6.3 Layout

Figure 6-3-1 and 6-3-2 show layout of the power plant.

(1) Turbine buildings for units R1 and R2 of a replacing plant will be extended 153m in a northern direction from a point 58m north of the turbine building for remaining unit nos. 1 ~ 4 in use.

(2) A new self standing 1-tower 2-flow type stack of 180m high will be installed at the center of units R1 and R2 of a replacing plant.

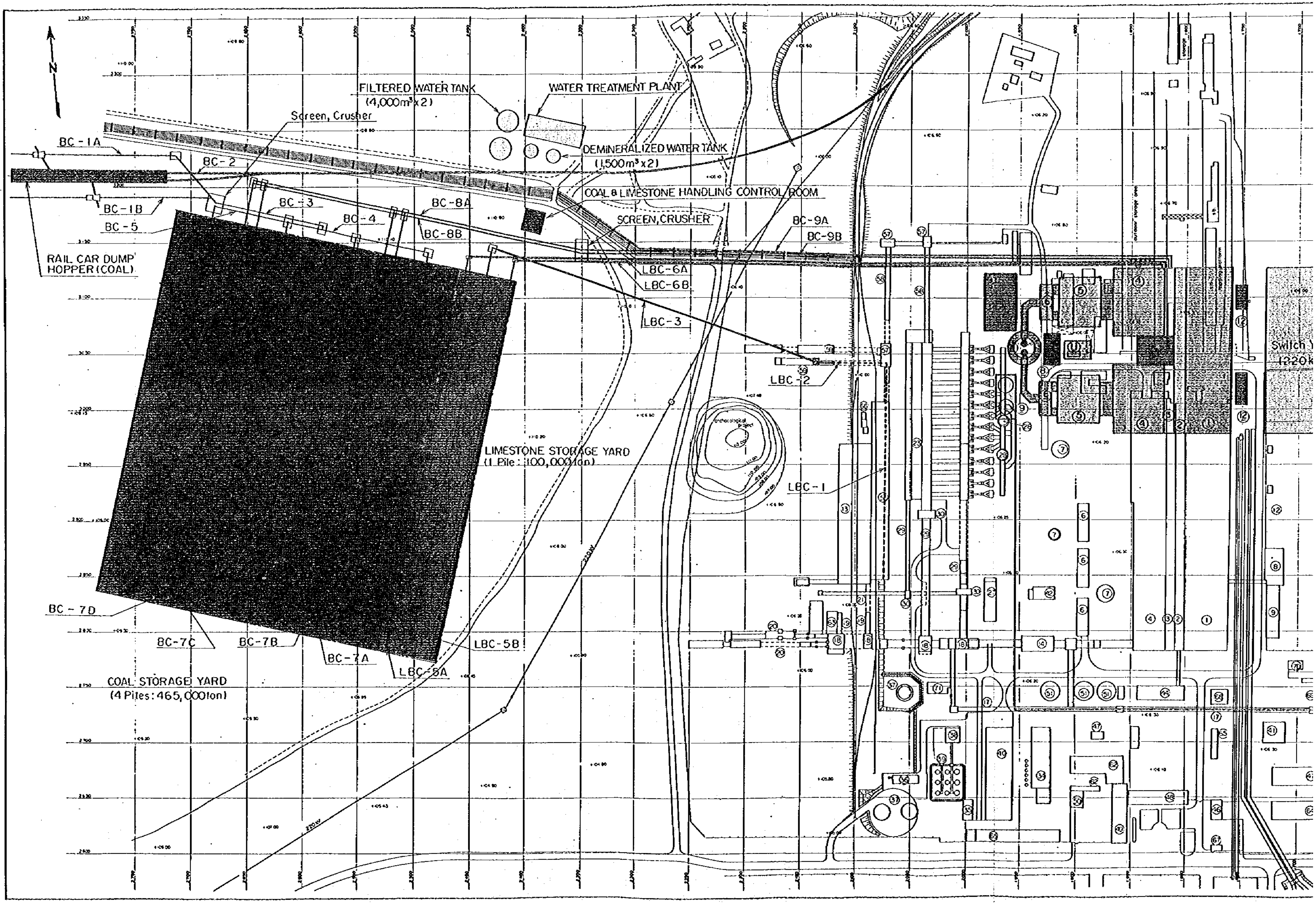
(3) Ash treatment unit will be allocated between electrostatic precipitators for units R1 and R2 of a replacing plant. Ash is transferred to railway freights to transport to outside through a storage tank.

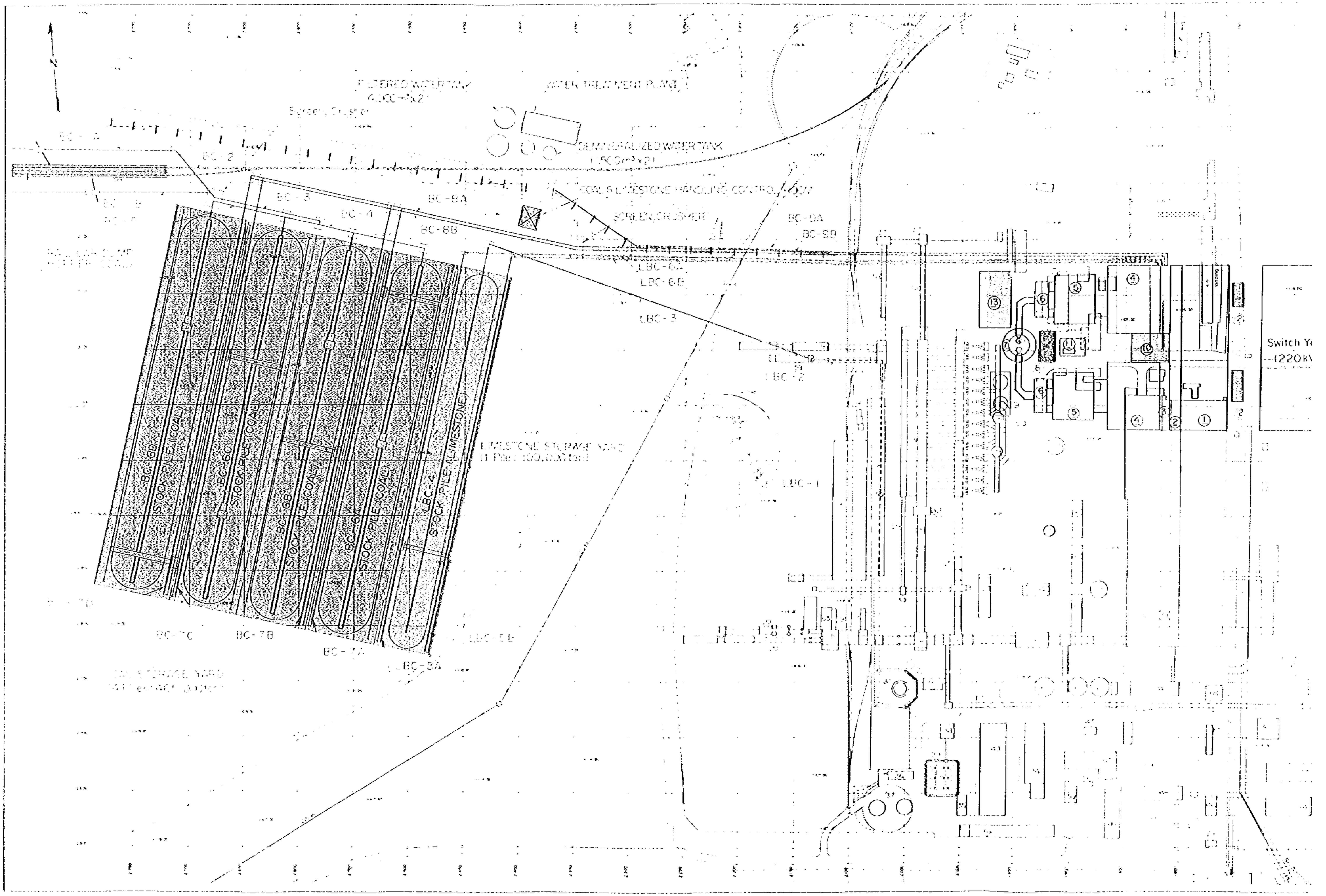
(4) A waste water treatment equipment will be allocated north west of a new stack.

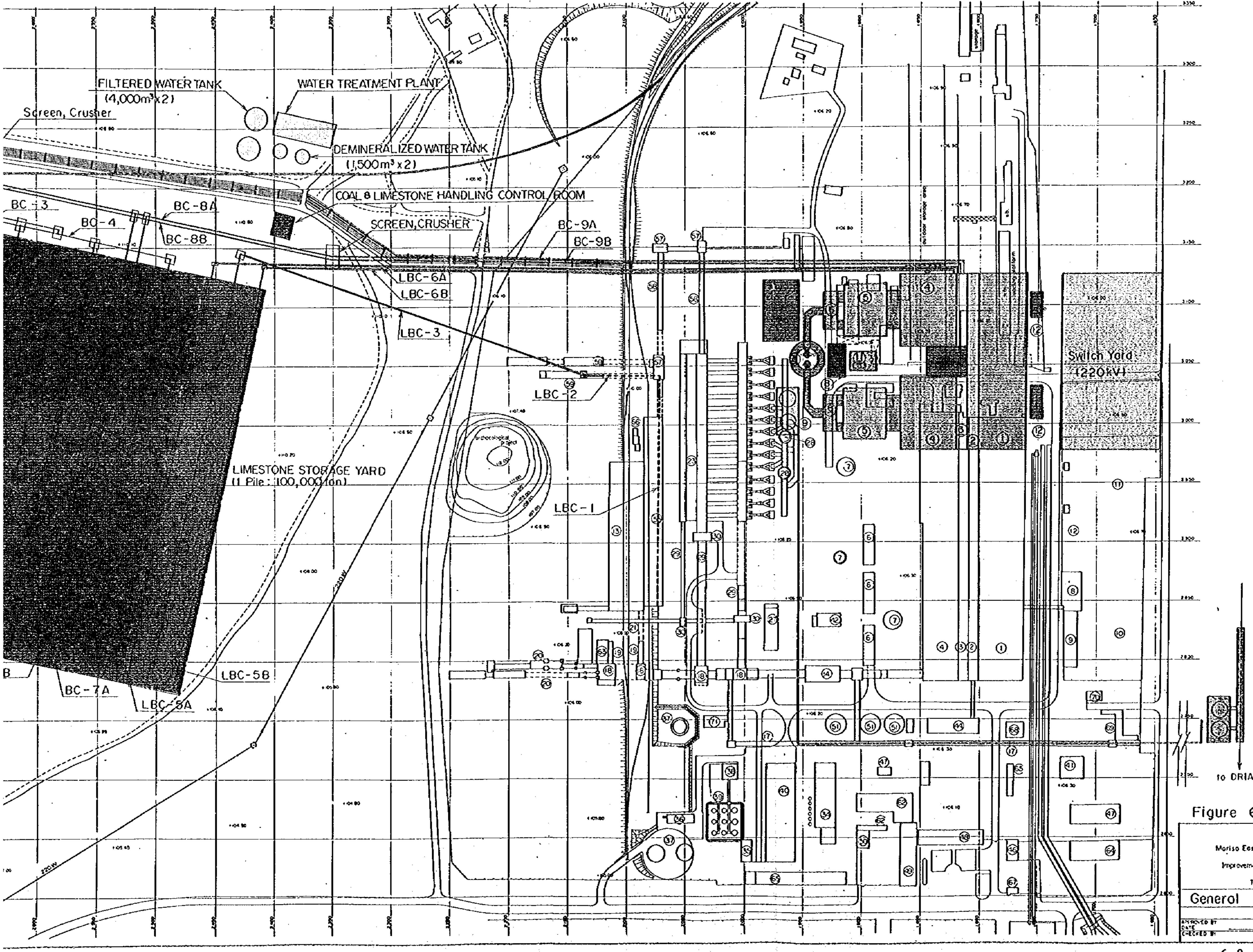
(5) A station water treatment equipment will be allocated north of a reclaimed ash disposal site.

(6) A coal storage yard will be allocated at the ash disposal site.

(7) A limestone storage place will be allocated at the reclaimed ash disposal site.


N
FILTERED WATER TANK
(4,000m³x2)
WATER TREATMENT PLANT
Screen, Crusher
DEMINERALIZED WATER TANK
(1,500m³x2)
BC-1A
BC-2
COAL & LIMESTONE HANDLING CONTROL ROOM
BC-1B
BC-3
BC-8A
BC-5
BC-4
SCREEN, CRUSHER
BC-9A
BC-8B
BC-9B
RAIL CAR DUMP
HOPPER (COAL)
LBC-6A
LBC-6B
LBC-3
Switch Y
(220k
LBC-2
LIMESTONE STORAGE YARD
(1 Pile : 100,000ton)
LBC-1
BC-7D
BC-7C
BC-7B
BC-7A
LBC-5B
LBC-5A
COAL STORAGE YARD
(4 Piles : 465,000ton)
220kV
220kV


N
FILTERED WATER TANK
4,000m³x2
WATER TREATMENT PLANT
Screen, Crusher
DEMINERALIZED WATER TANK
(1,500m³x2)
COAL & LIMESTONE HANDLING CONTROL ROOM
SCREEN, CRUSHER
BC-1A
BC-1B
BC-2
BC-3
BC-4
BC-8A
BC-8B
BC-9A
BC-9B
LBC-6A
LBC-6B
LBC-3
LBC-2
LBC-1
BC-6D
STOCK PILE (COAL)
BC-6C
STOCK PILE (COAL)
BC-6B
STOCK PILE (COAL)
BC-6A
STOCK PILE (COAL)
LBC-4
STOCK PILE (LIMESTONE)
LIMESTONE STORAGE YARD
(1 Pile 100,000ton)
BC-7C
BC-7B
BC-7A
LBC-5A
LBC-5B
COAL STORAGE YARD
①
②
③
④
⑤
⑥
⑦
⑩
⑪
⑬
Switch Y
(220kV



No.	Description
	I MAIN BUILDING
1	Turbine hall
2	Deorator section
3	Bunker section
4	Boiler section
5	Outdoor for flue gas fans
6	Switchgear for electric precipitators
7	Stack
	II ELECTROTECHNICAL STRUCTURES
8	Covered unloading
9	Indoor switchyard
10	Switchyard - 110kV
11	Switchyard - 220kV
12	Transformer site
	III STRUCTURES OF COAL SUPPLY SYSTEM
13	Electric control room
14	Coal crusher building
15	Coal transport trestles - 1st uplift
16	Coal transport trestles - 2nd uplift
17	Trestles from briquette plant
18	Transfer stations No 1, 2, 3, 4
19	Coal supply galleries
20	Trestles and galleries to outdoor coal storage
21	Trestle for dry fuel supply
22	Outdoor coal storage
	IV STRUCTURES OF COAL DRYING PLANT
23	Drying plant
24	Outdoor site under the drums
25	Building for cyclones
26	Outdoor site for funnel suckers
27	Compressor station to the drying plant
28	Stack
29	Trestles for the coal conveyers from drying plant
30	Transfer stations No 5, 6, 7
	V. STRUCTURES FOR SERVICE WATER SUPPLY
31	Bank pump station
32	Switching chamber
33	Open air outgoing channel
	VI SERVICE BUILDINGS AND STRUCTURES
34	Water treatment plant
35	Turners workshop to U.A. Building
36	Pump station for heavy fuel oil
37	Heavy fuel oil tanks
38	Oil facility
39	Outdoor oil storage
40	Unified auxiliary building
41	Open air hydrogen tanks
42	Dredger - pump station
43	Compressed-air station
	VII SECOND COAL SUPPLY TO DRYING PLANT
56	Covered unloading - extension
57	Transfer stations No 8, 9, 10
58	Coal transport trestles
59	Trestles and galleries to outdoor storage
60	Outdoor coal storage 3
	VIII AUXILIARY BUILDINGS AND STRUCTURES
44	Office building
45	Walkway
46	Security building and health centre
47	Amenities building
48	Administrative building
49	Garage
50	Carwash
51	Condensate tanks
52	Repair shop
53	Acetylene station
54	Carbide storage
55	Oxygen station
61	Accumulator battery
62	Bathroom
63	Garage for bulldozers
64	Restaurant
65	Covered storage
66	Building for
67	Bus stop
68	Boiler station for heating supply
69	Anti-fire defence
70	Garage for electric trucks
71	Tools workshop

Replacing Plant

1	Turbine hall
2	Decerator section
3	Bunker section
4	Boiler section
5	Electrostatics precipitator
6	IDF (Induced Draft Fan)
7	Stack
8	Fly ash transmitter tank
9	Fly ash silo
10	Central control room
11	Ash handling control room
12	Transformer yard
13	Waste Water Treatment Yard

Figure 6-3-1

The Feasibility Study
on
Mariso East No.1 Replacing Thermal Power Plant
for
Improvement of The Performance of The Units
and
The Environmental Protection

General Layout

SCALE:

JICA TEAM

APPROVED BY
DATE
CHECKED BY
REVIEWED BY
DRAWN BY


BC-6B
STOCK PILE (COAL)
BC-6A
STOCK PILE (COAL)
LBC-4
STOCK PILE (LIMESTONE)
⑬
⑥
⑤
④
⑦
⑩
⑥
⑤
④
②
①
Switch Yard
(220kV)

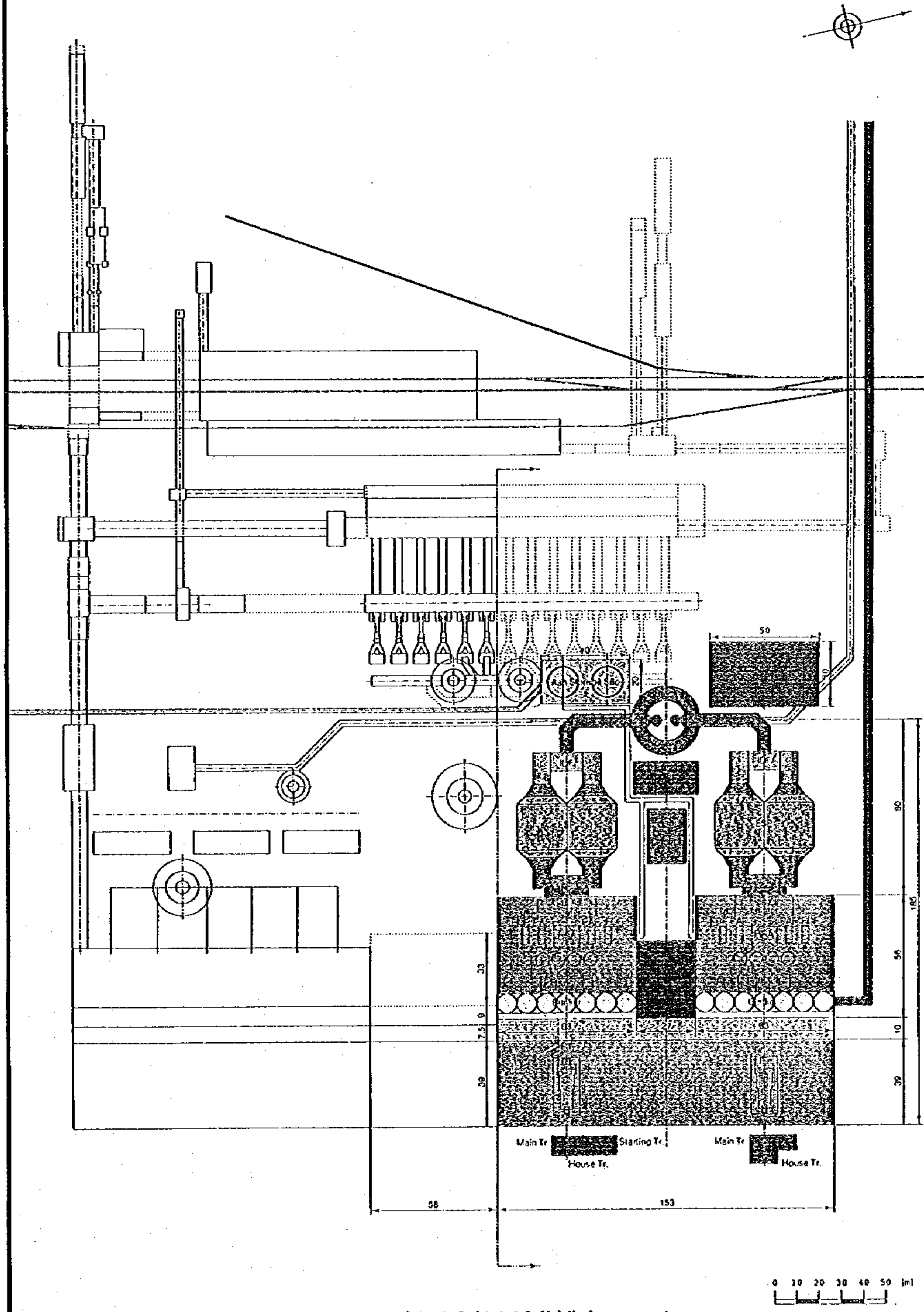


Figure 6-3-2 CFBC(230MW) Layout

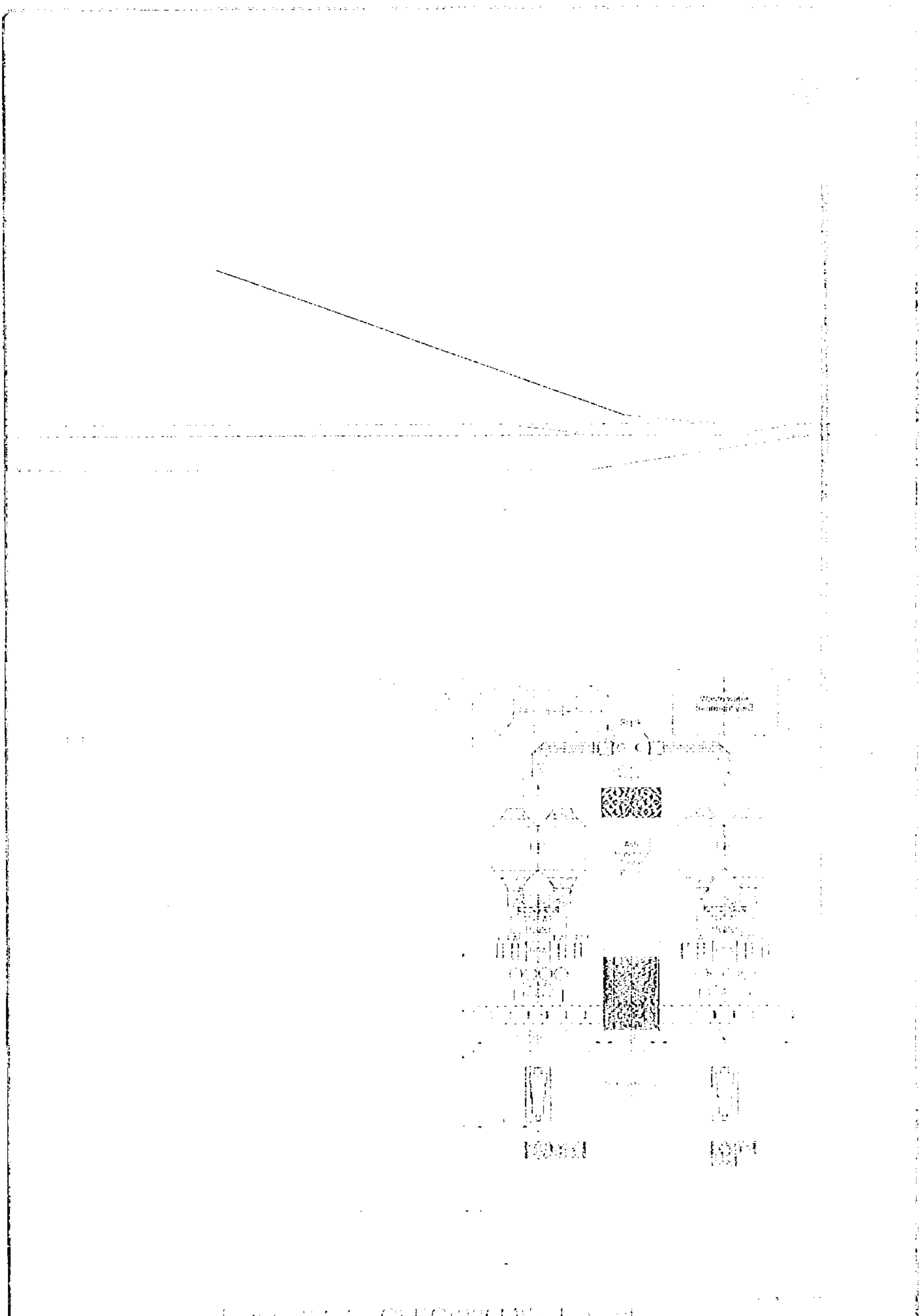


Figure 6.3.1 CFBC 350MW Layout

6.4 Material Balance and Schematic Diagram on Boiler

Figure 6-4-1 shows material balance and schematic diagram on the boiler side. The brief process of each system is as described below.

(1) Lignite supplying system

Fuel lignite is supplied to the boiler through the following process.

(a) Lignite is crushed to less than 40mm by crusher located between the coal storage place and the boiler building, and supplied to coal bunker in the boiler building.

(b) The coal bunker is so designed that bunker walls have a 72° inclination, in order to prevent clogging. Seven bunkers are provided per unit.

(c) There are seven coal storage bunkers and one of seven bunkers is for spare. Six storage bunkers hold a capacity of a 6-hour operation at MCR, and coal delivery is continuously performed for 24 hours.

(d) Lignite discharged from the coal storage bunker is crushed to less than 12mm by means of coal crushers and supplied to seven coal feed bunkers.

(e) Lignite through coal feeders (two feeders per coal feed bunker) from the coal feed bunker drops into the furnace bottom by gravity.

(2) Limestone supplying system

Limestone, desulfurizing agent, is supplied to the boiler through the following process.

(a) Limestone is crushed to less than 50mm by crushers located between the limestone storage place and the boiler building and supplied to limestone bunkers in the boiler building.

(b) Limestone discharged from the limestone storage bunker is crushed to less than 3mm by means of limestone crushers and supplied to the limestone feed bunkers.

(c) Limestone discharged from the limestone feed bunker by means of a rotary valve is supplied to lignite feeding tube by air and then supplied to the furnace bottom together with lignite.

(3) Air feed system

(a) Combustion air from FDF is divided to fluidizing air (primary air) and combustion air (secondary air) branched after pressurized by means of the FDF.

(b) Primary air is pressurized through PAF (primary air fan) and heated up through GAH (gas air heater) and then supplied into the furnace from a wind box.

(c) Secondary air also is heated up through GAH and supplied to the upper furnace for combustion and NOx control.

(4) Gas system

(a) Combustion gas from the furnace is introduced to a cyclone, where bed material (unburnt lignite, burnt ash, generated gypsum and unreacted limestone) is separated.

(b) Separated bed material is returned to the furnace bottom through a recirculating line, which contributes to higher combustion efficiency and for furnace temperature control.

(c) On the other hand, combustion gas separated through the cyclone is led to heat recovery area and undergoes heat exchange. Flue gas leaving a boiler is introduced to GAH to heat up air. After dust is removed by electrostatic precipitator, the flue gas is discharged from a stack through the IDF.

(5) Ash treatment system

(a) Bed material is pulled out of the furnace bottom, cooled by a bed material cooler and transferred by vacuum to an ash transit tank.

(b) Combustion ash and generated gypsum discharged from economiser hoppers, GAH hoppers and electrostatic precipitator hoppers are transferred by vacuum to an ash transit tank.

(c) Combustion ash and generated gypsum collected in the ash transit tank are transferred to ash disposal place through an ash storage silo.

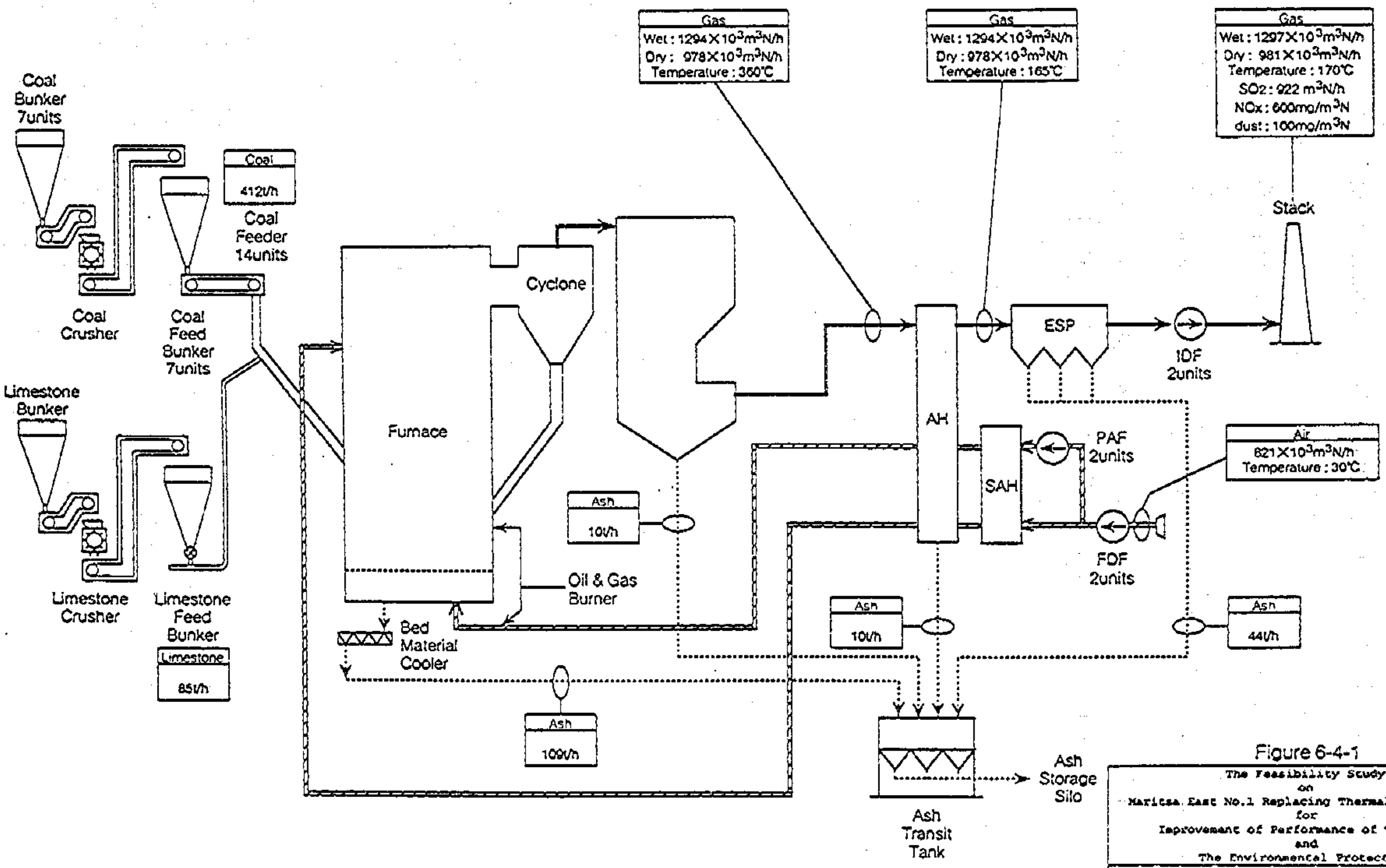


Figure 6-4-1

The Feasibility Study
on
Maritsa East No.1 Replacing Thermal Power Plant
for
Improvement of Performance of The Units
and
The Environmental Protection

Fuel Firing System & Air & Gas Draft System Material Balance	SCALE
JICA TEAM	
APPROVED BY DATE	REVIEWED BY
CHECKED BY	DRAWN BY

6.5 Turbine Cycle Heat Balance

6.5.1 In Case of 230MW Rated Output (Without the District Heating)

Figure 6-5-1 shows a heat balance diagram at 230MW (without district heating). A turbine cycle heat rate at the rated output of 230MW is 1,906 kcal/kWh (45.12%).

6.5.2 In Case of 200MW Rated Output (With the District Heating)

Figure 6-5-2 shows a heat balance diagram at 200MW (with district heating). A turbine cycle heat rate at the rated output of 200MW is 1,841 kcal/kWh (46.7%).

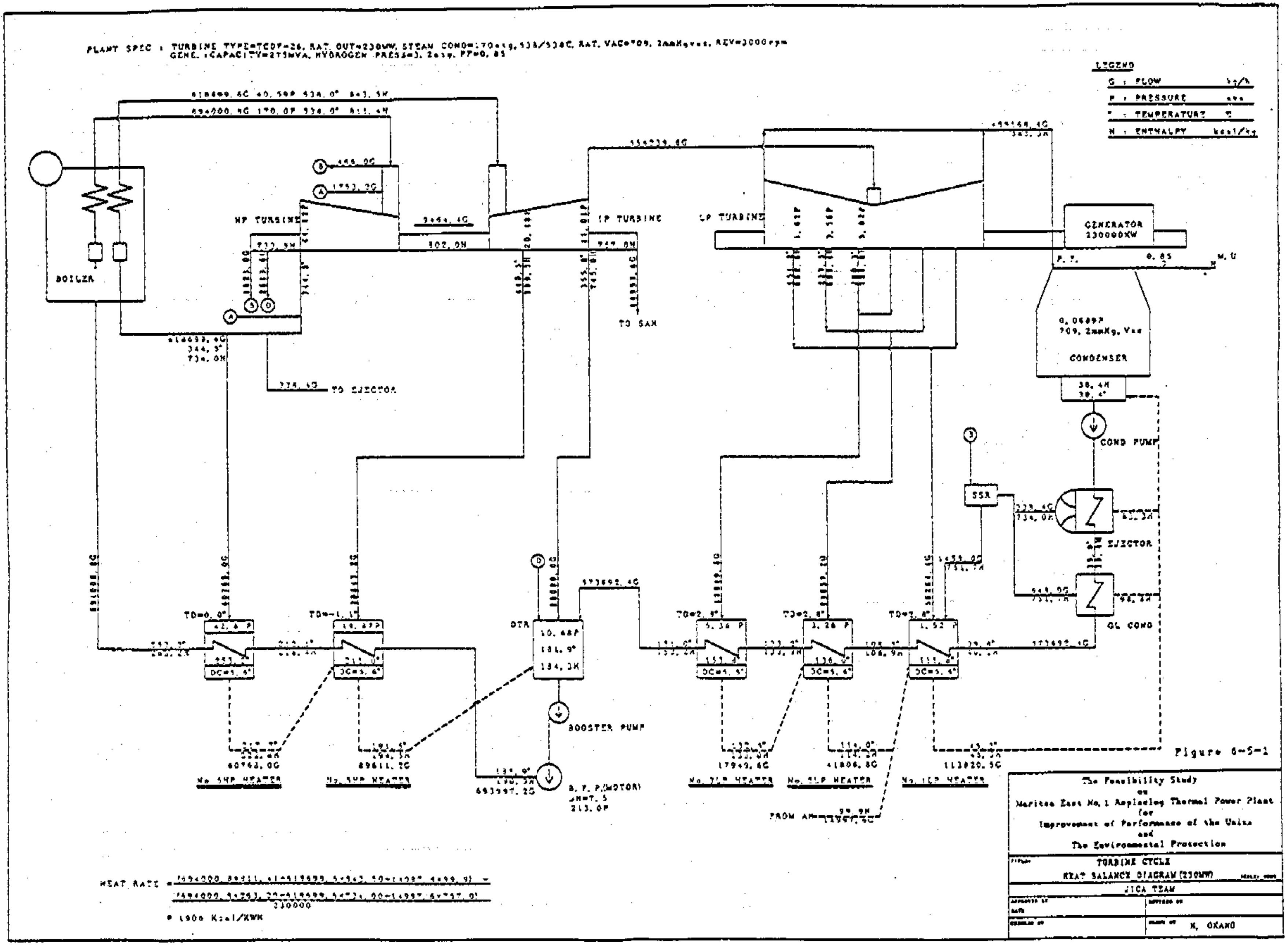

PLANT SPEC : TURBINE TYPE=TCDF-26, RAT. OUT=230MW, STEAM COND=170atg, 538/538C, RAT. VAC=709, 2mmHgvac, REV=3000rpm
GENE. :CAPACITY=273MVA, HYDROGEN PRESS=3, 2atg, PF=0, 85
LEGEND
G : FLOW
P : PRESSURE
° : TEMPERATURE
H : ENTHALPY kcal/kg
BOILER
HP TURBINE
IP TURBINE
LP TURBINE
GENERATOR 230000KW
P.F. 0.85
CONDENSER
0.0689P
709, 2mmHg, Vac
38.4H
38.4°
COND PUMP
SSR
EJECTOR
GL COND
TO SAH
TO EJECTOR
DTR
10.68P
181.9°
184.3K
BOOSTER PUMP
B. F. P.(MOTOR)
No. 6HP HEATER
No. 5HP HEATER
No. 3LP HEATER
No. 2LP HEATER
No. 1LP HEATER
FROM AH
TD=0.0°
TD=-1.1°
TD=2.9°
TD=2.8°
TD=2.8°
42.6 P
19.67P
5.36 P
3.26 P
1.52 P
DC=5.6°
DC=5.6°
DC=5.5°
DC=5.6°
DC=5.5°
618499.6G 40.59P 534.0° 843.5H
694000.9G 170.0P 534.0° 811.4H
614693.9G
344.5°
734.0H
9464.4G
302.0H
554739.6G
573692.4G
693997.2G
236.4G
60763.0G
89611.2G
17949.6G
41806.8G
113820.5G
HEAT RATE =
230000
= 1906 Kcal/KWH
The Feasibility Study
on
Maritsa East No.1 Replacing Thermal Power Plant
for
Improvement of Performance of the Units
and
The Environmental Protection
TURBINE CYCLE
HEAT BALANCE DIAGRAM (230MW)
JICA TEAM
N. OKANO

Figure 6-5-1

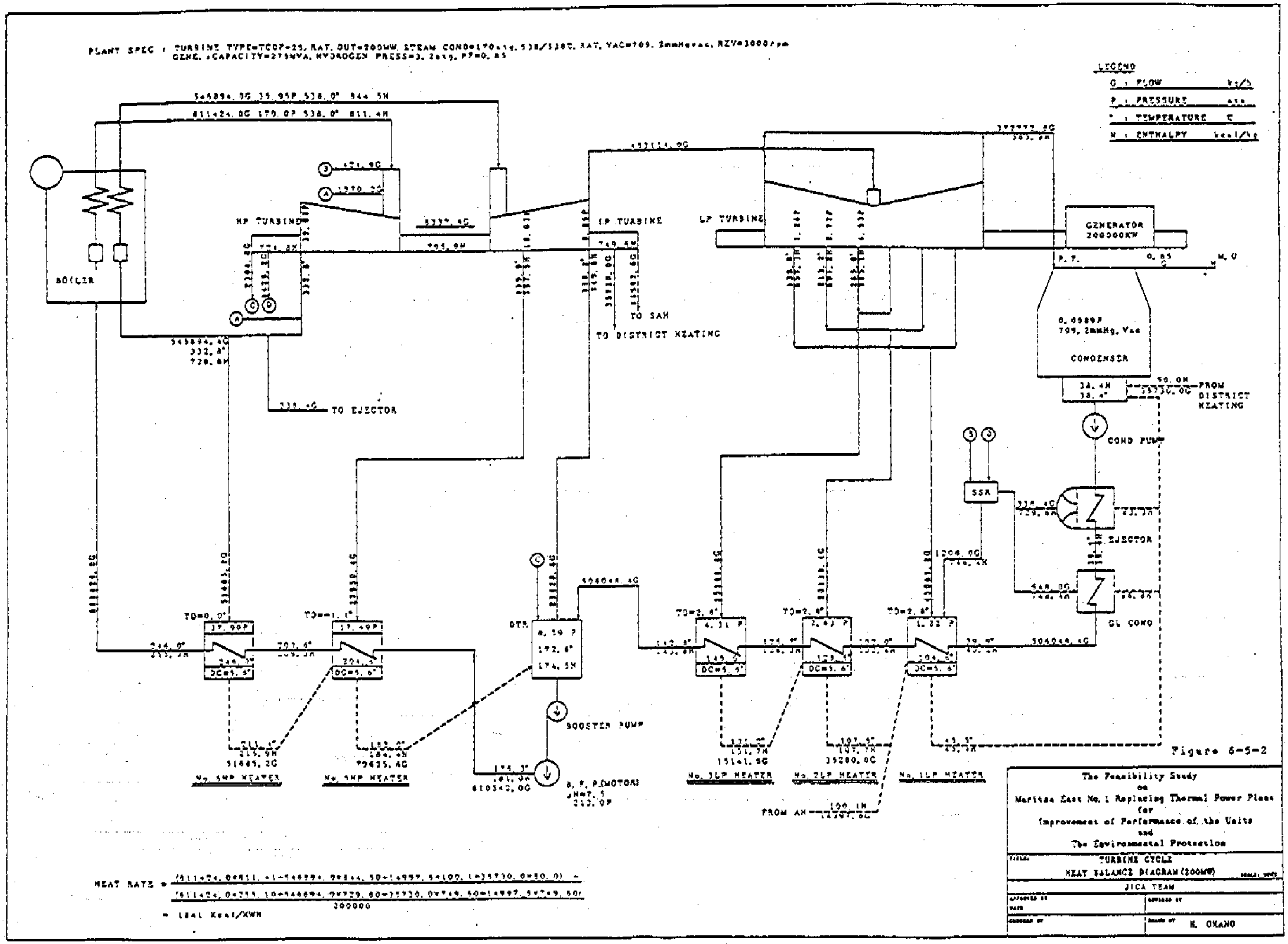


Figure 6-5-2

The Feasibility Study
on
Maritsa East No. 1 Replacing Thermal Power Plant
for
Improvement of Performance of the Units
and
The Environmental Protection

TURBINE CYCLE
HEAT BALANCE DIAGRAM (200MW)

JICA TEAM

H. OKANO

6.6 Boiler Equipment

6.6.1 Boiler Design Conditions

(1) Unit output : 230MW (ECR)

(2) Boiler type : Circulating fluidized bed combustion boiler (C-FBC)

(3) Steam conditions at MCR

(a) Main steam flow : 740 t/h
(b) Main steam pressure : 173 kg/cm^2g (at boiler outlet)
(c) Main steam temperature : 541°C (at boiler outlet)
(d) Reheated steam temperature : 541°C (at boiler outlet)

(4) Economiser inlet water temperature
(at MCR) : 252°C

(5) Draught system : Balanced

(6) Restrictions of emission (stack exit, on the basis of O_2=6%)

(a) SO2 : More than 90% of desulfurization efficiency
(b) NOx : Less than 600mg/m3N (292ppm)
(c) Dust : Less than 100mg/m3N
(d) CO : Less than 250mg/m^3N (200ppm)

(7) Boiler side view : Shown in Figure 6-6-1

6.6.2 Boiler Equipment Specification

Specifications for 1 plant design are as follows.

(1) Boiler Equipment

(a) Boiler pressure parts

1) Furnace

Type : Natural circulation, water cooled, welded membrane construction

2) Drum

Type : Single drum provided with steam separators, welded construction

3) Cyclone

Type : Centrifugal separation
Catching efficiency : More than 99.5%

4) Super heater

Type : Convection and if any radiant

5) Reheater

Type : Convection

6) Fuel economizer

Type : Bare tube

(b) Boiler casing

Type : Covered with corrugated steel plate

(c) Air preheater (GAH)

1) Specification

Type : Regenerative, bi-sector
Quantity : 1 unit

2) Temperature conditions

GAH outlet gas temperature : 165°C (MCR)
GAH inlet air temperature : 65°C (MCR)

(d) Steam air preheater (SAH)

1) Specification

Type : Finned tube
Quantity : 1 unit

2) Temperature conditions

SAH outlet gas temperature : 65°C (MCR)
SAH inlet air temperature : 40°C (MCR)

(e) Soot blower

Type : Automatic or manual operated, steam injection type

(f) Air duct and flue

Type : Steel plate welded construction

(2) Coal and limestone supplying equipment

(a) Coal supplying equipment

1) Coal storage bunker

Type : Steel plate lined with antifriction material
Quantity : 7 units (one for spare)
Capacity : 6 hour operation at MCR/6 bunkers

2) Coal crusher

Type : Hammer
Quantity : 7 (one for spare)
Capacity : 70 t/h/crusher

3) Coal feed bunker

Type : Steel plate lined with antifriction material
Quantity : 7 units (one for spare)
Capacity : 2 hour operation at MCR/6 bunkers

4) Coal feeder

Type : Enclosed belt, gravimetric
Quantity : 14 units
Capacity : 50 t/h/feeder

5) Coal chute

Type : Chute provided with air spreaders
Quantity : 14

(b) Limestone transportation equipment

1) Limestone storage bunker

Type : Steel plate
Capacity : 6 hour operation at MCR

2) Limestone crusher

Type : Hammer type
Capacity : 90 t/h

3) Limestone feed bunker

Type : Steel plate

4) Limestone rotary valve

Type : Rotary
Capacity : 90 t/h

(3) Heavy oil burning equipment

(a) Heavy oil burner

Type : Lance, steam atomized
Capacity : 30% MCR

(b) Start up burner

Type : Electric ignited, duct burner
Capacity : 15% MCR

(4) Draft fan

(a) Forced draft fan (FDF)

Type : Centrifugal
Quantity : 2 units

(b) Primary air fan (PAF)

Type : Centrifugal
Quantity : 2 units

(c) Induced draft fan (IDF)

Type : Centrifugal
Quantity : 2 units

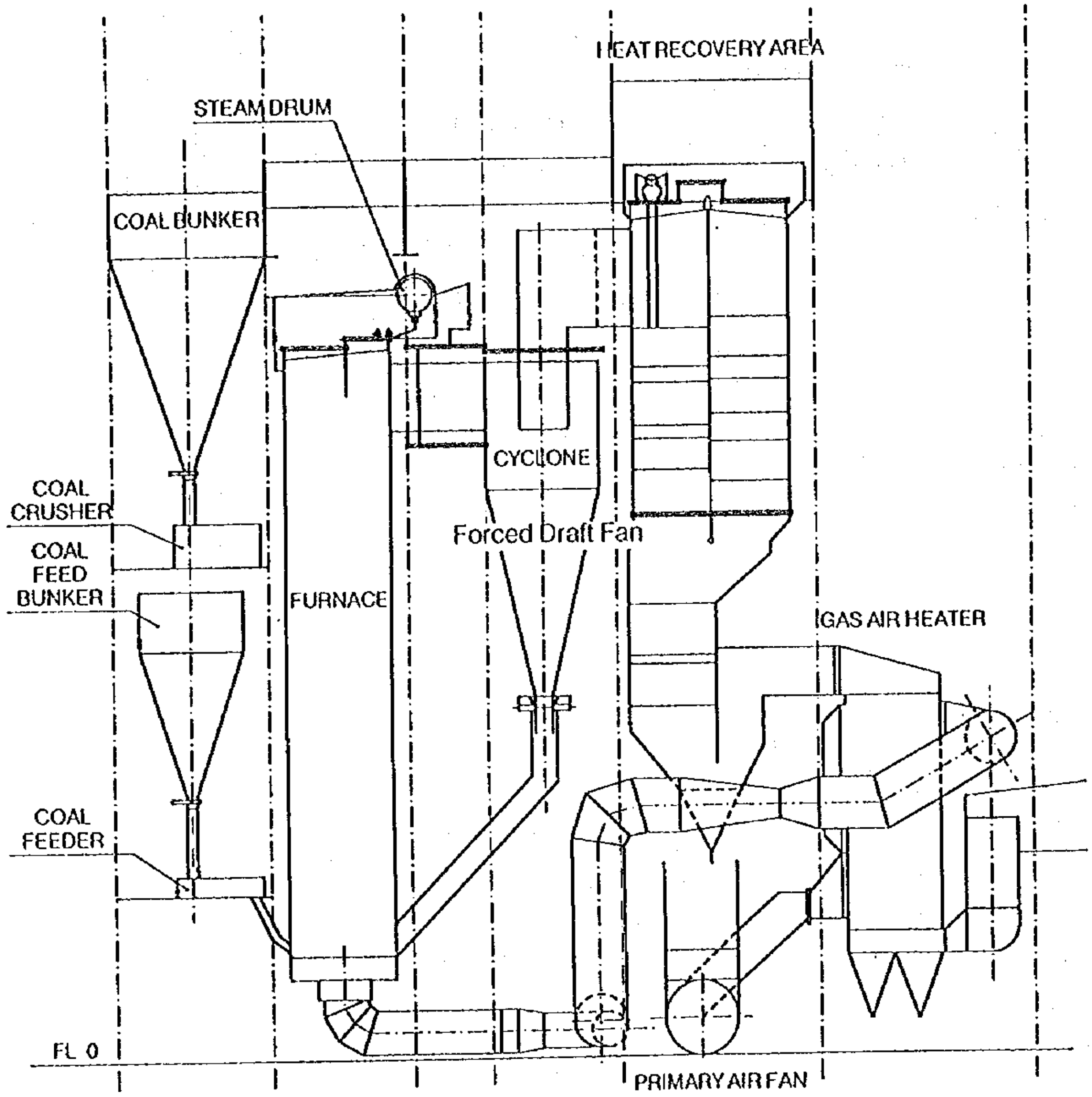


Figure 6-6-1 SIDE VIEW OF C-FBC BOILER PLANT

6.7 Steam Turbine

6.7.1 Steam Turbine

(1) Design Conditions

(a) Turbine Rated Output (Design point)

The rated output of steam turbine generator at the generator terminal is 200MW with the district heating and is 230MW without district heating at the rated inlet steam conditions and 50 mmHg abs. of exhaust pressure.
Condenser inlet cooling water temperature is 21°C.

(b) Capability Condition

Steam turbine is capable of generating the electric power of 200MW with the district heating and of 230MW without district heating at the rated inlet steam conditions and 90mmHg abs. of turbine exhaust pressure without any make-up water.
Maximum condenser inlet cooling water temperature is 32°C.

(c) Maximum Continuous Rating (MCR)

Steam turbine shall be ensured to be able to generate the output not less than 200MW with the district heating and 230MW without the district heating at the rated inlet steam conditions and 50mmHg abs. of exhaust pressure.
The inlet steam flow at maximum continuous rating shall be offered by a turbine manufacturer.

(d) Steam Conditions

It is preferable for design of a turbine having higher efficiency to adopt the higher temperature and higher pressure steam condition.
However, the following sub-critical steam condition is adopted for this plant considering the unit capacity, operability and maintainability.

Main steam pressure at turbine inlet : 169 kg/cm^{2}g (=16.7MPa)
Main steam temperature at turbine inlet : 538°C
Reheat steam temperature at turbine inlet : 538°C

(e) Design of turbine exhaust pressure

Turbine rated exhaust pressure is 50mmHg (when lake water temperature is water 21°C) integrally taking into consideration the annual average cooling water temperature, operating conditions and allowable temperature rise of condenser cooling water (Δ T=7°C from environmental protection point of view), fuel consumption and so forth.

(2) Study Results

(a) Specification of Steam Turbine

① Type : Tandem compound, two cylinder, double flow-exhaust, reheat turbine
② Number : Two (2)
③ Rated output : 230 MW without the district heating
200MW with the district heating
④ Steam conditions : Main steam pressure 169 kg/cm^{2}g (at turbine inlet)
Main steam temperature 538°C (at turbine inlet)
Reheat steam temperature 538°C (at turbine inlet)
⑤ Exhaust pressure : 50 mmHg. abs. (at the rated condition)
90 mmHg. abs. (at the capability condition)
⑦ Speed : 3,000 rpm
⑧ Governing system : High pressure type EHC system

(b) Steam Turbine Auxiliaries

Type and number of steam turbine auxiliaries for Maritsa East No.1 Power Plant Units R1 and R2 are selected hereunder. The number is shown per Unit.

① Main oil tank

One (1) main oil tank per unit is installed on the ground floor in the turbine building.

② Auxiliary oil pump

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

③ Jacking oil pump

Generally, turbine manufacturer will determine whether or not jacking oil pump will be provided, as per its design criteria.

In case jacking oil pump is provided, one pump is provided because this pump is only operated only at the turbine.

④ Gland steam condenser

One (1) gland steam condenser is provided.

⑤ Turbine bypass system

HP/LP turbine bypass system is adopted due to the following reasons.

1) To improve the characteristics of plant start up
2) To protect boiler at the emergency stop of the unit

⑥ Condenser

1) Condenser is of one (1) pass type and its water box shall be divided into two (2) boxes.
2) 90-10 Cupro-Nickel tube is adopted for the condenser tube material taking into consideration the water quality of Rozovkladnetz Lake.
3) Dissolved oxygen in the condenser is 0.03cc/l at this steam condition.

⑦ Circulating water pump

1) The number of circulating water pump is two (2) sets for each unit and one (1) set for common, five (5) sets in total.
2) Capacity of pump is 50% at the rated cooling water flow.
3) As for pump materials, stainless steel which is excellent for anti-corrosion is adopted for pump main parts, taking account of cooling water quality and other reasons.

⑧ Condensate pump

1) Capacity of condensate pump is 100% per pump at rated condensate flow.
2) The number of pump is two (2) sets because reliability of pump itself is increased.
3) Type of pump is of vertical multi-stage pit can with suction strainer.
4) Material of main parts is as follows.

- Impeller: Stainless steel
- Casing : Cast iron or Steel casting
- Shaft : Stainless steel

⑨ Feedwater heater

1) Type of high pressure and low pressure feedwater heaters are horizontal U tube type taking into consideration its operability and maintainability.
2) Material of main parts is as follows.
   a. Tube materials
      - High pressure feedwater heater : Carbon steel
      - Low pressure feedwater heater : Stainless steel
   b. Shell and tube plate : JIS SF490, SB450 or equivalent

⑩ Deaerator

1) Type of deaerator is of spray cum tray type which has many experiences in this class.
2) Capacity of deaerator tank is about $80m^3$ to $100m^3$ on 156MW to 600MW unit, and a tank is sized as follows.
   a. Dimension of tank: Inner diameter 3,500mm, length about 14,000mm
   b. Weight of tank: 59ton when empty, 240ton when filled with water

⑪ Boiler feed pump

1) Capacity of pump is 50% at rated feed water flow.
2) The number of pump is three (3) sets taking account of reliability and experiences.
3) Type of pump is of motor driven, variable pitch, horizontal, multi-stage barrel type with booster pump and water seal system.
4) Material for main parts is as follows.
   - Impeller : Stainless steel casting
   - Casing : Stainless steel
   - Shaft : Stainless steel casting

⑫ Bearing cooling water pump

1) The number of pump is two (2) sets taking account of reliability and experiences.
2) Capacity of pump is 50% at rated cooling water flow.
3) Type of pump is of horizontal volute.
4) Material for main parts is as follows.
   - Impeller : Bronze casting
   - Casing : Cast iron
   - Shaft : Carbon steel

⑬ Air extraction system

1) Steam jet air ejector which is advantageous in cost and maintainability is adopted for air extraction system.
2) The number of air extraction system is one (1) set per unit.

(3) Recommendation and matters to be considered

Turbine auxiliaries have basically no stand-by unit, considering reduction of equipment cost. However, it is necessary to decide the number of turbine auxiliaries considering the operator's technique in operation and maintenance, and easiness of the spare parts procurement, at the detail design stage.

6.7.2 General Arrangement in the Turbine Building

(1) Design conditions

(a) A part of the existing turbine building shall be reused. However, it is necessary to extend the turbine building to 85.25m or 95.25m because the newly installed stack and gas ducts are interfered by the existing coal dryer factory.

(b) The steam turbine and generator shall be arranged perpendicular to the turbine building (hereinafter called "I type arrangement").

(c) The turbine building has two floors; the ground floor and operating floor. New operating floor level should be same as the existing one because the existing overhead travelling crane is reused.

(d) Unloading area for erection and maintenance of main equipment shall be prepared at transformer side.

(2) Results of study

(a) General arrangement on the ground floor (GL+200, Figure 6-7-1)

① Main oil tanks, boiler feed pumps, bearing cooling water pumps, seal oil equipment, the heat exchanger for the district heating and the unloading area, etc. are installed on the ground floor.
② Condensers and condensate pumps shall be installed on the underground level (GL-4500).
③ Opening for the tube pulling space shall be installed on the ground floor.

(b) General arrangement on the operating floor (GL+8000, Figure 6-7-2)

① As the dismantling and inspection of the turbine generators is planned to be carried out on the operating floor, the operating floor shall be fully covered with tile. However, the opening should be provided with grating for the dismantling and inspection of main pump, and for the put in/out of the main equipment.

② Steam turbine, turbine generator, exciter, AVR, power center, etc. are installed on the operating floor.

(c) General arrangement of each floor in the deaerator bay (Figure 6-7-1, 6-7-2)

① The deaerator shall be installed on the level (GL+20,000) which is same as the existing deaerator level because a part of the existing deaerator bay is reused.

② Each feedwater heater shall be installed on the same level of operating floor and ground floor level.

③ In case the vertical feedwater heaters are installed, 22m height is necessary between the installed floor level and level of the overhead travelling crane hook because the length of the feedwater heater is about 12m and the space for tube pulling is about 10m. However, as the clearance between the ground floor level and the crane level is about 18m, the vertical feedwater heater can not be adopted.

(d) Section of turbine building (Figure 6-7-3)

The operating floor level shall be same as the existing operating floor level (GL+8,000) and the ground floor level shall be standard level (GL+200).

(3) Recommendation and matters to be studied

(a) Confirmation of operating floor level

The operating floor level (GL+8,000) of the reconstructed plant shall be same as the existing operating floor level because the existing overhead travelling crane is reused.
However, it is necessary to study whether or not the clearance between the operating floor level and the overhead travelling crane hook level is big enough to dismantle and inspect a turbine generator.

(b) General arrangement of steam turbine generator

I type arrangement is employed in this report. However, in case of adopting the PCF boiler, it is possible to arrange the turbine generator parallel to the long derection of the turbine building (hereinafter called "T type arrangement") because the length of the turbine building is long.

6.7.3 Condenser and Circulating Water System

(1) Design condition

(a) Condenser

① Type : One (1) pass, horizontal surface type, divided water box
② Turbine exhaust pressure : 50 mmHg abs.
③ Inlet cooling water temperature : 21°C (Design point)
④ Cleanliness factor : 0.85
⑤ Turbine exhaust steam flow : 458 t/h (at 230MW)
⑥ Turbine exhaust steam enthalpy : 565.3 kcal/kg
⑦ Condenser tube :
- Tube material should be selected based on the water quality of the Lake Rozovkladnetz.
- Size and thickness should be selected by the tube material.

⑧ Number of tube pass (N) : One (1)
⑨ Velocity of cooling water in tubes (V) : 2.0 m/sec.
⑩ Condensate water temperature : 38.4°C (saturated temperature at 50 mmHg abs)

(b) Circulating water system

The circulating water system of the replacing plant is shown in the Figure 6-7-4.

(c) Circulating water facilities

① Intake and discharge water channels

A part of common intake water channels and discharge channels should be re-used as described in item 5.4.1.
However, channels between common intake/discharge water channels and condensers should be newly constructed.

② Screen facility for intake water channel

Bar screen should be newly installed.

③ Circulating water pumps

Circulating water pumps should be replaced to the new pumps. It is, however, necessary to modify the existing pump house.

(2) Study results

(a) Condenser

① Condenser surface area : 6,990 m^2
② Number of condenser tube : 7,060
③ Distance between tube sheets : 9,918mm
④ Tube material : 90-10 cupro-nikkle
⑤ Tube size : Outer diameter 31.75mm Thickness 1.00mm
Effective length 9,918mm

(b) Calculation to decide specification of condenser

① Heat duty (H) when 230 MW : 242.25×10^6 (kcal/hr)

1) Turbine exhaust steam : $(565.3 - 38.4) \times 458{,}168.4 = 241.41 \times 10^6$ (kcal/hr)
2) Feedwater heater drain, etc. : 0.84×10^6 (kcal/hr)

② Heat transfer rate (K)

The heat transfer rate (K) is calculated based on the following formula derived from the Standards for Steam Condenser of the Heat Exchange Institute.

$$\begin{aligned} K &= C \times \sqrt{V} \times C_t \times C_m \times C_c \\ &= 2{,}550 \text{ kcal/m}^2\text{h}^\circ\text{C} \end{aligned}$$

where,

C : Coefficient of basic heat transfer rate (=2,290) (judging from the outerdiameter)
V : Velocity of cooling water in tubes (=2.0 m/sec.)
C_t : Correction factor based on the cooling water temperature at 21°C (=0.999)
C_m : Correction factor based on the material and thickness of tubes (=0.9275)
C_c : Tube cleanliness factor (=0.85)

③ Temperature rise of cooling water (Δt)

$$\Delta t = (t_s - t_i) \times (1 - \frac{1}{e^P})$$

$$= 6.87°C < 7°C$$

where,

t_s = 38.4°C, t_i = 21°C

$$P = \frac{N \times K \times L \times F}{3{,}600 \times V \times C_p \cdot \gamma}$$

$$= 0.5023$$

N : Number of tube pass (= 1)

K : K value i.e. Overall heat transfer rate (=2,550 kcal/m^{2}h°C)

L : Tube length (= 9.918 m)

F : Factor based on tube diameter

$$F = \frac{\pi \times (0.D)}{\pi \times (0.D - 2 \times T)^2 / 4}$$

$$= 143$$

V : 2.0 m/sec.

$C_p \cdot \gamma$: Specific heat x specific gravity (= 1000 kcal/m^3°C)

e^P = 1.6525

④ Required quantity of cooling water (Q)

$$Q = \frac{H}{\Delta t \cdot Cp \cdot \gamma}$$

$$= 35{,}342 \text{ m}^3/\text{hr}$$

$$= 9.817 \text{ m}^3/\text{sec.}$$

where,

H = 242.25 x 10^6 kcal/hr.

Δt = 7°C

⑤ Condenser surface area (F)

$$F = \frac{H}{K \cdot m}$$

$$= 6{,}985.3 \text{ m}^2$$

where,

$H = 242.25 \times 10^6$ kcal/hr.

$K = 2{,}550$ kcal/m^2h°C

$$m = \frac{t_1 - t_2}{\ln \frac{\theta_1}{\theta_2}} \quad (\theta_1 = t_s - t_1,\ \theta_2 = t_s - t_2)$$

$$= 13.6\ ^\circ\text{K}$$

⑥ Number of tubes (N_T)

$$N_T = \frac{Q}{\pi \times (0.D - 2t)^{2/4}}$$

$$= 7{,}061$$

where,

$Q = 9{,}817 \text{ m}^3/\text{sec}$

O.D. = 0.03175 m

$t = 0.001$ m

⑦ Distance between tube sheets (L)

$$L = \frac{F}{\pi \times 0.D \times Nr}$$

$$= 9.918 \text{ m}$$

where,

$F = 6{,}985.3 \text{ m}^2$

O.D.= 0.03175 m

Nr = 7.061

(c) Condenser Tube Materials

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

Cupro-nickel tube (90-10 Cu-Ni) is adopted for condenser tube for the following reasons.

Generally, alminium brass material has been adopted in many thermal power stations which use sea water for cooling water system. In the meantime, it is necessary to select the material which is anti-erosive against sand, etc. in the water because lake water (fresh water) is used as cooling water of the Maritsa East No.1 Power Plant.

Figure 6-7-1 shows the corrosion and erosion characteristics of various materials.

Table 6-7-1 Corrosion and erosion characteristics of various materials

Subject	Admiralty Brass	Aluminium Brass	90-10 Cu-Ni	70-30 Cu-Ni	Stainless Steel	Titanim
General Corrosion	2	3	4	4	5	6
Erosion-Corrosion	2	2	4	5	6	6
Pitting (Operation)	4	4	5	5	6(4)*1	6
Pitting (Shutdown)	2	2	5	4	5(1)*1	6
High Water Velocity	3	3	4	5	6	6
Inlet Attack	2	2	3	4	6	6
Steam/drain Attack	2	2	3	4	6	6
Stress Corrosion	1	1	6	5	6	6
Cl^- Attack	3	5	6	5	1	6
NH_3 Attack	3	2	4	5	6	6

Notes:
1. *1 For sea water use
2. Number shows resistivity 6 (Max.) to 1 (Min.)
3. For stainless steel and titanium, seamless tube are applied.

From the above table, titanium tube shows excellent resistivity compared with the other tube materials. Recently, titanium tube material has been adopted in many thermal power plants not only in Japan but also in many other countries in order to improve reliability of condenser and to achieve more increased plant utilization factors.

However, titanium material is much more expensive than other tube materials.

Therefore, adopted for this replacing plant shall be 90-10 cupro-nickel tube material which has better heat conductivity and is cheaper than other tube materials.

(d) Circulating Water Facilities

① Summary of Circulating Water System

1) Type : Vertical mixed-flow pump
2) Number : Five (5) sets per two (2) units (one set for common standby)
3) Capacity : 18,700m^3/hr/pump

   a. Quantity of condenser cooling water : 35,342 m^3/hr
   b. Quantity of cooling water for bearing cooling water heat exchanger : 1,873 m^3/hr
   c. Quantity of water for other use : 100 m^3/hr
   d. Total : 37,315 m^3/hr
   e. Required capacity of pump : 18,700 m^3/hr

4) Total head : 16.7 mAq

   a. Static head loss : hf_1 =0.3 mAq (according to Appendix 6-7-1)
   b. Maximum water level difference between pump station and discharge channel : hf_2 =1.446 mAq (according to Appendix 6-7-1)
   c. Head loss through common discharge channel : hp_1 = 1.654 mAq (according to Appendix 6-7-1))
   d. Piping head loss between common intake water channel and No.5 condenser : hp_2 = 3.78 mAq
   e. Condenser head loss : hc = 3.92 mAq
   f. Piping head loss between No.R1 condenser and discharge water channel : hp_3 = 5.54 mAq

g. Required head

Total of a. thru f. = 16.64 mAq

Therefore, in addition to total value, required head shall be 16.7 mAq with a margine.

5) Capacity of motor : 1,200 kW

a. Required shaft power

$$P = \frac{0.163 \times \gamma \times Q \times H}{\eta}$$

$$= 998 \text{ kW}$$

where,

γ : Specific gravity (= 1.000)

Q : Water quantity (= 311.67 m^3/min.)

H : Head (= 16.7 m)

η : Pump efficiency (= 0.85)

b. Motor power

The motor power shall be equivalent to or more than the following whichever larger.

i) Shaft power at design point x 1.2

ii) Shaft power at shut off point

Therefore, the shaft power shall be 1,200 kW.

② Calculation of Circulating Water Pump Head

a. Pump head (H) shall be the total value of the following head loss with a margine.

$H = hf_1 + hf_2 + hp_1 + hp_2 + hc + hp_3$

According to the calculation of intake and discharge tunnel head loss, pump head is calculated based on the maximum head loss when unit Nos.3 thru R1 are operated.

1) Static head loss : hf_1 (according to Appendix 6-7-1)

2) Maximum water level difference between pump station and discharge channel : hf_2 (according to Appendix 6-7-1)

3) Head loss of common discharge channel : hp_1 (according to Appendix 6-7-1)

4) Piping head loss between common intake water channel and No.R1 condenser : hp_2

5) Condenser head loss : hc

6) Piping head loss between No.R1 condenser and discharge water channel : hp_3

b. Piping head loss between common intake water channel and No.R1 condenser: hp_2

1) Piping head loss (Darcy's Formula)

$$hp_{21} = \lambda \cdot \frac{L}{D} \cdot \frac{V^2}{2g}$$
$$= 0.070 \text{ mAq}$$

where,

λ : Loss coefficient $= 0.020 + \dfrac{0.0005}{D}$

$= 0.0202$

V : Velocity = 2.724 m/s

D : Piping diameter = 2.2 m

L : Piping length = 20 m

2) Valve and fitting head loss

$$hp_{22} = \tau \cdot \frac{V^2}{2g}$$
$$= h_a + h_b + h_c + h_d$$
$$= 0.735 + 1.750 + 0.175 + 1.05$$
$$= 3.71 \text{ mAq}$$

i) 45° elbow: (1.5 m dia. x 2), V = 5.857 m/sec.

h_a = 0.21 x 1.750 x 2

= 0.735

ii) Y piece: (1.5 m dia. x 2)

h_b = 0.5 x 1.750x 2

= 1.750

iii) Expansion joint: (2.2 m dia. x 2), V = 2.724 m/sec.

h_c = 0.05 x 1.750 x 2

= 0.175

iv) Butterfly valve: (1.5 m dia. x 2)

$$h_d = 0.3 \times 1.750 \times 2$$
$$= 1.05$$

3) Piping head loss between common intake water channel and No.R1 condenser

$$hp_2 = hp_{21} + hp_{22}$$
$$= 0.070 + 3.71$$
$$= 3.78 \text{ mAq}$$

c. Condenser head loss: hc

1) Specification of condenser

i) Condenser tubes
- Outer diameter : 31.75 mm
- Thickness : 1.000 mm
- Length : 9,918 mm

ii) Number of passes : One (1)

iii) Velocity : 2.0 m/sec.

2) Head loss (according to the Standard for Steam Surface Condenser of the Heat Exchanger Institute)

i) Head loss per one (1) meter of tube length : 0.15 mAq

ii) Tube head loss at 21°C (cooling water temperature) : 1.488 mAq
(= i) x tube length x number of pass) (= 0.15 x 9.918 x 1)

iii) Water box head loss at 21°C : 0.52 mAq
(= 0.24 + 0.21 + 0.07)

iv) Total head loss : 2.008 mAq
(= ii) + iii)) (= 1.488 + 0.52)

d. Piping head loss between No.R1 condenser and discharge water channel: hp_3

1) Piping head loss (Darcy's Formula)

$$hp_{31} = \lambda \cdot \frac{L}{D} \cdot \frac{V^2}{2g}$$
$$= 0.070 \text{ mAq}$$

where,

λ : Loss coefficient $= 0.020 + \dfrac{0.0005}{D}$

= 0.0202

V : Velocity = 2.724 m/s

D : Piping diameter = 2.2 m

L : Piping length = 20 m

2) Valve and fitting head loss

$$hp_{32} = \tau \cdot \frac{V^2}{2g} = h_a + h_b + h_c + h_d$$

$$= 3.71 \text{ mAq}$$

i) 45° elbow: (1.5 m dia. x 2), V = 5.857 m/sec.

h_a = 0.21 x 1.750 x 2

= 0.735

ii) Y piece : (1.5 m dia. x 2)

h_b = 0.5 x 1.750 x 2

= 1.750

iii) Expansion joint: (2.2 m dia. x 2), V=2.724 m/sec.

h_c = 0.05 x 1.750 x 2

= 0.175

iv) Butterfly valve: (1.5 m dia. x 2)

h_d = 0.3 x 1.750 x 2

= 1.05

3) Head loss of strainer for ball cleaning system

hp_{33} = 0.15 mAq

4) Piping discharge head loss

$$hp_{34} = \tau \cdot \frac{V_1^2 - V_2^2}{2g}$$

$$= 1.61 \text{ mAq}$$

where,

τ : 1.0

V_1 : 5.857 mAq

V_2 : 1.651 mAq

5) Piping head loss between No.R1 condenser and discharge water channel

$$\begin{aligned} hp_3 &= hp_{31} + hp_{32} + hp_{33} + hp_{34} \\ &= 0.070 + 3.71 + 0.15 + 1.61 \\ &= 5.54 \text{ mAq} \end{aligned}$$

(f) Air Removal Equipment

Removal of air from a steam condenser may be accomplished either by a steam jet air ejector or by a mechanical pump. For the replacing plant, steam jet air ejectors are planned to be applied.

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

① Main Ejector

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

② Starting air ejector

1) Type : Single element, single stage
2) Capacity : Air suction capacity 1,850 kg/hr (dry air)
3) Number : One (1) set

(g) Condenser Protection System

① Screen system

1) As the condenser cooling water is taken in from Lake Rozovkladnetz, there is a possibility that foreign materials, such as pieces of wood, polyvinyl and other dumped materials will be sucked into the inlets.

Therefore, a suitable screen system should be provided to prevent the condenser from damage which may be caused by these floating and suspended materials.

2) For the screen system in the circulating water pump pit, a bar screen with bucket rake should be provided similarly to the existing one because the existing pump pit and house will be reused.

② Continuous Cleaning System for Condenser Tubes

1) As for the condenser tube cleaning system, a ball cleaning system will be adopted. At present, this system is widely used as an effective cleaning system in many power plants.

2) Numerous sponge balls are charged in the condenser cooling water just ahead of the inlet water box and pass through condense tubes, hence the inside of the tubes is automatically cleaned with the aid of cooling water differential pressure. These balls are then captured by a ball catcher, called a "strainer", collected at a ball collector and recirculated by the recirculation pump.

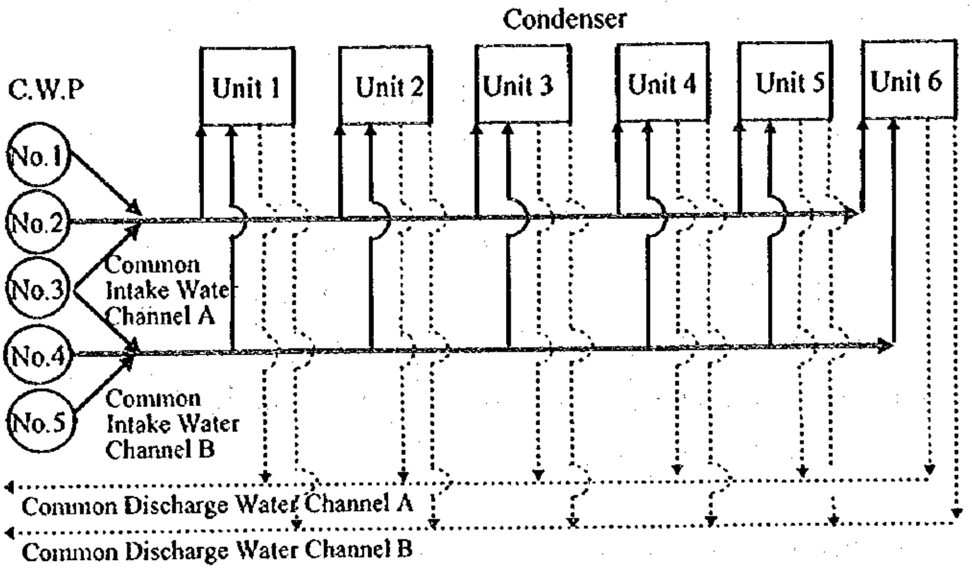
3) The balls, which have been injected into circulating water, should be collected and recirculated in a way that no balls become trapped in any part of the system. Therefore, the recovery rate of the balls is a highly important controlling factor.

(h) Replacing Works and Operation of the Circulating Water Pump

The existing circulating water pumps should be replaced due to deterioration. And during the replacing works of the existing pumps, the operation methods of the existing pumps and units are investigated hereunder.

① Outline of the circulating water system

The following figure shows the flow diagram of the circulating water system of the existing unit Nos.1 thru 6.



Flow diagram of the circulating water system

② Basic condition of replacing works of the circulating water pump

1) The two (2) common discharge water channels (2,200 ϕ/channel) will be reused.

2) All of the existing circulating water pump are replaced and its works shall meet the construction schedule of unit Nos.R1 and R2.

3) The number of newly installed pump shall be two (2) sets per unit each rated at 50% and one standby pump for common use. Accordingly, five (5) pumps is total for unit Nos.R1 and R2.

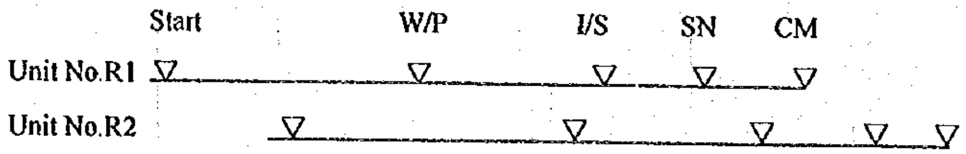
4) As shown in above-mentioned figure, one (1) common intake water channel shall be used for each unit, exclusively.

5) The existing pumps shall be replaced step by step in order not to reduce the electric power generation.

③ Replacing works and pump operation

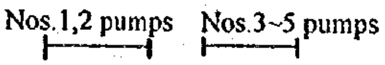
1) Schedule for replacing works of C.W. pump

a. Main schedule

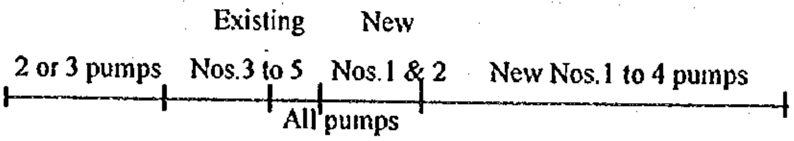


(Notes: W/P: Water Passing, I/S: Initial Steam, SN: Syncronizing,
CM: Commissioning)

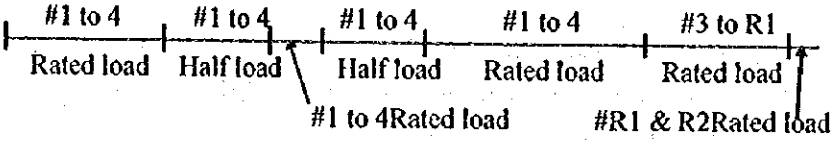
b. Pump replacing work



c. Pump operation



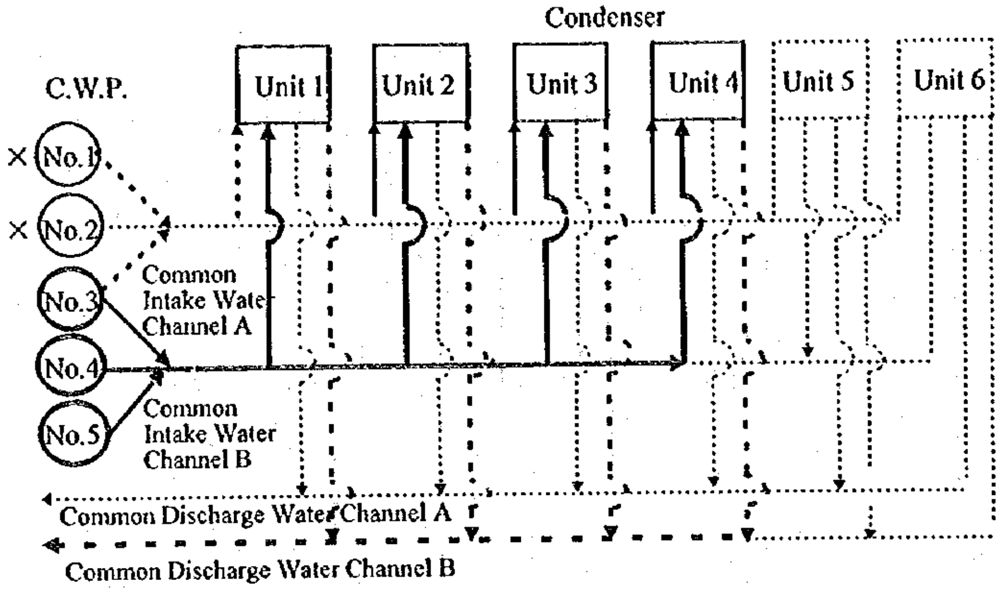
d. Unit output



2) Pump management

During the replacing works of the existing pumps, the pump operation management, unit output and flow of cooling water are described in the following items.

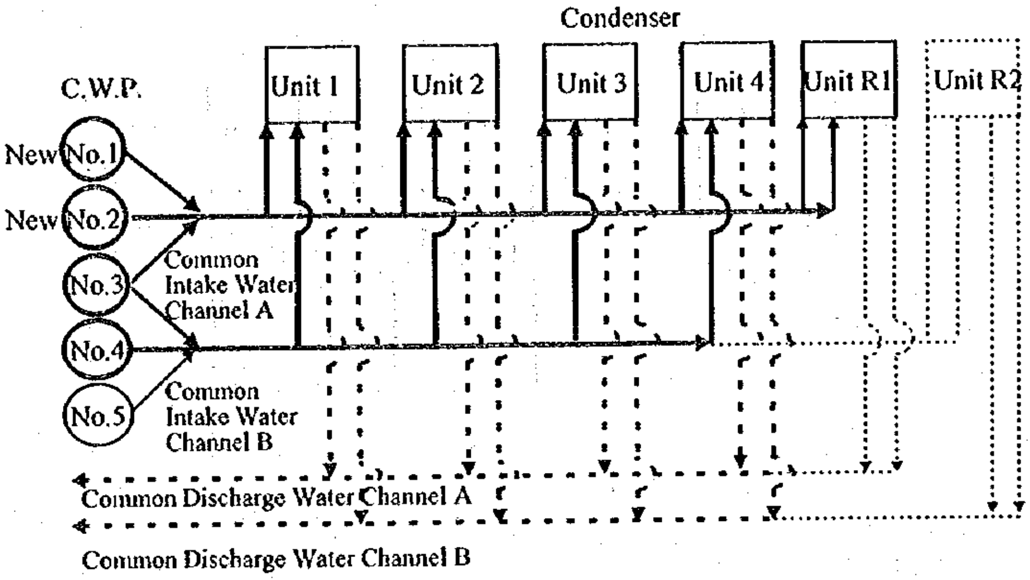
a. At the replacing the existing Nos.1 and 2 pumps
Two (2) pumps among Nos.3 thru 5 will be operated.



b. After completion of installation of new Nos.1 and 2 pumps

When unit Nos.1 thru 4 are operated at rated load, two (2) pump among Nos.1, 3 and 4 are operated.

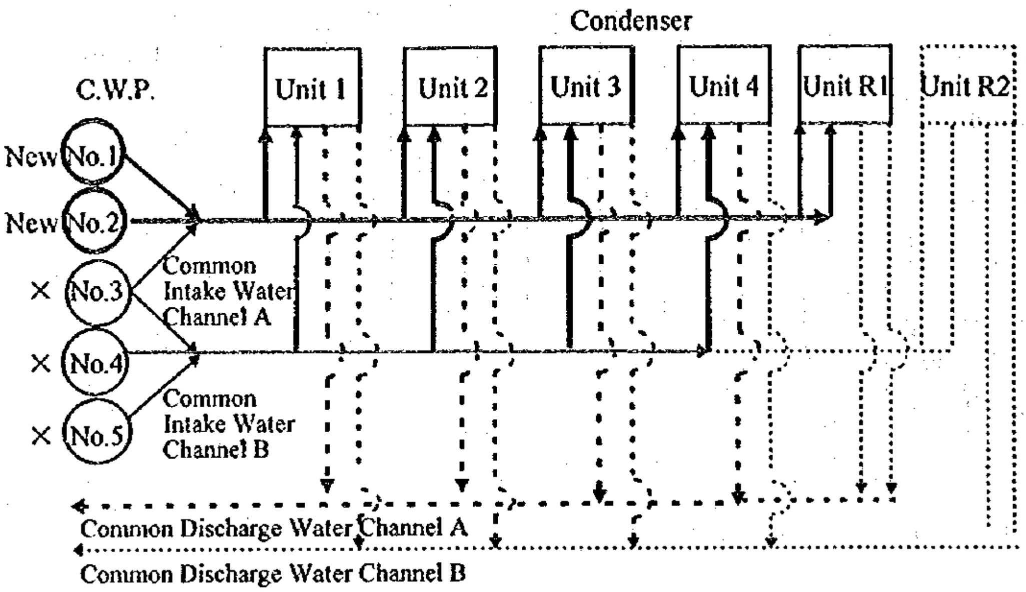
When unit R1 is put into trail operation, all pumps are operated.



c. At replacing the Nos.3 thru 5 pumps

As the common intake water channel A is used, unit Nos.1 thru 4 are operated at half load and new Nos.1 and 2 pumps are operated.

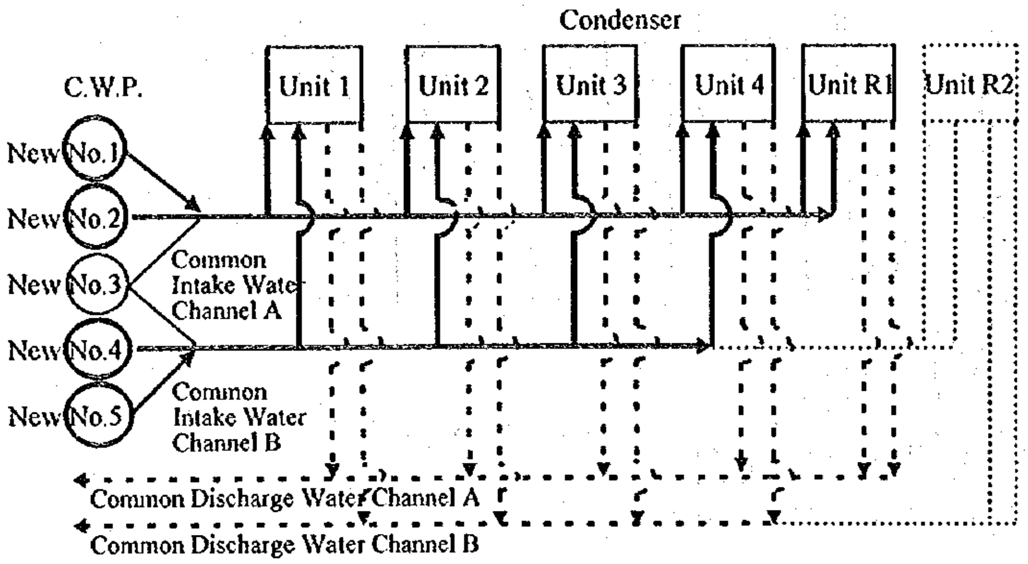
When unit R1 is put into trial operation, unit Nos.1 thru 4 are stopped because the cooling water is not available enough for unit Nos.1 thru 4.



d. After replacement of the existing Nos.3 thru 5 pumps (No.3 pump is stand-by)

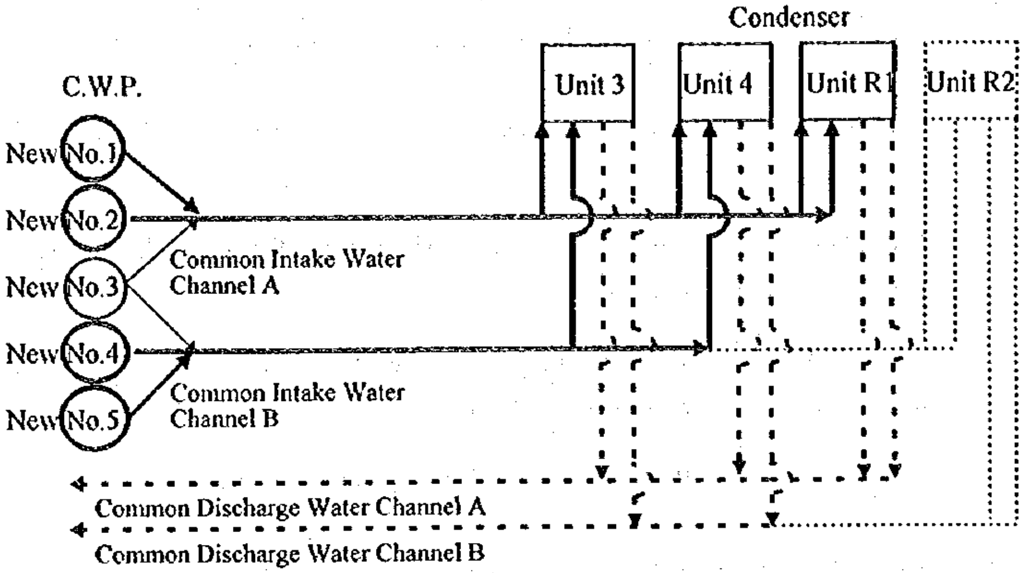
When unit Nos.1 thru 4 are operated at rated load, Nos.1 and 4 pumps or Nos.2 and 5 pumps are operated.

When unit R1 is put into trial operation, all pumps are operated.



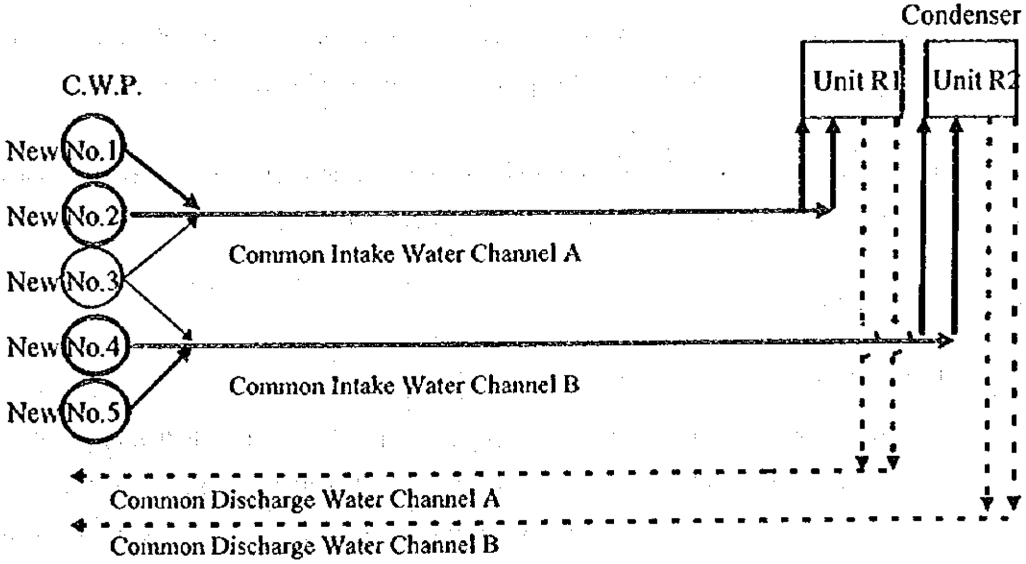
e. After unit R1 is commissioned

The existing unit Nos.1 and 2 are stopped and new four (4) pumps are operated.



f. After unit R2 is commissioned

The existing unit Nos.3 and 4 are stopped and new four (4) pumps are operated.



6.7.4 Feedwater Heating System

(1) Design conditions

(a) Condensate and feedwater system flow is shown in Figure 6-7-5.

(b) Type of feedwater heaters should be selected from horizontal or vertical type.

(c) Optimum number of feedwater heaters should be selected among the following three (3) cases which have experiences in the 200MW class power plants.

① Three (3) low pressure feedwater heaters + Deaerator + Two (2) high pressure feedwater heaters (total six (6) stages)

② Four (4) low pressure feedwater heaters + Deaerator + Two (2) high pressure feedwater heaters (total seven (7) stages)

③ Three (3) low pressure feedwater heaters + Deaerator + Three (3) high pressure feedwater. heaters (total seven (7) stages)

(d) A deaerator should be of a spray cum tray having many experiences.

(e) Condensate pumps shall be of vertical multistage type. The number of pump is two (2) each rated at 100% because of higher reliability of pump itself.

(f) Heating steam is extracted from the six (6) extraction stages of the main turbine and after heating feedwater in each heater, is condensed for drainage and led to the next lower pressure heater, thereby making effectiveness of its heat. It is finally pumped up into condensate line or directly led to the condenser from the lowest pressure heater.

(g) Alternative drain paths should be provided, however, to ensure trouble-free drainage in any operational case, including in an emergency operation.

(2) Study Results

(a) Type of feedwater heaters

Low pressure feedwater heaters are proposed of a horizontal shell and U-tube type or vertical shell and U-tube type. However, horizontal shell and U-tube type heat exchangers are adopted for the replacing plant, as a result of comparison between both types, as shown below.

Items	Horizontal shell and U-tube type heat exchanger	Vertical shell and U-tube type heat exchanger
Reliability	Base	A little bit worse
Maintainability	Base	A little bit worse
Space for installation	Base	A little bit better
Cost	Base	Same as left

A vertical and U-tube type heat exchanger requires smaller area in plan but higher clearance in elevation, while a horizontal and U-tube type heat exchanger dose vice versa.

Each high pressure feedwater heater is of the same horizontal shell and U-tube type as the low pressure heaters, and utilizes extraction steam from the main turbine and cold reheat steam as heating steam. The deaerator, high and low pressure feedwater heaters shall be mounted on the deaerator bay.

(b) Number of feedwater heaters

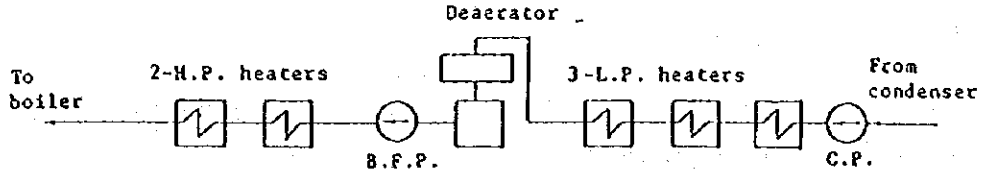
Six (6) heater system shall be adopted for the Maritsa East No.1 Power Plant Units R1 and R2, as a result of the technical and economical studies described hereunder.

The following three cases have been studied before concluded.

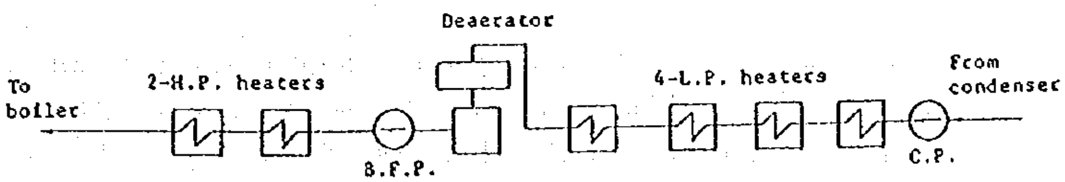
Case 1: Six (6 = 3+1+2) heater system (steam for top heater : from cold reheater)
Case 2: Seven (7 = 4+1+2) heater system (ditto)
Case 3: Alternative seven (7 = 3+1+3) heater system (ditto)

Flow diagram of each case is shown as follows.

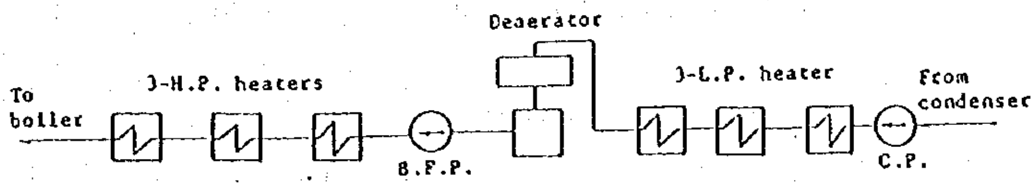
[Case 1]: Six (6) heater system (low press. 3 stages, high press. 2 stages)



[Case 2]: Seven (7) heater system (low press. 4 stages, high press. 2 stages)



[Case 3]: Alternative seven (7) heater system (low press. 3 stages, high press.3 stages)



① Technical evaluation

If the cycle steam is utilized effectively by increasing the number of extraction steam, that is, increasing of the number of feedwater heater, the turbine plant efficiency will be much improved theoretically.
However, it will cause increase of the construction cost in turn.

1) Heat rate (230MW base)

The turbine heat rate for each case is assumed as follows; (In this case, the steam conditions are the same (169 kg/cm^{2}g, 538°C/538°C)).

	Case 1	Case 2	Case 3
Heat Rate(Index)	100	99.53	99.16

2) Space for installation

Space for Case 1 is the smallest among three.

② Economical evaluation

The economical comparison among three cases is made by calculating an annual expense with fuel cost and construction cost.

1) The annual fuel costs

Fuel consumption is calculated by use of turbine cycle performance (heat rate). Then, annual fuel cost and difference among each case are obtained. The following table shows the sum (in index) of annual fuel cost and its difference.

	Case 1	Case 2	Case 3
Annual Fuel Cost (Index)	100	99.53	99.16

2) Construction cost of feedwater heater

The construction cost (index) of the feedwater heaters for each case is shown in the following table.

	Case 1	Case 2	Case 3
Construction Cost (Index)	100	100.27	100.81

3) Power Generation Cost

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

a. Fixed Cost

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

i) Annual interest : i
ii) Operation period : η
iii) Salvage value of property : β

In this case, the capital recovery factor α, is obtained from the below formula.

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

iv) Average maintenance cost rate

Therefore, the annual capital cost factor is α + average maintenance cost rate.

The annual capital cost is obtained from the following equations and is shown as follows;

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

	Case 1	Case 2	Case 3
Annual capital cost (Index)	100	100.27	100.81

b. Annual Power Generation Cost

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

	Case 1	Case	Case 3
Annual power generation cost (Index)	100	100.05	100.32

③ Conclusion

Resulting from the technical evaluation, case 3 is best because of the lowest fuel consumption.
On the other hand, resulting from the economical evaluation, case 1 is the most economical system.
Therefore, the six (6) heater system shall be adopted for the Maritsa East No.1 Power Plant Units R1 and R2.

(c) Tube Materials

① Tube materials to be adopted for the feedwater heaters should be carefully selected considering material reliability (resistance against corrosion and erosion, etc.), heat transfer rate (heat conductivity of the material) and their cost.

② Tube material of feedwater heaters is highly susceptible to corrosion and erosion due to mechanical and chemical effects imposed on their outer and inner surfaces during operation, if the proper materials are not selected.

③ The following tube materials are proposed for the Maritsa East No.1 Power Plant Units R1 and R2.

1) Low pressure feedwater heater

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

2) High pressure feedwater heater

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

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

4) Boiler feed water and condensate should be strictly controlled to keep their quality within the limits specified by the standards for feedwater quality control in order to minimize the corrosion and erosion in the all feed water and condensate system. For boiler protection, the PH value of boiler feedwater for units of this class should be controlled between 8.5 and 9.5, though a higher PH value is preferable for ferrous and their alloys.

5) For the above-mentioned reason, carbon steel or stainless steel is adopted for feedwater heater tube material.

④ For the Maritsa East No.1 Power Plant Unit R1 and R2, the following materials are recommended.

1) Low pressure feedwater heater: stainless steel
2) High pressure feedwater heater: carbon steel
3) The reason why stainless steel is recommendable for low pressure heater is that carbon steel tube is easily susceptible to corrosion and erosion.
4) The carbon steel tube is protected by the protective film which is formed by the controlled water quality suitable for the materials.
5) When the plant is shut down, the carbon steel tube should be protected by the hot blow, N_2 blanketing or steam seal.

(3) Recommendation and matters to be studied

(a) Number of feedwater heaters

Six (6) heater system is more advantageous than seven (7) heaters system as a result of comparison between both system. However, seven (7) heater system, especially three (3) low pressure stages plus three (3) high pressure stages gives rise to the best turbine cycle heat rate among three (3) cases.
Therefore, in case plant efficiency is thought much of with most priority, number of feedwater can be seven (7) or eight (8) at the detail design stage.

(b) Recovery of heater drain

Heater drain is led to condenser. In order to increase the turbine cycle heat rate, heater drain is recovered at the drain tank and returned to the low pressure feedwater heater.
It is, therefore, necessary to study the recovery of heater drain at the detail design stage.

6.7.5 Boiler Feed Pump

(1) Design conditions

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

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

(c) Type and number of the pump should be selected on the basis of the experiences in the same class power plants.

(d) Emergency feedwater facilities should be equipped to protect the boiler at the unit emergency stop.

(2) Study Results

(a) Prime mover for boiler feed pump

There are two possibilities for the Maritsa East No.1 Power Plant Unit R1 and R2 to select the prime mover. One is of a motor driven type and another is of a turbine driven type.
The turbine driven type boiler feed pump will usually be adopted for the unit capacity of larger than 300 MW.

① Motor driven feed pumps

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

1) Pump + Speed increasing gear + Motor

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

In general, the boiler feed pump of the combination 1) without booster pump is not suitable for higher operating pressure of boiler, because the pump size becomes large.
In the case where the motor driven boiler feed pumps are adopted for Unit R1 and R2, the above combination 2) should be selected.

The booster pump in the combination 2) is prepared in order to decrease the required NPSH. Thereby, it will be possible to install the deaerator on the proposed level..

3) Advantage of the motor driven pump

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

a. Easy to operate the pump
b. Easy to start up the pump
c. Easy maintenance
d. Easy to install the pump

② Turbine driven feed pump

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

1) Advantage of the turbine driven feed pump

a. It is possible to get high speed revolution easily without speed increasing gear set according to the requirement of the pump characteristics.
b. No throttling loss
   Less throttling loss is expected compared with the throttling feedwater by a feed water regulating valve.
c. It is possible to manufacture the boiler feed pump with a large capacity.
d. Required electric power for auxiliary power supply can be reduced.

(b) Selection of prime mover for boiler feed pump

Motor shall be adopted for the prime mover of boiler feed pump in the Maritsa East No.1 Power Plant Units R1 and R2 from the viewpoint of the general tendency of the feed pump selection.

Moreover, the fluid coupling (variable pit speed equipment) is adopted for the boiler feed pump in order to control the quantity of feedwater by the pump revolution speed for reduction of electric power consumption.

(c) Number of boiler feed pumps

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

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

② Three (3) sets each 50% capacity (One set for standby)

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

Generally, three (3) sets of boiler feed pump each 50% capacity are adopted for the pump with capacity of more than 200 ton/hr.
For the Maritsa East No.1 Power Plant Unit R1 and R2, three (3) sets of boiler feed pumps having 50% capacity each will be adopted.

(d) Specification of boiler feed water pumps

① Type : Motor driven, horizontal multistage centrifugal barrel type with booster pump and water injection seal system
② Number : Three (3) sets (One (1) set for standby)
③ Capacity : 50% each (350 ton/hr. x 210 kg/cm^2 g)
④ Speed : 6,000 rpm (with step-up gear and speed increasing gear set)

(e) Emergency feedwater facilities

In case C-FBC is adopted for this project, the following emergency feedwater facilities should be equipped to protect the boiler when unit will be stopped emergency.

① Emergency feedwater pump

1) Type : Diesel engine driven multi-stage centrifugal barrel pump
2) Capacity : 15% at the rated feedwater flow
3) Number : One (1)

② Emergency feedwater tank

1) Type : Steel, horizontal cylindrical tank
2) Capacity : To be supplied 15% of the rated feedwater flow in 30 minute.
3) Number : One (1)

(3) Recommendation and matters to be studied

(a) Capacity and number of boiler feed pump is 50% and three (3) based on the experiences.

It is, however, necessary to study 100% per pump and two (2) pump in the detailed design stage because the reliability of pump is increased.

(b) Emergency feedwater pump, etc. are planned to be equipped for emergency feedwater facilities. However, three (3) boiler feed pumps will be installed, it may be one of ideas to adopt a diesel engine driven pump for stand by use among them. As for this point, it is necessary to select the optimum facilities in the detailed design stage.

6.7.6 Bearing Cooling Water System (Unit Auxiliaries Cooling Water System)

(1) Design conditions

(a) The existing bearing cooling water system is of once-through type and supplied from condenser cooling water system.

(b) The new bearing cooling water system should be selected, comparing closed circuit type with open storage type.

(c) Bearing cooling water system is based on Figure 6-7-6 Flow Diagram of Auxiliary Cooling Water System.

(2) Study results

(a) Selection of bearing cooling water system

Bearing cooling water system consists of many kinds of equipment having respective properties, differently from main cooling water system.
Two (2) kinds of bearing cooling water system, that is, closed circuit type and open storage type have been studied and their systems are evaluated economically and technically. As a results of the study, closed circuit type is adopted.

(b) Comparison between closed circuit type and open storage type

Comparison table is attached hereunder.

	Closed circuit type	Open storage type
(a) Volume chamber	Stand pipe	Head tank and Underground tank
(b) Type of BCWP	Horizontal	Vertical
(c) Total head of BCWP	System head loss	System head loss plus static head
(d) Area to be exposed to atmosphere	Small	Large
(e) Emergency Case (all A.C. failure)	No cooling water flow Unit should be shut down in principle	In emergency cooling water flow by gravity, depending on storage capacity of the head tank in principle
(f) Space/loading on structure	Small	Large
(g) System (return) pressure	A little bit higher	Lower

Note. BCWP: Bearing Cooling Water Pump

From the above comparison, closed circuit type will be recommendable, because of the following merits.

① Lower running cost

Closed circuit type gives lower running cost because of smaller capacity of BCW motor and less inhibitor consumption due to lower total pump head requirement and smaller area to be exposed to atmosphere.

② Easy maintenance

Maintenance of horizontal pump is easier than that of vertical pump, and there is less tendency of resonance between the critical speed of its structure (especially motor support) and its revolting speed.
And it is easy for water quality control since contact area with air is limited only in small area of upper water surface of stand pipe.

③ Lower capital cost

In open storage type, considerably deep underground tank is necessary and BCWP should have an appropriate NPSH. Both head tank and underground tank shall have considerably large capacity to give large storage water capacity for emergency cooling. This arrangement causes higher tank cost and civil/architectural cost.

④ PH control

A pH checking/control once a week is sufficient for closed circuit type.

(c) Functions of control valves, etc.

① PCV (pressure control valve)

A PCV is used to keep a flow rate of overall system, but it can not be used for flow balancing of each line.
Accordingly, installation of the PCV is not so worthy in a system where it is not required to keep the flow rate of overall system in all operating conditions.
It will be more worthy to provide the PCV on main feed pipe line to prevent excess flow rate.

② TCV (three way valve)

TCV is useful to prevent overcooling of non-controlled equipment and to keep the design temperature of all equipment in the system. Design of size and rangeability of each temperature control valve (TCV), other than the TCV, is performed accordingly.
However, the TCV is rather worthless in case there is no possibility of overcooling of equipment and primary cooling water of the BCWC is nearly constant all the time.
And it is necessary to adjust setting temperature of the TCV during the turbine generator turning operation in some case.

③ Stand pipe

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

④ Water level control for stand pipe

Continuous level controller is applied in this system.

However, on-off control (two position control) by level switches (not continuous control) may be enough since the purposes of stand pipe are to play a role of surge tank and to keep the BCWP suction head within appropriate range.

(3) Recommendation and Matters to be studied

(a) Presently, shell and tube type is planned to adopt for cooling water heat exchanger which cool the bearing cooling water. It is, however, necessary to study adoption of the plate type heat exchanger for the cooling water heat exchanger because its performance is more improved and it has more merits in the space and cost than the shell and tube type.

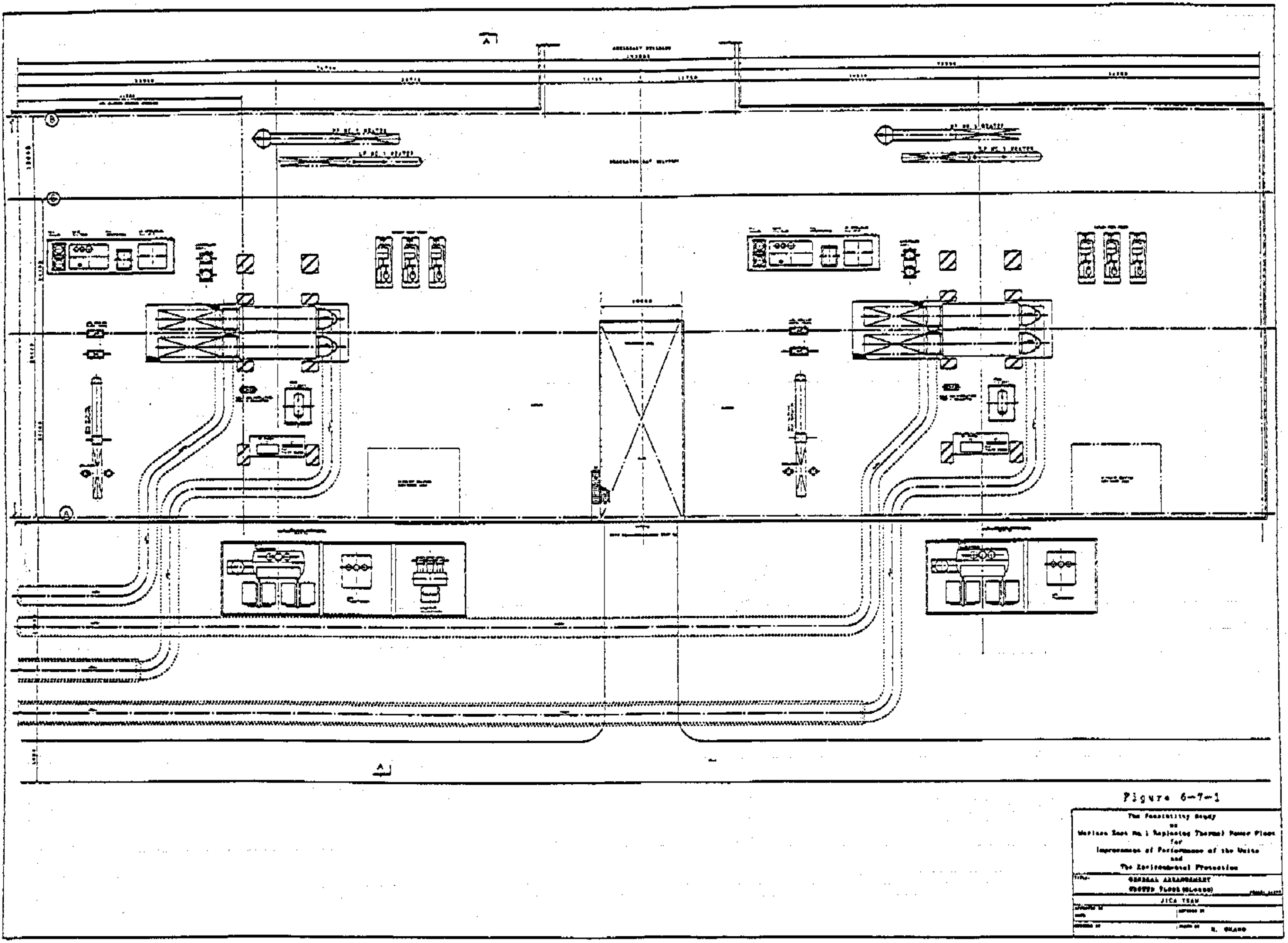
The Feasibility Study
on
Mariza East No.1 Replacing Thermal Power Plant
for
Improvement of Performance of the Units
and
The Environmental Protection
GENERAL ARRANGEMENT
GROUND FLOOR (EL±0000)
JICA TEAM
H. OKANO

Figure 6-7-1

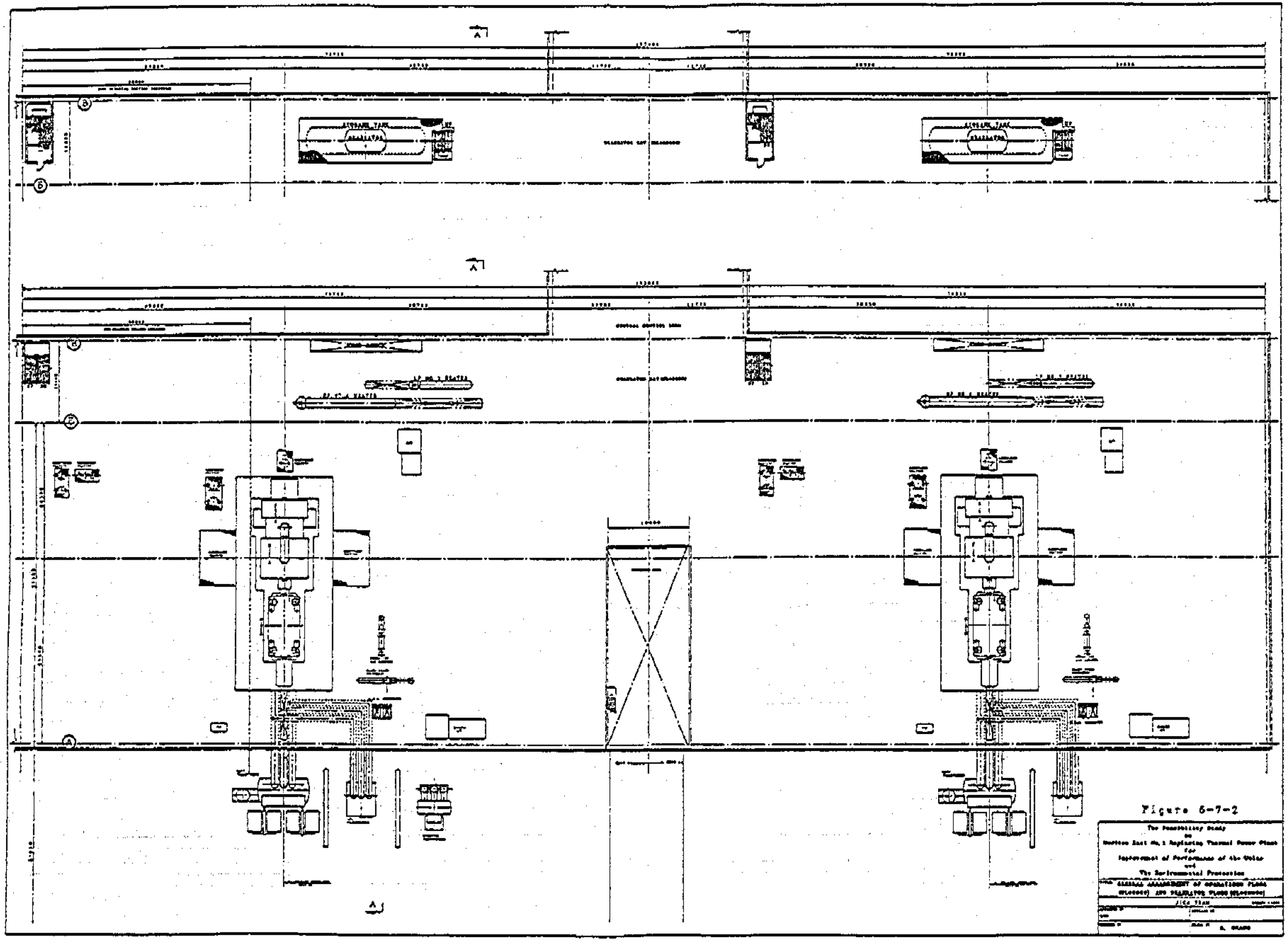
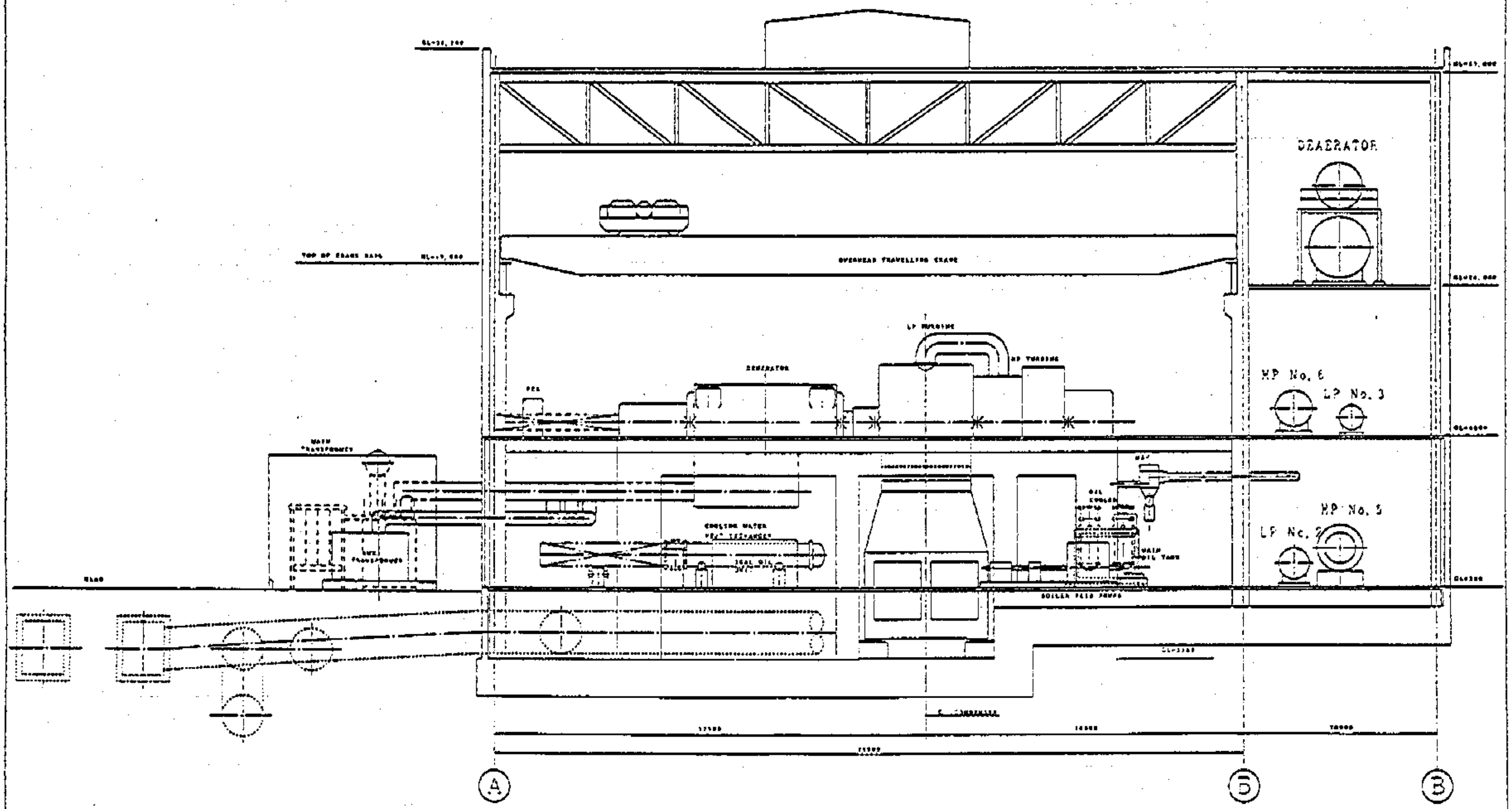


Figure 6-7-2

The Feasibility Study
on
[illegible] East No.1 Replacing Thermal Power Plant
for
Improvement of Performance of the Units
and
The Environmental Protection
GENERAL ARRANGEMENT of OPERATING FLOOR
(EL.[illegible]) AND DEAERATOR FLOOR (EL.[illegible])
JICA TEAM
STORAGE TANK
DEAERATOR
STORAGE TANK
DEAERATOR
A
B
C
D
E



VIEW A-A

Figure 6-7-3

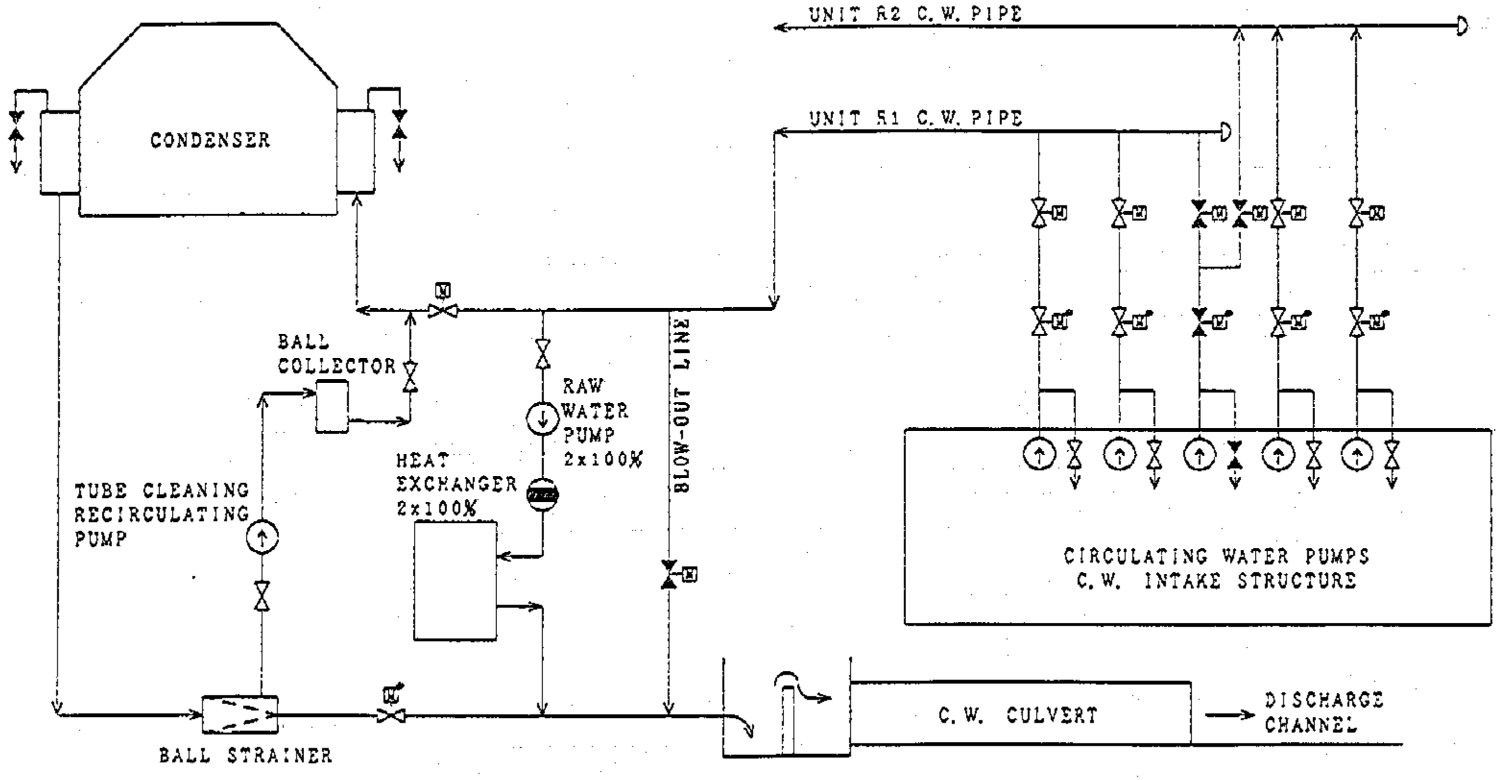


Figure 6-7-4

The Feasibility Study
on
Maritsa East No.1 Replacing Thermal Power Plant
for
Improvement of Performance of the Units
and
The Environmental Protection

FLOW DIAGRAM OF CONDENSER
COOLING WATER SYSTEM

JICA TEAM

M. OKANO

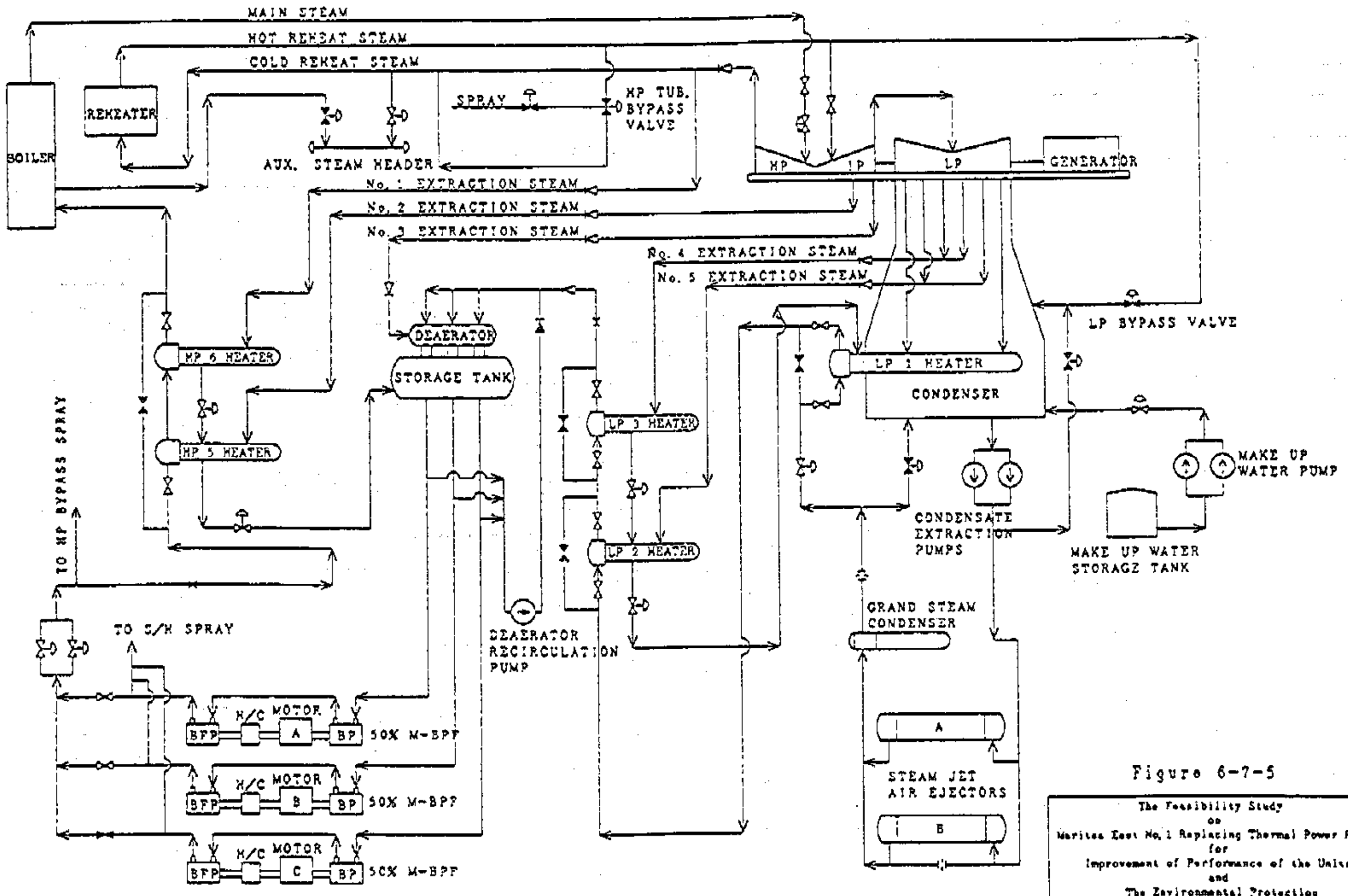


Figure 6-7-5

The Feasibility Study
on
Marites East No.1 Replacing Thermal Power Plant
for
Improvement of Performance of the Units
and
The Environmental Protection

TITLE: FLOW DIAGRAM OF CONDENSATE,
FEEDWATER AND MAIN STEAM LINE

JICA TEAM

APPROVED BY
DATE
REVIEWED BY
CHECKED BY
DRAWN BY H. OKANO

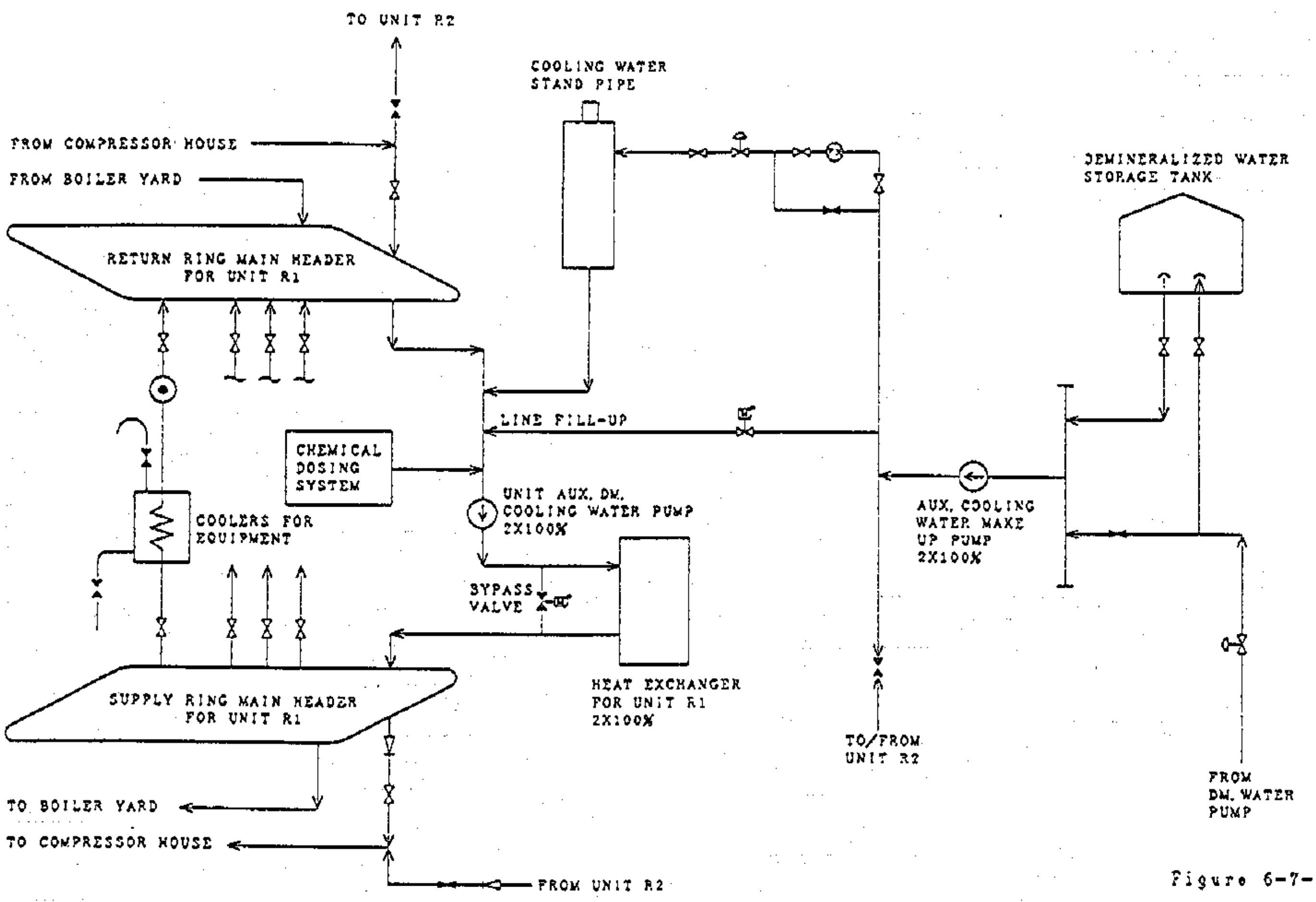


Figure 6-7-6

The Feasibility Study
on
Maritsa East No. 1 Replacing Thermal Power Plant
for
Improvement of Performance of the Units
and
The Environmental Protection

FLOW DIAGRAM OF AUXILIARY
COOLING WATER SYSTEM

JICA TEAM

N. OKANO

6.8 Generator Equipment

6.8.1 Generators and Excitation Equipment

(1) Conditions for study

(a) The generators to be adopted should be coupled directly to the steam turbine and be a horizontal, cylindrical, revolving-field type, three-phase AC synchronous generator of an explosion-proof construction. They should also be capable of 105% output operation.

(b) The hydrogen gas cooling system should be applied for the stator and rotor of the generators to increase the cooling effect, reduce the dimensions and weight of generator and ultimately save the equipment cost.

This cooling system has been applied to many generators of the equivalent class. It features good operability and easy maintenance, and is actually in use at the ME Power Plants Nos. 2 and 3.

(c) The hydrogen gas generator should be installed in the premises while the sealed oil processor required for oil sealing of the hydrogen gas should be installed in the 1st floor. In addition to an AC-driven oil pump (220 V, 100% capacity x 1), a DC-drive oil pump (220 V, 100% x 1) should also be installed as an emergency back-up.

(d) The excitation equipment should be a static type thyristor excitation system, and the power source should be supplied from an excitation transformer connected to the generator circuit.

(e) Consisting of an automatic voltage regulator, field regulator circuits, detectors, amplifiers and other components, the excitation equipment should be equipped with the reactive power regulator, power system stabiliser and high and low (voltage) excitation limiters to improve the static and dynamic stability of the power system.

(f) The generator main circuitry should be of a unit system configuration, connected to the main transformer through an isolated phase bus (IPB), and branched to the station service transformer, excitation transformer, power transformer (PT) and surge absorber (SA). Moreover, the generator synchronising circuit breakers should be connected to the 220 kV circuit on the main transformer high voltage side.

(2) Results of study

(a) Generator specifications

① Three-phase AC synchronous generators directly coupled to the steam turbine, with horizontal-cylindrical layout, revolving-field type and explosion-proof construction.
② Quantity : 2 sets
③ Rated capacity : 271,000 kVA
④ Power factor : 0.85 (delay)
⑤ Voltage : 14.7 kV
⑥ Frequency : 50 Hz
⑦ Rotation speed : 3,000 rpm
⑧ Cooling system : Hydrogen gas cooling for both stator and rotor
⑨ Hydrogen gas pressure : 3.2 kgf/cm^2
⑩ Connection system : Star
⑪ Excitation system : Static excitation (excitation transformer) type

(b) Excitation equipment

① Type : Excitation transformers, with quick-response excitation using thrystor
② Voltage : 500 V DC
③ Quantity : 2 sets
④ Drive system : Separately-installed, static type

(c) Hydrogen and sealed oil equipment for generators

① Vacuum pumps
Type : Rotary
Quantity : 2 sets
Vacuum : 1 x 10-2 mmHg
Motor : 1.5 kW

② Main sealed oil pump
Type : Gear pump
Quantity : 2 sets
Discharge pressure : 8.5 kgf/cm^2
Motor : 15 kW

③ Emergency (back-up) sealed oil pump

Type	Gear pump
Quantity	2 sets
Discharge pressure	7.4 kgf/cm^2
Motor (DC)	11 kW

④ Hydrogen gas dryer

Type	Silica gel filled, heater blower type
Electric heater	0.1 kW x 1
Blower	0.2 kW x 1
Quantity	2 sets

⑤ Hydrogen gas cooler

Type	surface cooling	
Quantity	4 sets	
Gas temperature	Inlet	85°C
	Outlet	45°C
Cooling water temperature	Inlet	35°C
	Outlet	45°C

6.9 District Heating System

6.9.1 Design Condition

(1) Hot water heated in the heat exchanger by the extraction steam from the main turbine is supplied from the Maritsa East No.1 Power Plant to the Galabovo district. The existing district heating facility will be reused.

(2) At present, the extraction steam is supplied from the Nos.1 thru 4 steam turbines. After the commissioning of the Units R1 and R2, hot water (12bar, 140°C) having a calorie of 25 Gcal shall be supplied from any of the units R1 and R2.

6.9.2 Study Results

(1) District heating system

(a) Figure 6-9-1 shows the Flow Diagram of the District Heating System of the newly installed Units R1 and R2.

(b) Heat source for the hot water is taken from intermediate pressure turbine outlet steam line.

(c) Water for the district heating is warmed by the steam in the heat exchanger installed on the ground floor in the turbine building, and hot water is supplied by the hot water transfer pump installed on the same floor. The steam drain from heat exchanger shall be led to the condenser.

(d) The hot water shall be circulated between the power plant and the Galabovo district by using the existing pipings.

(2) Specification of District Heating Facilities

(a) Heat Exchanger

① Type : Vertical type
② Number : One (1) set per unit
③ Capacity : 100% of the rated hot water quantity

(b) Hot water transfer pump

① Type : Horizontal pump
② Number : Three (3) sets per unit
③ Capacity : 50% per pump of the rated hot water flow

(c) Hot water piping

The existing hot water pipings shall be reused. However, the pipings shall be extended because the turbine building is extended.

6.9.3 Recommendation and Matters to be Studied

(1) At present hot water is supplied when it is below 12°C during three consecutive days. It is recommended to supply hot water through the year because steam extraction contributes to improvement of turbine efficiency and more income is brought in.

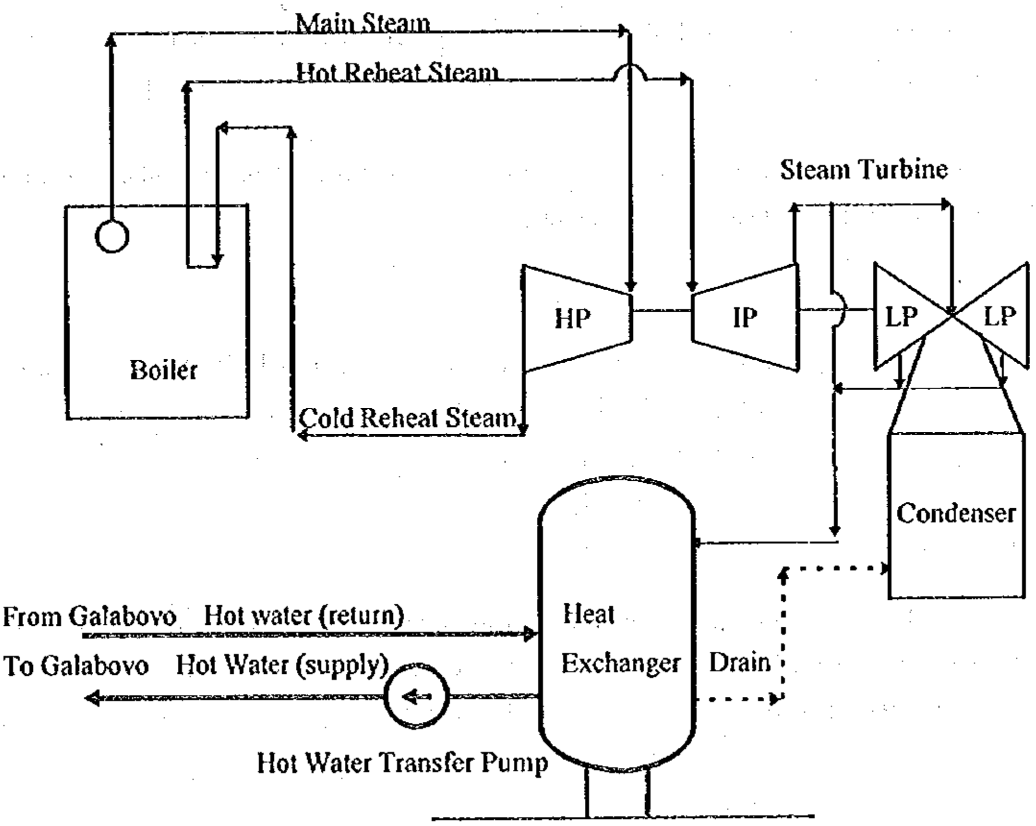


Figure 6-9-1 Flow Diagram of the District Heating System

6.10 Environmental Protection Facilities

6.10.1 Dust Removal Facility

(1) Properties of FBC Boiler Ash

The following is a description of the properties of the ash discharged from the FBC boiler.

(a) Shape of dust particle

Ash becomes fine in the fluid bed boiler due to a cyclone installed in the flue gas treatment system in addition to the dispersion of the degraded fluidized bed material. With the FBC boiler and pulverized coal firing boiler having different combustion mechanisms and different flame temperatures, the shape of generated ash also becomes different.

While the shape of the fly ash from the pulverized coal firing boiler is globular, the ash of the FBC boiler is not spherical and porous.

(b) Components and Electrical Resistivity of Dust

The major components of dust are SiO_2, Al_2O_3, $CaSO_4$, CaO, and $CaCO_3$. SiO_2 and Al_2O_3 are components found in coal ash and $CaSO_4$, CaO, and $CaCO_3$ are derived from the dispersion of powdered fluidized bed material.

(2) Dust Removal Facility

Coal fired thermal power plants employ electrostatic precipitators, fabric filters and cyclones as dust removal facilities. Electrostatic precipitator and fabric filter are compared in this study except cyclones because of low removal efficiency.

(a) Electrostatic Precipitator (ESP)

Theoretically, it is easy to collect dust by electrostatic precipitation. ESP use the following forces to collect dust, electrical force, dispersion and attachment force, inertia force, and gravity. Of these, the electrical force is the most essential.

Dust is negatively charged and collected by a positively charged collecting electrode when a gas containing that dust is passed through electrodes charged with high-voltage electricity.

The ESP's collection efficiency is basically represented by the Deutsch-Anderson equation as follows.

$$\eta = 1 - \exp(-\omega \cdot A/V)$$

Where, η is the ESP's collection efficiency (-), A (m^2) is the total collecting electrode surface area. V (m^3/sec) is the flue gas flow rate. ω (m/sec) is the migration velocity of the particles. In this equation, A means the size of the ESP as represented by the area of dust collection. A/V shows the area of dust collection per a unit quantity of gas, which is usually called a Specific Collecting Area (SCA) and used to compare the size of ESP per unit quantity of gas. ω (migration velocity) shows the degree of difficulty in dust collection by ESP. This is considered as the speed that the dust is drawn to the collecting electrode and a larger value is considered to mean that the ESP is more efficient, wherein the larger this value is, the faster the speed for the dust to reach the collecting electrode.

1) Electrical Resistivity of Dust and Collecting Efficiency

Figure 6-10-1-1 shows the general relationship between the electrical resistivity of fly ash and the collecting efficiency.

In the A zone of less than $10^4\Omega$-cm of electrical resistivity, the electrical resistivity is too weak to hold the fly ash at the collecting electrode, and the collecting efficiency is lowered by the jumping phenomenon where the dust is again removed by the gas stream.

The B zone, the range between $10^4\Omega$-cm and $5\times10^{11}\Omega$-cm, provides good dust collecting efficiency and is, therefore, best suited for an ESP.

In the C zone of more than $5\times10^{11}\Omega$-cm, the electrical potential of fly ash accumulated at the collecting electrode becomes high and partial electric destruction occurs. A reverse discharge phenomenon, back corona, occurs from the collecting electrode and the collecting efficiency is lowered. Here, a strong hammering force is required to remove the accumulated fly ash since it is pushed toward the collecting electrode by the electrical force.

2) Effect of the Properties of Ash and Flue Gas on Electrical Resistivity and Migration Velocity

As Figure 6-10-1-2 shows, electrical resistivity varies greatly in accordance with the temperature and humidity of the flue gas. As seen in Figure 6-10-1-3, the migration velocity also changes in accordance with the quantity of sulfur contained in the coal.

Because of its higher CaO content, the electrical resistivity of fluidized bed combustion ash is somewhat higher than that from the pulverized coal firing boiler. However, it is easily charged electrically as the ash is variant in shape and its surface is porous and has a wide surface area. Further, an abatement effect can be expected from the high moisture and SO_3 content in the flue gas at certain gas temperature.

(b) Fabric Filters (Baghouses)

Fabric filters physically collect particles into a filter cloth. This is known as a Surface Filtration System which separates and collects fine particles using the layer of particles that first attach to the surface of a filter cloth (known as the First Attachment Layer) as the filtration layer.

As Figure 6-10-1-4 shows, when dust with particles within a certain diameter range is put through the filter cloth, the coarse particles attach, due to their inertial collision actions, and the fine particles attach, due to their dispersion and screening actions, to the woven yarns to form bridges between the yarns. The first attachment layer thus created is very porous and it is these pores which collect the fine particles.

When operating fabric filters, it is, therefore, necessary to maintain the temperature of the processing gas to higher than the sulfuric acid dew point at the surface of the filter cloth to prevent it from blinding. In general, the quantity of collected dust per unit area of filter cloth is called the Dust Load (g/cm^2, kg/m^2), which becomes larger in accordance with the operation time.

In the case of a fabric filter, tapping for accumulated dust removal is conducted to maintain the maximum value of pressure loss within 150 - 200 mmH_2O as soon as it reaches this level. Figure 6-10-1-5 shows the structure of a fabric filter.

(3) Comparison of ESP and Fabric Filter

ESPs are the most widely employed for large-scale dust removal as a large-gas-quantity, high-efficiency dust removal facility since the pressure loss is low and the collecting efficiency is high even when the flue gas flows at high speed (a few m/sec).

Fabric filters do provide highly efficient dust collection regardless of the shape of the particles as it collects the dust physically. It does, however, only allow a gas speed of 1 to 2 m/sec and periodical replacement of the filter bag is necessary.

The comparison between dust collectors in Table 6-10-1-1 shows that an ESP is considered superior when the operational maintainability and reliability of the filter bag etc. is taken into consideration. In this F/S, an ESP is to be considered because an ESP is also used in the existing plant and the staff is well versed in its operation.

(4) ESP Facility

The particle charging methods are roughly divided into direct current charging (single pole, unidirectional), alternating current charging (single-pole, bi-directional), and pulse charging. As it provides a simple structure and is quite inexpensive, the direct-current (DC) charging system is the most popular ESP charging equipment.

It is necessary to raise the voltage and current density in order to increase the charging efficiency. However, in the case of a conventional DC corona charging system, the charging efficiency decreases as the corona current becomes inequality when back corona ionization occurs. Pulse charging systems are now drawing attention as a system able to offset this defect, especially for high-resistivity dust. Uniformed corona current can be obtained whole through the discharge electrode, and a peak voltage higher than that of DC charging is obtained and the collecting efficiency is improved by changing the crest value, amplitude, and cycle of the pulse. However, pulse charging would serve to further increase the cost of electric power facilities. On the other hand, intermittent charging method is also available, by which the output of the continuous charging system is eliminated at regular intervals. This method is adopted here in order to save electricity, to control reverse electrolysis, and to attain a little higher efficiency.

Regarding the relationship between boiler operation and the ESP performance, that performance progressively deteriorates when the ESP is operated with no hammering during the process from boiler ignition, parallel induction, through increment of boiler load, or when boiler operation is stopped. However, assured stable performance is as good as that obtained during regular boiler operation of boilers by applying periodical hammering to the ESP.

Below is an ESP facility outline when an assumed quantity of 5% of processed gas and a 10% inlet dust quantity is included in the design parameters.

a) Coal type : Bulgarian Lignite
b) Inlet gas flow rate : 1,359,000 m^3 N/h (wet)
c) Inlet dust concentration : 50 g/m^3 N
d) Outlet dust concentration : 0.1 g/m^3 N
e) Outlet gas temperature : 165°C
f) Temperature lowering : 5°C
g) Pressure loss : 20 mm Aq
h) Hopper capacity : Sufficient for 12-hour operation

Table 6-10-1-1 Dust Collector Comparison (1/2)

(Outlet Dust : 100 mg/m^3 N)

Item	Electrostatic Precipitator	Fabric Filter
1. Outline	Its performance would be affected by changes in the conditions around inlet as the specifications are based on those conditions (gas quantity, gas temperature and composition, content and properties of dust etc.)	This would not be affected by the type of coal or boiler operation conditions as dust in the gas is physically collected by a filter cloth.
2. Spec.		
(1) Pressure loss	Small (approx. 20 - 25 mmAq)	Large (approx. 150mmAq)
(2) Installation size	Same as bag filter	Same as an ESP
(3) Performance	Dust collection performance varies in accordance with the inlet conditions such as the type of coal used.	Only little affected by conditions such as coal and operational conditions.
(4) Reliability	• Employed for more than 20 years in coal-fired thermal power plants. • Requires constant monitoring and recording of charging conditions.	• Heavily dependent on the reliability of the filter bag. • Filter bag service life is 2 - 3 years. • The method of dust concentration and isolation require consideration as the outlet dust content could exceed the standards if the filter bag is broken. • Moisture proof is not known well.
(5) Operational Maintain-ability	• Possible to determine component anomalies by monitoring and recording charging voltage and current. • No major maintenance problems.	• Filter bag damage can be determined by monitoring and recording the inlet/outlet gas pressure loss and outlet dust concentration etc. However, methods to detect the damaged parts and isolation methods require examination. • Filter bag must be replaced regularly.

Table 6-10-1-1: Dust Collector Comparison (2/2)

(Outlet Dust : 100 mg/m^3 N)

Item	Electrostatic Precipitator	Fabric Filter
3. Economy		
(1) Facility cost	High	Low (dependent on the cost of filter bag)
(2) Annual running cost	Low	High
(3) Annual expenses	Low	High
4. Evaluation	Performance is affected by the inlet conditions. However, this causes no serious problem unless the electrical resistivity of the particles change drastically. Optimum design is possible as the facility costs and annual running costs change in accordance with the outlet dust concentration.	Performance almost stable regardless of the inlet conditions. However, since the facility costs and annual running costs do not change regardless of the designed outlet dust concentration, this system becomes advantageous when the outlet dust concentration is strict.

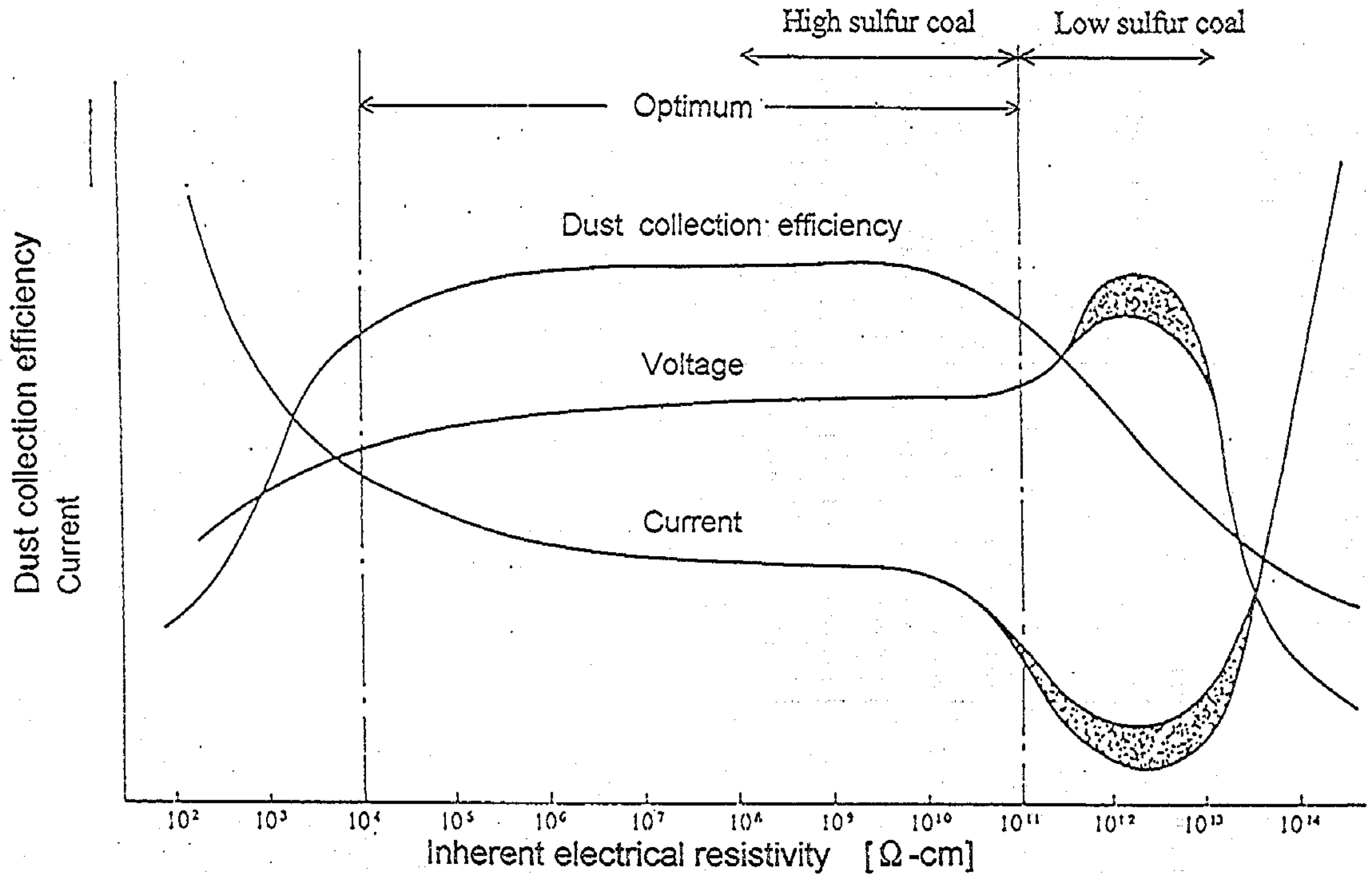


Figure 6-10-1-1 Influence of inherent electrical resistivity on dust collection efficiency (at 150 ℃)

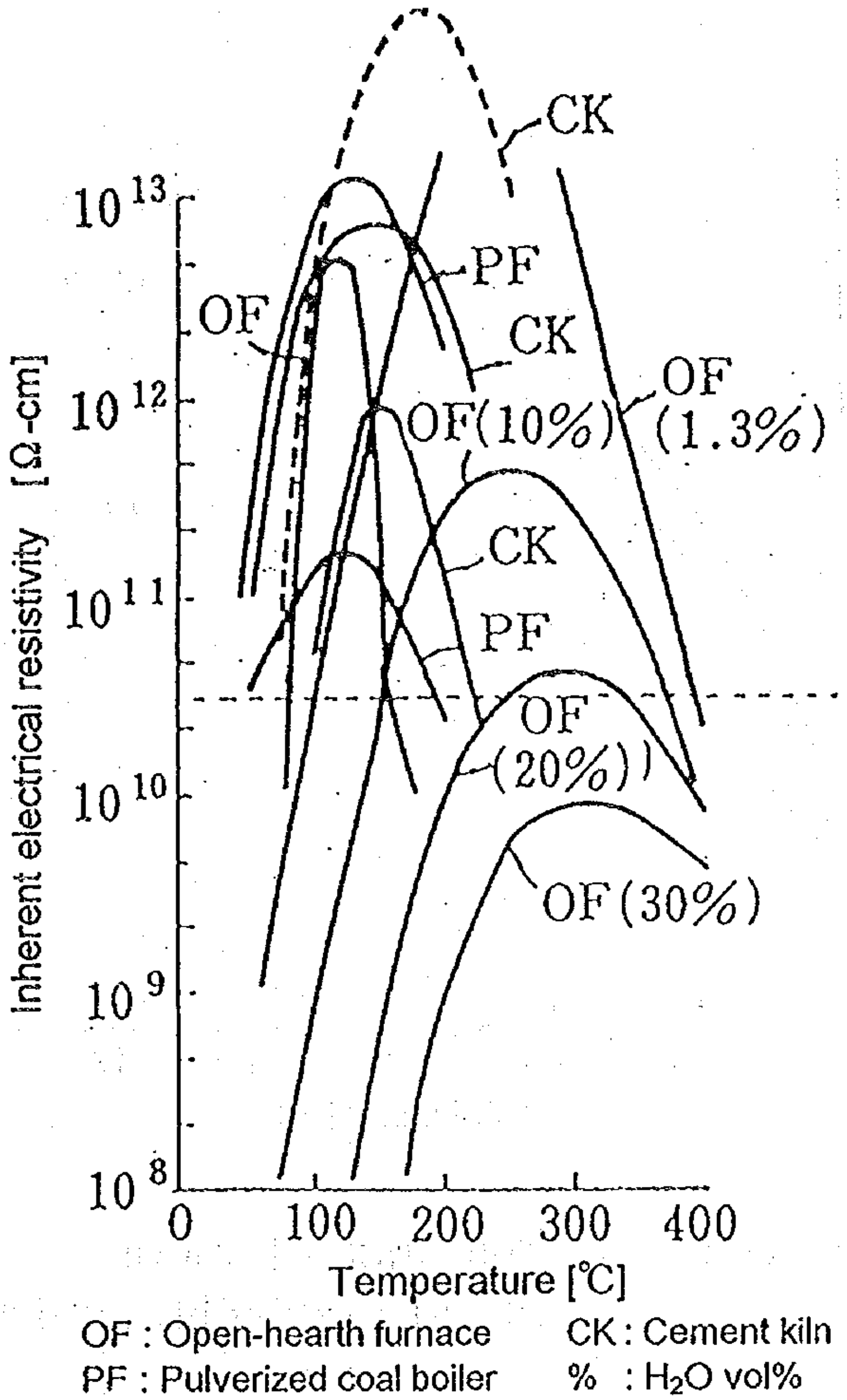


Figure 6-10-1- 2 Influence of temperature and moisture on dust collection efficiency

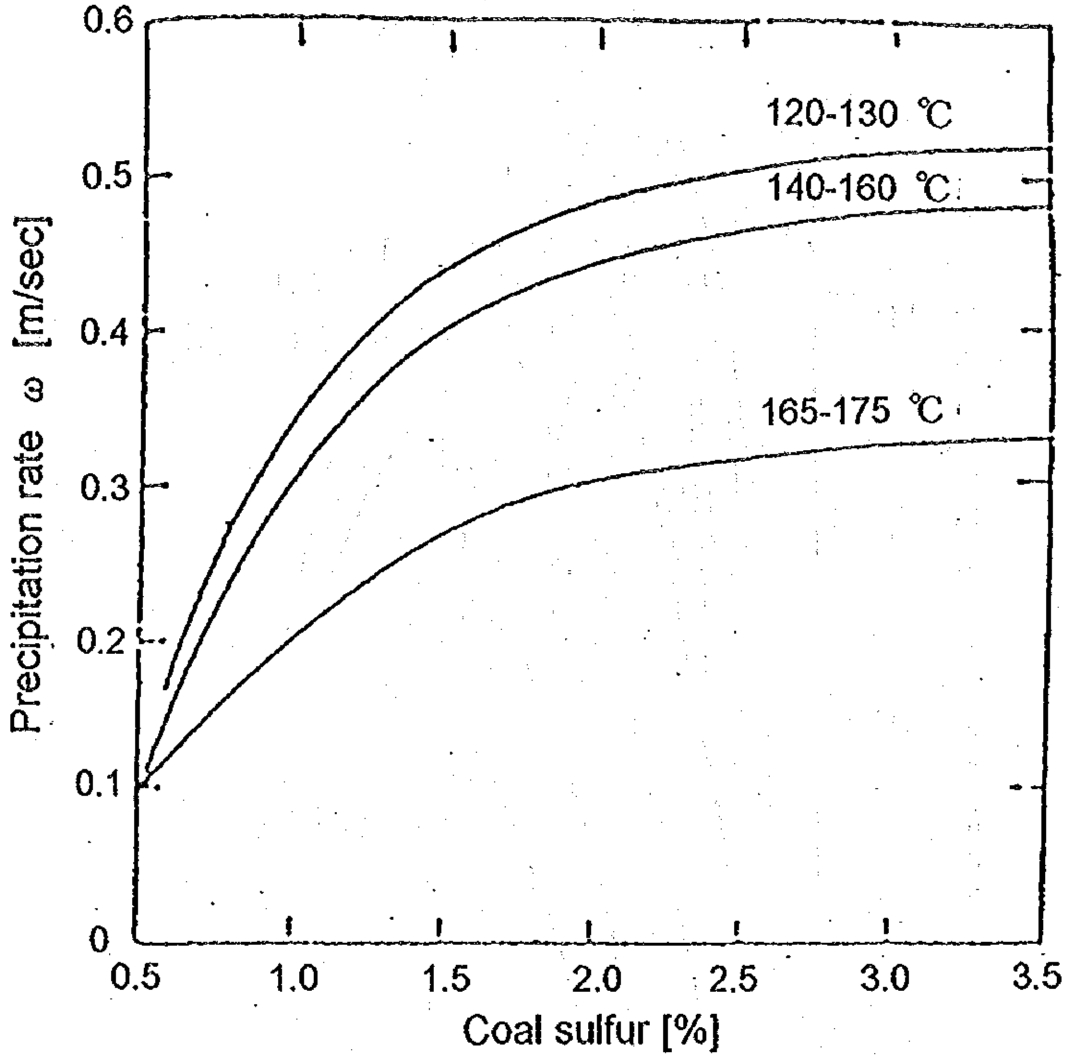


Figure 6-10-1- 3 Influence of sulfur on dust collection efficiency

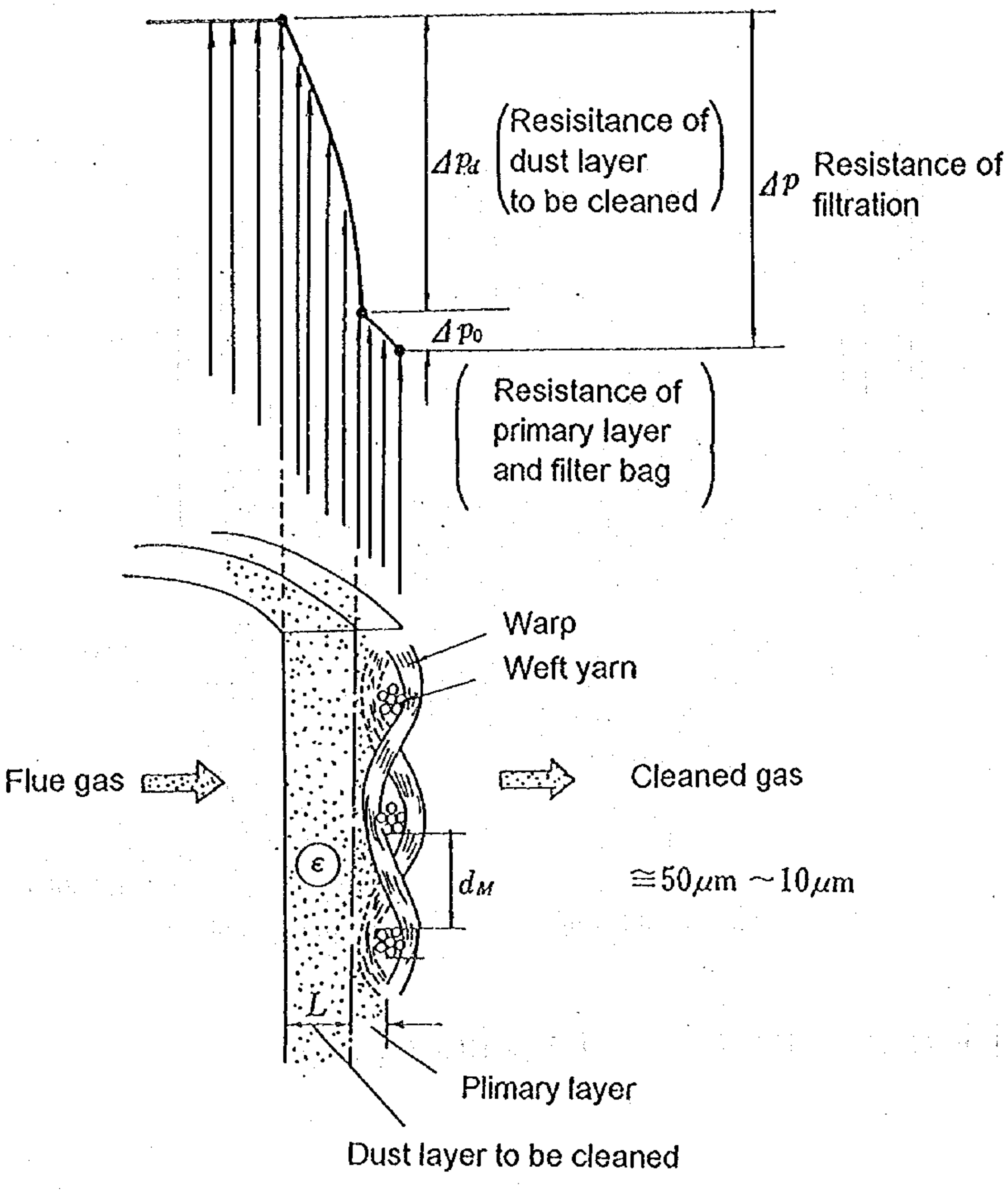


Figure 6-10-1- 4 Dust removal on bag filter

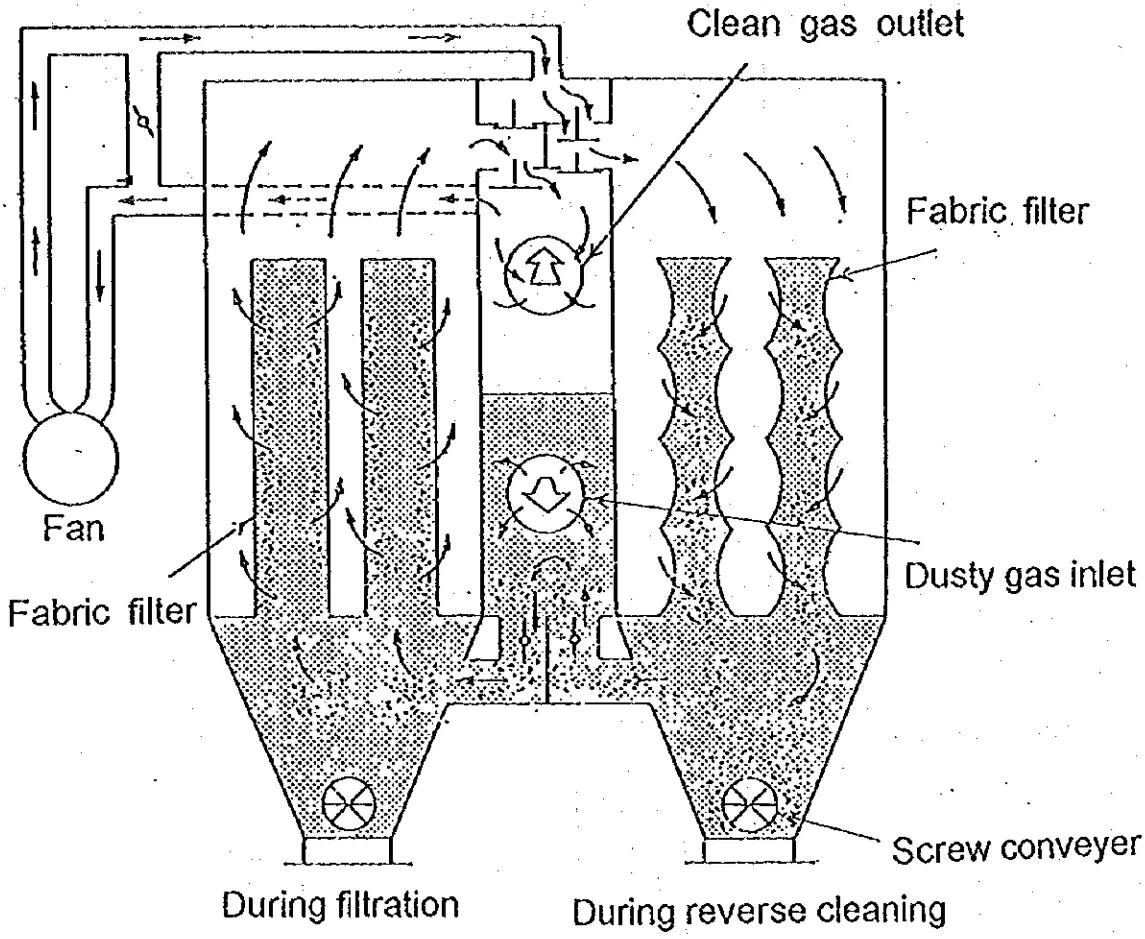


Figure 6-10-1- 5 Bag filter (reverse cleaning type)

6.10.2 Waste Water Treatment System

(1) Design Condition

(a) Scope of Design

A scope design is as follows.

① System for whole waste water system discharged from the replacing plant.

② Design for the low salt concentrated waste water facilities which consists of unit waste water pit, equipment washing waste water pit and facilities from common facilities to final check pit.

③ Design of the high salt concentrated waste water facilities which consists of unit waste water pit, equipment washing waste water pit and facilities from common facilities to final check pit.

④ Design for the living waste water facilities including from septic tank to final check pit.

However, specification of the living waste water treatment facilities can not be studied because there are available no data of the quantity of waste water discharged from the existing facilities.

(b) Basic System, and Waste Water Treatment Method

① Waste water system consists of "low salt concentrated waste water system" and "high salt concentrated waste water system".

② Low salt concentrated waste water treatment method should be waste water treatment facility composed of coagulation sedimentation, filteration and neutralization.

③ High salt concentrated waste water treatment method should be waste water treatment facility composed of coagulation sedimentation, filteration and neutralization. The facility should be equipped with a countermeasure of reducing COD.

④ Living waste water treatment method should be waste water treatment facility composed of filtration, synthetic absorbent and disinfection facility

⑤ Countermeasure for removal of COD

High COD waste water source such as equipment blow waste water to be discharged at start-up and during the periodical inspection containing high hydrazine is collected in a special pond (for non regular waste water). COD in individual waste water is oxidized and resolved by chemical injected.

⑥ Boiler chemical cleaning waste water

High concentrated special waste water such as boiler chemical cleaning waste water containing N, COD and P, etc. should be pre-treated by temporary facility as required.

⑦ Waste water system of condenser cooling water

Cooling blow waste water which is discharged at inspection of circulating water pipings and condensers should be discharged to the discharge channel through a system composed separately from plant waste water system.

⑧ Sludge

Sludge which is discharged from coagulation sedimentation tank, etc. should be dehydrated and transported to the ash disposal pond by trucks, etc. after temporary settlement.

(c) Quality and quantity of low and high concentrated salt waste water

① Water quality before treatment

1) Water quality, etc. which is discharged to the low concentrated waste water are shown in Table 6-10-2-1 "Forecast of Source, Quantity and Quality of Low Concentrated Salt Waste Water".

2) Water quality, etc. which is discharged to the high concentrated waste water are shown in Table 6-10-2-2 "Forecast of Source, Quantity and Quality of Low Concentrated Salt Waste Water".

② Treated water quality

Water quality should satisfy the following Bulgarian standard value.

pH	6 to 9	Cadmium	0.02 mg/ℓ
COD	40 mg/ℓ	Cyanides (total)	1 mg/ℓ
SS	100 mg/ℓ	NH_4-N	5 mg/ℓ
Oil products	0.1 mg/ℓ	Phosphates	2
Phenoles	0.5 mg/ℓ	Lead	0.2 mg/ℓ
Copper	0.5 mg/ℓ	Chromium (hexavalent)	0.1 mg/ℓ

Iron (total)	5 mg/ℓ	Arsenic	0.1 mg/ℓ
NO_3-N	20 mg/ℓ	Mercury (total)	should not be detected
P	3 mg/ℓ	Alkyl mercury	should not be detected
		PCB	should not be detected

③ Waste water quantity should be forecasted as follows.

1) Low concentrated waste water (daily maximum) : 1,030 m^3/day
2) High concentrated waste water (daily maximum) : 65 m^3/day

Forecasted values of waste water quantity are shown in Figure 6-10-2-2 "Flow Balance of Water and Waste Water".

(2) Study Results

(a) Specifications of waste water treatment equipment

① Low concentrated waste water treatment equipment

1) Coagulation sedimentation equipment : 1,500 m^3/day x 1 set
2) Filter : 1,500 m^3/day x 1 set
3) Neutralization equipment : 1,500 m^3/day x 1 set
4) Chemical oxidization equipment : Chemicals: Hydrogen peroxide solution Un-steady waste water batch processing
5) Waste water pond : Steady waste water pond 400m^3 x 2
Un-steady waste water pond 500m^3 x 1

② High concentrated waste water treatment equipment

1) Coagulation sedimentation equipment : 150 m^3/day x 1 set
2) Filter : 150 m^3/day x 1 set
3) Neutralization equipment : 150 m^3/day x 1 set
4) Synthetic absorbent equipment : 150 m^3/day x 1 set
5) Waste water pond : Steady waste water pond
1,500m^3 x 1 (for AH)
Un-steady waste water pond
1,000m^3 x 1(for EP)

③ Waste water pit for water treatment plant

1) Low concentrated waste water : 90m^3 x 1
2) High concentrated waste water : 90m^3 x 1

④ Waste water pit for pre-treatment plant

1) Low concentrated waste water : $200m^3$x 1

⑤ Unit waste water pit

1) Low concentrated waste water : $35m^3$ x 1
2) High concentrated waste water : $3m^3$ x 1

⑥ Blow pit : $100m^3$ x 1

Other pits and system equipment are shown in Appendix-6-10-2-1 "Calculation for Capacity of Waste Water Treatment Facilities and Equipment"

(b) Equipment arrangement plan

① Waste water treatment equipment is of outdoor type and located nearby the existing rail way for coal unloading which is situated on the westside of coal drying factory.

② Operating room, electrical room and control room of waste water treatment system are installed in the waste water treatment room of the above-mentioned area.

③ Blowers and compressors are installed in the waste water treatment room for prevention from their noise and vibration.

④ Unit waste water pit and blow pit is installed nearby the boilers.

(c) Plan for monitoring and control

① Low and high concentrated waste water treatment equipment should be operated full-automatically each waste water and sludge system, respectively.

② Operation and trouble conditions should be indicated on the control board individually and all main monitoring items should be indicated on the common monitoring panel in the central control room.

③ Monitoring instrument and flow meter which can monitored pH, conductivity and COD stated in the Bulgarian standard continuously should be installed at the outlet of waste water treatment equipment, and each data should be able to record by processing unit.

④ Input and record of operation management data should be able to be made at a computer controlling the water treatment system.

⑤ In case waste water quality treated by the low and high concentrated waste water treatment plant exceeds the limited waste water quality, the system should be changed over the circulating operation as soon as possible. In this case, return line to storage pond should be transferred to the steady and un-steady waste water storage ponds.

⑥ Valves which need to operate full-automatically should be of pneumatic or electrical type, and should be systematized not to discharge waste water having abnormal water quality in the event of loss of air and electric.

(3) Recommendation and matters to be studied

(a) It is necessary to study the specification, etc. of waste water treatment system by measuring the water quality and quantity of living waste water to be discharged from the offices, etc.

(b) Since there are no treatment facilities for rain water, waste water of coal storage yard and overflow water of ash disposal area in the existing power plant, it is necessary to study the thses treatment system. First of all, a rain drainage system in the power plant should be established.

Table 6-10-2-1 Forecast of Source, Quantity and Quality of Low Concentrated Salt Waste Water

Kind of Waste Water	Quantity (ton/day)	Water Quality (mg/ ℓ)			
		SS	COD	Oil	T-N
Waste water for equipment cooling	20				20
Regenerated waste water of pre-treatment Plant	155	150 - 1800	10 - 30	Tr	1
Regenerated waste water of demineralized water treatment Plant	50	Tr	5 - 15	–	10
Unit drain waste water	490	5 - 10	1 - 3	10 - 20	5
Others	315	1,000	1 - 10	1 - 2	5
Total	1,030				

Table 6-10-2-2 Forecast of Source, Quantity and Water Quality of High Concentrated Salt Waste Water

Kind of Waste Water	Quantity (ton/day)	Water Quality (mg/ℓ)				
		SS	COD	Oil	T-N	F
Regenerated waste water of water treatment plant	50	Tr	5 - 15	—	10	—
Unit drain waste water	15	5 - 10	1 - 3	10 - 20	2	—
Total	65					
Cleaning waste water of AH	1,300	<5,000	<15	Tr	400	10
Cleaning waste water of EP	900	<5,000	<20	1 - 2	500	250
Chemical cleaning waste water of boiler	730	15,000	15 - 30	Tr		

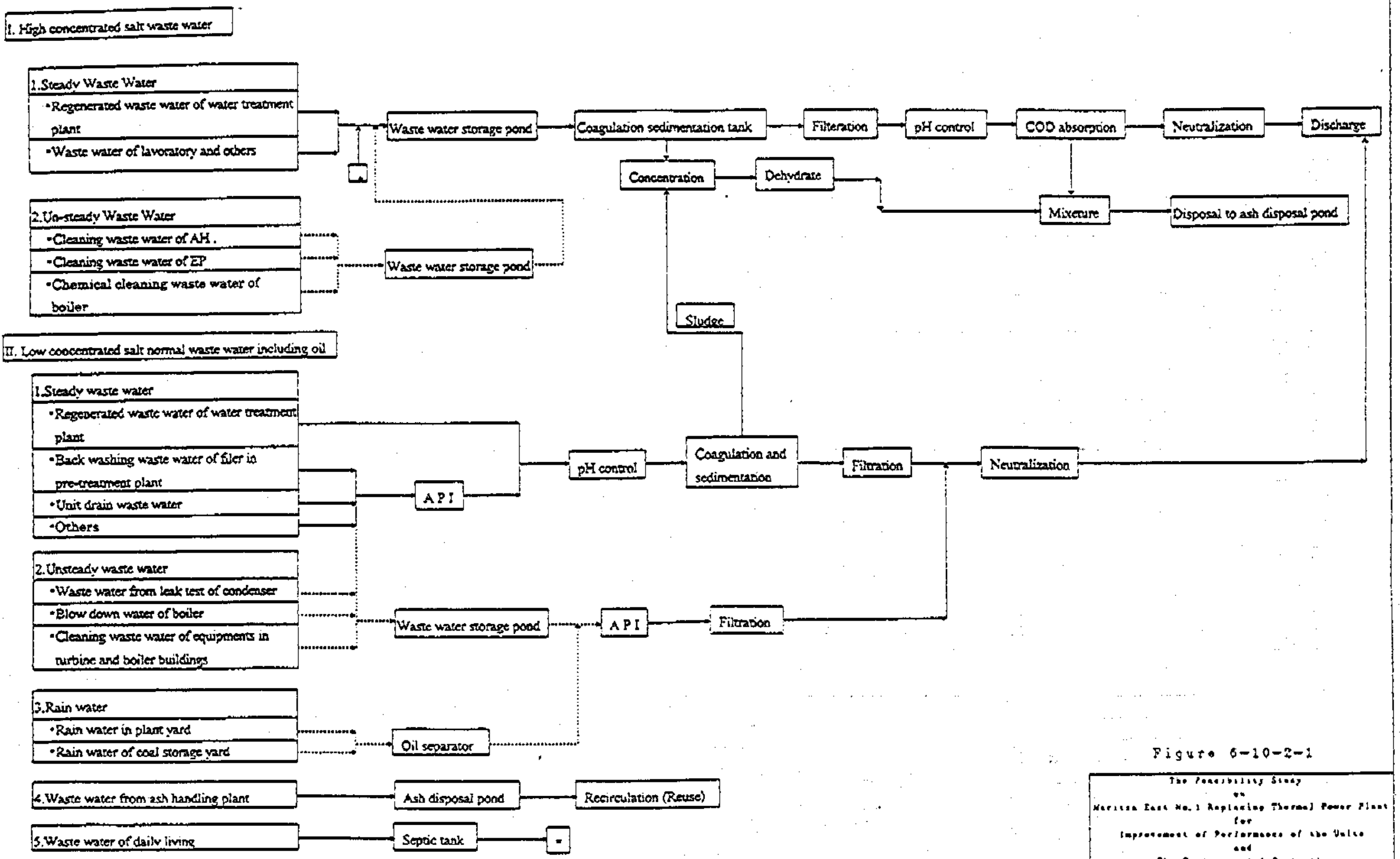


Figure 6-10-2-1

The Feasibility Study
on
Maritsa East No.1 Replacing Thermal Power Plant
for
Improvement of Performance of the Units
and
The Environmental Protection

FLOW DIAGRAM OF
WASTE WATER TREATMENT SYSTEM

JICA TEAM

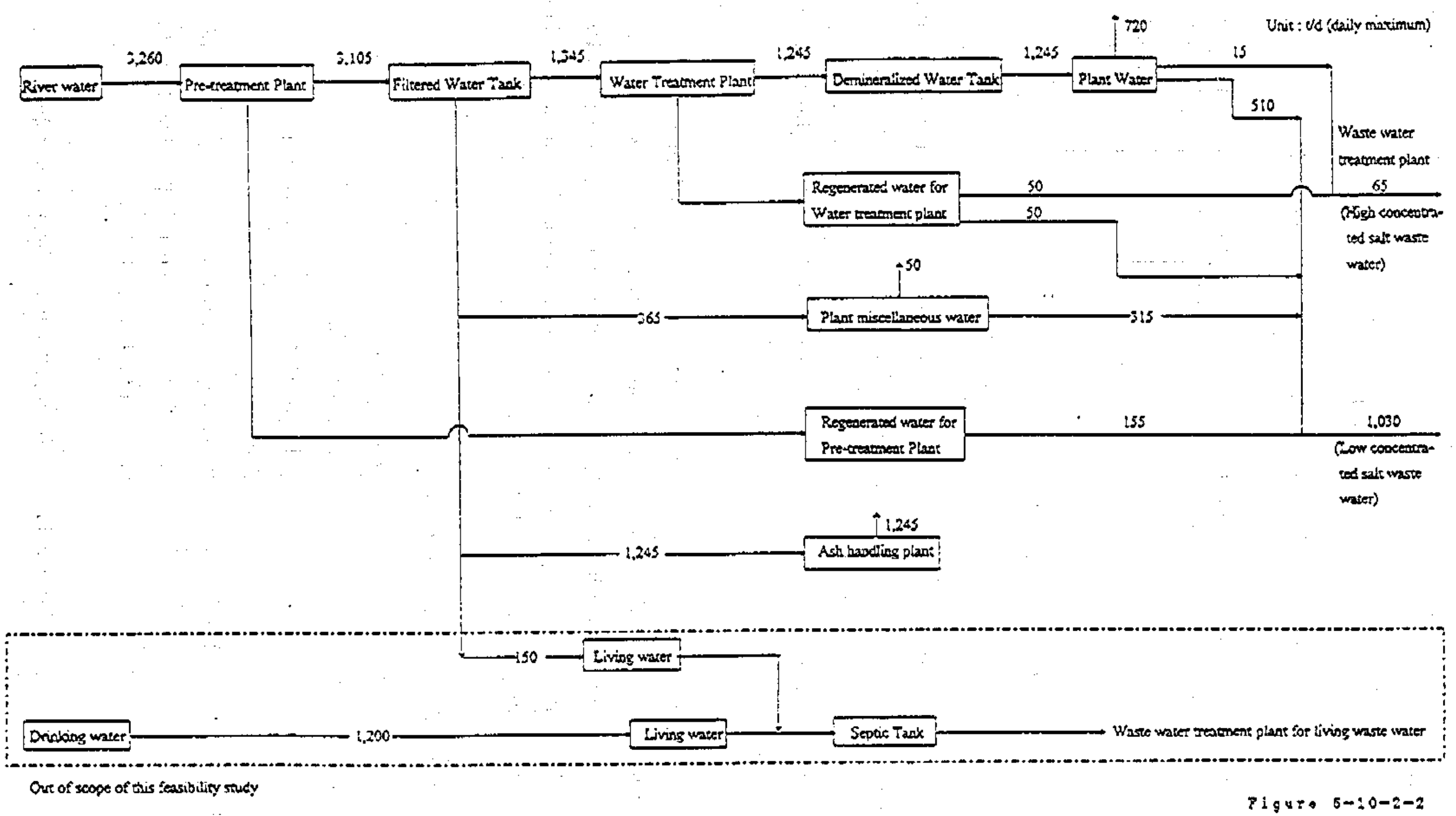


Figure 6-10-2-2

The Feasibility Study
on
Maritza East No.1 Replacing Thermal Power Plant
for
Improvement of Performance of the Units
and
The Environmental Protection

FLOW BALANCE OF
WATER AND WASTE WATER

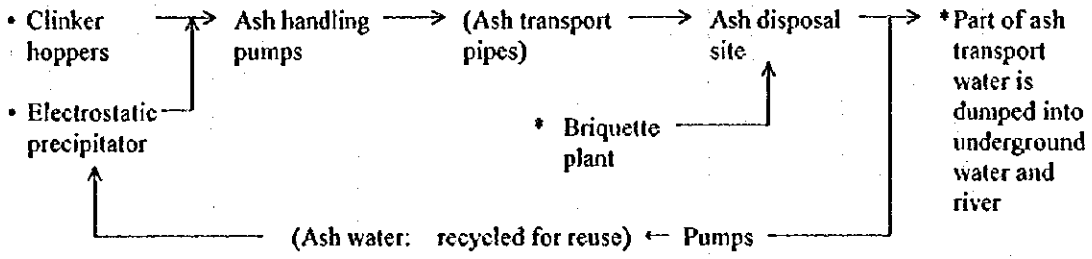
JICA TEAM

6.11 Ash Handling Facilities

(1) Study Parameters

(a) Existing ash handling is outlined below in flowchart form.

Ash transport water is recycled as diagrammatically shown in Figure 6-11-1.



(b) As for the characteristics of the existing ash transport system, ash transport pipes are installed to an ash dumping site from individual ash handling pumps (6 sets in all) on a one-to-one basis. A manifolding discharge valve arrangement is installed on the piping in the vicinity of the ash disposal site so that valves may be opened/closed selectively to achieve uniform discharge.

For use as ash transport pipes, Schemerz Basalt pipes (measuring 630 mm in diameter, 40 mm in wall thickness, and 3 mm in coating thickness) are used. By virtue of their measures to wear, these pipes have developed no particular trouble for a period of 10 years. They can also be procured easily from a manufacturer operating in the neighborhood of the power plant. (Unit price per 1m = 2,200 leva)

(c) The existing ash disposal site is as follows:

• Area	: 300 ha (3 km^2)
• No. 1 and No. 2 sections	: already filled to capacity (14 m in depth and 30 cm in cover-up soil thickness)
• No. 3 section (A and B subsections):	B in current use with a remaining capacity of 6,765,800 m^3 ≒ roughly equivalent to 12 years' volume of ash (at 200 MW)

(d) The amount of ash the reconstructed boilers is projected to discharge is as follows:

- Amount of dry ash (coal ash, by-product gypsum, limestone, impurities, etc.)

  350 t/h (≒ 173 t/h x 2 units)

8,400 t/d (≒ 350 t/h x 24 hr)
2,150,000 t/y (≒ 8,400 t/d x 365 d x 0.7)
(Breakdown) 350 t/h: On bottom = 220 t/h Beneath ECO = 20 t/h
Beneath AH = 20 t/h Beneath ESP = 90 t/h

- Amount of ash discharged (Water content: 30%)

450 t/h (≒ 173 t/h x 2 units x 1.3)
10,800 t/d (≒ 450 t/h x 24 hr)

(2) Study Results

(a) Design specifications based on the above are as follows:

1) If the existing ash disposal site will be used exclusively by the power plant, the site reaches full capacity in a little less than 3 years (on the condition that dry ash with an estimated ash accumulation height specific weight of 1.0 is disposed of).

However, ash from fluidized bed combination boiler is extremely difficult to handle/manage since it contains Ca components that produce heat and high pH readings (above 13) when it comes into contact with water.

For this reason, as an ultimate means of ash disposal, ash shall be transported on rail cars (41 tons/car) originally intended for carrying coal-mine topsoil, and be dumped at a topsoil dumping ground (at Drianovo) located 7 km south east of the power plant.

The rough locations of the coal-mine topsoil dumping ground and the coal mine are shown in Figure 4-1-3.

For information, if a new ash disposal site (Capacity for 15 years, depth: 14 m) is to be developed, it becomes necessary to procure a piece of land with an area of $3\ km^2$ (or 300 ha., which is approximately as large as the existing site).

- 3.2 y ≒ $[6{,}765{,}800\ m^3) \times (1.0) \div (2{,}150{,}000\ t/y)]$
- $2.3\ km^2$ ≒ $[(15\ y) \times (2{,}150{,}000\ t/y) \div (1.0) \div (14\ m) \div 10^6)]$

2) If ash is to be transported by water, ash's Ca components dissolve into water in transit and solve or precipitate in the form of sulfates. Furthermore, oxides within ash gradually dissolve into water as hydroxides which, in turn, drive up the pH of the ash transport water. What's worse, in parallel with changes in pH, metal ions that have seeped out into the water earlier precipitate and deposit on the inner surfaces of pipelines in the form of soft scales. Furthermore, these scales turn into harder scales by the action of dissolved CO_2, and grow into a cause of pipe clogging.

For this reason, a pneumatic transport system shall be adopted for transporting ash from the ash collection system to the ash loading facility. After the ash shall be moistened at the loading facility, it shall be placed on a conveyor transport system for transportation and loading onto rail cars.

3) As ash recovered from the bottom of the furnace cannot be cooled directly by water, an ash cooler shall be separately installed.

4) The ash loading facility shall be constructed at the point of loading onto freights (which is located behind the neighboring briquette plant) to cope with moistening-caused problems such as solidification and heat generation. Ash shall, therefore, be moistened (20% to 30%) prior to loading--and conveyors and trippers shall be designed to be heat-resistant. Care should, however, be taken in the maintenance of loading equipment following the addition of moisture because it tends to permit accretions of ash.

5) On the assumption that a single loading session takes an hour, and ash transport trains shall be operated 12 hours a day, it becomes necessary to operate 12 trains, each made up of 22 cars as calculated below:

   - The number of freights per train:
     22 [≒ (10,800 tons/day) ÷ (12 trains) ÷ (41 tons/freight)]

6) The capacity of ash transit tanks shall be designed to be large enough (to last for 10 hours), as determined by the footprint of ash-collection equipment to be installed atop the tanks.

   - Ash transit tanks:
     2,000 m^3 [≒ 173 t/hr x 10 hr x 1.0 x 1.15 (margin)] x 2 units

7) The combined capacity of silos (for storage and loading purposes) shall be large enough to last 2 days (48 hours). The loading silo shall have one day's capacity (4,200 tons/day). And, the remaining capacity required shall be met by the storage silos.
   - Loading silos : 4,200 m^3 [≒ 173 t/hr x 24 hr x 1.0] x 2 units
   - Storage silos : 4,200 m^3 [≒ (8,400 - 4,200) x 1.0] x 2 units

8) The (storage and loading) silos shall have systems that permit the receipt of ash from both R1 and R2 units.

9) The storage silos shall be equipped with emergency facilities (to take ash out of storage on trucks) which will be used in the event of trouble with loading facilities or the like.

(b) The specifications of major facilities have been determined on the basis of the above design specifications are as follows.

They are shown in flowchart form in Figure 6-11-2.

1) Ash collection system (BM: Ash on furnace bottoms, FA: ECO, AH, and ESP ash)

- BM ash coolers:

(Type)	Rotary ash coolers
(Capacity)	40 tons/hour x 3 sets/unit x 2 units

- Air intake valves:

(Type)	Spring-loaded check valves
(Quantity)	For BM: 3 sets/unit x 2 units
	For FA: 8 sets/unit x 2 units

- Ash transport pipes:

(Pipe diameter)	10 B
(Pipeline system)	For BM: 3 lines/unit x 2 units
	For FA: 2 lines/unit x 2 units

- Automatic selector valves:

(Type)	Rotary slide type
(Quantity)	For BM: 3 sets/unit x 2 units
	For FA: 8 sets/unit x 2 units

- Vacuum blowers:

(Type)	Dry-type Roots blowers
(Capacity)	For BM: 52 Nm^3/min. (-5400 mmAq)
	For FA: 57 Nm^3/min. (-5400 mmAq)
(Quantity)	For BM: 4 sets/unit (1 set for backup) x 2 units
	For FA: 3 sets/unit (1 set for backup) x 2 units

- Dust collectors:

(Type)	Integral-type bag filters
(Quantity)	For BM: 3 sets/unit x 2 units
	For FA: 2 sets/unit x 2 units

- Ash transit tanks:

(Type)	Cylindri-conical steel tanks
(Capacity)	2,000 m^3 (15 m across x 11 m high) x 1 set/unit x 2 units

2) Ash transport facilities

- Discharge vessel:

(Type)	Cylindri-conical steel pressure vessels
(Capacity)	50 tons/hour x 4 sets/unit x 2 units

- Ash transport pipes:

(Pipe diameter)	16 B
(Pipeline system)	1 line/unit x 2 units

- Pressurize blowers:

(Type)	Dry-type Roots blowers
(Capacity)	210 Nm^3/min. (13,000 mmAq)
(Quantity)	2 sets/unit (1 set for backup) x 2 units

- Ash storage silos:

(Type)	Cylindri-conical steel silos
(Capacity)	4,200 m^3 (16.5 m across x 20 m high) x 1 silo/unit x 2 units

- Dustless unloader: (For use in emergency)

(Type)	Dual-shaft paddle-equipped type
(Capacity)	100 tons/hour (dry ash) x 1 set/unit x 2 units

- Dustless unloader-feedwater pumps:

(Type)	Centrifugal pumps
(Capacity)	190 m^3/hour (5 kg/cm^{2}g) x 3 sets/2 units (1 set for backup)

- Feedwater pits:

(Type)	Rectangular concrete pits
(Dimensions)	8 m wide x 8 m long x 4 m high x 1 pit/2 units

3) Ash loading facilities

- Discharge vessel:

(Type)	Cylindri-conical steel pressure vessels
(Capacity)	50 tons/hour x 4 sets/unit x 2 units

- Ash transport pipes:

(Pipe diameter)	18 B
(Pipeline system)	2 lines/unit x 2 units

- Pressurize blowers:

(Type)	Dry-type Roots blowers
(Capacity)	270 Nm^3/min. (13,000 mmAq)
(Quantity)	3 sets/unit (1 set for backup) x 2 units

- Ash loading silos:

(Type)	Cylindri-conical steel silos
(Capacity)	4,200 m^3 (16.5 m across x 20 m high) x 1 silo/unit x 2 units

- Dustless unloader: (For regular use)

(Type)	Dual-shaft paddle-equipped type
(Capacity)	250 tons/hour (dry ash) x 3 sets/unit x 2 units

- Conveyors:

(Type)	Bucket conveyors (heat-resistant)
(Capacity)	950 tons/hour (moistened ash) x 1 set/unit x 2 units

- Trippers:

(Type)	Belt lifting type (heat-resistant)
(Capacity)	950 tons/hour (moistened ash) x 1 set/unit x 2 units

(3) Items to be considered for carry out the plan

(a) The amount of water required for moistening ash in preparation for transportation by rail cars varies in accordance with the proportion of Ca components contained in the ash--A large amount of water causes ash to solidify while a small amount of water causes ash to be loose and crumbly. It is, therefore, important to determine the optimum moisture content for in-transit ash in the test-run stage or in a separate study relating to the handling of ash derived from fluidized bed combustion (FBC) furnaces (as to humidification factor, heat generation, and the like) using "Bulgarian" lignite.

(b) Since underground water is flowing beneath the coal-mine topsoil disposal site (at Drianovo, 17 km^2), it is necessary to institute measures to prevent contamination with hazardous substances dissolved out of dumped FBC ash.

As example measures, the following are conceivable:

- Geologically, the site consist seams of clay, sand, and gravel. Under the circumstances, first of all, the clay seam shall be studied to determine whether it can be used or not--through the performance of water-permeability tests and the like on the clay to determine its properties such as permeability.
- Next, by capitalizing on FBC ash's property to solidify by the action of moisture, the lowermost seam on the bottom of the planned dump site shall be turned into a solid seam.
- Furthermore, to study various kinds of measures, it is extremely important to analyze and document chemical components that dissolve out of FBC ash with higher degrees of accuracy.

(c) Since the operation of coal-mine topsoil transport cars and ash transport cars is expected to be complicated, consideration should be given to the following:

- Freight car operation should be elaborately scheduled.
- Arrangements for liaison and coordination between the coal mining company and the power plant should be devised.
- To deal with freight-car operation which will be complicated, the number of safety operation personnel should be increased to better implement safety management.

(d) Since FBC ash shall be disposed of by using the railway and disposal site owned and operated by the coal mining company, there is a necessity of making prior adjustments/arrangements between the coal mining company and the power plant concerning such matters as the power plant's reconstruction schedule, the sharing of workload (including the employment of operating personnel), the sharing of costs of purchasing rolling stock (freight cars), and other attendant matters that are required to be settled such as ash-disposal contracts.

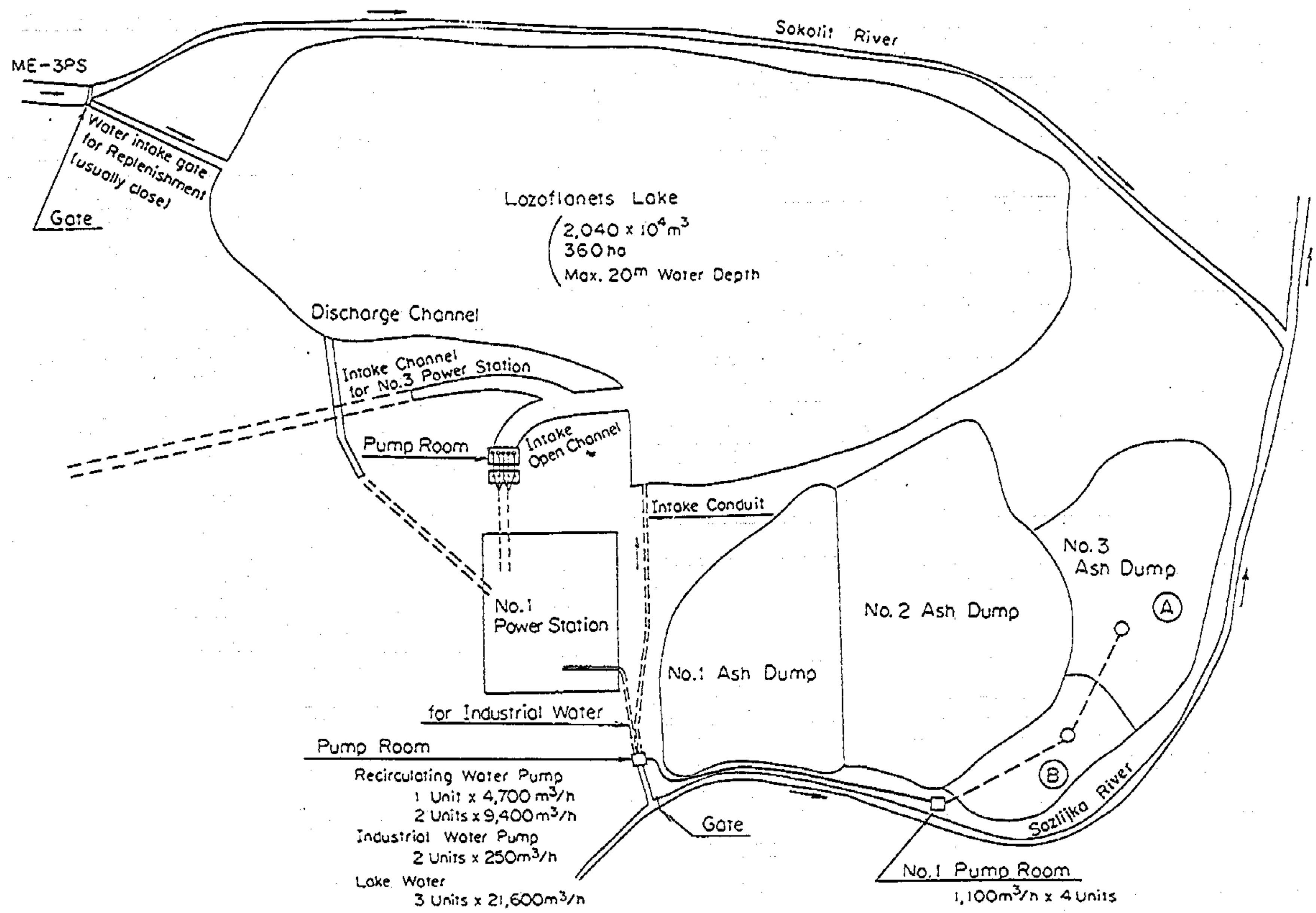


Figure 6-11-1 Water Intake and Discharge System in Power Station

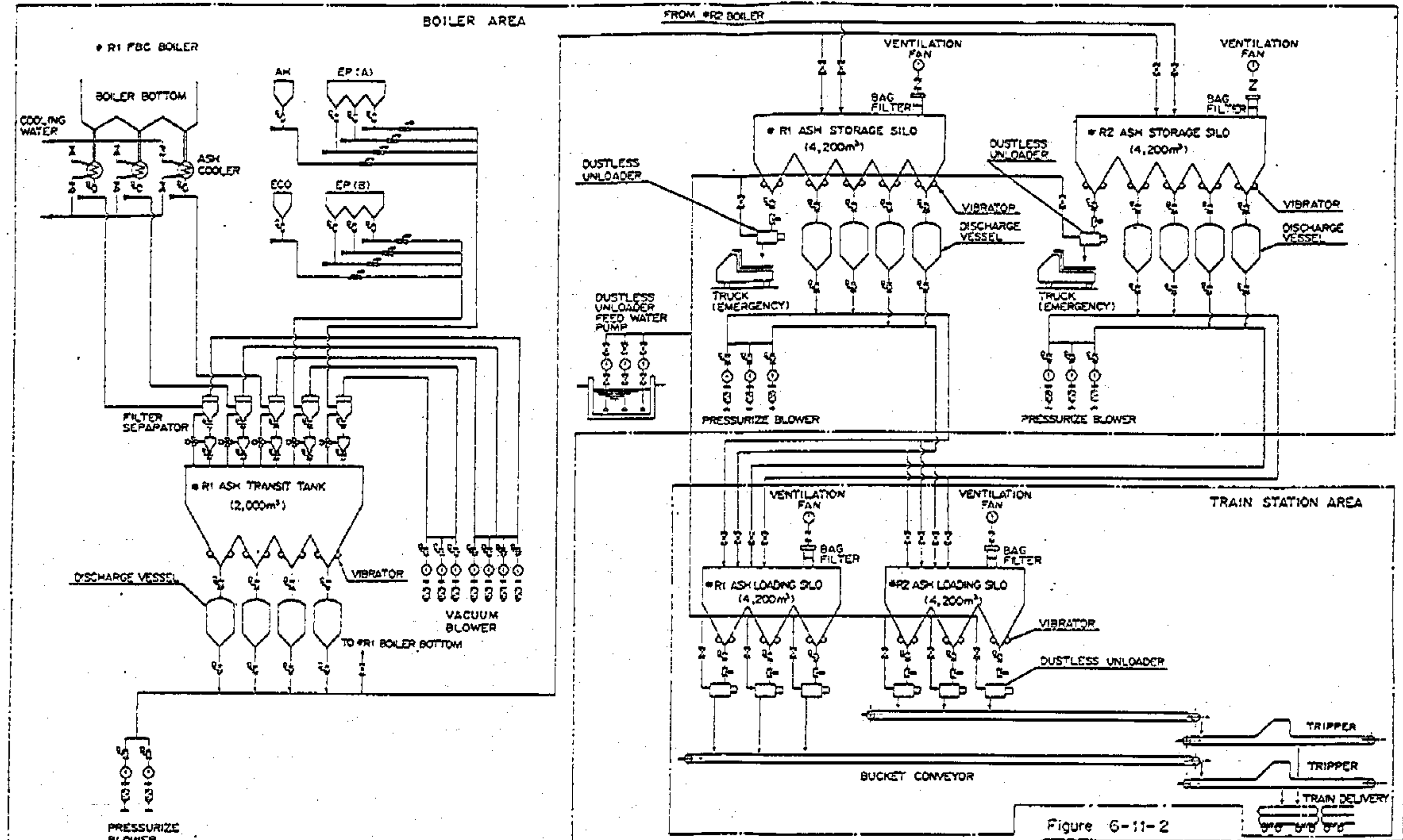


Figure 6-11-2

L E G E N D

BUTTERFLY VALVE	ISOLATE VALVE
GLOBE VALVE	AIR INTAKE
DAMPER	SEGMENT GATE
SOLENOID VALVE	ORIFICE FEEDER
DUST VALVE	

The Feasibility Study
on
Moritsa East No.1 Replacing Thermal Power Plant
for
Improvement of The Performance of The Units
and
The Environmental Protection

ASH HANDLING SYSTEM FLOW SCALE:

JICA TEAM

APPROVED BY
DATE
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DRAWN BY

6.12 Plant Water System

6.12.1 Design Condition

(1) Scope of Design

Scope of design for plant water system is to plan the whole facilities of pre-treatment system and water treatment system which covers from Sazlijka River water intake facilities to water treatment plant.

(2) Basic System, and Pre-treatment and Water Treatment Method

(a) Basic plant water system consists of "Plant water system (demineralized water and fresh water)" and "Living water system" in terms of water.

(Refer to Figure 6-12-1 "Flow Diagram of Water Treatment System".)

(b) As for plant water treatment method, the coagulation and sedimentation method is adopted for pre-treatment plant, and the mix bed type with polisher is adopted for water treatment plant, considering water quality of Sazlijka River and the experiences of water treatment plant.

Basic plant water system consists of the following system.

① Plant water system

1) Filtered water system for plant consists of intake from Sazlijka River, pre-treatment, storage in the filtered water tank and supplying the filtered water to each using place and for fire fighting.
2) Fire fighting system is separated from the filtered water system.
3) Demineralized water system for plant consists of facilities receiving the filtered water, producing the demineralized water in water treatment plant, storing in the demineralized water tank and supplying the demineralized water to each unit directly.

② Living water system

Living water is received from Gorno Botsuo city and its system is out of a scope of design.

(3) Basic Policy of Equipment Design

(a) Bearing cooling water system to be of closed circuit type

Closed circuit type system is adopted for bearing cooling water system in order to reduce a quantity of bearing cooling waste water.

Loss of bearing cooling water should be saved by equipping the mechanical seal with grand of B.F.P booster pump.

(b) Adoption of circulating water pump with cutless bearing (bearing without lubricating water)

In order to reduce the plant water, a circulating water pump should be provided with cutless bearing which does not require water.

(4) Receiving Water

(a) Water source

① Plant water : Sazlijka River
② Living water : City water from Gorno Botsuo City

(b) Water quality of plant water

Analized data of Sazlijka River water are shown in Table 6-12-1 "Raw Water Analysis for Design".

(5) Water Quality of the Treated Water

Water quality of the treated water should satisfy the Bulgarian Standard shown in Table 6-12-2 "Water Quality of the Treated Water".

However, conductivity should meet the Japanese Standard, (0.5μS/cm) in stead of the Bulgarian Standard, (0.2μS/cm) because the Bulgarian Standard is too severe and causes installation of large scale of water treatment plant for its capacity.

(6) Capacity of Water Treatment and Pre-treatment Plant

(a) Demineralized water tank and water treatment plant

① Number of the demineralized water tank and water treatment plant is two (2) tanks and two (2) trains, respectively.

② The maximum demineralized water quantity to be required for three (3) days should be catered by the one water treatment plant and one demineralized water tank.

(b) Filtered water tank

① The required capacity and number of tank should be decided on the conditions that two (2) tanks to be installed.

② The maximum filtered water should hold water quantity required for a day even in case a filtered water tank is out of service because of inspection.

(c) Pre-treatment plant

① Two (2) trains of pre-treatment plant should be installed.

② Capacity of pre-treatment plant should cater for the maximum filtered water quantity and water quantity for one water treatment plant in service.

6.12.2 Study Results

(1) Specifications of the Main Equipment and Facilities

(a) Pre-treatment plant

① Type : Coagulation, Sedimentation and Filter Method
② Capacity : 1,500 m^2/day per train
③ Number : Two (2) sets

(b) Filtered water tank

① Type : Steel made cylindrical tank (of dome roof type)
② Capacity : 4,000 m^2 per one tank
③ Number : Two (2) sets

(c) Water treatment plant

① Type : Mix bed type with polisher
② Capacity : 700 m^2/day per train
③ Number : Two (2) sets

(d) Demineralized water tank

① Type : Steel made cylindrical tank (of inner roof type)
② Capacity : 1,500 m^2 per one tank
③ Number : Two (2) sets

(2) Calculation of equipment capacity

Capacity of each facility is calculated hereunder. Detailed data of plant water quantity are shown in the Appendix 6-12-1 "Forecast of the required demineralized water quantity", Appendix 6-12-2 "Forecast of the required filtered water quantity" and Figure 6-12-2 "Flow Balance of Water and Waste Water".

(a) Demineralized water tank and water treatment plant

① Units R1 and R2 should not be started up simultaneously.

② In case Unit R1 is started up after periodical inspection and Unit R2 is in service, the required demineralized water is maximum. The water quantity required for three (3) days (peak period) are shown as follows.

First day :	Unit R1	Boiler hydrostatic test	500 ton	total 1,150 ton
	Unit R2	Continuous operation	650 ton	
Second day :	Unit R1	Boiler blow	360 ton	total 1,010 ton
	Unit R2	Continuous operation	650 ton	
Third day :	Unit R1	Boiler blow	360 ton	total 1,010 ton
	Unit R2	Continuous operation	650 ton	
			Grand total	3,170 ton

③ The following formula is established by applying the design policy considering the optimum design of water treatment plant and demineralized water tank.

Q = (three (3) days x one train x X) + (0.8 x Y) :

Where,

Q : Water quantity in peak three (3) days (ton)
(The maximum quantity is supplied by water treatment plant and demineralized water tank.)
X : Capacity of water treatment plant (ton/day)
Y : Capacity of demineralized water tank (ton)

In case capacity of water treatment plant is 700 ton/day, tank capacity is as follows.
Y = [3,170ton - (3 days x 1 train x 700 ton/day)]/0.8

= 1,338 ton

Therefore, the optimum capacity is 1,500 m^3.

By the above calculations, capacity of water treatment plant is 700 ton/day (two (2) sets) and capacity of demineralized water tank is 1,500m^3 (two (2) sets).

(b) Filtered water tank

Capacity of filtered water tank should be not less than the maximum filtered water quantity to be required for a day.

	The maximum required quantity of filtered water
·Filtered water for producing the demineralized water	1,345 ton
·Miscellaneous water	1,610 ton
·Filtered water for living	150 ton
Total	3,105 ton

Therefore, when a tank capacity is calculated applying 80% of tank effective storage rate, it is necessary to install two (2) sets of 4,000m^3 filtered water tank including one stand-by tank which will supply the required water in case the other tank is out of service because of inspection.

(c) Pre-treatment plant

Pre-treatment plant should be capable of supplying the water quantity required to operate one water treatment plant can be operated and the maximum required filtered water quantity.

· Water quantity required to operate one water treatment plant 700 ton/day + 100 ton/day	800 ton
· Filtered water 350 ton/day + 1,245 ton/day + 100 ton/day	1,710 ton
Total	2,510 ton

Therefore, the following capacity should be necessary in order to this quantity (2,510 ton) to be supplied by two (2) pre-treatment plants.

2,600 ton/day ÷ 2 trains = 1,300 ton/day

Taking into account of the regeneration time of the filters, the following capacity is required.
1,300 ton/day x (24/22 hours) = 1,500 ton/day

Resulting the above calculations, capacity and number of pre-treatment should be 1,500 ton/day x two (2) sets.

(3) Chemical Storage Equipment

Chemical storage equipment for the water treatment consists of chemical unloading equipment, chemical storage tank and chemical transfer equipment.
The plant for the system will be established on the following basic conditions.

(a) Chemical unloading equipment

Hydrochloric acid and caustic soda will be used for the water treatment and waste water treatment system. These chemicals will be delivered to the power plant by railway and transferred from railway tank to storage tank by relevant chemical unloading pump.

① Chemical storage tank

The storage capacity will, in principle, be more than requirement for 20 days for the following reasons.

1) The standard capacity is more than 15 days requirement.
2) The above chemicals will be commonly used for the waste water treatment system.
3) Maritsa East No.1 Power Plant is favorably located for obtaining the chemicals easily.

One set of hydrochloric acid tank and caustic soda tank will be of the horizontal cylindrical type.

② Chemical transfer equipment

The chemicals will be transferred from the storage tank to the water treatment system by a chemical transfer pump.
The chemical transfer pump for the waste water treatment system will be installed nearby the chemical transfer pump for the water treatment system within the dike for chemical storage tanks.
Specification and calculation results of other equipment are shown in Table 6-12-5.

(4) Equipment Arrangement Plan

(a) Pre-treatment and water treatment equipment are installed nearby Sazlijka River.
(b) Pre-treatment equipment is installed outdoors and water treatment equipment is installed in a house.
(c) Operating room, electrical room and control room of each treatment system are installed in the water treatment room.
(d) Filtered water tank, demineralized water tank, filtered water transfer pump and demineralized water transfer pump are installed near the water treatment room.

Outline of equipment arrangement is shown in Figure 6-3-1.

(5) Plan for Monitoring and Control

(a) Pre-treatment equipment

① Pre-treatment equipment except powder chemicals receiving and dissolving equipment should be operated full-automatically.
② Equipment could automatically be started and stopped by detecting the water level in the filtered water tank and number of equipment should also be decided by the water level.
③ Filters should be automatically cleaned by means of a back washing method by detecting the pressure difference of filter, etc.

(b) Water treatment equipment

① Equipment should automatically be operated by sequencer and a part or all equipment should be remote-operated manually from water treatment control panel.
② Regeneration of tower should automatically be put in operation by forecasting the constant treated water quantity, constant treated water quality and resin load.
③ Equipment should be automatically started and stopped by indication of a water level in the demineralized water tank, etc.

(c) Operation and trouble conditions of pre-treatment and water treatment equipment should be indicated on the control board individually and all main monitoring items should be indicated on the common monitoring panel in the central control room.

Table 6-12-1 Raw Water Analysis for Design

Items	Unit	Water Analyzed Data
pH at 20℃		7.89
Conductivity at 20℃	μ S/cm	1116
Total suspended matters	mg/ ℓ	33.0
Dissolved solids	mg/ ℓ	984
DCO	mgO_2/ ℓ	31.1
Oxydability with $KMnO_4$	mgO_2/ ℓ	12.6
Cl^-	mg/ ℓ	39.0
SO_4^{2-}	mg/ ℓ	328.4
F^-	mg/ ℓ	0.50
HCO_3	mg/ ℓ	
NO_3^-	mg/ ℓ	119.7
NO_2^-	mg/ ℓ	6.43
PO_4^{3-}	mg/ ℓ	2.89
TH	° F	55.0
TA	° F	0.0
TAC	° F	27.0
Ca^{2+}	mg/ ℓ	160.0
Mg^{2+}	mg/ ℓ	36.45
K^+	mg/ ℓ	5.60
Na^+	mg/ ℓ	116.0
NH_4^+	mg/ ℓ	0.80
Fe (total)	mg/ ℓ	1.00
Cu (total)	mg/ ℓ	0.005
Zn (total)	mg/ ℓ	0.073
Cr (total)	mg/ ℓ	< 0.05
Ni (total)	mg/ ℓ	< 0.02
Sr^+	mg/ ℓ	1.34
Ba^+	mg/ ℓ	< 0.05
SiO_2	mg/ ℓ	15.23

Table 6-12-2 Water Quality of Treated Water

	Unit	Demi. Water	Feed Water
Conductivity	μ S/cm	0.5	0.2
SiO_2	μ g/kg	20	40
Cu^{++}	μ g/kg	5	5
Na^+	μ g/kg	10	10
H^0	μ geqv/kg	–	1
pH		–	9.1 ± 0.1
Fe^{++}	μ g/kg	–	30
O_2	μ g/kg	–	10
Oil	mg/kg	–	5
NH_3	μ g/kg	–	1000
N_2H_4	μ g/kg	–	20 to 60

Table 6-12-3 Forecast of the Required Demineralized Water Quantity

(1) Steady (Forecast of the required demineralized water quantity required to two units under normal operation)

Item	Waste water quantity (ton/day)			Deisgn reasons
	Waste water be possible to recovery	Waste water be impossible to recover		
		Low salt	High salt	
① Boiler·turbine	500	500		BMCR : 740 t/h Boiler make-up water quantity : 740 t/h x 0.03 = 22.2 t/h × 2 unit × 24hr = 1,065.7 t/h →1,000 t/h The half quantity should be evaporated.
② Boiler sootblower	160			0.33ton/day·MW is applied by experience.
③ Heating steam for EP hopper	30			0.6 ton/hr·unit is applied by experience.
④ Bearing cooling water		10		It is assumed that is half quantity of 20 ton/day of ball recirculating pump grand seal water.
⑤ Other auxiliary steam	30			It is assumed the half quantity of 60 ton/day of the experienced data.
⑥ Lavoratory			5	By the experience
⑦ Sampling			10	It is assumed the half quantity of the experienced data.
Total	720	510	15	
Plant water quantity	1,245			

(2) Un-steady

Item	Waste water quantity (ton/day)			Design reasons
	Waste water be possible to recovery	Waste water be impossible to recover		
		Low salt	High salt	
① Boiler blow at startup		360		It is assumed by the experienced data.
② Boiler hydrostatic		500		It is assumed by the experienced data.
③ Boiler chemical cleaning			740	It is assumed by the experienced data.
④ Condenser hydrostatic		350		It is assumed by the experienced data.

Table 6-12-4 Forecast of the Required Filtered Water Quantity

(1) Steady (Forecast of the required filtered water quantity required for two units under normal operation)

Item	Waste water quantity (ton/day)			Design reasons
	Waste water be possible to recovery	Waste water be impossible to recover		
		Low salt	High salt	
① Turbine building miscellaneous water		210		0.45ton/day·MW is applied by experience.
② Cooling water for ash handling equipment		20		0.05ton/day·MW is applied by experience.
③ Waste water treatment system	1,245			Make-up water of dustless unloader : 51.48 t/h
④ Waste water sludge dehydrator		10		It is assumed the half quantity of 60 ton/day by the experiences.
⑤ Others				It is assumed by the experienced data.
Total	1,730	315	0	
Plant water quantity	2,045			

(2) Un-steady

Item	Waste water quantity (ton/day)			Design reasons
	Waste water be possible to recovery	Waste water be impossible to recover		
		Low salt	High salt	
① AH water washing			1,300	It is assumed by the experienced data.
② EP water washing			900	It is assumed by the experienced data.

Table 6-12-5 Calcualtion of Capacity of Power Plant Water Facilities

Items	Specification of Facilities	Planning Reasons
Raw water transfer pump	Capacity : 150 t/h Number : two (2) sets	Pump is capable of supplying the required water of pre-treatment plant $Q = 3{,}000\ \text{ton/day} \div 22\text{hr}$ $= 136\ \text{t/h} \times 1.1$ $= 150\ \text{t/h}$
Raw water pipings	Diameter : 250 A (Material : ATPG370Sch40)	Piping diameter is designed based on the design standard and flow velocity of 2.5m/sec. $d = \left\{\dfrac{4 \times 150 \times 2}{3600 \times \pi \times 2.5}\right\}^{1/2}$ $= 0.206\ \text{m}$
Pre-treatment plant	Capacity : 1,500 ton/day Number : Two (2) trains	From item 6.12.2, (c)
Filtered water under-groud tank	Type : Semi-undergroundconcrete tank	Tank is capable of storaging the maximum received water quantity for a hour. $Q = (3{,}000\text{ton/day} \div 22) \times 1$ $= 136\ \text{ton} \rightarrow 150\ \text{m}^3$
Filtered water transfer pump	Capacity : 150 t/h Number : Two (2) sets	Capacity of this pump is same as that of raw water transfer pump.
Filtered water tank	Type : Steel made doom roof Capacity : 4,000m^3 Number : Two (2) sets	From item 6.12.2, (2), (a)
Flitered water transfer pump	Capacity : 40 t/h Number : Two (2) sets	The pump is sized that two water treat ment plant can be operated by two pumps. $(1{,}400\ \text{ton/day} \div 20\text{hr}) \times 1.1 \div 2$ $= 38.5\ \text{ton/h} \rightarrow 40\ \text{ton/h}$
Filtered water pipings	Diameter : 150 A x 1 (Material : ATPG370Sch40)	Piping diameter is designed based on flow velocity of 2.5m/sec. $d = \left\{\dfrac{4 \times 40 \times 2}{3600 \times \pi \times 2.5}\right\}^{1/2}$ $= 0.106\ \text{m}\ (150\text{A})$
Water treatment plant	Capacity : 700 ton/day Number : Two (2) trains	From item 6.12.2, (2), (a)

Items	Specification of Facilities	Planning Reasons
Demineralized water transfer pump	Capacity : 50 t/h Number : Three (3) sets, one set for standby	The pump is capable of supplying the water quantity which is required for boiler hydrostatic test (500t/day). (500 ton/day ÷ 12hr) x 1.1 ≒ 45.8 ton/h → 50 ton/h
Demineralized water tank	Type : Steel made inner roof Capacity : 1,500m^3 Number : Two (2) sets	From item 6.12.2, (2), (a)
Demineralized water pipings	Diameter : 150 A x 2 (Material : SUS304TPSch20)	Piping diameter is designed based on flow velocity of 3 to 3.5m/sec. 2 pipe lines should be laid for reliability. $d = \left\{\frac{4x50x2}{3600x\pi x3.5}\right\}^{1/2}$ ≒ 0.101m (150A)
Fresh water pump	Capacity : 30 t/h Number : Two (2) sets	The pump is capable of supplying the maximum required fresh water. (1,600 ton/day ÷ 24hr) ÷ 2 ≒ 33.5 x 1.1 ≒ 40 ton/h
Fresh water pipings	Diameter : 150 A x 2 (Material : STPG370Sch40)	Piping diameter is designed based on flow velocity of 3 to 3.5m/sec. $d = \left\{\frac{4x40x2}{3600x\pi x2.5}\right\}^{1/2}$ ≒ 0.130m (150A)

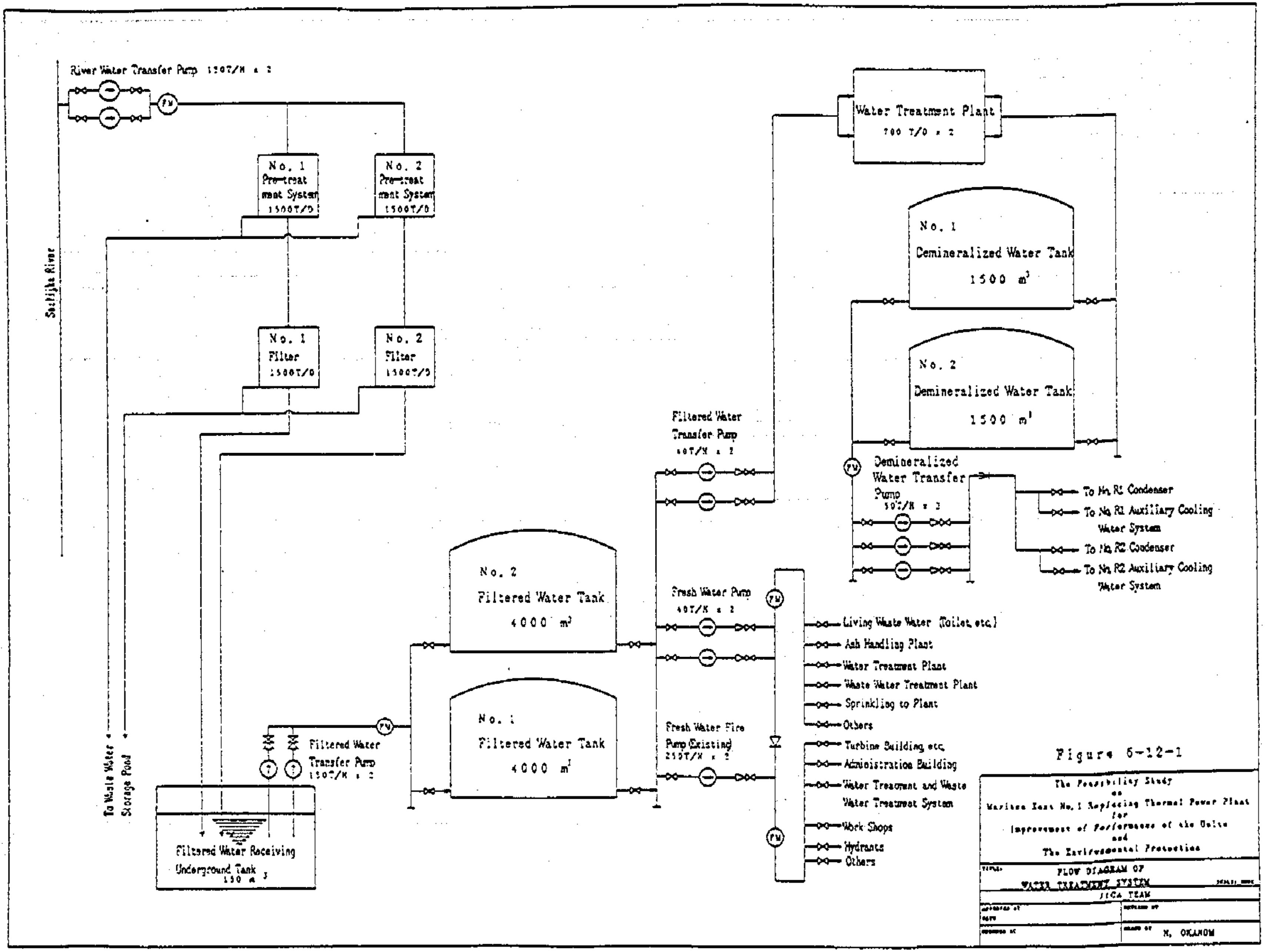
River Water Transfer Pump 150T/H x 2
FM
Sazlijka River
No. 1 Pre-treatment System 1500T/D
No. 2 Pre-treatment System 1500T/D
No. 1 Filter 1500T/D
No. 2 Filter 1500T/D
To Waste Water
Storage Pond
Filtered Water Receiving Underground Tank 150 m3
Filtered Water Transfer Pump 150T/H x 2
No. 2 Filtered Water Tank 4000 m3
No. 1 Filtered Water Tank 4000 m3
Filtered Water Transfer Pump 40T/H x 2
Fresh Water Pump 40T/H x 2
Fresh Water Fire Pump (Existing) 250T/H x 2
Water Treatment Plant 700 T/D x 2
No. 1 Demineralized Water Tank 1500 m3
No. 2 Demineralized Water Tank 1500 m3
Demineralized Water Transfer Pump 50T/H x 3
To No. R1 Condenser
To No. R1 Auxiliary Cooling Water System
To No. R2 Condenser
To No. R2 Auxiliary Cooling Water System
Living Waste Water (Toilet, etc.)
Ash Handling Plant
Water Treatment Plant
Waste Water Treatment Plant
Sprinkling to Plant
Others
Turbine Building etc.
Administration Building
Water Treatment and Waste Water Treatment System
Work Shops
Hydrants
Others
The Feasibility Study on Maritsa East No. 1 Replacing Thermal Power Plant for Improvement of Performance of the Units and The Environmental Protection
TITLE: FLOW DIAGRAM OF WATER TREATMENT SYSTEM
JICA TEAM
DRAWN BY N. OKANOM

Figure 6-12-1

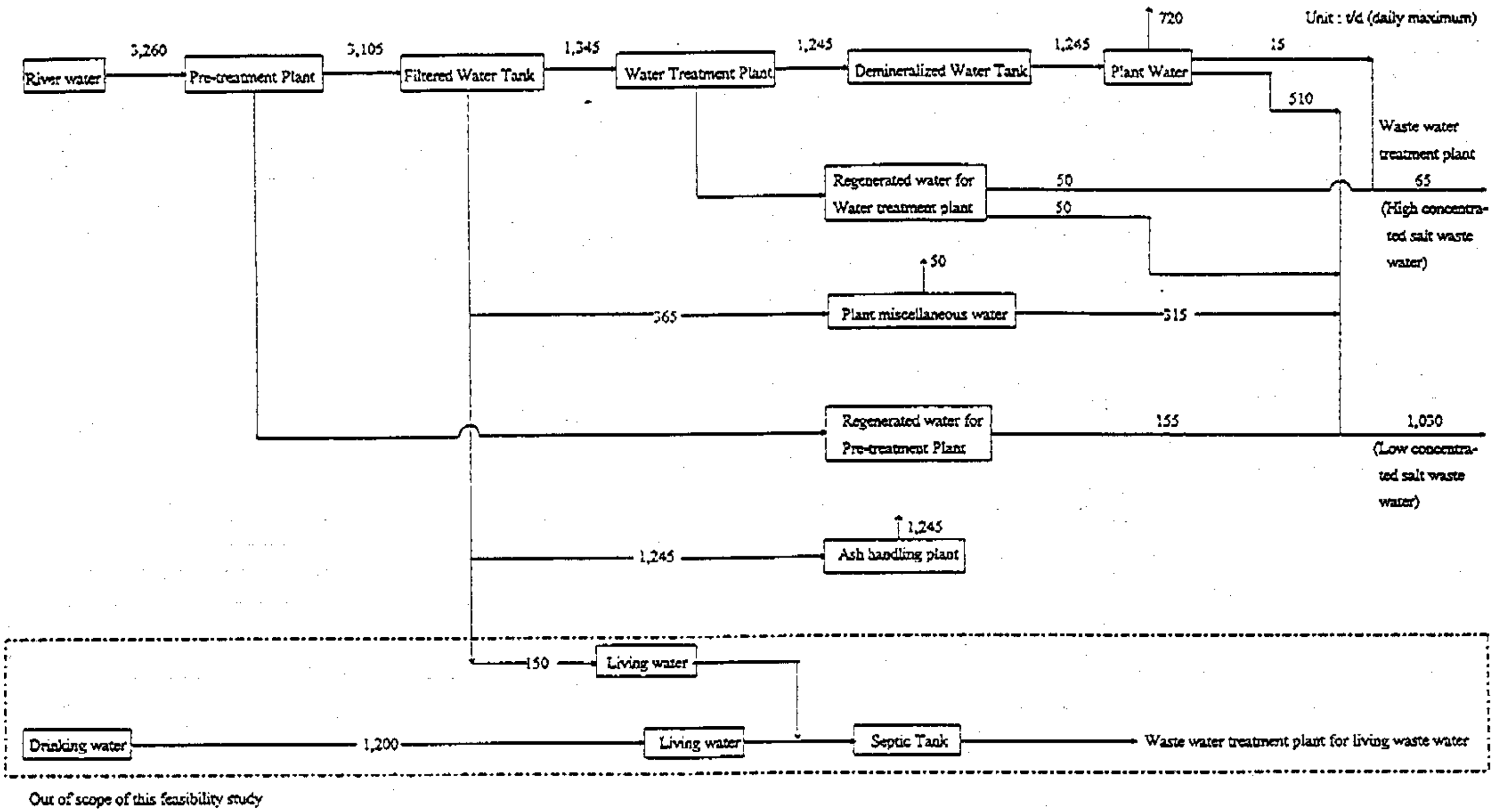

Figure 6-12-2

The Feasibility Study
on
Maritsa East No.1 Replacing Thermal Power Plant
for
Improvement of Performance of the Units
and
The Environmental Protection

TITLE FLOW BALANCE OF
WATER AND WASTE WATER

JICA TEAM

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