and organic polymer

Description	Specification
Dosage (ppm against holding water volume)	100
Dosing frequency	once/2 weeks
Dosing point	Cooling water basin

3. Chemical Consumption

The estimated chemical consumption for initial treatment and maintenance treatment based on the water balance specified in Table-1 are shown in Table-8 and Table-9 respectively.
The initial treatment is carried out at the start-up of plant and/or after the annual turn-around of plant.

Table-8 Chemical consumption for Initial Treatment

Description	Dosage	Annual Consumption Unit-1	Unit-2	Unit-3
Polyphosphates	400 ppm*1	700kg	1,300kg	1,300kg
Polymer	200 ppm*1	350kg	650kg	650kg

Table-9 Chemical consumption for Maintenance Treatment

Chemical	Dosage	Annual Consumption Unit-1	Unit-2	Unit-3
Polyphosphates and polymer	70 ppm*2	13,328Kg	24,752Kg	24,752Kg
Nitrogenous compounds and organic polymer	100 ppm/15 days *1	4,200Kg	7,800Kg	7,800Kg
Chlorine	1 ppm*4	9,324Kg	17,316Kg	17,316Kg

*1 Concentration against holding water volume (5000 m3) of the system.

*2 Concentration against the total blowdown quantity.

*3 For 8000 hours operation.

*4 Concentration against recirculating water quantity.

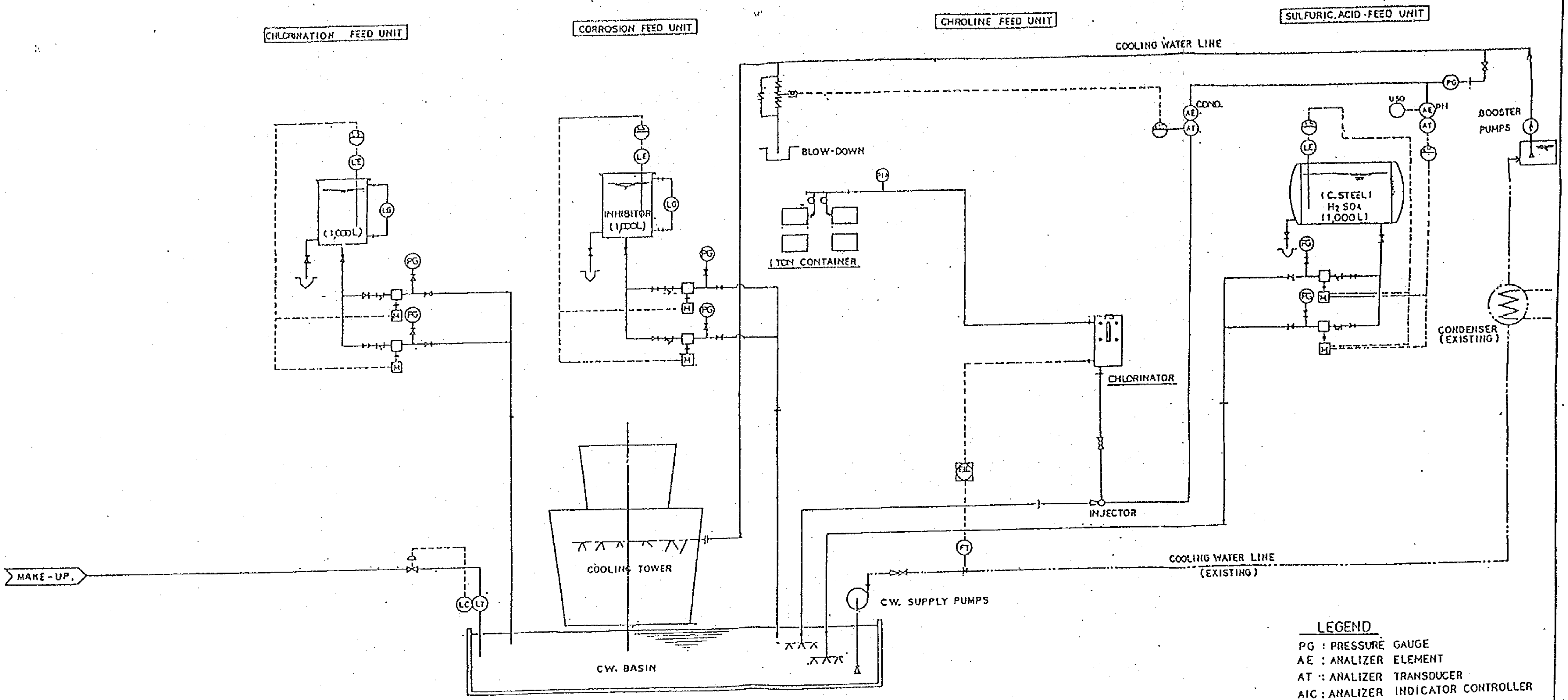
*5 Chlorine is out of scope.

Drawing

4-1. P&I flow diagram for chemical injection unit
4-2. Layout drawing for chemical injection unit

Note

This is a brief proposal based on the given conditions as show on TABLE-1 and TABLE-2.
When the conditions will be very changed in the actual operation, the chemical treatment program, especially the cycle number might be re-considered.



LEGEND

PG : PRESSURE GAUGE
AE : ANALIZER ELEMENT
AT : ANALIZER TRANSDUCER
AIC : ANALIZER INDICATOR CONTROLLER
LG : LEVEL GAUGE
LS : LEVEL SWITCH
LE : LEVEL ELEMENT
LT : LEVEL TRANSDUCER
FT : FLOW TRANSDUCER
FIC : FLOW INDICATOR CONTROLLER

Fig. V.4.1 P & I FLOW DIAGRAM OF CHEMICAL INJECTION UNIT FOR COOLING WATER SYSTEM

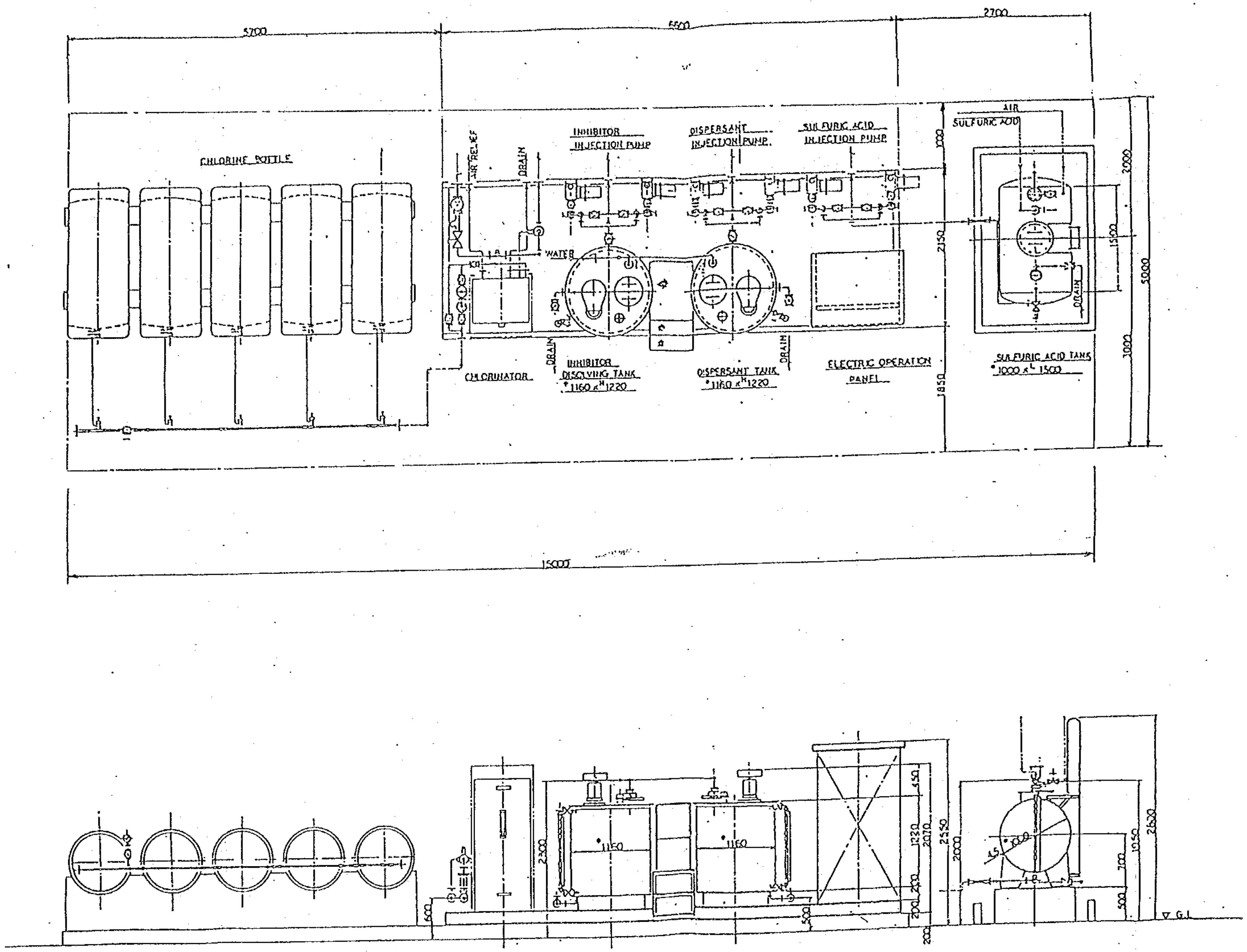


Fig. V.4.2 GENERAL ARRANGEMENT OF CHEMICAL INJECTION UNIT FOR COOLING WATER SYSTEM

V.4 Cooling System Maintenance and Inspection Manual (Draft)

Foreward

The cooling towers, cooling water booster pumps, circulating pumps, and condenser units are connected by the cooling system through pipelines and concrete ducts.

The following equipment units are involved in the cooling system:

No.	Name of Equipment Unit	Number of Units			Remarks
		No. 1	No. 2	No. 3	
1	Cooling Tower	1	1	1	
2	Circulating Pump (existing)	1+1	1+1	1+1	One for normal use and one for standby
3	Condenser (existing)	1	1	1	
4	Cooling Water Booster Pump	1+1	1+1	1+1	One for normal use and one for standby
5	Make-up Water Pump		2+1		Two for normal use and one for standby
6	Chemical Injection Equipment	1	1	1	
7	Auxiliary Cooling Water Pump (existing)	1+1	1+1	1+1	One for normal use and one for standby

Since the operation, inspection, and maintenance manual for equipment unit will be provided by the equipment supplier, only a general outline of the cooling system's operation and maintenance method is described hereunder.

1. Item to be Considered for daily Operational Maintenance

(1) Air Temperature and Cooling Water Temperature
Air and cooling water temperatures are factors having a great affect on the thermal efficiency of power generating equipment,
it is important that they be observed continuously. The observations made over a long period of time should be compared to the equipments' design temperatures.

(2) Cooling Water Qualities

Cooling water that is condensed by condenser units is concentrated when it circulates through the cooling water system. Certain types of water qualities are detrimental to the equipment units and piping of the cooling water system. It is important for possible problems to be forecast and to improve the quality of the cooling water by setting the concentration levels, by adding chemicals to the water, and by properly conducting blowdown operations.

For detailed information pertaining to the operation and maintenance of the chemical injection equipment, reference should be made to the manuals provided by the manufacturer.

(3) Mixture of Foreign Substances

Any mixture of foreign substances that may damage the cooling system pumps or that may interrupt plant operations by clogging the condenser tubes must be avoided.

2. Inspection of Cooling System

Items and objectives of the general inspections of the cooling system are as shown in Table. The inspection schedule for the cooling towers are attached to ANNEX III for reference purposes.

3. Inspection and maintenance schedule for cooling tower

3.1 Time to Replace Mechanical Equipment Parts.

Mechanical equipment parts are manufactured to withstand use for a long period of time. To ensure smooth operation, however, it is advisable to disassemble mechanical equipment for inspection and replacement of the parts according to the following schedule:

(1) Replacement of speed reducer oil seal	----	every 3 years
(2) Disassembly and inspection of speed reducer and replacement of shaft bearing	----	every 6 years
(3) Disassembly of motor and replacement of shaft bearing	--	as per motor instruction
(4) Replacement of fan clamping bolt	----	every 6 years
(5) Replacement of speed reducer flexible hose	----	every 3 years

3.2 Fill and Eliminator.

Remove dirt and algae from fill and eliminator to prevent clogging.

3.3 Inspection and maintenance schedule

Please refer to attached Table-1.

Table-1 Inspection of Cooling System (1 of 3)

No.	Inspection Item	Location and Purpose of Inspection	Observation Frequency Daily	Weekly	Periodic Inspection Time	Method of Inspection	Evaluation Standard	Remarks
1	Air Temperature (°C)	At appropriate outdoor and indoor locations at the power station	○			Visual thermometer reading and temperature recording		Wet bulb and dry bulb temperatures and relative humidity (%)
2	Cooling Water Temperature (°C)	(1) At cooling tower inlets (2) At cooling tower outlets (3) Make up water (at the inlet of cooling tower water basin)	○ ○ ○			Visual readings of temperature gages and temperature recording	Design temperature of condensers and cooling towers	
3	Water Quality	(1) Cooling tower basins (2) Booster pump basins (or booster pump outlets) (3) Make up water (at the inlets of cooling tower water basins)	△ △ △	○ ○ ○		1) Water sampling and water quality analysis by water test equipment	1) Values shown in Table__. Inspect especially for corrosive components such as acid and ammonia. 2) Values shown in the chemical injection equipment manuals provided by manufacturers.	Turbidty, electric conductivity, and PH values must be observed daily.
4	Mixture of foreign Substance	(1) Cooling tower water basins (2) booster pump basins and basin inlets' bar-screens (3) Inlet strainers of auxiliary cooling water pumps	○ ○ ○			Visual inspection Visual inspection 1) Observation of inlet and outlet pressure differences	Inspection of foreign substance in water tanks that may damage pump propellers, shafts, or casings, or that may clog the cooling water pipes of the condensers. *If foreign substances* are found, they must be removed immediately.	
5	Operating Conditions of *Cooling Towers*	(1) Presence of excessive vibrations (drive shafts, fans, motors, *reduction gears*) (2) Presence of abnormal sound (fans, motors, reduction gears) (3) Overheating of motors (4) Abnormal water level in basin	○ ○ ○ ○			1) By touching the units. If necessary, observe by vibration gage 1) By hearing 1) By touching the units If necessary, observe by temperature gage 1) Visual observation of water level indicators and recording.	1) Compare with daily recorded values	

Table-1 Inspection of Cooling System (2 of 3)

No.	Inspection Item	Location and Purpose of Inspection	Observation Frequency Daily	Weekly	Preiodic Inspection Time	Method of Inspection	Evaluation Standard	Remarks
6	Operating Conditions of Pumps	(1) Presence of exessive vibration	○			1) By touching the units. If necessary, observe by vibration gauge.		
		(2) Overheating	○			1) by touching the units. If necessary, observe by a temperature gauge.		
		(3) Abnormal sound	○			1) By hearing		
		(4) Abnormal discharge pressure			○	1) confirm valve opening	1) Compare with daily recorded values	1) Measure pump discharge pressure under valve closed conditions once or twice a year. Examine the annual changes of the pressures to determine the intervals of the periodical inspection.
		(5) Abnormality of bearings	○			1) Visual inspection	1) Confirm smooth rotation	1) Replace parts having dimensions deviating from allowable values.
		(6) To measure disassembled parts' dimensions and check electrical system			○	1) Based on pump manual 2) Measuring of insulation and coil resistance 3) Confirmation of rotating direction	1) Based on pump manual (provided by manufacturer)	2) Replace worn parts
		(7) To confirm adequate cooling liqui through a sight glass of self-cooling type pumps						
		(8) For non-self-cooling type pumps, to confirm if the cooling water inlet pressure is slightly higher (0.3-0.4 kg/cm2) than the pump discharge pressure						
7	Valves	(1) Valve glands	○			Visual inspection	Water leakage through glands	1) Refasten gland or replace gland gaskets
		(2) Valve seat seals			○	Inspection by disassembring, based on valve manual	Existence of cracks, corrosion, and wear.	
		(3) Spindle and moving part			○			
		(4) Water level control valves	○			Visual inspection	Inspection of operating conditions (per manufacturer's manuals)	

Table-1 Inspection of Cooling System (3 of 3)

No.	Inspection Item	Location and Purpose of Inspection	Observation Frequency Daily	Weekly	Preiodic Inspection Time	Method of Inspection	Evaluation Standard	Remarks
8	Chemical Injection Units (1) Pump operarating condition	(1) Oil level in crankcase				Visual inspection	1) Oil level must be within the range of allowable levels	1) Stop operation and replace parts if leakage is excessive
		(2) Oil leakage through carnkcase parts						1) Refasten joints
		(3) Chemical liquid leakage through joints						2) If leakage is excessive, replace gaskets
		(4) Presence of excessive vibration				1) By touching. Observe by vibration gauge if necessary		
		(5) Overheating				1) By touching. Observe by vibration gauge if necessary		
		(6) Presence of abnormal sound				1) By hearing		
		(7) Discharge pressure				By gauge		
		(8) Discharge rate						
		(9) Inspection of disassembled parts				Based on manufacturer's manual		
	(2) Confirmation of chemical quantity	(1) Examination of remaining quanitity (2) Examination of operating conditions of self-melting type equipment				1) Visual inspection 2) Visual inspection	Based on manufacturuer's manual	
	(3) Leakage of equipment parts	(1) Leakage through valve glands, various containers, liquid level gauges, pipes and pipe fitting joints				1) Visual inspection		Refasten joints
	(4) Instruments i) Relief Valves	(1) Leakage				1) Visual inspection		1) Smooth out poor seats or replace then
		(2) Operating test for set pressure				2) Based on manufacture's manual		
	ii) Presure Gauges	(1) Operating conditions				(1) Visual inspection	Compare with daily recorded pressures	1) Readjust if necessary
	(5) Control systems	(1) Adjustment of each control equipment unit and testing of entire system				Based on manufacturer's manual	Based on manufacturer's manual	
	(6) Warning systems	(1) Operating test				Based on manufacturer's manual tors and recording.	Based on manufacturer's manual	