11.5.6 Lignite, Limestone Crushing and Mixing Facilities

From the pilot combustion test, it is confirmed that the lignite, limestone crushing process has key point for the desulfurization efficiency of A-FBC.

The confirmed items are as follows;

i.	Lignite size	:	10 mm under and 20 mm under has same desulfurization efficiency.
ii.	Limestone size	:	3 mm under size has better desulfurization than 10 mm under size. The smaller size of limestone also has better desulfurization.
iii.	Powder of lignite	:	The powder of lignite increases the SOx emission density 200~300 ppm by the over feeding system and 100~150 ppm by the under feeding system.
iv.	Overflow B.M.	:	The amount of the overflow B.M. is almost same amount of fly ash. The component of the overflow B.M. is consisted of Ca-compound and less amount of the SiO_2 is recognized in the overflow B.M.
v.	Unborn Carbon	:	Less than 1% of the unborn carbon was recognized in the ash because of the high content of volatile matter.

From the above points, the following sizing is recommended for the A-FBC.

Lignite : 20 mm under, Less powder
Limestone : 3 mm under, Much powder

To achieve the above condition, the roller crusher is recommended to apply for the lignite and the hummer crusher for the limestone. Table 11-18 shows the particular of the respective crushing machine.

Table 11-18 Particular of Crushing Machine

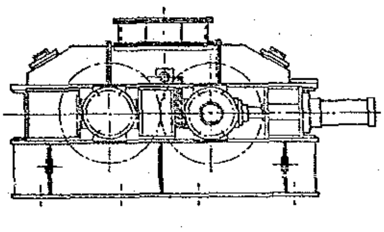
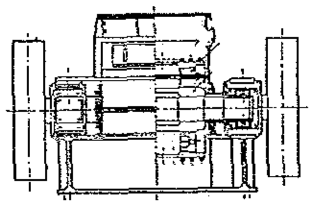
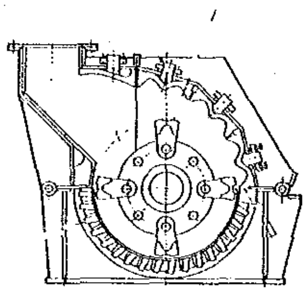
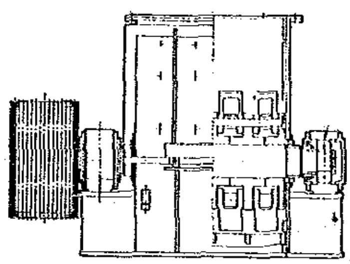
	Roller Crusher	Hammer Crusher
Outline	 	 
Crushing Rate	4 - 5	more than 20
Particular	• Less Powder Particle • Good performance for high moisture material • Easy tuning of sizing	• High crushing rate and powder particle content • Less maintenance cost for limestone crushing

Fig. 11-12 shows the lignite limestone preparation system. The lignite and limestone mixing is carried out on the conveyor with the coarse mixing as shown in Fig. 11-12.

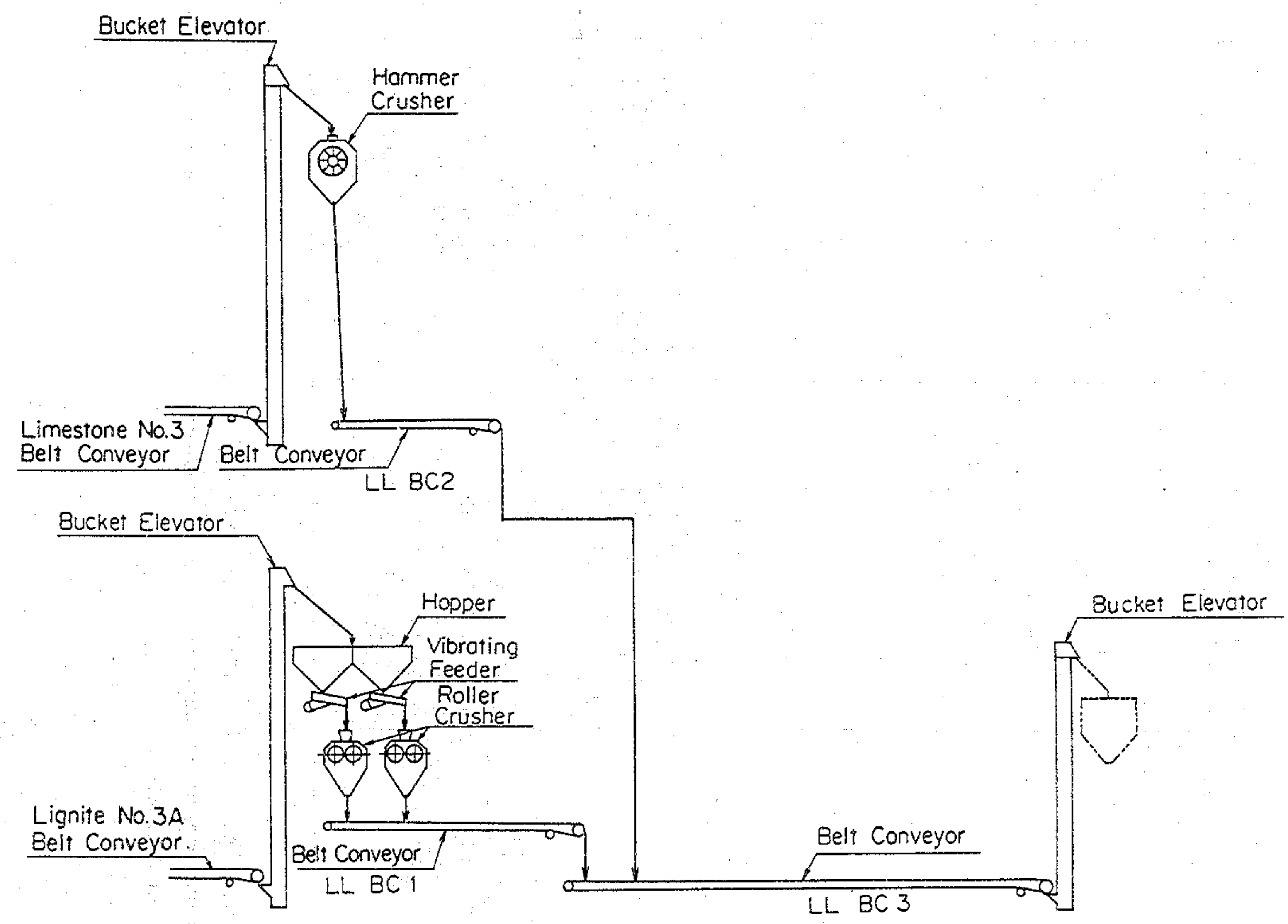


Fig. 11-12 Lignite Limestone Preparation System

11.5.7 Lignite-Limestone Bunker and Conveying Facilities

The lignite-limestone bunker stores the mixture of large and medium size of lignite and limestone for being fed to the FBC boiler by the spreader type feeders with over feeding method. The bunkers are designed to be installed with same number of the spreader type feeders. Since the spreader can feed the lignite up to 7 ~ 8 m only, the feeders are installed on both side of boiler and the bunkers also installed on both side of boiler.

The capacity of bunker has equivalent amount of 12 hours full operation to meet the two shift operation for the lignite and limestone preparation system, (2 shift x 8 hours). As atternate plan, 10 hours full operation capacity is also designed in the study. The mean operation time of conveyor is designed 12 hours per day. The capacity of the dispatching conveyor is designed 500 t/h (100 t/h x 24 hours ÷ 12 hours x 2 units x 1.25). The capacity of the shuttle conveyor No.1 and the conveyor tripper No.2 are designed 275 t/h (>100t/h x 24 hours ÷ 12 hours x $\frac{60}{56}$ x 1.25) Fig. 11-13 shows the time schedule of the bunker operation in respective case.

From the above point, each lignite-limestone bunker is designed to have a capacity 150 ton for 12 hours and 125 ton for 10 hours bunker as shown in Fig. 11-14.

For the further strict regulation of SOx emission, the operation time shall be prolonged by applying the automatic control system in later stage. (130 t/h for Ca/S Molar Ratio 4) x 24hours ÷ 14hours x 2unit x 1.1 < 500t/h).

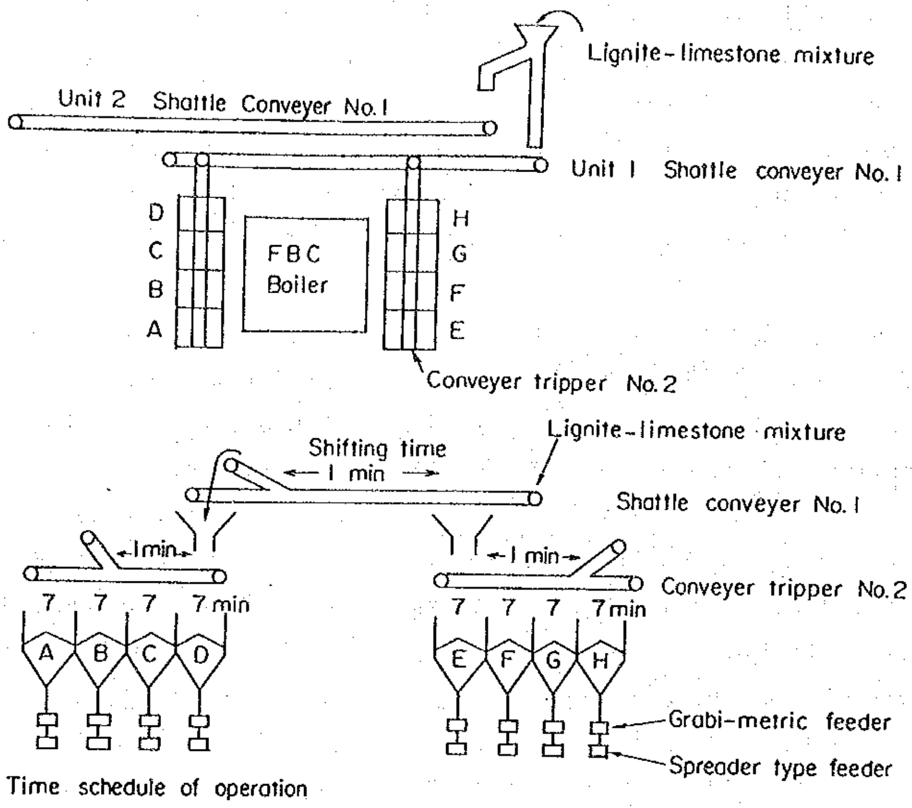
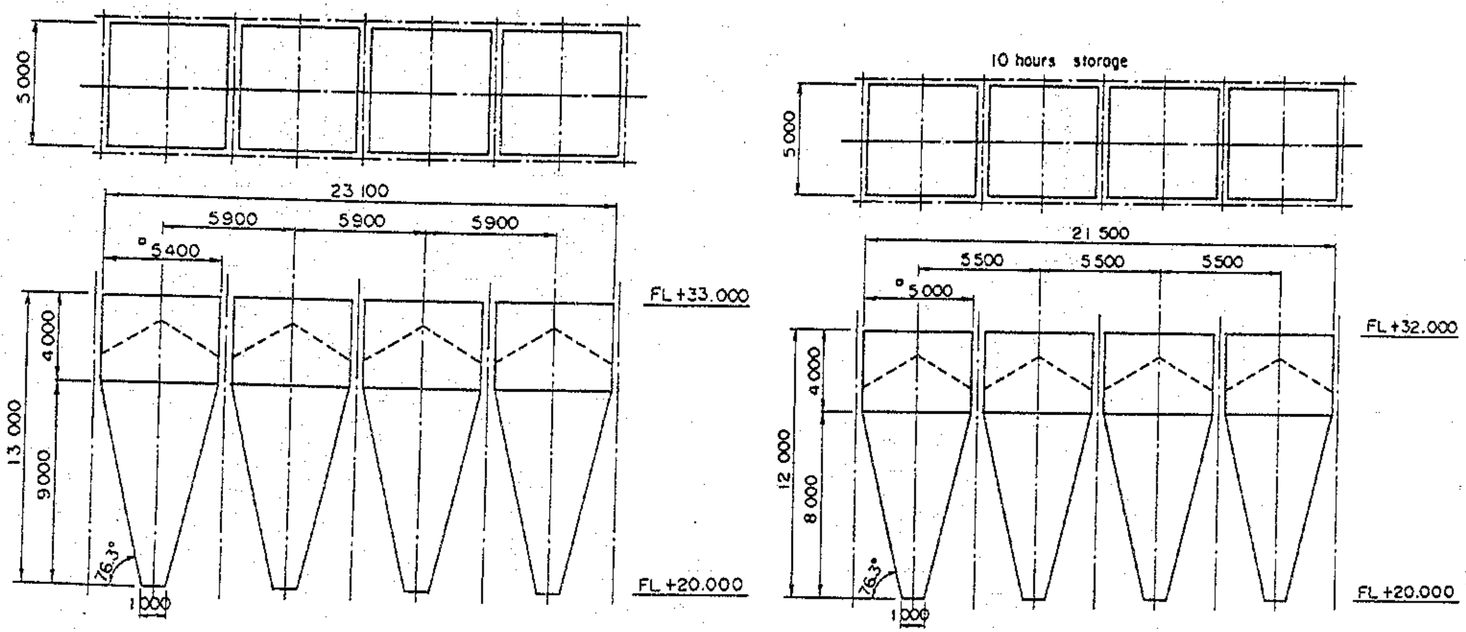


Fig. 11-13 Time Schedule of Bunker Operation

Time schedule of operation

7:30	Preparation of operation
8:30	Start feeding to bunker (Morning) Every 7 minutes, the lignite limestone mixture is feeding to the respective bunker and 4 minutes per hour is idle time for the shift movement of the shuttle conveyors.
12:00	Lunch time
13:00	Preparation time
13:15	Start feeding to bunker (Afternoon)
18:00 19:00	Dinner time
19:15	Start feeding to bunker (Night)
23:00	Stop feeding to bunker
23:30	Finish the day work

Note) Bunkering time is altered to 3min in case of 10hours storage.



Design Condition

	Case 1	Case 2
1. Storage	12 hours storage 150 ton	10 hours storage 125 ton
2. Relative density	1.4	1.4
3. Number of Bunker for Unit	8	8

Fig. 11-14 Lignite-Limestone Bunker
(One side of one boiler)

11.6 Oil Storage Tank

11.6.1 Light Oil Storage Tank

The light oil is utilized for the heating of the bed materials above 800°C which ignites the lignite during the start up of the FBC boiler. As the process of the start up, the draft system will be started first to fluidize a part of the fluidized bed which called as a starting cell as shown in Fig. 11-15.

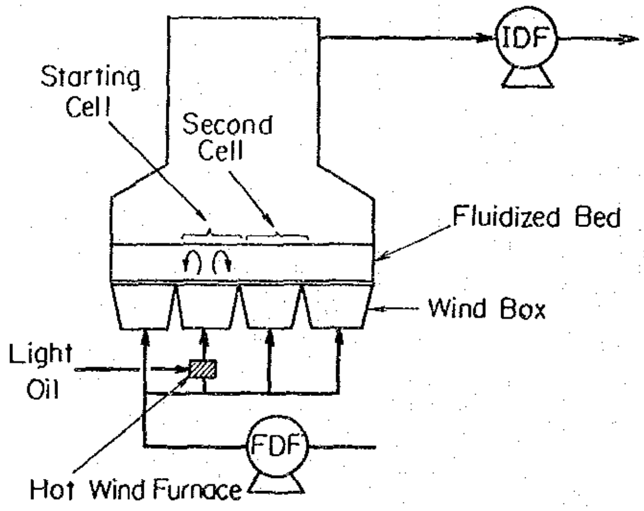


Fig. 11-5 FBC Boiler Start-up Outline

The light oil is utilized to heat this starting cell up to 800°C around through the hot flue gas of the light oil. After heating up the starting cell, the lignite will be fed on this starting cell and the light oil feeding is stopped. The light oil is utilized 2 hours every start up as shown in Fig. 11-16 and the required amount of the light oil is 1,600 kg/h.

Taking into consideration of 20 times start-up for the light oil tank, the required amount of the light oil is 64 t. With the relative density 0.8, 80 kl light oil storage tank is required for the project.

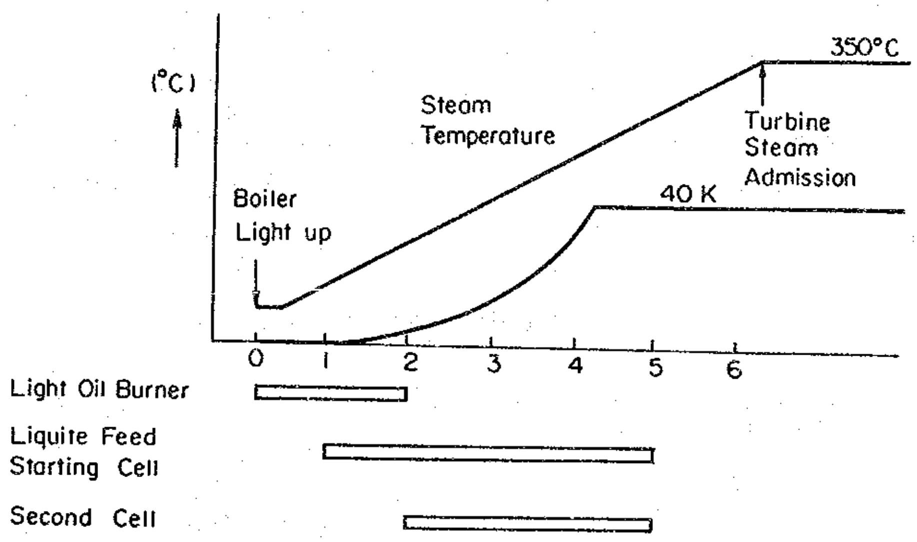


Fig. 11-16 FBC Boiler Start-up Process

11.7 Raw Water Supply

11.7.1 Quantity of Raw Water Supply

The FBC boiler system requests the raw water for the boiler make up and the general service. In case of applying the wet DeSOx system, another 420 T/Day of raw water will be requested. The ash handling system applies the dry treatment system, so that the considerable amount of water will not be requested in the system. Table 11-19 shows the typical water quantity requested by 2x75 MW power station.

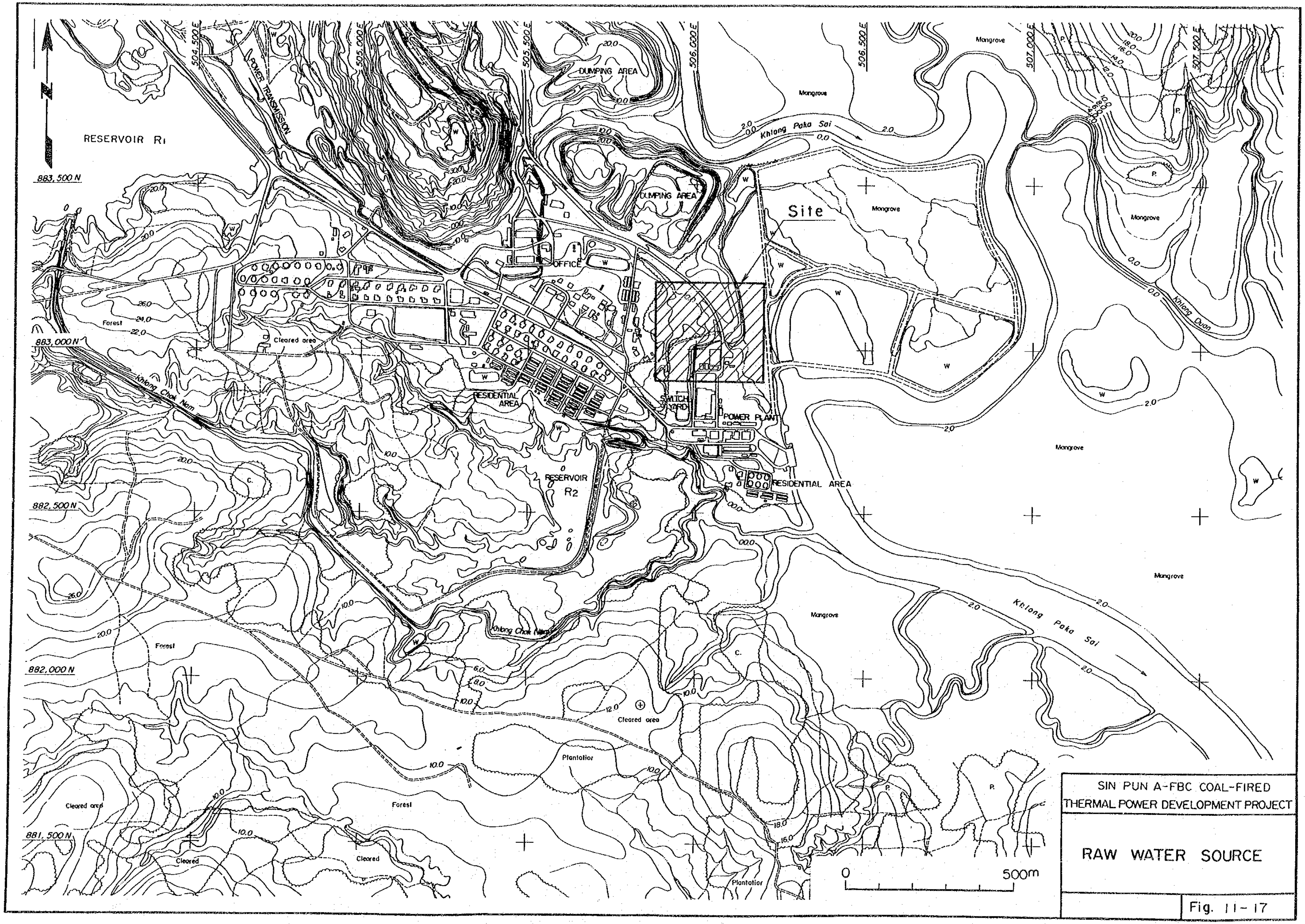
Table 11-19 Raw Water Request in Krabi Site

Boiler Make up Water	150 T/Day
General Service Water	150 T/Day
Total	300 T/Day

Since the large water reservoir is existing inside the power station, 3 days storage tank of raw water is enough to supply the necessary raw water even taking into account of the repair work on the water receiving pipes. The 1,000 m^3 tank is designed for the project. The tank is located in vicinity of the demineralized plant and the office for the optimum design as shown in Fig. 11-4.

11.7.2 Selection of Raw Water Supply Sources

As for the raw water supply source, reservoirs R1 and R2 showing Fig. 11-17 seem to have surplus capacity even for a new power plant, though they are already used as raw water sources for the existing Krabi 1 Power Plant. The distance from the project site to the reservoirs R1 and R2 is approximately 500 m and 1,500 m respectively. Water pumping stations having appropriate capacities will be prepared to supply raw water to the Power Plant over those distances by means of pipelines.



SIN PUN A-FBC COAL-FIRED THERMAL POWER DEVELOPMENT PROJECT

RAW WATER SOURCE

Fig. 11-17

11.8 FBC Boiler System

11.8.1 FBC Boiler

(1) Basic Condition

Sin Pun FBC boiler is designed based on the experience of Wakamatsu FBC (50 MW) in Japan and the combustion test result. The basic conditions for the design are shown in Table 11-20.

Table 11-20 Basic Design Condition of A-FBC

Type	Atmospheric Building Type
Bed Load	1.2 x 10^6 kcal/m^2·h (L.H.V.)
Height of Bed	1,200 mm
Space Velocity	Max 2.0 m/s
Air Ratio	1.2
Bed Temperature	800°C - 850°C

(2) Boiler

Self stantion FBC boiler is applied for the economical design as shown in Fig. 11-18. From the combustion test, it is confirmed that the lignite is burnt with the high efficiency 99% with the one bed cell and the long pass free board zone is not requested to let the unburn carbon burn. It is also confirmed by the pilot scale combustion test that the emission of NOx is low as the level of 150 ppm with the free board height 7 m which is enough to let NOx reduce in the reduction atmosphere. Therefore, FBC boiler is designed with the height 14.5 m only including the fhuidized bed and the fuel gas pass. Since the lateral force in Krabi area is only 0.07, and the low boiler height, the boiler is designed with the self stantion type. The concrete structure is designed for the basement of the boiler. In this concrete structure, the B.M. cooler is installed since the extraction pipe of B.M. shall be straight to let B.M. fall by the gravity because of the high temperature 850°C.

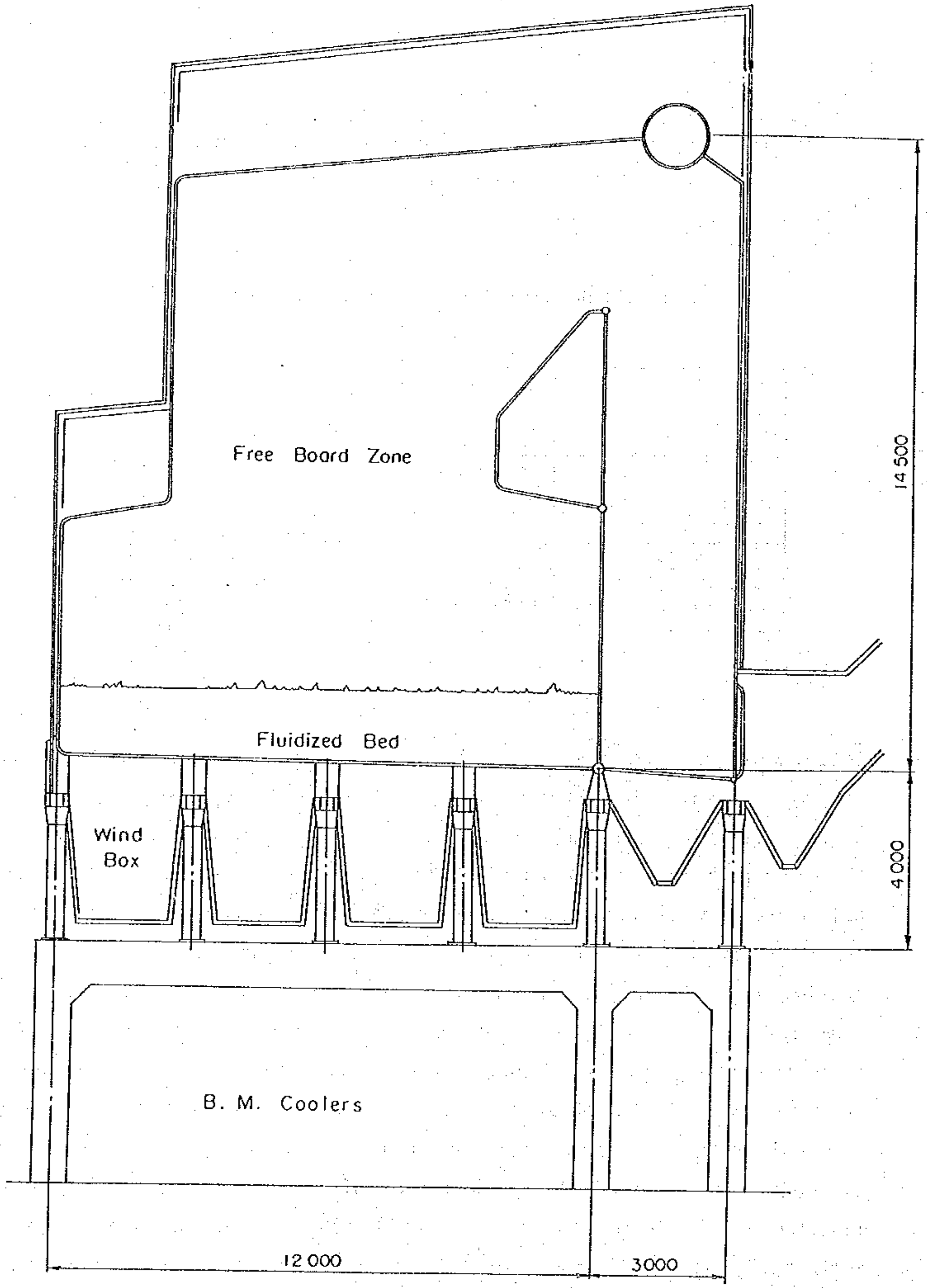


Fig. 11-18 Outline of A-FBC for Sin Pun Lignite

The bed surface for 75 MW is culculated as follows;

$$\frac{75,000kW \times 860kcal/kWh}{0.409 \times 0.86 \times 0.97 \times 1,200,000kcal/m^2 \cdot h} \times 1.1 = 173m^2$$

(0.86: Boiler Efficiency for Ca/s moler ratio 3 for the future SOx emission regulation)

With the above required bed area, the fluidized bed is designed as the lunch box type boiler with the surface 15 m x 12 m = 180 m^2 supported from the bottom.

Fig. 11-19 and Table 11-21 shows the compariosn of the outline and the total weight of Boiler among Sin Pun FBC, Lignite Boiler and circulation type FBC. By applying the self stantion type boiler, the Sin Pun bubling FBC has a economical merit compared with the other two types. Fig. 11-20 shows the water and steam flow diagram of the bubling FBC boiler. S.H., R.H. and Evaporator are installed in the fluidized bed.

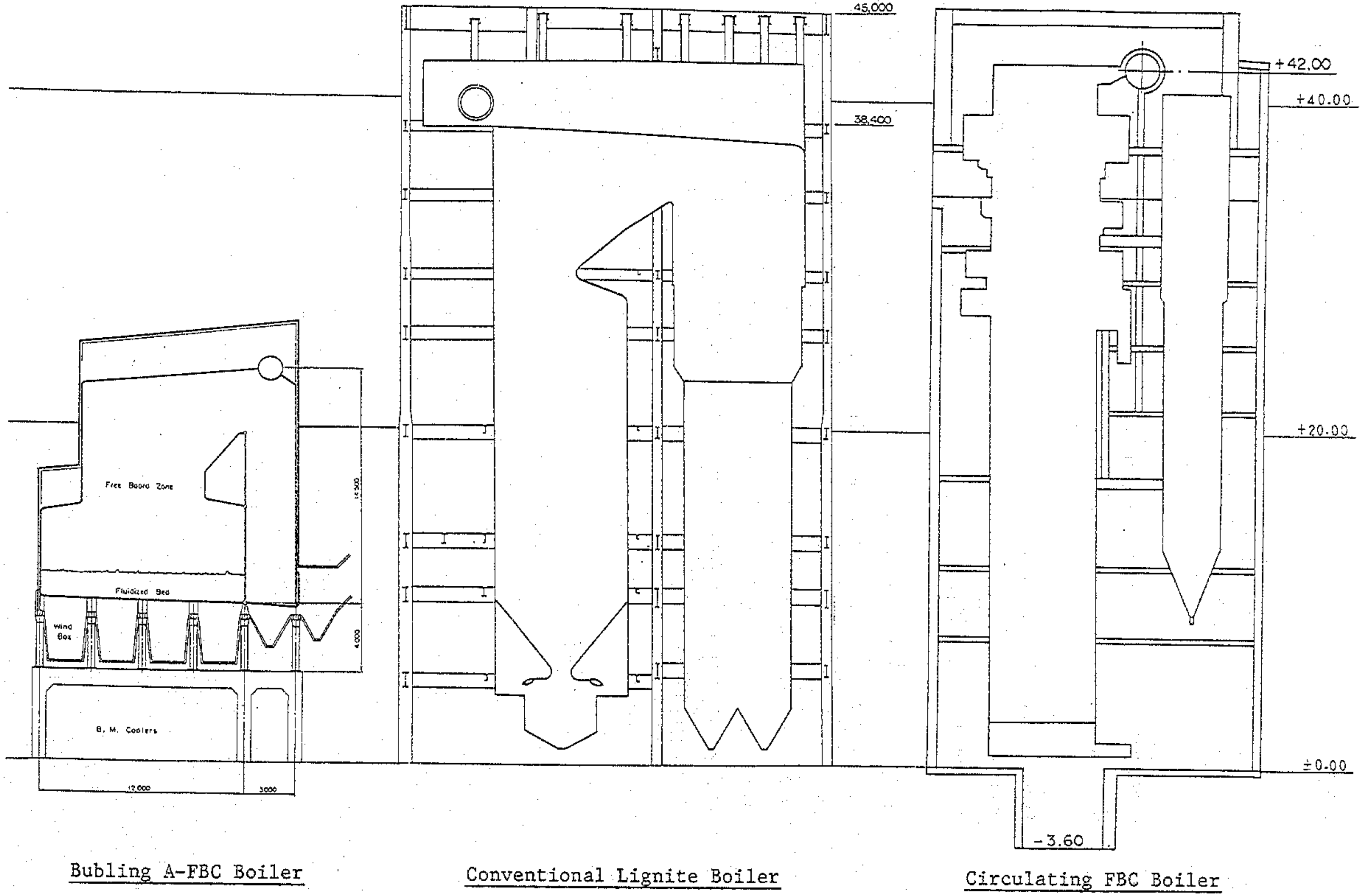


Fig. 11-19 Comparison of Outline for Respective Boiler

Table 11-21 Comparison of Boiler Weight (per unit)

[t]

	Bubling FBC (Sin Pun Project)	Lignite Boiler	Circulation FBC
Boiler Pressure Part	(800)	(530)	(970)
Drum (including accessory)	110	110	110
Header	30	30	30
S.H.Spray	5	5	5
Evaporator in Bed	60	0	0
Evaporator (Radiation)	310	130	380
R.H.	15 (in Bed)	20	30
S.H.	90 (in Bed)	125	235
ECO	130	80	130
Accessory	50	30	50
Boiler Non Pressure Part	(800)	(1,150)	(1,270)
Steel Structure	10	750	750
Stairs Hand Rail, etc.	50	100	100
Boiler Support	25	15	15
Wind Box	40	5	35
Casing	25	20	20
Boiler Auxiliary	60	60	60
A.H.	190	190	190
B.M. Cooling System	300	-	-
Cast	100	-	200
Total	1,600	1,680	2,240

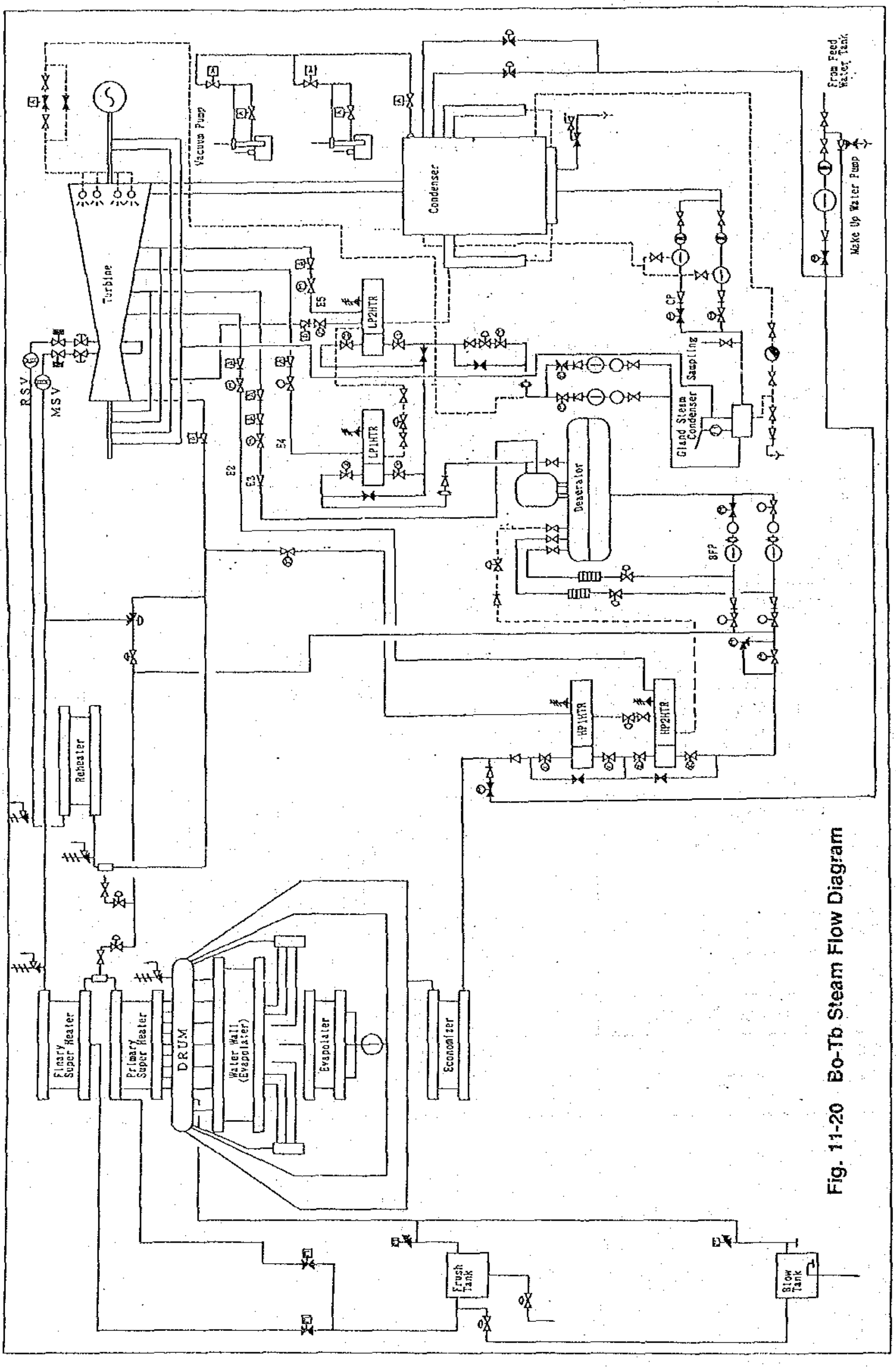


Fig. 11-20 Bo-Tb Steam Flow Diagram

(3) Air Heater

The pressure of FDF outlet for A-FBC is 2,000 mmH_2O to let the bed fluidize. Therefore, the leakage of A.H. is very large in applying the conventional rotary regenerative type A.H. Table 11-22 shows the comparison for the regnerative type, the tubler type and the heat pipe type A.H. By applying the evaluation factor of the electricity and heat, the rotary regenerative type A.H. with the senser drive unit is recommendable.

Table 11-22 Comparison of Gas Air Heater

1992 Base

		Rotary Regenerative Type		Tubular Type	Heat Pipe
		With sancer drive	Without sancer drive		
(1)	Pressure Loss	Base (100)		200%	100%
(2)	Air Leakage	5%	15%	3%	Non Leak
(3)	Heat Exchange Rate	Large		Small	Medium
(4)	Space	10m x 10m (100) Base		17m x 35 m (600)	14m x 8m (110)
(5)	Cost (for 2 units)	+40 Million Yen	Base	+ 120 Million Yen	+ 200 Million Yen
(6)	Station Power	+100 kW	+290 kW	Base	Base
(7)	Radiation Loss	Base		0.8 x 10^6 kcal/h unit	Base
(8)	Total Cost (Million Yen)	-59	Base	+60	+49
(9)	Particular				Non practice record for Larger unit than 100 MW
	Recommendation	o			

(4) Start Up Burner System

The hot wind generator by the light oil burner heats up the temperature of B.M. for lignite to be burn up during the start up.

To rize up the temperature of B.M. effectively, the hot wind is blown to the fluidized bed through the distribution board by the hot wind furnace set on the line to the wind box as shown in Fig. 11-21.

Furthermore the hot wind may be blown also above the fluidized bed i.e. the free board zone to shorten the start up time by means of the making the bed surrounding area hot.

The effect for the shortening of the start up time by appling the over bed hot wind blowing is only 30 min. In this project, the under bed hot wind blowing system is only applied for the economical design of the base load plant.

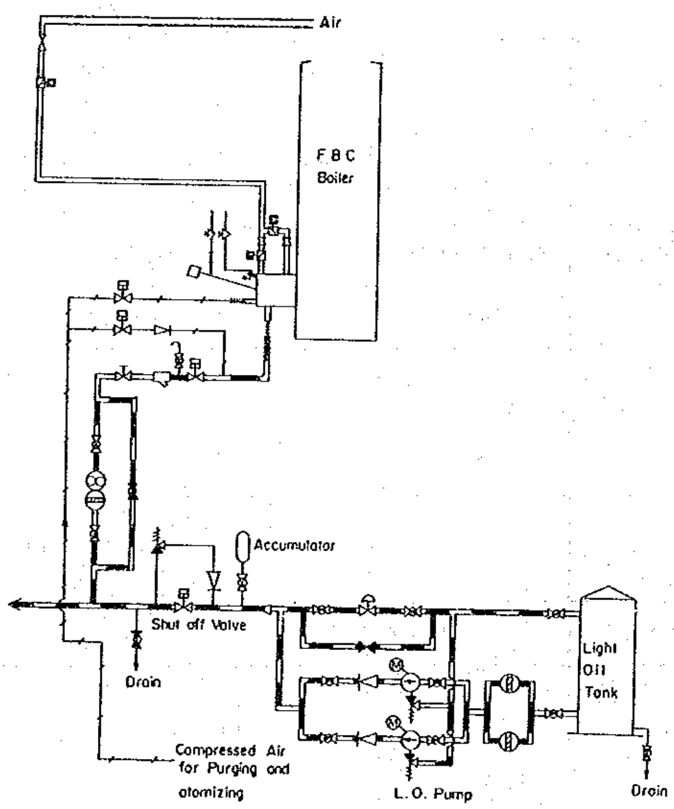


Fig. 11-21 Start Up Burner System

(5) Air-Flue Gas System

Balanced draght system is applied for the air-flue gas system with one FDF and one IDF. The design value of the respective fan is shown in table 11-23.

Table 11-23 Design Value of FDF and IDF

	FDF	IDF
Amount of Air/Gas (Sin Pun case) (Sin Pun, Krabi mixture)	A $= 3.784 \times 63 \times 10^3$ $= 2.39 \times 10^5$ Nm^3/h	$V = V_o$ + Wet. $= (3.714 + 0.663) \times 63 \times 10^3$ $= 2.76 \times 10^5$ Nm^3/h
Pressure	2,560 mmH_2O	600 mmH_2O
Temperature	27°C	130°C

The value of FDF pressure is taken higher than the normal operation condition taking into account of the cell starting up and cell slamping as follows;

Bed Fluidization	1,300 mmH_2O
Cell Starting	11% up
Over Accumulation of B.M.	10% up
Duct Loss	720 mmH_2O x 1.3 (margin)
Total	2,560 mmH_2O

During the normal operation, FDF pressure is 2,000 mmH_2O only. One line diagram of the draft system is shown in Fig. 11-22.

For the conventional PCF boiler, the draft in the furnace has a salient point to control the pulverized coal injection to the furnace. Therefore IDF control vene is set at the 60-70% of the total IDF pressure for the sensitive and quick response of the furnace draft.

On the other hand, FBC boiler does not request the quick response of the furnace pressure since the lignite is fed by the spreader and the air is supplied with 2,000 mmH_2O pressure. The purpose of the FBC furnace pressure control is carried out for the prevention of the ash leaking from the furnace and duct. Therefore, the pressure of IDF for A FBC boiler is designed 20% smaller than that for the conventional PCF boiler. With 10% margin, IDF pressure is designed 600 mmH_2O.

Since the regeneration type A.H. is adopted for this project, the required air is 2.51×10^5 Nm^3/h with 5% air leakage and FDF is designed 5,520 m^3/min with 20% margin. Followingly, IDF is designed 8,510 m^3/min with 20% margin. For the calculation of the power consumption of FDF as house load, the pressure 2,000 mmH_2O is adopted.

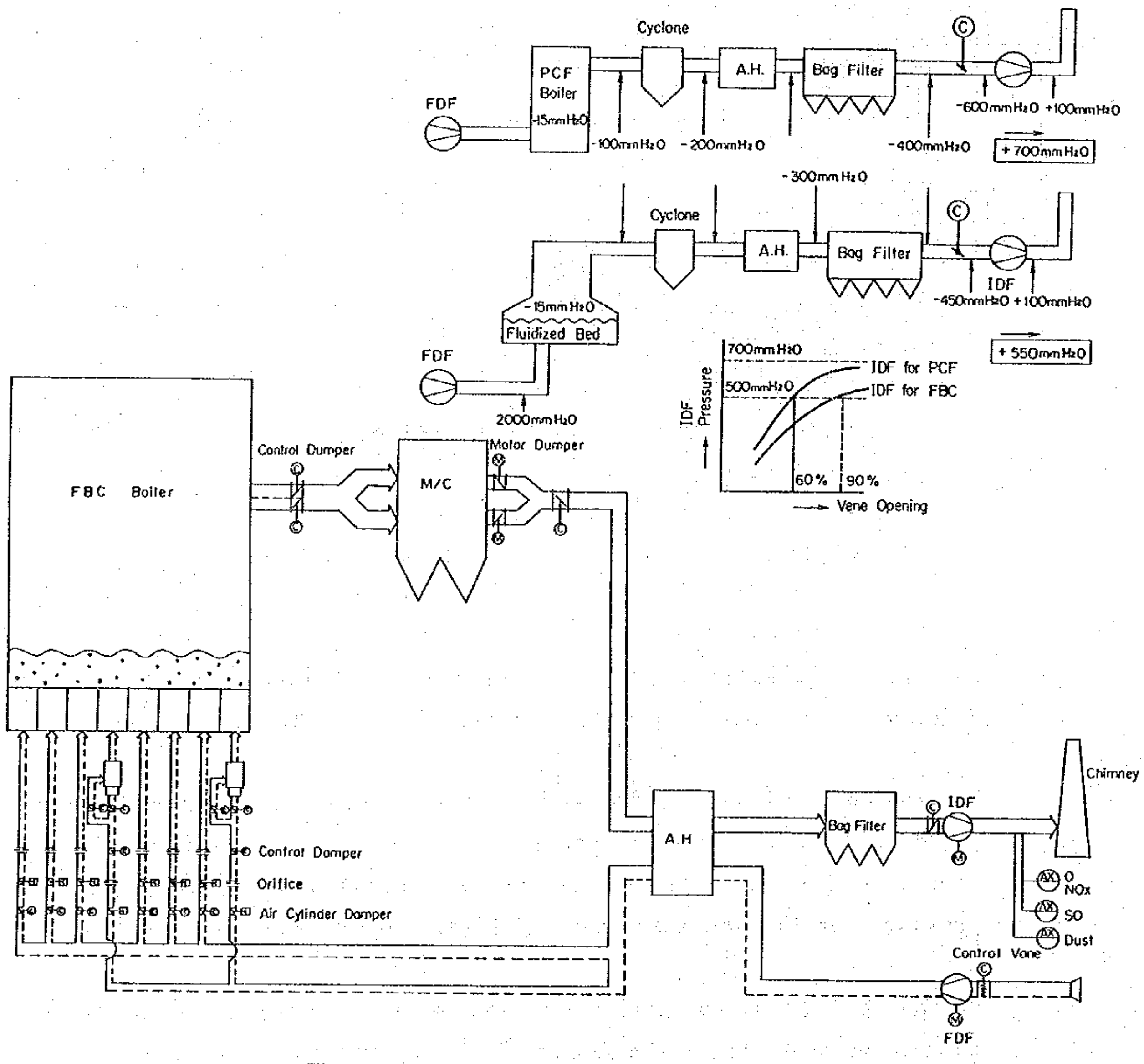


Fig. 11-22 Air-Flue Gas System of FBC

(6) Ash Collecting System

Three kinds of ash are generated from A-FBC as follows:

(i) B.M. Ash

B.M. is extracted from the bed bottom because of the material unbalance on bed. In blowing B.M. out, the large ash particles, which cause the unstable fluidizing condition on bed and are settled on the bottom of the fluidized bed, are extracted from the bed bottom also.

(ii) Mechanical Cyclone Ash

The medium size of ash is collected by the mechanical cyclone and some of them is recycled to the FBC boiler for saving the limestone injection.

(iii) Fine Ash

The fine ash is collected by the bag filter. The bag filter is recommendable to apply for the desulfurization effect on the bag by the remaining CaO content in Ash.

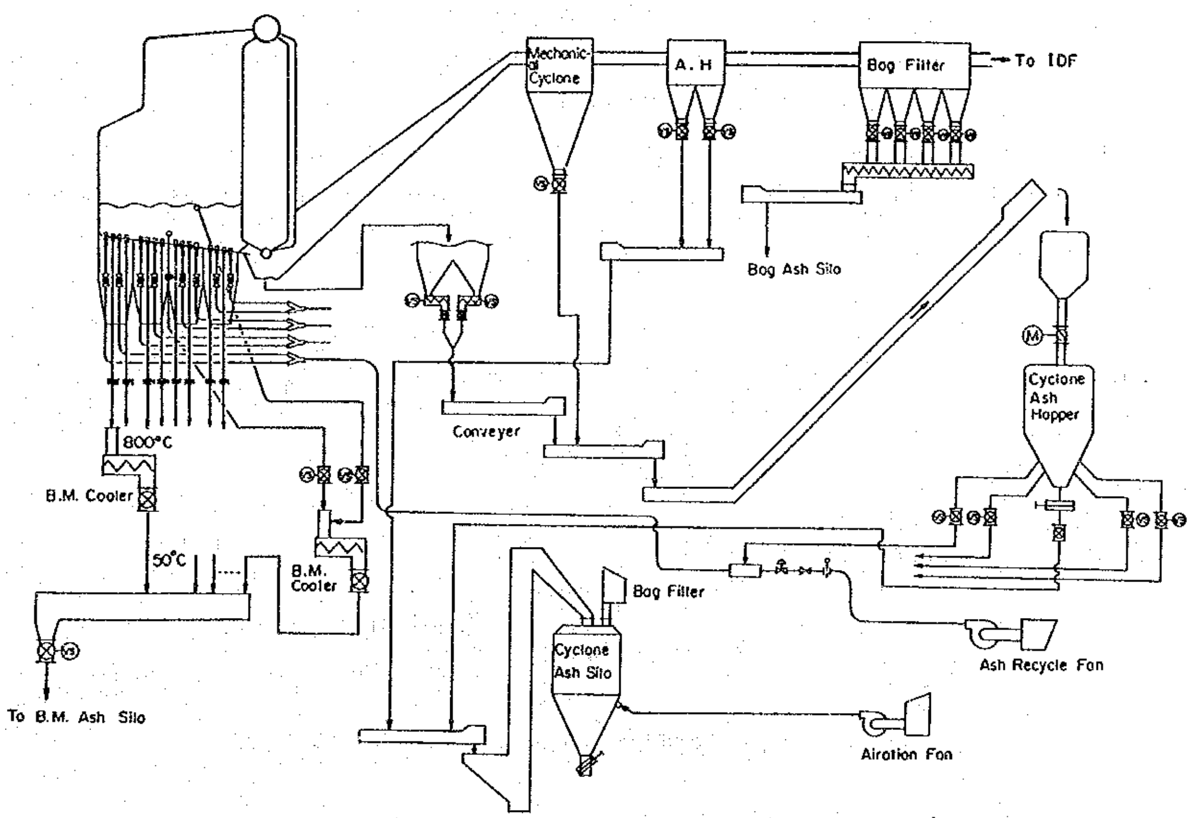


Fig. 11-23 One Line Diagram of Ash Collecting System

11.8.2 Lignite Feed Systems

The lignite feed systems for the bubbling type FBC are generally categorized to two systems. The one called underfeeding system feeds the fuel to the fluidized bed from the bottom together with the fuel transportation air as shown in Fig. 11-24.

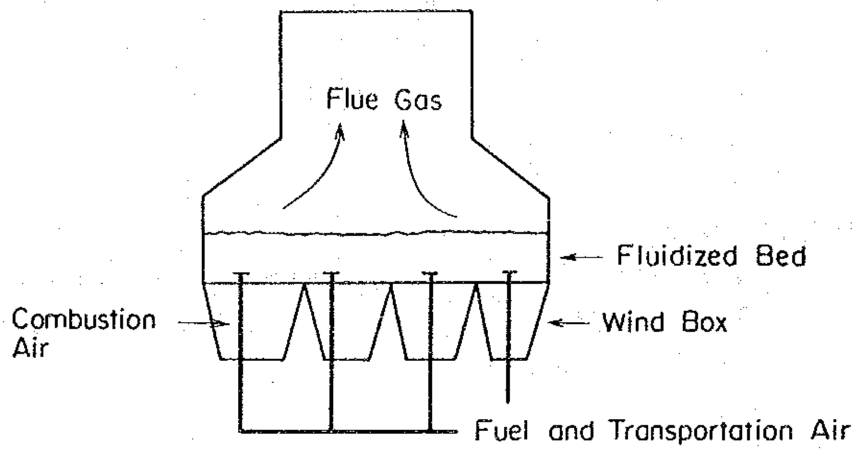


Fig. 11-24 Under FeedingSystem of Bubbling FBC Boiler

This system has a merit to increase the combustion efficiency by increasing the chance for small particle of fuel to meet the high temperature of the bed materials and the burn up before flying out from the fluidized bed system. Wakamatsu Demonstration Plant (50 MW) in Japan applies this feeding system because the plant consumes the sub-bituminous coal which is not combusted in the bed faster than that of the lignite and leaves the 10% unburn carbon at most.

The other called overfeeding system feeds the fuel from the upper part of the FBC boiler by the spreading feeders as shown in Fig.11-25.

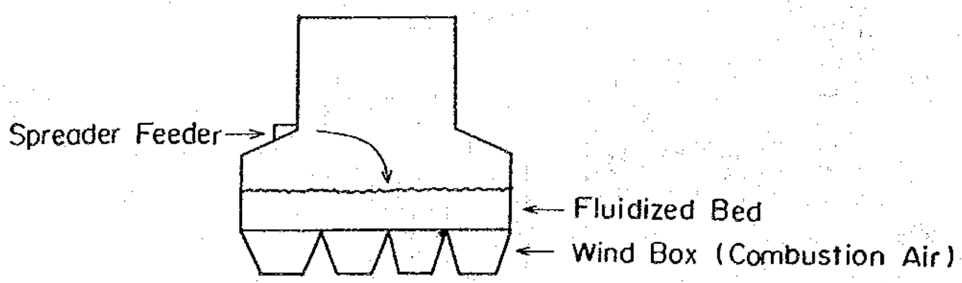


Fig. 11-25 Over Feeding System of Bubbling FBC Boiler

This system has a merit to simplify the fuel feeding system, but has a tendency to decrease the combustion efficiency for the coal of high fuel ratio.

By the combustion test in this study, the combustion efficiency of 99% is confirmed by the overfeeding system with Sin Pun lignite and Krabi lignite because of the high volatile matter content i.e. low fuel ratio.

But for the desulfurization aspect, the small particle of the lignite makes the high SOx emission by over feeding system because the small particle burns up on the top of the fluidized bed without contacting the desulfurizer in the bed and emits the SOx. Sin Pun and Krabi lignite content the high sulfur and will emit high SOx even the small particle.

Therefore it is designed to apply the overfeeding system as main feeding system pursuing cost performance of the investment and also to apply the suitable crushing system for reducing fine lignite to keep the low desulfurization cost, i.e. the less limestone consumption.

Overfeeding system has a particular to make the unbalance of combustion in the fluidized bed. Fig. 11-26 shows the distribution of the oxygen, the carbon monoxide and the Sulfur dioxide according to the distance from feeding point.

The SOx emission has tight co-relation with the oxygen density in the fluidized bed. In the atmosphere of low oxygen density, the captured SOx by lime has tendency to be released with the following action.

$$CaSO_4 + C + \tfrac{1}{2}O_2 \rightarrow CaO + CO + SO_2 \uparrow$$

For achieving the high DeSOx efficiency, it is a key point to levelize the carbon content in the fluidized bed in any point. Therefore, the variable speed control type spreader system is recommended to apply for this project to maintain the SOx emission as low as possible with low consumption of the limestone i.e. low operation cost.

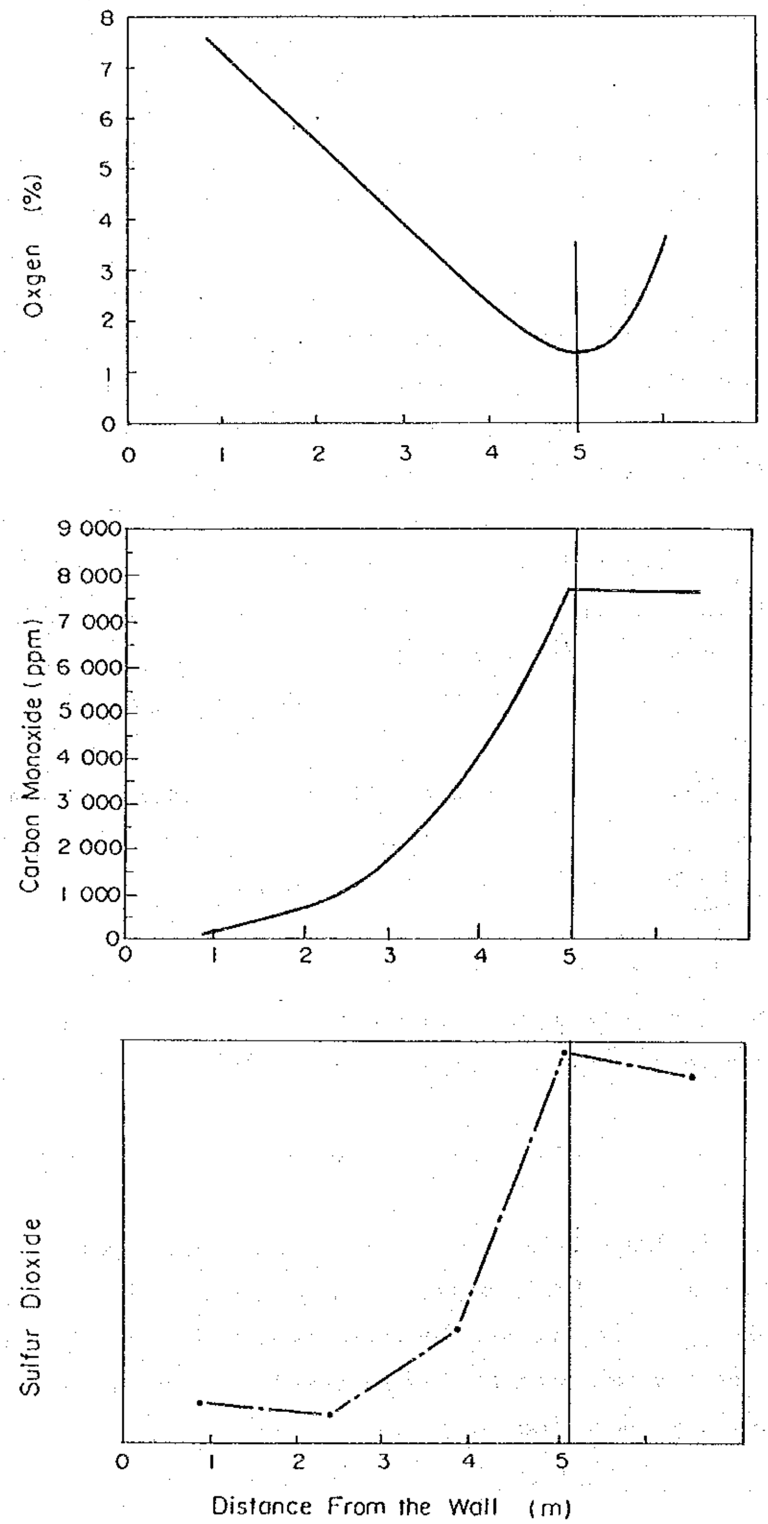


Fig. 11-26 Correlation among Oxygen, Carbonoxide and Sulfur Dioxide on the Fluidized Bed

11.9 Steam Turbine

11.9.1 Steam Turbine

The basic condition for the design of the conventional steam turbine is shown in the Table 11-24.

Table 11-24 Basic Condition for Turbine Design

Type	
Nominal Output	75,000 kW
Rotation	3,000 rpm
Sea Water Temperature (Cooling Water)	32°C
Steam Condition	
Main Steam Temperature	538°C
Pressure	125.53 bar (127 kg/cm^2g)
Reheat Steam Temperature	538°C
Pressure	29.40 bar (30 kg/cm^2g)
Extraction steam	5 stages
Efficiency	41.5%
Vacuum	0.0892 bar (at nominal output, all extraction steam activated, ambient pressure 760 mmHg and cooling water temperature 32°C)

The popular turbine system is designed to apply in this study.

11.9.2 Steam Condensing System

The temperature difference of the cooling water for the steam condenser is designed with 7°C. The cooling water flow in the condenser cooling tube is designed 2.0 m/s to avoid the inlet attack of the tube. The forced cathodic protection and the sponge ball type tube cleaning system is designed to apply. The outline of the steam condensing system is shown in Table 11-25.

Table 11-25 Outline of Steam Condensing System

Condenser	
Designed Vacuum	0.0892 bar at cooling water 32°C
Cleanliness Factor	75%
Water Velocity in Tubes	2.0 m/s
Temperature Difference between Inlet and Outlet	Less than 7°C
Cooling Water	Sea Water
Forced Cathodic Protection	Condenser Inlet
Condenser Cube Cleaning System	Sponge ball type
CWP (circulating on water pump)	
Amount	2 sets for 1 unit
Capacity	6,900 m^3/h
Head	8.2 m (Required head at mean seawater level : 3.52 m)

The head of CW Pump is set with the following reasons;

Syphon Limit	8 m
Condenser Top	FL-1m
Floor Level	MSL (Mean Sea Water Level) + 7 m
	LLSL (Lowest Sea Water Level) = MSL-2.3m

CW Pipe Loss Inlet

$$\left(\alpha + 16\frac{\sqrt{\alpha \cdot \gamma}}{Vd}\right)\frac{\ell}{d} \cdot \frac{V^2}{2g}$$

$$= \left(0.025 + 16\sqrt{\frac{0.025 \times 0.00783}{2 \times 1.1 \times 10^4}}\right) \times \frac{500}{1.1} \times \frac{(2)^2}{2 \times 9.8}$$

$$= 2.46\ m$$

Outlet

$$(0.025 + 16\sqrt{\frac{0.025 \times 0.00783}{2 \times 1.6 \times 10^4}} \times \frac{200}{1.6} \times \frac{(2)^2}{2 \times 9.8}$$

$$= 0.67\ m$$

α: Friction factor for used cost iron: 0.025

V: Water velocity (m/s): 2 m

ℓ: Pipe length (m): 500 m (Inlet),
200 m (Outlet)

d: Diameter of Pipes (m): 1.1m (Inlet),
1.6 m (Outlet)

γ: Coefficient of kinematic viscosity:
0.00783×10^{-4} (at 32°C)

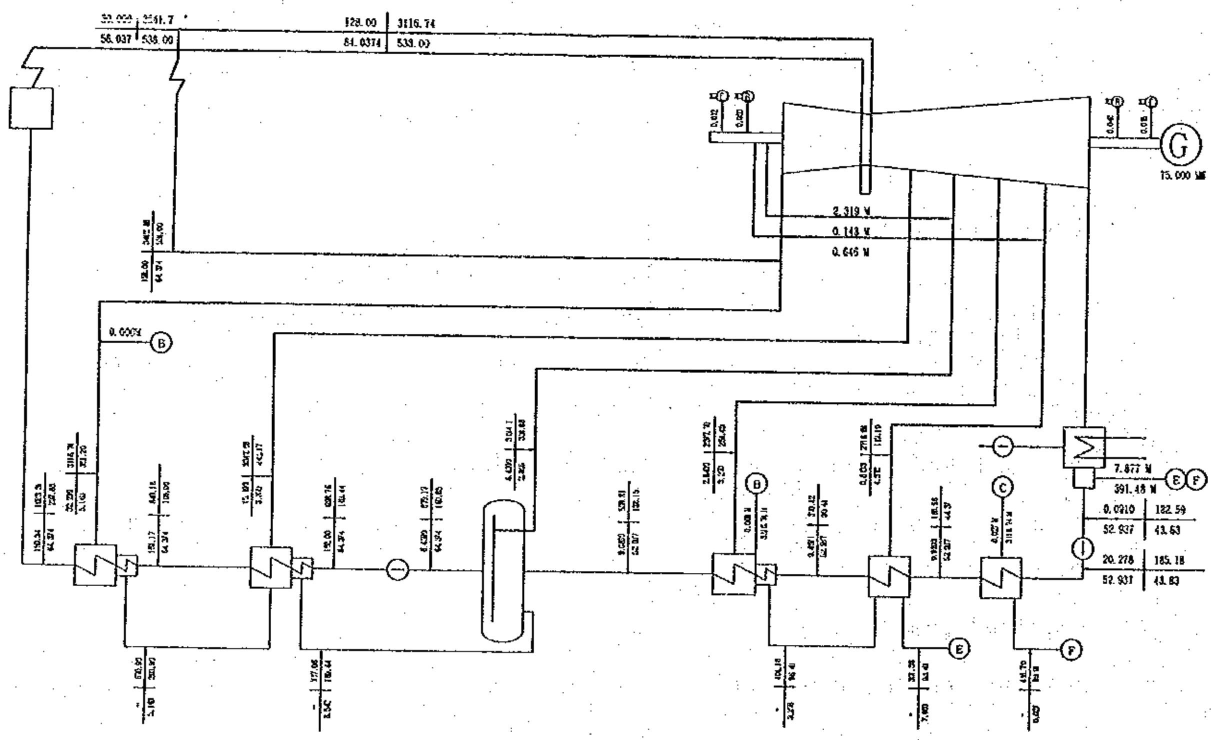
Condenser tube loss	3.06 m
	Tube loss 0.192 mAq/mx6.5mx2 = 2.496m
	Condenser water chamber loss 0.75m
	Temperature coefficient 0.94 (at 36°C)
	(2.496+0.75)x0.94=3.055
Outlet head	0.21 m ($=V^2/2g$)
Total loss to condenser outlet	2.46 m + 3.06 m = 5.52 (LLSL Case)
Required pump head	χm
Head of condenser outlet top	- 2.3m - 6m + χ - 5.52m > - 8m (Syphon Limit)
	$\therefore \chi > 5.82$ m
Total loss to outlet	2.46 + 3.06 + 0.67 + 0.21 = 6.4 m
Outlet head at LLSL	-0.5 m
	$\therefore \chi > 6.4$ m + (2.3-0.5) $\therefore \chi > 8.2$ m

11.9.3 Feed Water Heater

One pass feeding water system is designed for this project. The feed water system is designed to compose the following items which are the typical design component with the scale of 75 MW thermal power station.

1. Low Pressure First Feed Water Heater
2. Low Pressure Second Feed Water Heater
3. Deaerator
4. Boiler Feed Water Pump
5. High Pressure First Feed Water Heater
6. High Pressure Second Feed Water Heater

Two sets of 100% capacity BFP are drived by the motor and one of two is stand-by unit. The heat flow diagram for this project is shown in Fig. 11-27.



kg/cm^2	KJ/kg
kg/s	°C

Fig. 11-27 Heat Flow Diagram

11.10 Cooling Water System

11.10.1 Basic Design Conditions

Water from the Khlong Pakasai River 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 and sand are all needed.

Cooling water facilities are roughly divided into an intake pump pit, inlet and outlet pipes, an outlet pit, and a discharge channel.

The major conditions for the design of the above facilities are as follows:

Quantity of cooling water used : 7.5 m^3/sec/2 units
Temperature increase of cooling water: 7°C(*)

(*) Note : Since river water temperature is 32°C, the design temperature difference between at the intake and the outlet is determined to be 7°C so that discharged water temperature does not exceed the upper limit of 40°C.

11.10.2 Location and Type of Intake and Outlet

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

- Intake and outlet route as short as possible

- Considerable distance between the intake and the outlet so that recirculation of thermal effluent cannot occur

- Stable intake that is almost free from scouring by river flow

Considering that there is already an intake of the existing plant under operation at eastside of the area, the outlet of new plant cannot be installed near it.

Therefore, the new outlet is located approximately 400 m north of the plant area. On the other hand, the new intake is installed at adjoining place of the existing one which is located at southeast of the planning site at the right bank of the Khlong Pakasai River.

As a result, distance between the new intake and outlet is approximately 2,500 m along the river.

For the intake type, the surface water intake method is adopted because the water depth of the river is not so deep.

For the outlet type, the surface water outlet method is also adopted for the economical reason.

11.10.3 Intake Pump Pit

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

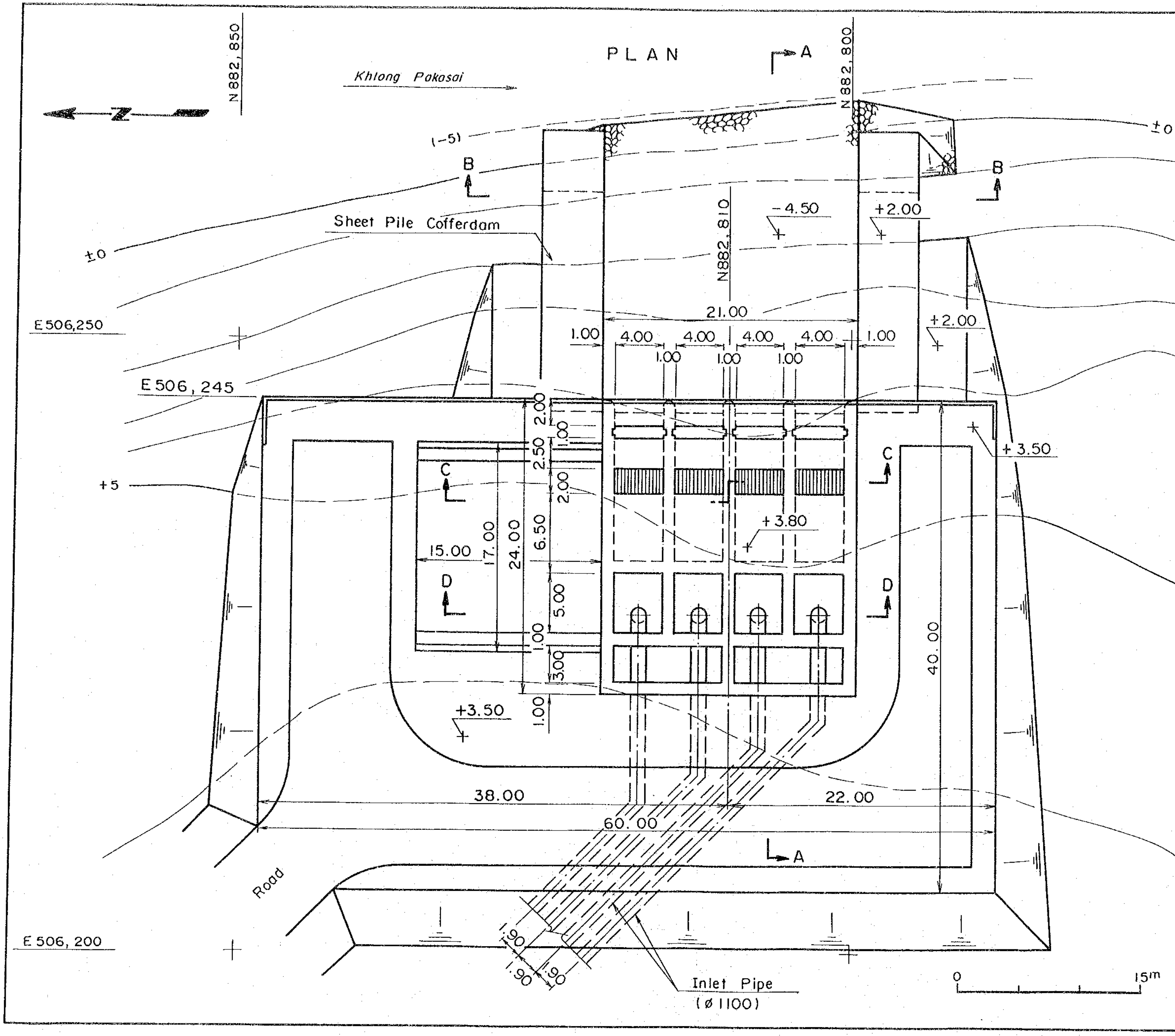
The intake pump pit is about 21 m (W), 8 m to 11 m (H), 24 m (L), reinforced concrete structure with openings for intake, bar screens and pump chambers.

As the bedrock surface is assumed to be so shallow, the structure foundation can be constructed on bedrock. (Refer to Fig. 11-28, 11-29)

The characteristics of the intake pump pit structure are as follows:

- Bar screens are installed at the screen chamber as debris-eliminating apparatus so as not to clog the condenser pipes by removing floating debris entering the intake.

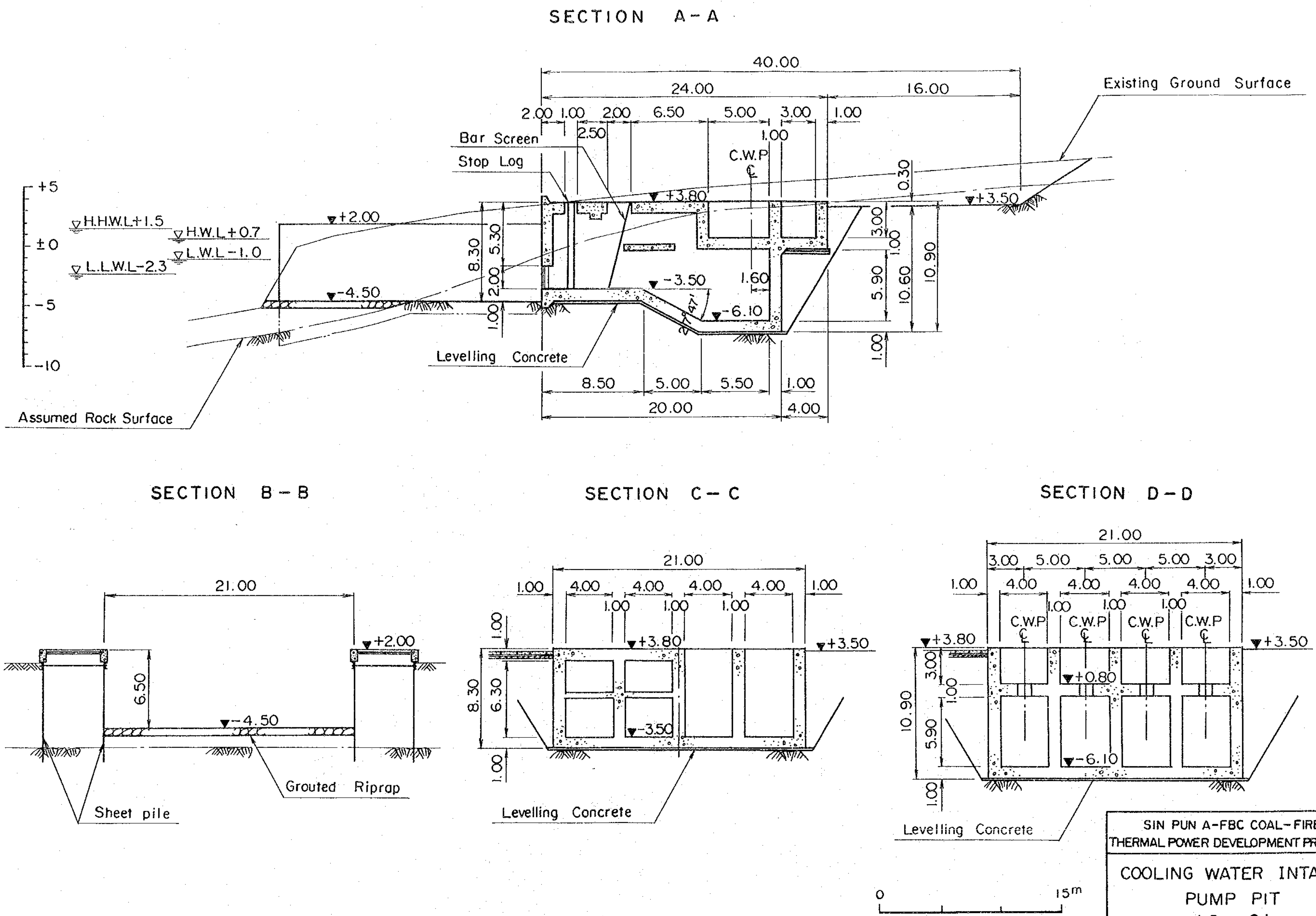
- A stop log is provided at each pump chamber so that repair of the pump chamber can be performed in dewatered condition.



SIN PUN A-FBC COAL-FIRED
THERMAL POWER DEVELOPMENT PROJECT

COOLING WATER INTAKE,
PUMP PIT
(2-1)

Fig. 11-28



SIN PUN A-FBC COAL-FIRED THERMAL POWER DEVELOPMENT PROJECT

COOLING WATER INTAKE, PUMP PIT (2 - 2)

Fig. 11-29

- Approach velocity to the screen is set at about 40 cm/sec in consideration of debris removing capability of the screens.

- Thickness of 10 cm of sea shells adhering to the screen and pump chamber is considered as one of the basic design conditions.

- The depth at the bottom and width of the pump chamber should be decided in consideration of the adequate dimensions necessary for stable operation of pumps during shallow water level.
- The top elevation of the intake pump pit should be decided at the detailed design stage taking the design flood stage in account. So far it is set at +3.5 m a.s.l. taking into consideration surplus of 2 m to highest water level (+1.5 m a.s.l.).
- The structure of the intake pump pit is designed to prevent it from floating even when the pump chamber is empty.

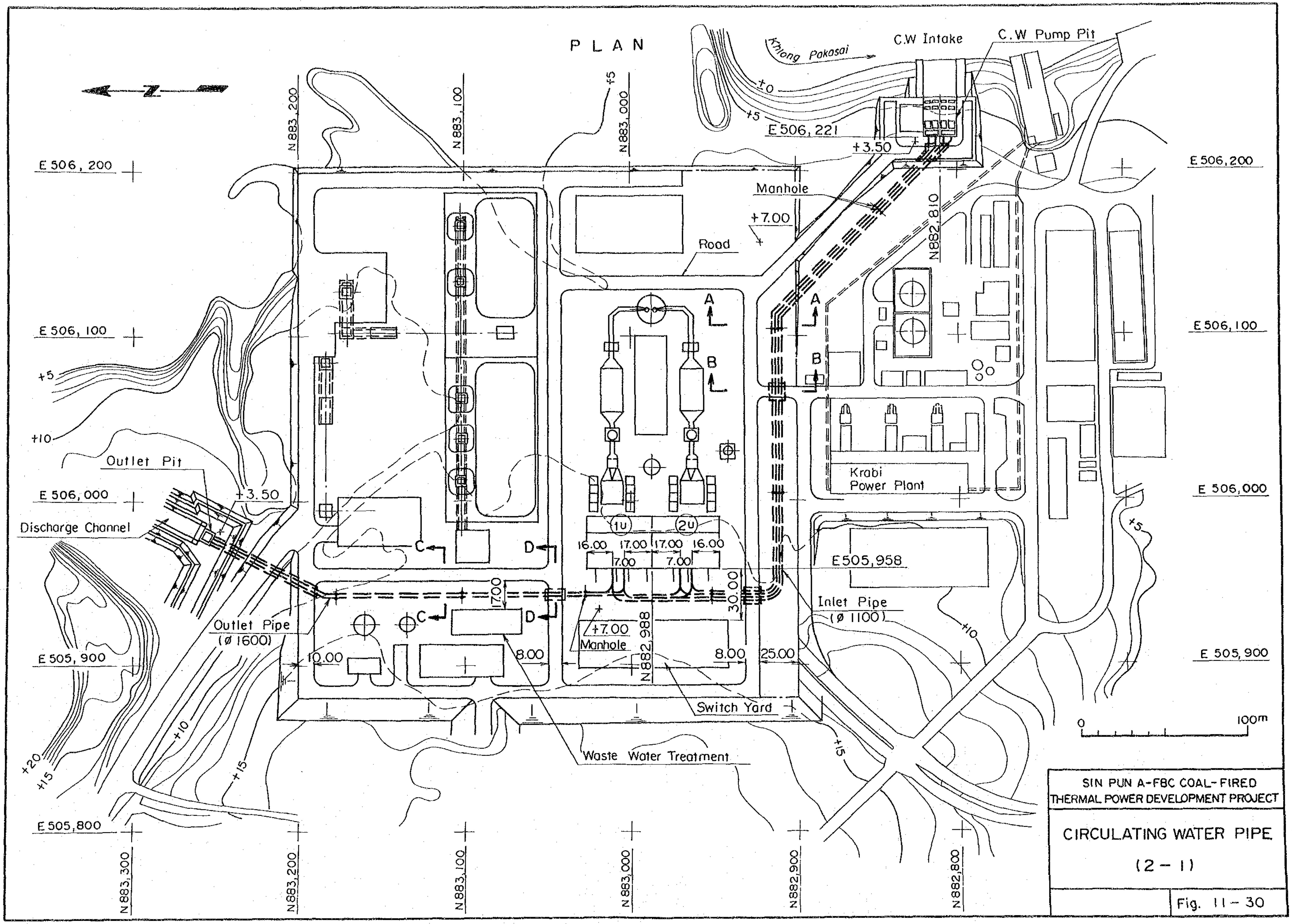
11.10.4 Inlet and Outlet Pipelines

Fig. 11-30, 11-31 shows the route and structure of inlet and outlet pipes.

The inlet pipe is made of steel to supply cooling water from the intake pump pit to the condenser, and two pipelines with a diameter of 1.1 m is provided per one unit. The diameter is decided taking into consideration the appropriate fluid velocity of 2.0 m/s.

The outlet pipe is made of steel to release water discharged from the condenser to the outlet pit, and one pipe with a diameter of 1.6 m is provided per one unit.

Some portions of pipelines which traverse roads are protected with concrete coating outside of the pipe.

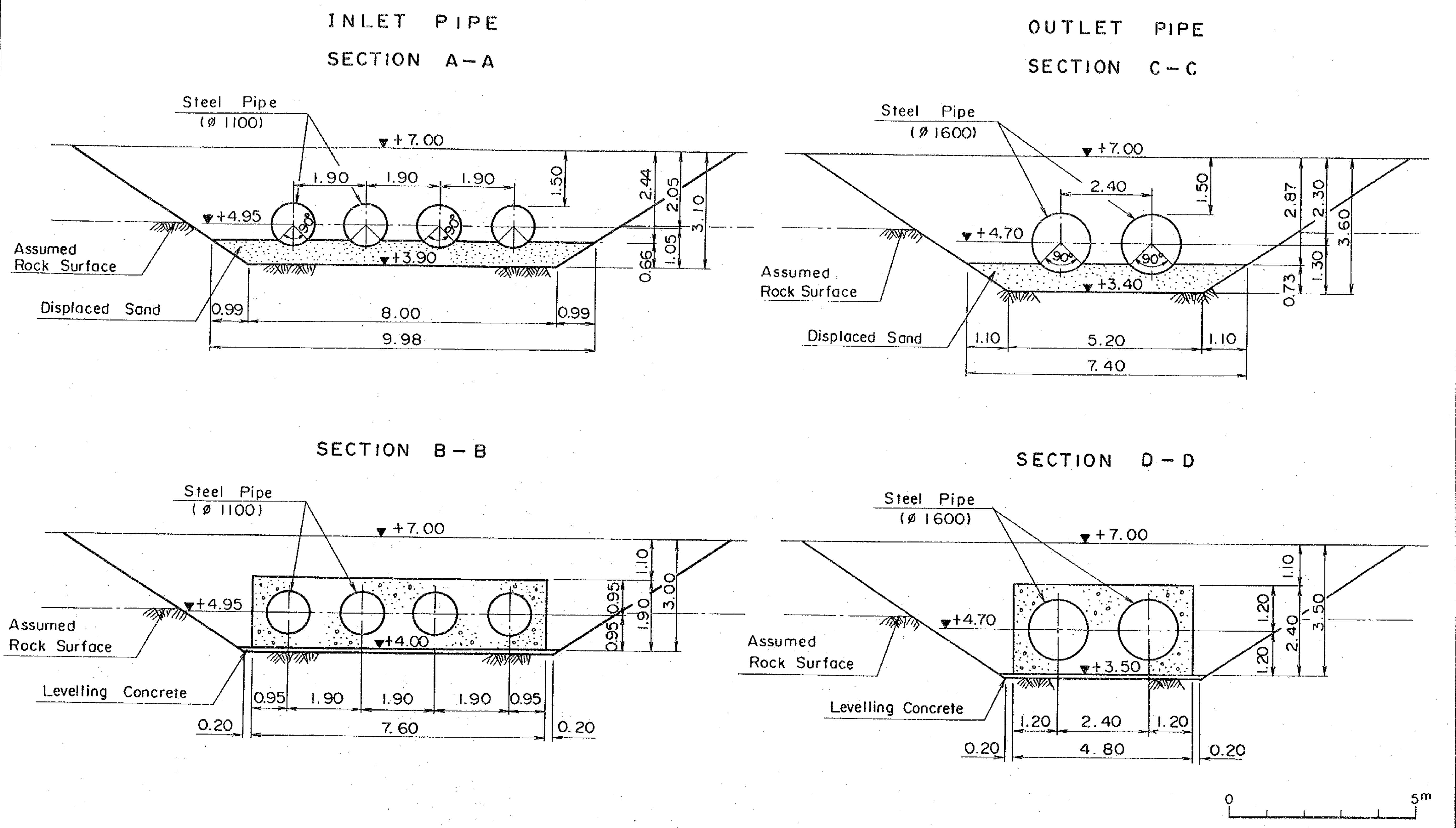


SIN PUN A-FBC COAL-FIRED THERMAL POWER DEVELOPMENT PROJECT

CIRCULATING WATER PIPE

(2 − 1)

Fig. 11 − 30



SIN PUN A-FBC COAL−FIRED
THERMAL POWER DEVELOPMENT PROJECT

CIRCULATING WATER PIPE
(2 − 2)

Fig. 11−31

11.10.5 Outlet Pit and Discharge Channel

Fig. 11-32 shows the location and structure of the outlet pit and the discharge channel. Cooling water which passes the condenser and the outlet pipe is discharged into the outlet pit, then released into the Khlong Pakasai river through the discharge channel.

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

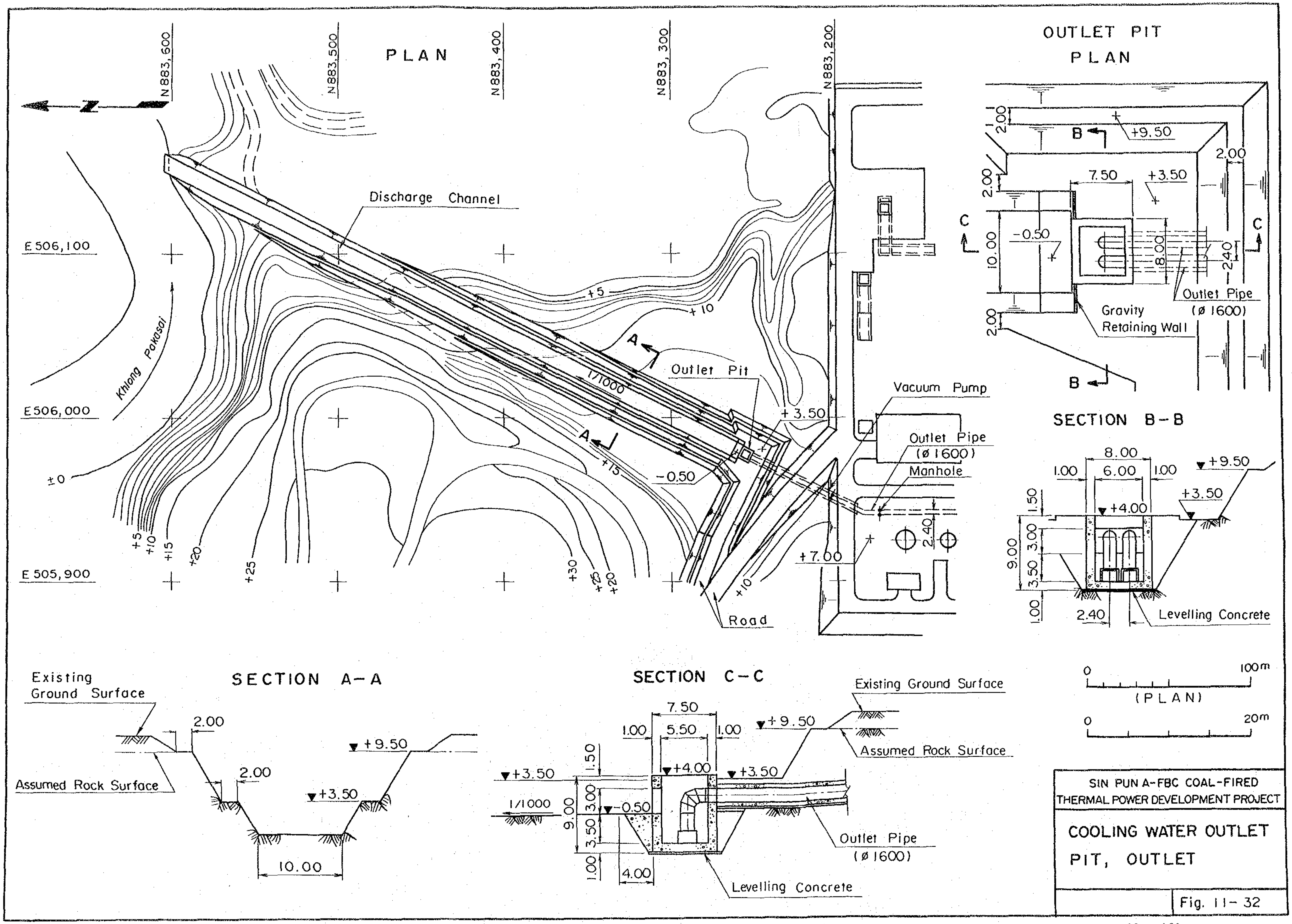
The discharge channel is 10 m wide at the bottom, 1/1000 - gradient, trapezoidal shaped open channel.

The both side slopes of the open channel are excavated bare rock surface with appropriate berms.

11.10.6 Thermal Effluent

With respect to the influence of thermal effluent, a report titled "A STUDY ON IMPACTS OF THERMAL DISCHARGE AND ASH POND EFFLUENT ON THE RECEIVING ENVIRONMENT FROM 75 MW LIGNITE KRABI THERMAL POWER PLANT" was already prepared by Asian Institute of Technology in May 1990.

This study was conducted using a hydraulic model based on available observed data. The conclusion of that report regarding thermal effluent is as follows. (Refer to Page 1-58 of the Report)



SIN PUN A-FBC COAL-FIRED THERMAL POWER DEVELOPMENT PROJECT

COOLING WATER OUTLET PIT, OUTLET

Fig. 11-32

CONCLUSION

In general, it can be mentioned that the use of water from Khlong Pakasai for cooling the proposed 75 MW Krabi lignite thermal power plant at the design rate of 3.6 m^3/s can be done safely without affecting the plant operation. The effects of temperature on aquatic lives and other environmental factors are explained and discussed separately in subsequent parts of this report.

The detailed results of the thermal discharge study can be summarized as follows:

(1) Changes of the flow field in the river are characterized by the existence of the warm water plume interacting with ambient flow.

(2) The region in which the velocity field is disturbed due to the warm water discharge is limited to the reach of 290 m from the outfall along the ebb flow direction (stage 8) and 80 m from the outfall along the flood flow direction (stage 4). On the other hand, compared to the velocity field, the affected horizontal area due to temperature rise extends over a larger area, e.g. the 1°C temperature rise extends in the order of 300 m from the outfall along the ebb flow direction (stage 8) and in the order of 125 m from the outfall along the flood flow direction (stage 4).

(3) There is insignificant temperature rise at the intake during flood flow. During the ebb flow, a maximum temperature rise at the intake of only 0.3°C is observed. The large distance between the intake and outfall locations of 2.6 km is one of the main factors which help in reducing the temperature rise at the intake location.

(4) The far-field temperature is less influenced by the warm water discharge from the outfall but is more dependent on the velocity and direction of the tidal current.

However, the effluent condition assumed for that study was for the capacity of 75 MW, that is, only for the design rate of 3.6 m^3/s.

The design rate for 150 MW is estimated 7.5 m^3/s at this time. Therefore, based on the results of the abovementioned study using a hydraulic model, we conducted additional numerical analysis using computer.

The result of calculation is shown in the Appendix V attached herein.

According to the calculation result, the maximum temperature rise at the proposed intake point is only 0.3°C.

So, the same conclusion as the AIT report can be said in the case of 150 MW.

11.11 Electrical Facilities

11.11.1 Selection of Voltage

The transmission line nominal voltage in the Krabi power station is 115 kV. This project also applies same voltage. The voltage of the auxiliary power applies 6.6 kV and 380 V which are commonly applied in EGAT.

Fig. 11-33 shows the one line diagramme of this project.

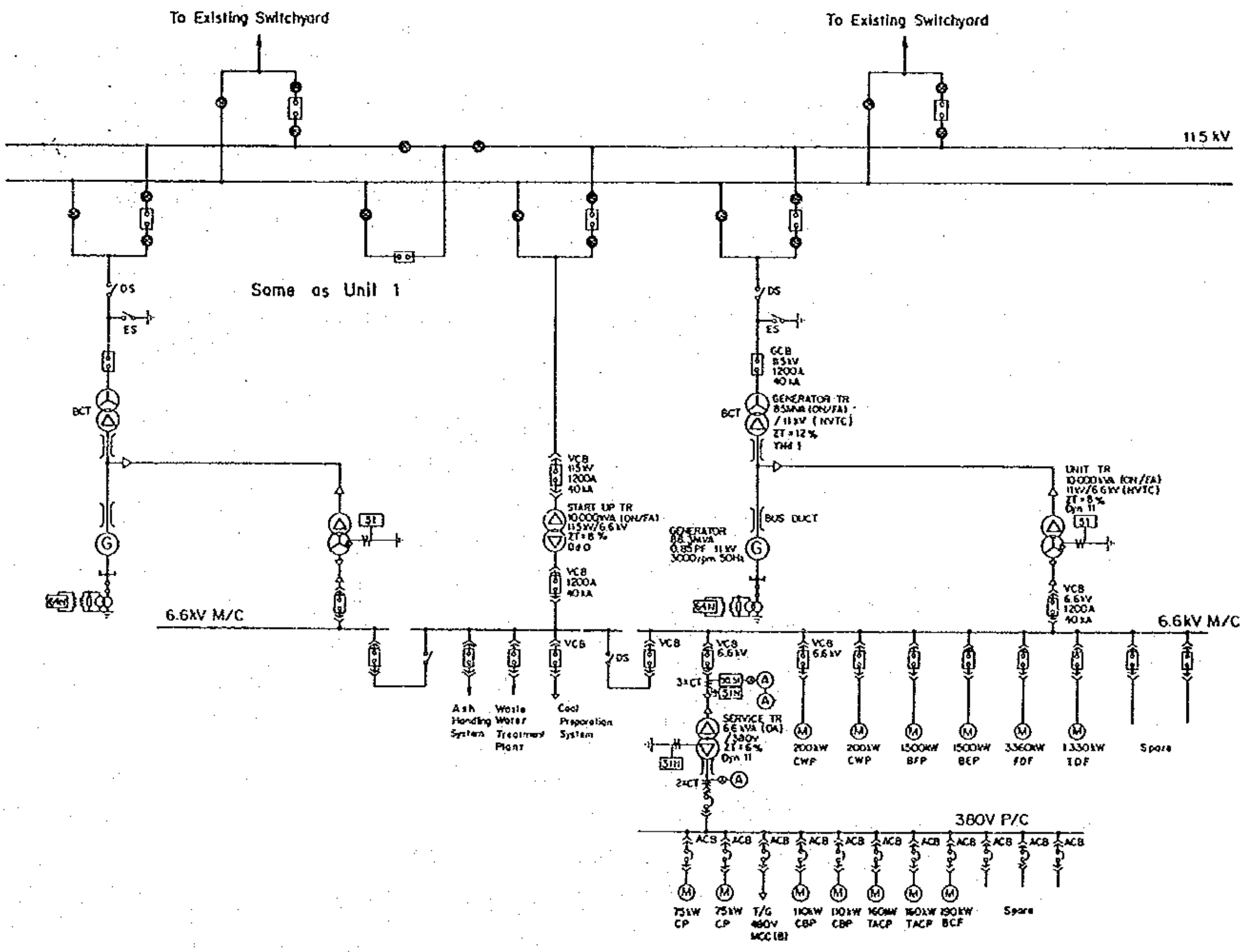


Fig. 11-33 Electrical One Line Diagram

11.11.2 Capacity of Generator

The power factor 0.85 (Lag) is applied for this project. Therefore the capacity of the generator to be 88.3 MVA.

Table 11-26 shows the admittance and impedance of the transmission line between Krabi and Phanguga, Lam Poo Ra respectively.

Table 11-26 Transmission Line Admittance and Impedance

Transmission Line Route	Line	Length of Line	Admittance 1/2Y at 100MVA Base	Impedance at 100MVA Base
1. Krabi-Phangnga	$150mm^2$ AAAC	abt 97.5 km	1.85%	29.35%+12.5%= 41.85%
2. Krabi-Lam Poo Ra	$150mm^2$ AAAC	abt 84.7 km	1.61%	25.49%+12.5%= 37.99%

Condition $150mm^2$ AAAC 1/2Y=0.019%/km X=0.301%/km at 100MVA 115kV
step up Transformer 10% Impedance at 80 MVA

Fig. 11-34 shows the power flow of the respective transmission line.

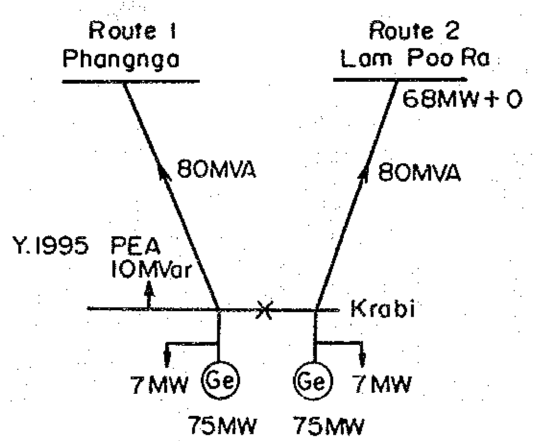


Fig. 11-34 Load Flow for Krabi Site (Tentative)

The image power of the respective line is calculated as shown in below with the condition for the receiving terminal image power to be 0 MVar.

Image Power

$|V| = 1$ p.u. $|I| = 0.8$ p.u.

Lead

$Y_1|V|^2 = 0.0185$ - Route 1

$Y_2|V|^2 = 0.0161$ - Route 2

Lag

$X_1|I|^2 = 0.2678$ - Route 1

$X_2|I|^2 = 0.2431$ - Route 2

Route 1 Total

(-0.0185x2+0.2678) 100 MVar = 23.08 MVar

Route 2 Total

(-0.0161x2+0.2431) 100 MVar = 21.09 MVar

Since the required image power (Lag) is 20~25 MVar on the respective transmission line and transformer and 10~15 MVar for PEA, the power factor of the generator is selected 0.85 for the economical point of view.

$$(\sqrt{1-(0.85)^2} \times 75 \fallingdotseq 40MVA)$$

Location	Type	Existing Generator in Region 3			
Rajraprabha	Hydro	3x89 MVA	0.9 pf	355 rpm	13.8 kV
Surat Thani	Gas	3x21.1 MVA	0.85 pf	3,000 rpm	11.5 kV
	Thermal	42 MVA	0.8 pf	3,000 rpm	10.5 kV
Khanom	Thermal	2x88.3 MVA	0.85 pf	3,000 rpm	13.2 kV
Nakhon Si Thammarat	DG	2x1.25 MVA	0.8 pf	750 rpm	3.5 kV
Phuket	DG	4x3.3 MVA	0.8 pf	500 rpm	6.3 kV
Krabi	Lignite	3x25.8 MVA	0.8 pf	300 rpm	10.5 kV
	DG	2x1.2 MVA	0.8 pf	420 rpm	11 kV
Hat Yai	Gas	3x20 MVA	0.8, 0.85 pf	3,000 rpm	10.5/11.5 kV
Banglang	Hydro	3x26.2 MVA	0.85 pf	214 rpm	13.6 kV
	Mini-Hydro	1.3 MVA			
	DG	5x1.2 MVA	0.8 pf	750 rpm	3.5 kV

Regarding the cooling method of the generator, it is designed air cooled type for the economical reason as shown in Table 11-27.

Table 11-27 Loss of Generator and Cost Comparison

Loss		Air Cooled Type	Hydrogen Cooled Type
Friction Loss	kW	51	48
Windage Loss	kW	332	168
Core Loss	kW	153	168
Stator Winding Ohmic Loss	kW	166	180
Stray Load Loss	kW	242	204
Rotor Winding Loss	kW	319	420
Exciter Loss	kW	12	12
Total	kW	1,275	1,200
Cost		Base	+180 Million Yen
Loss (ref Table 11-2)		+20 Million Yen	Base
Total		Base	+160 Million Yen

Note) 1 Baht = 5 Yen

11.11.3 Capacity of Transformer

(1) Capacity of Step-up Transformer

The rating capacity of the transformer is designed 85 MVA in the secondary circuit of the transformer.

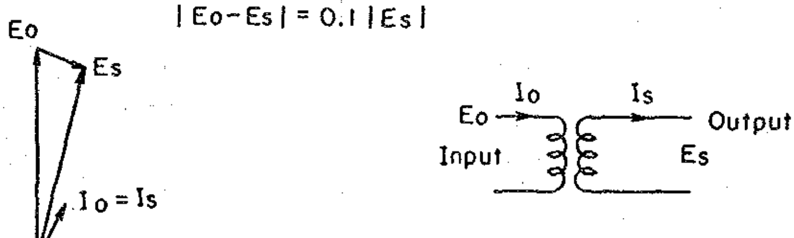
For the design of the transformer, the following conditions are considered.

Generator Output	75 MW
Power Factor	0.85
House Load	> 7.1 MVA (6,430 kW ÷ 0.9)

$\therefore \quad \frac{75MW}{0.85} - 7.1MVA < 81.2MVA$

Taking into consideration of the lag image power consumption of the transformer, the step up transformer input capacity is larger than the output circuit with the amount of 3 MVA as shown in Fig. 11-35.

$$|Eo - Es| = 0.1\,|Es|$$



$$|Es| = |Eo|\ \sqrt{1 + (0.1)^2 - 2 \times 0.1 \times \sin\theta}$$

$$= 0.9511\,|Eo| \qquad \text{at } \cos\theta = 0.85$$

Fig. 11-35 Transformer Input and Output

Therefore, the minimum required transformer capacity is 79 MVA with JIS transformer as shown in Fig. 11-36.

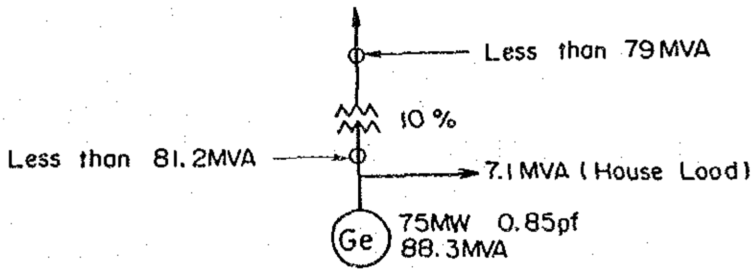


Fig. 11-36 Minimum Required Capacity of Step Up Transformer

On the other hand, the maximum required capacity of the step-up transformer is calculated with the following formula with the condition that the house load is supplied from the starting transformer side.

$\frac{75MW}{0.85} \times 0.9511 = 83.92MVA$ (at secondary circuit of Tr.)

From the practical and economical point of view, the capacity of the step up transformer is recommended to apply 85 MVA at secondary circuit. The impedance of the transformer is selected 10% as practical standard of the manufacturing as shown in Table 11-28.

Table 11-28 Practical Standard of Transformer Impedance

Nominal Voltage (kV)	Impedance Voltage (%)
66/77	7.5
110	10
154	11
187	12
220	13
275	14
500	14

(2) Capacity of Unit Transformer

The power consumption of the auxiliary equipment shows in Table 11-29. The total power consumption for 75 MW FBC system is 6,500 kW. Table 11-30 shows the power consumption record in Wakamatsu (50 MW) FBC plant in Japan for the reference, and 0 marked portion shows the unnecessary equipment for the lignite over feeding system. The house load factor of the Wakamatsu (50 MW) FBC plant is 9.5% of the generator output.

Compared with Wakamatsu FBC, Sin Pun project has adopted the simple lignite-limestone feeding system. Therefore, the house load factor 9.1% is reasonable amount.

For the capacity of unit transformer, the following condition was considered.

Load factor	0.85
Margin	20% for future equipment

Unit Trans. Capacity 10 MVA

Impedance 5% (Practical Standard)

Table 11-29 Power Consumption of House Load Auxiliary Equipment (at Rated Load 75 MW)

Item	Power Consumption (kW or kVA)	
	Rated Value	Design Power Consumption
<u>6.6 kV Auxiliary (M/C)</u>		
CWP (Circulation Water Pump)	200 kW x 2	360 kW (at MSL)
BFP (Boiler Feed Water Pump)	1,500 kW	1,350 kW
FDF (Forced Draft Fun)	3,360 kW x 1	2,600 kW
IDF (Induced Draft Fun)	1,330 kW x 1	1,100 kW
<u>380 V Auxiliary (P/C)</u>		
Motor Load		80% of Rated Value
C.P. (Condensed Water Pump)	75 kW	60 kW
C.B.P. (Condensed Water Booster Pump)	132 kW	105 kW
T.A.C.P. (Turbine Auxiliary Cooling Water Pump)	160 kW	128 kW
B.C.P. (Boiler Circulation Pump)	190 kW	152 kW
Bag Filter	125 kW	100 kW
		545 kW
<u>480 V Auxiliary (C/C)</u>		
100% OF P/C Load		545 kW
Total		6,500 kW

Table 11-30a Actual Power Consumption Record for 50 MW A-FBC

	Actual Power Consumption	Remark
1. Unit M/C		
Sea Water Booster Pump	97	
Circulation Water Pump	240	
Condensate Water Pump	141	
Boiler Feed Water Pump	1,156	Utilizing the existing BFP
Induced Draft Fan	672	
Forced Draft Fan	1,275	
	0	
Soot Blower Compressor	255	o
Boiler Circulation Pump	149	
Coal Dryer Fan	130	o
Primary Air Fan	132	o
	0	
Bag Filter	88	
Dryer Induced Fan	63	o
440 V Power Center	375	
Sub-total	4,773	
2. Common M/C		
Ash Handling	4	
Coal Handling	116	
Common P/C	334	
Sub-total	454	
Total	5,227	

Note) O mark in the remark column is unnecessary load for Sin Pun project.

Table 11-30b Actual Power Consumption of P/C and C/C for 50MW-A-FBC

	Actual Power Consumption	Remark
1. Power Center		
APC Compressor	66	
Cooling Water Pump	68	
Ash Transportation Pump	70	o
Extract Fan for Coal Preparation System	13	o
	217	
2. Control Center	158	

(3) The Capacity of the Starting Transformer

The power consumption of the station load is shown in Table 11-31. The capacity of the station transformer is designed with the following condition.

Station Load + 100% of one Unit Load (for Back up).

From the above point, the capacity of the stating transformer is recommended 10 MVA also.

Table 11-31 Power Consumption of Station Load Auxiliary Equipment (at Rated Load 2x75MW Full Load)

Item	Power Consumption	
	Rated Value	90% of Rated Value
Common Auxiliary		
Lignite-Limestone Receiving System	200 kW	180 kW
Lignite-Limestone Preparation System	100 kW	900 kW
Ash Handling System	400 kW	360 kW
Waste Water Treatment System	200 kW	180 kW
Demineralized Water System	100 kW	90 kW
Ash Disposal Area Water Removal Pump		100 kW
Total		1,810 kW
Back up		
100% Unit Back up		6,500 kW
Total		8,310 kW

11.11.4 Control System

(1) Basic Condition

The cost of control system is occupying heavy weight in these days from 6% of the equipment cost to 10% because of the high needs for quality and the increasing of computer engineer wages.

Especially for the smale capacity of the generation plant, the weight of the cost in the control system is much higher then that of the large scale plant since the software design and the hardware price and number are more or less same either small or large capacity of the plant.

Therefore, it is recommendable to apply the simple control system with the manual operations for optimization of the cost for the control system as shown in Table 11-32.

Table 11-32 Control System Scheme

Item	
A-FBC System	Automatic Remote Control
Turbine-Generator	Automatic Remote Control
Lignite-Limestone Preparation System	Manual Remote Control
Ash Handling System	Manual Remote Control
Waste Water Treatment	Manual Remote Control
Demineralized Water System	Manual Remote Control
Switch Yard Equipment	Manual Remote Control
Data Acquisition System	FBC and Turbine-Generator only

Fig. 11-37 shows the outline of the boiler, turbine and generator automatic control system.

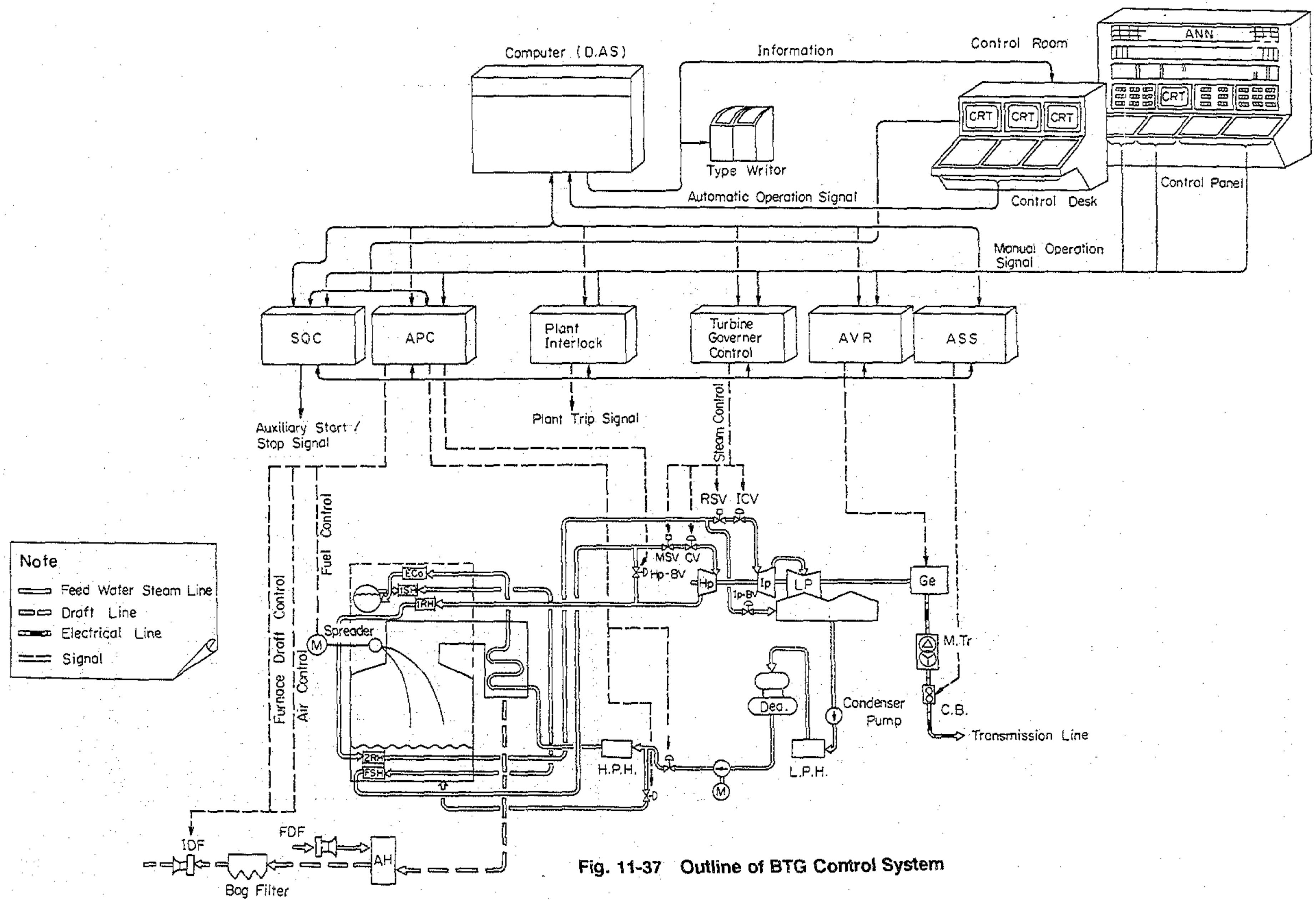


Fig. 11-37 Outline of BTG Control System

(2) FBC Control

The boiler response time of FBC is longer than that of the pulverized coal fired boiler (PCF) because the fluidized bed acts as a big heat chamber and the coal is burn with the longer time due to the larger size of coal.

The response time of FBC boiler is twice longer than that of PCF boiler as shown in Table 11-33.

Table 11-33 Boiler Response Time of FBC and PCF

	FBC	PCF
Coal Combustion Time	2 - 4 min (5 mm size)	20 - 40 sec.
Time lag of Bed Material Temperature	abt. 1 min	---
Boiler Response Time	7 - 11 min	5 - 7 min
Total	abt. 10 - 16 min	abt. 6 - 8 min

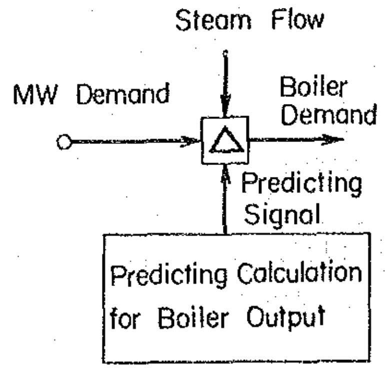
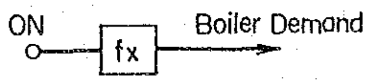
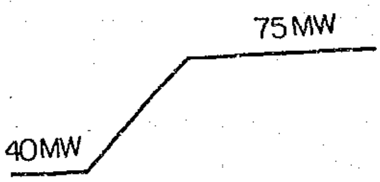
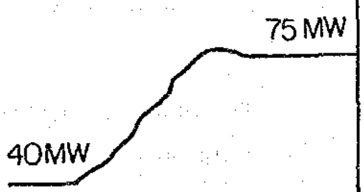
Because of the longer response time, it is recommendable to apply the turbine follow control for the economical and simple design.

In developing FBC APC in Japan, the predicting control skill is applied to meet the generator output for the scheduled power demand with investing more than 300 million yen for the software development.

Those software development shall be carried out for the respective boiler because of the different characteristic of the boiler and coal.

Table 11-34 shows the difference of the above two control method.

Table 11-34 Predicting Control and Turbine Follow Control

	Predicting Control	Turbine Follow Control
Circuit		
Boiler Demand Signal		
Generator Output		
Particular	• Load Patter can be changed according to the power demand.	• Fixed Load Pattern only be available • Generator out put is depend on the change of the fuel characteristic also. • This mode is available for base load power plant.
Hardware cost and Software Development	Abt. +100 Million Yen	Base

Since the grid system in Thailand is big enough to absorb the few M.W. deviation of the generator out put and the scheduled load demand during the load increase and decrease, it is designed to apply the turbine follow mode control for the boiler control for the economical design.

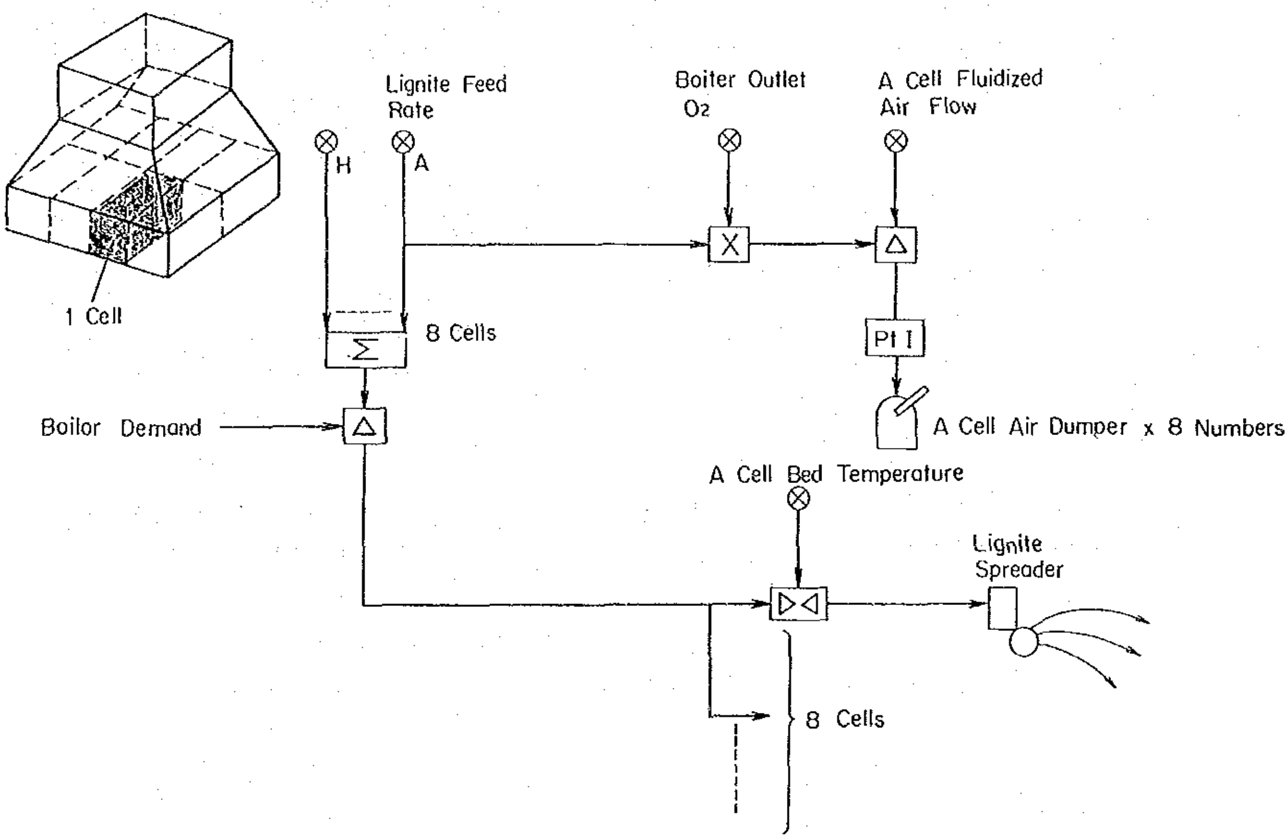


Fig. 11-38 FBC Control Diagram

11.11.5 Switchgear

(1) 115 kV Switchgear

Table 11-35 shows the comparison of 115 kV switch configuration. Before coming new transmission line, the case No. 1 is best selection to minimize the construction cost. However, the case No. 1 is completely depend on the retirement schedule of the existing power plant.

Therefore, the tentative plan is recommended to apply in this stage of the availability of the connection for the FBC plant before the retirement of the existing plant.

The tentative plan can be expanded to the future plan of the transmission line also with saving two switches, i.e. for P.E.A. and one existing transmission line.

This tentative plan is available without the unit 5 switches also when the unit 5 is coming behind the schedule.

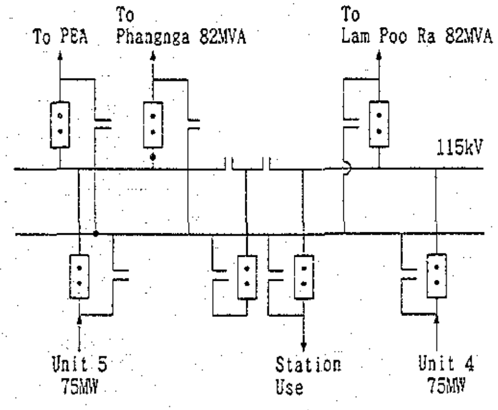
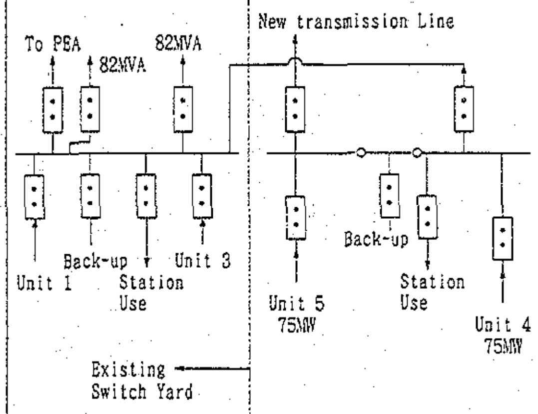
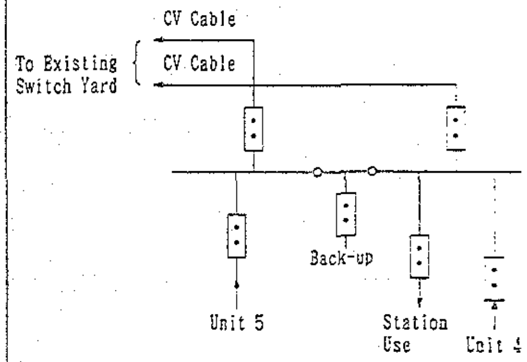
With the economical point of view and the practical way of construction, the tentative plan is recommended in this study.

Fig. 11-39 shows the switch diagram of the tentative plan, 115 kV switch and auxiliaries arrangement (one bloc) and the layout of the 115 kV switchyard.

(2) 6.6 kV Auxiliary Switch

The main auxiliary motor more than 200 kW is supplied by the 6.6 kV switches which are V.C.B. or G.C.B. type. The number of switches is shown in Table 11-36.

Table 11-35 Comparison of Switch Yard Configulation

	No. 1	No. 2	Tentative Plan (Recommendation)
Circuit			
Number of Additional Switch	0	6	6
Condition · Additional Transmission Line To Utilize Existing Switch Yard	 × ○	 ○ ○	 × (Teutative) ○
Merit	No additional switch is requested.	Bus interconnect switch can be available as back-up switch. In appling new transmission line, the power station can be operated continuously when the transmission line fault happens. Unit 4 can be commissioned without the retirement of the existing units.	Before coning new transmission line, the existing transmission line to Lam Poo Ra will be connected to the new switch.
Demerit	· One of the unit shall be stopped when the transmission fault happens. · Reconnection of the transmission line is depend on the retirement schedule of the existing power station.	Additional cost for the transmission line and swich is is requested.	

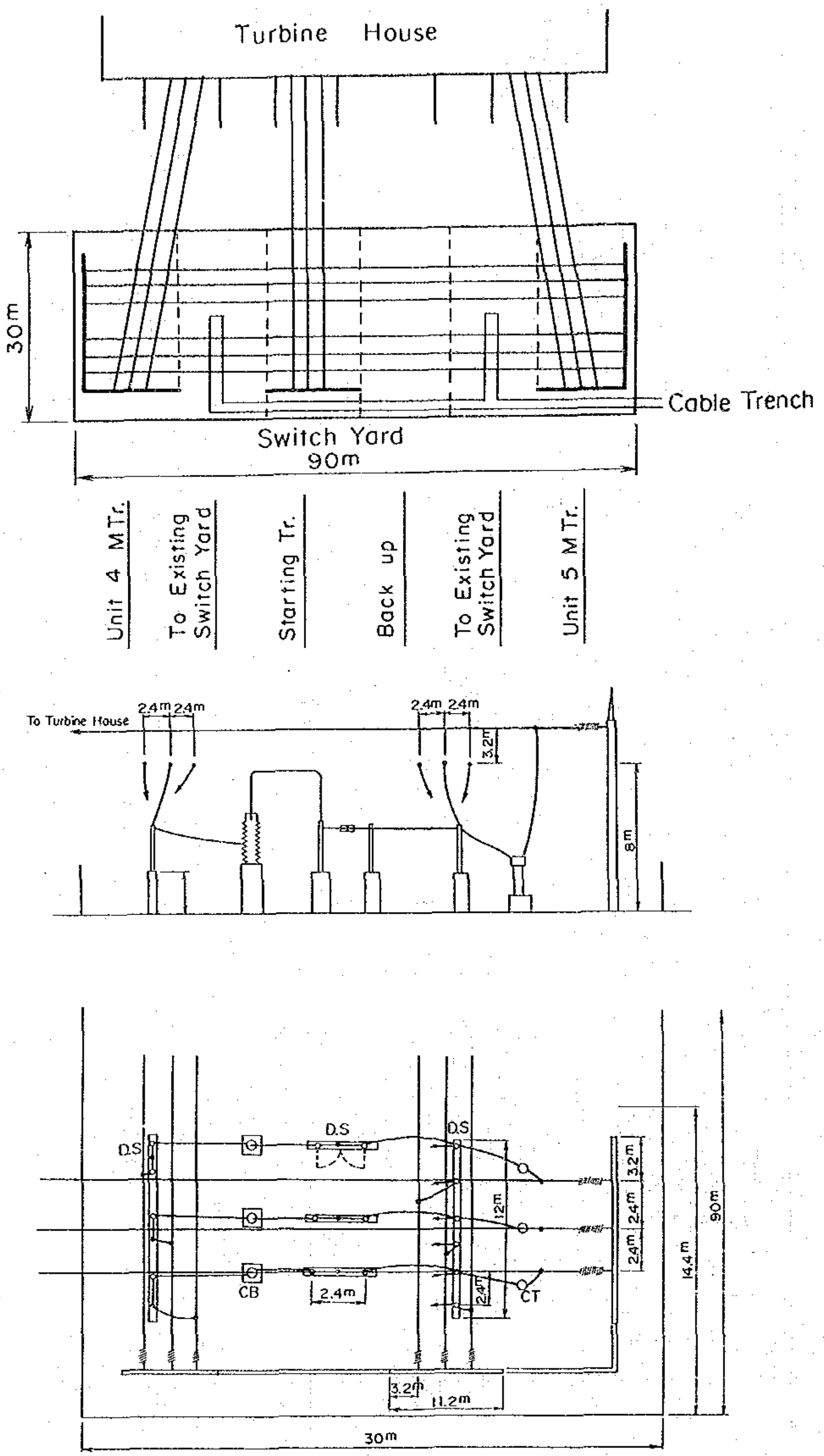


Fig. 11-39 115 kV Switch and Auxiliaries Arrangement (One Block)

Table 11-36 6.6 kV Switches

Name of Auxiliaries	Number of Switches
C.W.P.	2 x 2 units = 4
B.F.P.	2 x 2 units = 4
F.D.F.	1 x 2 units = 2
I.D.F.	1 x 2 units = 2
Bus Receiving Switches	3
Power Center Feeder	3
Bus Interconnection Switches	4
Auxiliary Equipment Feeder	1
Total	

(3) 380 V Auxiliary Switch

The auxiliary motor below 200 kW is supplied by 380 V auxiliary switch. 380 V auxiliary switch is segregated into two seciton, i.e. more than 75 kW for P/C and below 75 kW for C/C. A.C.B. is applied for P/C and M.C.C.B. for C/C.

11.11.6 Emergency Power

Emergency Power is designed to be supplied by the diesel generator set. One set of D.G. is supplied for two units.

Table 11-37 shows the load schedule for A-FBC emergency power.

Table 11-37 Emergency Power Load

Item		
A.H. Lub. Oil Pump	1 kW x 2	2 kW
A.H. Motor	11 kW x 2	22 kW
Switchyard Compressor	40 kW	40 kW
Turbine Turning Oil Pump	10 kW x 2	20 kW
Turbine Turning Motor	7.5 kW x 2	15 kW
Main Oil Tank Extract Fan	2.2 kW	2.2 kW
Emergency Lighting	10 kVA	10 kVA
Elevator	22 kW	22 kW
Communication	10 kVA	10 kVA
Vacuum Pump	2.2 kW x 2	4.4 kW
M-BFP aux. oil pump	20 kW x 2	40 kW
M-BFP Turning Motor	2.2 kW x 2	4.8 kW
CVCF (Battery)	1.5 kW x 2	15 kW
T.V. Cooling Fan	4 kW x 2	8 kW
Total		195 kW + 20 kVA

P.F. of Motor	0.8	264 kVA
Margin	11%	300 kVA

11.12 Ash Handling System

11.12.1 General

A-FBC generates three kind of the ash, i.e. FBC. Bed Material (B.M.) ash, the cyclone ash and the bag filter ash. FBC. B.M. ash is the extraction out ash to keep the fluidized bed height. The cyclone ash is collected by the mechanical cyclone (M/C) in front of A.H. The bag ash is collected by the bag filter after A.H.

The chemical analysis of the respective ash is shown in Table 11-38. (ref Fig. 9-14 Test No. T-20)

Table 11-38 Chemical Analysis of Ash

		B.M. ash	M/C ash	Bag ash
CaO	%	31.71	24.67	10.16
$CaCO_3$	%	4.22	6.87	1.84
$CaSO_4$	%	56.14	36.70	41.43
SiO_2	%	3.28	17.29	15.49
Fe_2O_3	%	0.79	5.67	13.67
Na_2O	%	0.01	0.03	0.08
Others	%	3.85	8.77	17.33

High CaO content makes the alkaline water by the rain and it is necessary to dispose the ash in proper way for avoiding to let the alkaline water penetrate into the living city water.

11.12.2 Quantity of Ash

From the pilot combustion test, the material balance of respective ash is balanced as follows;

B.M.	45%	(1)
Mechanical Cyclone Ash	45%	
Bag Ash	10%	

Total ash generation of Sin Pun-Krabi lignite mixture is about 50 t/h per unit as follows;

Ash from Lignite		16.7 t/h
Ash from Limestone		
	Non lime portion	42.9 x 0.1 = 4.3 t/h (Molar Ratio 3)
	Lime portion	$42.9 \times 0.9 \times \frac{56}{100} = 21.6\ t/h$
	Gypsum-Line	6.6 t/h
Total		49.2 t/h

As explained in Clause 9.5, the size distribution of the respective ash and limestone is outlined as shown in Fig. 11-40.

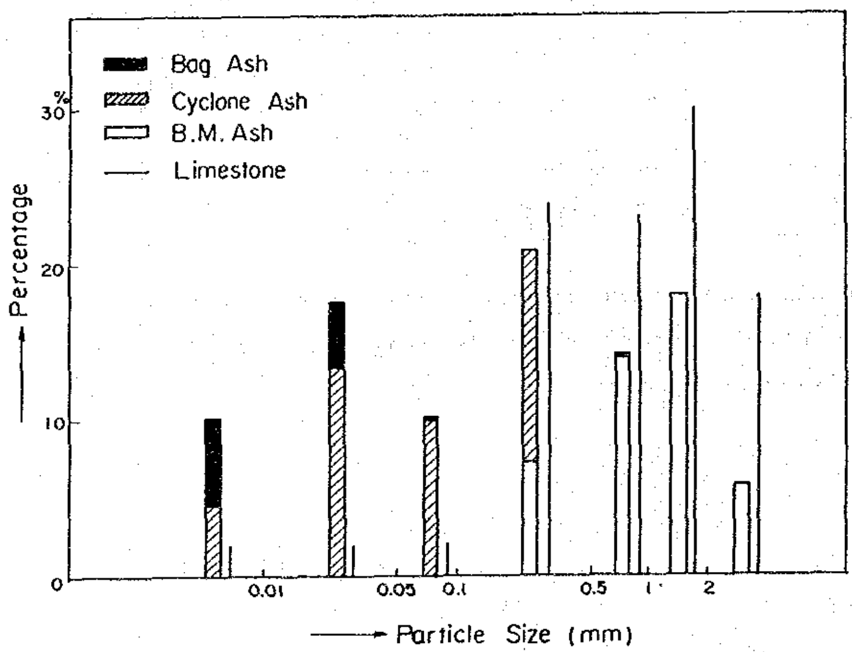


Fig. 11-40 Outline of Respective Ash Distribution and Limestone

Therefore, the quantity of the respective ash is designed with 10% margin as follows;

B.M. Ash	50 t/h	for 2 units
M/C Ash	50 t/h	for 2 units
Bag Ash	10 t/h	for 2 units

As indicated in Clause 9.6, B.M. ash is recommendable to reduce the amount by applying the small limestone particle. Fig. 11-41 shows the alternate limestone distribution which can be carried out the hammer crusher.

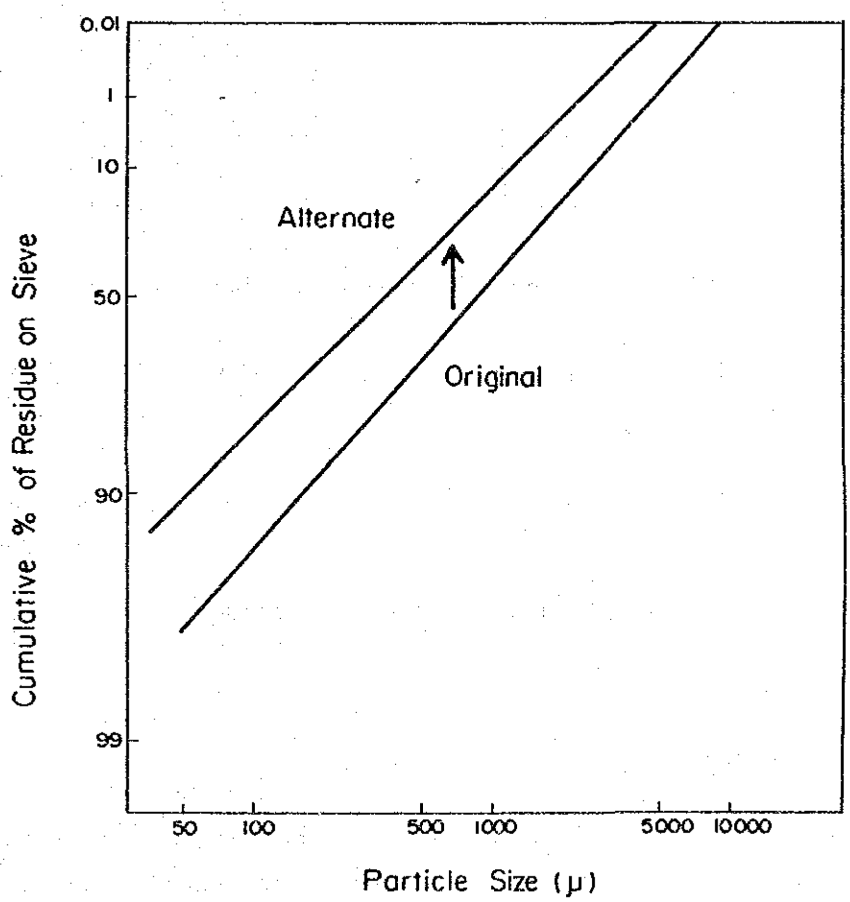


Fig. 11-41 Alternate Limestone Distribution

By applying the small particle of the limestone, the material balance would be changed as shown in Fig. 11-42.

B.M. ash	37%
Fly ash	63%

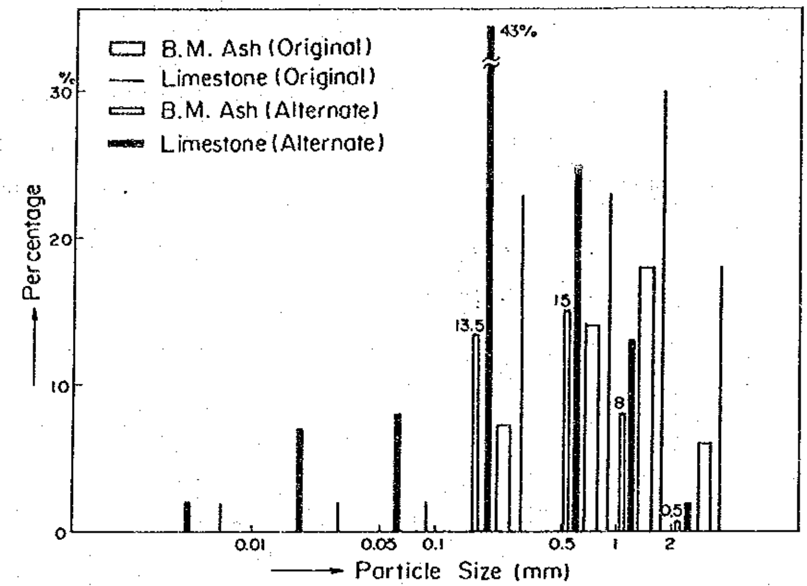


Fig. 11-42 Outline of Ash Distribution for Alternate Limestone

By the performance of the mechanical cyclone, the bag ash could be increased from 10% to, 40%.

$$\left(50\ t/h \times 0.4 \times \frac{(1-0.998)}{1-0.999} \times \frac{1}{30,000\,Nm^3/h} = 133\ mg/Nm^3 < 500\ mg/N^3\ \textit{Thai Regulation}\right)$$

Therefore, the alternate material balance is assumed as follows;

B.M. ash	37%	
Cyclone ash	23%	(2)
Bag ash	40%	

For the equipment design, the quantity of the respective ash is designed with the higher value of (1) and (2). Therefore, the quantity of the respective ash is designed with 10% margin as follows;

B.M. ash	50 t/h	for 2 units
Cyclone ash	50 t/h	for 2 units
Bag ash	40 t/h	for 2 units

11.12.3 Ash Handling Process

There are several grade of ash handling process as shown in Table 11-39.

Table 11-39 Ash Handling Process

	BM Ash	Cyclone Ash	Bag Ash
High Grade Cost: +300 Million Yen	• Cool down B.M. ash form 830°C to 50°C by B.M. Cooler • Pneumatic ash transportation to ash silo • Slurry transportation to ash disposal	• Pneumatic ash transportation to ash silo • Slurry transportation to ash disposal	• Pneumatic ash transportation to ash silo • Slurry transportation to ash disposal
Medium Grade Cost: Base	• Cool down B.M. ash from 830°C to 50°C by B.M. cooler • Pneumatic ash transportation to ash silo • Dump truck ash transportation to ash disposal	• Pneumatic ash transportation to ash silo • Dump truck ash transportation to ash disposal	• Pneumatic ash transportation to ash silo • Dump truck ash transportation to ash disposal
Economic Grade Cost: -700 Million Yen	• Cool down B.M. ash from 830°C to 300°C by the pneumatic cooler • Hopper Receiving • Special anti-heat dump truck for transportation to the ash disposal	• Dump truck transportation directly from the M/C hopper	• Pneumatic ash transportation to ash silo • Dump truck ash transportation to ash disposal

Since the dump truck is already available in this project in return way of the lignite and limestone transportation, the high grade system is not recommendable.

The medium grade and the economic grade system is shown in Fig. 11-43 and Fig. 11-44. The economic grade system is recommended at this moment from the following reasons;

(1) The labor cost for the dump truck transportation is not high at this moment to meet the additional investment for the medium grade design.

(2) The material balance of the ash is drastically changeable during the operation for finding the suitable operating condition to meet with the emission regulation. Therefore, the equipment design is preferable to be carried out after several year operation.

(3) The ash is generated abt 70% of lignite consumption. The investment of ash handling system is so large that the financial feasibility is very hard to recover during the initial stage, if the medium grade system is applied from the beginning.

However, the medium grade system is recommended to apply the later stage to balance the labor cost for these ash transportation. Therefore, in this study, the medium grade ash handling system also itemized in the equipment schedule as a future equipment.

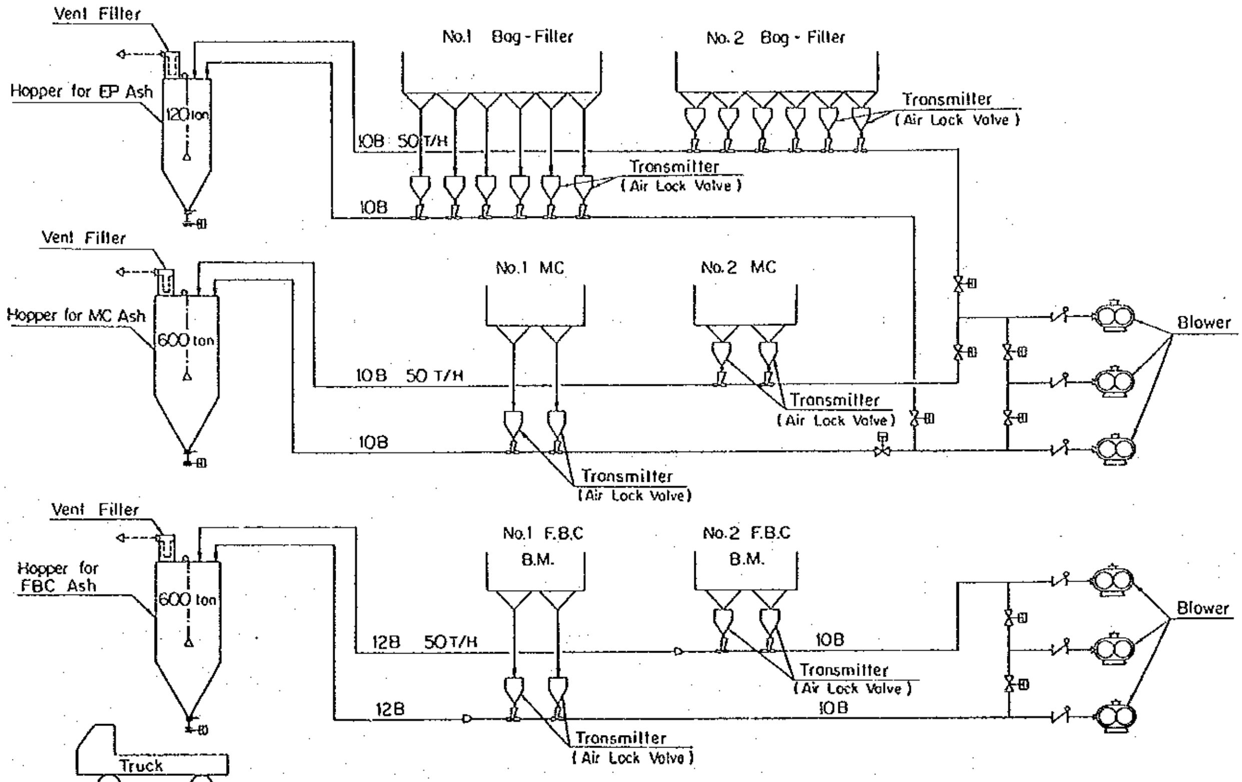


Fig. 11-43 Medium Grade Ash Handling System

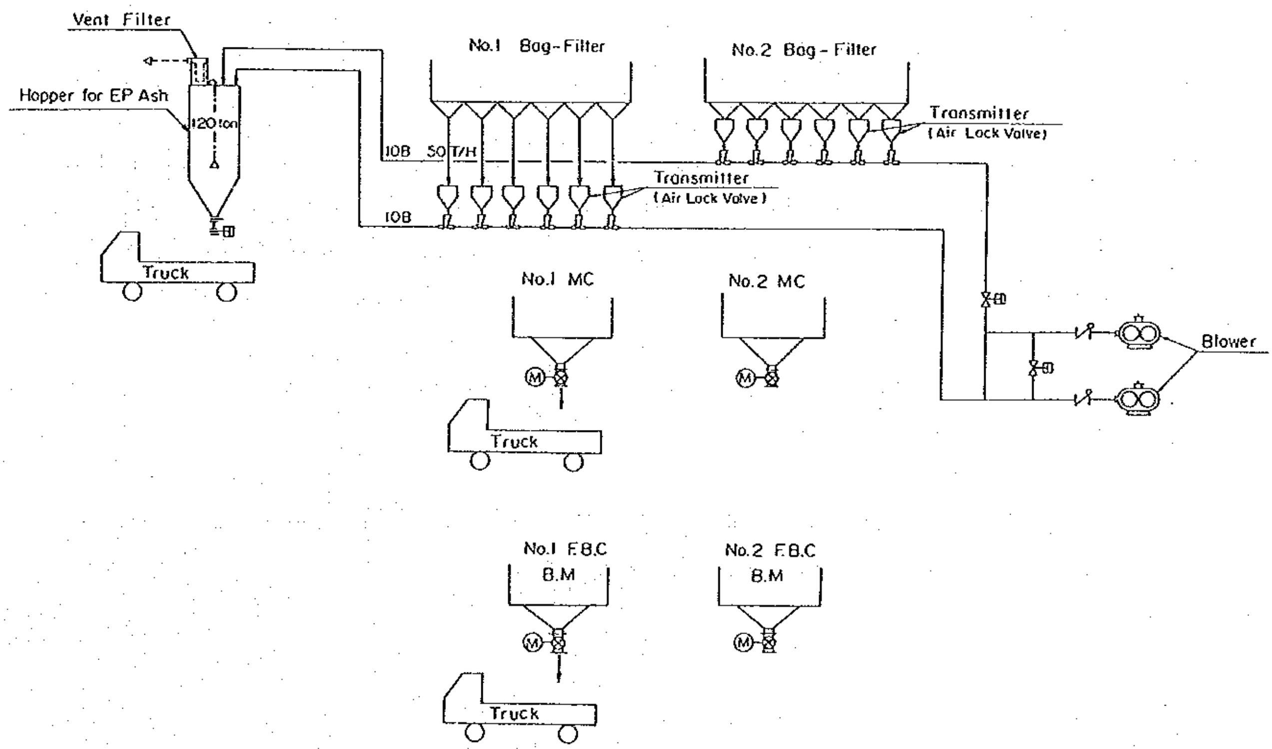


Fig. 11-44 Economic Grade Ash Handling System

11.12.4 Ash Disposal Area

(1) Location of Ash Disposal Area

Two existing coal mining pits, Ban Pu Dam Mine and Khlong Wai Lek Mine, can be utilized as ash disposal pits. The distances from the planing power plant to those existing mines are about 1.5 km to the Ban Pu Dam Mine (indicated as "No. 1 Ash Disposal Area" in Fig. 11-45) and about 3 km to the Khlong Wai Lek Mine (indicated as "No. 2 Ash Disposal Area" in Fig. 11-45).

(2) Capacity of Ash Disposal Area

The abovementioned ash disposal area No. 1 and No. 2 have the capacity of 17×10^6 m^3 and 15×10^6 m^3 respectively. Total capacity of 32×10^6 m^3 is sufficient for more than 25 years ash volume, approximately 20×10^6 m^3, which will be generated in the planning power plant.

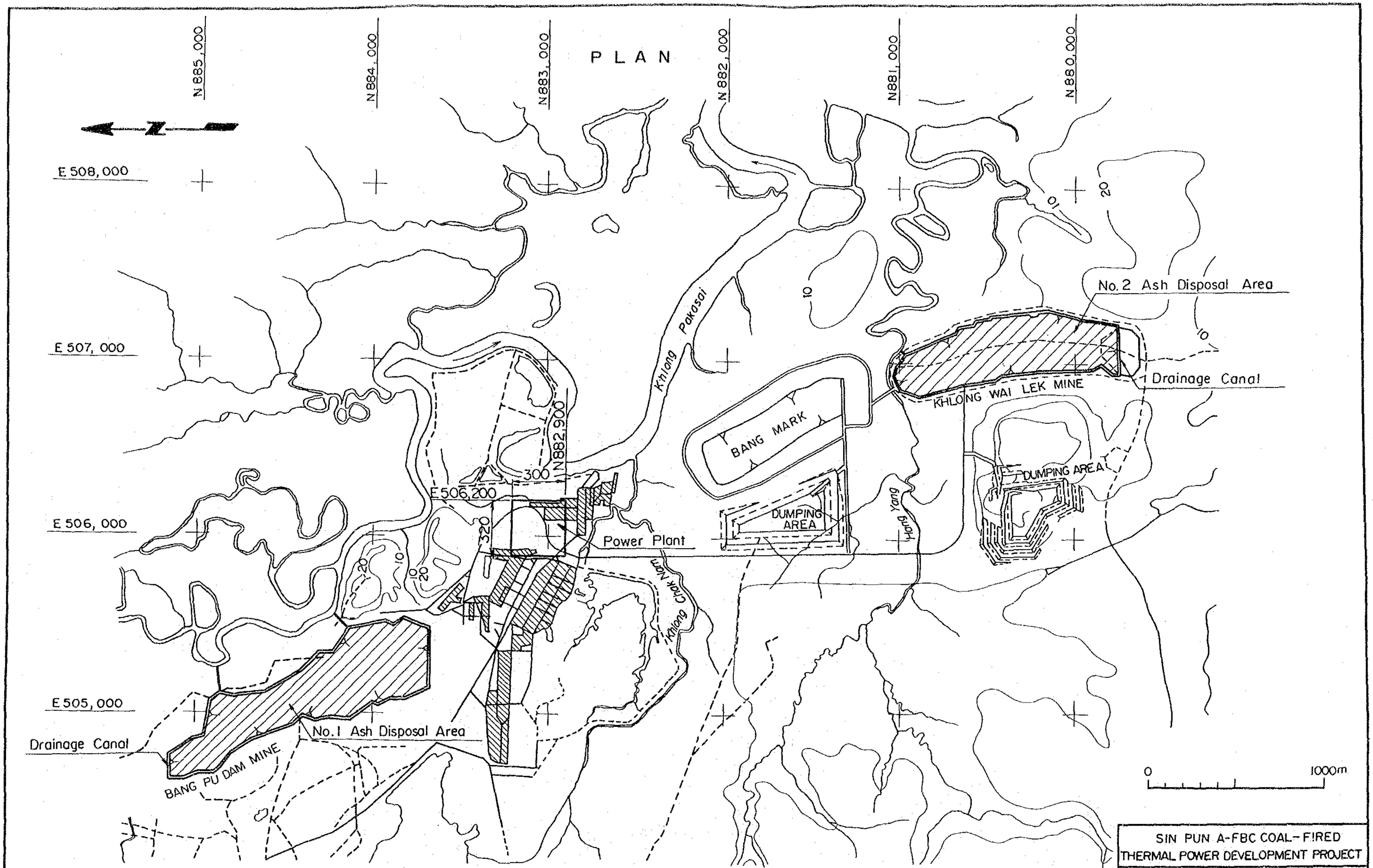
As a matter of course, it is recommended to use No. 1 ash disposal area first for about 20 years because of its nearness which means economical ash transportation compared to using No. 2 ash disposal area.

(3) Ash Filling

Ash generated in the planning power plant is transported to the ash disposal area by dump trucks, and is dumped and filled from the bottom of the ash disposal pit, -50 m below ground level toward the existing ground level. Bulldozers are used to fill and compact dumped ash.

At the final stage, the surface of disposed ash will be covered with soil and leveled to the ground surface.

Remained temporary road used for coal transportation previously can be utilized also for ash transportation.



SIN PUN A-FBC COAL-FIRED THERMAL POWER DEVELOPMENT PROJECT

ASH DISPOSAL AREA (2-1)

Fig. 11-45

(4) 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:

1) Rainwater Inside the Ash Disposal Area

Rainwater inside the ash disposal area, that is rainfall inside the pit, will be collected to temporary shallow sumps, then pumped up to a sedimentation basin as shown in Fig. 11-46.

The pumps should have such capacity as can discharge the volume of maximum mean monthly rainfall considering evaporation under the condition of 8 hours operation per day.

The storage capacity of the sedimentation basin is decided taking into consideration the water volume for eight hours retention period, effective water depth of 1.5 m and surplus depth of 1 m for deposit.

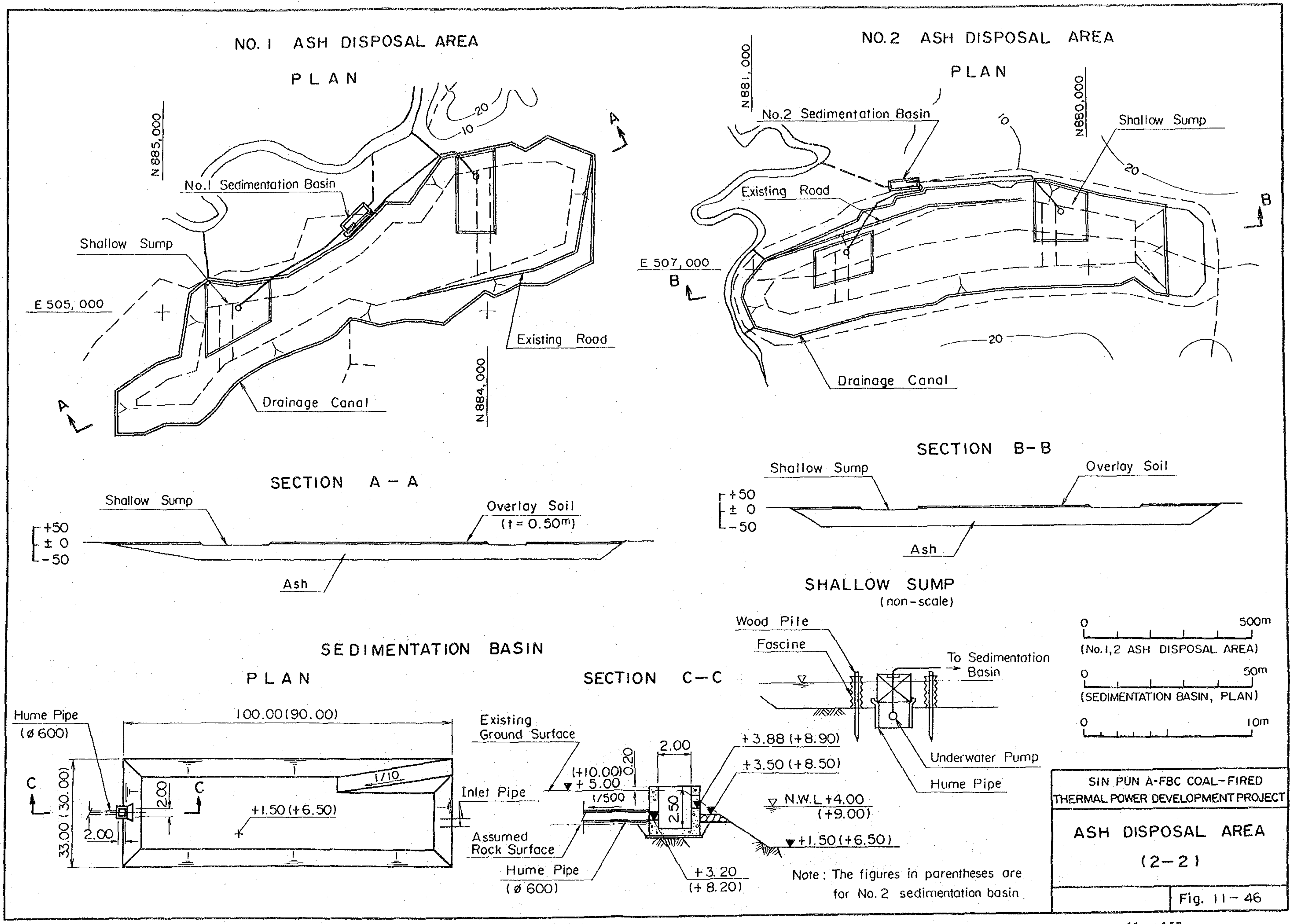
So the each capacity will be as follows.

- Sedimentation basin for No. 1 ash disposal area: approx. 4,000 m^3
- Sedimentation basin for No. 2 ash disposal area: approx. 3,000 m^3

After sedimentation the water will overflow from the sedimentation basin and will go outside through a pipeline.

2) Rainwater Outside the Ash Disposal Area

Rainwater falling outside the ash disposal area will be gathered in a drainage canal surrounding the ash disposal pit in order to prevent rainwater overflowing into the pit. The collected rainwater will be discharged directly into the river.



NO. 1 ASH DISPOSAL AREA
PLAN
N 885,000
No.1 Sedimentation Basin
Shallow Sump
E 505,000
Existing Road
N 884,000
Drainage Canal
A
20
10
NO. 2 ASH DISPOSAL AREA
PLAN
N 881,000
N 880,000
No.2 Sedimentation Basin
Shallow Sump
Existing Road
E 507,000
B
Drainage Canal
10
20
SECTION A – A
Shallow Sump
Overlay Soil
(t = 0.50m)
+50
± 0
-50
Ash
SECTION B – B
Shallow Sump
Overlay Soil
+50
± 0
-50
Ash
SHALLOW SUMP
(non-scale)
Wood Pile
Fascine
To Sedimentation Basin
Underwater Pump
Hume Pipe
0 500m
(No.1,2 ASH DISPOSAL AREA)
0 50m
(SEDIMENTATION BASIN, PLAN)
0 10m
SEDIMENTATION BASIN
PLAN
Hume Pipe
(ø 600)
100.00 (90.00)
33.00 (30.00)
2.00
2.00
1/10
+1.50 (+6.50)
C
SECTION C – C
Existing Ground Surface
(+10.00)
+5.00
0.20
2.00
+3.88 (+8.90)
+3.50 (+8.50)
Inlet Pipe
1/500
2.50
N.W.L +4.00
(+9.00)
Assumed Rock Surface
+1.50 (+6.50)
Hume Pipe
(ø 600)
+3.20
(+8.20)
Note: The figures in parentheses are for No. 2 sedimentation basin
SIN PUN A-FBC COAL-FIRED THERMAL POWER DEVELOPMENT PROJECT
ASH DISPOSAL AREA
(2–2)
Fig. 11 – 46

11.12.5 Ash Utilization Methodology in Japan

(1) General

Coal ash in Japan which was originated from power utility industry in 1988 was approximately 4 million tons per year, and that from general industry fields was estimated to be around 1 million ton.

Of the above mentioned 5 million tons of coal ash, approx. 1.8 million tons were put to efficient use, and the remaining 3.2 million tons were disposed of in landfills or as waste.

Major uses of coal ash application are as cement material, cement and concrete admixture, and construction materials such as road material and board material.

Fig. 11-47 shows the rate of coal ash utilization in 1987.

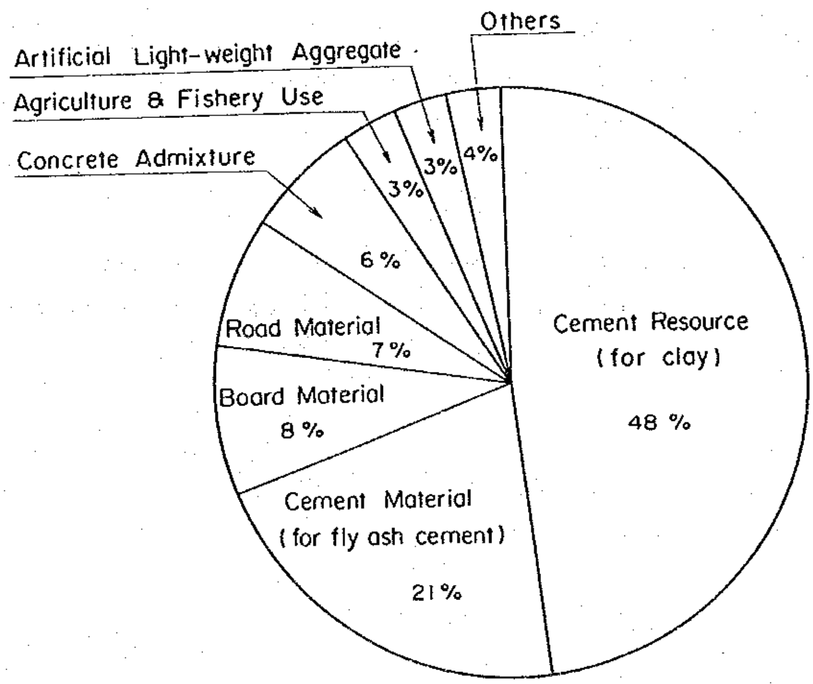


Fig. 11-47 Utilization of Coal Ash in 1987

(2) Cement Material

Fly ash is utilized as cement material for fly ash cement and also for concrete admixture.

The properties of mortar or concrete are improved by adding fly ash. There are two methods by which fly ash is added, that is, "mixing on site" and "mixing at the plant." With the former method, fly ash is added when mortar or concrete is made on site. With the latter, fly ash is added to the cement at the factory to make fly ash cement.

Merits of fly ash cement when used for mortar or concrete are as follows.

Merits of fly ash cement:

- Reduced heat from hydration
- Increased long-term strength
- Improved watertightness
- Improved resistance to chemical reactions
- Improved workability
- Reduced shrinkage by drying, etc.

Also, the following construction methods which display the merits of fly ash have found practical applications, and are now attracting the attention of those concerned.

- Grouting
- Roller Compacted Dam-Concrete System (RCD)
- Prepacked Concrete Method

(3) Raw Material of Cement

Coal ash is utilized as raw material of cement in several ways such as follows.

1) Ordinary portland cement (mixed material)

JIS (Japan Industrial Standard) R 5210 prescribes the method of manufacturing of ordinary portland cement as follows:

"Fly ash and limestone should be mixed before crushing, or crushed before mixing. They should then be blended to achieve homogeneity. The total amount of this homogeneously mixed material should be less than 5% of the cement."

2) Clinker for portland cement (as clay replacement)

Clinker is used to replace clay, one of main types of raw material used to produce portland cement, which consists of various types of cement.

3) Clinker for new composite cement (as clay replacement)

The fly ash used as the clinker for new composite cement completely replaces all such materials as clay (one of the main types of raw material used to produce cement), iron oxide material, and others. In the period from 1984 to 1986, led by the Central Research Institute of the Electric Power Industry, an investigation into its properties and tests on practical use were conducted in order to obtain a proper evaluation.

The economical efficiency of fly ash is expected to lead very quickly to new fields of use.

(4) Materials for Road Construction

Coal ash is utilized as several kinds of road construction materials such as follows.

1) Asphalt filler

The results of the tests conducted to determine the suitability of fly ash as filler material shows that fly ash has characteristic values equivalent to those of conventionally used limestone powder, in terms of grain distribution, flow value, Marshal stability, stiffness, residual stability, fatigue resistance, stripping resistance and abrasion resistance.

Therefore, fly ash can serve as asphalt filler in applications such as to public roadway construction through appropriate quality control and construction execution management.

2) Subbase Course Material

Clinker ash has already been introduced into practical use as subbase course material in some countries, while in Japan fundamental research efforts were only commenced in the 1960's. Just recently, this area of application was adopted in "Manual for Asphalt Pavement."

Tests were conducted to determine the suitability of clinker ash as subbase course material. The results indicate that the properties of clinker ash produced from both domestic and improved coals satisfy the material quality standards set forth in "Manual for Asphalt Pavement."

When all the test results are taken into consideration, appropriate quality control and construction execution management permit clinker ash to be utilized in applications such as to public roadway construction.

Furthermore, clinker ash has pH value of 8.2 to 10.8, which is lower than that of cement, and also sufficiently meets other disposal requirements so that it can be used in an environmental innocuous manner.

(5) Others

In addition to the uses described above, many other fields of coal ash application as shown in the followings have been found.

- Materials for interior and exterior walls
- Fertilizers
- Filling material for mines and tunnels
- Soil improvement material
- Drainage improvement material, etc.

11.13 Power House

11.13.1 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.

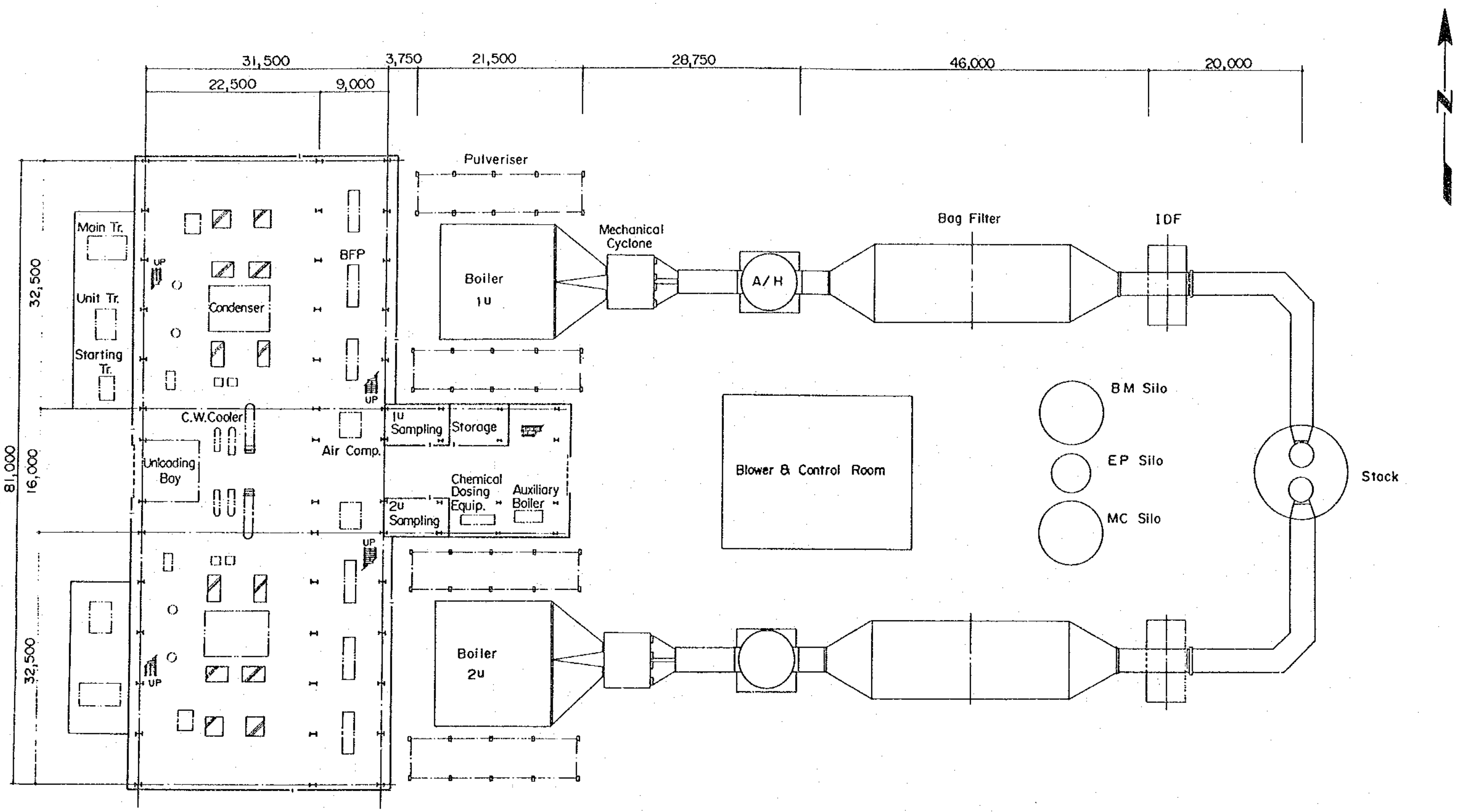
In the turbine house, steam turbines and generators are arranged in a straight line and overhead traveling crane is installed above these equipment to facilitate maintenance work.

Furthermore, unloading bay is located between No.1 and No.2 turbine house to facilitate installation of the power plant equipment 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.

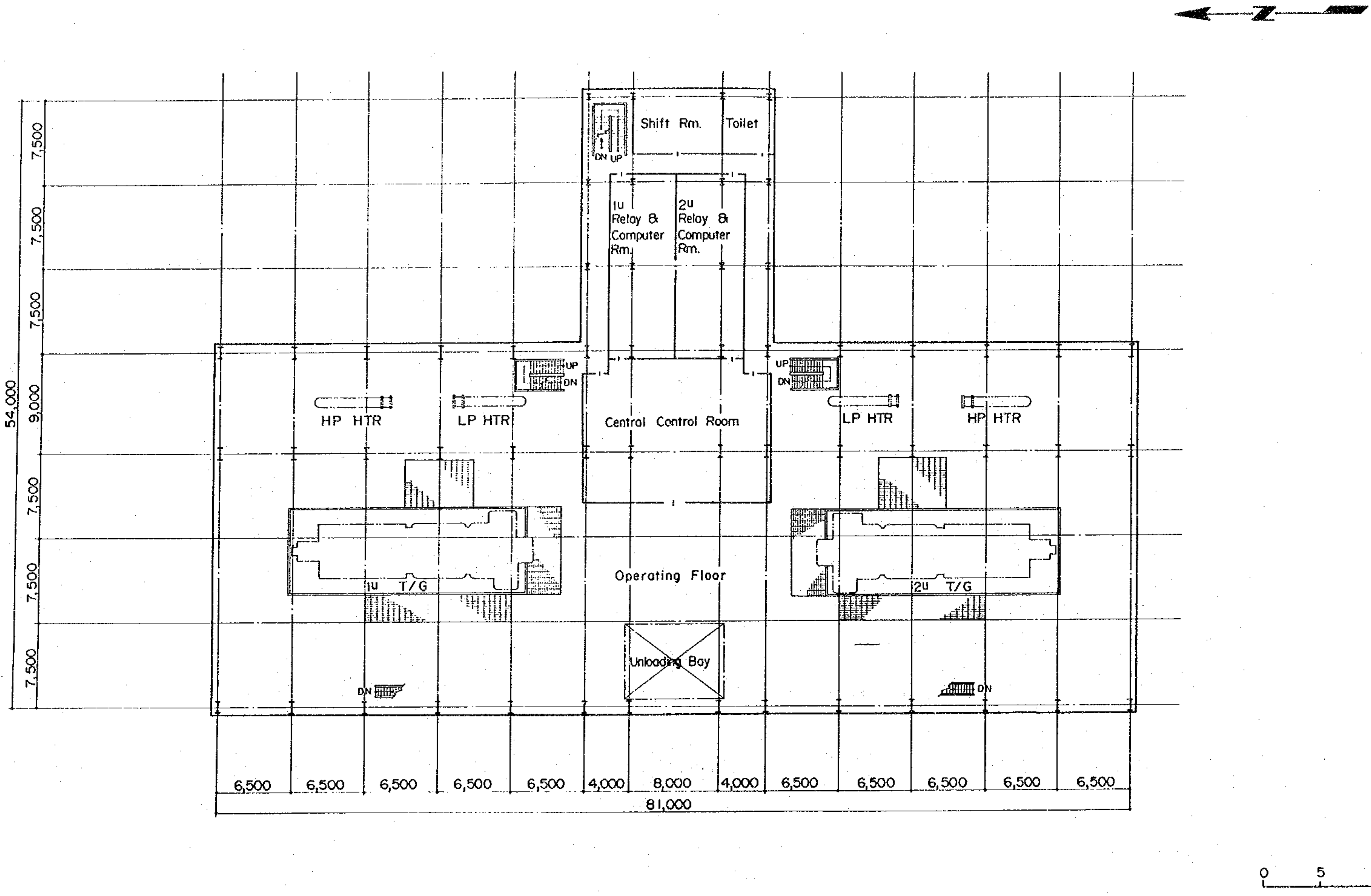
Taking a look at the layout of the control house, various facilities for control the power plant are arranged mainly on the second and third floors. These include the central control room, relay and computer room, electricity room, and instrument testing room. An auxiliary boiler equipment, chemical dosing equipment, etc. are located on the grand floor.

When mapping out the floor plans for the individual structures, No.1 and No.2 units are symmetrically arranged by locating the control house halfway between these units for functionally organizing the control system and also arranging the facilities of these units similarly as much as possible. These arrangement is shown in Fig. 11-48 and 11-49.



POWERHOUSE YARD

SIN PUN A FBC COAL FIRED THERMAL POWER DEVELOPMENT PROJECT
POWERHOUSE YARD GENERAL ARRANGEMENT
Fig. 11 - 48



PLAN EL+10,000

SIN PUN A-FBC COAL-FIRED THERMAL POWER DEVELOPMENT PROJECT

POWERHOUSE

PLAN EL+10,000

Fig. 11-49

11.13.2 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 designed in such a manner that these facilities can be supported on firm ground. In addition, the foundation in placed on firm ground so that it safely supports the weight of the superstructures such as equipment and its supporting frames and it lessens troubles arising from vibration caused by the equipment. The foundations 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 EGAT revealed that bedrock in the area where the power station is planned.

11.13.3 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 + 10 m) are supported by rigid reinforced concrete.

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.

11.13.4 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, 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.

11.14 Stack

11.14.1 Design Condition

Height: 80 m

The stack height is about twice as high as powerhouse one. Because dawnwash will have a harmful effect on other Building.

Inner flue diameter: 2.5 m at the top and 3.5 m for the rest

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

11.14.2 Stack Type

Stack type is a reinforced concrete which consists of two inner flues made of steel and reinforced concrete outer tube.

The reason can be summarized as follows:

- The construction cost of reinforced concrete stack is lower than that of steel structure.
- The construction period of reinforced concrete stack is slightly shorter than that of steel structure.
- A concentric stack type is advantageous in terms of overall space efficiency.
- As this type consists of two inner flues, it is possible to do the inspection of lining for inner flue and repair at one unit's annual inspection.

11.15 Ancillary Building

(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, telecommunications equipment room, library, dining room, depot Locker room etc. 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-extinguishing facilities and fire alarms.

(2) Other Building

Various other buildings that are required to be constructed along with the administration building include warehouse, limestone house, guardhouse.

(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.

11.16 Environmental Equipment

11.16.1 Dust Collector

Major dust collectors for flue gas treatment employed at coal fired power plans are electrostatic precipitators and bag filters. A comparison of electrostatic precipitators and bag filters is shown in Table 11-41.

Table 11-41 Comparison of ESPs and Bag Filters for Coal Fired Power Plant

Item	ESP	Bag Filter
Dust-collecting performance	Dust-collecting performance sometimes depends on coal.	Dust-collecting performance is stable and does not depend much on coal.
Maintainability	Maintenance frequency of once a year may be sufficient.	The filter must be changed periodically.
Pressure loss	Low (About 20 mmH_2O)	High (100 to 150 mmH_2O)
Space for installation	Small	Large
Cases of use	Used much in Japan, US and Europe	Used in US and Australia

The dust collecting efficiency of electrostatic precipitators depends much on electrical resistivity of dust. Effects of electrical resistivity of dust on the dust collecting efficiency of electrostatic precipitators are shown in Fig. 11-50.

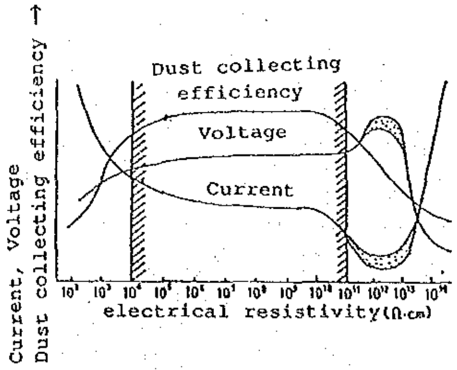


Fig. 11-50 Effects of Electrical Resistivity of Dust on dust Collecting Efficiency (1)

Ordinary electrostatic precipitators show high dust collecting efficiency when the electrical resistivity of dust is in the range of 5×10^4 to 10^{11} Ωcm. The dust collecting efficiency of electrostatic precipitators deteriorates outside the range due to jumping phenomenon ($< 5 \times 10^4$), charge instability (10^{11} - 10^{12}) and back discharging ($> 10^{12}$). The electrical resistivity of dust depends on coal type, gas temperature, etc. In general, however, the electrical resistivity of dust from high sulfur coal is lower than those from low sulfur coal. The electrical resistivity of dust for the case of sulfur content on the order of 4% and gas temperature on the order of 130°C is estimated to be on the order of 5×10^9 Ωcm, and it falls in the normal range.

Dust characteristics in fluidized-bed combustion, however, are different from those in pulverized coal combustion, and the electrical resistivity of dust is also different between them. The electrical resistivity of ash in fluidezed-bed combustion is in the range of 10^{12} to 10^{13} Ωcm according to the demonstration test made at Wakamatsu 50 MW-FBC, and it falls in the range where the dust collecting efficiency of ordinary electrostatic precipitators deteriorates due to back discharging. Pulse-charged electrostatic precipitators are effective to suppress the back discharging phenomenon and maintain the dust collecting efficiency, and such electrostatic precipitators were employed at Takehara 350 MW-FBC plant based on the results of demonstration test at Wakamatsu 50 MW-FBC. Effects of electrical resistivity of dust under pulse charging are shown in Fig. 11-49. As seen in the figure, the method allows to collect dust of high electrical resistivity, which were difficult to collect by conventional charging method.

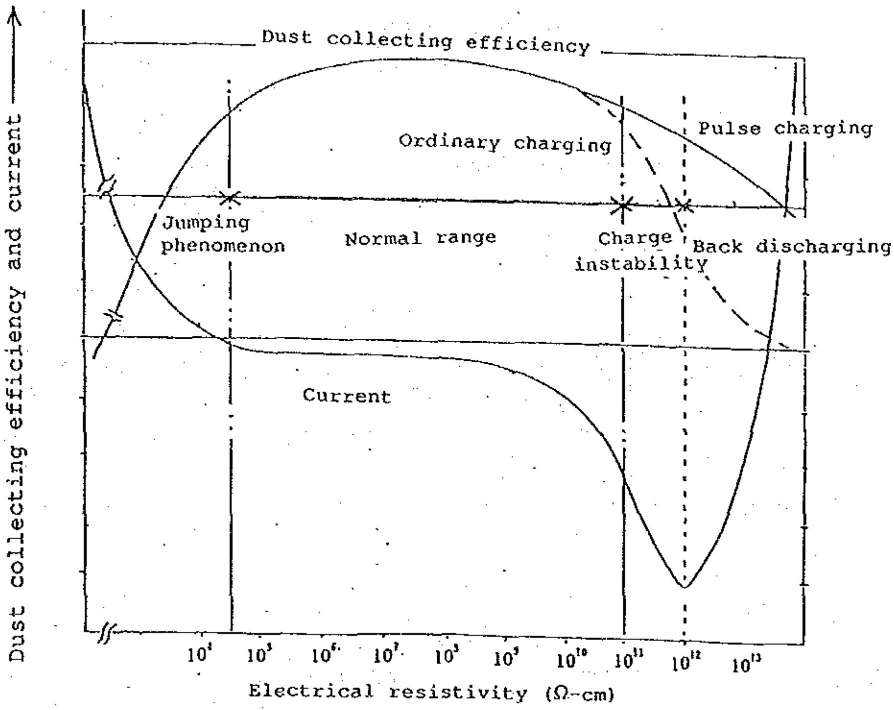


Fig. 11-51 Effects of Electrical Resistivity of Dust on Dust Collecting Efficiency (2)

Then it is possible to achieve the dust emission level of 500 mg/m^3N by either pulse-charge Esp or bag filter.

11.16.2 Flue Gas Desulfurizers

One of the advantages of fluidized-bed combustion is that the method allows in-situ desulfurization by the use of limestone as a fluidized bed medium. Desulfurizing reactions which occur in the furnace are as follows:

$$CaCO_3 \rightarrow CaO + CO_2$$

$$CO_2 + \left(\frac{1}{2}\right)O_2 + SO_2 \rightarrow CaSO_4$$

The desulfurization efficiency depends generally on the combustion temperature, air ratio of combustion, amount of limestone charging, etc., but desulfurization efficiency of over 94% has been attained by adjustment of such factors in bench-scale and pilot-scale combustion tests. When environmental and emission standards of Thailand are considered, it is possible to meet such regulations only by the in-situ desulfurization, and it is judged that no specific flue gas desulfurizer is necessary.

11.16.3 Smoke and Soot Emissions for Sin Pun Lignite

(1) Kinds and Ratios of Fuels to Use

Use of Fuel	Fuel Consumption (Dry Coal)	Boiler Efficiency
Coal only	63 t/h (100%)	91.7%

(2) Boiler Fuel

Item	Unit	Value
Heating Value	kcal/kg	2,716
Moisture	%	16.9 (Air dry basis)
Carbon Content	%	43.5 (Dry basis)
Hydrogen Content	%	3.4 (Dry basis)
Oxygen Content	%	11.5 (Dry basis)
Sulfur Content	%	8.7 (Dry basis)
Nitrogen Content	%	0.8 (Dry basis)
Ash Content	%	21.08 (Dry basis)
Total Moisture	%	32.67

(3) Combustion Gas Volumes

1) Fuel Characteristics (at use)

- Total moisture : $W = 32.67\%$

- Carbon content : $C = \frac{C'(100-W)}{100} = 29.28\%$

- Hydrogen Content: $H = \frac{H'(100-W)}{100} = 2.29\%$

- Nitrogen Content: $N = \frac{N'(100-W)}{100} = 0.55\%$

- Sulfur Content : $S = \frac{S'(100-W)}{100} = 5.91\%$

- Oxygen Content : $O = \frac{O'(100-W)}{100} = 7.74\%$

where,

C' = Carbon content, dry basis (43.5%)

H' = Hydrogen content, dry basis (3.4%)

N' = Nitrogen content, dry basis (0.8%)

S' = Sulfur content, dry basis (8.7%)

O' = Oxygen content, dry basis (11.5%)

2) Theoretical Air Requirement (A_0)

$$A_0 = 8.89C + 26.7\left(H - \frac{O}{8}\right) + 3.33S = 3.153\ m^3N/kg$$

where,

C = Carbon content in unit fuel (0.2928 kg/kg)

H = Hydrogen content in unit fuel (0.0229 kg/kg)

O = Oxygen content in unit fuel (0.0774 kg/kg)

S = Sulfur content in unit fuel (0.0591 kg/kg)

3) Theoretical Quantity of Combustion Gas (Q_0)

$$Q_0 = 0.79A_0 + 1.867C + 11.2H + 0.8N + 0.7S + 1.244W$$
$$= 3.746\ m^3N/kg$$

where,

A_0 = Theoretical air requirement ($3.153\ m^3N/kg$)

W = Total moisture in unit fuel (0.3267 kg/kg)

N = Nitrogen content in unit fuel (0.0055 kg/kg)

4) Excess Air Ratio (λ)

$$\lambda = \frac{21}{21 - O_2} = 1.2$$

where,

O_2 = Oxygen concentration in flue gas at exhaust port (3.5%)

5) Actual Quantity of Combustion Gas (Q')

Wet $Q'_w = Q_0 + (\lambda - 1)A_0 = 4.377\ m^3N/kg$

Dry $Q'_d = Q'_w - 1.244\ (9H + W) = 3.714\ m^3N/kg$

6) Fuel Consumption (F)

Wet coal consumption F_{CW} = 63,000 kg/h

Dry coal consumption F_{Cd} = 42,400 kg/h

Boiler efficiency η_B = 91.7%

7) Quantity of Gas at Boiler Outlet (Q)

Wet $Q_w = Q'_w\ F_{CW}$ = 275,800 m^3N/h

Dry $Q_d = Q'_d\ F_{CW}$ = 234,000 m^3N/h

where,

Q'_w = Actual quantity of combustion gas, wet ($4.377\ m^3N/kg$)

Q'_d = Actual quantity of combustion gas, dry ($3.714\ m^3N/kg$)

F_{CW} = Wet coal consumption (63,000 kg/h)

8) Quantity of Gas Discharged from Stack ($Q_{(stack)}$)

Wet $Q_{w(stack)} = Q_w = 275,800\ m^3N/h$

Dry $Q_{d(stack)} = Q_d = 234,000\ m^3N/h$

9) Discharge Temperature (T)

$T = t + 273 = 403^\circ K$

where,

t = Discharge temperature in centigrade (130°C)

10) Discharge Velocity (V)

$$V = Q_{w(stack)}\ \frac{T}{273} \times \frac{1}{3,600} \times \frac{1}{\text{Stack top cross section}} = 27.3\ m/s$$

where,

$Q_{w(stack)}$ = Wet quantity of gas discharged from stack (275,800 m^3N/kg)

Stack top cross section = 4.15 m^2

T = Discharge temperature at stack outlet (403°K)

11) Corrected Exhaust Height

$$H_e = H_0 + 0.65(H_m + H_t) = 125\ m$$

$$H_m = \frac{0.795(Q_t V)^{1/2}}{1 + \frac{2.58}{V}} = 34.1\ m$$

$$Ht = 2.01 \times 10^{-3} \times Q_t(T-288)\ (2.3\,logJ + \frac{1}{J} - 1)$$
$$= 45.8\ m$$

where,

$$J = \frac{1}{(Qt\,V)1/2}\left(1,460 - 296 \times \frac{V}{T-288}\right) + 1$$
$$= 30.6$$

where,

H_0 = Actual exhaust height (80 m)

Q_t = Quantity of discharge gas at 15°C

= $Q_{w(stack)} \times \frac{273+15}{273} \times \frac{1}{3,600} = 80.8\ m^3/s$

V = Discharge velocity (27.3 m/s)

T = Discharge temperature (403°K)

12) Sulfur Oxide Emissions (SOx)

(a) Quantity of SOx generated in boiler (q_b')

$$q_b' = 0.7 \times \frac{S}{100} \times F_{cw} = 2,606\ m^3N/h$$

where,

S = Sulfur content in fuel (5.91%)

F_{cw} = Fuel consumption, wet coal (63,000 kg/h)

(b) Quantity of SOx at boiler outlet (q_b)

In-situ desulfurization with an expected desulfurization efficiency of η=94.0% occurs in the fluidized-bed boiler using limestone, and the quantity of SOx at boiler outlet will be as follows:

$$q_b = q_b' \times \left(1 - \frac{\eta}{100}\right) = 156\ m^3N/h$$

where,

q_b' = Quantity of SOx generated in boiler (2,606 m^3N/h)

(c) Quantity of SOx at exhaust (q)

$q = q_b$ = 156 m^3N/h

(d) SOx concentration at exhaust (x)

$$x = \frac{q}{Q_{dstack}} \times 10^6 = 667\ ppm\ dry$$

where,

q = Quantity of SOx at exhaust (156 m^3N/h),

$Q_{d(stack)}$ = Quantity of dry gas discharged from stack (234,000 m^3N/h)

13) Dust Emissions

(a) Dust concentration at boiler outlet (d_b)

$$d_b = \frac{0.55 \times D \times 10^6}{Q_d} \times \frac{21-6}{21-O_2}$$
$$= 82\ g/m^3N$$

where,

D : Ash generated in the boiler (40.61 t/h)

Q_d = Quantity of dry gas at boiler outlet (234,000 m^3N/h)

O_2 = Oxygen concentration in flue gas at exhaust (3.5%)

(b) Dust concentration at cyclone outlet ($d_{0(cy)}$)

The dust collecting efficiency of cyclone of η_{cy}=85.0% is expected from the results of demonstration test at Wakamatsu 50 MW-FBC, and the dust concentration at cyclone outlet can be as follows:

$$d_0(cy) = d_b \times \left(1 - \frac{\eta_{cy}}{100}\right) = 12\ g/m^3N$$

where,

d_b = Dust concentration at boiler outlet (82 g/m^3N)

(c) Dust concentration at dust collector outlet ($d_{0(EP)}$)

The dust collecting efficiency of electrostatic precipitator of η_d=98.0% is expected from the results of demonstration test at Wakamatsu 50 MW-FBC, and the efficiency of bag filter of η_d=98.0% is expected from the same result. In the case of ESP, the dust concentration at the outlet can be as follows:

$$d_0(EP) = d_0(cy) \times \left(1 - \frac{\eta_d}{100}\right) = 0.24\ g/m^3N$$

where,

$d_{0(cy)}$ = Dust concentration at cyclone outlet (12 g/m^3N)

In the case of bag filter, lower dust concentration is expected.

(d) Dust concentration at exhaust (d_0)

$$d_0 = d_0(EP) = 0.24\ g/m^3N$$

14) [Reference] Maximum ground concentration of SOx and its location (C_{max}, X_{max})

$$C_{max} = 1.72 \times \frac{q}{He^2} = 0.0172\ ppm$$

$$C_{max2} = 2 \times C_{max} = 0.0344\ ppm$$

$$C_{max2} = C_{max2} \times \frac{SO_2}{22.4} = 0.10\ mg/m^3N$$

$$X_{max} = 20.8 \times He^{1.143} = 5{,}186\ m$$

where,

C_{max1} = Maximum ground concentration (at 1 unit operation)

C_{max2} = Maximum ground concentration (at 2 units operation)

C_{max2} = Maximum ground concentration (at 2 units operation)

X_{max} = Location of maximum ground concentration

q = Quantity of SOx discharge (156 m^3N/h)

He = Corrected exhaust height (125 m)

15) [Reference] Exhaust concentration of nitrogen oxides (NOx) (C_{NOx})

C_{NOx} = 150 ~ 350 ppm

C_{NOx} = $C_{NOx} \times \frac{NO_2}{22.4} = 310 \sim 720\ mg/m^3N$

where,

NO_2 = Molecular weight of nitrogen dioxide (46 g/mol)

16) [Reference] Exhaust concentration of carbon monoxide (CO) (C_{CO})

From the results of combustion test, the carbon monoxide concentration is estimated as follows:

C_{CO} = 100 ~ 400 ppm

C_{CO} = $C_{CO} \times \frac{CO}{22.4} = 130 \sim 500\ mg/m^3N$

where,

CO = Molecular weight of carbon monoxide (28 g/mol)

(4) Observance of Emission and Environmental Standards

Results given above and emission and environmental standards are summarized in Table 11-42.

Table 11-42 List of Estimated Emission Characteristics and Standards

Item	Standard	Estimated Value
Emission standards		
Dust	500 mg/m^3N	240 mg/m^3N
Carbon monoxide	1,000 mg/m^3N	130-500 mg/m^3N
Sulfur dioxide	700 ppm	667 ppm
Nitrogen oxides	1,000 mg/m^3N	310-720 mg/m^3N
Environmental standards		
Sulfur dioxide	0.30 mg/m^3N	0.10 mg/m^3N

As seen in the table, estimated emissions are well below the emission and environmental standards for all items.

11.16.4 Waste Water Treatment Facility

It is planed, for this project, to treat waste water of the power plant by waste water treatment facility and discharge to the Phakasai River.

(1) Waste Water Characteristics at Inlet of the Waste Water treatment Facility

The volume and characteristics of waste water at the inlet of the waste water treatment facility are estimated as given in Table 11-43.

Table 11-43 Estimated Volume and Characteristics of Waste Water at the Inlet of the Waste Water Treatment Facility

Waste Water	Volume	pH	SS	Remarks
Regular waste water				
Plant waste water	120 m^3/day	6-9.5	10 mg/ℓ	2 units
Water purifier regeneration waste water	60 m^3/day	6-8	100 mg/ℓ	
Life waste water	30 m^3/day	6-8.5	100 mg/ℓ	
Irregular waste water				
Boiler blow water	150 m^3/blow	9-9.5	5 mg/ℓ	1 unit
Boiler wash water	500 m^3/wash	6-9	100 mg/ℓ	1 unit
Deaerator wash water	90 m^3/wash	6-9	100 mg/ℓ	1 unit

(2) Equipment Capacity

Ash shown in Table 11-43, sources of regular waste water are the plant, water purifier regeneration and life, and the total volume is 210 m^3/day. Thus, the equipment capacity of the waste water treatment facility can be as follows:

$$(210\ m^3/day \div 24\ h/day) \times 1.1 = 10\ m^3/h$$

The storage capacity can be as follows assuming the case of single unit operation and single unit boiler washing:

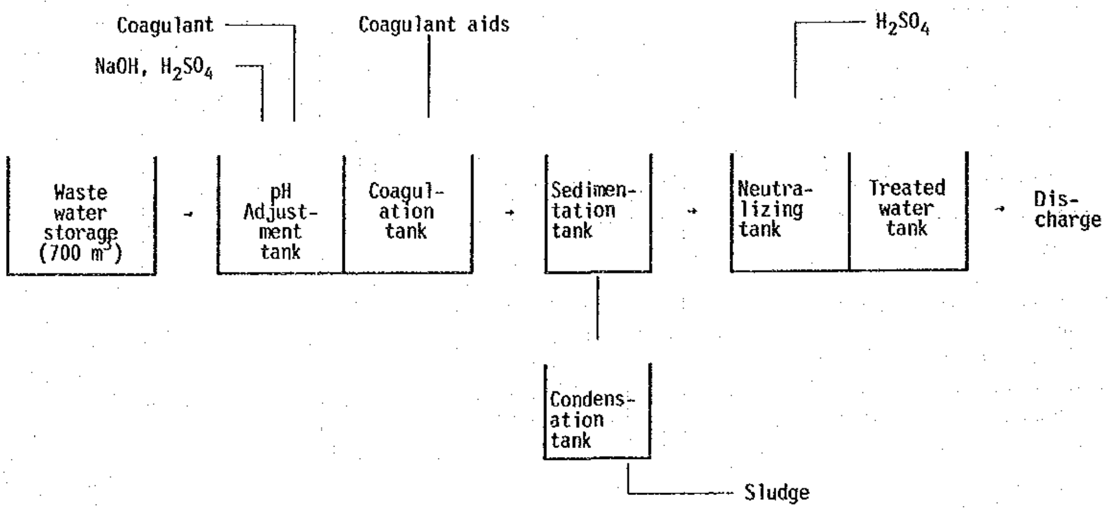
Plant waste water (Single unit)

+ Water purifier regeneration waste water
+ Life waste water
+ Boiler wash water
= 650 m^3

With some margin, the storage capacity of 700 m^3 can be appropriate.

(3) Waste Water Treatment System

With the employment of ordinary coagulation and sedimentation processes, the waste water treatment system can be as shown below.



(4) Waste Water Characteristics at Facility Outlet

The volume and characteristics of waste water at the facility outlet are compared with discharge standards in Table 11-44.

Table 11-44 Comparison of Waste Water Volume and Characteristics at Facility Outlet and Discharge Standards

Waste Water	Volume	pH	SS
Discharge water	240 m^3/day max.	6-8	< 25 mg/ℓ
Discharge standards	---	5-9	30 mg/ℓ max.

11.17 Transmission Line Planning

In the preliminary stage of this feasibility study, the comprehensive economic evaluation has been carried out to select suitable project site, through the discussion between EGAT and JICA Team. The evaluation study concluded that the optimal site for this project among three alterative sites, is Krabi Thermal Power Plant area. Obviously, it is the most economic option, if two existing transmission lines connected from Krabi to Phangnga and to Lam Poo Ra can be used as useful transmission lines for this project. Therefore, in order to reduce investment for this project, JICA Team has been seeking the possibility of using these transmission lines from the technical view points. For this study, power flow analysis and short circuit analysis have been already carried out based on future power system configuration projected by EGAT. JICA team obtained the satisfied results through these analyses. However, an indispensable bus configuration or plant operation conditions will be involved in these existing lines use. Two considerable options for these restrictions are shown as follows.

(1) Bus configuration with one tie breaker

One tie breaker between No.1 unit and No.2 unit will be required for the bus configuration, because thermal capacity of these transmission line is not sufficient for transmitting associated power by two units. That is, the thermal capacity of these transmissions line under designed solar condition, is limited up to 82MVA which closes the maximum sending power of 80MVA of each unit. In order to serve reliable power for the local load center as Krabi area, this tie breaker will contribute to this objective, even if some continual problems occur concurrently on the transmission line and power plant.

(2) Some restrictions and control equipment requirements

Provided that above-mentioned tie breaker will be not applied for this project, sending power from each power plant should be regulated automatically up to thermal capacity of the transmission line with using some control equipment. In addition this useless control will be required frequently, because the value of power flow from this power plant will be governed by load condition in the power network.

Furthermore, this control will influence to reduce the value of plant factor of this project.

Through the power flow analysis and short circuit analysis, JICA Team recommends (1) option for this project. This is because (1) option does not require complicated power flow control and does not reduce plant utilization factor by load condition. The result of short circuit analysis does not desire any special requirements.

Fig. 11-50 shows the results of power flow in Region III network as of 2001 based on the condition projected by EGAT. However, some additional requirements was assumed to provide sound condition such as reactive power compensator. Therefore, if the development program will be revised, these analyses should be carried out with the another condition.

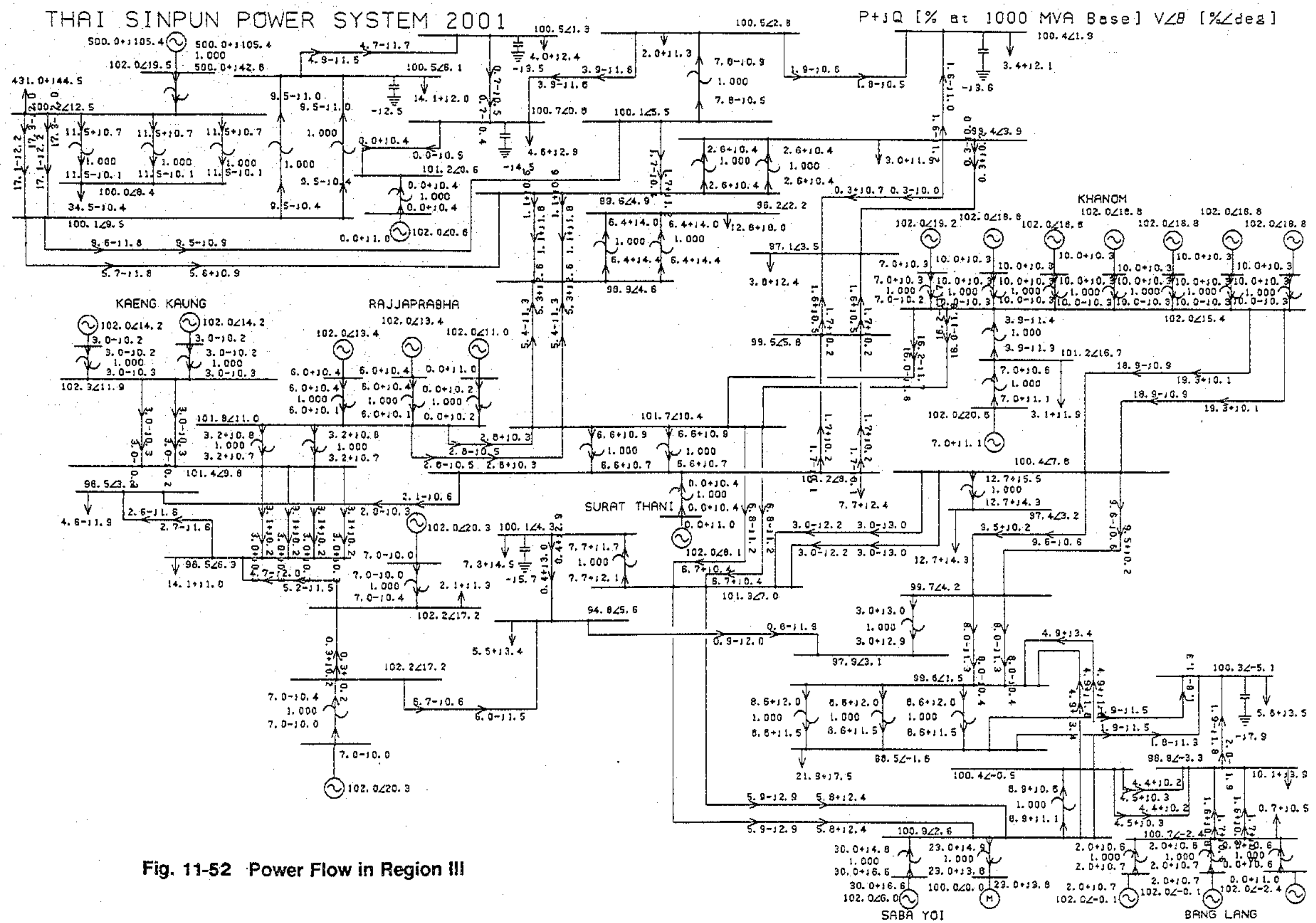


Fig. 11-52 Power Flow in Region III

12. CONSTRUCTION SCHEDULE AND COST

CHAPTER 12 CONSTRUCTION SCHEDULES AND COST

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12. Construction Schedule and Cost

12.1 Construction Schedule

Sin Pun Conceptional mining report studied that the labor cost occupies 30% of total mine operating cost during first 8 years.

The increasing rate of the labor wages in Thailand is very rapid in these days and this affects the cost of lignite production.

Table 12-1 shows the recent movement of the wages and salaries, the unit of generation and the consumer price index in Thailand. From the table, the generation cost is keeping constant or decreasing while the wages and the consumer price index is increasing annually around 6% form 1981.

Therefore, it is recommendable to develop Sin Pun mine and the power plant as soon as possible to minimize the increase of the electric generation cost.

This project is the air polution protected type generation plant and the easy land acquisition because of the site in the existing Krabi power station. Therefore, the project can be imprementai with the short lead time without any against of the inhabitant and environmental issues.

Table 12-1 Increase of Wage and Salaries, Unit of Generation and Consumer Price Index

	1981	1986	1988	1989	Annual Increase Average
Average Monthly Income per Household Wages and Salaries (Whole Kingdom)(Baht)	903	1223	1411	-	6.58% (1981-88)
Unit of Generation (Baht)	1.30	1.33	1.26	1.25	-0.49% (1981-89)
Consumer Price Index (All Items) 1976 = 100	-	197.7	210.4	221.7	5.90% (1986-89) 6.32% (1976-89)

Fig. 12-1 shows the development schedule of Sin Pun FBC as earliest case.

The target commissioning date of the first A-FBC unit is located the end of December 1996 and the second unit is followed 6 months after to optimize the commissioning cost.

The break down of the power plant construction schedule is shown in Fig. 12-2.

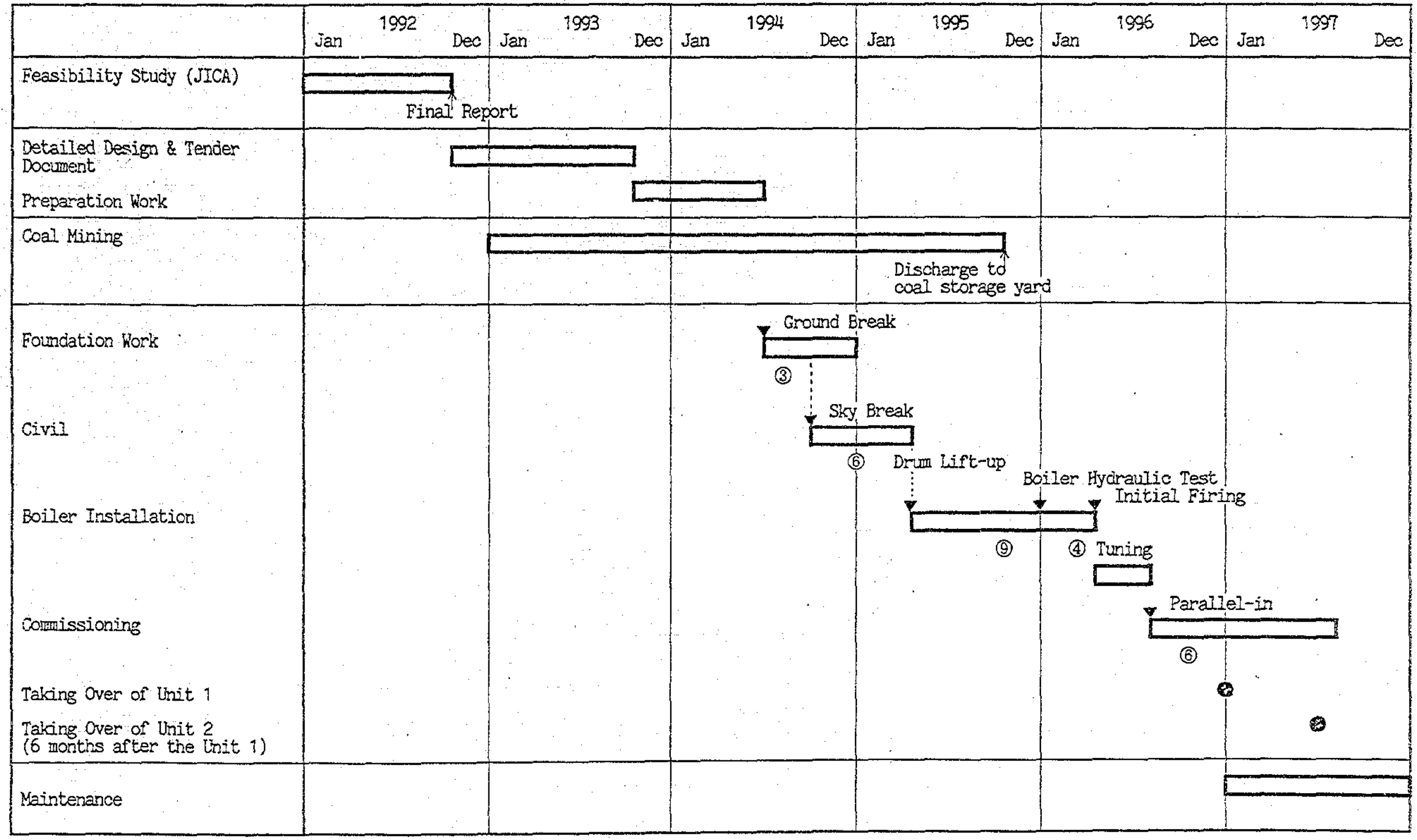
The FBC boiler commissioning period is scheduled longer than that of the conventional boiler for the following reasons;

(1) Operation Training for A-FBC

(2) Miner Tuning of Lignite-Limestone preparation system for best combination of the respective particle size to achieve the optimum limestone consumption.

As a total, it takes 3 years from the contract to the completion of the commissioning for unit 1.

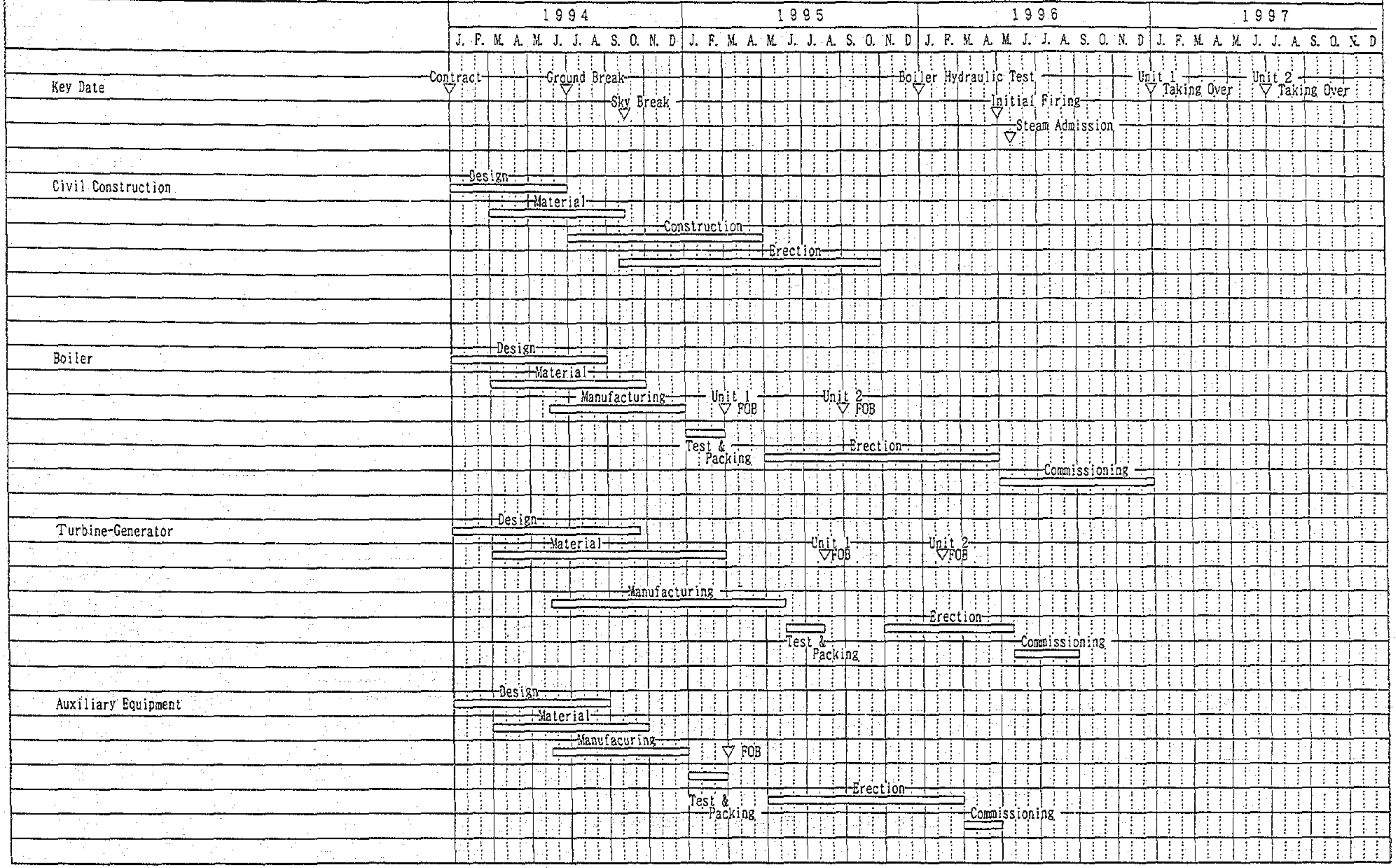
Fig. 12-1 Development Schedule of Sin Pun A-FBC



Nationality : Thailand

Name of Project : A-FBC Sin Pun

Fig. 12-2 A-FBC Construction Schedule



12.2 Construction Cost

12.2.1 General

The construction cost is estimated with the following items.

(1) Civil Construction and Structure Cost
(2) Boiler facilities
(3) Turbine Generator Facilities
(4) Miscellaneous Facilities
(5) Administration Cost
(6) Import Duty
(7) Interact During Construction

The foreign currency portion is estimated based on Japanese product. The exchange rate of Japanese yen and Thai Baht is 5 yen/Baht, Japanese yen and U$ is 130 yen/U$.

Fig. 12-3 shows the recent movement of the exchange rate and the wholesale price index of the mechanical equipment between Japan and United State from 1984. During 1985 to 1988, the value of Japanese yen has increased drastically against U$ (as same as Thai Baht) while the wholesale price index of the mechanical equipment is kept within 10% difference only during these 6 years from 1985. It is considered that the fair exchange rate of Japanese yen for U$ is 180 yen/U$ at this moment, and that Japanese product is still kept expensive in the world market with exchange rate 130 yen/U$. Therefore, to optimize the construction cost, the cost estimate is carried out to utilize the local material on the light load steel structure and equipment as much as possible.

From now on, the construction cost may change the amount because of these social background. However in the report, the cost estimate is carried out based on the Japanese product cost and current exchange rate, and it is remained for EGAT to consider these social background since EGAT has ample experience to purchase the equipment from the world market.

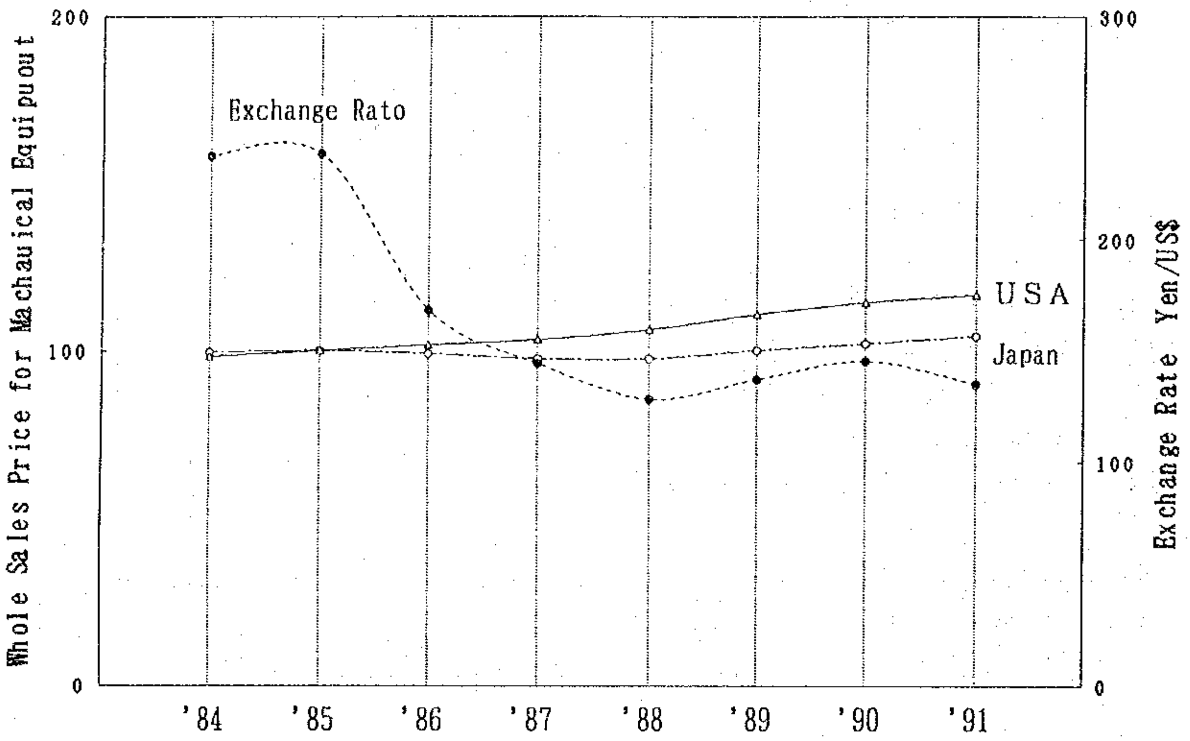


Fig. 12-3 Exchange Rate and Wholesale Price Index between Japan and United States

12.2.2 Civil Construction and Structure Cost

The civil construction and structure cost is shown in Table 12-2.

Table 12-2 Civil Construction Cost

Item	Cost (Million Baht)	Remarks
Land	88	Land Reclamation
Building	417.4	Power House, Store House, Limestone storage House, Administration Building, P.R. Building and Gate House
Structure	466	Raw Water Tank, Cooling Water Intake, Cooling Water Pipes, Cooling Water Outlet and Outfall, Chimney, Rainproof storage yard and conveyor basement, Ash Disposal Facilities, Road and Drainage, Fence, Housekeeping
Foundation	84.6	Boiler foundation and others
Total	1056	Foreign: Domestic = 145.8:910.2

12.2.3 Boiler Facilities

The cost estimate is based on Japanese product and the local material. The lignite-limestone bunker, the air and flue gas duct, the compressed air pipes the pipe rack, the cabling materials are supplied form the local material. 10% of the contingency is involved in the respective equipment.

The boiler facilities cost is shown in Table 12-3.

Table 12-3 Boiler Facilities Cost

Item	Cost (Million Baht)	Remarks
Steam Generator	963.6	A-FBC Boiler, Lignite Spreader, A.H., Ash Collecting Facilities, B.C.P.
Draft System	170.6	FDF, IDF, Duct, Mechanical Cyclone
Lignite-Limestone Receiving System	200.9	Conveyor Facilities, Lignite-Limestone Spreader Bunker
Light Oil Firing System	37.5	Start-up Burner, Pipes, and Tank
Pipes	53.1	Compressed Air Pipes
Chemical Dosing System	4.8	Chemical Dosing and Sampling System
Miscellaneous Equipment	24.4	Station Air Compressor
Electrical and C&I	349.8	All Cabling, Motor and Control & Instrumentation of the above. Instrument Compressor
Spare Part	25	
Total	1829.7	Foreign: Domestic = 1363:466.7