6.12 Condenser Cooling Water Facilities

6.12.1 Basic Conditions

Sea water is used to cool the condenser and the bearing cooling apparatus at the power plant. A stable intake of cooling water, low water temperature, and with little debris, mud, sand and marine life are all needed. These facilities are roughly divided into intake, pump pit, inlet and outlet pipes and outlet. The major conditions for the design of the above facilities are as follows:

Quantity of cooling water used :	25 m3/sec/2 units
Temperature of cooling water at intake:	31°C
Temperature of cooling water at outlet:	39°C
Temperature increase of cooling water :	8°C

6.12.2 Location and Type of Intake and Outlet

The following were considered in deciding the location and type of intake and outlet.

- Intake and outlet route as short as possible
- Separate locations of the intake and the outlet so that recirculation of thermal effluent cannot occur
- Stable intake that is almost free from wave effects of sea water and should be low temperature and clean
- Environment will not be affected by thermal effluent

In consideration of the above-mentioned items, deep water intake is installed at the back of the coal unloading jetty. On the other hand, the outlet which discharges water to the sea surface is located 800 meters west of the intake. The reasons are as follows:

- Coral reefs lie in the shallow submarine topography on the south of Bani Point (Refer to Fig. 6.6-1). From the standpoint of taking sea water at low temperature through the intake and diffusion effects (reduction of diffusion area) of thermal effluent discharged through the outlet, both of the facilities need a certain water depth. Therefore, the intake which needs more calmness is located in deep water to the east of Bani Point and the outlet to the west of it.

As a result distance L between the intake and the outlet which is necessary to prevent recirculation of thermal effluent can be maintained (L = 20•Q = 20 x 25 m/s = 500 m).

- For the intake type, the deep water intake method was adopted because there is a little problem of stagnation of thermal effluent as the intake site is in a partially closed sea area next to Oyon Bay in order to minimize wave effects.

- For the outlet type, the more economical surface discharge method was adopted as recirculation of thermal effluent does not occur in deep water intake method. The portal of the outlet is located about 300 meters off the shoreline to minimize adverse effects to the shore and to secure adequate water depth.

6.12.3 Intake and Intake Pipe

Fig. 6.12-1 shows the intake and the route and structure of the intake pipe.

(1) Intake

The typical methods of deep water intake are curtain wall type and under-sea intake tower type. As the sea area is a well developed coral reef shoal beach, the under-sea intake tower type of steel construction which is easy to fabricate and install is adopted.

A velocity cap is installed at the tap of the intake to prevent disturbance of the layer of discontinuity and inflow of fishes, etc. The diameter (D = 9 m) and height (H = 2.5 m) of the velocity cap was decided to satisfy the inflow velocity, V = 0.2 m/s. Water depth DL -5.0 m to -7.5 m at the crest of the intake was adopted to reduce wave effects and to ensure that recirculation does not occur even if thermal effluent spreads to around the intake. The crest is 1.5 m above the seabed is to prevent the inflow of sand and silt.

Two intakes are installed for two units and are located 30 meters a part to prevent the effects of mutual interference.

(2) Intake Pipe

As to pipe diameter, inside velocity V = 1.5 to 3.5 m/s, giving a pipe diameter of (D = 3 m) at which the total of costs for intake pipe, pump pit and pump facilities, and pump operating costs becoming the least was selected. The velocity inside the pipe is about 1.8 m/s.

In order to prevent erosion by eroding waves, the intake pipe is buried after seabed dredging, its surroundings are protected with sand, and its surface is covered with rock.

6.12.4 Pump Pit

Two pumps are installed per unit in consideration of reliabilities of operation and maintenance.

The pump pit is 24.6 m (W), 11.9 m to 12.7 m (H), 35 m (L), reinforced concrete structure with screen and pump chamber. As the ground is bedrock, the structure foundation is constructed on bedrock. (Refer to Fig. 6-12-2)
The characteristics of the pump pit structure are as follows:

- A bar and rotary screens are installed at the screen chamber as debris-eliminating apparatus so as not to clog the condenser pipe by removing floating debris entering the intake.

- A stop log is provided so that repair of the screen and pump chamber can be performed in dewatered condition.

- Approach velocity to the screens is set at 0.35 m/s in consideration of debris removing capability of the screens.

In hydraulic calculations for the screen and pump chamber, 10 cm of sea shells adhering to the screen and pump chamber is considered.

- The depth, DL -7.0 m, at the bottom of the pump chamber was decided in consideration of the loss between the intake and the pump chamber during the time when the water level is lowest (DL -0.5 m), and the depth necessary for stable operation of pumps during shallow sea water.

- The top of the pump chamber is set so that the water level rise by surging will not reach the pump chamber top when the two pumps of one unit are out of service.

- The structure of the pump pit was designed to prevent it from floating even when the pump chamber is empty and on the assumption that there is underground water around the pump pit.

6.12.5 Intake and Discharge Pipe

Fig. 6.12-3 shows the route and structure of intake and discharge pipe.

The intake pipe is made of steel to supply cooling water from the pump pit to the condenser, and one pipe with a diameter of 1.8 m is provided per pump.

The discharge pipe is made of steel to release water discharged from the condenser to the discharge pit, and one pipe with a diameter of 2.6 m is provided per one unit.

The intake and the discharge pipes are protected with concrete because most parts of the pipe traverse roads, and passes under the foundation of the switch yard. The pipe routes are relatively short.

6.12.6 Discharge Pit and Discharge Portal

Fig. 6.12-4 shows the route and structure of the discharge pit and discharge portal.

Cooling water which passes the condenser and the discharge pipe is collected in the discharge pit and released into the sea through the discharge portal, an open channel.

(1) Discharge Pit

The water level of the discharge pit must be kept at a certain level so as not to impair the siphon effect on the assumption that the pump pit, condenser and discharge pit form a siphon.

Therefore, the water level at the exit of the discharge pit must be over DL +0.5 m, and a weir of DL $\pm$0.0 m is provided at the exit of the discharge pit in consideration of 0.5 m water depth in the discharge pit.

(2) Discharge Portal

The discharge channel is 5 m (W), 1/800-gradient, trapezoidal shaped open channel to produce a water velocity, V = 1.0 to 2.0 m/s. The revetments of both sides of the open channel are 6 m (W) dikes with a crest height of DL +3.0 m.

Considering influence of waves, the discharge portal is provided with wave-breaker blocks in front of the dikes.

6.12.7 Chlorinating Plant

Measures to prevent adherence of marine life, slime, etc. in the sea water are needed to maintain the function of the condenser cooling water system at the thermal power plant. A chlorinating plant utilizing chlorine is normally adopted.

Chlorinating methods are roughly divided into;

(a) A system to pass liquid chlorine through a vaporizer and inject it into sea water.

(b) A system to electrolyze sea water in order to produce sodium hypochlorite and inject it into sea water.

The recent tendency for a chlorinating plant is the adoption of electrochlorination system to control dangerous handling of liquid chlorine.

The adoption of the electrochlorination system is recommended from the standpoint of security and reliability.

(1) Determination of Chlorine Concentration

Chlorine concentration for injecting into sea water is selected in consideration of the following:

i) The safety value of residual chlorine concentration should be under 0.02 mg/1 at the discharge point.

ii) Consumption characteristics of injected chlorine. The characteristics of chlorine consumption are related to the time sea water from the intake reaches the discharge portal.

A speed at which sea water travels from the intake to the discharge in this project is estimated as follows:

Fig 6.12-5 Estimated Pass time of Sea Water

	Intake – Cooling Water Intake	Cooling Water Intake – Cooling Water Outlet	Cooling Water Outlet – Condenser Inlet	Condenser Inlet – Condenser Outlet	Condenser Outlet – Discharge Point	(Total)
Distance (m) S	550	50	150	20	700 (⇧ 175 *)	T.L. 1,470 m ⇒ M.P. 945 m
Velocity (m/s) V	2.0	0.3	3.0	2.0	0.4	
Pass Time (sec)	275	167	50	10	440 (⇧)	942 sec≒16 min

Length of cooling water system 945 m
Pass time of sea water 16 min
* 175 means measuring from Comdenser Outlet

T.L : Total length
M.P : Measuring point

iii) Residual chlorine concentration is related to the time required for sea water to reach the discharge portal. Fig. 6.12-6 shows this relation.

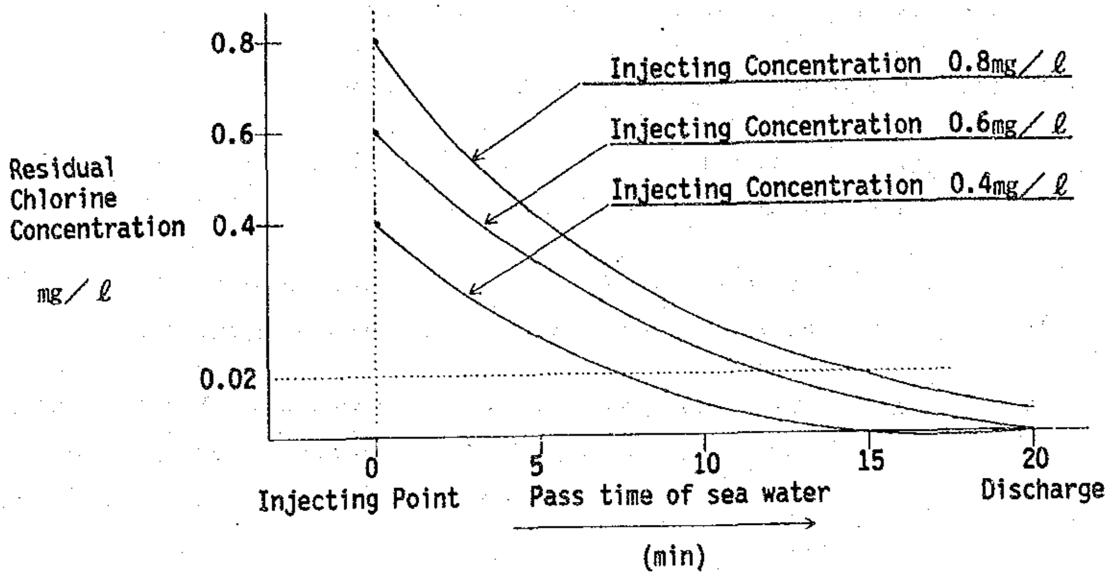


Fig. 6.12-6 The Relation between Residual Chlorine Concentration-Pass Time of Sea Water

Chlorinating plants in existing power plants are chlorine-injecting concentration of 0.6 mg/l to control residual chlorine concentration to under 0.02 mg/l case 14.3 min. is required for water to travel through the cooling water system.

In the adoption of the above values in this project, the most suitable travelling time of sea water is 16 min., residual chlorine concentration below 0.02 mg/l, and chlorine-injecting concentration 0.6 mg/l.

(2) Capacity of Electrochlorination System

Trial calculations of the capacity of the electrochlorination system is as follows:

Conditions

Travelling time of sea water through the cooling water system (T)	16 min.
Chlorine-injecting concentration (D)	under 0.6 mg/l
Residual chlorine concentration (R)	under 0.02 mg/l
Quantity of cooling water (Q)	45,000 m^3/h

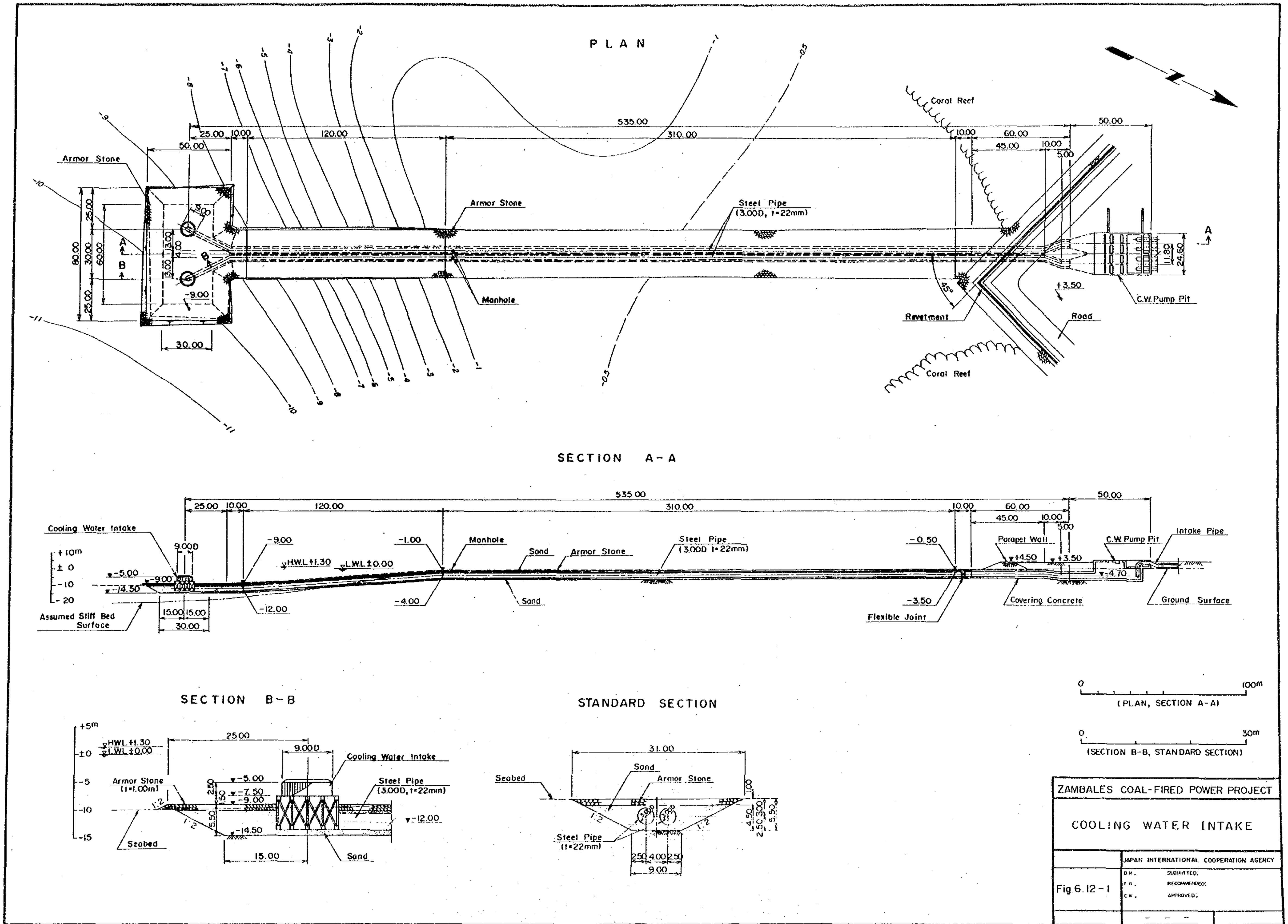
Capacity of electrochlorination tank (per 300 MW)

$= Q \times D \times 10^{-3}$

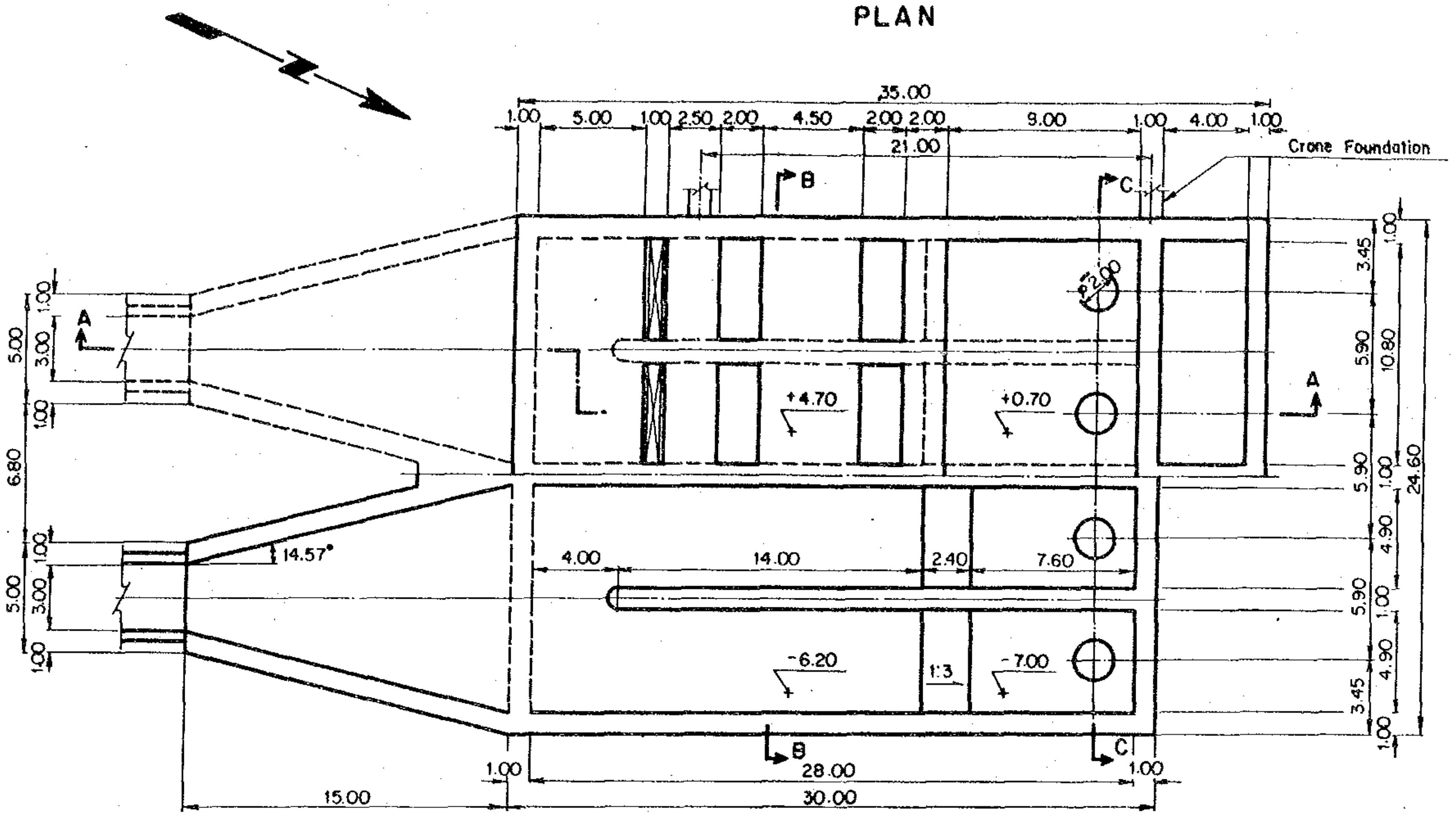
$= 45{,}000\ m^3/h \times 0.6\ mg/l \times 10^{-3}$

$= 27$ kg/h

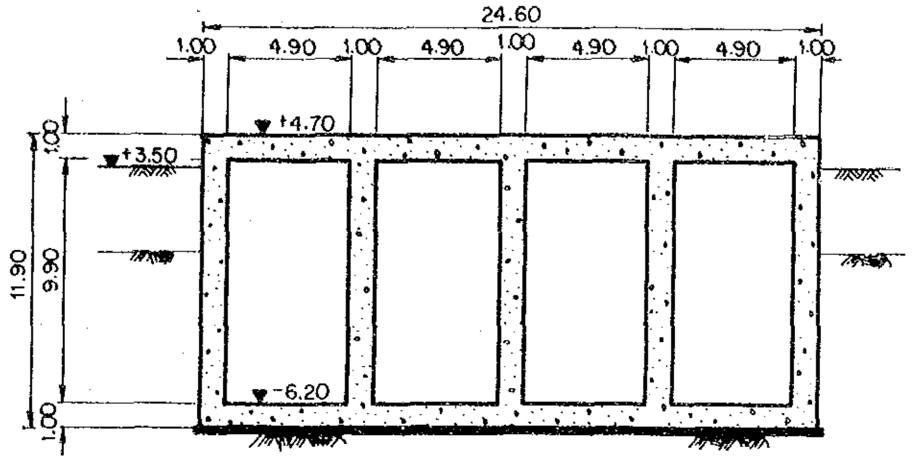
$\fallingdotseq 30$ kg/h


PLAN
Coral Reef
Armor Stone
Steel Pipe (3.00D, t=22mm)
Manhole
Revetment
Road
C.W. Pump Pit
SECTION A-A
Cooling Water Intake
Monhole
Sand
Armor Stone
Steel Pipe (3.00D t=22mm)
Parapet Wall
C.W. Pump Pit
Intake Pipe
Covering Concrete
Ground Surface
Flexible Joint
Assumed Stiff Bed Surface
HWL +1.30
LWL ±0.00
SECTION B-B
Cooling Water Intake
Armor Stone (t=1.00m)
Seabed
Sand
STANDARD SECTION
Seabed
Sand
Armor Stone
Steel Pipe (t=22mm)
(PLAN, SECTION A-A)
(SECTION B-B, STANDARD SECTION)
ZAMBALES COAL-FIRED POWER PROJECT
COOLING WATER INTAKE
JAPAN INTERNATIONAL COOPERATION AGENCY
Fig 6.12-1

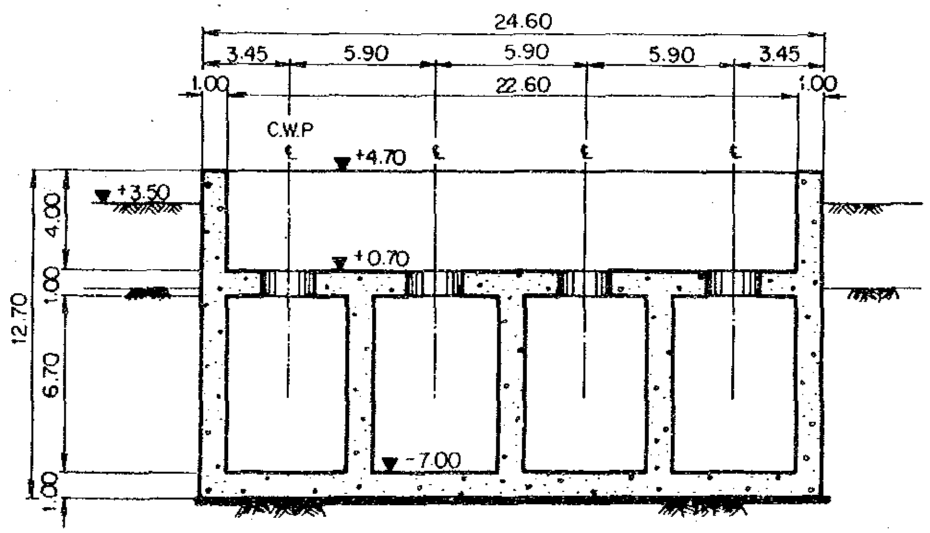
PLAN



SECTION B-B

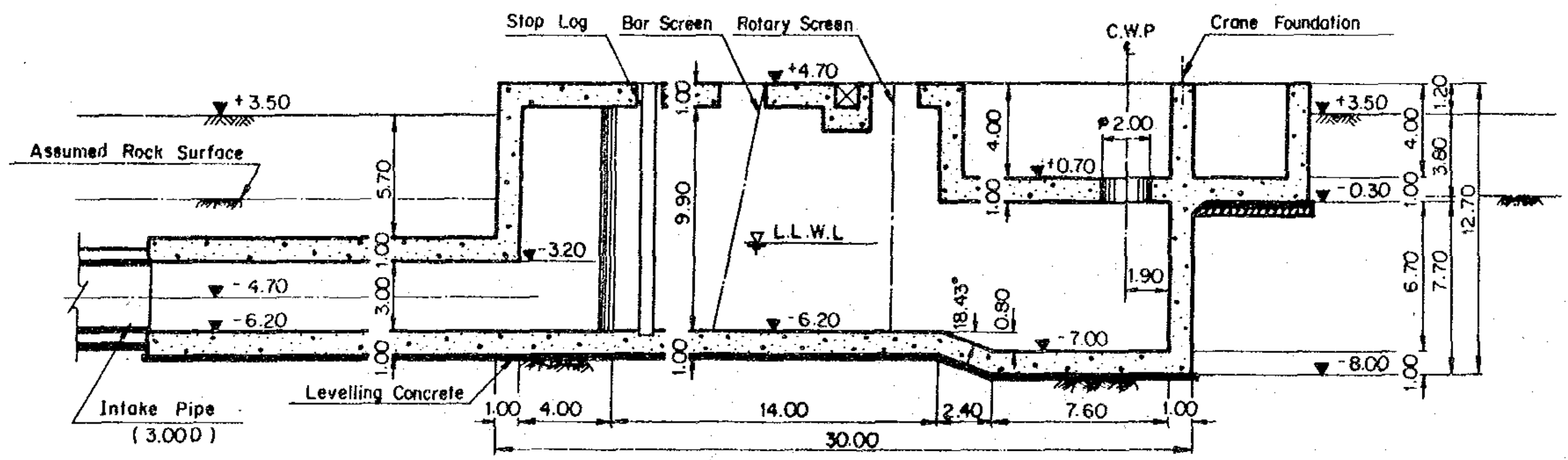


SECTION C-C



0 10 m

SECTION A-A



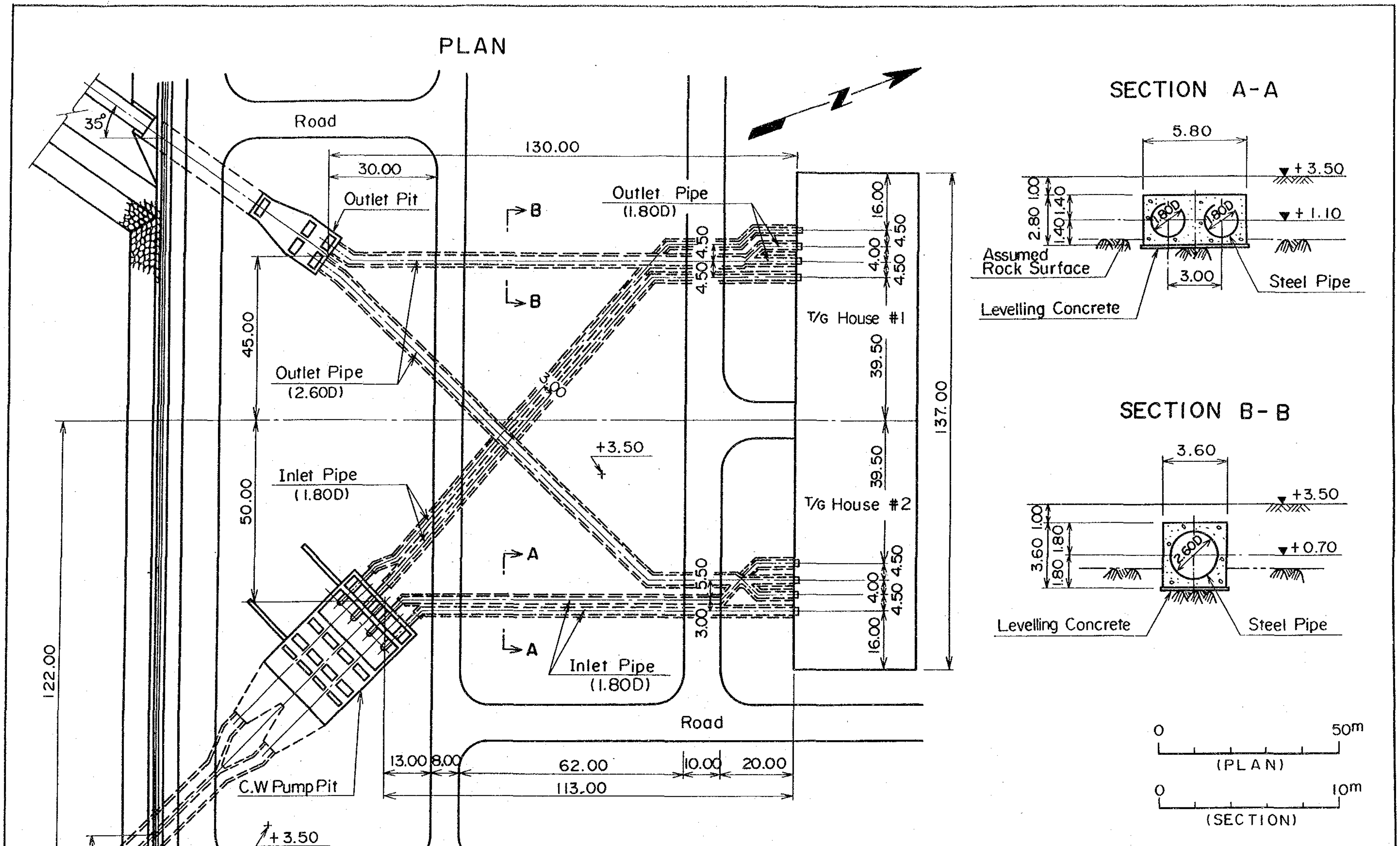
ZAMBALES COAL-FIRED POWER PROJECT

COOLING WATER PUMP PIT

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 6.12-2

D.R.:	SUBMITTED:
F.R.:	RECOMMENDED:
C.K.:	APPROVED:

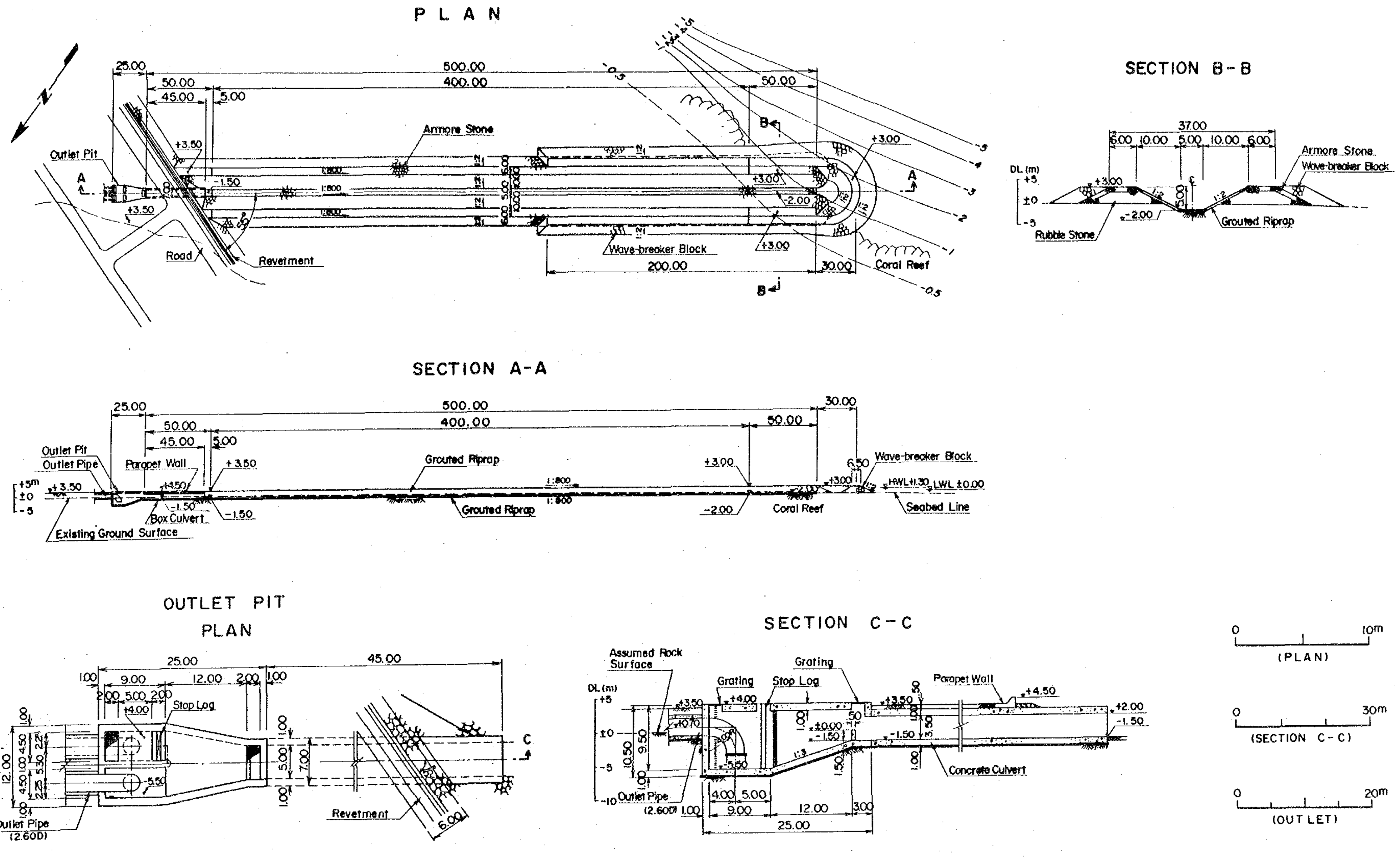


ZAMBALES COAL-FIRED POWER PROJECT

COOLING WATER PIPE

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 6.12-3	D.R.;	SUBMITTED;
	T.R.;	RECOMMENDED;
	C.K.;	APPROVED;



ZAMBALES COAL-FIRED POWER PROJECT

COOLING WATER OUTLET

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 6.12-4	DR.:	SUBMITTED:
	TR.:	RECOMMENDED:
	CK.:	APPROVED:

6.13 Electrical Facilities

6.13.1 General

The electrical system and equipment for this project are studied basically for safety of operation, conveniences of maintenance and reliable operation from the technical and economical points of view.

Furthermore, it is recommended that the electrical system and protection scheme of the Calaca 1 thermal P/S which has the equivalent machine capacity with this project is taken into consideration.

The study that has been carried out for the main electrical items are as follows;

i) Selection of Rated Voltage
ii) Generator Capacity
iii) Transformer Capacity
iv) Switchyard
v) Emergency Power Supply
vi) Control and Instrumentation

The recommended Electrical System is shown in the Fig. 6.13-1 "One line Diagram."

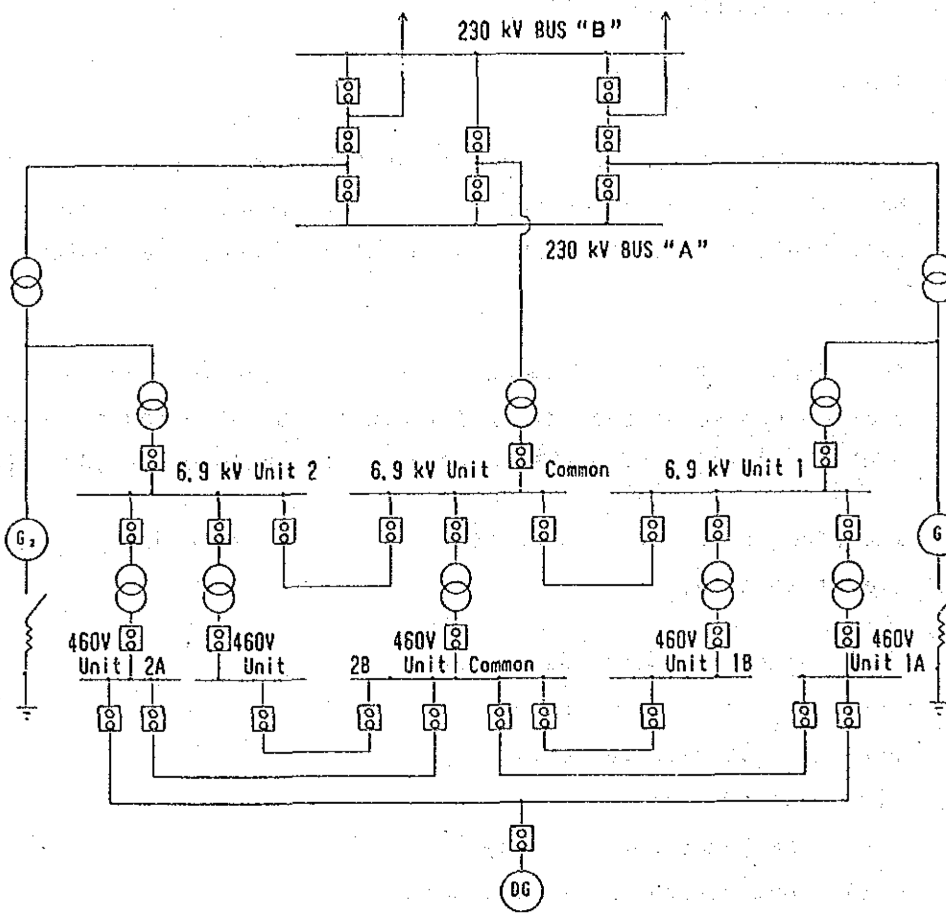


Fig. 6.13-1 One-Line Diagram

Feature of this one-line diagram are:

* Generator circuit and house load using the unit system.

* One and a half breaker scheme is applied for the 230 kV Bus and transmission system following NAPOCOR's practice in other power stations.

* 6.9 kV auxiliary system is applied from the technical and economical point of view. (Details are shown in 6.13.2 selection of rated voltage)

* Two unit boards system are applied for 460 V auxiliary board to segregate the A and B auxiliaries.

* One common board system for two units is applied.

* Each board of 6.9 kV and 460 V unit board is backed up by common boards.

* One diesel generator for two units to supply emergency power.

* The starting transformer receives power from the 230 kV Bus.

6.13.2 Selection of Rated Voltage

The following rated voltages are recommended to be selected:

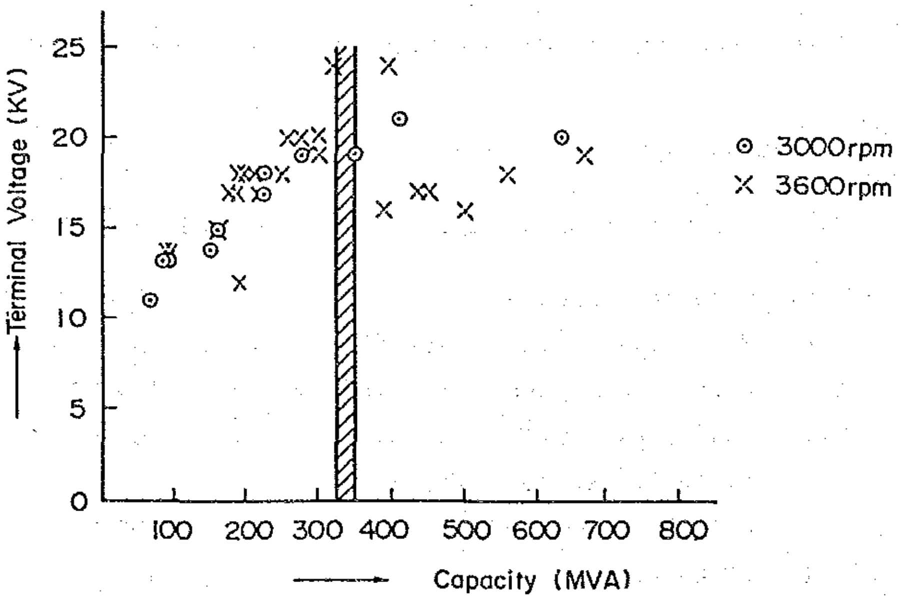
i)	Generator Voltage	18 to 24 kV
ii)	Main Transformer Primary/Secondary	18 to 24 kV/230 kV
iii)	High Voltage Auxiliary Power Supply	6.9 kV
iv)	Low Voltage Auxiliary Power Supply	460 V & 220 V/120 V
v)	DC Auxiliary Power Supply/ Switchgear Control	125 V
vi)	DC Control	48 V
vii)	AC Control (Illumination)	220 V/120 V
	(Uninterrupted Power Supply System)	120 V

(1) Generator Voltage, Main Transformer Primary Voltage

To determine the generator voltage, it is important to achieve the minimum total cost for the generator, the main transformer, the house transformer and the isolated phases bus system.

Especially, in order to minimize the generator cost which occupies the greater part of the costs, for determination of the generator. However, generator over 100 MVA capacity has the economic advantage of generator under the respective manufacturer's design as shown in Fig. 6.13-2 "Generator Capacity - Outlet Voltage".

Fig.6·13-2 Generator Capacity-Terminal Voltage



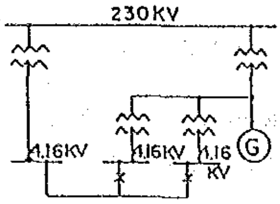
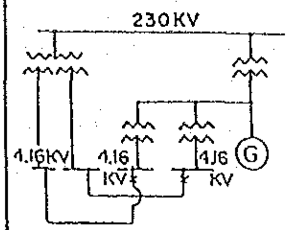
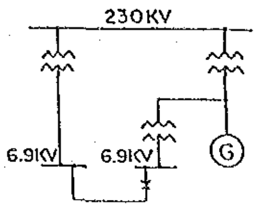
The generator voltage should be selected between 18 kV to 24 kV according to the manufacturer's design.

(2) High Voltage Auxiliary Power Supply

For high voltage auxiliary power supply system, the following three cases were studied and it has been decided that the one house transformer and 6.9 kV, 40 kA switchgear combination is the best case and recommendable from the technical and economic viewpoint.

Table 6.13-1 "High Voltage Switchgear System" shows the result of the study.

Table 6.13-1 High Voltage Switchgear System

		Case 1	Case 2	Case 3
Configuration				
Short Circuit Current		House Tr. Side :40KA Starting Tr. Side :40KA	House Tr. Side :40KA Starting Tr. Side:40KA	House Tr. Side :39.8KA Starting Tr. Side:34.6KA
Impedance of Main Tr. House Tr. Starting Tr.		13% (at 320MVA) 6% (at 15MVA) 16% (at 40MVA)	13% (at 320MVA) 6% (at 15MVA) 8% (at 20MVA)	13% (at 320MVA) 8% (at 30MVA) 11% (at 40MVA)
Max. Voltage Drop *during* BFP (4.5MW) Starting		20.2%	15.3%	13.9%
Technical Evaluation		The tap position of the secondary voltage for the Starting Transformer shall keep 7% higher than the nominal voltage. Small value of the starting multiplying factor of the BFP current shall be selected.	The special order of the transformer is required. The tap position of the Starting Transformer shall keep higher than the nominal voltage.	The operating flexibility is wider than the other two cases.
Economical Evaluation (1,000 US$)	Motors	Base	± 0	± 0
	Tr.	Base	+ 70	-300
	Incoming Switchgear	Base	+ 40	-140
	Cable	Base	+ 140	-240
	Total	Base	+ 250	-680
Recommendation		Base	Not Recommendable	Recommendable

Note : Grid system impedance 1.8%
Generator transient impedance 15%
BFP starting current multipling factor 5.5

From the economic view point and based on the many actual operation results, a 6.9 kV system is recommended for this project, though this high voltage auxiliary system is new to NAPOCOR.

(3) Low Voltage Auxiliary Power Supply

The 460 V system is recommended for the low voltage auxiliary power supply based on the following points.

i) Standard voltage of NAPOCOR for low voltage auxiliaries
ii) Easy handling by the maintenance staff of NAPOCOR

The auxiliaries below 200 kW are at this low voltage auxiliary power supply for economic reason as shown in the attached Table 6.13-2 "Motor Capacity - Critical Cable Length" because most of these auxiliaries are located within 400 m radius from the switchgear.

However, the criteria of the low voltage auxiliary of the coal handling equipment is recommended to be studied after confirming the layout of the auxiliaries since the coal handling auxiliaries are allocated in a wider area and the critical length of the high voltage auxiliaries are dependant on this length.

Table 6.13-2 Motor Capacity - Critical Cable Length

Motor Capacity for High Voltage (kW)	Critical Cable Length
50 kW	More than 780 m
100 kW	More than 550 m
150 kW	More than 420 m
200 kW	More than 380 m
300 kW	More than 300 m

The segregation of the power center and control center is recommended to be 80 kW auxiliaries, i.e. the auxiliaries above 80 kW receive power from the power center and the auxiliaries below 80 kW from the control center.

6.13.3 Generator Capacity

(1) Generator Capacity

The generator capacity of 334 MVA is recommended for the following reasons.

i) The power system analysis in 1996 shows that at a power factor of the generator of 95% voltage at the receiving end can be maintained since the long transmission line produces reactive power.

ii) At a power factor 90%, the voltage of a generator is 110% of the rated value for the same reason as above.

iii) A machine of pf 90% is 6% more economical than that of pf. 85% machine.

Table 6.13-3 Cost Comparison from Power Factor/ Short Circuit Ratio

Rated Capacity of Generator [MVA]	pf.	Short Circuit Ratio	Cost of Generator
353	0.85	0.58	100%
334	0.90	0.58	94%
334	0.90	0.64	97%

(2) Short Circuit Ratio

The fault calculation (Fig. 3.3-3) shows that SCR of 0.58 is a critical condition of the stability within 45° Phase displacement without AVR.

In this study, SCR of more than 0.58 is recommendable for economic reason.

From the above points, 334 MVA, pf 0.9 and SCR 0.58 is recommended for this project.

6.13.4 Transformer Capacity

(1) Main Transformer Capacity

The transformer capacity is determined by the secondary voltage and current.

There are two philosophies applied to determine the main transformer capacity as follows;

i) About 10% greater than the generator capacity to send out all power generated by the generator in all cases.

ii) Less capacity than the generator capacity considering transformer lagging power factor.

The first case is applied to the power station that would be operated capacitance load with full load.

Under reactive load, the selection for economic reason of the transformer capacity could be achieved with the above second philosophy.

Since the short circuit ratio selected is 0.58, the transformer impedance does not necessarily have to be below 13% for stability, and in this study the standard impedance of 13% is recommended to for economic design under this voltage.

The sending power of the main transformer (13% impedance) is less than 320 MVA during generator output of 334 MVA at pf. 0.9 lag.

Since capacitive operation is rare under full load, the net output of the main transformer is selected to be 320 MVA.

Table 6.13-4 "Standard Impedance of Transformer" shows the economic design standard in the Japan market decided by the factor of no-load loss, load loss and total weight of transformer.

Table 6.13-4 Standard Impedance of Transformer (Economic Design Standard)

Nominal Voltage (kV)	Impedance Voltage (%)
154	11
187	12
220	13
275	14

(2) House Transformer Capacity

The total rated capacity of auxiliaries would be applied for the house transformer capacity.

The amount of spare feader is not included in the above total amount.

The capacity of the house transformer is 30 MVA and the loads on the board are shown in the attached Table 6.13-5 "Capacity of MC Feeders", respectively.

Table 6.13-5 Capacity of MC Feeders

	No. of Unit	Capacity		
		One Unit	Total kW	kVA
BFP	2	4,500	9,000	10,350
IDF	2	1,440	2,880	3,300
FDF	2	1,050	2,100	2,400
Mill	4	570	2,280	2,600
PAF	2	1,000	2,000	2,300
CWP	2	900	1,800	2,100
ESP	1	800	800	800
Ash	1	1,400	1,400	1,500
Others		2,500	2,500	3,000
Total				28,850 kVA

Note BFP : Boiler Water Feed Pump
IDF : Induced Draft Fan
FDF : Forced Draft Fan
Mill: Coal Mill (Pulverizer)
PAF : Primary Air Fan
CWP : Circulating Water Pump
ESP : Electro-static Precipitator
Ash : Ash Handling System

(3) Station Service Transformer (Starting Transformer Capacity)

The capacity of the starting transformer is decided by the full house load of one unit plus the common service load.

With the above criteria, the capacity of the Starting Transformer selected is 40 MVA as shown in the Table 6.13-6 "Load of Starting Transformer".

Table 6.13-6 Load of Starting Transformer

Item	Capacity (kVA)
One unit house load	28,850
Coal Handling Facility	7,000
C. W. Intake Facility	300
Water Treatment Facility	1,000
Fire Fighting Pump	500
460 V Auxiliary Power Tr.	1,500
Total	39,150

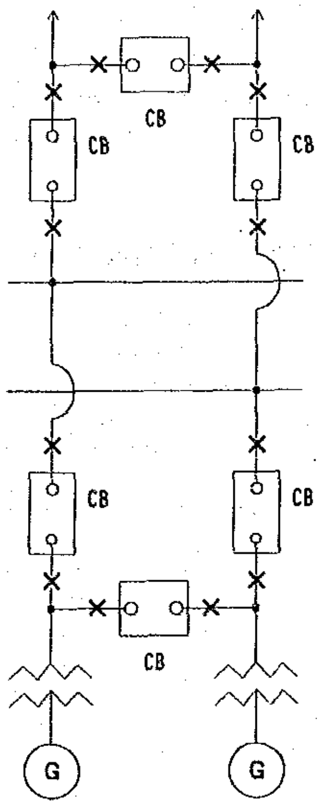
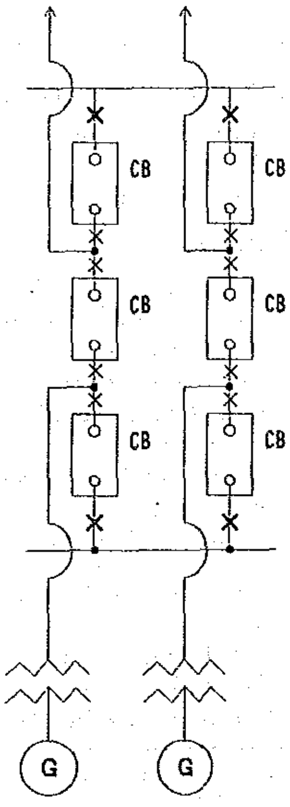
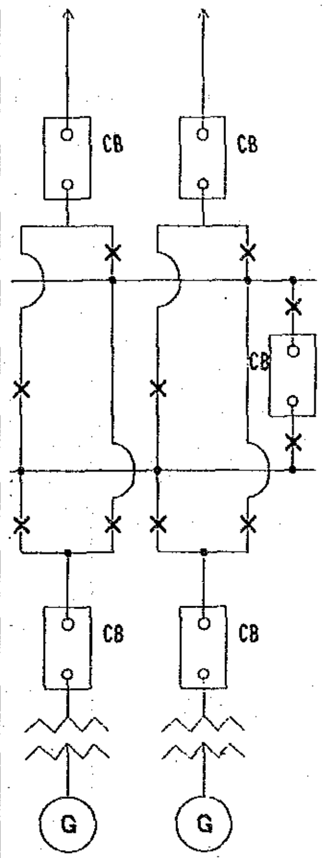
6.13.5 Switchyard

One and a half circuit breaker scheme is applied for the switchyard equipment.

The configuration of the switchgears is shown in the following Table. The capacity of C.B. is 2,000 A (rated), 31.5 kA (short circuit) and are air breakers.

Table 6.13-7 "Comparative Table of Circuit Breaker Scheme" shows the comparative results of the circuit breaker scheme between "one and a half circuit breaker scheme" and a "two breaker scheme".

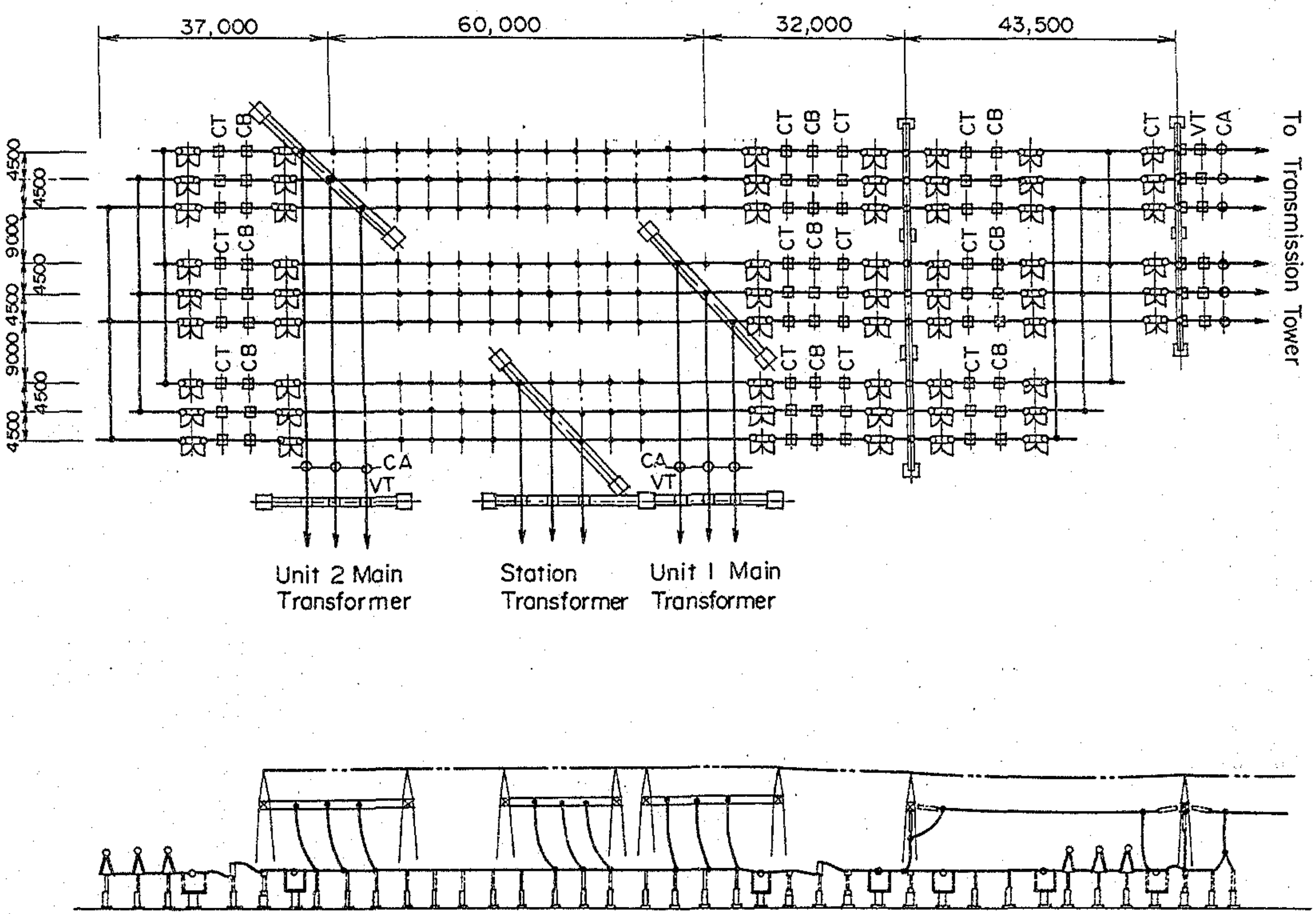
Table6・13－7　Comparison Table of Circuit Breaker Scheme

	One and a Half Breaker Scheme		One Breaker Scheme
	Case 1	Case 2	
Skelton	Transmission Line 	Transmission Line 	Transmission Line 
Technical Evaluation	・Even one breaker makes trouble, the power can transfer with the two transmission line, i.e. the reliable system with the back up breaker. ・Monitoring and protection circuit is very complicated.	・Even one breaker makes trouble, the power can transfer with the two transmission line, i.e. the reliable system with the back up breaker. ・Monitoring and protection circuit is rather complicated. ・The NAPOCOR is familier with this system so that the reliable operation could expected.	・One breaker troulbe makes less availability of the transmission line or the generator. ・Monitoring and protection circuit is simple.
Number of C.B	6	6	5
Monitoring and Protection Circuit	Rather Complicated	Rather Complicated	Simple
Equipment cost	High	High	Low
Recomendation	Not recommended	Recommended	Not recommended

For reasons of reliability and NAPOCOR's familiarity of the system, case 2, that is one and a half breaker scheme is recommended.

Fig. 6.13-3 "Switchyard Layout" shows the layout of the one and a half breaker scheme.

Fig. 6.13-3 Switchyard Layout



Regarding the type of circuit breaker, the conventional substation (CS) is recommended rather than gas insulated switchyard (GIS) for economic reason.

Table 6.13-8 "Comparison of CS and GIS for switchyard" shows the result of study.

Table 6.13-8 Comparison of CS and GIS for Switchyard

Item	CS	GIS
Area to be required	100%	25%
Extension	Easy	Adapter for GIS required because of its particular characteristics
Replacement of Components	Easy	Replacement of GIS component takes longer time
Equipment and Material cost	50%	100%
Recommendation	Recommen-dable	Not recommendable

The selection and details of countermeasures against salt pollution shall be carried out during the detail design stage after reviewing the site condition of the salt deposition from annual average rain-fall and average wind velocity.

6.13.6 Emergency Power Supply

Diesel generator is selected as the source of supply for emergency power for safe shutdown of the plant.

The starting time of the D.G. is less than 40 sec. after complete blackout of electrical system.

The capacity of D.G. is 500 kVA for emergency power source of both units.

During blackout of the grid, this power station is waiting until recovery of the grid voltage for re-starting.

For emergency lighting, emergency auxiliary motor and uninterrupted power supply (UPS) of control instrument, DC 125 V power supply by battery system for one hour interruption of power supply.

6.13.7 Control and Instrumentation

Semi automatic control system is considered.

The main equipment for control of Boiler and Turbine/Generator consist of the following:

i) DAS (Data Acquisition System)
ii) APC (Automatic Plant Control System)
iii) MBC (Mill Burner Control System)
iv) B-SQC (Boiler Sequence Control System)
v) T-SQC (Turbine Sequence Control System)

6.14 Ash Handling Facilities

6.14.1 Amount of Ash Generation

(1) The amount of ash generation will vary with the calorific value and the ash content of the coal used. In the tables below, the situation of the ash generation is shown:

	50/50 Blended Coal	Lemington Coal	Semirara Coal
1. Heating Value (kcal/kg)	5,262	6,524	4,000
2. Ash Content (%)	11.2	10.4	12
3. Plant Thermal Efficiency (%)	38	38	38
4. Coal Consumption (t/h)	138	110	180
5. Ash Generation (t/h)	15.5	11.4	21.5
6. Ash Generation (t/y)	94,000	70,000	132,000
7. Ash Generation in 30 Years (ton)	2,800,000	2,100,000	3,960,000

Note: In case of 1 unit of 300 MW.

(2) Ash Generation Ratio

There will be four (4) ash collecting places including the clinker hopper in the coal firing boiler.

The table below show the assumed amounts of ash to be generated in the case of the design coal.

	No. of Hoppers	Ash Generation Ratio (%)	Standard Ash Generation Amount (t/h)	Design Value (t/h)
1. Clinker Hopper	1	5 to 25 (15)	2.3	3.9
2. ECO Hopper	3	1 to 5 (2.5)	0.5	0.8
3. AH Hopper	3	1 to 5 (2.5)	0.5	0.8
4. ESP Hopper	2 x 9	75 to 85 (80)	12.2	13
Total		(100)	15.5	18.5

Note: In case of 1 unit of 300 MW.

Figures in parentheses are standard values

6.14.2 Ash Handling and Ash Disposal Method

(1) Bottom Ash

i) Extracting bottom ash

A chain conveyor is installed at the bottom of the boiler, chain conveyor is submerged with fresh water, and ash that drop from the furnace to the chain conveyor are continuously extracted by continuous operation.

Bottom ash are crushed in the bottom ash crusher that is installed at chain conveyor outlet.

ii) Transportation of ash

Bottom ash that have been crushed are fed to the belt conveyor and conveyed to the bottom ash silo.

Ash that has been temporarily stored in the bottom ash silo are conveyed by trucks to the ash disposal area located approximately two (2) km from the plant.

(2) Fly Ash

i) Extracting from the hopper

Ash from the hoppers of economizer, air-preheater and electrostatic precipitator are sequentially extracted and conveyed to the fly ash silo by vacuum.

ii) Extracting from fly ash silo

Ash in the fly ash silo in determined quantities is drawn out from the bottom and humidified at the dustless unloader.

The humidified ash is transported to the ash disposal area by trucks.

6.14.3 Capacity of Ash Handling System

(1) Bottom Ash System

i) Chain conveyor

The chain conveyor operates continuously and therefore a capacity of 3.9 t/h would be adequate. But, the normal discharge capacity which proportionally increases in weight by moisture contained in the discharged ash is taken into consideration. The maximum discharging capacity is considered the safety factor for large ash dropping during soot blower operation, or during load change.

Therefore,

Normal discharge capacity	:	3.9 t/h x 1.33 = 5.2 t/h (proportional increase rate by moisture 33%)

Maximum discharge capacity : $3.9 \text{ t/h} \times 3 = 11.7 \text{ t/h}$ (safety factor 3)

ii) Bottom ash crusher

The bottom ash crushing is a continuous operation and therefore the maximum capacity of the bottom ash crusher is designed for 11.7 t/h.

iii) Bottom ash transporting conveyor

The clinker transporting conveyor is considered to have the same capacity as the bottom ash crusher and the maximum capacity is 11.7 t/h.

iv) Boiler bottom sealing water and heat exchanger

The sealed water which is fresh water is circulated. The fresh water becomes heated by the falling ash and therefore heat exchanger is used to cool the circulating fresh water.

v) Bottom ash silo

The operation of removing ash should stop on holidays and therefore, the bottom ash silo will have the capacity of storing bottom ash generated during 2 days of operation for one unit. The bottom ash silo capacity is determined by taking the bulk density of the humidified ash into consideration.

$$3.9 \text{ t/h} \times 24 \text{ h} \times 2 \text{ days} \times \frac{1}{0.7 \text{ t/m}^3} = 267 \text{ m}^3$$

vi) Ash unloader capacity of bottom ash silo

The ash unloader capacity is based on 4 hour handling.

$$\frac{267 \text{ m}^3}{4 \text{ h}} = 67 \text{ m}^3\text{/h}$$

(2) Fly Ash Flow

i) Vacuum transporting facility of fly ash

Vacuum transporting facility of fly ash will be designed to dispose fly ash every four (4) hours and to transport the fly ash within a handling time of three (3) hours. The required capacity is therefore as follows:

$$(0.8 + 0.8 + 13.0)\ t/h \times \frac{4\ h}{3\ h} = 19.5\ t/h$$

ii) Fly ash silo

The fly ash silo will have a capacity of two days operation from one unit, and the capacity of the fly ash silo will be established as follows, taking the bulk density of fly ash into consideration:

$$(0.8 + 0.8 + 13.0)\ t/h \times 24\ h \times 2\ days \times \frac{1}{0.9\ t/m^3}$$
$$= 779\ m^3$$

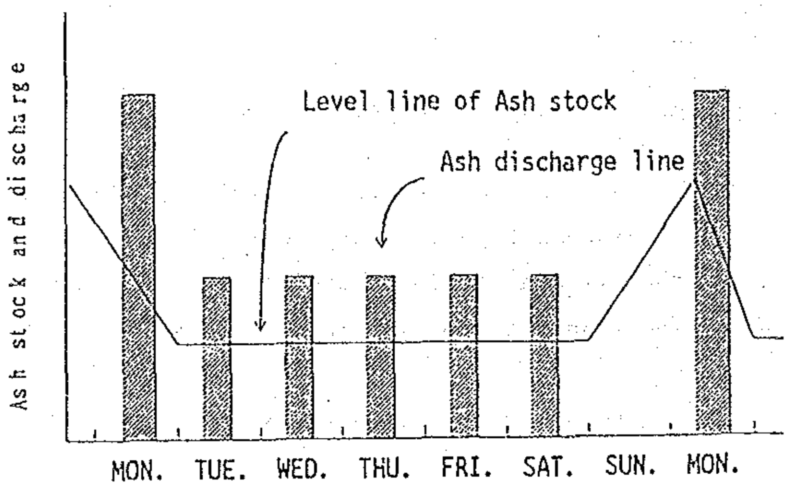
Including a margin of (1.3), the capacity will be 1,000 m^3.

iii) Dustless unloader

The capability of the dustless unloader will be in accordance with the program in the figure below for ash storage and ash shipment.

Basic plan of the utilization program

Ash transporting hours	From 8 AM to 4 PM
Ash transporting working day	Monday to Saturday
Non operating day	Sunday



Ash handling program:

Tuesday	:	From 8 AM to 4 PM; ash transporting time
Saturday	:	Generated ash in a day is disposed in 8 hours.
Monday	:	From 8 AM to 4 PM; ash transporting time Generated ash during the 40 hours from 4 PM on Saturday to 8 AM on Monday is disposed in 8 hours.

From the above, the volume of ash to be disposed on Monday would be ash generated during the 40 hours plus ash generated during 8 hours on Monday, a total accumulated amount of ash in 48 hours shall be disposed in eight (8) huors.

Capacity of the dustless unloader:

$$\frac{(0.8 + 0.8 + 13.0)\ t/h \times 48\ h}{8\ h} = 87.6\ t/h$$

Taking into consideration a humidity of 20%, the capacity is calculated

$$87.6 \times 1.2 = 110\ t/h$$

Taking into consideration breakdown, one stand-by unit should be installed.

6.14.4 Ash Transporting Trucks

Ash transporting trucks and related facilities required for one unit (300 MW) are as follows:

(1) Fly Ash Transportation

i) Calculation conditions

24 ton class dump truck
Distance of transportation: Average round trip 4 km
Travelling speed : Average 30 km/h

ii) Ash amount

Amount of ash to be handled during 8 hours a day : 840 tons
Capacity of transporting facility : 110 ton/h

a) Travelling time per one round trip

$$\frac{4\ \text{km}}{30\ \text{km/h}} = 0.13\ \text{h} = 8\ \text{min} \doteqdot 10\ \text{min}$$

b) Loading time per truck

$$\frac{24\ \text{ton}}{110\ \text{ton/h}} = 0.22\ \text{h} = 13\ \text{min}$$

c) Loading and round trip travelling time per truck

$$10\ \text{min} + 13\ \text{min} = 23\ \text{min} \doteqdot 30\ \text{min}$$

From the above one truck can make 2 round trips in one hour.

d) Number of trucks required

$$\frac{110 \text{ t/h}}{24 \text{ ton/truck x 2 round trips}}$$

= 2.29 trucks

≑ 3 trucks

(2) Bottom Ash

i) Transportation item: same as fly ash

ii) Ash volume: 267 m3 to be handled in 4 hours per day

iii) Capacity of unloading facility: 67 m3/h

a) Travelling time per one round trip : 10 minutes

b) Unloading time per one truck : 10 minutes

c) Unloading and round trip travelling time per one truck : 30 minutes

From the above one truck can make 2 round trips in one hour.

d) Number of trucks required

$$\frac{67 \text{ m}^3\text{/h}}{24 \text{ ton/truck x 2 round trips}}$$

= 1.4 trucks

≑ 2 trucks

(3) Number of Trucks Required

Fly ash system	:	3 trucks
Bottom ash system	:	2 trucks
Total	:	4 trucks
Spare	:	1 truck
Grand Total	:	6 trucks

(4) Other Facilities

i) Bulldozer for work in ash disposal site: 2 bulldozers

ii) Fuel storage facilities for ash disposal trucks and bulldozer : 1 set

iii) Garage for ash disposal trucks : 1 building
Garage for bulldozers : 1 building

6.14.5 Ash Disposal Area

(1) Location of Ash Disposal Area

Ash disposal methods can be roughly divided into inland disposal method and offshore disposal method. As a result of comparing the two methods in Chapter 4 "Site Selection Study", the inland ash disposal method was selected for its economic advantages.

In the selection of the site for ash disposal, the area adjacent to the west side of the power station was selected because the location is situated close to the power plant, retaining wall for the ash disposal area can be readily made and rainwater can be easily drained.

The south and the west sides of the ash disposal area have hills that are 15 to 25 meters high and these hills can be utilized in place of retaining wall which would be economical.

In regards to drainage, there is almost no rainwater from other areas flowing into this location and drainage of rainwater can be easily performed.

(2) Space of Ash Disposal Area

Ash disposal will be started from the south side of the ash disposal area and retaining wall will be extended every 10 years while ash is being disposed. The required space of the ash disposal for 10 years and 30 years shall be as follows (Refer to Fig. 6.14-2).

10 years : 31 ha

30 years : 73 ha

6.14.6 Retaining Wall of Ash Disposal Area and Drainage System

(1) Retaining Wall of Ash Disposal Area

Ash that is generated in the power plant is transported to the ash disposal area by dump trucks where bulldozers will level and compact the ash. In order to prevent ash from flowing, retaining wall will be constructed before the ash disposal area is used. (Refer to Fig. 6.14-2.)

The sequence of constructing the retaining wall of the ash disposal area will be as follows:

i) An embankment having a height of DL + 5.5 m and a width of 5.0 m (and extending approximately 600 m) will be constructed at the area where ash generated in 10 years can be disposed. Embankment will not be provided on the south side of the sedimentation basin.

ii) An embankment having a height of DL + 5.5 m and a width of 5.0 m (and extending for approximately 530 m) will be constructed to prepare a sedimentation basin on the east side of Bani Point.

iii) Ash disposal from DL + 1.5 m to DL + 5.0 m will be carried out on the power plant side (area east of the ash disposal area). One half of the area for disposal of ash generated in 10 years will be used first.

iv) When disposed ash has reached DL + 5.0 m, embankment of 2 m will be added to on DL + 5.0 m, and ash will be disposed in this area.

By repeating this sequence every 2 m height, it will be possible to dispose of ash up to 13.50 m.

v) When ash disposal has reached up to DL + 13.50 m, the surface will be covered with approximately 50 cm of soil to prevent dispersion of ash and for utilization of land created by disposed ash.

vi) By performing the operation from iii) to v) above, filling ash in one half of the areas provided for 10 years will be completed. This will be continued by filling the remaining area for the additional 10 years by the same method.

vii) When ash disposal for 10 years has been completed through the above procedure, the same procedure will be repeated to dispose ash for 30 years. The gradient of slope of embankment is 1:2, and a berm of 10 m wide will be constructed at each 3.5 m elevation. A portion of the berm will be used as road for transportation of ash, and water channel on the side of the road will be provided for drainage of rainwater.

(2) Drainage System

Rainwater inside the ash disposal area will be treated separately from rainwater outside the ash disposal area. The characteristics of the respective drainage system are as follows:

i) Rainwater inside the ash disposal area

Rainwater inside the ash disposal area which is encircled by retaining wall and hills will flow over the surface of the ash disposal area and will be routed to the sedimentation basin by excavated water channel that will be provided in the ash disposal area. After ash particle has settled in the sedimentation basin, water is discharged into the sea on the west side.

The sedimentation basin will initially treat rainwater in the 10 years section of ash disposal area and after the 10th year, rainwater from the 10 to 30 year section of ash disposal area will be treated.

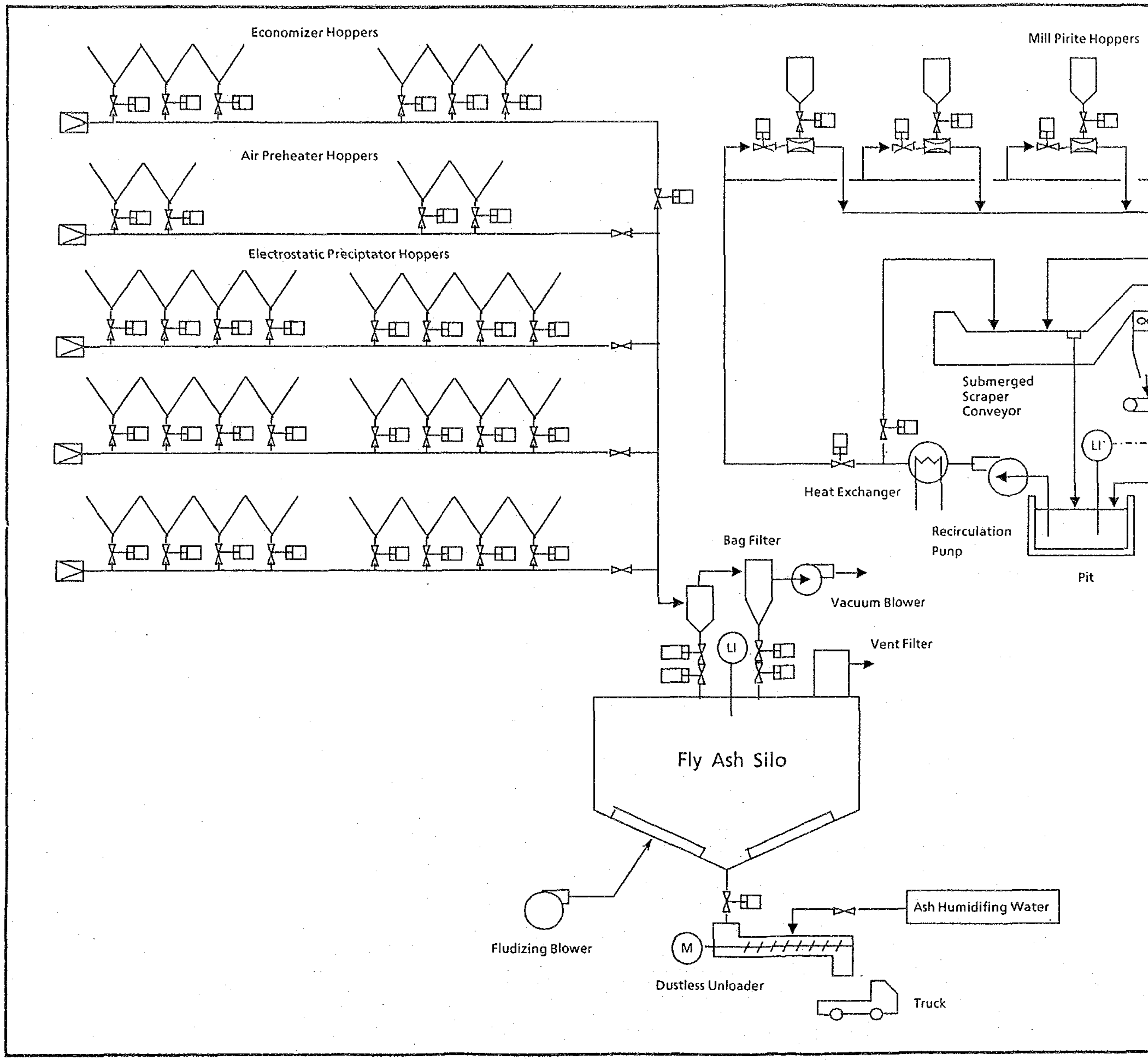
The capacity of the sedimentation basin will be able to accommodate a volume of 60,000 m^3 which will be equivalent to the time required to completely perform natural sedimentation in 8 hours.

ii) *Rainwater outside the ash disposal area*

Rainwater falling outside the ash disposal area, rainwater falling on the embankment surface will be gathered in the water channel provided on the berm of the revetment and will be routed to the sand basin on the west side. The rainwater will be discharged after ash has settled.

Rainwater falling on top of the ash disposal area where ash disposal has been completed will be routed to the sand basin by the water channels that are provided around the top surface of the ash disposal area.

One sand basin will be located on the north side of Bani Point and the other on the north side of ash disposal area.



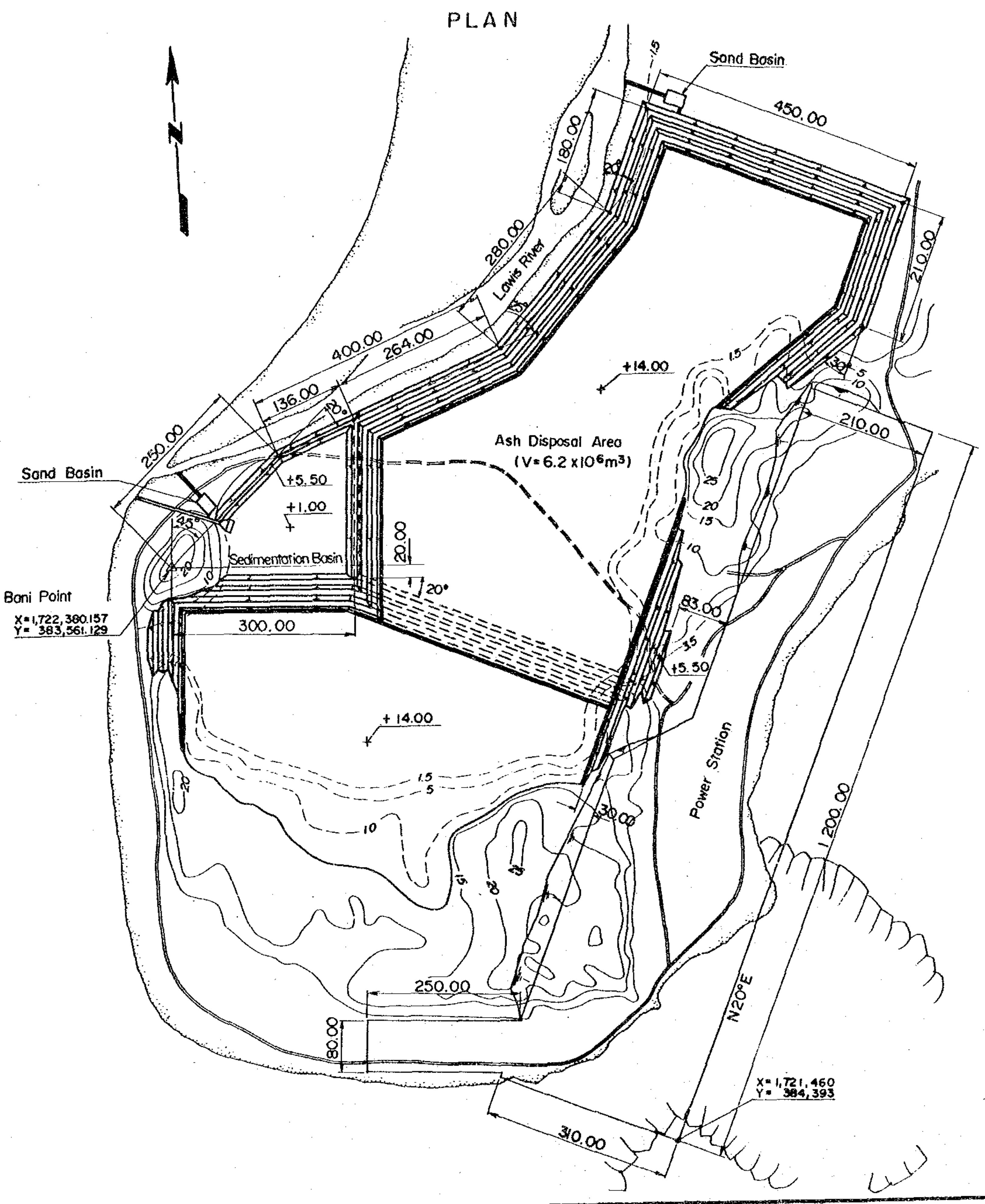
ZAMBALES COAL-FIRED POWER PROJECT

ASH HANDLING SYSTEM
FLOW DIAGRAM

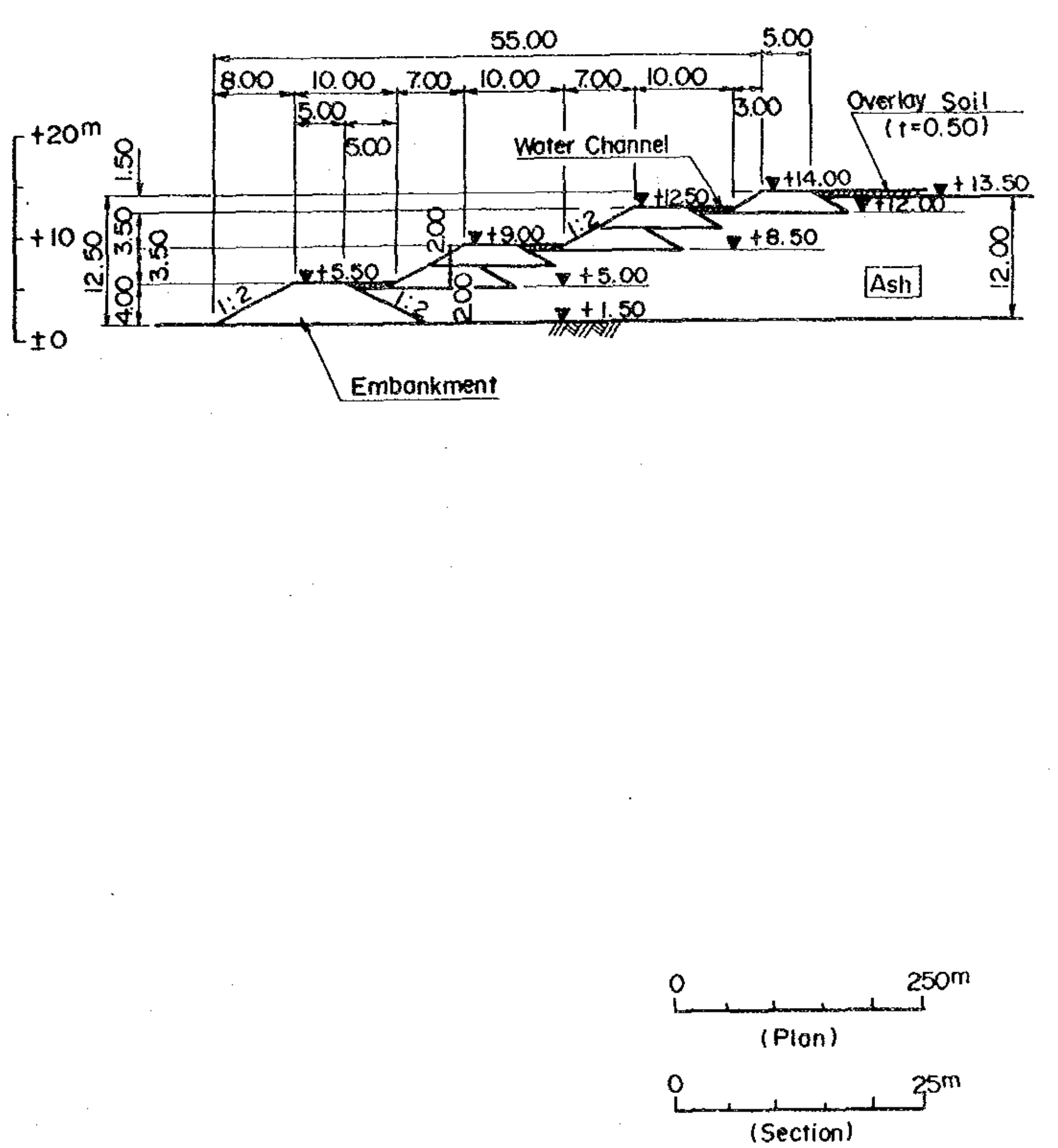
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 6.14-1

D.R; SUBMITTED
T.R; RECOMMENDED
C.K; APPROVED



EMBANKMENT STANDARD SECTION



ZAMBALES COAL-FIRED POWER PROJECT

ASH DISPOSAL AREA

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.6.14-2

6.15 Powerhouse

6.15.1 Powerhouse Layout

The powerhouse consists of turbine house, heater bay and control house. Planned to be installed adjacent to these structures are the boiler and bunker areas.

In the turbine house, steam turbines and generators are arranged in a straight line and overhead traveling crane is installed above these equipment to facilitate maintenance work.

Furthermore, an unloading bay is installed between No. 1 and No. 2 turbine house to facilitate construction of the power plant facilities and implementation of annual inspections in the future.

Planned to be installed next to the turbine house is the heater bay which houses the boiler feed water heater, deaerator, etc. Boiler feedwater pumps are also installed on the ground (first) floor of this heater bay.

Taking a look at the layout of the control house, various facilities for control of the power plant are arranged mainly on the second and third floors. These include the central control room, relay & computer rooms, electricity room, telecommunications equipment room and instrument testing room. An auxiliary equipment room for accommodating an emergency diesel-engine generator, house service boiler, chemical dosing system, sampling racks, compressors, etc. shall be the first floor.

When mapping out the floor plans for the individual structures, No. 1 and No. 2 units are symmetrically arranged by installing the control house halfway between these units for functionally organizing the control system and also arranging the facilities of those units similarly as much as possible.

As for the arrangement of the bunker, the bunker area and the boiler area are integrated into one unitized construction, namely; the side-bunker, so that the each building can structurally balance out and the control room can be efficiently isolated from the pulverizer's vibration.

6.15.2 Foundations of Powerhouse and Major Facilities

The foundations of the power station's major facilities such as the powerhouse, the boiler area and the bunker area are designed in such a manner that these facilities can be supported on firm ground. In addition, the foundation is placed on firm ground so that it safely supports the weight of the superstructures such as equipment and its supporting frames and lessen troubles arising from vibration caused by the equipment. The foundation is also designed to have sufficient bearing strength against possible differential settlements.

As to the foundations for the powerhouse, reinforced concrete mat foundations are adopted because the results of core-drilling survey conducted by NAPOCOR revealed that bedrock in the area where the power station is planned to be sited is relatively near the ground surface.

6.15.3 Superstructures

Two kinds of construction, namely reinforced concrete construction and steel construction, are conceivable. Considering the large room span and ease of equipment installation, light weight, and other advantages arising from shorter construction period, the latter is adopted for the main frame construction. Each floor is of reinforced concrete slab construction.

Turbine and generators to be installed on the operating floor (FL + 12 m) are supported by rigid reinforced concrete block.

As to the ventilation of the turbine room, air inlets are installed on the external walls so as to release heat emanated from indoor equipment to the outside and, thereby, maintain a favorable indoor environment. In addition, air outlets through which warm air naturally escapes are installed on the rooftop along with mechanical ventilating fans to be used when the outside temperature is extremely high.

6.15.4 Facilities

Rooms which operators constantly occupy, such as central control room and rest room for shift operators, as well as those rooms in which various kinds of high-precision equipment that are sensitive to ambient conditions, notably temperature and humidity, are installed, such as the relay room, the computer room, and the communications equipment room, are air-conditioned. On the other hand, those rooms in which heat-generating electricity boards are installed are equipped with mechanical ventilating facilities.

Other facilities installed throughout the entire building include lighting fixtures, plumbing and sanitary systems, fire-extinguishing facilities and fire alarms.

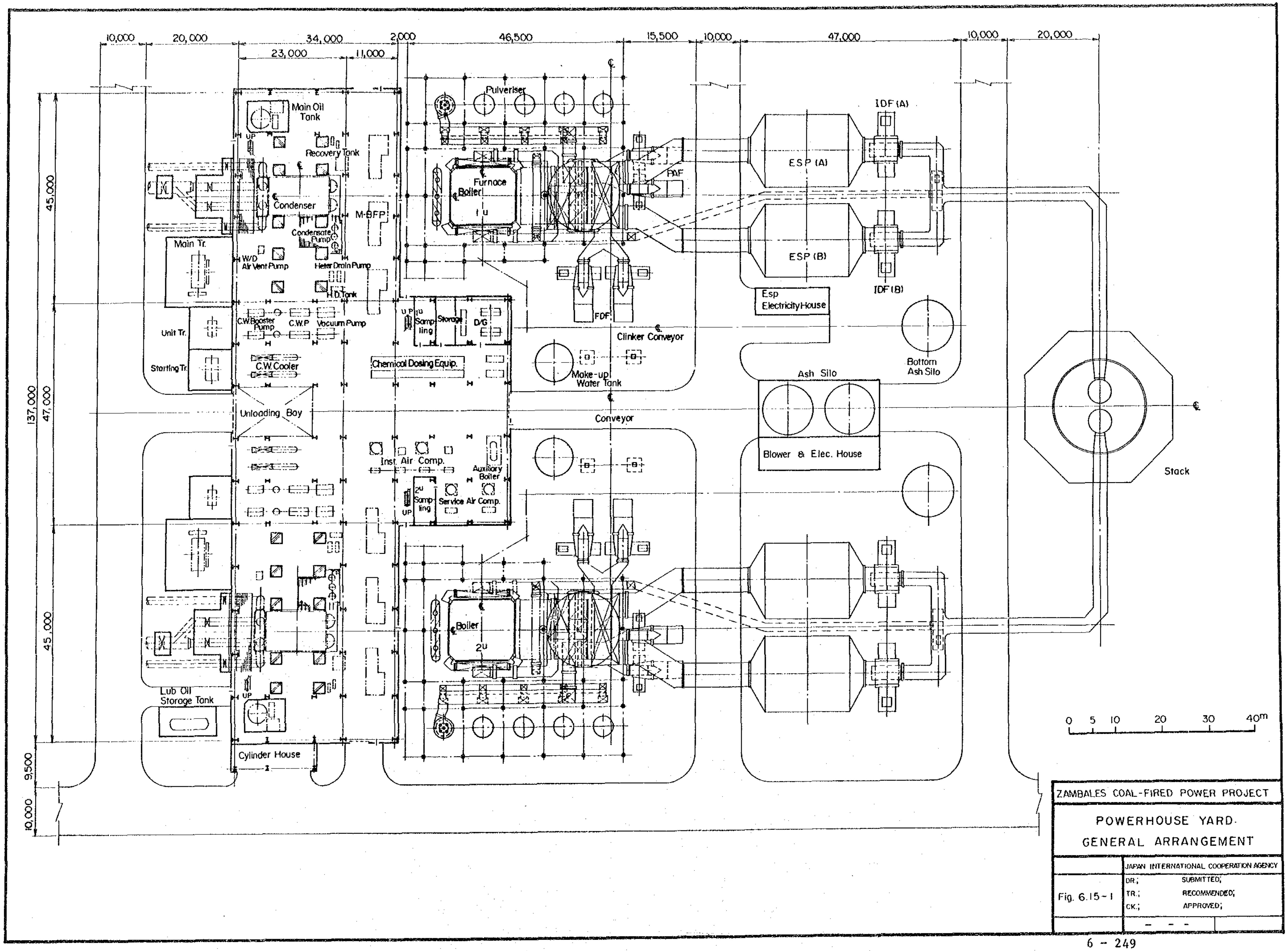
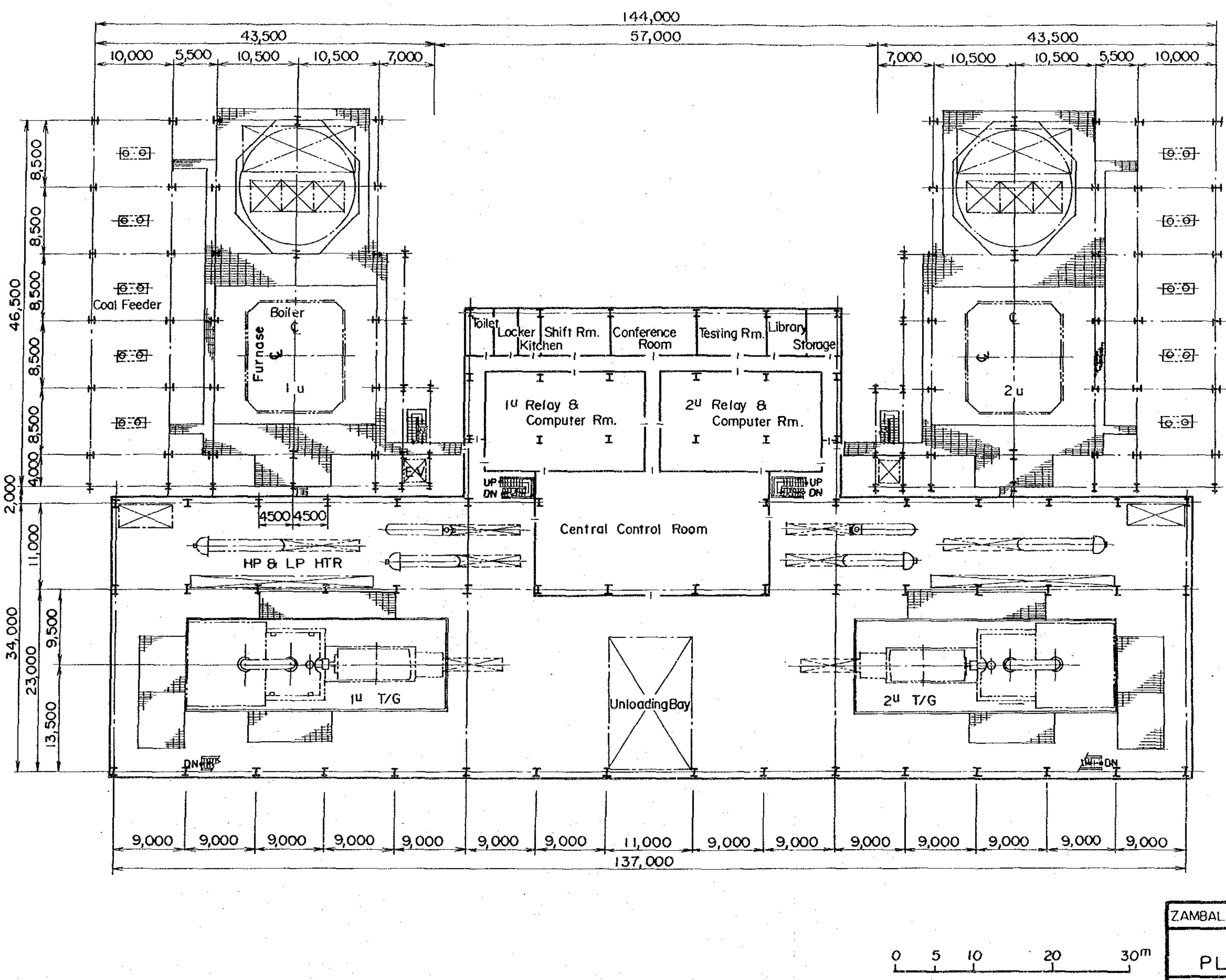

10,000
20,000
34,000
23,000
11,000
2,000
46,500
15,500
10,000
47,000
10,000
20,000
45,000
137,000
47,000
45,000
9,500
10,000
Main Oil Tank
Recovery Tank
Condenser
Condensate Pump
M-BFP
Main Tr.
W/D Air Vent Pump
Heter Drain Pump
H.D. Tank
C.W. Booster Pump
C.W.P
Vacuum Pump
Unit Tr.
Starting Tr.
C.W. Cooler
Unloading Bay
Sampling
Storage
D/G
Chemical Dosing Equip.
Inst. Air Comp.
Auxiliary Boiler
Service Air Comp.
Lub Oil Storage Tank
Cylinder House
Pulveriser
Furnace
Boiler
1u
2u
PAF
FDF
Clinker Conveyor
Make-up Water Tank
Conveyor
ESP (A)
ESP (B)
IDF (A)
IDF (B)
Esp Electricity House
Bottom Ash Silo
Ash Silo
Blower & Elec. House
Stack
0 5 10 20 30 40m
ZAMBALES COAL-FIRED POWER PROJECT
POWERHOUSE YARD
GENERAL ARRANGEMENT
JAPAN INTERNATIONAL COOPERATION AGENCY
DR;
TR;
CK;
SUBMITTED;
RECOMMENDED;
APPROVED;

Fig. 6.15-1



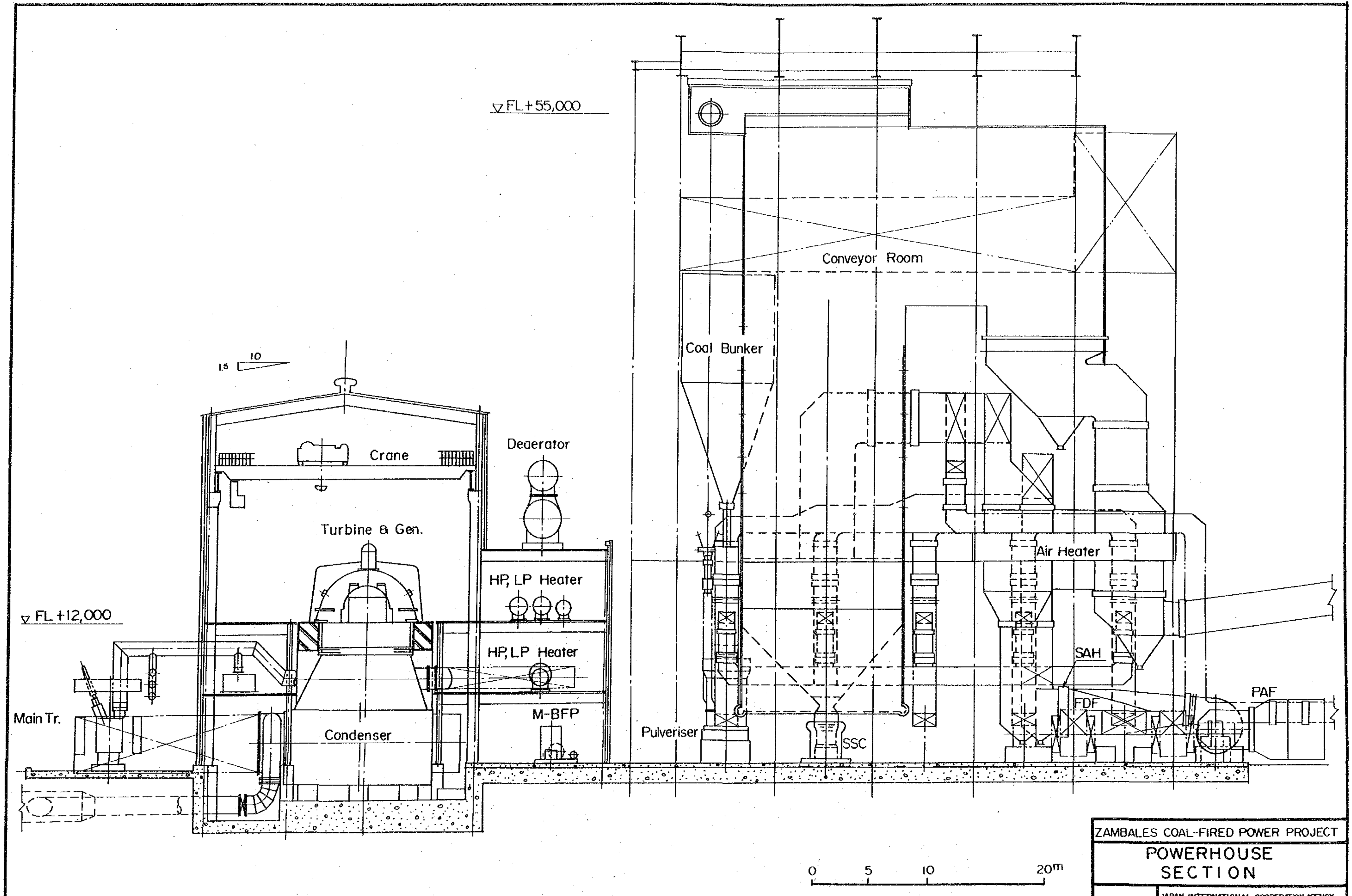
ZAMBALES COAL-FIRED POWER PROJECT

POWERHOUSE

PLAN EL +12,000

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.6.15-2	DR.;	SUBMITTED;
	TR.;	RECOMMENDED;
	CK.;	APPROVED;



ZAMBALES COAL-FIRED POWER PROJECT

POWERHOUSE SECTION

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig.6.15-3	DR.;	SUBMITTED;
	TR.;	RECOMMENDED;
	CK.;	APPROVED;

6.16 Stack

6.16.1 Design Conditions

Height: 120 m

The stack height is determined by giving consideration to the preservation of the environment, namely flue gas diffusion in the environment.

Inner flue diameter: 4 m at the top and 5 m for the rest (2 flues)

The above inner diameter is determined by giving consideration to the discharge velocity, the quantity, and the temperature of flue gas, the induced draft fans' discharge-side loss balance, and other factors.

6.16.2 Stack Type

There are two stack types. One is a reinforced concrete structure and the other is a steel structure.

In general, the former consists of two or more self-supported inner flues made of steel or some other material and reinforced concrete outer tube, while the latter is a combination of steel flue and supporting steel structure.

After analyzing the results of our study, a reinforced concrete structure, which has the following advantages, is decided to be adopted.

i) Unlike a steel-structure stack, reinforced-concrete stack requires no appplication of anti-corrosive repaint after completion.

ii) The construction period of reinforced-concrete stack is slightly shorter than that of steel-structure.

iii) Work safety in and around the stack construction site can be secured through the adoption of slip form construction method.

iv) The bottom portion of reinforced-concrete stack requires less area than that of all-steel structure and is, therefore, more advantageous in terms of overall space efficiency.

v) The space between the inner flues and the outer tube can be used as maintenance space which facilitates the implementation of maintenance and control, and provides more space for stack work.

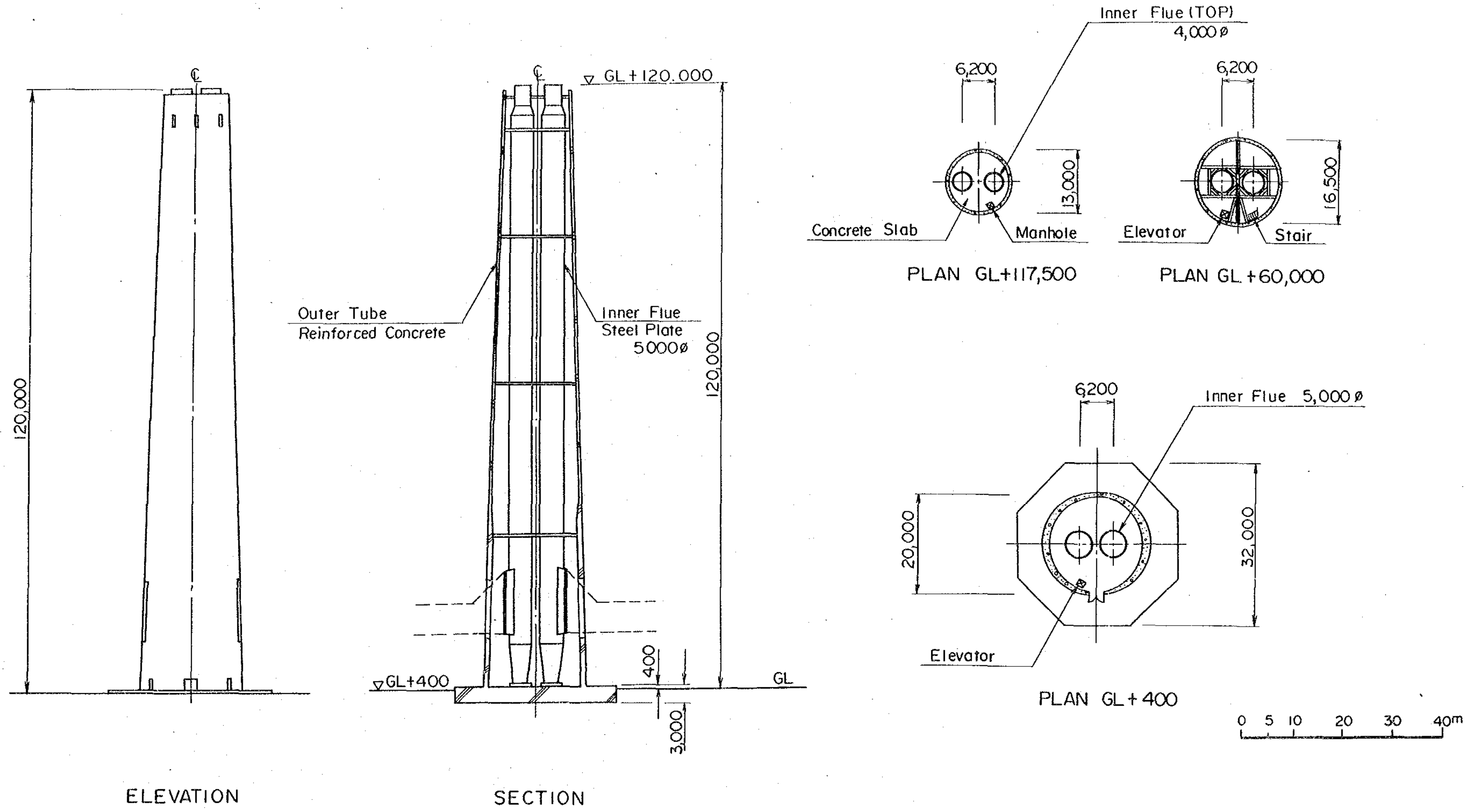
6.16.3 Construction Method

A technique called "slip form method", in which bottomless form panels are continuously jacked up to construct a tower-like reinforced concrete structure, is employed to construct a high reinforced-concrete stack for the power station. The number of stacks completed using this method has been on the increase in recent years.

6.16.4 Others

The inner surfaces of the steel flues are lined with an acid-resistant, waterproof cement-based material to prevent the surfaces from being corroded by sulfur acids (sulfur dioxide) contained in flue gas.

Other facilities installed on the stack include lightening arrester and aircraft warning lights.



ZAMBALES COAL-FIRED POWER PROJECT	
STACK PLAN, ELEVATION & SECTION	
Fig. 6.16-1	JAPAN INTERNATIONAL COOPERATION AGENCY DR.; SUBMITTED; TR.; RECOMMENDED; CK.; APPROVED;

6.17 Ancillary Buildings

(1) Administration Building

The administration building is intended to be occupied by all of the full-time staff of the power station other than the equipment operators. The building accommodates administration office, conference room, plant manager's room, chemical analysis laboratory, library, dining room, depot, locker room, etc. The dining room is intended to be used by the entire work force of the power station. The administration building is of reinforced concrete structure.

Utilities that are planned to be installed in the building include air-conditioning and ventilation system, lighting fixtures, plumbing and sanitary system, fire alarms, and fire-extinguishing facilities.

(2) Other Buildings

Various other buildings that are required to be constructed along with the administration building include workshop, spare-parts warehouse, coal handling control building, ESP electricity house, water-treatment house, chlorination plant house, garage, guardhouse, etc.

The size and floor areas of the workshop and the spare-parts warehouse are determined on the assumption that all maintenance and repair work can be conducted on the premises of the power station and spare parts that are likely to be used shall be stored in the spare-parts storage so that any equipment failure can be speedily dealt with by replacing a faulty part with a new one which is retrieved from the warehouse.

In addition, guesthouse and dormitory are to be constructed in the miscellaneous-facilities yard.

(3) Miscellaneous Facilities

The site of the power plant is landscaped in order to improve the aesthetic aspect of its on-premises environment. In addition, the premises of the power station are fenced off with a boarder fence to keep out trespassers and thereby prevent possible intruder-caused accidents/faults from happening. Sewage is treated in a septic tank before it is discharged into the sea.

As additional amenities, basketball and tennis courts are arranged in the miscellaneous facilities yard.

CHAPTER 7

ENVIRONMENTAL ASSESMENT AND CONTROL MEASURES

Chapter 7 Environmental Assesment and Control Measures

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CHAPTER 7 ENVIRONMENTAL ASSESSMENT AND CONTROL MEASURES

7.1 General

In this coal-fired thermal power project study, Masinloc has already been selected from among the three proposed sites as a result of the first stage study. Therefore, environmental control problems, if a coal-fired thermal power station having 2 x 300 MW is constructed in Masinloc, are studied from various angles in this chapter.

The Philippines have already established legal regulations on environmental control. The JICA study team has evaluated the environment and studied the environmental control facilities with reference to the legal regulations.

(1) Effects of Air Pollution

The power station will be equipped with a high-performance electrostatic precipitator (ESP) (dust-collecting efficiency is 99% min.) as well as a 120 m high stack to diffuse flue gas and reduce ground-level concentration of pollutants. According to the short-term diffusion prediction results using Bosanquet's and Sutton's formula, the air pollutant concentration is far below the ambient air quality standard even at the place of maximum ground-level concentration. The place of maximum ground-level concentration from the power station is 12.5 km during 1 unit operation, 17.1 km during 2 units operation, and consequently there will be no influence to the environment of the surrounding area.

	Ambient Air Quality Standard	Max. Ground-Level Concentration (Stability of Atmosphere: Neutral, 5 m/s) 1-unit Operation	2-unit Operation
SOx	0.30 ppm (H) 0.14 ppm (D)	0.024 ppm 0.014 ppm	0.028 ppm (H) 0.016 ppm (D)
NOx	0.10 ppm (H)	0.015 ppm	0.017 ppm (H)
Dust	0.25 mg/scm (H) 0.18 mg/scm (D)	0.004 mg/scm 0.002 mg/scm	0.005 mg/scm (H) 0.003 mg/scm (D)

Remarks (H): Hourly value
(D): Daily average value
scm: Standard cubic meter

In order to prevent dispersion of coal dust, the coal storage yard and the coal unloading facility will be equipped with water sprinkler and the coal conveyor will be equipped with a cover. Water sprinkler will be installed in the ash disposal yard and after ash is disposed in the yard, the surface, shall be covered with soil. The environment of the surrounding area will not be affected as a result of taking such measures to prevent dispersion of particulates.

(2) Influence of Thermal Effluent

Calculation of thermal effluent diffusion was conducted by simulation using computer and "Mostafa A. Shirazi and Lorin R. Davis' formula" developed by the U.S. Environmental Protection Agency (EPA).

The calculation was conducted assuming a discharge volume of 25 m^3/s with two units in operation.

The results are summarized below:

Table 7.1-1 Simulation Results

Case	Discharged Volume (m^3)	Intake Water Temp (℃)	Permanent Current Velocity (m/s)	1℃ Increase Area			3℃ Increase Area		
				Reaching Distance (km)		Diffusion Area (km^2)	Reaching Distance (km)		Diffusion Area (km^2)
				Coastal Direction	Toward Offshore		Coastal Direction	Toward Offshore	
1	25	31	0.0	0.274	1.704	0.6741	0.030	0.252	0.0134
2			0.05	0.840	1.266	0.4029	0.064	0.236	0.0114
3			0.15	1.014	0.465	0.1387	0.141	0.177	0.0083

The simulation study revealed that 1°C increase in water temperature will be the area 1.7 km in terms of reaching distance toward offshore and 0.67 km^2 in terms of diffusion area, while 3°C increase in water temperature will be an area 0.3 km offshore and 0.01 km^2. Therefore, the environment of the surrounding area will not be affected by the thermal effluent as explained below.

- The thermal effluent will diffuse over the surface of the sea, so it will not affect marine life on the bottom of the sea.

- As to the effects on shallow water on the coast, marine life will not be affected due to the fact that the water discharge portal extends about 300 m out to the sea from the shore, and the calculation results indicate that thermal effluent will not approach the coast even if the permanent current speed should be 15 cm/s.

- As to the effect of thermal effluent on the water intake, there will be no recirculation since the distance between the water intake and outlet is about 800 m and deep water intake system is adopted.

7.2 Present Conditions of Environment and Emission Control Standards

7.2.1 Present Conditions of Environment

The present conditions of environment in Masinloc are shown below:

(1) Ambient Air Quality

There are no industrial activities to pollute air within a radius of 10 km from the planned site. Though there are effects of emission by automobile, etc. and the smoke generated by burning trash after harvesting and from houses, the air pollutant concentration is expected to be at a very low level.

(2) Water Quality

As to the prospective fresh water sources, there are the Lawis river to the east of the site and the Masinloc river to the south of the site. Since Coto chromite mine is in operation in the upstream of the Lawis river, there is the possibility of water pollution from the mine. Therefore, a water analysis was conducted, but the total chromium turned out to be a maximum of 0.02 ppm in terms of quantitative limit value. Silt adhered to stones of the Lawis river contained chromium of 0.65%, indicating that chromium is flowing down the river.

(3) Climate

The Philippine archipelago is classified into four areas according to the Philippine meteorological classification. This area belongs to Type I, where there is a clear distinction between the dry season and the rainy season.

The wind direction and velocity in the site are explained below in relation to the diffusion of power station flue gas into the atmosphere.

From February to March, northwest wind prevail, so the flue gas will diffuse toward the city and municipality facing Masinloc Bay.

In the other months, it will diffuse toward Oyon Bay or the South China Sea.

When the wind speed is low, the stability of atmosphere is expected to become low. This will be particularly significant in the dry season.

(4) Tidal Condition

While the site faces the outer sea, the tidal velocity is low at about one (1) knot. Little data of tidal current in Oyon Bay are available.

(5) Topography

There is a gently sloping hill of from 5 m to 25 m in elevation to the northwest of the site. Rice paddies lie between the site and the coastline. There is vast, flat land on the side of Lawis river. The shore is shallow to a considerable distance and there is a stretch of coral reef.

Near the site to the south is Oyon Bay. Masinloc Town with a relatively large population is located six (6) km to the southeast. The Zambales ridges (elevation is 1,000 m max.) can be seen about fifteen (15) km away to the east.

(6) Population and Industrial Activities

As previously stated, the inhabitants near the planned site are engaged mainly in agriculture and fishery. There are developed settlements along a national road running north to south along the coastline. However, there is no major source of smoke to pollute the air within a radius of 30 km.

(7) Land Utilization around the Site

There are rice paddies and coconut farms in the area which must be acquired as part of the plant site. A few fishermen are living on the coast.

7.2.2 Environmental Quality Standards and Emission Standards

(1) Environmental Quality Standards

Tables 7.2-1 to 3 show the environmental quality standards for air, noise and water quality.

The area category of the noise control to be applied to the site is not yet determined while the marine category for water pollution control is expected to be SC.

Table 7.2-1 Ambient Air Quality

Pollutant	Sulfur Dioxide SO_2	Nitrogen Dioxide NO_2	Carbon Monoxide CO	Suspended Particulate Matter SPM	Photo-chemical Oxidant OX
24 hour value	369 μg/scm 0.14 ppm			180 μg/scm	
8 hour value			10 mg/scm 9 ppm		
1 hour value	850 μg/scm 0.30 ppm	190 μg/scm 0.10 ppm	35 mg/scm 30 ppm	250 μg/scm	120 μg/scm 0.06 ppm

Remark: scm stands for standard cubic meter

Table 7.2-2 Environmental Quality in Noise Level

		Day Time	Morning and Evening	Night Time
AA	Quiet Area	50 dB	45 dB	40 dB
A	Residential Area	55 dB	50 dB	45 dB
B	Commercial Area	65 dB	60 dB	55 dB
C	Light Industry Area	70 dB	65 dB	60 dB
D	Heavy Industry Area	75 dB	70 dB	65 dB
Time Zone		AM 9 to PM 6	AM 5 to AM 9 PM 6 to PM 10	PM 10 to AM 5

Table 7.2-3 Environmental Standard of Water Quality (Sea & River Mouth)

Quality Parameter \ Type	SC
Temperature ℃	3 (a)
Dissolved Oxygen	5
5-day BOD at 20 ℃	20
PH	6.5~8.5
Coliform, MPN/100ml	5000
Phenolic Substances /mg/l	0.02
Trace Elem^nts	
Arsenic	0.05
Barium	0.05
Cadmium	0.01
Chromium	0.05
Copper	0.02
Cyanide	0.05
Lead	0.05
Mercury	0.002
Selenium	0.05
Silver	0.05
Organic Chemicals	
Synthetic Detergents (MBAS)	0.5
Oil and Grease	5
Persistent Pesticides	(μ/l)
Aldrin	0.01
DDT	0.02
Dieldrin	0.005
Chlordane	0.04
Endrin	0.002
Heptachlor	0.01
Lindane	0.02
Taxaphane	0.01
Methoxychlor	0.005
2,4-D	2.0
Nutrients	(b)

Remarks: 1. (a) Rise in temperature.
(b) Shall not be present in concentrations to cause deleteriou or abnormal biotic growth.
2. All values are maximum permissible except for dissolved oxygen which is minimum permissible.
3. All units are in mg/l except those indicated.

Water usage and classification:

Classifications Best Usage

Class SC For the propagation and growth of fish and other aquatic resources.

(2) Emission Standards

Tables 7.2-4 to 5 show the emission standards for air pollutant and effluent.

Table 7.2-4 Emission Standards for Air Pollutant

Pollutant	Total Oxides	Nitric Acid or Oxides of Nitrogen	Solid Particles Oxides
Emission Limit	* 250 mg/scm (as sulfur dioxide)	2 g/scm (as NO_2)	300 mg/scm

Remarks
* Where limit cannot be met, control to be by stack height.

Table 7.2-5 Effluent Regulations

Quality Parameter \ Type		Other Coastal Waters (SC)
Color in platinum cobalt unit		200
PH		5.5~9
Temperature in °C		40
Phenols		1
Suspended solids		200
BOD		250
Oil/Grease		15
Detergents		10
Barium	(Ba)	5
Cadmium	(Cd)	0.1
Copper	(Cu)	1
Chromium (Hexavalent)	(Cr^{+6})	0.1
Dissolved Ferrous	(Fe)	20
Lead	(Pb)	0.5
Lithium	(Li)	1
Dissoled Manganese	(Mn)	5
Mercury Total	(Hg)	0.002
Molybdenum	(Mo)	0.5
Nickel	(Ni)	1
Selenium	(Se)	1
Silver	(Ag)	1
Zink	(Zn)	10
Arsenic	(As)	0.5
Beryllium	(Be)	1
Free Chlorine	(Cl)	1
Cyanide	(CN)	0.5
Fluoride	(F)	10
Polychlorinated Byphenyl	(PCB)	0.003

Remarks

Maximum allowable levels in mg/l.
"Coastal Water" means an open body of Water along the country' coastline starting from the shoreline(MLLW) and extending outward up to the 200-meters isobath or three-kilometer distance, whichever is farther.

7.3 Environmental Control Measures and Facilities

7.3.1 Basic Concept for Environmental Control Measures

In planning a coal-fired thermal power plant in Masinloc, the most important point in environmental protection is that the consideration into the future should be paid as far as possible as well as the plant does not have a negative affect on the environment of the surrounding area.

The following matters have been studied based on the above fundamental concept.

(a) Air pollution
(b) Influence of thermal effluent
(c) Influence of waste water treatment and ash disposal area

In order to identify these items, the natural and social environment around Masinloc area have been studied.

Based on this study, appropriate environmental system is planned to suit the Masinloc area.

7.3.2 Coal-fired Thermal Power Station and Environmental Protection

Environmental pollution problems of a coal-fired thermal power station include air pollution (sulfur oxide, nitrogen oxide, dust, etc.), water pollution (thermal effluent, ash treatment effluent, etc.), noise, dust, coal ash treatment, etc.

Environmental pollution problems of coal-fired thermal power plant differs from those of heavy oil-fired thermal power plant, in particular, air pollution and coal ash treatment.

Table 7.3-1 shows that flue gas characteristics of coal-fired power plant are largely different from those of oil-fired plant. Untreated flue gas has 100 times or much higher dust concentration. SOx and NOx concentrations are also higher. Dispersion of ccal dust occurs during coal transportation and storage, so higher-level air pollution control measures are required than in an oil-fired power plant.

Ash content of coal, being 15 to 20%, is much higher than in other types of fuels, so coal ash treatment is a serious problem.

In addition, it is necessary to take measures for effluent from coal storage yard, power plant facilities, etc. So environmental protection measures will require considerable efforts.

Fig. 7.3-1 shows a general coal-fired power plant block flow, and Fig. 7.3-2 shows typical environment protection measures of a coal-fired power plant to be constructed in an industrialized area of Japan.

7.3.3 Outline of Environmental Protection Measures

The environmental protection facilities of the planned project are considered as follows:

(1) Air Pollution Control Measures

(a) Sulfur oxide

- To adjust the sulfer content of coal, coal blending facility to be considered

- To reduce the ground-level concentration of pollutant, 120 m stack height with 30 m/s discharge rate is adopted.

(b) Nitrogen oxide

- Same as in case of sulfur oxide

(c) Dust

- To install high efficiency electrostatic precipitator (dust removal efficiency should be considered as more than 99%)

- Same as in case of sulfur oxide

(2) Thermal Effluent Control Measures

- Temperature rise of condenser cooling water shall be less than 8°C.

(3) General Effluent Control Measures

- To equip waste water treatment facility (waste effluent is purified to SS 200 mg/l max., oil content 15 mg/l max. and pH 5.5 to 9 by means of coagulation and sedimentation, oil separator and pH controller)

(4) Noise/Vibration Control Measures

- Major noise/vibration generating equipment will be installed far away from the site boundary and the main equipment will be located indoors.

(5) Other Countermeasures

- To prevent dispersion of dust from coal storage yard and ash disposal yard

- To remove suspended solid in rainwater from coal storage yard and ash disposal yard by sedimentation pond before releasing water into the sea

Table 7.3-1 Flue Gas Characteristics of Coal, Heavy Oil and LNG Firing Boiler

	Fuel Type	Coal	Heavy Oil	LNG
Fuel characteristics	High calorific value (kcal/kg)	6000～7000	10 500	13 000
	Ash content (%)	15 ～ 20	0.1max	0
	Sulfur content (%)	0.5～2.0	1 ～ 2	≒ 0
	Nitrogen content (%)	1.5～2.0	0.1～0.3	0.01～0.05
Flue gas characteristics	Eco outlet dust concentration (g/Nm^3)	10 ～ 25	0.1～0.2	0
	AH outlet SOx (ppm)	400～1600	500～1000	≒0
	Eco outlet NOx (ppm)	400～600	200～300	150～250

Remarks: The concentrations in the flue gas column are on a dry gas base.

Figure 7.3-1 Coal-Fired Thermal Power Station Block Flow

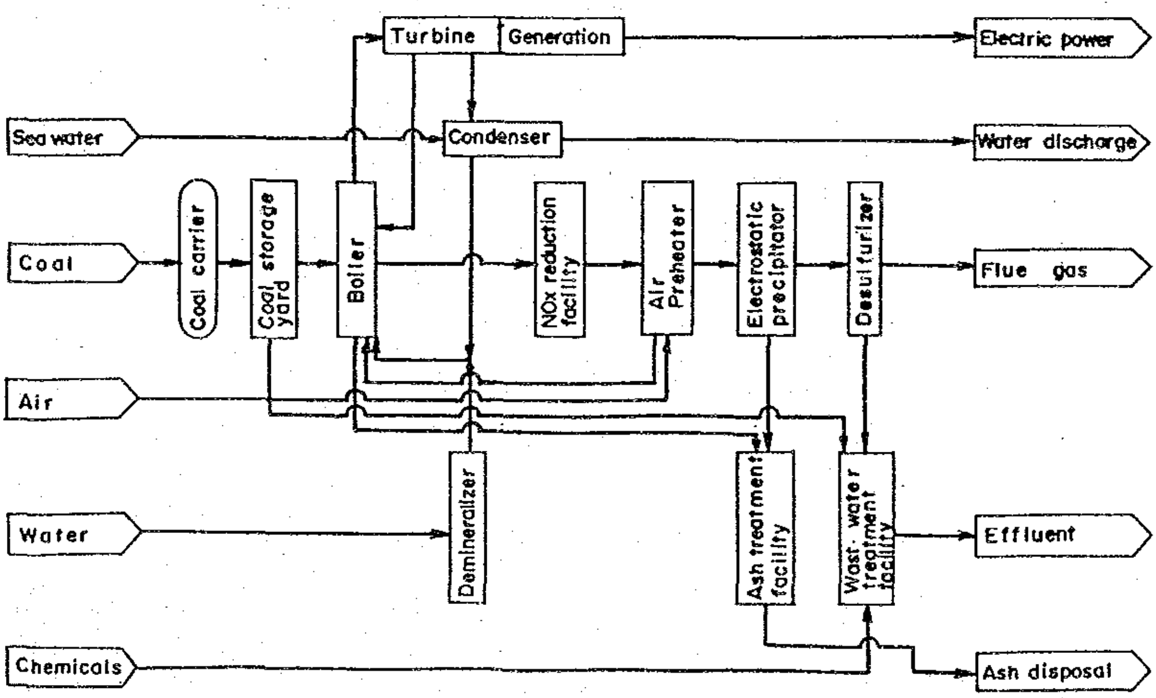
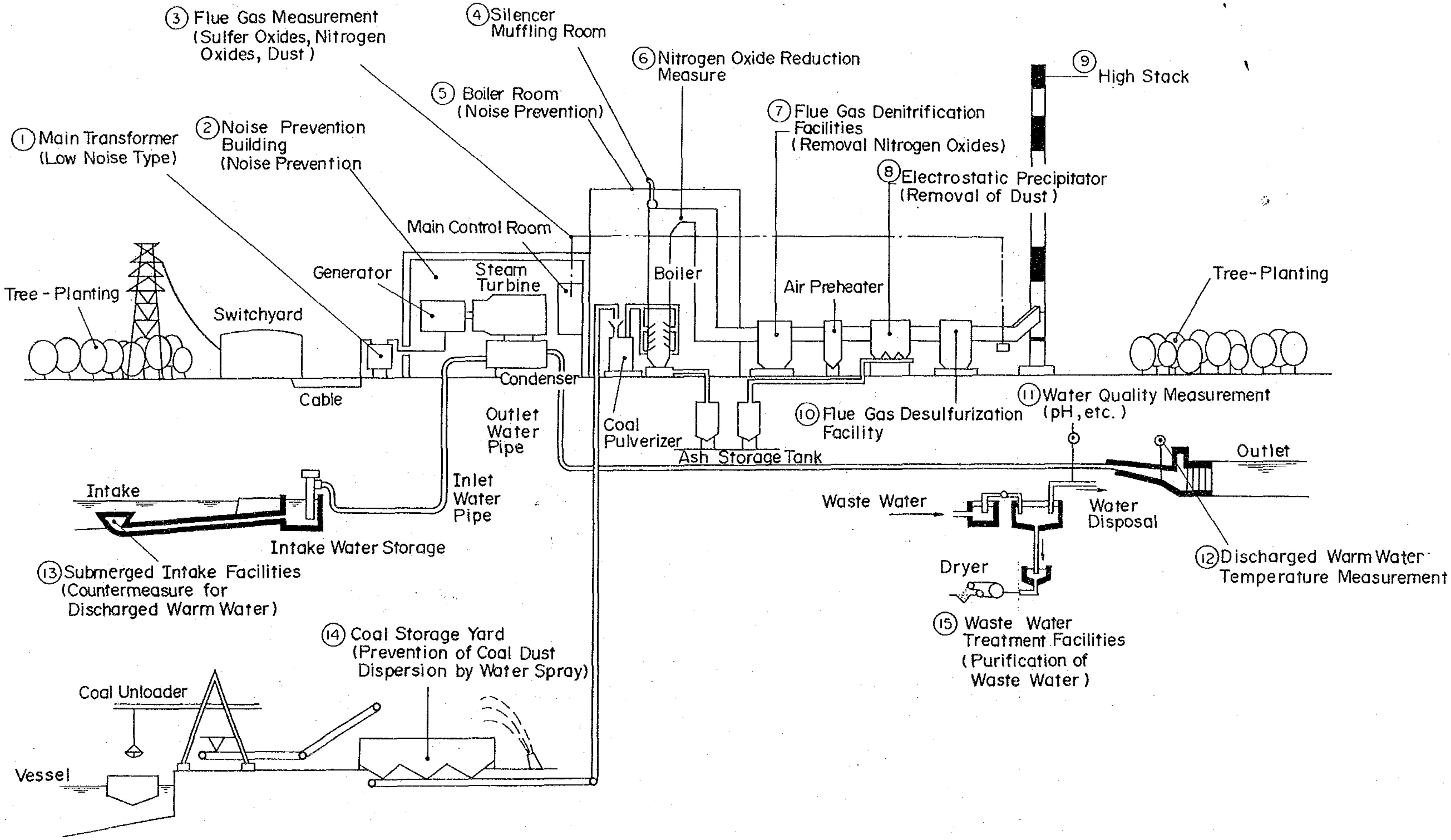


Fig.7.3-2 Environmental Conservation Countermeasures for Thermal Power Plant



7.3.4 Electrostatic Precipitator (ESP)

(1) Cold ESP and Hot ESP

When coal burn at high temperature (1,200 to 1,600°C) in a furnace, carbon, hydrogen, etc. contained in coal burn almost completely to form ash and combustion gas. While some of the ash generated in the furnace adheres to the water wall or falls down into furnace bottom, most of it is carried to the downstream of gas duct together with combustion gas.

Generally, about 10% of ash generated in pulverized coal-firing boiler melts and falls into chain conveyor and another about 10% accumulates in economizer and air preheater hoppers as cinder ash. And the remaining about 80% is discharged from boiler as fly ash. An electrostatic precipitator is installed to collect this fly ash.

i) Types

The following three (3) types of fly ash collectors are available.

(a) Mechanical dust collector (cyclone type)
Easily collect large particle size of ash.
Particulate emission density is more than 1.0 g/m^3N.

(b) Low temperature electrostatic precipitator
(temperature is about 120 to 150°C, called Cold-ESP.)
Adopted for ash of low electric resistivity.
(10^4 to 10^{11} ohm-cm)

(c) High temperature electrostatic precipitator
(temperature is about 300 to 400°C, called Hot-ESP).
Adopted for high electric resistivity ash (more than 10^{12} ohm-cm).

ii) Comparison of Cold and Hot-ESP

Cold and Hot-ESP are compared in terms of economy and dust-collecting performance.

(a) Economy

Cold-ESP is installed at the downstream of the air preheater, in a zone of about 130°C, similar to heavy oil-fired thermal power generation. Hot-ESP is installed between the economizer and the air preheater. It is a system to draw out about 350°C gas, treat it in ESP and then return it to the air preheater.

The actual gas volume of Hot-ESP is about 1.5 times ($\frac{273 + 350}{273 + 130} = 1.5$) of Cold-ESP's.

Hot-EP, gas duct, etc. become considerably larger and more costly than Cold-ESP.

(b) Performance of ESP

Performance of ESP is largely affected by the electric resistivity of ash. Namely, if the electric resistivity of ash exceeds 10^{12} ohm-cm, back ionization (back corona) occurs in the dust-collecting electrode, and this results in the instability of electric charge and finally reduces the dust-collecting efficiency.

Fig. 7.3-3 shows the general relationship between electric resistivity of ash and dust-collecting performance.

Electric resistivity of ash is affected largely by sulfur content of coal, alkali metal (Li, Na, K) of ash and gas temperature.

Fig. 7.3-4 shows these relations. The chemical composition of fly ash also affects the electric resistivity. Electric resistivity is low if the percentages of Na_2O and SO_3 are high, while it is high if those of SiO_2, Al_2O_3, CaO_2, MgO are high.

(c) Selection of type

Considering the characteristics of the design coal to be used in this project, electric resistivity is assumed to be about 10^{10} to 10^{11} ohm-cm at gas temperature 140°C. Therefore cold ESP is recommended in view of economy.

In the detail design stage, it is desirable to check the characteristics of ash.

Fig. 7.3-3 Efficiency Curve of Electrostatic Precipitator

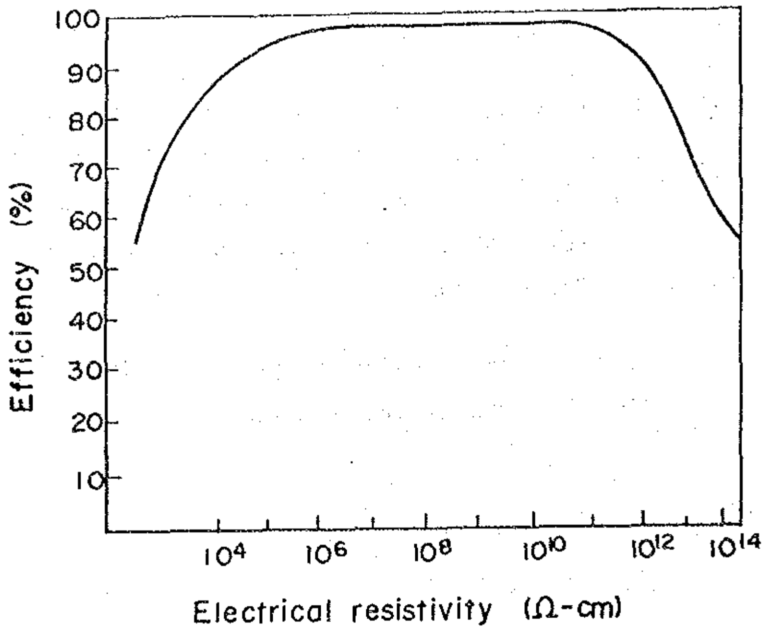
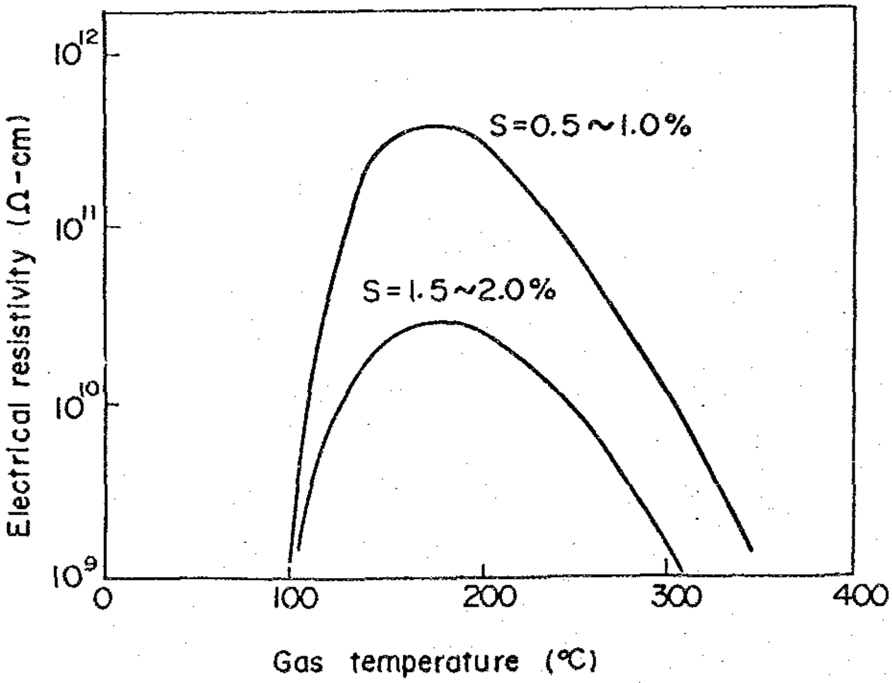


Fig. 7.3-4 Gas Temperature and Electrical Resistivity of Fly Ash



(2) Study of Basic Specifications

i) Basic specifications

The design coal is assumed as 50/50 wt% of Semirara/ Lemington. However, in studying the basic specification of the ESP, the blending ratio may be biased to Semirara or Lemington.

Type	:	Dry, horizontal
Number of sets	:	2 sets/boiler
Processing volume of gas	:	Approx. 1,050 $m^3N/h \cdot wet$
Inlet gas temperature	:	140°C
Dust collection rate	:	more than 99%
Conditioner	:	Water injection method to be considered in the future.

(Requirement of Conditioner)

The method of injection of SO_3 or NH_3 as a conditioner is often adopted in foreign countries as a measure to improve the existing ESP's performance.

However, this practice is not desirable for a newly installed thermal power plant, because of possible secondary problems as troublesome handling of conditioning agent, treatment of collected ash (due to NH_3 in dust), etc.

As an alternative method, conditioning by water injection into the gas duct seems to be the optimum method for easy handling and less secondary problems. However, the effect of improvement of performance by water injection into the gas duct changes according to coal characteristics.

Therefore, it is desirable to study this method after understanding the actual results of ESP efficiency by each type of coal after commissioning of the plant.

ii) Calculation of optimum Specific Collecting Area (SCA)

Dust collection rate of ESP for a coal-fired boiler is expressed as follows:

$$\eta = 1-e^{-(wk \cdot f)^k} \times 100$$

where,

η : Dust collection rate (%)

f : Specific collecting area ($m^2/m^3/s$)

$$f = \frac{\text{Specific collecting area}}{\text{Actual gas volume}}$$

wk: Apparent dust travelling velocity (m/s)

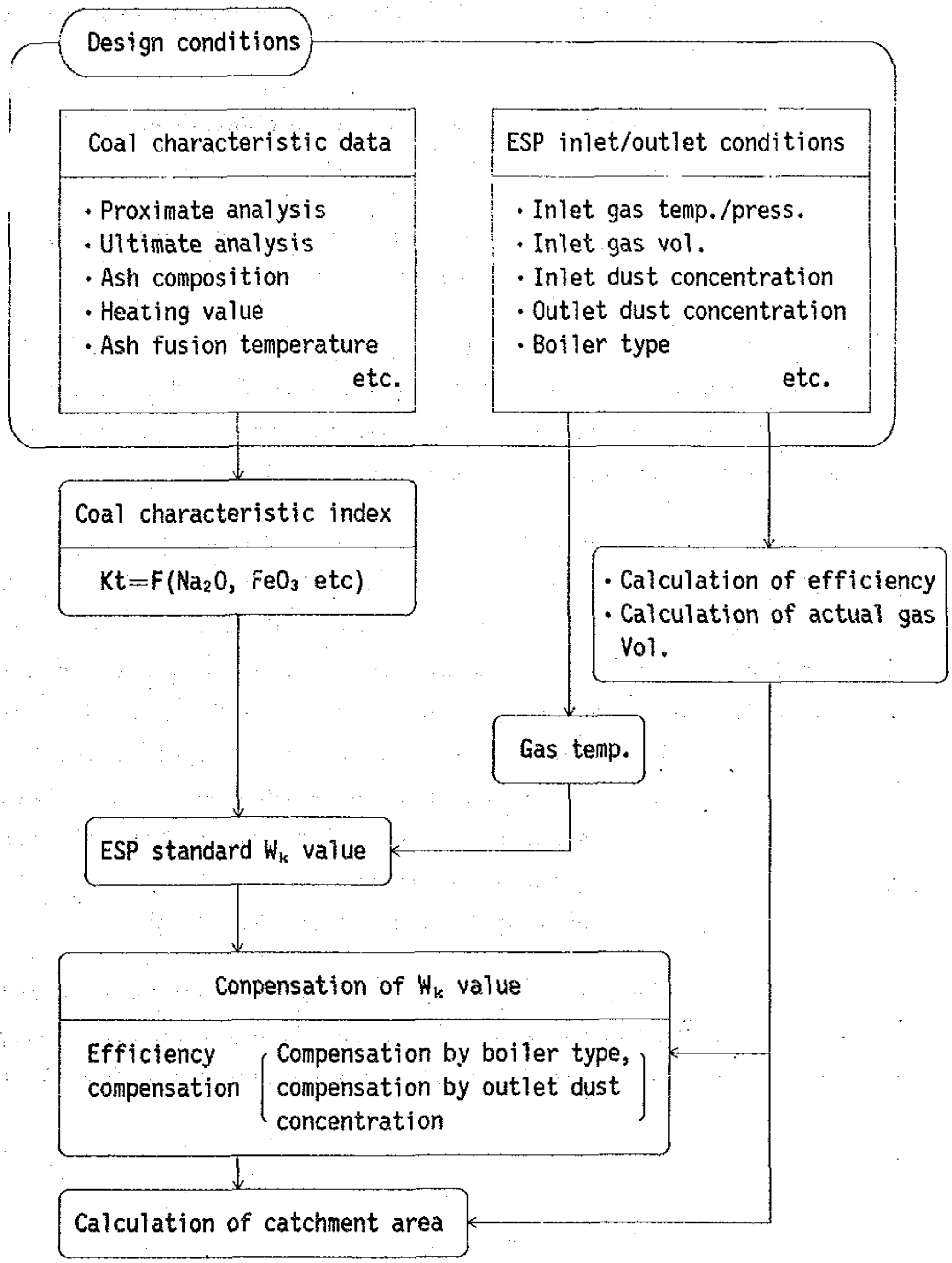
k : Constant determined by particle size distribution

Note: 0.5 is adopted for fly ash.

In the above formula, the dust travelling velocity Wk which represent the dust collectivity of each type of coal depends on the boiler operating conditions (in particular gas temperature) in addition to coal/ash characteristics of each type of coal.

Therefore, basic dimensions of dust collector are decided by the SCA calculation procedure shown in Fig. 7.3-5 based on the coal and coal ash characteristics, and by the basic specifications explained in i).

Fig 7.3-5 ESP's collecting Area Calculation Mode



7.3.5 Stack Height

From the view point of effective environmental protection, the stack will be of a type to serve 2 boilers. Its basic features will be as follows:

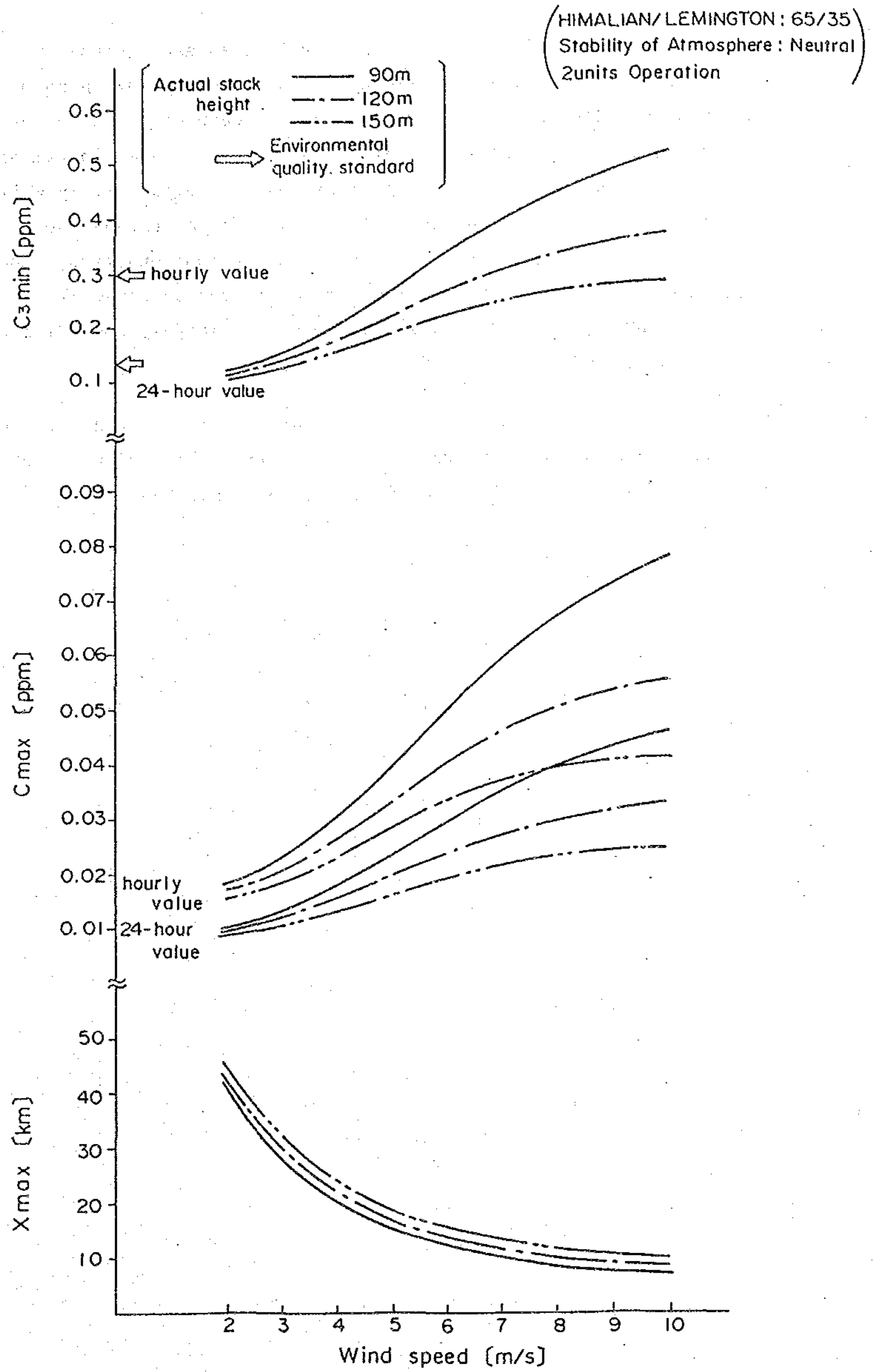
120m	Height	:	Decided in consideration of diffusion of flue gas
4 m (top)	Diameter	:	Decided from flue gas discharging speed, volume and temperature.

In selecting the stack height and diameter, it is essential to understand the ambient air quality standards and emission standards, the present environmental air quality, the flue gas characteristics and the meteorological conditions.

At present, available data of present environmental air quality and meteorological conditions around the site are not sufficient. The 3-minute, 1-hour and 24-hour values of SOx emission were calculated using Bosanquet's and Sutton's formula under the conditions of two-units to be operated, blending ratio of Semirara and Lemington coal is 65/35 percent weight, and the stability of atmosphere is neutral. The stack height has been decided to be 120 m based on the calculation results shown in Fig. 7.3-6, taking into consideration the present environmental conditions in Masinloc area and the stack height at Calaca power station No. 1 and No. 2 units.

If the atmosphere is unstable, the place of maximum ground-level concentration (Xmax) is nearer to the flue gas source compared to neutral but the maximum ground-level concentration (Cmax) is smaller.

Fig. 7. 3-6 SOx Ground Concentration and Wind Speed, Actual Stack Height

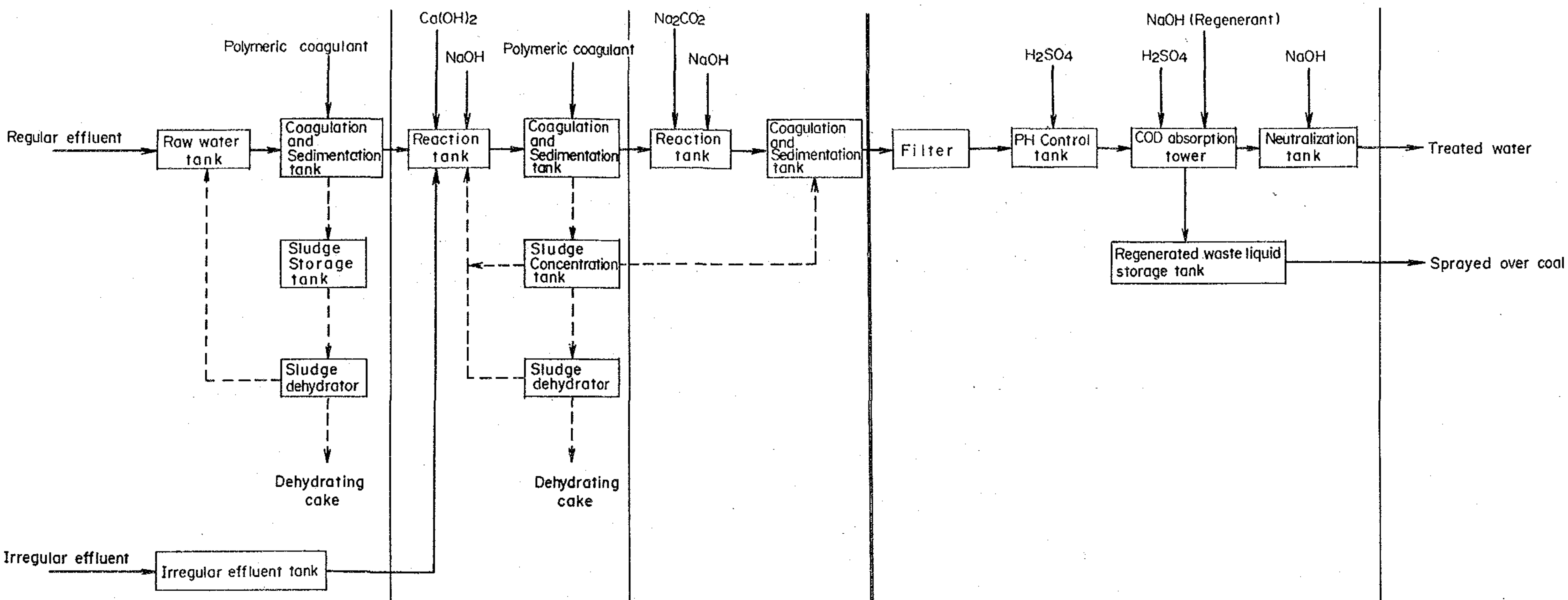


7.3.6 Waste Water Treatment Facility

Waste water of coal-fired power plant facilities and equipments is classified into two types of discharged continuously during normal operation and discharged at start-up and shutdown of the plant or during annual inspection and maintenance. Water volume, contaminant concentration at normal operation condition are comparatively well-controlled and grasped. However, it is hard to understand the actual discharge condition at off-normal operation condition, since a large water volume of high pollutant concentration water is irregularly discharged and the water volume varies largely according to the operating mode.

Fig. 7.3-7 shows the waste water treatment facility flow diagram and Fig. 7.3-8 shows the waste water treatment flow sheet of a general coal-fired power plant (without flue gas desulfurizer).

Figure 7.3-7 Waste Water Treatment Facility Flow Sheet



Major functions	Raw water storage, water quality control	Reaction, coagulation, sedimentation	Demineralizing reaction, coagulation, sedimentation	SS separation, PH control, COD removal
Major substances removed	Fry Ash	Heavy metal, Al, F	Heavy metal, F, Ca, Mg	SS, COD
Operation PH		6.0 ~ 8.0	10.0 ~ 12.0	6.0~8.0 → 4.0~5.0 → 7.0~ 8.5

Figure 7.3-8 Power Station Waste Water Treatment Flow Sheet

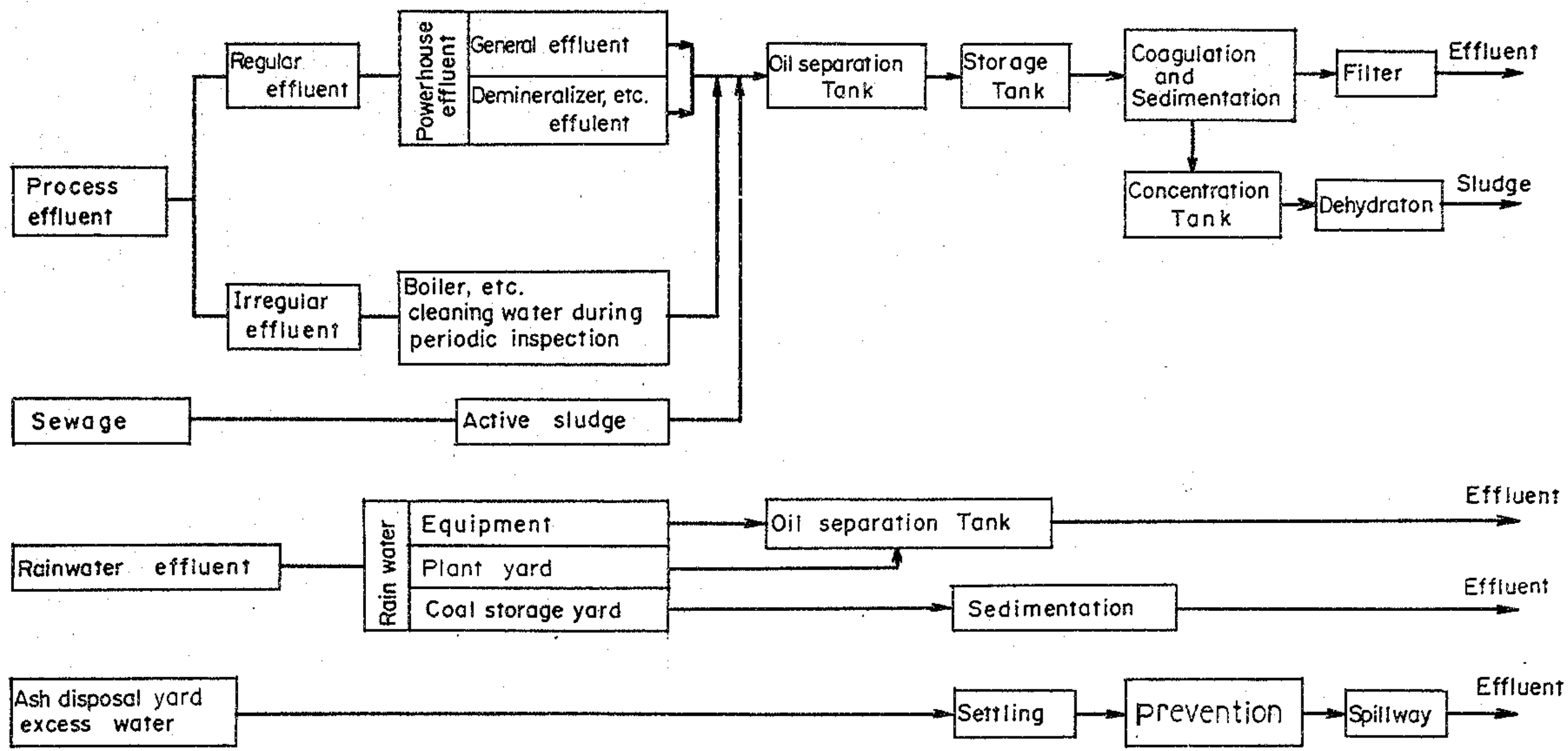
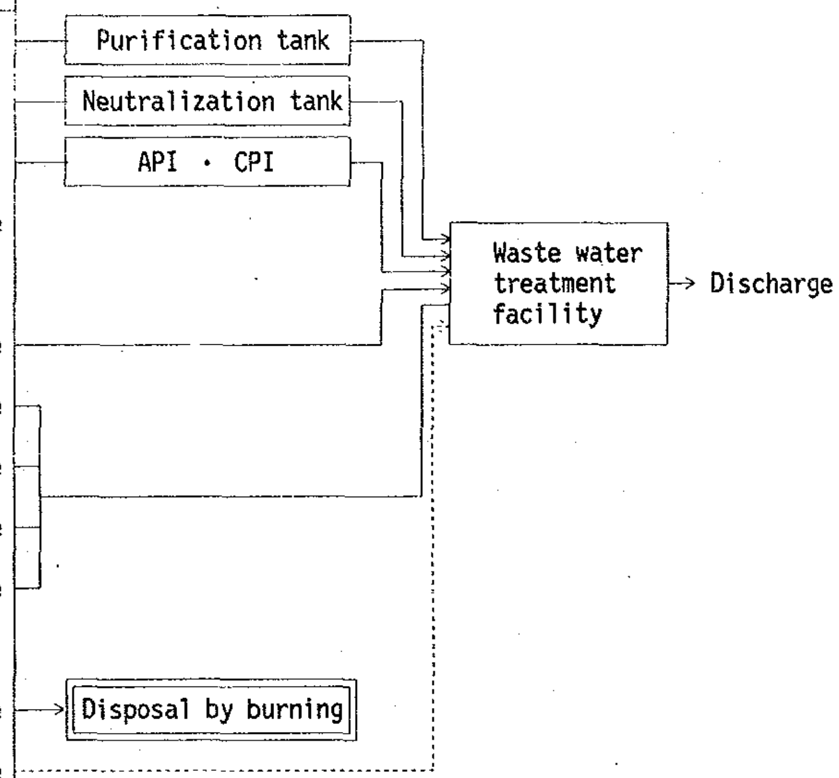


Table 7.3-2 Basic Design of Waste Water Treatment Facility

Item	Waste water quality: PH	Electric conductivity	COD	SS	Fe	Ni	Mn	Oil	Water vol.	Treatment System
(Constant waste Water)	—	μs/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	t/day, t/time	
• Sewage (Office, Powerhouse Port)	7	400	150	150	0.1	0.1	0.1	5	80 t/day	
• Water treatment facility	12	15,000	10	30	5	0.1	1	0	100 t/day	
• Oil containing effluent	8	200	5	20	1	0.1	0.1	10	120 t/day	
• Boiler blowdown water	9	6	0	Tr	1	0.1	0.1	0	1,200 t/time	
(Non-constant waste Water)										
• Condenser leak test effluent	9	10	2	1	1	0.1	0.1	0	120 t/time	
• Boiler washing effluent	9	25	100 (N_2H_4)	2	1	0.1	0.1	0	500 t/time	
• Deaerator washing effluent	9	25	100 (N_2H_4)	2	1	0.1	0.1	0	120 t/time	
• EP washing effluent	5	7,000	20 (Fe^{2+})	25,000	1,000	50	50	0	800 t/time	
• AH washing effluent	3	5,000	200 (Fe^{2+})	2,000	1,000	50	50	0	1,200 t/time	
• Boiler chemical cleaning										
Waste liquid	9		30,000 (inhibitor)	5,000	5,000	10	10	0	500 t/time	
Cleaning water	2	50,000	100 (Fe^{2+})	5,000	2,000	100	50	0	1,500 t/time	
Design value	5.5 ~9	——	[BOD] 250	200	20	1	5	15		
Waste water standard	5.5 ~9	——	[BOD] 250	200	20	1	5	15		



7.3.7 Others

(1) Preventive Measures of Particulate Emission

(a) Dust suppression during coal handling

The coal unloader, conveyor, etc. have the possibility of dust emission. Countermeasures of dust dispersion are installation of sprinkler, conveyor cover, etc.

(b) Water will be sprinkled to prevent dust dispersion from coal storage yard.

(c) Dust suppression in ash disposal area

To prevent dust dispersion from ash disposal area, water will be sprinkled on the ash, ash will be covered with soil, and so on.

(2) Preventive Measures of Noise/Vibration

Various facilities such as boiler, turbine, compressor, etc. are installed in a power station. These generate noise and vibration during operation. To prevent them, it is desirable to install noise/vibration-generating equipment in-doors inso as far as possible. Of these facilities to be installed outdoors necessary preventive measures should be taken as well as providing a buffer green belt.

7.4 Evaluation of Effects on Environment

7.4.1 Prediction Method

(1) Prediction of Air Diffusion

i) Prediction method of flue gas diffusion

In predicting flue gas diffusion, short-term predictive calculation is conducted using Bosanquet's and Sutton's formula.

Diffusion of flue gas is a phenomenon which changes from time to time both in time and space.

In predicting diffusion in the air, therefore, it is important to be able to utilize effectively information of the natural environment that can be known technically and to select a prediction method applicable to the level of such available information.

Generally, prediction method based on theoretical/ verificative research results include numerical calculation prediction method using computer and experimental method using wind tunnel test apparatus. The effects of atmospheric diffusion in the environment of a power station is predicted mainly by numerical calculation prediction method.

ii) Predictive calculation formulas of short-term diffusion

Predictive calculation of short-term diffusion is conducted using Bosanquet's and Sutton's formulas. The substances of prediction are sulfur oxide, nitrogen oxide and dust. It is assumed that they behave in the same manner.

a) Effective stack height calculation formula by Bosanquet I formula

$$He = Ho + \alpha (Hm + Ht)$$

$$Hm = \frac{4.77}{1 + 0.43 \cdot U/V} \cdot \frac{\sqrt{Q \cdot V}}{U}$$

$$Ht = 6.37g \cdot \frac{Q (T - T_1)}{U^3 \cdot T_1} (\log e J^2 + \frac{2}{J} - 2)$$

$$J = \frac{U^2}{\sqrt{Q \cdot V}} (0.43 \sqrt{\frac{T_1}{g \cdot G}} - 0.28 \cdot \frac{V}{g} \cdot \frac{T_1}{T - T_1}) + 1$$

Where

- He : Effective stack height (m)
- Ho : Actual stack height (m)
- α : Flue gas rising coefficient
- U : Wind velocity (m/s)
- V : Flue gas velocity (m/s)
- Q : Flue gas vol. (m³/s, 28°C equivalent)
- T_1 : Temp. at which flue gas density is equal to atmospheric density (K)
- T : Flue gas temp. (K)
- G : Potential temp. gradient (°C/m)
- g : Gravitational acceleration (9.8m/s²)

b) Sutton's diffusion calculation formula

$$C(X) = \frac{2q \cdot \eta}{\pi \cdot Cy \cdot Cz \cdot U \cdot X^{2-n}} \cdot \exp\left(-\frac{1}{X^{2-n}} \cdot \frac{He^2}{Cz^2}\right)$$

$$Cmax = 0.234 \cdot \frac{Cz}{Cy} \cdot \frac{q}{U \cdot He^2} \cdot \eta$$

$$Xmax = \left(\frac{He}{Cz}\right)^{\frac{2}{2-n}}$$

Where

- $C(X)$: Ground-level concentration in place at distance X on leeward axis (sulfur oxide and nitrogen oxide : m³/m³, dust : kg/m³)
- X : Leeward distance in wind direction (m)
- $Cmax$: Maximum ground-level concentration (sulfur oxide and nitrogen oxide : m³/m³, kg/m³, dust : kg/m³)
- $Xmax$: Distance to place of maximum ground-level concentration (m)
- q : Pollutant emitting rate (sulfur oxide and nitrogen oxide: m³/s 28°C equivalent, dust : kg/m³)
- Cy : Diffusion parameter in horizontal direction
- Cz : Diffusion parameter in vertical direction
- U : Wind velocity (m/s)
- n : Atmospheric disturbance coefficient
- He : Effective stack height
- η : Time correction coefficient

(2) Prediction of Diffusion of Thermal Effluent

i) The prediction method

Cooling water absorbs heat of steam while passing through condenser and is discharged through cooling water outlet. The temperature of cooling water rises about 7 to 9°C at this time.

As the thermal effluent has a temperature higher than the surrounding sea water, it has the property of density current due to reduced density which spreads thinly over the sea surface. Such thermal effluent diffusing and cooling process takes place mainly by the following three physical phenomena which are complicatedly combined.

- Movement of heat by water flow caused by discharge of thermal effluent itself.
- Mixing and dilution with surrounding cool sea water.
- Heat radiation from sea surface to atmosphere.

Meanwhile, the following conditions govern the diffusion of thermal effluent.

a) Discharge conditions of thermal effluent
   - Layout and shape of discharge outlet
   - Discharge velocity
   - Discharge volume
   - Discharge water temperature

b) Natural conditions
   - Coastal and seabed topography
   - Sea water flow and diffusion characteristics
   - Meteorological conditions

Prediction method of diffusion area of thermal effluent are simulation by computer and experiment using hydraulic model.

For this project, it was decided to adopt the simulation model using computer, which is convenient and widely used. The prediction model is "Mostafa A. Shirazi and Lorin R. Davis' formula" developed by the U.S. Environmental Protection Agency (EPA) in 1974 and authorized by the International Atomic Energy Agency (IAEA).

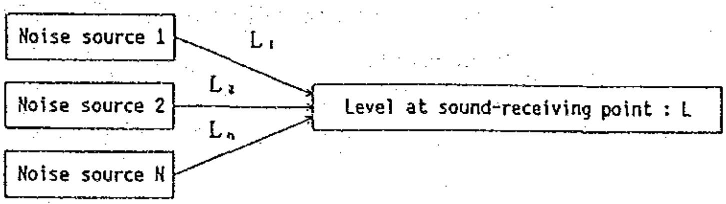
Assuming the temperature difference of water between the intake and outlet to be 8°C, the areas where the sea water temperature rise in front of the discharge outlet is 1°C and 3°C were predicted.

(3) Prediction of Noise

It is difficult to predict influence of noise of a power station with a certain degree of precision in the feasibility study stage even if computer is used. Therefore, as a standard for studying the problem of noise, predictive calculation was conducted using personal computer for this report.

i) Outline of calculation method

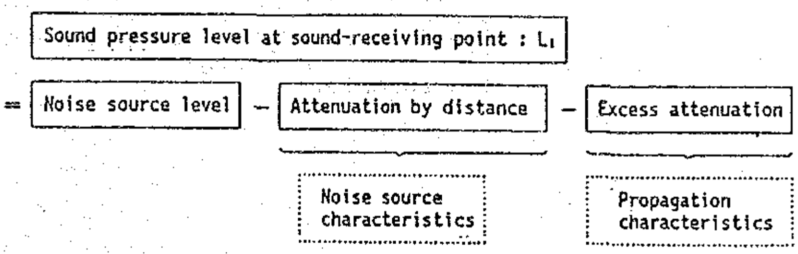
The sound pressure level at a sound-receiving point by number of pieces of noise source equipment in a plant is obtained by the following formula.



$$L = 10 \log \left(10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}} + 10^{\frac{L_n}{10}} \right)$$

L : Sound pressure level at sound-receiving point (dB)

L_1 : Sound pressure level at sound-receiving point if noise source 1 exists independently (dB)



ii) Predictive calculation formula (point noise source)

Prediction of noise level caused by power station operation was calculated by the following formula in consideration of attenuation by distance, effects of sound barrier, absorption in air, etc.

$$SPL = PWL - 20 \log r - 8 - Ar - A_E$$

where,

- SPL : Sound pressure level at prediction point (dB-A)
- PWL : Power level of noise source (dB-A)
- r : Distance from noise source to prediction point (m)
- Ar : Attenuation by barrier (dB-A) (Note 1)
- A_E : Attenuation by absorption in air (dB-A) (Note 2)

Note 1: Attenuation by barrier

Fresnel number (N) is calculated from the difference between direct sound and barrier diffraction sound paths between the noise source and the prediction point and the attenuation is obtained using Figure 7.4-1.

Note 2: Attenuation by absorption in air "A_E"

The following approximate formula of Beranek (I) was used.

$$A_E = 5.5 \times f \times r \times 10^{-6}$$

where; f: frequency
r: distance between sound-receiving point and noise source

The overall noise in dB(A) was calculated from the octave band component using the reaching noise from the noise source obtained by the above formula.

(a) Compensation of A-characteristic

SPL(A)f was obtained by compensation of A-characteristic shown in the table below on the octave band component SPLf.

SPL (A) f = SPL f + f

f (Hz)	63	125	250	500	1000	2000
f (dB)	-26	-16	-9	-3	0	+1

(b) Composition of SPL(A)f

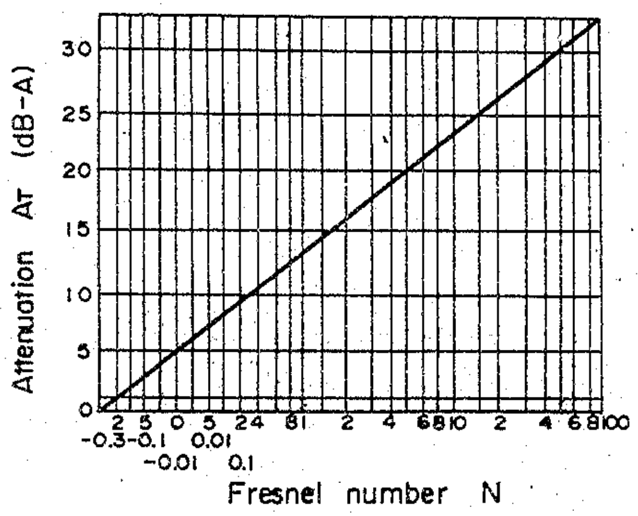
The overall reaching noise in dB(A) was obtained by composing SPL(A)f by the following formula.

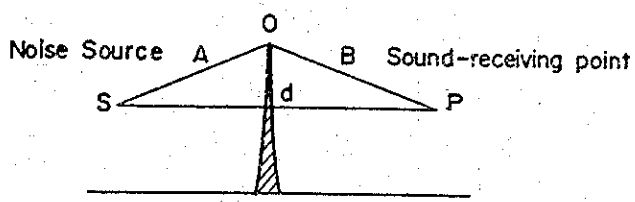
$$dB(A) = 10 \log_{10} \left\{ \sum_{f} 10^{\frac{SPL(A)f}{10}} \right\}$$

f = 63, 125, 250, 500, 1000, 2000 (Hz)

Figure 7.4-1 Attenuation by Barrier

N is calculated from the difference between the direct sound and barrier diffraction sound paths between the noise source and the prediction point and the attenuation is obtained using the following chart.





$$N = \frac{2}{\lambda}(A + B - d)$$

λ = Acoustic wave length (m) = c/f

f = Frequency (Hz)

c = Speed of sound in air (m/s)

7.4.2 Results and Evaluation of the Prediction

(1) Ambient Air Quality

i) Calculation Conditions

The calculation conditions for Sutton's diffusion formula are based on the assumption of wind velocity to be 5 m/s and stability of atmosphere to be neutral. Table 7.4-1 shows the constants used in this calculation.

The calculation conditions of the flue gas are based on the value of rated output of boiler (Table 7.4-2).

Table 7.4-1 Constants of Calculation Formula

Item		Unit	1 Hour Value	24 Hour Value
Ground level concentration		—	Sutton's formula	
Effective stack height		—	Bosanqet's formula	
Atmospheric conditions	Ambient	℃	28	28
	Wind velocity	m/s	5	5
	Diffusion parameter	—	Cy=Cz=0.07	Cy=Cz=0.07
	Atmospheric disturbance coefficient	—	n =0.25	n =0.25
	Temperature gradient	℃/m	G =0.0033	G =0.0033
	Flue gas rising coefficient	—	α =0.65	α =0.65
Time correction coefficient		—	η =0.15	η =0.15×0.59 =0.089

Table 7.4-2 Calculation Conditions of the Flue Gas Source

Item			Unit	Unit No.1	Unit No.2	Total
Stack		Type	—	serve 2 boilers		—
		Height from G.L	m	120		—
		Equivalent Diameter	m	4	4	5.7
Flue gas volume (wet gas)			$10^3 m^3N/h$	941	941	1,882
Stack outlet gas		Temp.	℃	130	130	—
		Speed	m/s	30	30	—
Emission concentration and volume	Sulfur oxide	Emission concentration	ppm	936	936	—
		Emission volume	m^3N/h	803	803	1,606
	Nitrogen oxide	Emission concentration	ppm	550	550	—
		Emission volume	m^3N/h	500	500	1,000
	Particulate	Emission concentration	mg/m^3N	181	181	—
		Emission volume	kg/h	155	155	310

Nate: (1) Each values are at the rated out put of the boiler.
Coal blending ratio is 50/50 wt% of semirara/lemington.

(2) The emission concentration is calculated under the dry-gas basis.

(3) The emission concentration of the nitrogen-oxide is converted to the value of 6%- oxygen

ii) Calculation Results

Table 7.4-3 shows the maximum ground-level concentration and distances of maximum ground-level concentration.

Fig. 7.4-2 shows ground-level concentration curves.

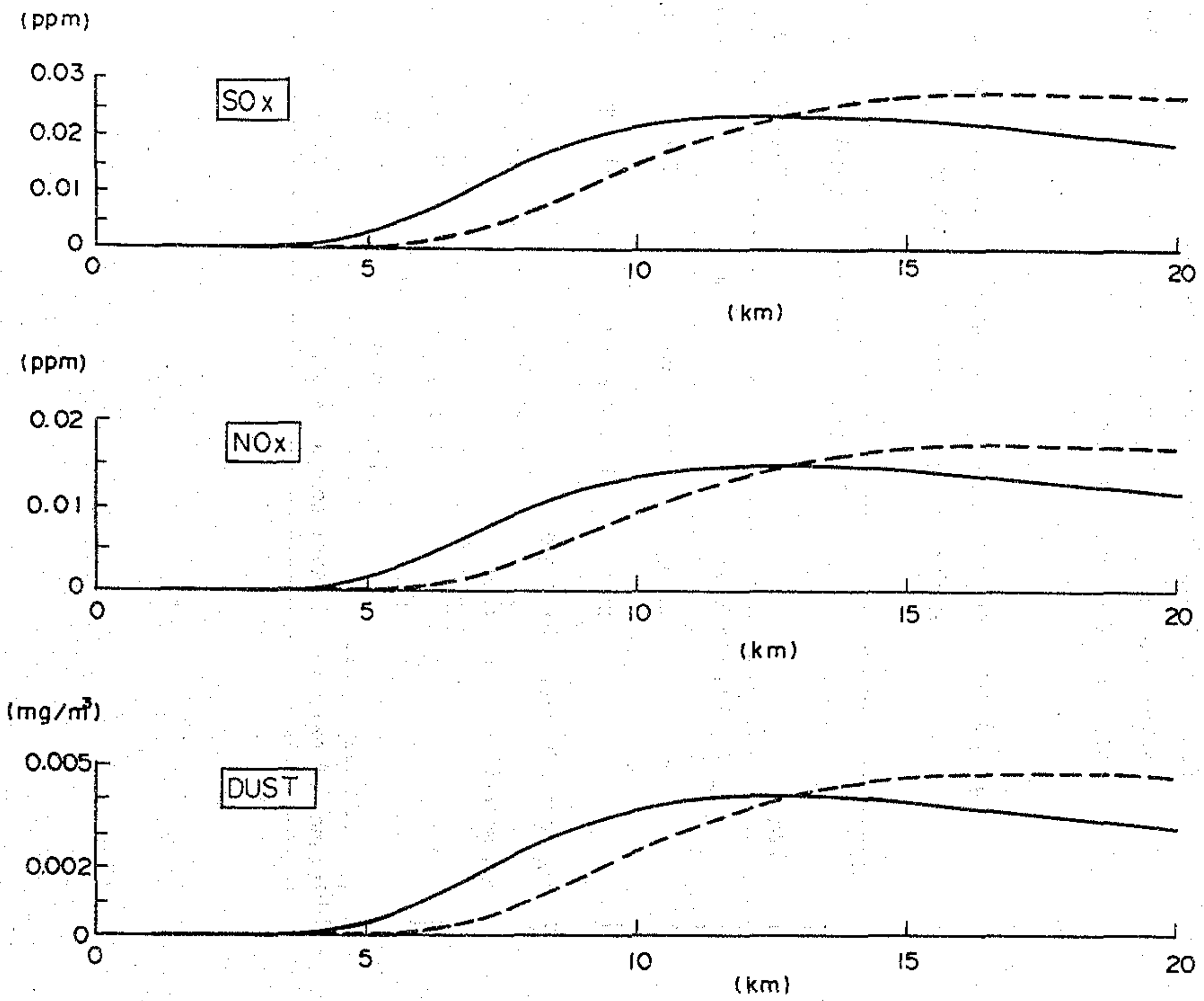
iii) Evaluation of Effects on Environment

According to the predictive calculation results of the above mentioned short-term diffusion, the contributed concentration of sulfur oxide, nitrogen oxide and particulate from unit 1 and 2 to the ground is extremely low. The environment is scarcely expected to be affected by the emissions from unit 1 and 2.

Table 7.4-3 Maximum Ground-Level Concentration and Distance of Maximum Ground-Level Concentration

Item \ Operation condition				1-unit operation	2-unit operation
Effective stack height			m	270	354
Max. ground-level concentration	Sulfur oxide	1-hour value	ppm	0.0237	0.0276
		24-hour value		0.0140	0.0163
	Nitrogen oxide	1-hour value	ppm	0.0148	0.0172
	Dust	1-hour value	mg/m²	0.0041	0.0048
		24-hour value		0.0024	0.0028
Distance of max. ground-level concentration			km	12.5	17.1

Fig.7.4-2 Ground Level Concentration Curve (Hourly Average)



Remarks	
———	1unit operation
- - - -	2units operation

SOx

	Cmax.	Xmax.
1 unit ope.	0.0237ppm	12.5km
2 units ope.	0.0276ppm	17.1km

NOx

	Cmax.	Xmax.
1 unit ope.	0.0148ppm	12.5km
2 units ope.	0.0172 ppm	17.1km

DUST

	Cmax.	Xmax.
1 unit ope.	0.0041mg/m³	12.5km
2 units ope.	0.0048mg/m³	17.1km

(2) Thermal Effluent

1) Calculation Conditions

The calculation conditions are decided taking into consideration plant layout, operating condition, meteorological and tidal conditions of the site.

(a) Discharge

Discharge rate	:	25.0 m^3/s (2 units operation)
Initial discharge velocity	:	0.7 m/s
Width of outlet	:	11.0 m
Water depth	:	3.3 m

(b) Intake water quality

Water temperature	:	31°C
Salt content	:	3%
Density	:	1.0176659

(c) Discharge water quality

Water temperature	:	39°C
Salt content	:	3%
Density	:	1.0146516

(d) Tidal current

The following three cases are assumed based on the observation results of current direction and velocity at the site, and to be on the conservative side of predicted valves.

i) No current at the sea
ii) Stable current : 0.05 m/s
iii) Stable current : 0.15 m/s

2) Calculation Results

Table 7.4-4 shows the reaching distance and the diffusion area in each case of 1°C increase and 3°C increase areas on the sea surface.

Fig. 7.4-3 shows the envelope of distribution area of thermal effluent.

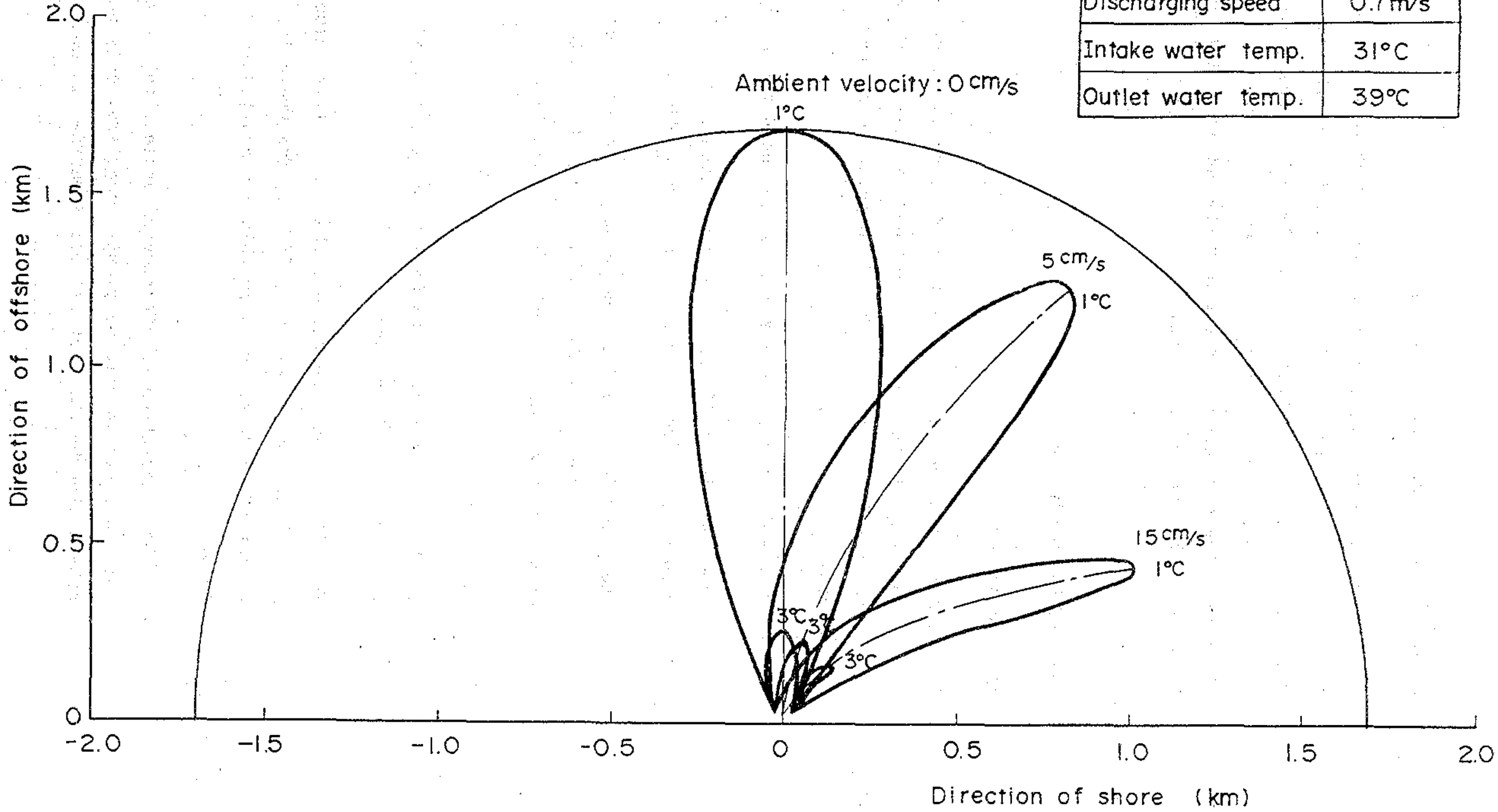
As a result of the calculation, the maximum values of both of reaching distance toward offshore and diffusion area in the 1°C increase area, at the no-current condition are 1.7 km and 0.67 km^2 respectively. The 3°C increase area of the reaching distance toward offshore and the diffusion area are 0.3 km and 0.01 km^2, respectively.

The maximum reaching distance in the coastal direction appear when the stable current velocity is the maximum (V = 0.15 m/s). It is 1.0 km at 1°C and 0.1 km at 3°C, respectively.

As this prediction is by simple method, the envelope of distribution is expressed as half-circle distribution having a radius of maximum reaching distance.

Table 7.4-4 Simulation Results

Case	Discharged Volume (m^3)	Intake Water Temp. (℃)	Permanent Current Velocity (m/s)	1℃ Increase Area			3℃ Increase Area		
				Reaching Distance (km)		Diffusion Area (km^2)	Reaching Distance (km)		Diffusion Area (km^2)
				Coastal Direction	Toward Offshore		Coastal Direction	Toward Offshore	
1	25	31	0.0	0.274	1.704	0.6741	0.030	0.252	0.0134
2			0.05	0.840	1.266	0.4029	0.064	0.236	0.0114
3			0.15	1.014	0.465	0.1387	0.141	0.177	0.0083



Discharging volume	25 m³/s
Discharging speed	0.7 m/s
Intake water temp.	31°C
Outlet water temp.	39°C

Fig.7.4-3 Envelope Distribution of Thermal Effluent

3) Evaluation of Effects on Environment

The 1°C increase area by thermal effluent turned out to be 1.7 km in terms of reaching distance toward offshore and 0.67 km^2 in terms of diffusion area. The 3°C increase area turned out to be 0.3 km and 0.01 km^2 respectively. Therefore, the environment of the surrounding area will not be affected by thermal effluent.

(3) Noise

1) Calculation Conditions

(a) Noise source

- All the noise sources are assumed to be point noise sources. Those which are regarded as line or plane noise sources are converted into point noise sources.

  Each noise source is assumed to have no directivity.

- The power level of the noises are given in 6 bands with central frequency from 63 Hz to 2,000 Hz.

- The power level (Lw) of the noises at input point are the values of sound pressure level (Lp) which is obtained on the machine side by calculation.

(b) Barrier

- The barrier is assumed to be a thin wall erected vertically on the ground.

- For diffraction attenuation, the upper limit value of attenuation is set to be 25 dB. The Fresnel number (N) corresponding to this attenuation is N = 15.8.

- In the calculation of diffraction attenuation where there are two or more overlapped barriers, only the attenuation by the most effective barrier is considered and all the effects of the other barriers are neglected.

The barrier transmissive sound is neglected.

2) Input Data

(a) Noise source data format

Number of noise sources		
Night time	:	86 points
Day time	:	143 points
Height	:	as meter
Position	:	as meter
Power level	:	as dB

(b) Barrier data format

Number of barrier	:	48 sheets
Height	:	as meter
Position	:	as meter

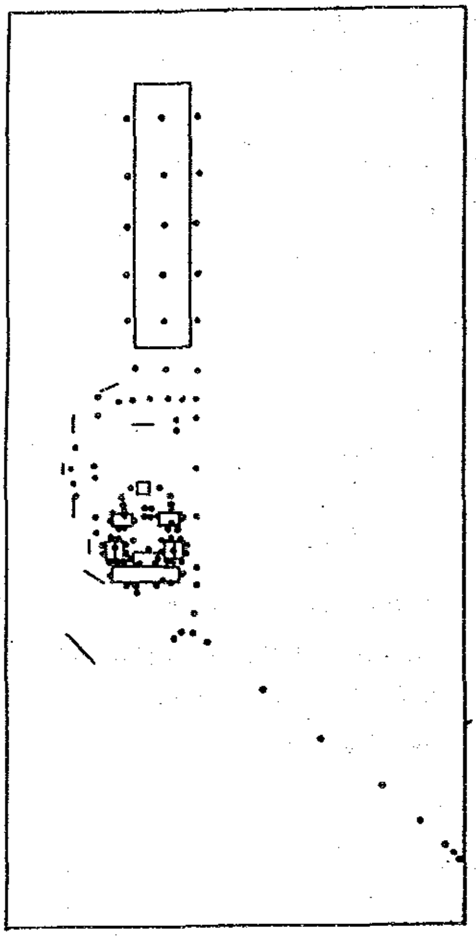
3) Calculation Results

Fig. 7.4-5 shows the noise level contour map around the power station when the coal unloading and conveying equipment are stopped during the night-time, and Fig. 7.4-6 shows the noise level contour map during the day time when they are in operation.

4) Evaluation of Effects on Environment

The environmental standard of the noise level during night-time is stipulated as 45 dB and 55 dB for residential and commercial areas respectively. If operation of coal unloading and conveying equipment during the night-time is also considered, it is necessary to study noise reduction measures depending on the designation of area type in the future.

Figure 7.4-4 Noise Source and Barrier Position



—— Barrier position

• Noise source position

Major Noise Source Levels

(dB·A)

Major Noise Source	SPL	PWL
Boiler house	63	
Turbine house	65	
Main transformer		109
Induced draft fan		125
Circulation water pump		107

Major Barriers

(m)

Major Barrier	W x D x HxUnit
Boiler house	20.5x42.5x80x2
Turbine house	137x34 x30x1
Bunker room	16x42.5x40x2
Dust collector	36x25 x23x2
Coal storage yard	100x520 x13x1

Figure 7.4-5 Noise Level Contour Map
(during Nighttime)*

* Note
To be applied in the case that the coal handling facilities are stopped.

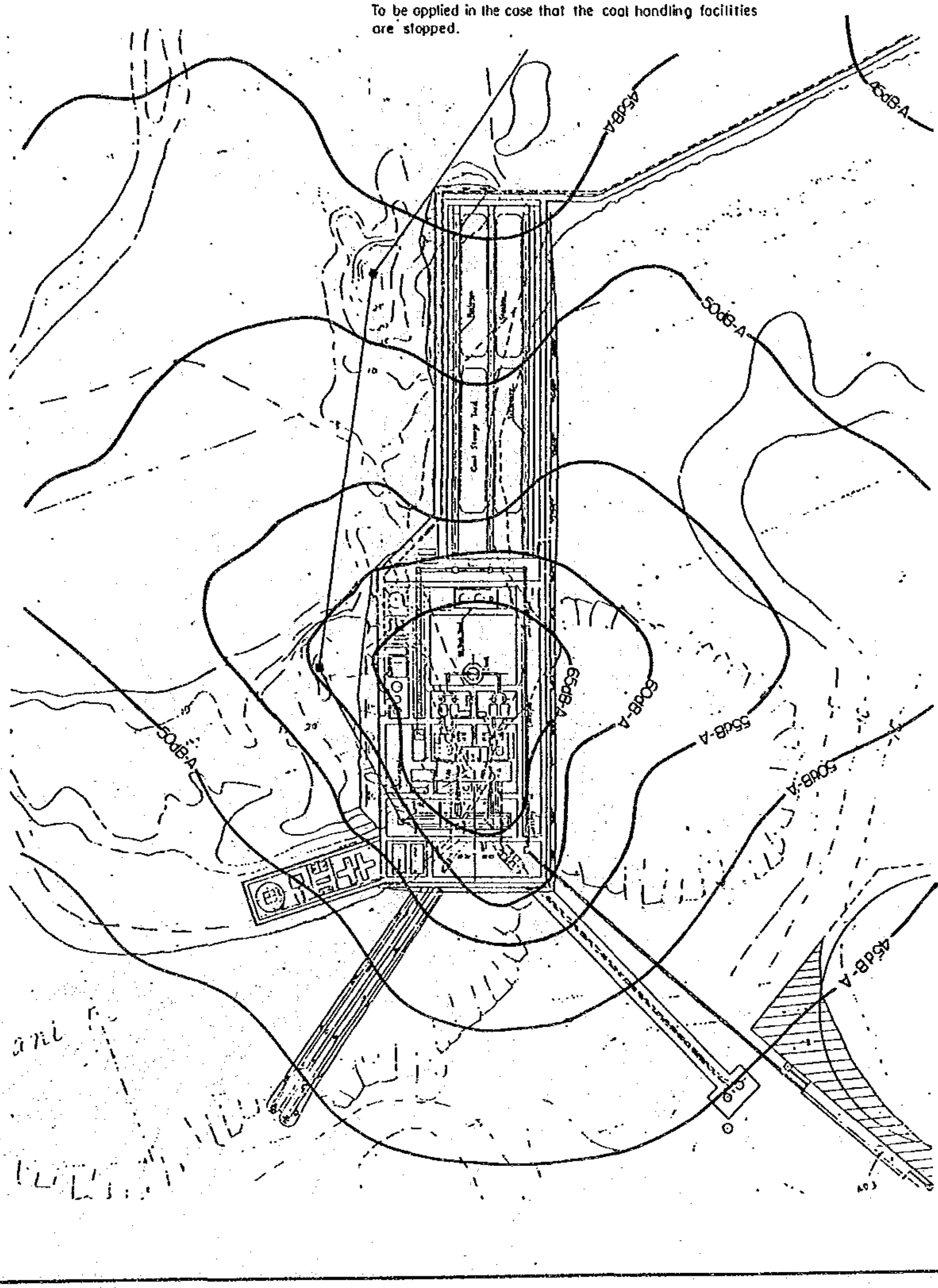
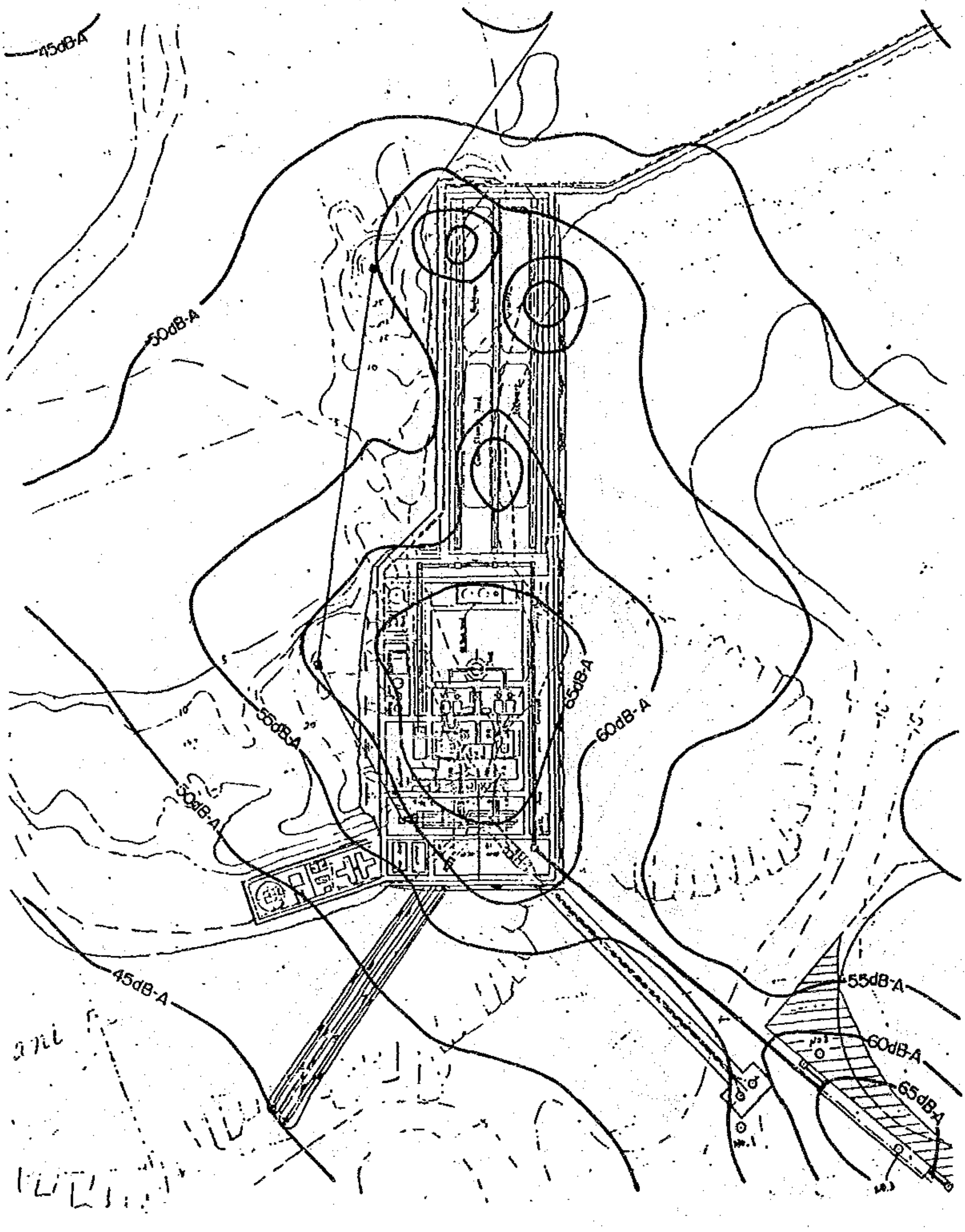


Figure 7.4-6 Noise Level Contour Map

(during Daytime)



7.5 Monitoring of the Environment

The prediction of the environment caused by plant operation is as stated above. However, it is expected that the local inhabitants and government concerned will want these predicted values to be verified.

Under such circumstances, it is desirable that NAPOCOR monitor the environment in the surrounding area before and after the taken-over of the power station to survey the degree of changes and effects in order to win the understanding and trust of those concerned.

Table 7.5-1 shows desirable monitoring items, timing and places. In order to compare the conditions before and after the power station taken-over, it is recommended that the monitoring be started 18 months before the commissioning of unit No. 1 (about 1 year before initial firing).

Among the monitoring items, air pollution is to be measured at the points shown in Fig. 7.5-1 in consideration of the predicted ground-level concentration, wind direction and population density. It would be economical to mount the monitoring equipment for all the items on one car and to make measurements at four points every week by mobile measurement.

At each monitoring point, a fixed place should be selected to see the fluctuations in measurements without being affected by automobile emission.

After initial firing, it becomes necessary to monitor the pollutants emitted from the stack.

While the power station is being constructed, it is recommended that the environment in the surrounding area be monitored on the basis of the items to be selected.

Table 7.5-1 Monitoring Items

Category	Item	Place	Timing	Remarks
Atmosphere	SOx NOx Dust Wind direction Wind velocity Air temp.	4 points shown in separate figure	1 time/month at each point (1-week continuous recording at each point)	Mobile measuring station
Water Quality	P.H SS Water temp.	Intake Outlet Ash disposal area wast water	1 time/month	Manual analysis
Noise	——	10 points along power station	1 time/month (daytime and night)	Manual analysis
Vibration	——	ditto	1 time/year	Manual analysis
Flue gas	SOx NOx Dust Gas temp.	Stack or flue	Continuous recording	Full time monitoring at Power Station

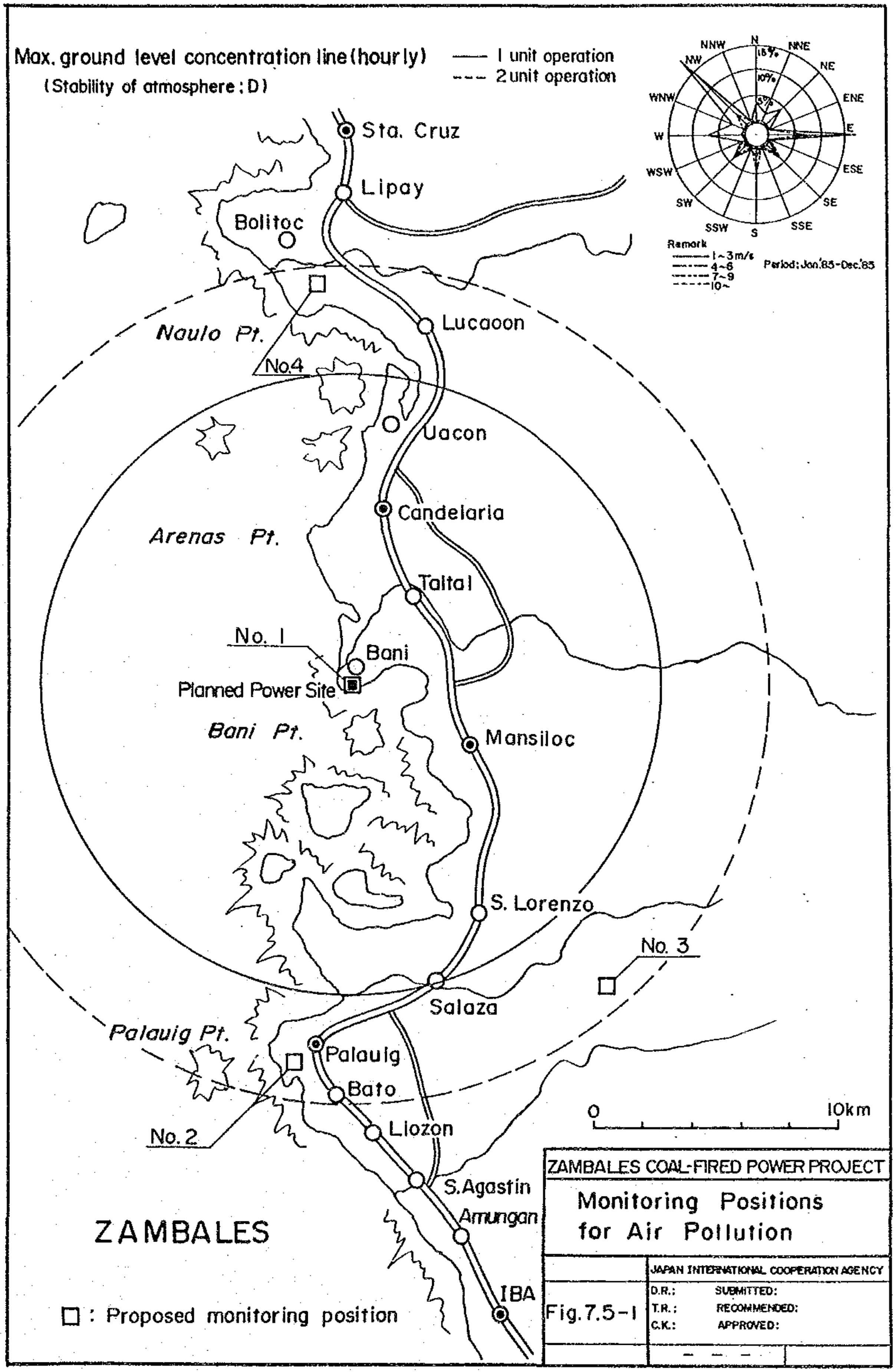


Fig.7.5-1 Monitoring Positions for Air Pollution

CHAPTER 8

PROJECT SCHEDULES

Chapter 8 Project Schedules

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CHAPTER 8 PROJECT SCHEDULES

8.1 General

The schedule for planning and construction of a coal fired power plant of 2 x 300 MW at the Masinloc site can be roughly divided into two (2) stages. The schedule prior to commencing construction, after submission of this feasibility study report in March, 1990, is selection of contractor, and award of contract. 30 months will be needed for the preparatory stage. The schedule for construction will be 43 months from the award of the contract until taking over of No. 1 unit. From this time schedule, the award of the contract will be October, 1992, and taking over of No. 1 unit will be May, 1996. No. 2 unit will be scheduled to start operation 6 months after taking over No. 1 unit.

8.2 Various Procedures Prior to Undertaking Construction

The project schedule prior to undertaking construction has been attached as Fig. 8-1. The following matters are involved as procedures to be undertaken prior to construction:

1) Arrangement of financing to be performed by NAPOCOR

2) Negotiation to obtain the required land (including negotiation and other matters related to utilization of freshwater source)

3) Loan approval

4) Preparation of tender documents by NAPOCOR

5) Selection of consultant

6) Selection of contractor

In order to implement this project as early as possible, it is considered that it would be necessary to smoothly advance the work up to the following three (3) critical points from among the schedules to be performed prior to undertaking award of contract. The first is the arrangement of financing. NAPOCOR must prepare necessary documents for arranging of financing as soon as possible after receiving this feasibility report, and to obtain the approvals of the competent authorities. The second is the preparation of tender documents. NAPOCOR is at present implementing the construction of Calaca power plant. It is the aim of NAPOCOR to prepare the tender documents with the experience gained with the Calaca power project and with the information of the preliminary design of this report. The third is the selection of the contractor. In order to implement this project smoothly and at an early stage, this report has been made under the premise that the project will be awarded on a full turn key basis. Under the above premise, the milestone will be as follows:

Loan Approval	January, 1991
Consultancy Contract	July, 1991
Tendering	October, 1991

8.3 Construction Schedule

Construction schedule after the contract has been awarded is shown in Fig. 8-2. This schedule has been prepared taking into consideration construction experience gained in coal-fired thermal power projects of similar scale constructed in Japan and overseas.

The six (6) month period from award of contract to commencement of work would be the design period for civil structures based on equipment design data.

The main milestone of No. 1 unit are as shown below. All milestones for No. 2 unit would be scheduled to proceed six (6) months after No. 1 unit.

Commencement of Work	April, 1993
Steel Erection	May, 1994
Drum Lifting	November, 1994
Hydraulic Test	May, 1995
Initial Firing	November, 1995
Steam Admission	January, 1996
Taking Over	May, 1996

Fig. 8-1 Zambales Coal-Fired Power Project Schedule

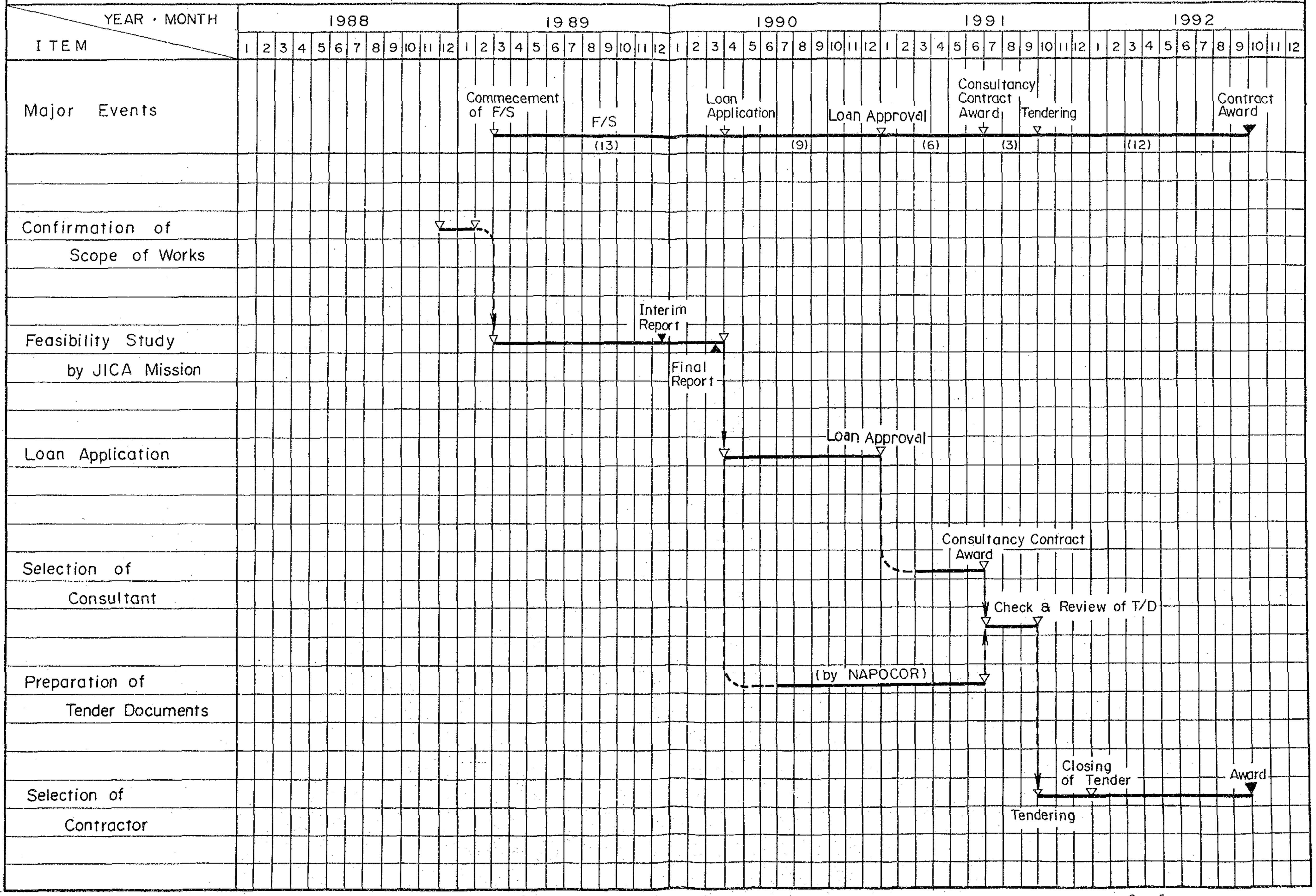

Fig. 8-2 Zambales Coal-Fired Power Project Construction Schedule