Fig. 7.3.4 (4) C.W. Outlet

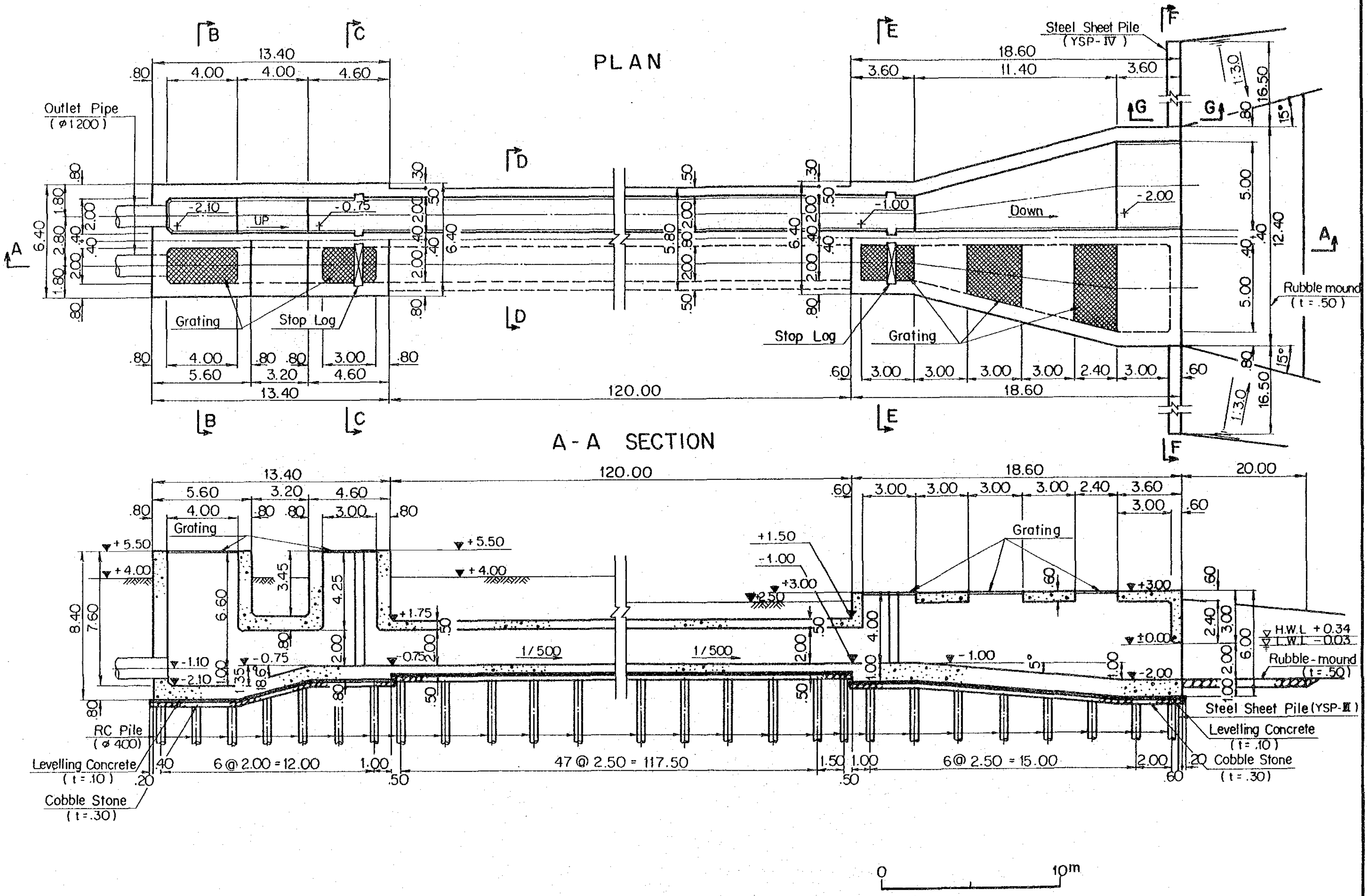


Fig. 7.3.4 (5) Section of C.W. Outlet

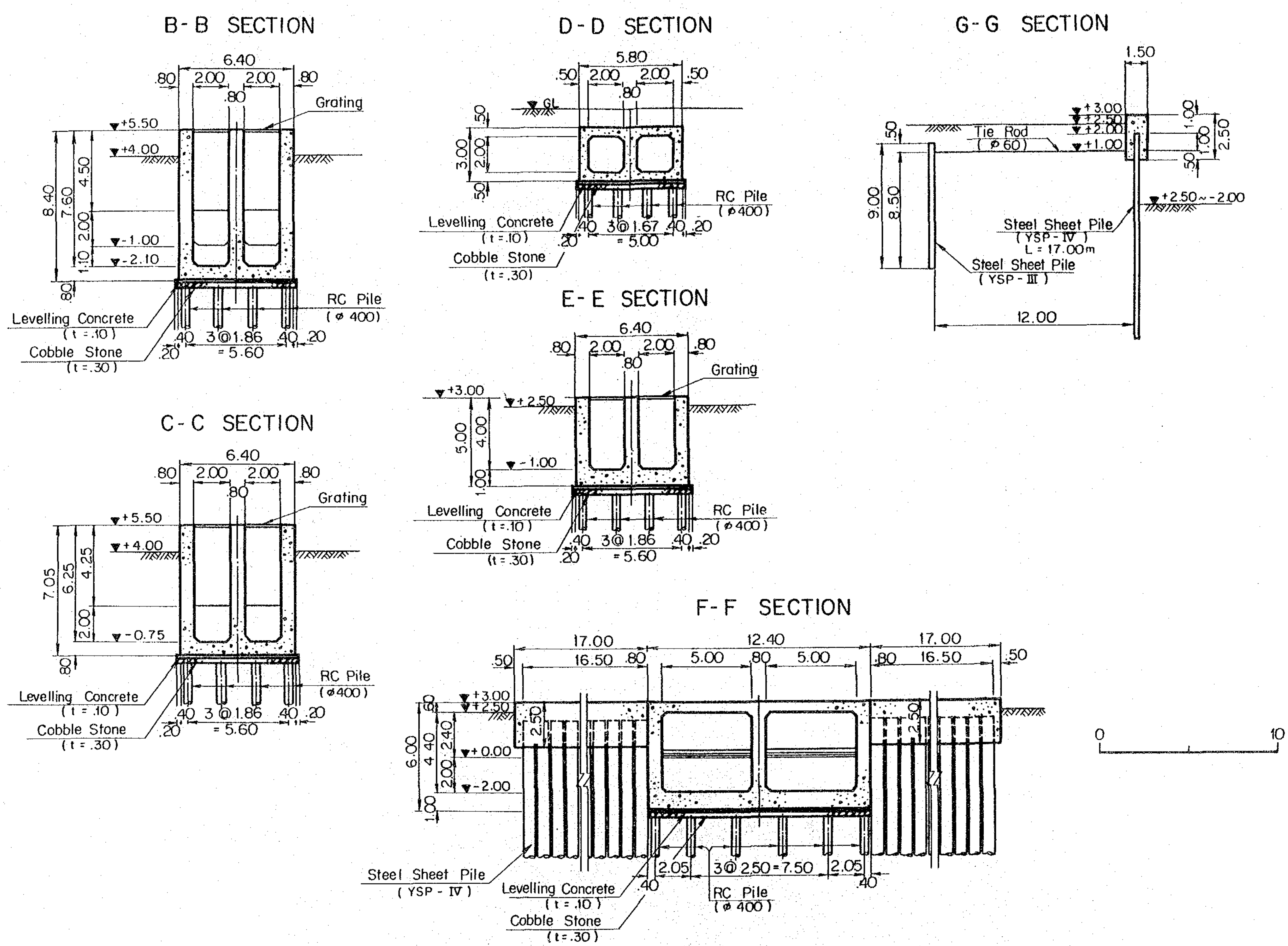
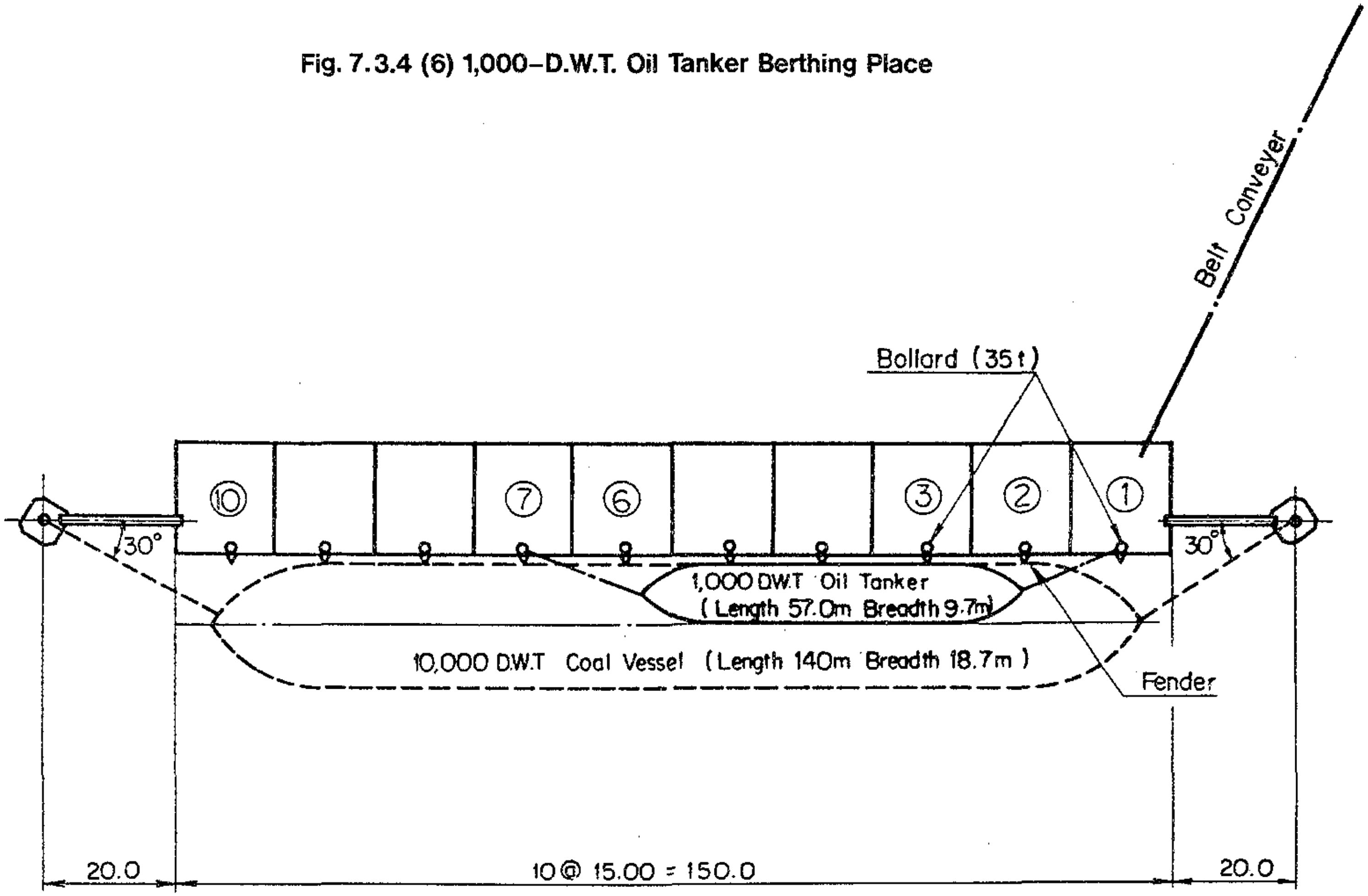


Fig. 7.3.4 (6) 1,000-D.W.T. Oil Tanker Berthing Place



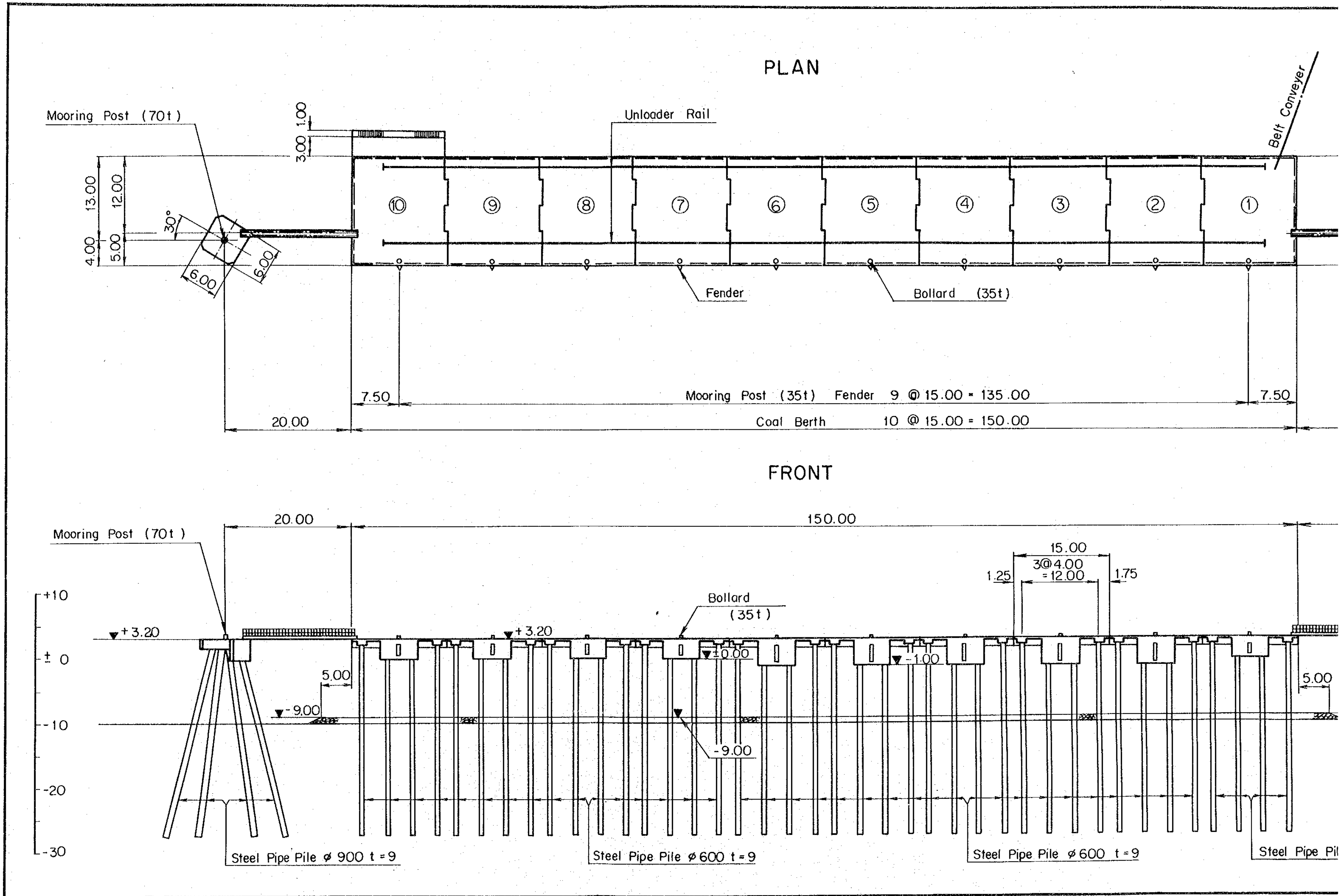

PLAN
Mooring Post (70t)
Unloader Rail
Belt Conveyer
Fender
Bollard (35t)
Mooring Post (35t) Fender 9 @ 15.00 = 135.00
Coal Berth 10 @ 15.00 = 150.00
20.00
7.50
7.50
13.00
12.00
4.00
5.00
1.00
3.00
6.00
6.00
30°
FRONT
Mooring Post (70t)
20.00
150.00
15.00
3@4.00 = 12.00
1.25
1.75
Bollard (35t)
+3.20
+3.20
±0.00
-1.00
5.00
5.00
-9.00
-9.00
+10
± 0
-10
-20
-30
Steel Pipe Pile ϕ 900 t = 9
Steel Pipe Pile ϕ 600 t = 9
Steel Pipe Pile ϕ 600 t = 9
Steel Pipe Pi

Fig. 7.3.4 (7) Plan and Front of Coal Unloading Jetty

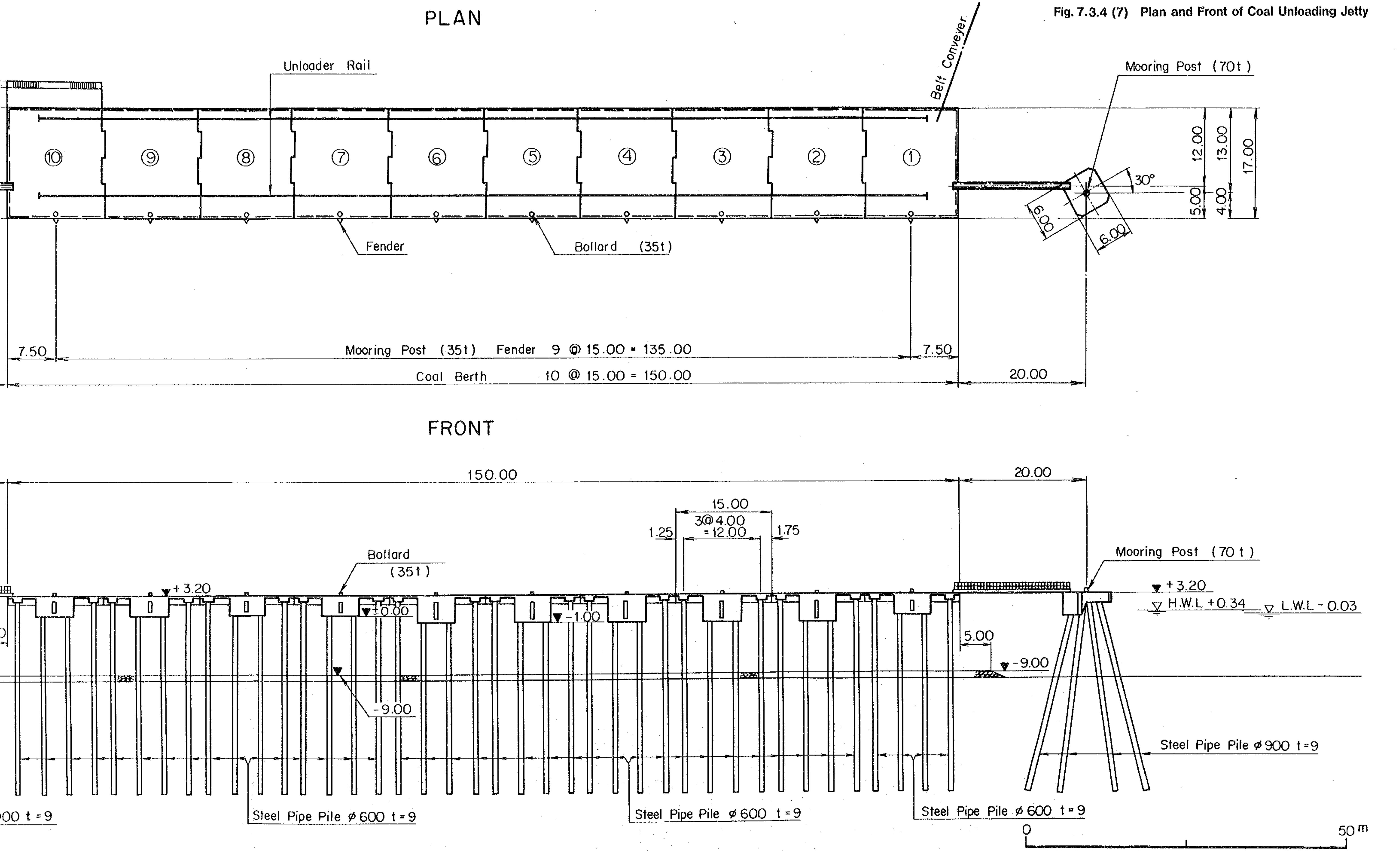


Fig. 7.3.4 (8) Typical Section of Coal Unloading Jetty

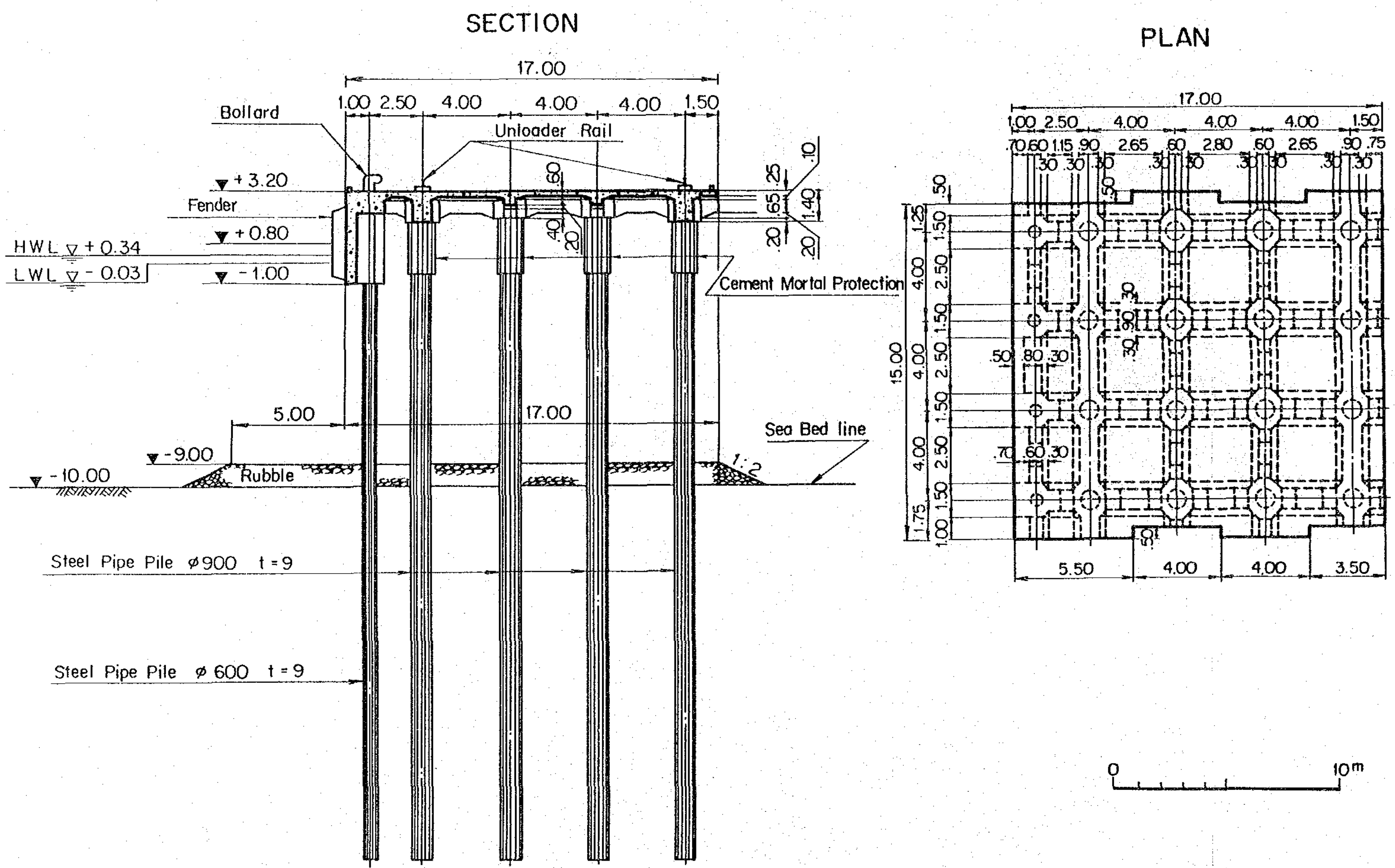
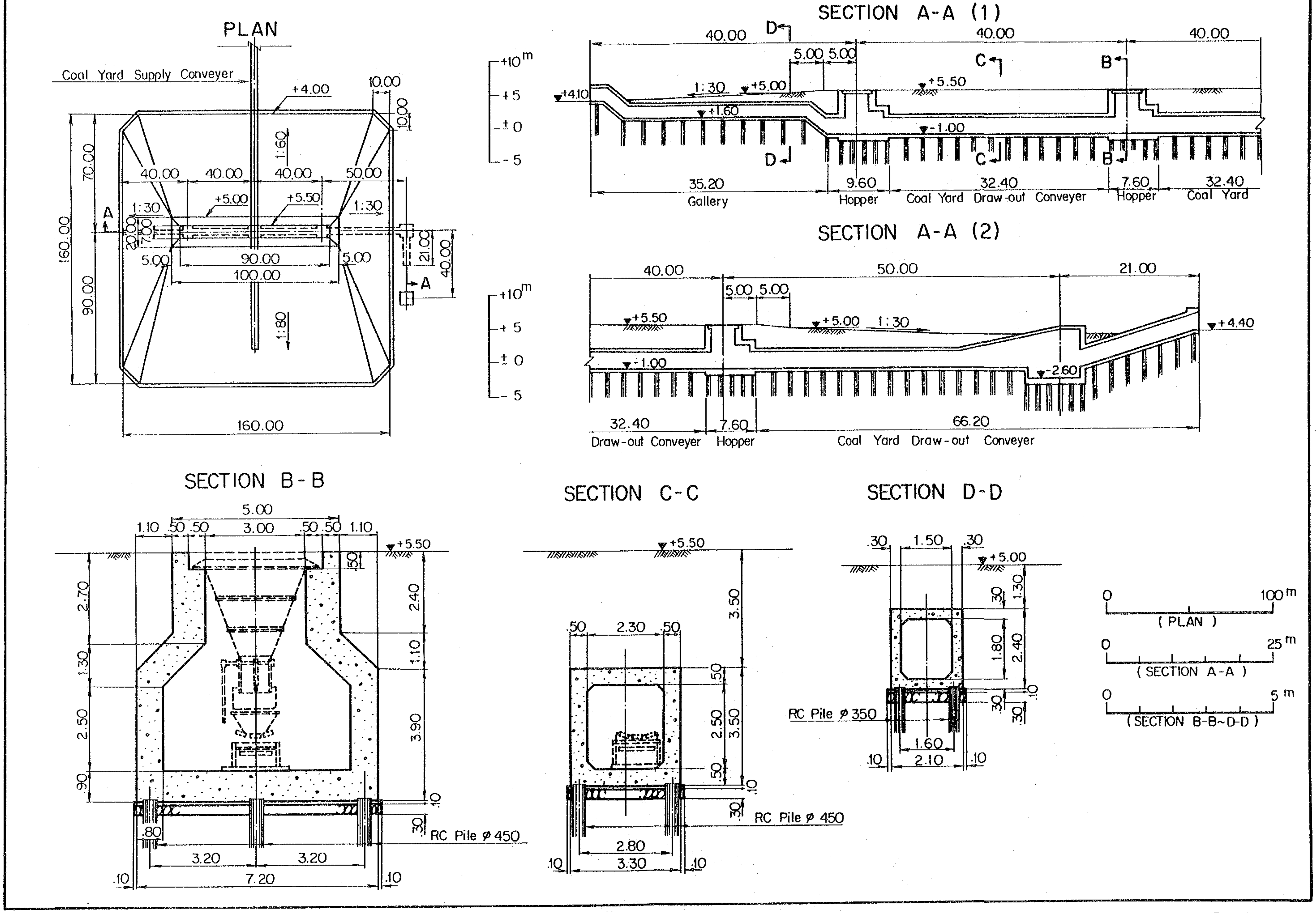


Fig. 7.3.4 (9) Coal Storage Yard and Coal Handling Facilties



7.3.5 Water for Power Plant

In addition to condensor cooling water, the power plant needs boiler feed water, bearing cooling water, drinking water, miscellaneous water and fire extinguishing water. Fortunately, Telfers Island site has the Mount Hope Water Treating Plant in its adjacent area, which has about 500 tons of water available for the power plant, ensuring water supply by installing pipelines.

Water produced from Mount Hope Water Treating Plant is drinkable and requires no particular treatment before using as plant water except in the case of boiler feed water.

Water requirements for power plant are classed by quantities as follows:

(1) Water Requirements

a) Boiler makeup water (demineralized water)

$Qb = Z \times Rm \times$

Qb : Boiler makeup water (t/day)
Z : Boiler evaporation from 2 boilers per day (t/day)
$= 240$ t/h x 24 h x 2 units
Rm : Makeup ratio 0.8 (%)
: Allowance 2

$Qb = 240$ t/h x 24 h x 2 units x 0.008 x 2
$= 184$ t/day

b) Cooling water for bottom ash hopper and makeup water for seal water (Fresh Water)

$Qh = Qc \times Rm$

Qh : Cooling water and makeup water for seal water (t/day)
Qc : Circulation water quantity for two boilers per day (t/day) = 20 t/h x 24 h x 2 units
Rm : Makeup water ratio 10 (%)

$Qh = 20\ t/h \times 24\ h \times 2\ units \times 0.1$
$= 96\ t/day$

c) Humidifying water for fly ash (Fresh Water)

Fly ash is humidified to 20% of moisture content by using a dustless unloader.

Quantity of humidifying water is:

$Qw = Qf \times W$

Qw : Quantity of humidifying water		(t/h)
Qf : Treatment quantity of fly ash		(t/day)
= 10 t/h x 10h		
W : Necessary moisture content		20 (%)
Qw : 100 t/day x 0.2 = 20 t/day		

d) Living water (Fresh Water)

$Ql = Np \times C$

Ql : Quantity of living water		(t/day)
Np : Number of personnel		
= 400 persons		
C : Consumption	0.15 t/day/person	

$Ql = 400 \times 0.15\ t/day$
$= 60\ t/day$

e) Miscellaneous-use water (Fresh Water)

Quantity of miscellaneous-use water such as for washing equipment and floors are estimated to two tons/h per unit.

Miscellaneous water = 2 t/h x 24 h x 2 units
= 96 t/day

f) Makeup quantity of bearing cooling water (Demineralized Water)

$Q = Qc \times Rm$

Q : Makeup quantity of bearing cooling water	(t/day)
Qc : Quantity of cooling water circulation	(t/day)

= 600 t/h x 24 h x 2 units

Rm : Makeup ratio 0.001

Q = 600 t/h x 24 h x 2 units x 0.001
= 29 t/day

g) Others (Fresh water)

Plantation sprinkler = 2 t/h x 12 h
= 24 t/day

Total of a) to g) : 509 t/day

Requirement of water for power plant is estimated to about 500 t/day per two units.

(2) Capacity of Service Water Storage Facilities

a) Service water tank

Two units of 600-ton service water tank shall be installed to maintain the power plant operation in the case of Mount Hope Water Treating Plant failure in supplying water.

b) Drinking water tank

It is estimated that the drinking water consumption will accounts for 15 t/day per unit of the living water. Drinking water tanks shall be installed in such a way that each unit is provided with a head tank whose capacity equals 1/3 of daily requirement of drinking water.

$$\text{Capacity of drinking water head tank} = \frac{15\ t}{3} = 5\ t.$$

(3) Capacity of Demineralization Plant

a) Demineralization plant

Demineralized water consumption in normal operation is estimated to total 213 t/day for two units, which is broken down to 184 t/day of boiler makeup water and 29 t/day of bearing cooling makeup water.

Capacity of demineralization plant is as follows, taking into consideration the allowance for boiler blow:

20 t/h x 1 line = 20 t/h x 20 h
= 400 t/day

b) Capacity of demineralized water tank

On the conditions that one boiler has been blowing and filling of water simultaneously with the other boiler has been makeuping the capacity is as follows:

Capacity of demineralized water tank = Blowing and filling of boiler water (t/day) + Makeup of boiler water (t/day)
= (240 t x 3 times) + (97 t) = 817 t/day
817 t/day x 1.5 = 1,226 t.

Hence, two 600-t demineralized tanks are to be provided.

7.3.6 Fuel Facilities

(1) Fuel

The Project will use coal from Columbia, Cerrejon Coal, as the main fuel, and, in order to avoid difficulties in coal supply due to the political uncertainty, strike, etc. in the coal supplying country, designate not only Columbia but also the East America as the source of supply of the coal. The power plant will use the 50-50 mixture of the Columbia and American coal as the specified coal, using an auxiliary fuel the heavy oil from Panama Refinery, Bia Las Minas.

(2) Fuel Properties

a) Coal

Table 7.3.6 (1) Specification of Coal and Ash specifies the plant coal.

Table 7.3.6 (1) Specification of Coal and Ash

Item	Unit	Value
a) Gross Calorific Value	kcal/kg	6,600 (6,300-6,900) (A.D)
b) Total Moisture	%	9.0 (10.0-9.0) (A.R)
c) Surface Moisture	%	5.2 (8.5-1.9) (A.R)
d) Proximate Analysis		
Inherent Moisture	%	4.0 (1.6-7.2) (A.D)
Ash	%	13.0 (16-10) (")
Volatile Matter	%	35.0 (33-37) (")
Fixed Carbon	%	48.0 (49.4-45.8) (")
e) Total Suffer	%	1.0 (1.0-0.8)
f) Total Nitrogen	%	1.5 (1.5-1.3)
g) Hard groove Index		45 - 55 (45-55)
h) Fusion Temperature	°C	1,300 - 1,400 (1,400-1,300) (I.D.)
i) Specific Gravity of Ash	gr/cm^3	1.4 - 1.5 (1.4-1.5)

Note: ( ) Range of designed value

Item	Unit	Value
Composition of Ash		
SiO_2	%	58.3
Al_2O_3	%	26.4
Fe_2O_3	%	6.5
CaO	%	1.6
MgO	%	1.6
Na_2O	%	0.8
K_2O	%	2.2
P_2O_5	%	0.3
SO_3	%	1.3
TiO_2	%	0.8
Others	%	0.2

Note: A.R As received
A.D Air dried
I.D Initial deformation

b) Heavy oil

Properties of heavy oil used an boiler auxiliary fuel are as follows:

Table 7.3.6 (2) Specification of Heavy Oil

Item	Unit	Value
Sort		Bunker C
API gravity at 60°F		15
Flash point PM°F		172
Surfur content	wt%	2.1
Visc. SSF at 122°F		169
Pour point	°F	25
B.S W	%	0.05
High heating value	Btu/Lb	18,790 (10,439 kcal/kg)

(3) Fuel Consumption

a) Coal

Following equations express the coal consumption of the power plant whose annual capacity factor is 68.5% with annual averaged thermal efficiency of 35.0%:

$Wh = P_G \times 860/\ _p \times H_h$

Wh	:	Coal consumption (t/year/2 units)	
P_G	:	Generating end output (MW)	
p	:	Annual averaged thermal efficiency	35%
H_h	:	Gross Calorific Value (A.D Base)	6,600 kcal/kg

$$Wh = \frac{75MW \times 860}{6,600 \times 0.35} = 27.9 \text{ t/h/unit (A.D)}$$

55.8 t/h/2 units (A.D)

yearly consumption is,

Wy = Wh x Hy x Fa

Wy	:	Coal consumption (t/yen/2 units)	
Hy	:	Yearly hours	8,760 h
Fa	:	Annual capacity factor	68.5%

Wy = 55.8 t/h x 8,760 h x 0.685 = 334,800/2 units (A.D)

Since heavy oil is burnt at the rate of averaged 5% of coal per year, actual coal consumption is:

334,800 t x 95% = 318,100 t (A.D)

Since average surface moisture of as received coal is 5.2%, the coal quantity is:

$$\frac{318,100 \text{ t}}{0.948} = 335,500 \text{ t (A.R)}$$

b) Heavy Oil

Since heavy oil accounts for 5% of energy supplied by coal, the heavy oil consumption is:

$$Wyo = Wyc \times 5\% \times \frac{Hhc}{Hho}$$

Wyo:	Yearly heavy oil consumption	t/y/2 units
Hyc:	Yearly coal consumption	334,800 t/2 uits
Hhc:	Gross calorific value of coal	6,600 kcal/kg
Hho:	Gross calorific value of heavy oil	10,439 kcal/kg

$$= 334{,}800 \text{ t} \times 0.05 \times \frac{6{,}600}{10{,}439}$$

$$= 10{,}600 \text{ t}$$

Since, mixed combustion of heavy oil for coal is 50%, heavy oil consumption per hour is:

$$Who = 55.8 \text{ t/h} \times 50\% \times \frac{6{,}600}{10{,}439} = 17.6 \text{ t/h/2 units}$$

(4) Coal and Heavy Oil Unloading

a) Coal unloading

Coal is transported on board of a 10,000-DWT coal vessel which is berthed along the power plant coal unloading jetty where the coal is unloaded by two coal unloaders on the jetty onto the belt conveyor on the same jetty and delivered to coal storage yard.

1) Capacity of coal unloader

The capacity of coal unloader is determined by the following equations:

$$Cu = \frac{Q}{N.T. \; t \cdot w}$$

Cu	:	Nominal unloading capacity	(t/h)
Q	:	Annual handling capacity	335,500 t
N	:	Annual unloading days available	242 d
T	:	Working hours per day	12 h

$$t : \text{Operation efficiency} = \frac{\text{Actual working hours (year)}}{\text{Annual Working hours}}$$

$$= 0.67$$

$$w : \text{Unloading efficiency} = \frac{\text{Actual unloading capacity}}{\text{Normal unloading capacity}}$$

$$= 0.65$$

N = Annual working days - Unworking days

Unworking days = Festivals (A) (13 days) + Sunday (52 days) + Bad-weather days invalidating coal unloading operation (C) (30 days) + Unloader inspection days invalidating the coal unloading operation (D) (20 days) + Accidents (E) [(365 days - A - B - D) x 0.03 = 8 days)] = 123 days

Hence N = 365 days - 123 days = 242 days

$$t = \frac{7\ h \times 242\ d}{12\ h \times 242\ d} = \frac{1{,}936\ h}{2{,}904\ h} = 0.67$$

Annual actual working days = [Working hours per day (12 h) - Lunch time (1 h) - Inspection of unloader and replacement of work (3 h)] x 242 d
= (12 h - 1 h - 3 h) x 242 d
= 1,936 h

Annual working hours = working hours per day (12 h) x 242 d

Therefore, capacity of coal unloader is:

$$Cu = \frac{335{,}500\ t}{242\ d \times 12\ h \times 0.67 \times 0.65} = 265\ t/h$$

Hence, installation of 300 t/h x 1 set or 150 t/h x 2 sets of coal unloader are considered.

Berthing days (Dh) in the case of installation the 300-t/h coal unloader is:

$$Dh = \frac{10{,}000\ t}{300\ t/h \times 12\ h \times 0.67 \times 0.65}$$

Providing allowance for actual berthing and deberthing days for a vessel to be 7 days, since the number of coal vessel in berthing and deberthing will account for 34 vessels, the Berth Occupation Ratio (ρ) is:

$$= \frac{7\ d \times 34\ vessels}{242\ d} = 0.98$$

which is 50% over the normal berth occupation ratio. Since, however, this jetty is used chiefly as the coal unloading jetty, using = 60 %:

Berthing days (Dh) is:

$$Dh = \frac{242\ d \times 0.6}{34\ vessels} = 4.3\ d$$

Hence, coal unloader capacity (Cu) is:

$$Cu = \frac{10{,}000\ t}{4.3 \times 12 \times 0.67 \times 0.65} = 445\ t/h$$

Hence the total capacity of coal unloader is 500 t/h. Taking into account the time required for periodical inspection of the coal unloader, two sets of 250 t/h coal unloader should be installed.

2) Capacity of belt conveyor

The belt conveyor on the coal unloading jetty shall be designed to 500 t/h x 1.2 = 600 t/h in capacity.

b) Heavy oil unloading

Heavy oil (Bunker C) is delivered from Panama Refinery on board of a 1,000 t tanker into heavy oil tank via heavy oil unloader system on the coal unloading jetty.

(5) Delivery and Storage of Fuel in the Power Plant Site

a) Coal

1) Delivery to the coal storage yard

Unloaded onto the belt conveyor on the coal jetty, the coal is delivered via belt conveyor (600 t/h) in to the coal storage yard where it is scattered over the yard by means of a tripper.

2) Storage capacity

Due to complexities of factors, e.g. coal quantities on board of ship, power plant periodical inspection, variations of fuel consumption, marine meteorologies, etc., the storage capacity is shown by the following equation:

Storage capacity = Fluctuations for fuel consumption (1 month) + Minimum required storage (0.5 months) = 1.5 months

$$= 55.8 \text{ t/h} \times 24 \text{ h} \times 45 \text{ days}$$

$$= 60{,}264 \text{ t (A.D)}$$

$$= \frac{60{,}264}{0.948} \text{ t} = 63{,}600 \text{ t (A.R)}$$

Assuming the coal specific gravity 0.9 t/m^3 and pile height 5 m,

$$\text{Space required} = \frac{63{,}600}{0.9 \times 5} = 14{,}130 \text{ m}^2$$

Since the fuel is a mixture of two types of coal,
Project space = Required space x 1.5 = 21,200 m^2

$$\doteqdot 150 \text{ m} \times 150 \text{ m}$$

b) Heavy oil

1) Heavy oil storage

Two units will consume 10,600 tons of heavy oil per year. Assuming that one of two units is operated under a 50% load for one week and the other is operated under a 5% load for one week, the heavy oil storage is shown by the following equations:

° One unit operated for one week under a 50% load:

$$= 27.9 \text{ t/h} \times \frac{6{,}600 \text{ kcal/kg}}{10{,}439 \text{ kcal/kg}} \times 0.5 \times 24 \text{ h} \times 7 \text{ d}$$

$$= 1{,}482 \text{ t} \quad \text{———————} \quad 1$$

° The other unit operated for one week under a 5% load:

$$= 17.64 \text{ t/h} \times 0.05 \times 24 \text{ h} \times 7 \text{ d}$$

$$= 148 \text{ t} \quad \text{———————} \quad 2$$

Total of 1 and 2 = 1,482 t + 148 t = 1,630 t

Hence tank capacity is 2,000 tons.
The tank shall be of cone roof type, with an about 20 m inside diameter, oil tanker tonnage shall be 1,000 DWT.

2) Heavy oil supply to boiler

Heavy oil is delivered from storage tank by a heavy oil pump on the tank outlet into the boiler heavy oil burner and then sprayed into the furnace by means of steam astomizing through the burner nozzle.

c) Light oil

Light oil for burner light-up and start-up is delivered by tank lorrey into the 200 kl storage tank. Light oil is delivered from the storage tank by light oil pump on the tank outlet into light-up burner and start-up burner from where sprayed into the furnace by air atomizing.

The light oil storage tank is of a cone roof type, with an about 7 m inside diameter.

(6) Fuel Handling Facilities

a) Coal

1) Coal storage yard supply conveyor (BC-3)

Unloaded onto the coal unloading jetty, the coal is delivered onto coal unloading jetty conveyor (BC-1), marine conveyor (BC-2) and then coal storage yard conveyor (BC-3). Conveyors which are of stationary stacker type are provided respectively with a tripper which scatters coal onto the coal storage yard from a given point on the conveyor.

Conveyors BC-1, BC-2 and BC-3 are each independently consisting of one line whose delivering capacity is 600 t/h.

2) Coal storage yard draw-out conveyor (BC-4, BC-5)

Coal is delivered from the coal storage yard by magnetic feeders on the bottom of the three storage yard underground hoppers onto the coal storage yard draw out conveyor from the yard. The conveyor from the yard is installed in the coal storage yard underground duct. Since the coal storage yard's underground hoppers have their openings on the ground surface, they are covered under a simple-designed roof respectively so that thereby rainwaters are controlled from creeping into the duct in heavy rains but that thereby buldozer operation may not be affected. The conveyor from the yard is 250 t/h and the number is one.

3) Crusher house

A crusher house is installed on the downstream of the Conveyor BC-5, accomodating a screen, crusher and return conveyor for crushed materials.

4) Coal bunker room supply conveyor (BC-6)

Capacity of the supply conveyor is 250 t/h and the number is 1.

5) Coal bunker hopper supply conveyor (BC-7A, 7B)

The power plant consumes a day per two units 1,413 t. of coal:

$$\frac{55.8 \text{ t/h}}{0.948} \times 24 \text{ h} = 1{,}413$$

Assuming that the above-cited quantities of coal are fed into bunker for 9.5 h (lunch time: 1 h. Inspection and shifting: 1.5 h) between 8.30 AM and 6.00 PM, the capacity of the supply conveyor will be:

$$\text{Conveyor capacity} = \frac{1{,}413 \text{ t}}{7 \text{ h}} = 202 \text{ t/h}$$

$$202 \text{ t/h} \times 1.2 = 242 \text{ t/h} \fallingdotseq 250 \text{ t/h}$$

Coal is fed into the bunker hopper by means of a tripper on the belt conveyor.

Each belt conveyor is installed respectively on Unit No. 1 and No. 2 and the capacity is 250 t/h each.

6) Capacity of coal bunker

Assuming that coal feeding is shut down from 6.00 PM to 8.30 AM in the next morning, one unit in this period will consume:

$$29.4 \text{ t/h} \times 14.5 = 426.3 \text{ t.}$$

Taking the coal specific gravity as 0.9 g/cm^3 and actual volume ratio of the hopper as 0.8, the bunker capacity totals:

$$426 \text{ t} \times \frac{1}{0.9} \times \frac{1}{0.8} = 592 \text{ m}^3 \fallingdotseq 600 \text{ m}^3$$ (Per two sets of normal service bunker)

$$600 \text{ m}^3 \times 1.2 = 720 \text{ m}^3$$

Since pulverized system consists of two normal service pulverizers and one spare pulverizer, there 300 m^3 bunker hoppers should be installed.

(7) Fuel Firing System

a) Coal system

Coal feeder delivers coal from bunker into the pulverizer, where it is dried by hot air therein supplied and then pulverized between the balls and rings of the pulverizer.

Pulverized coal is delivered into pulverized coal burner by hot air cited above.

Hor air volume and pulverized coal quantities are controlled in accordance with the load necessary for the boiler.

1) Coal feeder

Coal consumption is calculated for the equipment capacity on the basis of the maximum continuous load in the case of 36% power plant thermal efficiency. The coal consumption as received basis is:

$$Wh = \frac{75 \text{ MW} \times 860 \times 1.05}{6.600 \times 0.36 \times 0.948} = 30.1 \text{ t/h}$$

Since the coal feeder are equipped two normal service feeders and one spare coal feeder, capacity of each feeder is:

$$\frac{30.1 \text{ tons}}{2 \text{ units}} = 15.05 \text{ t/set} = 16 \text{ t/h/set}$$

Hence the feeder capacity is 16 t/h.

2) Pulverizer

16 t/h x 3 sets, as in the case of coal feeder, are installed.

3) Primary air fan

Each coal pulverizer is provided with a primary air fan.

4) Seal air fan

Each boiler is provided with two sets of seal air fan.

5) Pulverized coal burner

Fuel consumption per unit on the basis of AD is:

$$30.1 \text{ t/h} \times 0.948 = 28.5 \text{ t/h}$$

Since there are 6 normal service burners, capacity per burner is:

$$\frac{28.5 \text{ t/h}}{6 \text{ sets}} = 4.8 \text{ t/h/burner} \doteqdot 5.0 \text{ t/h/burner}$$

Each burner demonstrates thermal load of:

$$5.0 \text{ t/h} \times 6{,}600 \text{ Kcal/kg} = 33.0 \times 10^6 \text{ Kcal/h}$$

It means that nine 5.0 t/h burners are to be installed.

b) Heavy oil system

Heavy oil, heated by suction heater in the tank, is heated by heavy oil heater at the heavy oil pump outlet until it provides such a viscosity that is suited for the spray into boiler controlled under a constant pressure at the outlet of the heavy oil pump.

1) Heavy oil burner

Heavy oil burner is required a capacity equivalent to 50% of the boiler load.

Heavy oil consumption per unit under 50% load on boiler is:

$$27.9 \text{ t/h} \times \frac{6.600}{10,439} \times 0.5 = 8.8 \text{ t/h}$$

$$8.8 \text{ t/h} \times 1.2 = 10.6 \text{ t/h}$$

Since 9 heavy oil burners are installed, each capacity will be:

$$\frac{10.56 \text{ t/h}}{9 \text{ sets}} = 1.2 \text{ t/h}$$

Meanwhile the relationship between boiler and coal burner may sometimes reduce the heavy oil light-up numbers.

Hence the capacity per burner is:

$$1.2 \text{ t/h} \times 2 = 2.4 \text{ t/h}$$

It means that nine 2.4 t/h heavy oil burners should be installed.

2) Heavy oil pump

Heavy oil consumption per unit under 50% load on boiler is 10.6 t/h. It means that two 10.6 t/h H.O.P. should be installed for two units.

3) Heavy oil heater

Since heavy oil flow amount per two units is:

$$10.6 \text{ t/h} \times 2 = 21 \text{ t/h}$$

one 21 t/h heater should be installed per two units.

c) Light oil system

Light oil is used for light-up the burner and startup the boiler. Light oil for light-up is delivered to each burner pressurized by light oil pump.

Light oil for startup is pressurized by pump with pressure adjusted to match the specified flow amount and sprayed into the furnace by air atomizing from startup burner.

1) Light-up burner

None burners shall be installed per unit.

2) Startup burner

Each unit shall be provided with two startup burners.

3) Light oil pump

Two light oil pumps shall be provided for two units.

7.3.7 Ash Handling and Ash Disposal Facilities

(1) Ash Quantities

Since coal contains 13% of ash, ash is produced per unit/hour at the following rate:

27.9 t/h x 0.13 = 3.63 t/h

(2) Ash Production Ratio

Following describes ash accumulations per place:

Item	No. of hoppers	Ratio (%)	Accumulations (t/h)	Design Value (t/h)
Chain conveyor		(10) 5 - 15	0.36	0.54
ECO hopper	2	(1.5) 1 - 3	0.05	0.11
Multicyclone hopper of GRF	1	(7.5) 5 - 10	0.27	0.36
AH hopper	2	(1) 1 - 2	0.05	0.07
EP hopper	2 x 2	(80) 75 - 85	2.90	3.09
Total		(100%)	3.63 t	4.17 t

Since it is estimated that the ash production ratio changes as above indications, design should use the upper value.

(3) Ash Disposal Quantities

While the utilization of ash produced from the power plant under project depending on future study, this present Study plans total ash to be disposed.

It is estimated that ash production from two units in 25 years power plant operation will account for:

318,100 t/y x 25 years x 0.13 = 1,034,000 tons

(4) Ash Disposal Area

Taking the ash specific gravity as 0.9 g/cm^3 and pile height as 6 m, necessary space of ash disposal area should be:

$$\frac{1.034,000}{0.9\ t/m^3 \times 6\ m} = 191,480\ m^2$$

Taking 20% allowance into account:

$$191,480\ m^2 \times 1.2 = 229,800\ m^2$$

$$\doteqdot 230,000\ m^2$$

(5) Ash Handling and Ash Disposal System

a) Bottom ash (clinker ash) system

1) Bottom ash removal

In the bottom of the filled with fresh water, a chain conveyor is operated continuously so that the clinker from furnace onto the chain conveyor may continuously be removed. Clinker which is removed by the chain conveyor is crushed by a clinker crusher on the outlet.

2) Ash transportation

Clinker which is crushed by the crusher is delivered onto the conveyor belt and then into the ash disposal area by five belt conveyor.

b) Fly ash system

1) Removal from hopper

Ash removed from Hoppers, ECO, GRF, AH and EP, in this order sequentically, by vacuum pneumatic transportation system into fly ash silo.

2) Removal of fly ash from silo

Ash in the fly ash silo is removed by being removed from the bottom and simultaneously humidifying by dustless unloader. Humidified ash is delivered onto the conveyor belt, thereby conveyed into the ash disposal yard together with clinker ash. Both clinker ash and fly ash are moistened and provide no possibility of dust being scattered. For the sake of precaution, however, the ash conveyor belt should be covered by a cowl.

c) Ash disposal area

In the ash disposal area, ash is enclosed by soil by bulldozers so that it may not fall down, and then piled up in several stages while drainage ditch being constructed arount it.

(6) Capacity of Ash Handling and Disposal Facilities

a) Clinker ash system

1) Chain conveyor

Chain conveyor capacity of 0.54 t/h may suffice for continuous operation, but taking into account the shutdown of chain conveyor and clinker crusher, it should be determined on the basis of 2 hrs operation:

$0.54\ t/h \times 2\ h = 1.1\ t/h\ ...\ 1.5\ t/h$

2) Clinker crusher

Clinker crusher should be designed to 2 t/h with some allowance.

3) Clinker carrying conveyor

Clinker conveyor should be designed to 2 t/h.

4) Boiler bottom sealing water

Fresh water should be used as boiler bottom sealing water which is designed to 20 t/h per unit.

a) Fly ash system

1) Fly ash vacuum pneumatic carrying system assuming that fly ash is carried at the rate of 1.5 h once per 4 h:

$$\text{Ash handling quantity} = (0.11\ t/h + 0.36\ t/h + 0.07\ t/h + 3.09\ t/h) \times 4\ h = 14.5\ t$$

$$\text{Carrying capacity} = \frac{14.5\ t}{1.5\ h} \doteqdot 10\ t/h$$

2) Fly ash silo

Assuming that the fly ash silo capacity is enough to store 12 h's production of fly ash from two units, the fly ash silo capacity is to be designed in the following equation:

$3{,}63\ t/h \times 12\ h \times 2\ \text{units} = 87\ \text{tons}$

$87\ \text{tons} \times 1.2 \doteqdot 100\ \text{tons}$

3) Dustless unloader

Assuming that 87 tons of fly ash is treated in 10 hours, the dustless unloader capacity is:

$$\frac{87 \text{ tons}}{10 \text{ h}} \fallingdotseq 10 \text{ t/h}$$

4) Carrying conveyor for clinker and fly ash

Assuming that 1.1 t/h of clinker and 10 t/h of fly ash are to be carried, the conveyor capacity is:

(1.1 + 10) t/h = 11.1 t/h
11.1 t/h x 1.2 = 13.3 t/h

Hence capacity of conveyor shall be 15 t/h.

7.3.8 Boiler Facilities

(1) Adoption of Natural Circulation Type Boiler

The boiler can be roughly classified into two types, i.e., bending tube type boiler (middle pressure of about 100 kg/cm^2g or less) and radiant type boiler (high pressure of above 100 kg/cm^2g), the latter of which being adopted by power plant who is required high capacity and high reliability.

Also the boiler may be classified by water circulation type in three categories, i.e. natural circulation type, forced circulation type and once-through type. The Project will adopt the natural circulation system on the following reasons:

a) The water circulation is based on the principle of two-phase flow of the saturated steam and water in the tube and specific gravity difference between boiler waters in the downcomer of boiler.

   At critical pressure, latent heat vaporization (=h'-h') is zero. However, at about 190 kg/cm^2g, there is no particular failure in boiler water circulation even in the absence of auxiliary means, e.g., circulating pump, etc.

b) Boiler mechanism is simple in connection with the above factors.

c) Damage spreads little in the case of tube breakage.

d) Ease in operation and maintenance.

e) This type of boiler has been found immensely in practical applications, in the scope of boiler pressure ranging from 100 kg/cm^2g to 190 kg/cm^2g.

(2) Steam Conditions

The steam conditions in the Las Minas Power Plant Unit No. 4 (40 MW) are:

Steam temperature	(superheater outlet)	513°C
Steam pressure	(")	90.6 kg/cm^2g

This project has adopted reheating cycle for improving the turbine thermal efficiency and also the following steam conditions on the following grounds:

Steam temperature (inlet of main stop valve/inlet of reheat stop valve)	538°C/538°C
Steam pressure (inlet of main stop valve/inlet of reheat stop valve)	102 kg/cm^2g/26 kg/cm^2g

While units whose capacity is upto 125 MW provide such steam conditions as the steam temperature of 538°C/538°C and the steam pressure of 102 kg/cm^2g or 127 kg/cm^2g, in the case of units whose capacity is 75 MW, almost all such units adopt the steam pressure of 102 kg/cm^2g.

Increasing the steam pressure from 102 kg/cm^2g to 127 kg/cm^2g decreases the thermal consumption by about 1%, improving the power plant efficiency while inviting following demerits:

a) Improvement in turbine efficiency results in the rating altered from 1,450 psi to 1,800 psi in the boiler/turbine high-pressure portion constituting materials, leading to the increased production/installation/maintenance expenses of boiler and turbine.

b) The 102 kg/cm^2g type is nearer than the 127 kg/cm^2g type to present operational experience which is 90.6 $kg/cm2_g$ and, in addition, the former is easier than the latter for operators to familiarize.

(3) Adoption of Semi-outdoor Type Boiler

It pours in Panama's rainy season. However, the climate is mild in genral without a strong wind. Consequently boiler and other systems may be installed outdoors, except bunker house and burner floor which should be roofed.

The above facts promise the following merits:

a) Less dead space during construction leads to shorter construction period.

b) Construction expenses are economical.

c) Boiler house can be maintained clean.

d) Less hazards in fuel leakage.

(4) Adoption of Gas Recirculation System

Introducing part of boiler combustion gas into the furnace through the bottom contributes to improvement in boiler thermal efficiency and supterheater/reheater temperature control.

(5) Adoption of Direct Firing Pulverized Coal System

This is a system in which the pulverized coal is fed into the pulverized coal burner from the pulverizer without storing in a storage tank, offering the following merits over the storage system:

a) Simpel facilities economized installation expenses, with easier operation.

b) The system which dries the pulverized coal by blowing pre-heated air into the pulverizer, can save the coal drier.

c) This system is free from spontaneous combustion due to pulverized coal storage.

(6) Adoption of Balance Draft System

a) This system ensures ample draft maintaining furnace pressure lower than atmospherec, offering safety without a combustion gas leak.

b) Ease in air flow control

(7) Adoption of Rotating Regenerative air Preheater

a) The air preheater offers little clogging due to ash.

b) Larger heat transfer per unit of space requires lesser installation space.

(8) Adoption of Steam Type Air Preheater

Coal used by the Project contains sulphur is low as 1%. Mixed combustion with heavy oil may, however, possibly lead to contamination, clogging and corrosion in the low temperature zone of the air preheater, due to sulphuric acid produced by sulphur in heavy oil. SO_3 in combustion gas causes the dew point of combustion gas to rise. If the metal surface temperature of the rotaling regenerative air preheater is lowered below the dew point of SO_3, SO_3 reacts with H_2O to produce sulphuric acid vapor which cause the contamination, clogging and corrosion on metal surface.

Consequently the combustion gas temperature is maintained above the dew point by heating the metal surface of the low temperature zone of the rotating regenerative air preheater by installing a steam air preheater near the air inlet of the rotating regenerative air preheater.

(9) Selection of Electrostatic Precipitator

Combustion of coal of this power plant produces ash quantity equivalent to about 13% of coal.

Fine ash called fly ash accounts for about 75 - 85% of the coal ash. It is therefore of prime importance to efficiently catch the fly ash.

This Project has adopted the electrostatic precipitator on the following reasons:

a) Collection of minute particles whose diameter is less than 1 (minimum : 0.001μ) is possible.

b) Dust collection efficiency is extremely high.

c) Lesser pressure loss means lower operation expenses

d) Ease in maintenance leads to economized maintenance expenses

e) The more the treatment gas volume, the more advantageous the operation expenses become.

f) Applicable to a wide range of characteristics of soot to treat.

7.3.9 Turbine System

(1) Adoption of T-type Arrangement

Turbine is installed in T-type with respect to the position of the boiler, taking into consideration the relations between positions of condensor cooling water pipes and main transformers.

(2) Adoption of Reheating Cycle

As explained in the Steam Conditions, the reheating cycle is adopted for avoiding the increase in steam humidity and increasing the turbine thermal efficiency.

(3) Adoption of Tandem Compound System

Tandem compound system is economical in construction expense with ease in maintenance by virtue of comparatively little capacity of 75 MW output.

(4) Condensor Cooling Water

a) Availability of cooling water

Sea water is taken from Limon Bay in the Colon area for the condenser cooling water.

b) Quantity of condenser cooling water

Exchanged heat by condenser (Q) is:

$$Q = Gi(it-ic)$$

Gi	: Turbine exhaust quantity	164,524 kg/h
it	: " " enthalpy	578.7 kcal/kg
ic	: Condensate water enthalpy	41.5 kcal/kg

$$Q = 164{,}524\ (578.7 - 41.5)$$
$$= 88.38 \times 10^6\ \text{kcal/h}$$

Assuming that the heat brought into the condenser as heater drain is 0.45×10^6 kcal/h.

$$Q = 88.38 \times 10^6\ \text{kcal/h} + 0.45 \times 10^6\ \text{kcal/h} = 88.83 \times 10^6\ \text{kcal/h}$$

Quantity of cooling water (Gw) is:

$$Gw = \frac{Q\ x}{(Cpx\ )(t2-t1)}$$

Cp	: Specific heat of cooling water	0.957 kcal/kg°C
	: Specific gravity of cooling water	1,019.3 kg/m^3
t1	: Inlet temperature of cooling water	29°C
t2	: Discharge temperature of cooling water	36°C
	: Allowance	1.02

$$Gw = \frac{88.83 \times 10^6 \times 1.02}{0.957 \times 1{,}019^3 \times 7}$$
$$= 13{,}269\ m^3/h$$
$$= 13{,}300\ m^3/h$$

Assuming that the quantity of bearing cooling water etc. is 900 m^3/h:

$$Gw = 13{,}300\ m^3/h + 900\ m^3/h$$
$$= 14{,}200\ m^3/h$$

(5) Condenser Cooling Water Pump

a) Capacity of cooling water pump

A pump whose capacity is 100% per unit is installed.

b) Total head of the pump

Total head (H) is:

$H = Lc + hp1 + hp2 + hc + Ls + LD$

Lc : Loss in intake, screen, discharge 1.5 m

hp1: Loss in pipeline (two line portion) 3.16 m

Hp2: Loss in pipe (one line portion) 0.95 m

hc : Loss in condenser (tube + water box) 3.9 m

Ls : Cyphone loss 0.16 m

(Cyphone height in operation x 0.03 = 5.3 m x 0.03)

LD : Discharge speed loss in condenser discharge pipe 0.62 m

H = 10.29 m

Hence total head of condenser cooling pump is 10.5 m.

c) Brake horsepower and motor output of cooling water pump

Brake horsepower (Lp) is:

$$Lp = \frac{Lw}{p}$$

Lw : Hydraulic power = $0.163\,\gamma QH$

ηp : Pump efficiency = 0.85

γ : Specific gravity of water 1.0193 kg/ℓ

Q : Discharge quantity 118 m^3/min.

H : Total head 10.5 m

$$Lp = \frac{0.163 \times 1.0193 \times 237 \times 10.5}{0.85}$$

$$= 486 \text{ kW}$$

Motor output (Lm) is:

$$Lm = \frac{Lp\ (1+\alpha)}{\eta\ t}\ (kW)$$

α : Allowance 0.15

ηt : Transfer efficiency 1.0

= 559 kW

Hence 560 kW shall be applied.

(6) Condenser

Design conditions of condenser are as follows:

Exhaust vacuum	700 mmHg
Cooling water inlet temperature	29°C
" discharge temperature	36°C
Exchange heat	88.83×10^6 kcal/h
Cooling tube material	Aluminum brass
Flow velocity inside of cooling tube	2 m/sec max.
Cleanliness factor of cooling tube	85%

(7) Capacity of Condensate Pump

Condensate flow quantity at boiler MCR is about 240 t/h. Two condensate pumps of 50% capacity (100 t/h) are installed.

(8) Boiler Feed Water Pump

Feed water flow quantity at boiler MCR is about 240 t/h. Two feed water pumps of 50% capacity (120 t/h) are installed.

From the consideration of pump maintenance, electrical motor driver system shall be applied.

Fig. 7.3.8 (1) Heat Balance Diagram

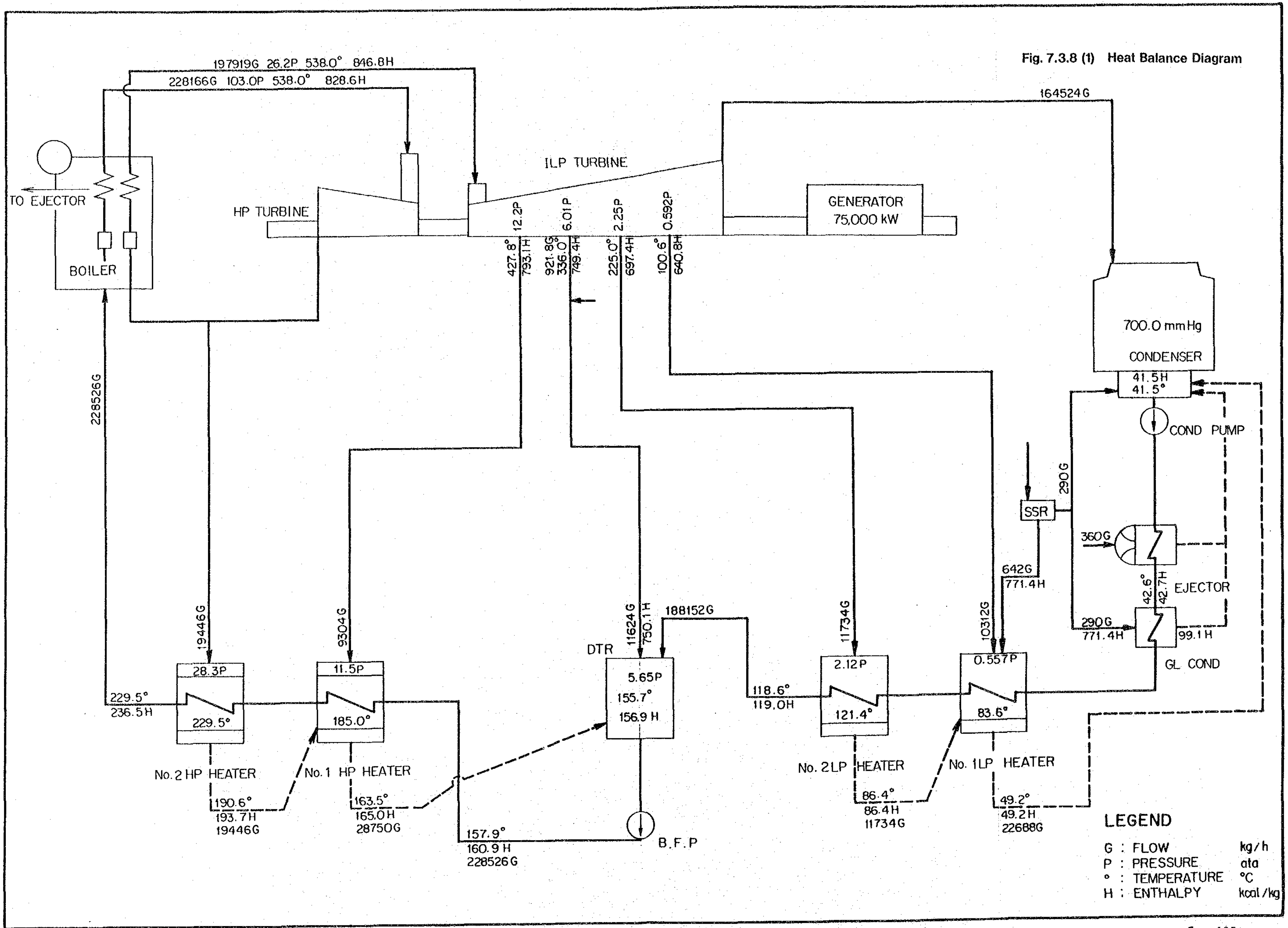


Fig. 7.3.8 (2) Steam, Auxiriary Steam, Condensate, Feed Water Flow Diagram

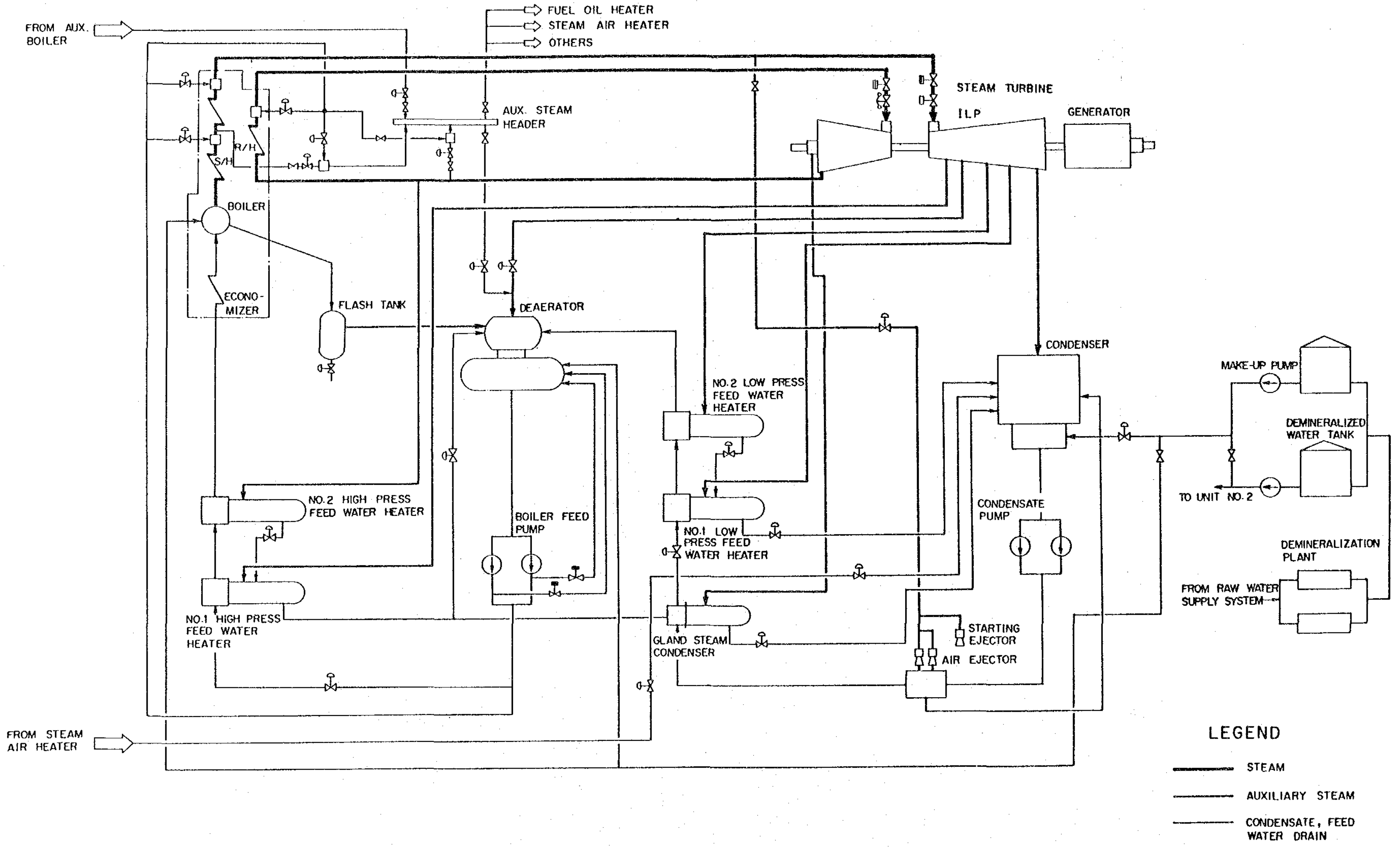


Fig. 7.3.8 (3) Coal, Oil, Flue Gas, Air, Ash Diagram

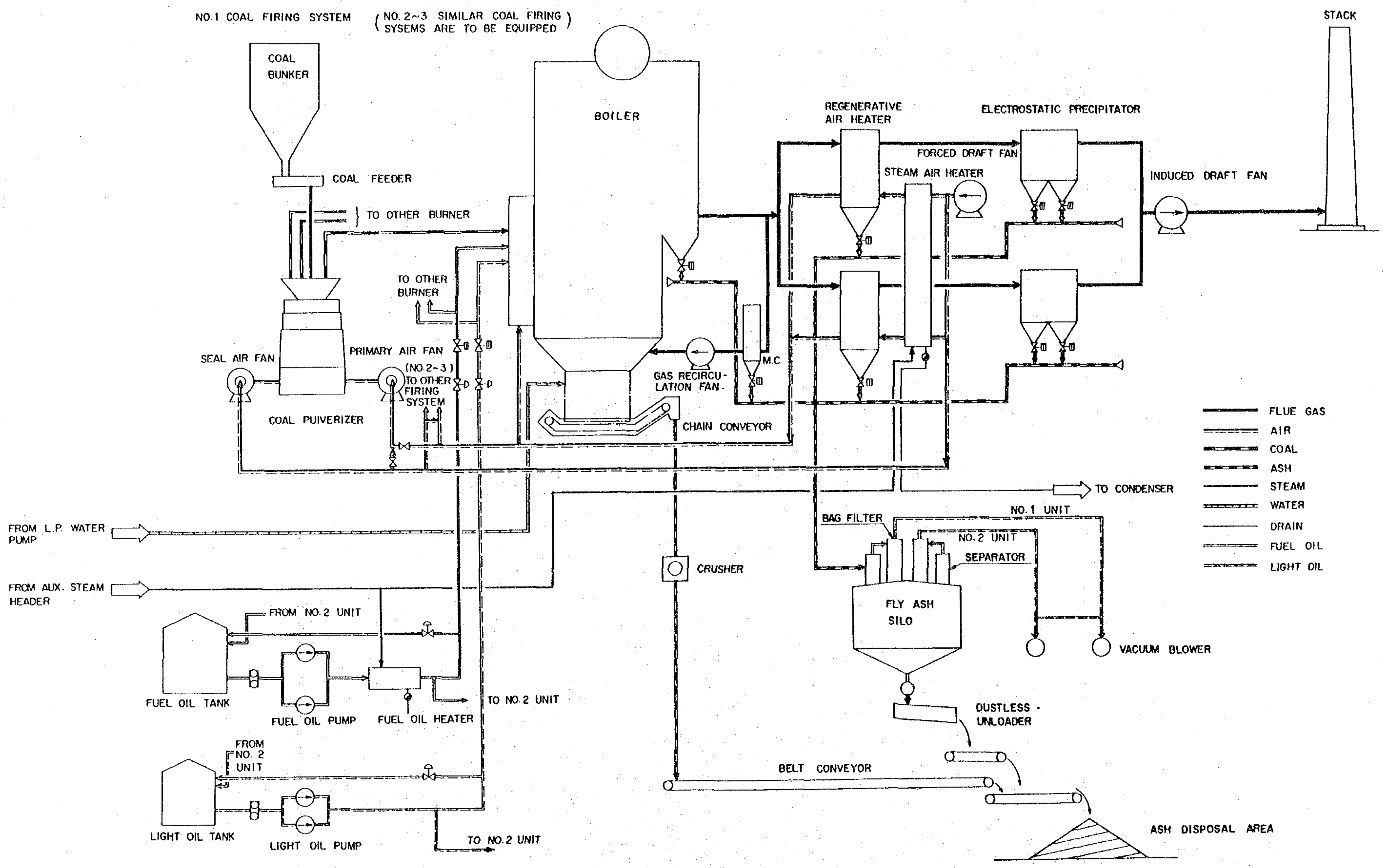
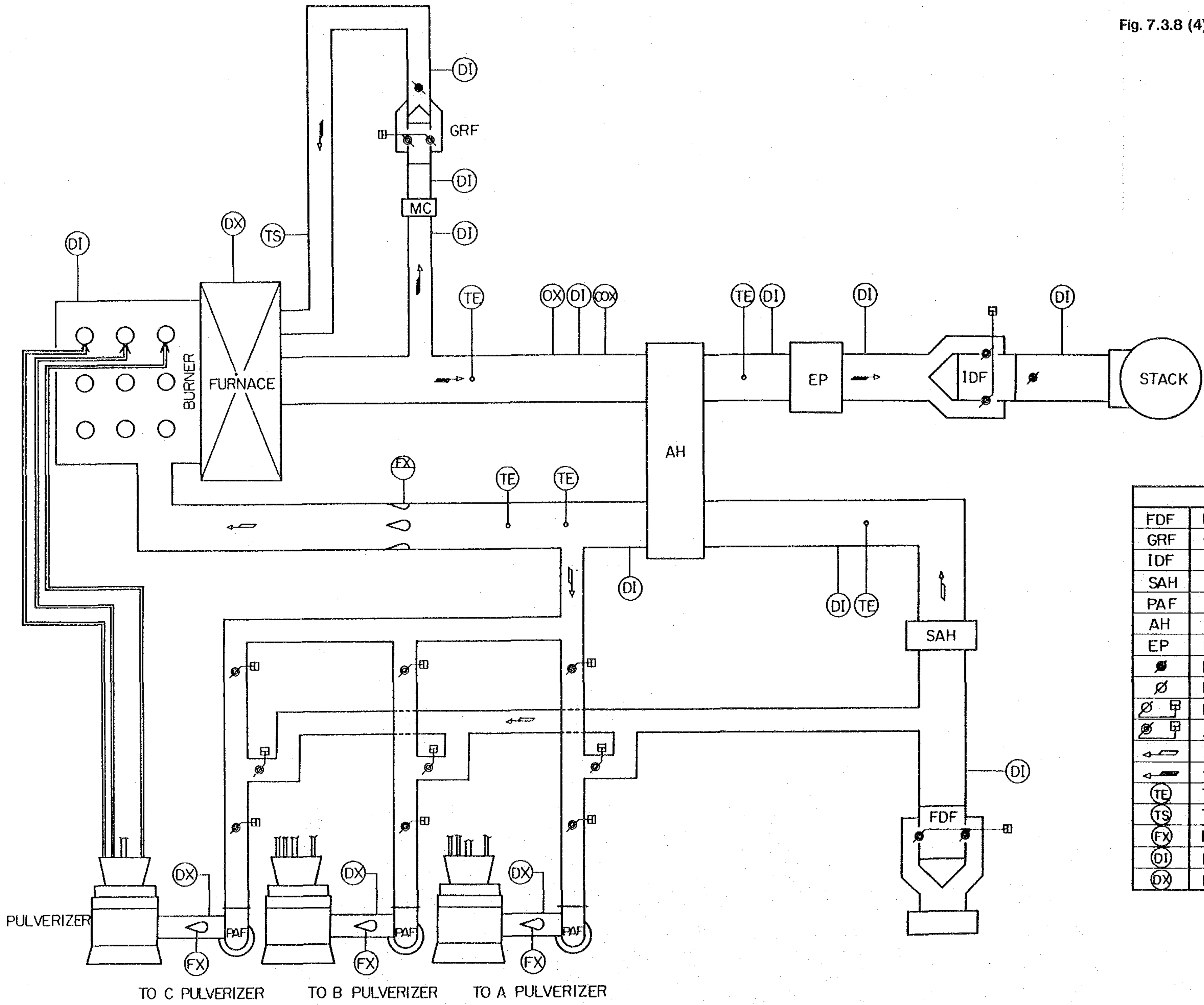


Fig. 7.3.8 (4) Air and Gas Flow Diagram



LEGEND	
FDF	FORCED DRAFT FAN
GRF	GAS RECIRCURATING FAN
IDF	INOUCED DRAFT FAN
SAH	STEAM AIR HEATER
PAF	PRIMARY AIR FAN
AH	GAS AIR HEATER
EP	ELECTROSTATIC PRECIPITATOR
Ø	HAND OPERATED DAMPER
Ø	REMOTE MANUAL DAMPER
Ø ⊞	REMOTE CONTROL DAMPER
Ø ⊞	AUTOMATIC CONTROL DAMPER
◁	AIR FLOW
◁	GAS FLOW
TE	TEMPERATURE ELEMENT
TS	TEMPERATURE SWITCH
FX	FLOW TRANSMITTER
DI	DRAFT INDICATOR
DX	DRAFT TRANSMITTER

Fig. 7.3.8 (5) Condenser Cooling Water Flow Diagram

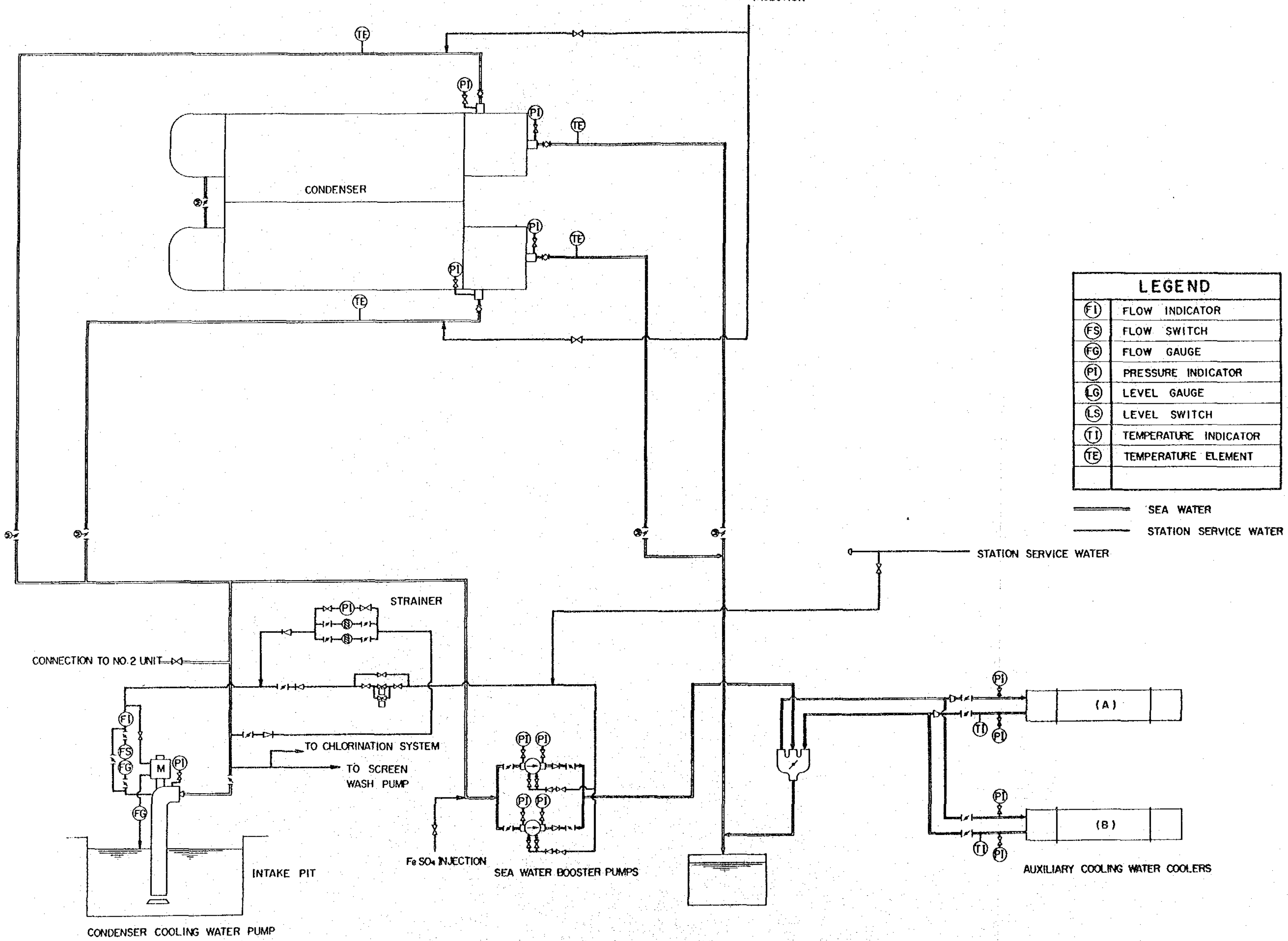
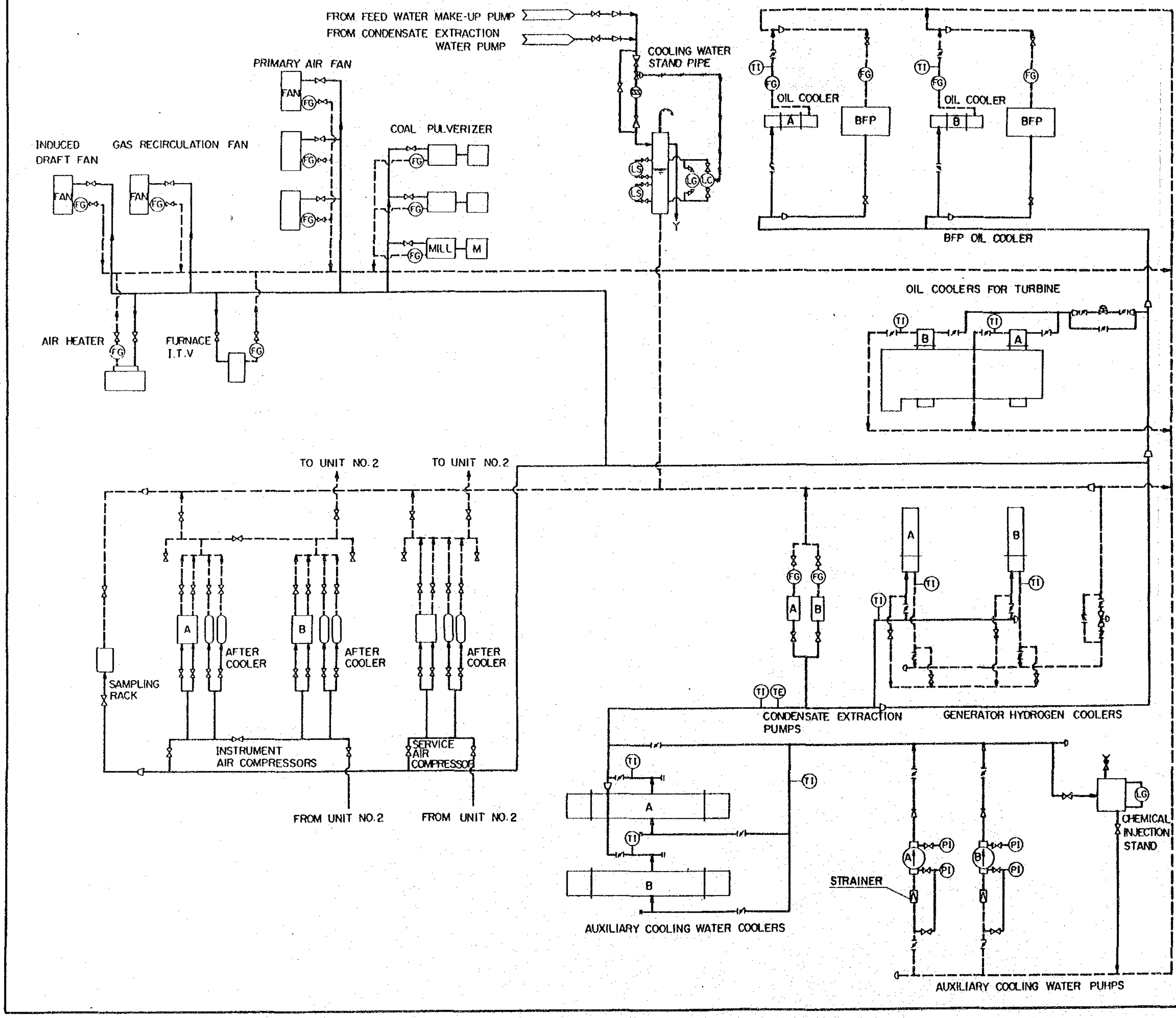


Fig. 7.3.8 (6) Cooling Water Flow Diagram



LEGEND	
FG	FLOW GAUGE
TI	TEMPERATURE INDICATOR
LG	LTVEL GAUGE
LC	LEVEL CONTROLLER
LS	LEVEL SWITCH
PI	PRESSURE INDICATOR
TE	TEMPERATURE ELEMENT

7.3.10 Environmental Protection Facilities

(1) Emission Standard

The emission standard with respect to the construction of power plant varies with various situations from country to country and therefore there exist no international standards.

JICA Survey Mission's investigations has been carried out in conformance with the Study Procedures, as shown in Fig. 7.3.10 (1), on the basis of discussions with IRHE. While in general investigation should follow the emission standard established by a country or her local municipal, if any, Panama has not, as of August 1986, established an emission standard, act of life environmental standard nor IRHE guideline. She has no measured data the current environmental conditions.

Under the above circumstances, JICA Survey Mission has established an emission standard as indicated in Table 7.3.10 (1) on the basis of descriptions in Chapter 13 and related evaluation.

The emission standard has been established on theses of:

(1) The construction of the power plant will not affect the Panama Canal operation

(2) The construction of the power plant will not affect the surrounding environments

at the level applicable to the countries in the world, particularly, the USA.

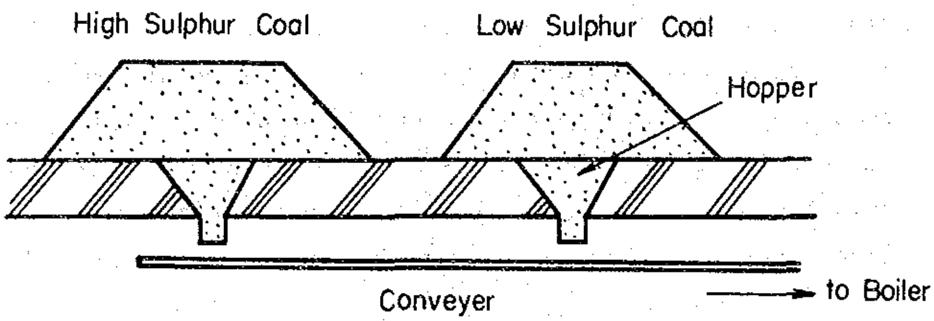
Reference is made to Chapter 13 as for the evaluation and computations of the environmental influence.

(2) SOx Emission Standard

a) SOx emitted from a stack depends upon sulfur content of the coal used by the plant.

Meanwhile, the power plant under this Project will use coal of Columbian or US (East) origin whose sulfur content is ranging from 0.7% to 1.1% (average: Abt. 1%).

Firing of high sulfur content coal leads to the increase in SOx emission, worsening the surrounding environment. It is therefore necessary to average sulfur content by sorting coal in two categories, low and high sulfur content, in the course of pile-up of the coal storage yard so that they may be mixed up while being delivered onto a conveyor belt through separated hoppers respectively.



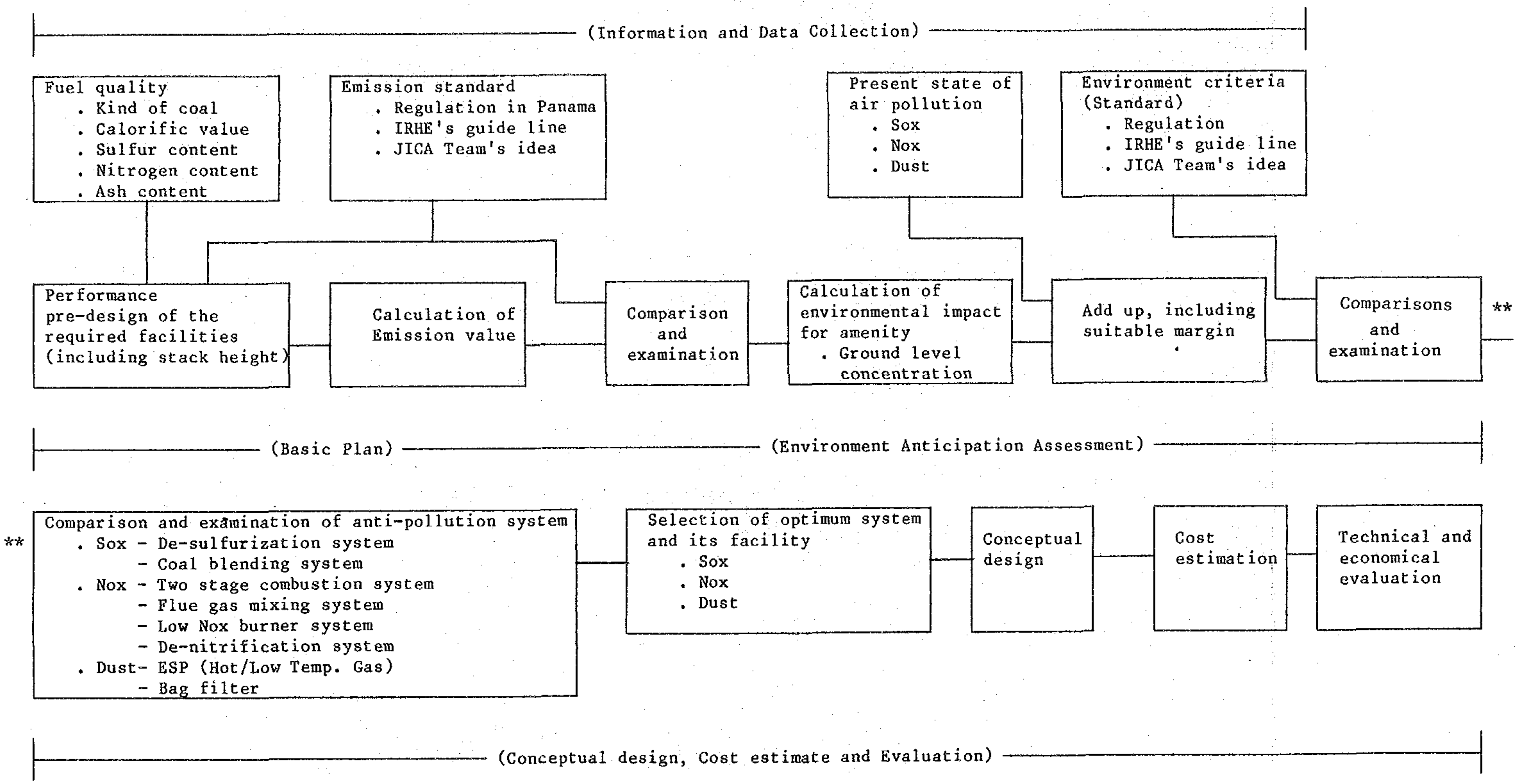
b) Emitted SOx is diffused from the stack into atmosphere and diluted before reaching the ground. Maximum ground level concentration is decreased as the effective stack height (actual chimney height + emission rising due to momentum + emission rising by its buoyancy) increases. As for the relationship between the factors cited above, reference is made to Fig. 13.3.1. In the case of the power plant under this Project, the gas velocity has been designed to 30 m/s to maximize the emission rising due to momentum. While it is recommended to increase the emission temperature for increasing the emission rising by its buoyancy, since this method tends to deteriorate the boiler thermal efficiency, the emission temperature is assigned a normal temperature of 140°C. The stack actual height minimum is 95 m which is necessary to ultimately achieve the design value, Cmax = 0.015 PPM.

The stack height or gas emission velocity has been increased exerts the same effect in controlling NOx and dust.

c) The installation of 95 m stack under the above-cited conditions (Cmax = 0.015 PPM. S = 1%) will preclude the expensive desulphurizing system.

Fig. 7.3.10 (1) Study Procedure for Environment Control (for air pollution)

The optimum environment control countermeasure for the proposed project is selected according to the following procedure.



(3) NOx Emission Control

NOx produced in boiler is classified in following two categories:

a) Fuel NOx — Oxidation of nitrogen content in fuel by combustion in boiler produces NOx. Normally NOx amount increases by 1% per every 0.1% increment of nitrogen content.

b) Thermal NOx — Oxidation of nitrogen content in the air required for fuel combustion by combustion in boiler produces NOx.

There are meanwhile four following approaches to control or inhibit the NOx emission (which are enumerated below in the order of low to high cost):

1) Two stage combustion system
2) Flue gas mixing system
3) Low NOx burner system
4) Denitrification system

Fig. 7.3.10 (2) and Fig. 7.3.10 (3) respectively show the system principle and effect.

Two-stage combustion system and flue gas mixing system may suffice if the power plant under this Project specifies its designed NOx emission concentration upto 300 PPM. Since, however, this value is critical, taking into consideration the future increase in nitrogen content in fuel, for the sake of prudence, the low NOx burner is additionally installed.

(4) Dust Emission Control

Coal to be used by this Project contains 13% of ash and 1% of sulfur content.

Normally about 15% of the ash produced in the pulverized coal combustion boiler is molten and allowed to drop into clinker hopper, while about 5% accumulating in the economizer hopper and air preheater hopper in the form of cinder ash whose particle size is comparatively large. Remaining about 80% of ash is exhausted from the boiler in the form of fly ash of fine particulate size. In the case of boilers under stringent NOx emission control as those of the power plant under Project, however, since the furnace temperature is designed on the lower side, majorities of ash are exhausted in the form of fly ash. The power plant is equipped with dust removal equipment to catch the fly ash, which are classified in the following five categories (in the order of low to high cost):

a) Mechanical dust removal equipment (Cyclon)

This type of equipment is suited for catching the ash of coarse particle size.
Dust emission concentration : More than 0.5 g/Nm^3

b) Dry-type cold side electrostatic precipitator (Cold ESP)

This type of equipment is suited for catching the ash whose electric resistance is low (10^4-10^{11} ohm-cm) in the low temperature zone (120-150°C).
Emission concentration : 0.08 - 0.5 g/Nm^3

c) Dry-type hot side electrostatic precipitator (Hot ESP) (about 300-400°C)

This type of equipment is suited for catching the ash whose electric resistance is high (10^{12} ohm-cm or more) in the low temperature zone (120-150°C). Emission concentration : 0.08 - 0.5 g/Nm^3

d) Bag filter

This type of equipment is adopted in the case of stringent emission concentration control.
Emission concentration : 0.04 - 0.1 g/Nm^3

e) Wet-type ESP

This type of equipment is adopted in the case of necessity to extremely lower the emission concentration.
Emission concentration : 0.02 - 0.05 g/Nm^3

In the case of the power plant under the Project where the emission concentration design value is 0.1 g/Nm^3, the above-cited factors require either dry type cold side electrostatic precipitator (hereinafter called Cold ESP) or dry type hot side electrostatic precipitator (hereinafter called Hot ESP). Comparison between Cold ESP and Hot ESP is investigated from the viewpoint of economics and dust removing performance.

a) Economics

Like heavy oil-fired power plant, Cold ESP is installed in an about 140°C zone on the downstream side of boiler air pre-heater, while Hot ESP is installed in between boiler economizer and air preheater so that gas (about 350°C) is admitted into ESP where it is treated and then returned to the air preheater.

Consequently the gas capacity of Hot ESP is about 1.5 times that of Cold ESP $\frac{273 + 350}{273 + 140} = 1.5$, implying a considerably increased size and cost due to the ESP size and flue gas ducts involved.

b) Dust removal performance

The dry type electro static precipitator depends largely upon the ash electric resistance for its performance. In another expression, if the ash electric resistance exceess 10^{12} ohm-cm, a back corona phenomenon takes place in the dust removal equipment, leading to charge uncertainty and ultimately to the deterioration of dust removal performance.

Fig. 7.3.10 (4) shows normal relationship between electric resistance of ash and dust removal performance.

Meanwhile the ash electric resistance varies significantly with sulfur content in coal and gas (ash) temperature. Fig. 7.3.10 (5) shows the relationship between them. The fly ash chemical structure is associated with electric resistance in such a way that increase in percentage of NaO_2 and SO_3 decreases electric resistance whereas increase in percentage of SiO_2, Al_2O_3, CaO, MgO and K_2O increases electric resistance.

c) Selection

As discussed in Chapter 6, ash composition of the coal to be used in the power plant under Project is specified:

S	1%	NaO_2	1.0%	SO_3	1.0%	SiO_2	62.0%
Al_2O_3	20%	CaO	2.0%	MgO	2.0%	K_2O	2.0%

It is therefore estimated that electric resistance resulting from the above specification will approximately account for

1.5×10^{11} ohm-cm (Flue gas temperature : 140°C)

Taking the above estimation together with economics into consideration, Cold ESP has been adopted.

The inlet dust concentration in Cold ESP design has been designed so that 100% of coal ash is came into Cold ESP. It is recommended to identify the ash properties for plotting a detail design, by conducting the analysis of coal samples.

(5) General Waste Water Treatment

In general waste water other than heated effluent, which poses problems in way of operation of coal-fired power plant is classified in the following three categories:

a) Waste water from equipment

This is waste water arising from the operation of equipment in the power plant, e.g., power house waste water, reused water of demineralized water system, washing water used in periodical inspection of equipment, etc.

b) Coal storage yard rainwater

c) Ash disposal area rainwater

Fig. 7.3.10 (6) shows the general waste water amount, water quality and treatment flow estimated with respect to the waste water cited above.

The waste water amount and water quality parameters are the conversions from Japanese in those of the Project by JICA Survey Mission on the basis of its experience, except the waste rainwater which has been calculated using the following equation in accordance with the precipitations data in the rainy season at Colon:

$$Q = R \times A \times (1-S) \quad m^3/d$$

Where :

Q : Drainage amount 800 m^3/d

R : Precipitations (daytime) 70 mm/d

A : Space of ash disposal area 230,000 m^2

S : Coefficient of penetration into ground

Ash disposal are 0.95

Others 0.90

As apparent in the figure, the equipment effluent treatment requires not only SS treatment but also PH control and neutralization. In addition, since rainwater from heavy/light oil tank yard and waste water from repair shop contain leaked oil and are therefore hazardous, oil separators should be installed.

The periodical inspection produces a large quantity of washing water from equipment at one time. It is therefore economical to temporarily reserve the waste water by means of a relay tank so that it may slowly be treated in several days, since this method will save filters and other tools.

As called squall, it pours in a brief time at Panama in its rainy season. It is therefore possible that part of the surface of the coal or ash pile in the coal storage yard or ash disposal area may be washed away. The coal storage yard and ash disposal area should therefore be provided with drain gutter on all their laterals so that waste rainwater may be collected were ash set, while the surfacial clean water used as spray to prevent dust from being scattered on fine days.

* Parameters in Colon Area have been estimated as follows:

Survey data in Puerto Cristobal indicate the monthly maximum precipitations in the recent 22 years (1962 - 1984) as 891 mm. In the absence of data as to the number of rainy days in the corresponding month, the estimation has been operated, assuming that it rains for 15 days or half a month, from which has ensued the design value of effluent treatment 60 mm/day (891 mm 15 days).

(6) Heated Effluent Countermeasure

Requirement for cooling water of the power plant accounts for 3.5 m^3/s x 2 units, as calculated in Fig. 7.3.10( ), taking the design value of the temperature rise in the condenser cooling water for as 7°C. The cooling water is taken from Cristobal Harbor and discharged into the French Canal. JICA Survey Mission experiences in Japan tell that, while the 7°C temperature rise may not affect the surrounding environment, computation of temperature rise distribution in the French Canal has revealed the temperature rise scope where the temperature rising above 2°C covers 680 x 10^3 m^2, which means that there is no temperature rise re-circulation. As for the details, reference is made to Chapter 13.

(7) Sound-proof Countermeasure

There are two types of noises sources at the impact noise level on the site border line, continuous noise source and intermittent noise source.

Large continuous noise sources are turbines, BFP (Boliers Feed Water Pump), FDF (Forced Draft Fan), mill, air compressor, etc., which, however, may be enclosed in a power house.

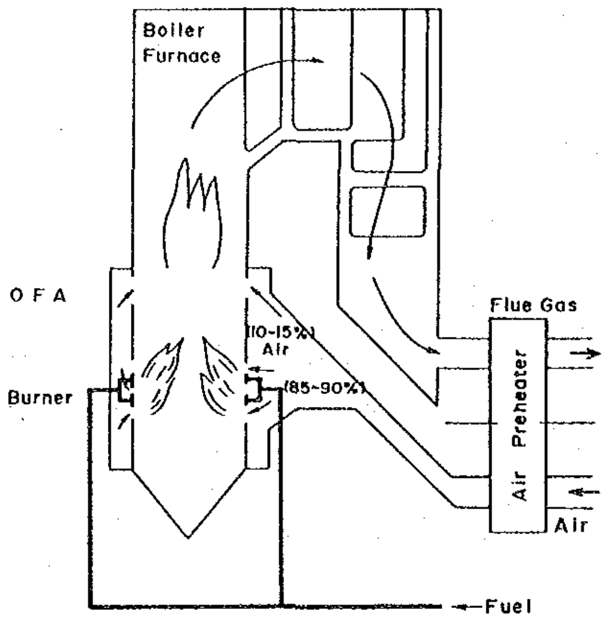
The noise may be controlled by adopting as much low-noise equipment and installing them as apart from the site border line as possible. The coal unloading work should be operated only in daytime from the viewpoint of safety operation, setting two design noise value on the site border line, daytime and night. Intermittent noises, e.g. safety valve blowing noises, etc. should be lowered by means of silencer.

(8) Vibration Countermeasures

Sourcs of noises at impact vibration level on the site border line are turbine, generator, mill, etc. These sources may be controlled by installing equipment on concrete foundations of ample dimensions and

Fig. 7.3.10 (2) NOx Control System

a) Two Stage Combustion System

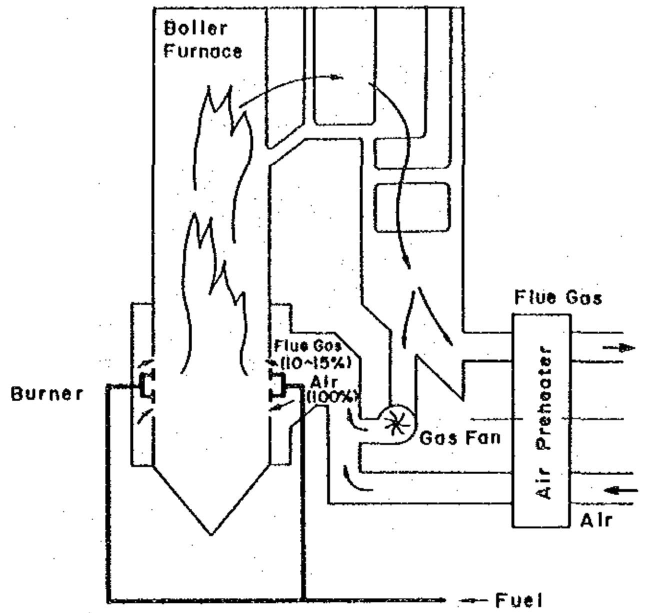


Combustion air is supplied in two stages into the boiler furnace.

At the first stage, the combustion air is controlled under less stoicheometic air condition for incomplete combustion and at the second stage, supplementary air is sent so as to achieve complete combustion.

Through this process of combustion, the temperature of the hottest part of flame is lowered thus the NOx emission is decreased.

b) Flue Gas Mixing System

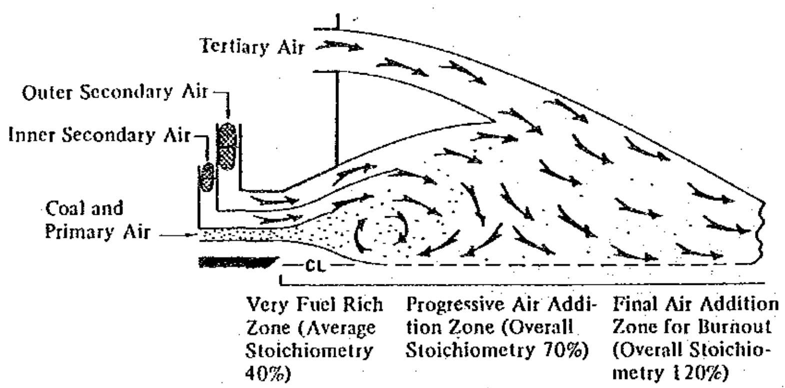


Combustion air is partially mixed with flue gas which contains less oxygen after combustion so as to decrease oxygen content of combustion air and to delay combustion speed.

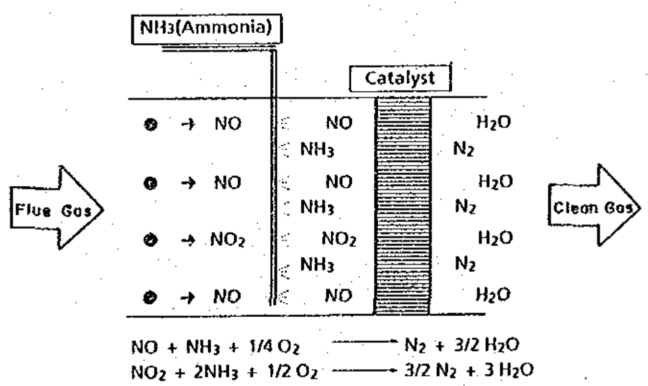
Through this process of combustion likewise the two stage combustion, the temperature of the hottest part of flame is lowered with longer flame thus the NOx emission is decreased.

c) Low NOx Burner System

This burner is designed in such a manner that NOx emission is repressed through the means of feeding combustion air from several positions so as to cause slow combustion of pulverized coal and to keep flame temperature low by properly adjusting air flow.



d) Fuel Gas Denitrification System



o Ammonia is injected into the flue gas which contains nitrogen oxides. The flue gas passes through metallic catalyst bed where chemical reaction takes place.

o Nitrogen oxides in flue gas are decomposed with the catalyst aid to nitrogen and water.

Fig. 7.3.10 (3) NOx Control and Its Effect

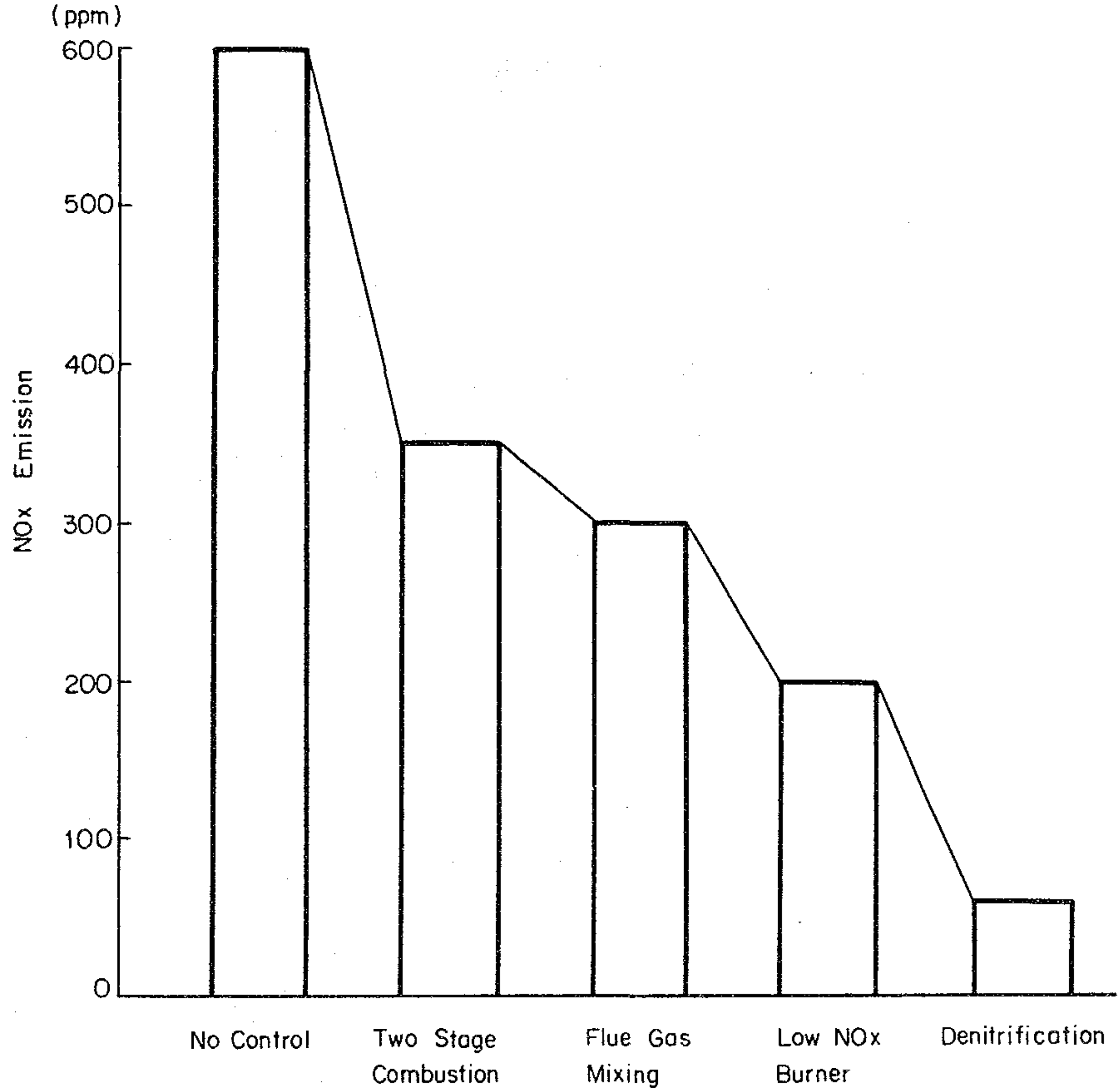


Fig. 7.3.10 (4) Relation of Gas Temperature and Electrical Resistivity of Fly Ash

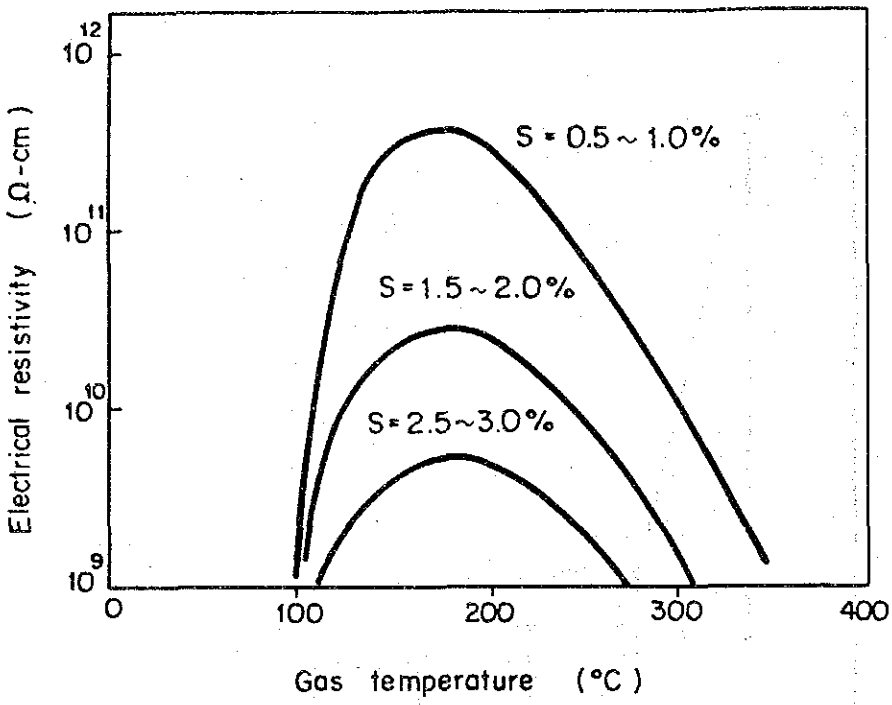


Fig. 7.3.10 (5) Dust Collecting Efficiency curve

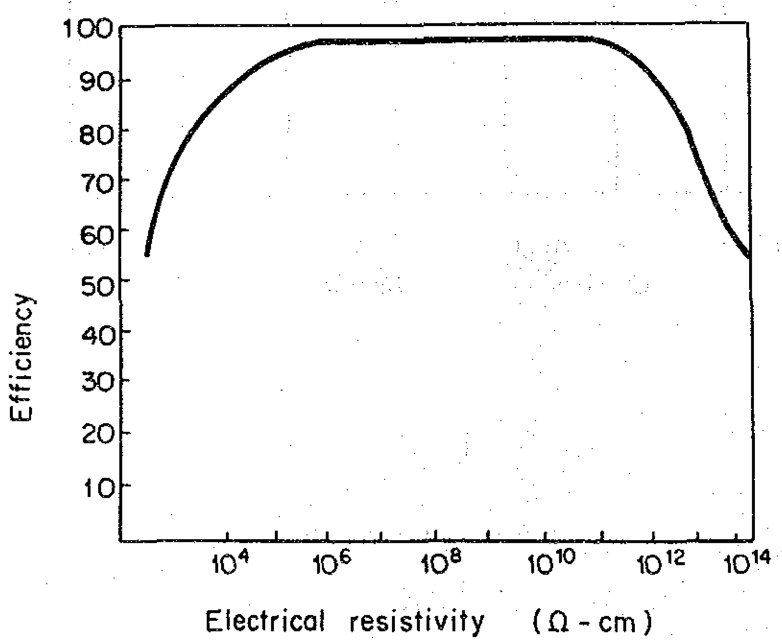
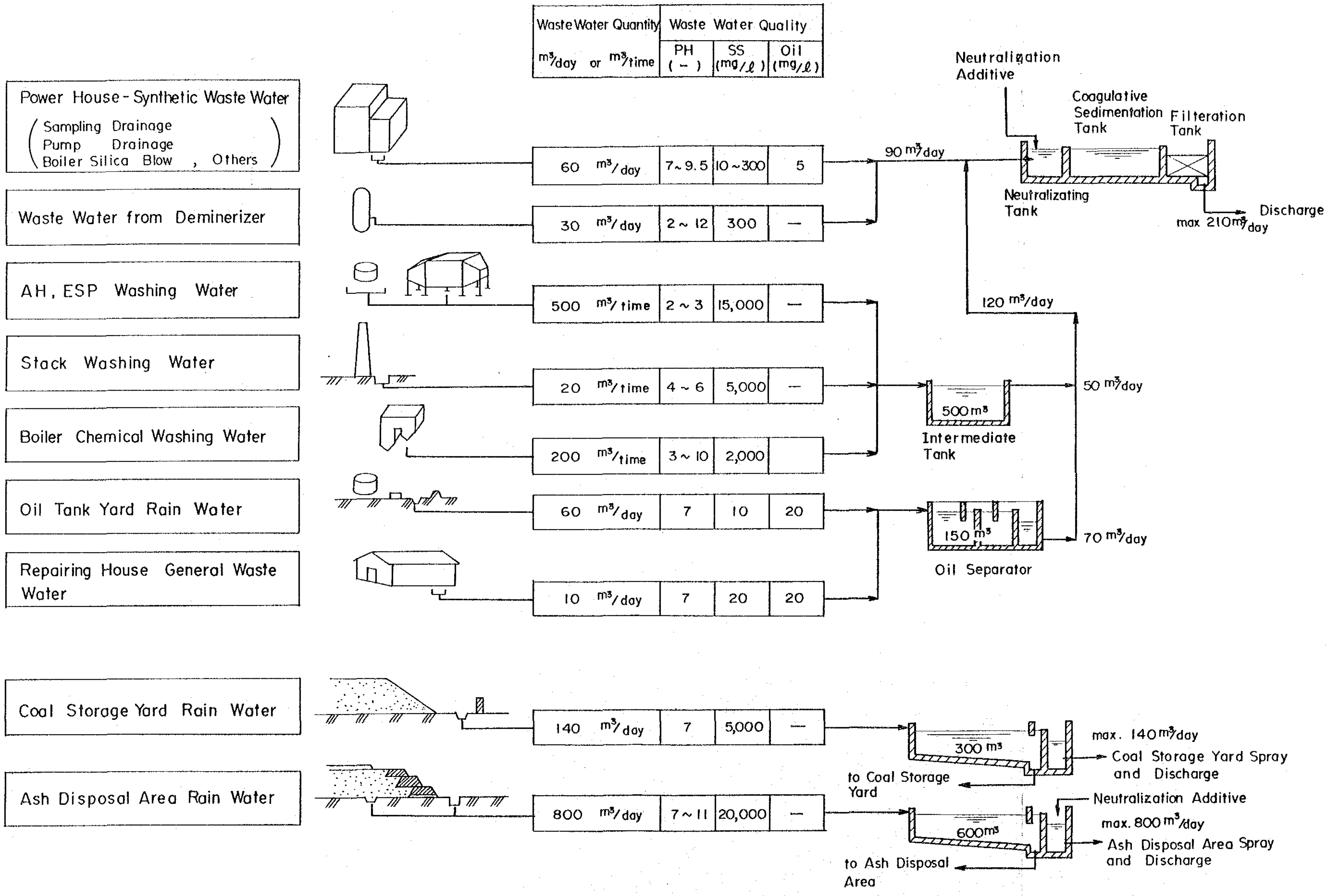


Fig. 7.3.10 (6) Waste Water Flow Diagram



Source	Waste Water Quantity m³/day or m³/time	Waste Water Quality PH (–)	SS (mg/ℓ)	Oil (mg/ℓ)
Power House - Synthetic Waste Water (Sampling Drainage, Pump Drainage, Boiler Silica Blow, Others)	60 m³/day	7 ~ 9.5	10 ~ 300	5
Waste Water from Deminerizer	30 m³/day	2 ~ 12	300	—
AH, ESP Washing Water	500 m³/time	2 ~ 3	15,000	—
Stack Washing Water	20 m³/time	4 ~ 6	5,000	—
Boiler Chemical Washing Water	200 m³/time	3 ~ 10	2,000	
Oil Tank Yard Rain Water	60 m³/day	7	10	20
Repairing House General Waste Water	10 m³/day	7	20	20
Coal Storage Yard Rain Water	140 m³/day	7	5,000	—
Ash Disposal Area Rain Water	800 m³/day	7 ~ 11	20,000	—

Table 7.3.10 (7) Calculation of Cooling Water Quantity

Calculation Condition

(1) Rated capacity — 75 MW x 2 units

(2) Max. temperature rise of cooling water — 7°C

(3) Plant efficiency (at 100% load) — 36%

Breakdown

Boiler efficiency	86%
T-G efficiency	42%
Plant loss	0.5%
(Therefore, 0.86 x 0.42 x (1-0.005) = 0.36)	

Calculation

(1) Heat Value from Boiler

$$\frac{75{,}000^{MW} \times 860}{0.36} \times 0.86 \times (1-0.005) = 153.3 \times 10^6 \text{ kcal/h}$$

(2) Heat Value to Condenser

$$\frac{153.3 \times 10^6 \times (1-0.42)}{3600^s} = 24{,}700 \text{ kcal/s}$$

(3) Required Cooling Water Quantity

$$\frac{24{,}700}{7 \times 1{,}019} \times 1.07 \times 10^{-3} = 3.7 \fallingdotseq 4.0 \text{ m}^3\text{/s}$$

Specific gravity — for Aux. equipment

(4) Total Cooling Water Quantity

$4.0 \text{ m}^3/\text{s} \times 2 \text{ units} = 8 \text{ m}^3/\text{s}$

as apart from the site border line as possible, so that the vibration on the site border line may be reduced.

(9) Others; countermeasures against dust scattered coal or ash handling spots are provided as necessary with sprays or splinklers. Outdoor-type belt conveyors are provided with covers to prevent dust from being scattered.

7.3.11 Electric Equipment

(1) Selection of Rated Voltage

Standard voltage of each electrical circuit have been selected as follows in accordance with IRHE standard :

Transmission voltage	230 kV
Generator output voltage	13.8 kV
High-voltage auxiliary system voltage	4.16 kV
Low-voltage auxiliary equipment system voltage	208 V
Illumination fixture voltage	208 V
DC auxiliary system and operating circuit	110 V

(2) Generator capacity P_G

$$P_G = \frac{\text{Generator rated output}}{\text{Rated power factor}}$$

$$= \frac{75,000\ (\text{kW})}{0.85} = 88,250\ \text{kVA}$$

In the case of generator charging by itself the transmission line of 230 kV, double circuits and 72 km distance, the minimum capacitance Q without abnormal overvoltage or self-excitation is found in the following equation 83,713 kVA. Therefore the generator produces neither selfexcitation nor abnormal overvoltage:

$$Q = \frac{Qo}{K} \times (\frac{E}{E'})\ 2 \times (1 + \sigma)$$

$$= \frac{44.139}{0.58} \times (\frac{230}{230})\ 2 \times (1 + 0.1)$$

$$= 83,713$$

88.250 kVA (Generator rating) > 83,713 kVA (Q)

Q = Generator capacitance - self-excitation, overvoltage

Qo = Transmission line charging capacity 44,139 kVA

K	= Generator short-circuit ratio	0.53
E	= Rated voltage	230 kV
E'	= Charging voltage	230 kV
σ	= Generator saturation factor	0.1

(3) Main Transformer Capacity

Generator capacity requires the following value under such conditions that generator is operated under 100% load with safety with the least auxiliary power, that is, with 50% of the mill in shutdown and 50% heavy oil combustion.

88,250 - 2,650 = 85,600 kVA

(4) House Transformer Capacity

The capacity should cover auxiliary power for one unit plus is ensured auxiliary power of back-up for one other unit in the case of station power for the unit as well as starting transformer are in downtime simultaneously due to periodical inspection.

a)	Auxiliary power for the unit	6,200 kVA
b)	Common equipment power supplied normaly from starting transformer	600 kVA

c) Power for the other units in downtime — 600 kVA

Total	7,400 kVA
	= 7,500 kVA

(5) Stating Transformer Capacity

The transformer should be installed one set, common for Unit No. 1 and No. 2, from the viewpoint of design which takes the base load as about 70% of annual utilization factor, regardless of simultaneous starting of Unit No. 1 and No. 2. Capacity should be enough to permit the entire backup for house transformer and the same as that of the house transformer.

(6) Outdoor Switchyard

As discussed in the previous section, the power plant is important for base load and therefore designed in the double bus bar system, from the consideration of improvement in reliability and easy maintenance and inspection. Taking the future expansion (75MW x 2 Units) into consideration the breaker capacity is 31.5 kA in accordance with the result of computer simulation which reads 9.3 kA or over, having regard to the ANSI standard and co-use of spares in Panama II Substation.

(7) House Power Source Configuration

It should be so designed that a failure in the station supply, if any, should not affect the operation of other units, by adopting the unit system in which each unit is connected independently with the station service circuit for improving the power plant reliability.

Since, meanwhile, the generator is of the high-voltage synchronized parallel in method due to its capacity, the system in which station service power is supplied from the starting transformer at starting operation and switched to the house transformer after the generator has been synchronized, is adopted.

Furthermore such facilities, as cool handling facilities, which do not hinder the powerplant immediately in case of power failure, No. 1 and No. 2 Units are commonly used due to economy and power is supplied from the starting transformer.

(8) 4 kV Switchgear

The switchgear should be of 4.34 kV metal clad type, adopting a vacuum-type circuit breaker (V.C.B) for powering high-power auxiliary equipment (more than 150 kW). The actual interrupting capacity more than 16.3 kA is acceptable, and the rated interrupting capacity should be IEC Standard 20 kA.

(9) 210V Power Center

Air blast circuit breaker (A.C.B.) of 600V steel enclosed type is adopted for powering medium-capacity auxiliary equipment (abt. 75 - 200 kW). The actual interrupting capacity more than 19.8 kA is acceptable, and the rated interrupting capacity should be JIS Standard 20 kA.

(10) 210V Control Center

600V steel enclosed type provided with different types of breaker (NFB) and magnet switch for different types of auxiliary equipment is adopted, for powering low-capacity auxiliary equipment (less than 75 KW abt.).

The control center may be assigned the interrupting capacity the same as that of the power center in the preceding section, but, eventually 15 kA from the consideration of economics. The control center will be provided with current limit equipment.

(11) Power Center Transformer

Taking the load on power center and control center into consideration, the transformer capacity is 500 kVA. Taking the requirement for spare parts into account, each unit will be designed to a uniform capacity.

(12) Emergency Power Supply

The power supply will be installed for the supply of power required to completely shut down both units and for the illumination necessary for unit operation, in the case of in power service interruption whole power plant due to the accident in the power plant or operation system.

Since there are many hydraulic power plants in Panama, power required for re-start of the unit after the failure has been repaired will be supplied from the hydraulic power plant and not reckoned here.

(13) Control and Instrumentation

Power plant is operated by the main control room of the power house, and coal unloading/transportation control room of the coal unloading/ and handling administration room.

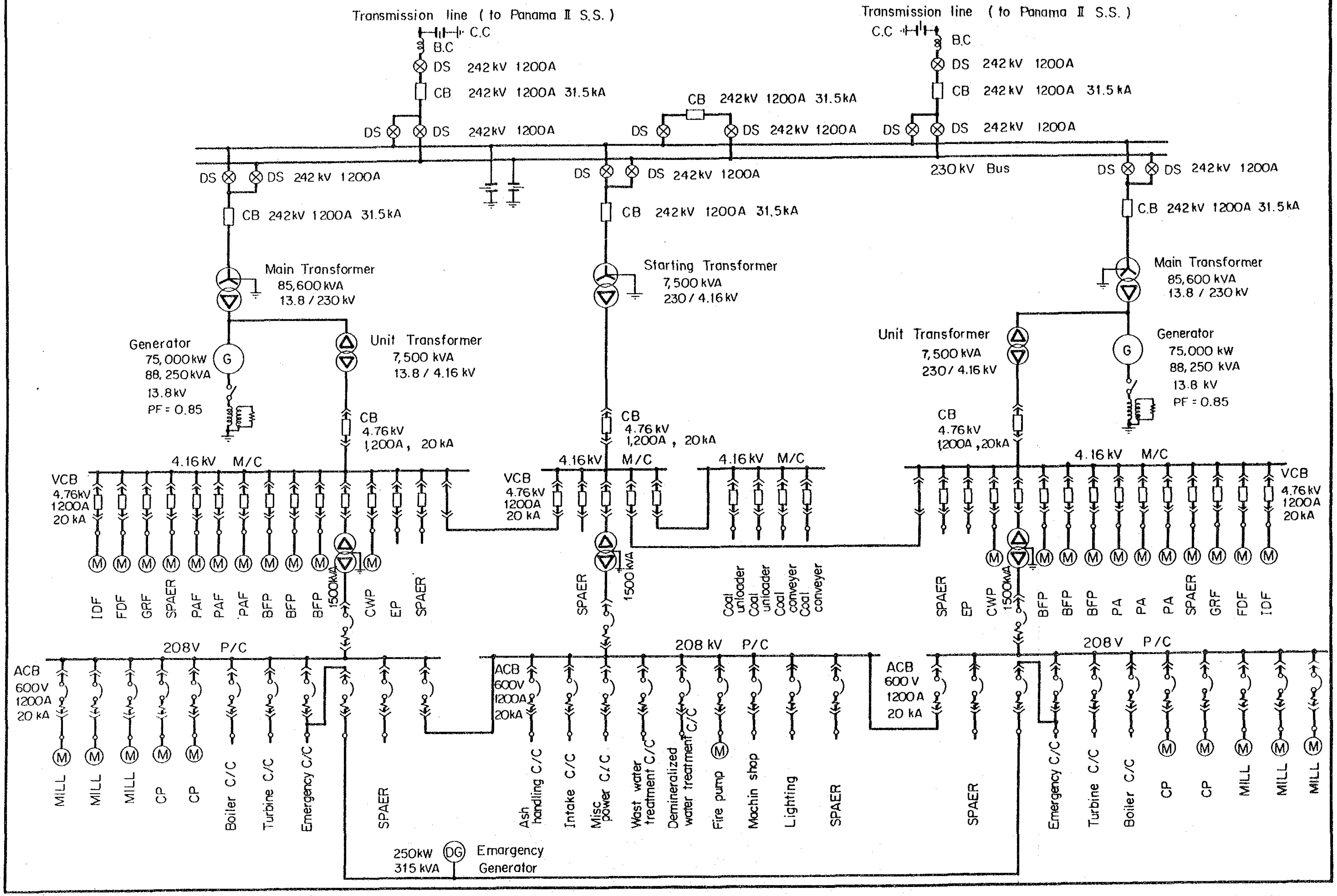
The main control center is equipped with BTG panel, computer, auxiliary operating board, auxiliary relay board, etc. for either automatic or remote-controlled operation of boilers, turbines, generator, outdoor switchyard, dust removal equipment, etc. for boiler water filling, parallel in load control, parallel off, etc. including all the operation, handling and supervision.

Computers are on-line connected with units and responsible for data logging, abnormalties supervision, computation for startup and shutdown schedule, operation guide, turbine life control, etc.

Coal unloading/transportation control room is equipped with coal unloading panel, ash treatment board, etc., for operating, handling and supervising the coal unloading, transporting and ash treatment facilities.

Each of coal unloaders is manned from the viewpoint of operation safety and efficiency.

Fig. 7.3.11 Power Station One line Diagram



7.3.12 Powerhouse

Powerhouse consists of the following three areas:

Equipment area: In this area, the main equipment of the turbines, generators, steam condensers, and various auxiliary equipment as well as electrical facilities such as the power center are to be installed.

Control area: This area in which various kinds of control equipment are to be installed serves as the nucleus of the power plant. Operators are always stationed in this area.

Bunker area: This is a coaling area in which a bunker and pulverizer are installed.

The equipment area is comprised of four layers. The turbines and generators are installed on the third floor. The turbine room shall be furnished with an overhead traveling crane to facilitate the inspection and maintenance of the turbines and generators. The turbine room measures 16 m in width, 90 m in depth and 13 m in height. These dimensions have been determined by the clearance space required when disassembling equipment for checkup and maintenance purposes. In its vicinity, the required auxiliary equipment and electrical facilities are installed in four layers for the sake of increased efficiency.

Located in the control area are the control room, relay room, computer room, communications equipment room, rest room, chief room, etc. These rooms are laid out in the central section of the power generating facilities in order to form a highly functional central control system as well as aimed at providing a comfortable working environment for operators.

(1) Construction and Finish

Two kinds of construction, namely a reinforced concrete construction and a steel construction, are conceivable. However, a steel construction has been adopted for the main frame construction in consideration of the large roof span and workability for equipment installation, light weight, and advantages arising from short construction periods.

The turbine generators are supported by a reinforced concrete frame featuring high rigidity.

As a rule, each floor is covered by reinforced concrete slabs. However, those floors that need to be opened for maintenance shall be covered with steel gratings that permit to be removed. The outer walls and roof shall be slated.

As a general rule, concrete blocks shall be used for indoor partitions. To expel heat emanated by equipment installed indoors to the outside, air inlets and outlets shall be installed in order to secure sufficient ventilation.

(2) Utilities

Those rooms, such as the control room, relay room, computer room, rest room, etc., in which operators are constantly stationed and precision devices that generate heat are installed shall be air-conditioned. Other facilities that shall be installed throughout the entire building include lighting system, plumbing and sanitary systems, fire extinguishing facilities and fire alarms.

7.3.13 Foundation of the Powerhouse and Major Facilities

The foundation of the power station's major facilities such as the powerhouse, boiler and bunker shall be designed in such a manner that these facilities can be securely supported from a firm ground with sufficient reliability. In addition, the foundation plate shall be placed in such a fashion that it safely conveys the weight of the superstructures such as equipment and its supporting frames to the foundation ground and lessens troubles arising from vibration caused by the equipment. The foundation plate must also be designed to show sufficient rigidity and strength against possible uneven settlements.

After having studied the results of the boring operations conducted on the site where the powerhouse and major facilities are planned to be constructed, the depth from the ground surface to a supporting ground which takes on an N value of 50 or greater is estimated at 9 to 14 meters deep. Since this depth is too deep for us to directly use the supporting ground even though the thickness of the foundation plate is taken into calculation, we have decided to adopt a pile foundation.

To select the best suited construction method from among various pile-foundation construction methods, it is necessary to comprehensively consider the weight of the equipment and the superstructure, horizontal force and drawing force, the depth to the supporting ground, the conditions of the intermediate ground, and so forth. The following foundation plates and piles have been chosen for this project.

(1) Powerhouse

Reinforced concrete mats (double slabs for some sections), concrete piles.

(2) Boiler and Bunker

Reinforced concrete mats, concrete piles

(3) Dust Collector and Other Facilities

Reinforced concrete underground beams, concrete piles

7.3.14 Stacks

The height of the stacks has been determined in consideration of the preservation of the environment as well as the discharge speed and concentration diffusion of waste gas.

There are two stack types to choose from: the one is a reinforced concrete structure type and the other is a steel structure type.

As a general rule, concrete stacks are frequently adopted for heights of up to approximately 100 meters and they are considered to offer no problem in terms of economy and safety. There is no particular difficulty in supporting weighty concrete stacks on the project site in question since there is a supporting foundation ground at a relatively shallow (depth) level.

Since stacks are typical static structures, they must be designed to show structural safety.

As the results of our structural design comparison made between two different stack types, namely a reinforced concrete type and steel type stack, we have found out that both of them involve no safety problem. When both of them are compared with each other from the viewpoint of economy, the concrete type is a little more economical. This is because the materials (concrete, reinforcing steel bars, and steel parts) required for constructing the concrete type can be easily procured, and the steel type necessitates frequent costly repainting for the prevention of rust and corrosion.

Furthermore, since only short construction periods are required to erect concrete stacks, they are advantageous from the viewpoint of meeting construction schedules.

After having conducted comparative studies on the above points, we have decided to adopt reinforced concrete stacks. For information, their inner surfaces shall be coated with an acid-resistant waterproof cement-based coating material in order to prevent the inner surfaces from being corroded by sulfur oxides contained in waste gas.

7.3.15 Administration Building and Other Buildings

(1) Administration Building

The administration building is designed to accommodate a total daily time administrative staff of approximately 50, excluding those who are responsible for operating individual equipment. A chemical analysis laboratory, dining room, rest room, air-conditioning machine room, and storage are installed on the first floor. Office rooms, conference room, plant manager room, locker room, and library are located on the second floor. Office rooms are divided into two separate blocks, one each for the clerical and technical staff members. As needs dictate, they can be further divided into smaller sections using simple partitions. The dining room is designed on the assumption that all the personnel of the power station dines there.

The administration building shall be a two-story reinforced concrete construction with a pile foundation. The reason two-story house is recommended is to use the area effectively with regard to expansion works and cut down the construction cost by reduction of roof area.

works and cut down the construction cost by reduction of roof area. Furthermore, as ground condition is bad, piles at foundation work is required in spite of one-story house. Therefore the one-story house is not so economical as ordinary case. As its utilities, air-conditioning and ventilation systems, lighting systems, plumbing and sanitary systems, fire alarms, and fire extinguishing facilities shall be installed.

(2) Other Buildings

In addition to the administration building, workshop, warehouse, coal-handling (unloading/transport) control building, oil drum and cylinder storage, demineralization house, worker's room, garage, and a guard-house are required.

The necessity and scale of the workshop and warehouse has been decided upon in consideration of the need for performing all equipment repair and maintenance operations within the premises of the power station as well as for promptly procuring thereby required spare parts.

The coal-handling (unloading/transport) control building is designed to accommodate the operation control rooms of the coal handling equipment,. various other outdoor equipment, and their power supply faciliteis.

(3) Ancillary Facilities

The ancillary facilities to be installed on the premises of the power station include utility water-supply and waste-water plumbing systems, outdoor lighting fixtures, outdoor fire hydrants, fire alarm facilities, etc.

Water supply is obtained from the city's waterworks. Waste water is treated in a sewage purifier chamber and treated water is discharged into the sea. In addition, a landscape garden with vegetation shall be installed for the improvement of the environment. A border fence which surrounds the power station shall be installed in order to prevent general people from trespassing the premises and ward off possible accidents that befall to such intruders.

These facilities are already included in the estimated construction costs.

Fig. 7.3.12 (1) Section of Power Station

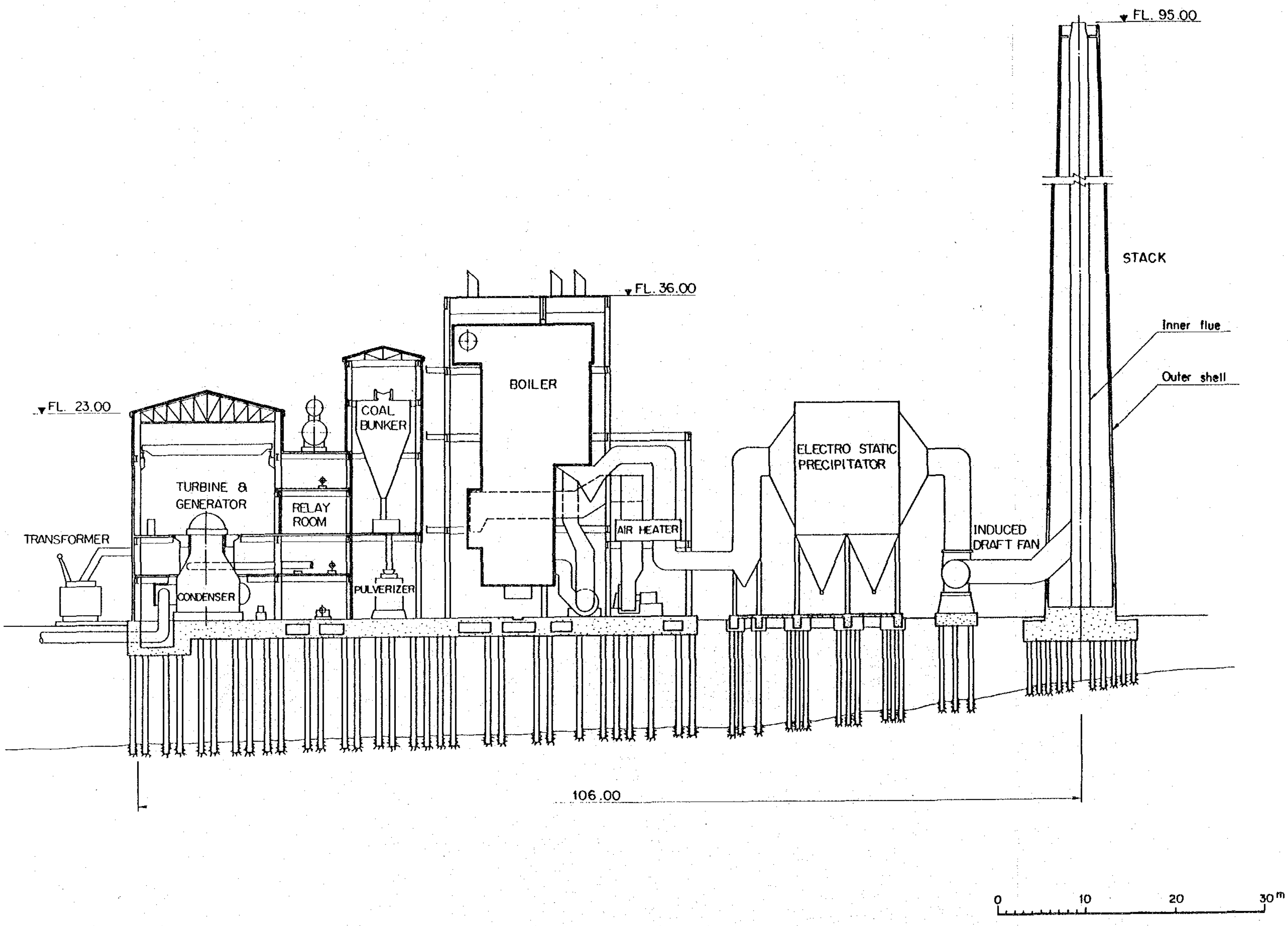


Fig. 7.3.12 (2) Power House (1st Floor Plan)

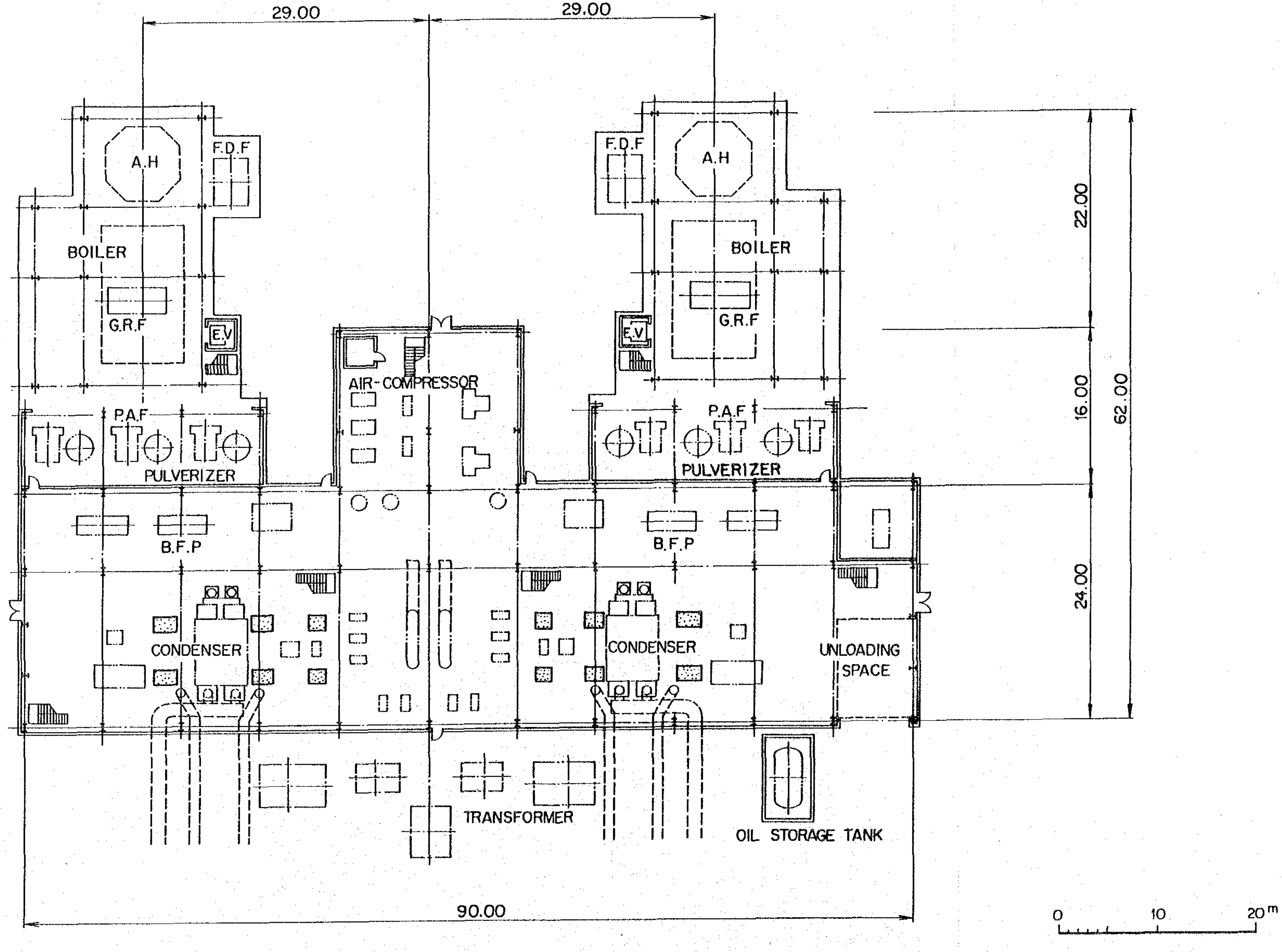


Fig. 7.3.12 (3) Power House (3rd Floor Plan)

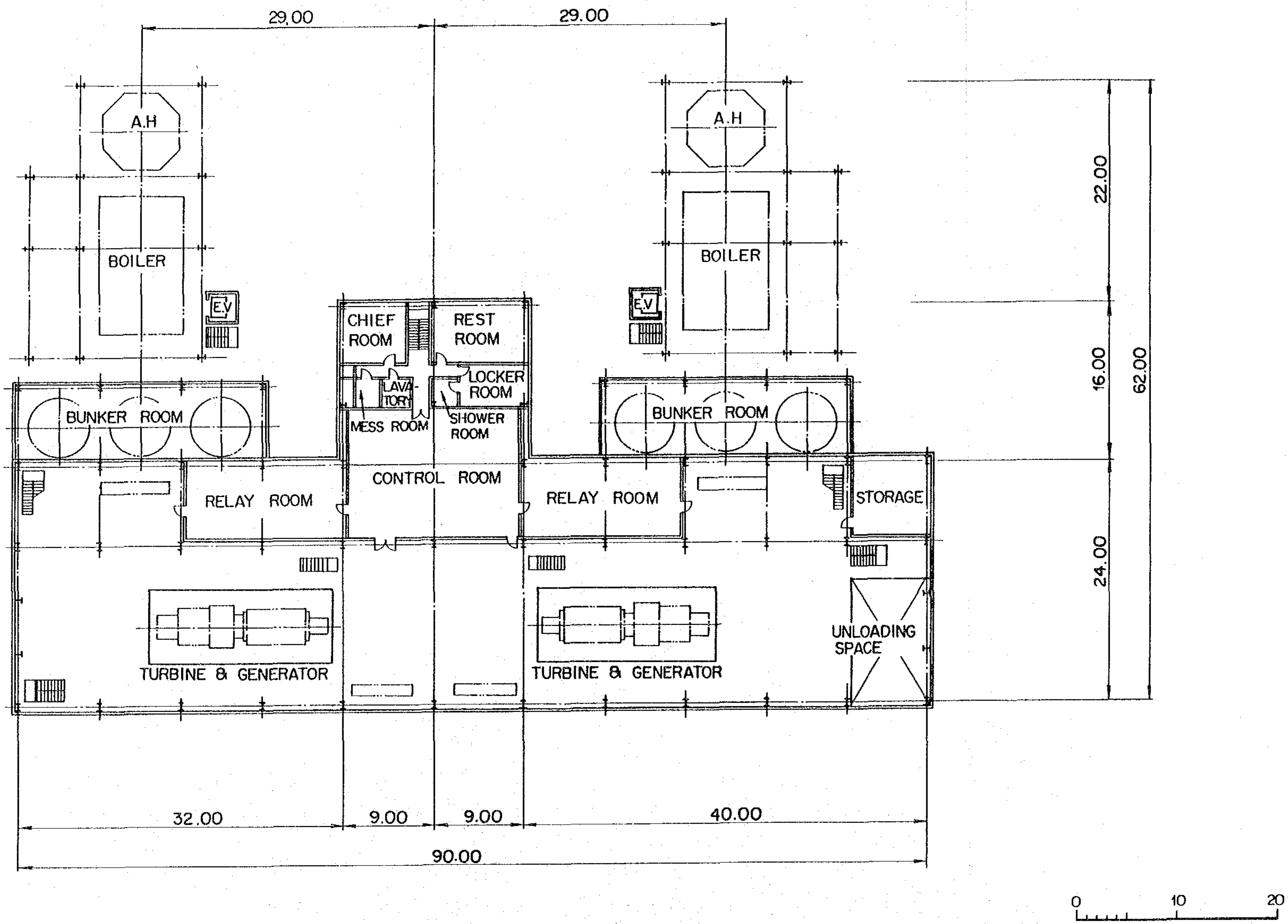
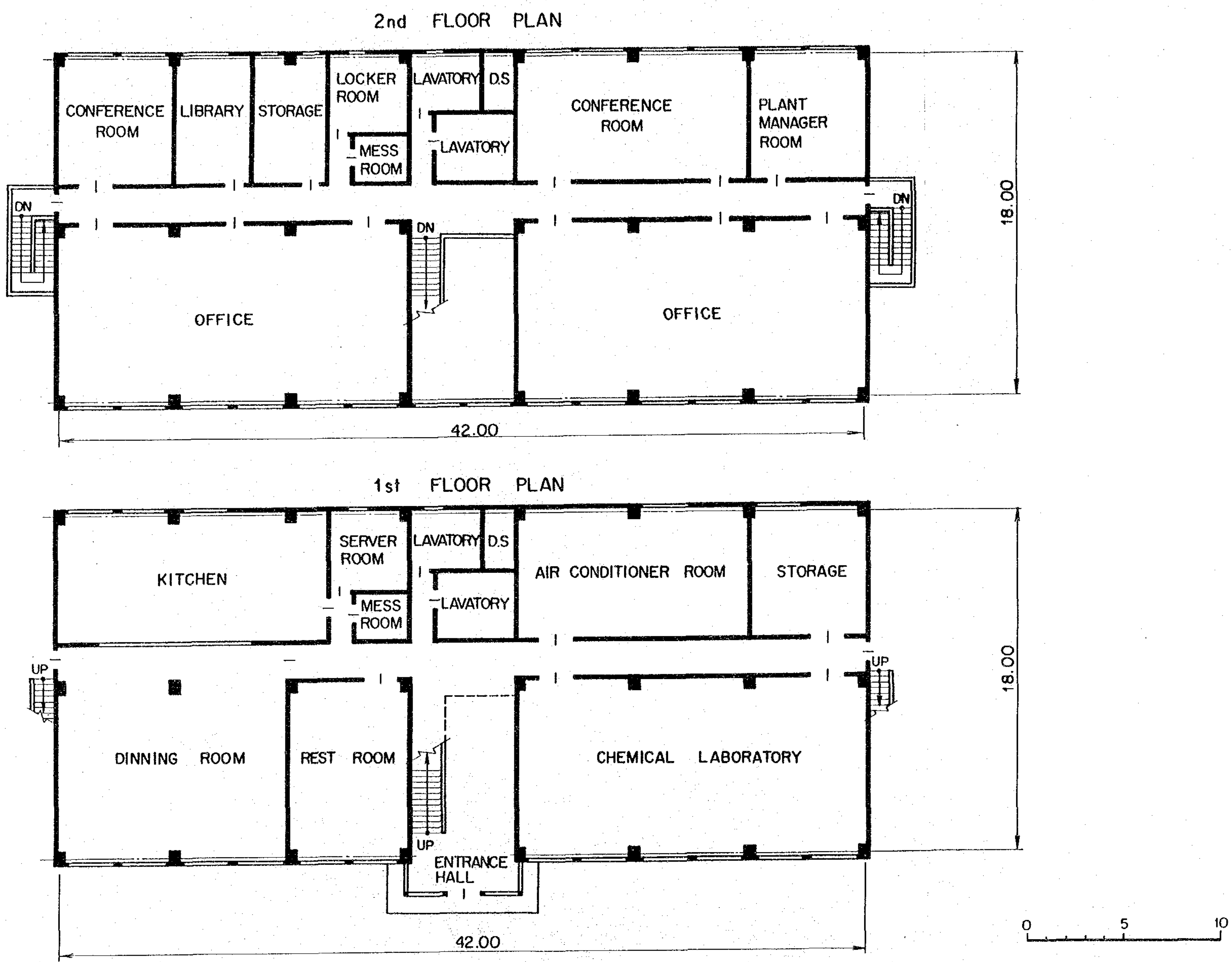


Fig. 7.3.15 Administration Building



7.3.16 Transmission Line and Substation Facilities

(1) Selection of Transmission Line and Substation Facility Plans

a) Basic criteria

In order to make possible the integration of the Panama coal-fired power plant project, consideration must be given to the following items when determining what facilities are required to be reinforced.

- Most of the generated power by the project in question shall be transmitted to Panama City, which is the center of the demand.

- The transmission lines shall be designed in such a manner that they are most advantageous when comprehensively judged on the basis of construction costs, ease of maintenance/checkup operation, transmission loss, etc. In addition, they must permit transmission line to be continued without trouble even if one of the lines is disconnected in the even of an accident.

- The substation to be integrated shall be designed in line with the IRHE's power-supply system reinforcement plan.

- Consideration must be given not to lower the reliability of existing transmission line and substation facilities.

b) Comparison of power transmission and substation facility plans

Three alternative substations could receive power transmitted from the proposed power station. They are (i) Panama II substation, (ii) switchyard of Bahia Las Minas power station, and (iii) Panama substation. Of these three alternatives, Panama II substation was judged to be the most suitable from viewpoints of economy, reliability and compatibility with IRHE's power system expansion plan.

(i) Panama II substation

In IRHE's power system, the main power sources are hydro power stations in Chiriqui province and Bayano power station in Panama province. Power generated by these hydro power stations is sent to the Panama substation by 230 kV transmission lines, then to secondary substations in the surrounding areas by 115 kV transmission lines.

However, in the rainy season, on these 230 kV lines trip frequently due to lightning. This is a serious problem for supply reliability of electricity.

IRHE has a plan to construct a 400 to 500 kV transmission line in connection with the Changuinola hydro power project. To receive power transmitted by this ultra high voltage transmission line, Panama substation has unfavorable conditions in extension space, excessive concentration of power flow and supply reliability. Therefore, IRHE plans to construct a Panama II substation to receive power sent from Changuinola. This will diversify power flow and improve supply reliability of electricity.

(ii) Las Minas power station

This power station is approximately 15 km from the Telfers island. Four 115 kV transmission lines destined for the National Capital Region of Panama originate from the switchyard of this power station. If the projected power station is integrated into the bus of this power station and when the Las Minas power station and the Telfers island power stations operate at full capacity, the transmission line from the Las Minas power station to the L. Tablitas substation becomes overloaded with excessive current which is greater than the operating limit specified by the IRHE. Furthermore, other associated transmission lines also approach their respective maximum operating limit, and they are prone to be overloaded if one of these lines becomes inoperative in the event of an accident.

c) Panama substation

According to the power flow calculation for the year 1993, if the Las Minas power station is down at the time of peak load, nearly 100% of the load destined for the National Capital region of Panama passes through the transformers which links Panama 230 kV with 115 kV. (For information, approximately 60% of the load passes through the transformers, when the Las Minas power station operates at full load.) For this reason, it is not appropriate to integrate additional power source lines into the Panama substation. Under the circumstances, the transmission line is decided to be integrated into the Panama II substation.

(2) Transmission Facilities

a) Transmission routes

After conducting feasibility studies using maps drawn on a scale of 1 to 50,000 and after taking the advice of IRHE's counterpart engineers, We have selected technically practicable rough routes. As the projected rough route, which is to connect between the Telfers island and the Panama II substation measures approximately 200 meters at most in altitude, no paticular problem has been found in the course of our rough route selection studies. Therefore, this route which runs along side already existing transmission lines or national road in most of the regions, is selected by the viewpoint of construction and maintenance.

However in the detail design stage, it is necessary to further conduct more detailed route investigation studies, including geographical surveys and studies on ease of maintenance. It needs special attention to study of the route section of the power station's neighbourhood and the crossing section of Rio Chagres.

The transmission line shall be drawn out in the direction of south-southwest from the power station located on the Telfers island. The line takes a roundabout route around the cities of Colon and Margarita, because many buildings and houses gather closely together in this place. Then it runs along on the south side of the No.3 National Road and reaches Cativa. In the vicinity of Cativa, the route takes a southeasterly route and runs alongside the existing 115 kV transmission lines spanning between the Bahia Las Minas power station and the Panama substation and runs southward through the narrow region which is constructed between Bahia

Las Minas and the Gatun Lake down to Chilibre located in the neighborhood of Panama City.

This route section involves the crossing of the Rio Chagres. Since there are a few points where the line can cross the Rio Chagres, and existing transmission lines and bridges crowed in narrow areas, it is necessary to conduct throughgoing route studies.

Further from Chilibre onward, the line takes a route alongside the C20 route and reaches Las Cumbres. Then it travels eastward alongside the existing 230 kV transmission lines connecting between the Panama substation and the Bayano power station and reaches the Panama II substation.

Line route is shown in Fig. 7.3.16(2).

b) Transmission voltage and number of circuits

To transmit a 150 MW power over a distance of 72 km from the Telfers island to the Panama II substation, the adoption of 115 kV or 230 kV is conceivable. Considering stability, transmission loss, the IRHE's system expansion plans, economic comparisons, and various other factors, we have decided to adopt the 230 kV transmission voltage. As for the number of circuits, we have decided to adopt two circuits based on the IRHE's standard.

c) Conductor

The size of conductor is determined by the current capacity, stability, and corona discharge starting critical voltage. However, the largest determining factor in this case is the corona discharge starting critical voltage. For this reason and considering the IRHE's standard, we have decided to adopt the ACAR750MCM conductor.

d) Lightning proof design

Although no lightning observation data and actual data on lightning-induced accidents were available to us, we have decided to install two 7 x NO.8 AWG wires in harmony with the IRHE's existing 230 KV transmission lines in the hope of reducing possible lightning-caused troubles.

For information, no arcing horns shall be installed on the insulator sets of the line.

e) Type and the number of insulators

As to the insulation design of the 230 kV transmission line, studies have been conducted as a system with solidly earthed neutral on the basis of a maximum system voltage of 242 kV and a route altitude of less than 1,000 m.

Since salt damage is judged to be virtually nonexistent, the number of insulators has been decided on 250 mm standard suspension insulators of 14 discs are decided to be used in harmony with the IRHE's existing facilities.

f) Supporting structure

According to the IRHE's standard steel tower design for supporting transmission lines, design wind velocity is 60 mil/s. Under the circumstances, this value was also adopted for our preliminary design.

As for supporting structures for the 230 kV transmission line, we have decided on the use of angles and conducted design studies for steel towers that feature high mechanical reliability.

Fig. 7.3.16 (3) shows a sketch drawing of a standard suspension-type steel tower.

(3) Substation and Communications Facilities

We suppose that the construction of the Panama II substation will be completed before this project reaches completion and the two 230 KV lines connecting between the Panama substation and the Bayano power station are divided by the Panama II substation.

In this feasibility study, studies are conducted only on line-extraction facilities for the two lines that are destined for the Telfers island and existing facilities shall be studied for reference only.

Fig. 7.3.16(4) shows the Panama II S/S single line diagram.

a) Switching facilities and bus system

The number of equipment required for the switching facilities have been calculated on the assumption that the Panama II substation uses the 1-1/2 system as with the other 230 kV substations.

b) Interrupting capacity

The interrupting capacity has been determined on the basis of short-circuit capacity computation results obtained using a computer. Fig. 8.3.2 (5) shows short-circuit capacities at individual nodes.

c) Protective equipment for the 230 kV transmission line

The 230 kV transmission line is an important line from the viewpoint of electrical power supply to the Metropolitan Area of Panama, we have decided to adopt a power line carrier direction comparison system. Furthermore, the reliability of the system has been enhanced by the incorporation of a single-phase reclosing system.

d) Telephone line for load-dispatching instruction and maintenance purposes

In this project, load-dispatching instructions to the power station and substations are supposed to be issued from the central load-dispatching office. For this purpose, toneringer system load-dispatching telephone circuits shall be installed to interconnect individual stations. CDT (cyclic digital transmission) equipment shall be installed at individual stations. Its capacity shall be approximately five items of telemeter.

e) Carrier protection relay circuits

For the protection of the 230 kV transmission line connecting between the Telfer island power station and the Panama II substation, carrier protection relay equipment which is designed to operate on a power line carrier shall be installed.

The equipment shall be a directional comparison system which features a frequency shift method and is designed to use a signal channel of power line carrier.

Fig. 7.3.16 (5) shows the telecommunication system diagram.

Table 7.3.16 (1) Economic Comparison of Transmission Voltage

	Unit	230 kV	115 kV
1. Bases for calculation			
Plant capacity	MW	150	150
Annual plant load factor	%	68.5	68.5
Annual energy production	GWh	900	900
Annual energy sent out (at Power Station)	GWh	836.1	836.1
Station service loss	%	7.1	7.1
Annual plant efficiency	%	35	35
Service life of facilities	years	35	35
Generation cost	c/kWh	4.77	4.77
Transmission loss factor	%	0.66	3.16
2. Construction cost			
FC portion	$10^6$$	17.88	12.52
DC portion	$10^6$$	9.92	7.29
3. Annual expenditure			
(1) Depreciation	$10^3$$	794	566
(2) Interest	$10^3$$		
FC portion		896	627
DC portion		139	102
(3) Operation & maintenance cost (include administration cost)	$10^3$$	639	456
(4) Transmission loss	$10^3$$	264	1,260
(5) Total	$10^3$$	2,732	3,011

Table 7.3.16 (2) Construction Cost

(in million US$)

Item	230 kV			115 kV		
	FC	LC	Total	FC	LC	Total
Direct Cost	12.31	6.77	19.08	8.61	4.97	13.58
a) Transmission line	5.64	5.25	10.89	4.63	4.20	8.83
b) Sub-station and Others (Telfer island, Panama II)	6.67	1.52	8.19	3.98	0.77	4.75
Indirect Cost	1.12	0.64	1.76	0.78	0.46	1.24
a) Contingency	0.62	0.34	0.96	0.43	0.25	0.68
b) Administrative expenses	-	0.30	0.30	-	0.21	0.21
c) Engineering fee	0.50	-	0.50	0.35	-	0.35
Escalation	1.16	1.30	2.46	0.81	0.97	1.78
Interest during construction	3.29	1.21	4.50	2.32	0.89	3.21
Total	17.88	9.92	27.80	12.52	7.29	19.81

Fig. 7.3.16 (1) Power System in the Metroporitan Area 1993

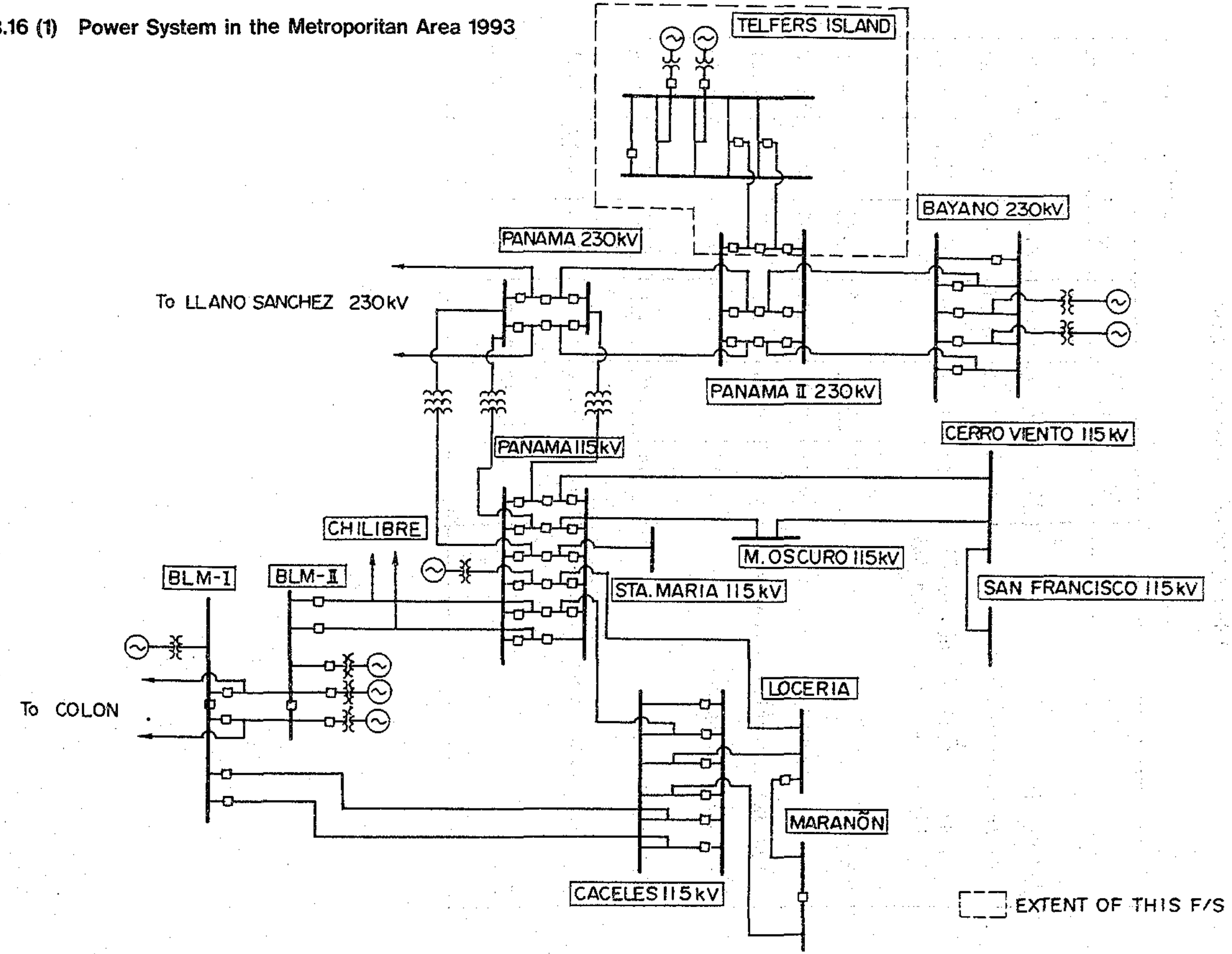


Fig. 7.3.16 (2) 230kV Transmission Line Route

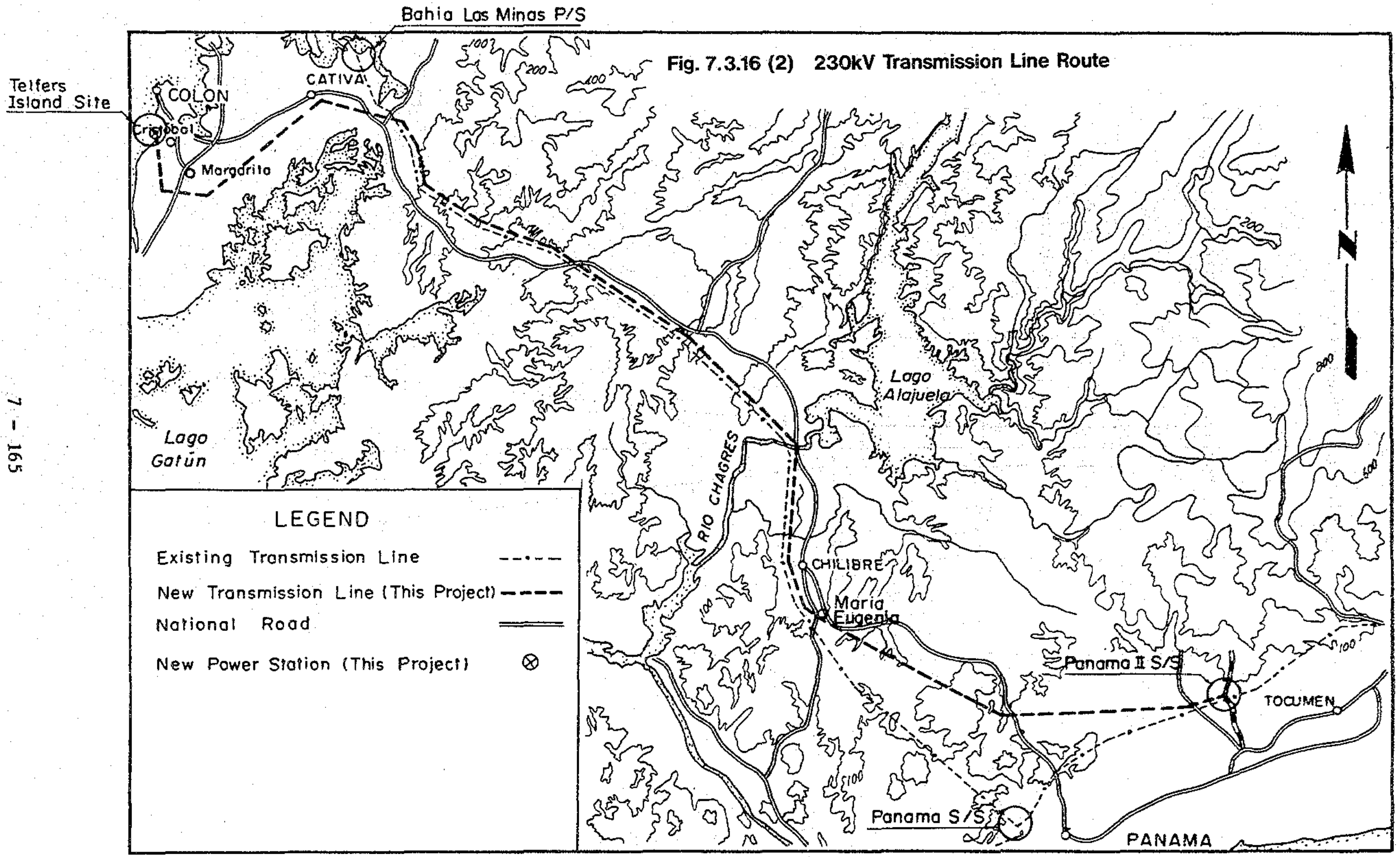


Fig. 7.3.16 (3) Standard Tower

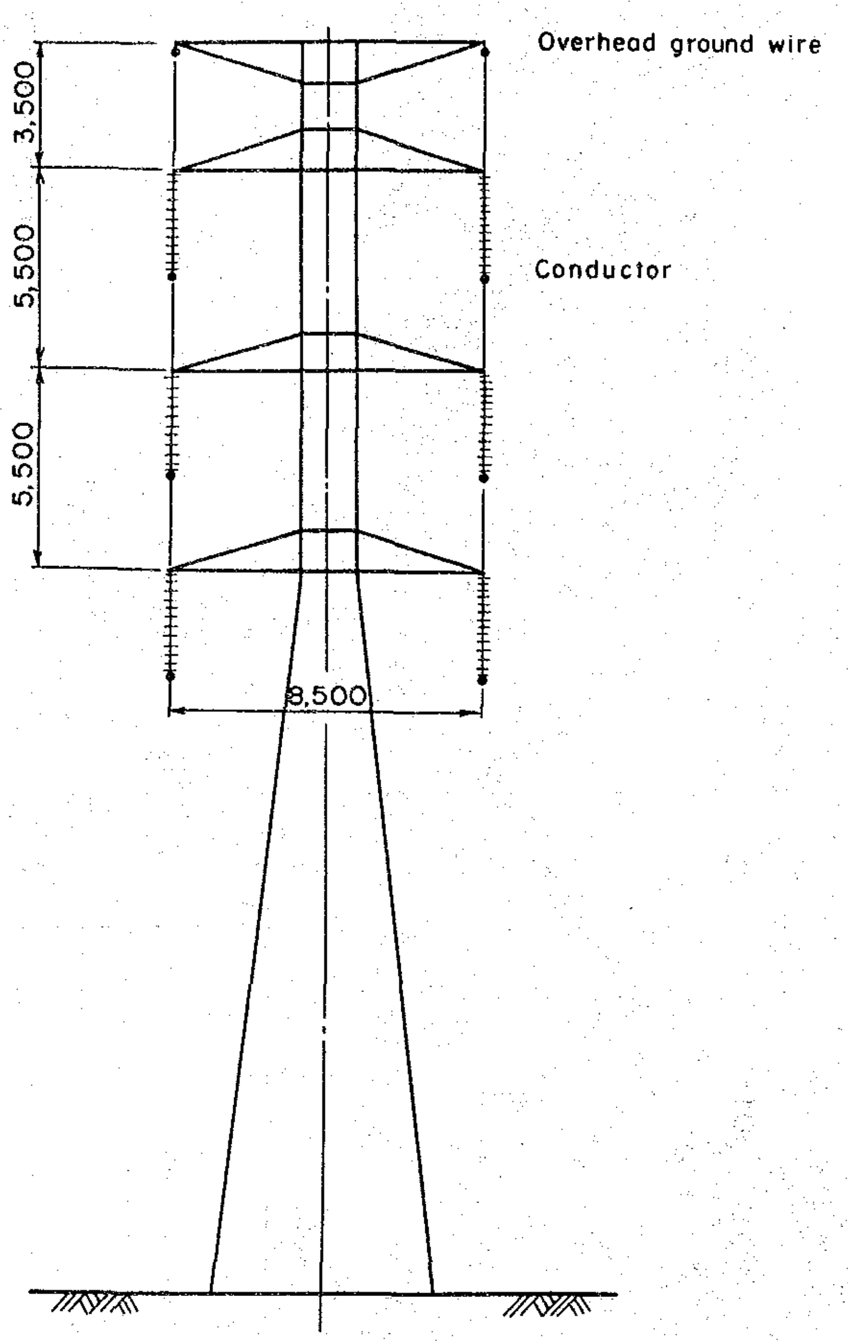
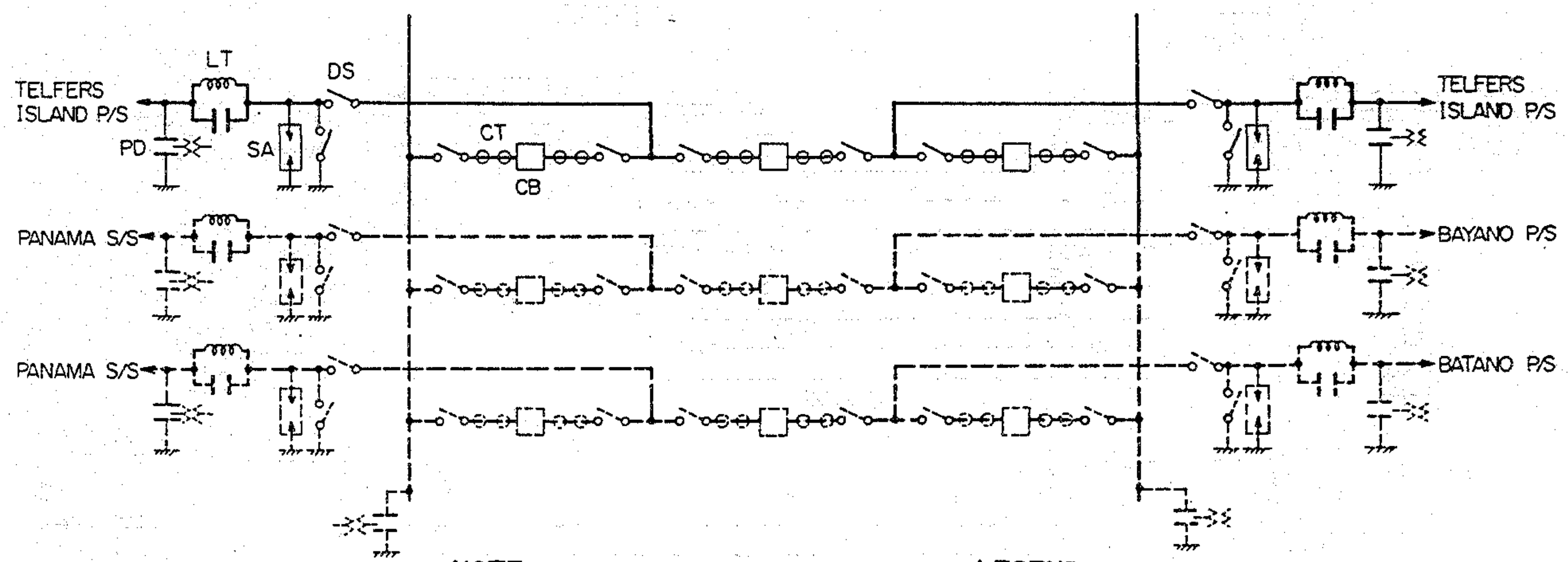


Fig. 7.3 16 (4) Panama II S/S Single Line Diagram



NOTE

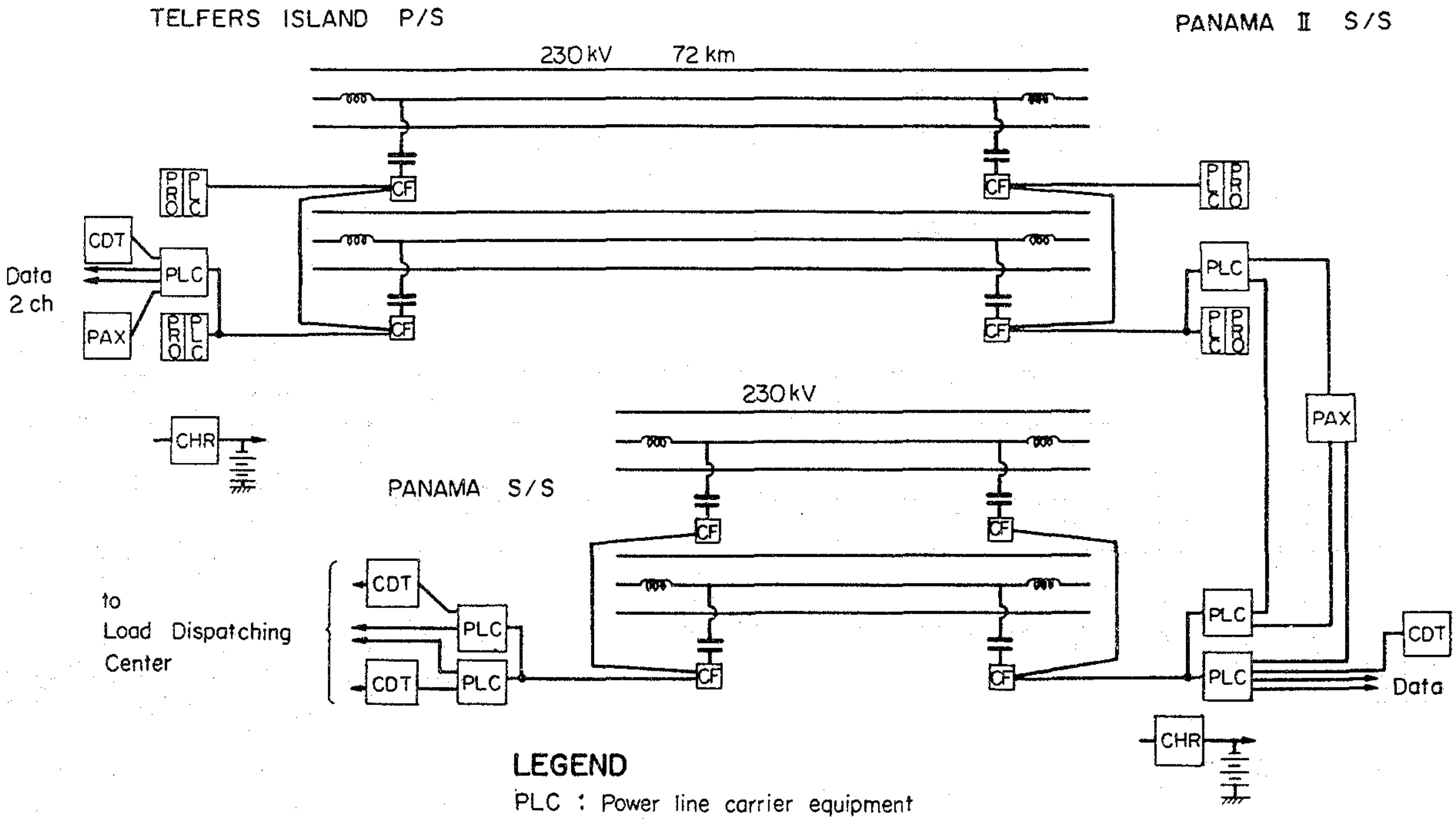
- - - - EXISTING EQUIPMENT

——— NEW EQUIPMENT INCLUDED IN THIS F.S.

LEGEND

PD : POTENTIAL DEVICE
LT : LINE TRAP
DS : DISCONNECTING SWITCH
CB : CIRCUIT BREAKER
CT : CURRENT TRANSFORMER
SA : SURGE ARRESTER

Fig. 7.3.16 (5) Telecommunication System Diaram



LEGEND

PLC : Power line carrier equipment
PRO : Protection reley
PAX : Private automatic exchange
CDT : Cyclic digital transmission equipment
CHR : Charging rectifier
CF : Coupling filter

CHAPTER 8 ELECTRIC POWER SYSTEM ANALYSIS

CHAPTER 8 ELECTRIC POWER SYSTEM ANALYSIS

8.1 OUTLINE OF THE POWER SYSTEM

One major feature of the electric power system of the Republic of Panama is that all of the nation's hydraulic power stations (401.0 MW in total) other than the Bayano hydraulic power station are located in the western part of the nation called the Chiriqui region and most of the generated power is consumed in Panama city, the nation's Capital City, and its environs that are over 300 km away from the power-generating region.

The trunk transmission line of the Republic of Panama is made up of double circuits 230 kV transmission lines. They originate at the Bayano power station (150 MW) located in the eastern part of the nation and are linked through the Panama substation, the Llano Sanchez substation, the Mata de Nance substation, the Fortuna power station (300 MW), Pregreso substation, and interconnect with Costa Rica at Rio Claro substation.

By means of these trunk transmission lines, electric power generated in the Chiriqui power-generating region as well as at the Bayano power station is transmitted to Panama where the Panama substation serves as a key station to supply individual substations scattered around the Panama city with power using its 115 kV transmission lines.

8.2 TRANSMISSION LINE AND SUBSTATION FACILITY PLANS

For the Panama coal-fired power station project, double circuits 230 kV ACAR750MCM transmission lines are planned to be installed over a distance of 72 km between the Telfers island site and the Panama II substation.

8.3 ANALYSIS OF THE POWER SYSTEM

In connection with the development of the new power source, analytical studies shall be conducted to determine the various characteristics of the power system. Here, the following themes shall be studied.

(1) Power Flow Calculations

Based on demand predictions and the economic output distribution of the power station, power flow calculations shall be performed for the year to be studied on (1993). Results obtained from the above calculations shall be then checked to determine whether there are overloaded transmission lines and/or transformers. If overloaded facilities are found, overload-alleviating operations shall be carried out while trying not to disorder the economic load dispatching as much as possible by making output adjustments and system switching operations. If there are still overloaded facilities, the expansion of such facilities shall be considered.

(2) Voltage Calculations
[These calculations shall be performed in parallel with the power flow calculations discussed in (1).]

Voltage, reactive power and power flow calculations shall be carried out while adjusting the taps of the LRT and the reactive power of the generator in order to determine whether the bus voltage remains within the permissible operation voltage range. As a result, if the specified voltage conditions cannot be satisfied, appropriate electrical stations shall be additionally installed there. Furthermore, the balance of reactive power shall be calculated and phase modifiers shall be installed in appropriate places.

(3) Stability Calculations

After power flow and voltage calculations have been performed under specified power flow conditions, stability calculations shall be carried out. Based on stability calculation results, the stability of the system shall be checked by calculating the maximum phase angle power flow, voltage and frequency fluctuations of the synchoronous machines.

As a result, if the system is found out to be unstable, various stability-enhancement measures shall be adopted and stable power-transmission methods shall be devised.

(4) Short-Circuit Capacity Calculations

Current diversion calculations for three-phase short-circuit capacities and short-circuit currents shall be made for all the buses of the system. Based on the results of these calculation, existing series equipment shall be checked for possible capacity shortages. If there are equipment with insufficient capacities such as circuit breakers with insufficient interrupting capacities and/or insufficient short-time currents, the adoption of bus operation, system switching, and equipment replacements shall be pointed out.

8.3.1 System Calculation Conditions

System calculations have been conducted on a digital computer using the Y computation method, in which the system's dynamic characteristics were determined in the time domain using effective (rootmean-square) value data by handling each individual equipment as it is as a model and representing it in the form of a program.

(1) Voltage and Power Flow Calculations

The folowing operating conditions were adopted for the system in consideration of the IRHE's operating conditions, and voltage and power flow calculations were performed.

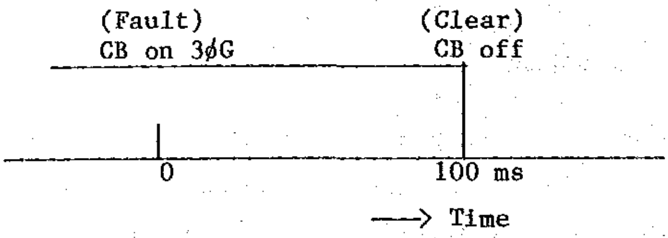
Voltage to be maintained for the system	:	Within 100±5%
Operation voltage of the generators	:	Within 100±5%
Operating power factor of the generators	:	0.85 or over
Load power factor	:	0.90

In order to maintain the above voltage, appropriate electrical stations shall be found and voltage-compensation static capacitors or shunt reactors shall be additionally installed.

(2) Stability Calculations

Stability calculations shall be carried out for the system which integrates the Telfers island power station. On the assumption that a three-phase ground fault has happened to the transmission line which connects between the Telfers island power station and the Panama II substation as a disturbance to the system, any possible vibration resulting from this fault shall be studied.

In this case, the value of the fault resistance was assumed to be zero. Furthermore, high-speed re-closing operation is not performed for the faulty transmission line. An accident sequence is as shown below. Calculations were conducted with an accident elimination time of 100 ms on the assumption that the protective relay functions properly.



(3) Short-circuit Capacity Calculations

Short-circuit capacity calculations are the most severe conditions for the serial equipment and are carried out on the assumption that all the generators are operated in parallel. The constants of the generators and transformers used for the above calculations are as follows:

Generator Constans (Self Base)

Generator	Generator's overall rated capacity (MVA)	Transient reactance Xd'(%)
Estrella	54	20
Los Valles	54	20
Fortuna	333	29.97
Bayano	168	29
Las Minas	94	19
Combined	80	23
Telfers	177	23

Transformer Impedance (100 MVA Base)

Transformer	Impedance Voltage (%)
Estrella	16.39
Los Valles	16.393
Fortuna	3.66
Bayano	6.405
Las Minas	9.4
Combined	9.4
Telfers	12.0

(4) Demand of Substations and Impedance Map

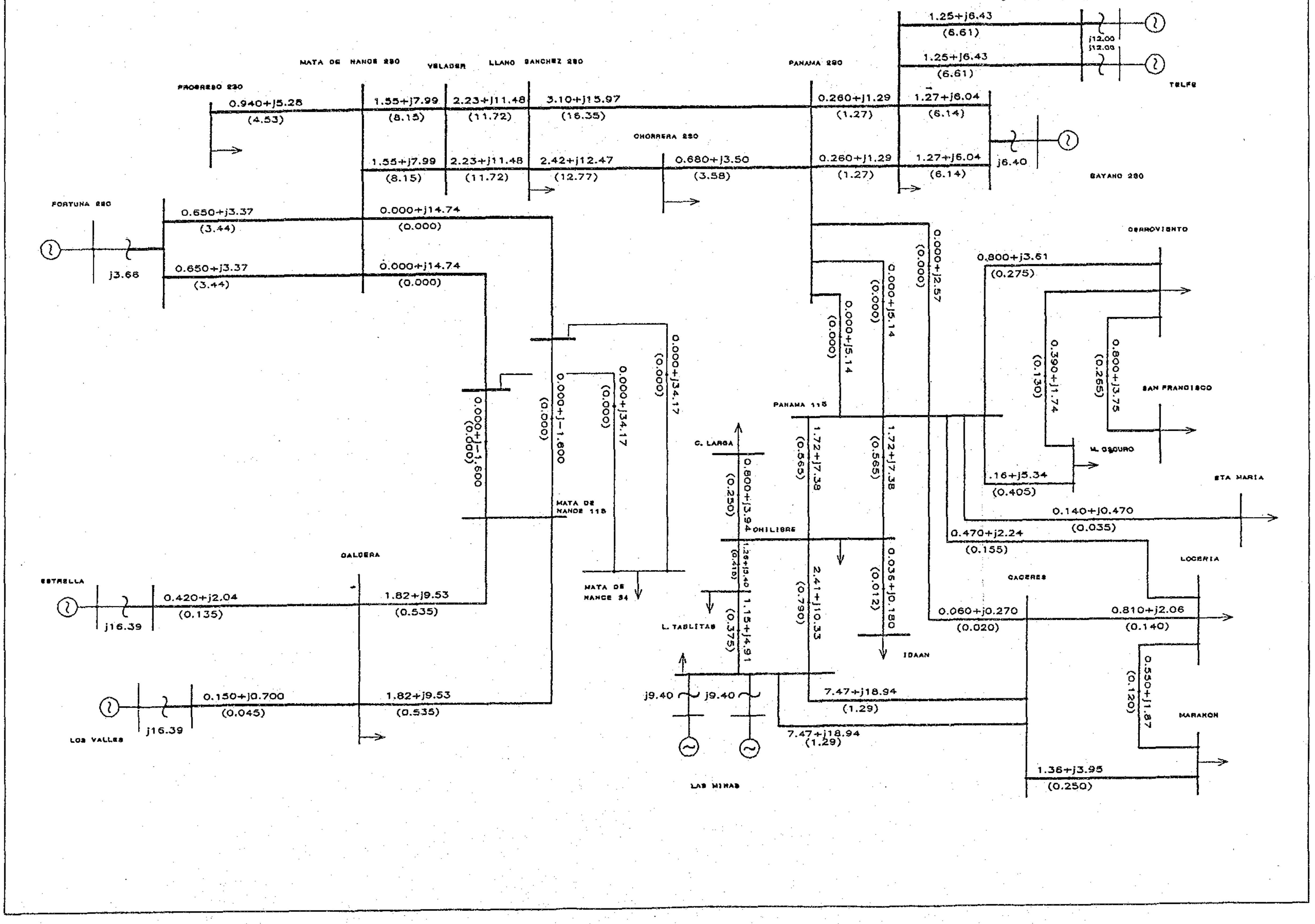
Table 8.3.1 (1) shows the peak demand and off-peak demand adopted in the power flow calculations and Fig. 8.3.1 (1) shows an impedance map.

Table 8.3.1 (1) Demand of Substations

Substation	1993 Max	1993 Min
Santa Maria	54.59	24.57
Loceria	72.96	32.83
San Francisco	85.09	38.29
Cerro Viento	54.64	24.59
Maranon	80.9	36.41
Chilibre	10.5	4.73
Calzada Larga	7.95	3.58
Monte Oscuro	32.98	14.84
Las Tablitas	7.53	3.39
IDAAN	15.2	6.84
Colon+Las Minas	42.11	18.95
Chorrera	42.75	19.24
Llano Sanchez 34	3.4	1.53
Llano Sanchez 115	56.86	25.3
Mata de Nance 34	35.86	16.14
Progreso 34	9.41	4.23
Caldera	14.9	6.71
Charco Azul	15.0	6.75
Total	642.0	288.92

Fig. 8.3.1 Expected Impedance Map

R+jX(Y/2) [% at 100 MVA Base]



8.3.2 Analysis Results

(1) Voltage and Power Flow Calculations

Voltage and power flow calculations have been conducted for the years 1993 in which the coal-fired power station (75 MW x 2 units) commences operation under the project in question.

Voltages and power flow at the maximum and minimum load for the year 1993 are shown in Figs. 8.3.2 (1) and 8.3.2 (2).

It has been found out from the results of the calculations that there are no overloaded transmission lines and transformers for the years 1993 and there is no need for installing extra power transmission lines and transformers in excess of those currently planned for installation. Furthermore, it has also been found out that the voltage-compensation static capacitors and shunt reactors shown in Table 8.3.2 (1) are required to be installed even when the LRT's taps and the generators' reactive power have been fully adjusted in order to maintain the bus line voltage within the permissible voltage range. For this reason, the capacity of the static condensers must be increased to 146.4 MVar by the year 1992.

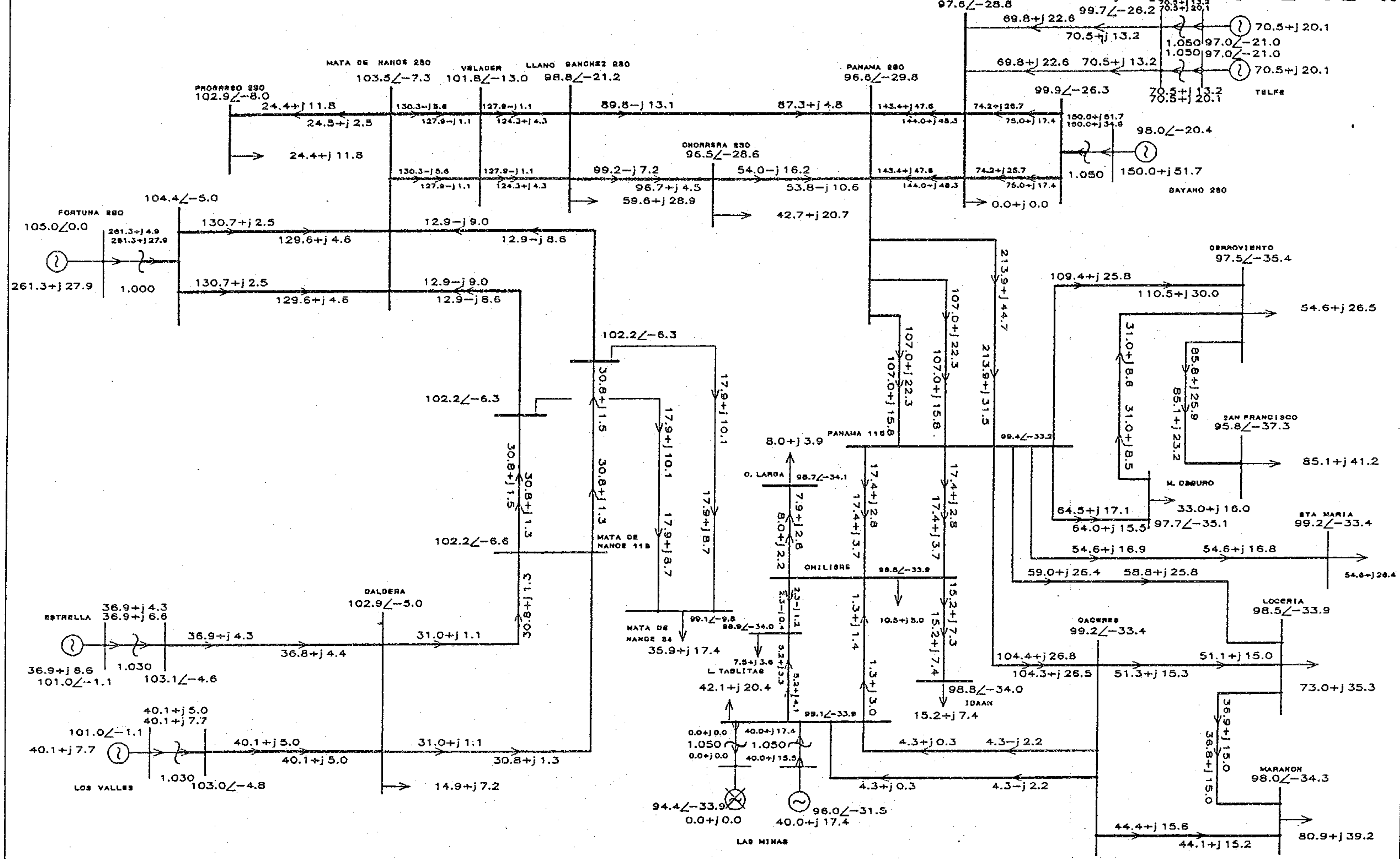
Table 8.3.2 (1)

		1993 Max	1993 Min
Power demand (MW)		642.0	288.92
Active powerloss (MW) (Loss ratio) (%)		27.4 4.3	4.8 1.7
Required Static Condensers or Shunt Reactor (MVA)	Panama	6.0	-
	Loceria	9.6	-
	Chilibre	3.0	-
	St. Maria	9.6	-
	C. Viento	18.0	-
	Las Minas	9.0	-
	Maranon	9.0	-
	Monte Osco	9.0	-
	Llano Sanchez	-	(20)
	Mata de Nance	-	(20)
	Total	146.4	(40)

* ( ) : Shunt Reactor

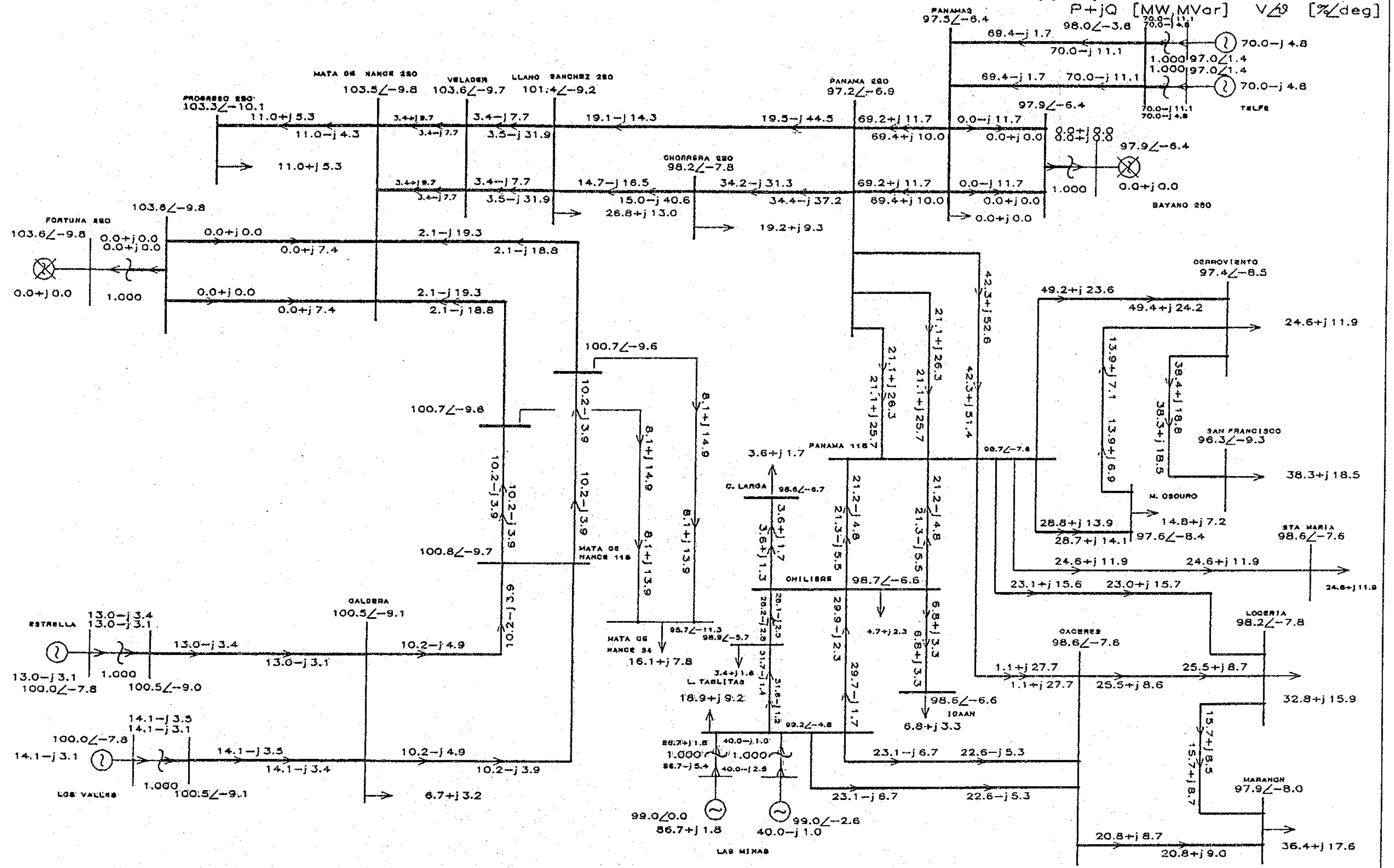
Fig. 8.3.2 (1) Expected Power Flow at Maximum 1993

P+jQ [MW,MVar] V∠θ [%/deg]



Note:The right part of each bus voltage shows its phase which is measured based on the swing generator bus

Fig. 8.3.2 (2) Expected Power Flow at Minimum 1993



Note:The right part of each bus voltage shows its phase which is measured based on the swing generator bus

(2) Stability

The results of peak-load transient stability calculations for the years 1993 is shown in Fig. 8.3.2 (3). In the transient stability calculations, a single-circuit three-phase ground fault was simulated on the 230 kV power transmission line in immediate proximity to the Telfers island power station and each individual generator's thereby induced phasic vibration was calculated on the assumption that the ground fault was eliminated after 100 ms.

As can be understood from the swing curves, no generators step out of synchronization under all conditions and power vibration converges within seconds. For this reason, it has been confirmd that the system is adequately stable even after the project in question have gone into operation.

For information, Xd' was assumed as constant in the above calculations and damping characteristics, AVR effects and governor effects were not incorporated into the above calculations, it is considered that power vibration converges faster than the simulation in the case of the actual system.

(3) Short-circuit Capacity

Short-circuit capacity calculations have been conducted based on the system configuration designed for the year 1993. The short-circuit capacity of each individual bus and its current diversion are shown in Fig. 8.3.2 (5).

Since these values are adequately small as compared with the rated capacities of existing serial equipment, they will pose no problem to the system.

Furthermore, since the short-circuit capacities at the Telfers island power station and the Panama II substation are 1176 MVA and 1383 MVA, respectively, the short-circuit capacities of switches to be newly installed or added must be greater than those values.

Fig. 8.3.2 (3) Transient Stability Calculation at the Maximum Load for the 1993

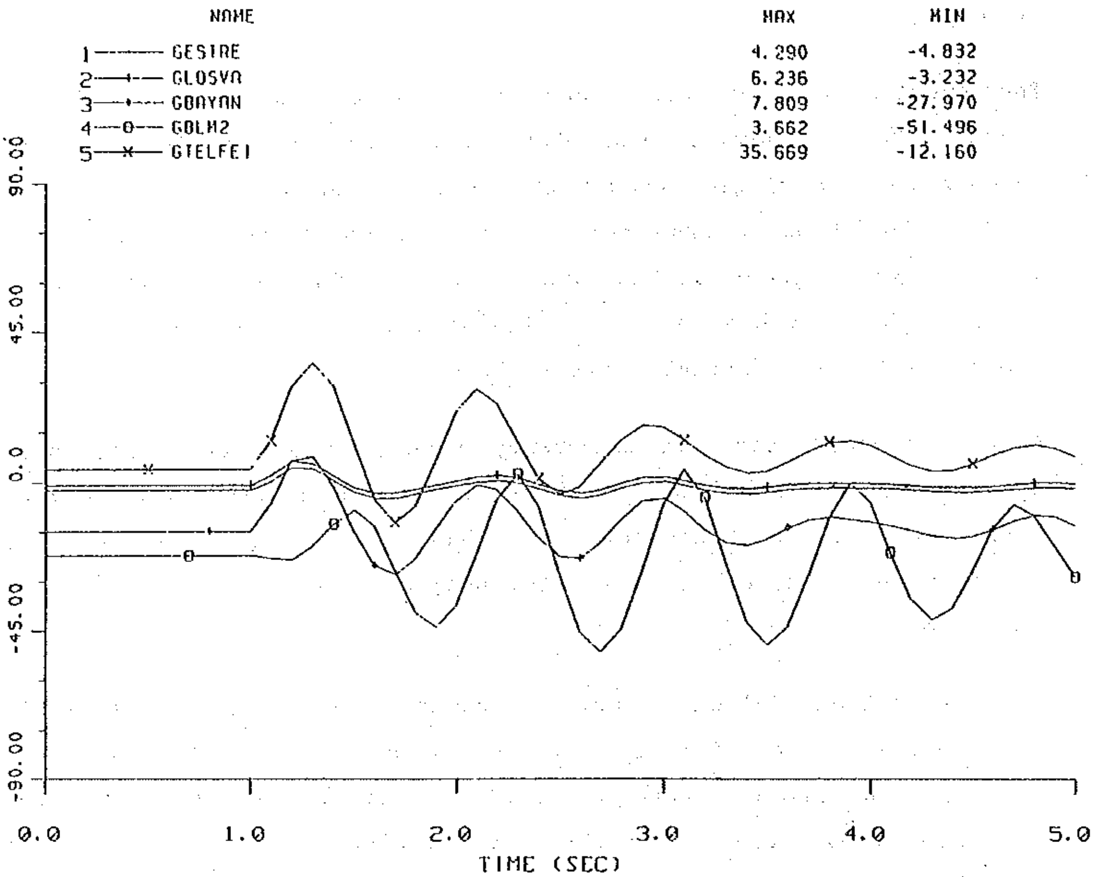


Fig. 8.3.2 (4) Transient Stability Calculation at the Minimum Load for the 1993

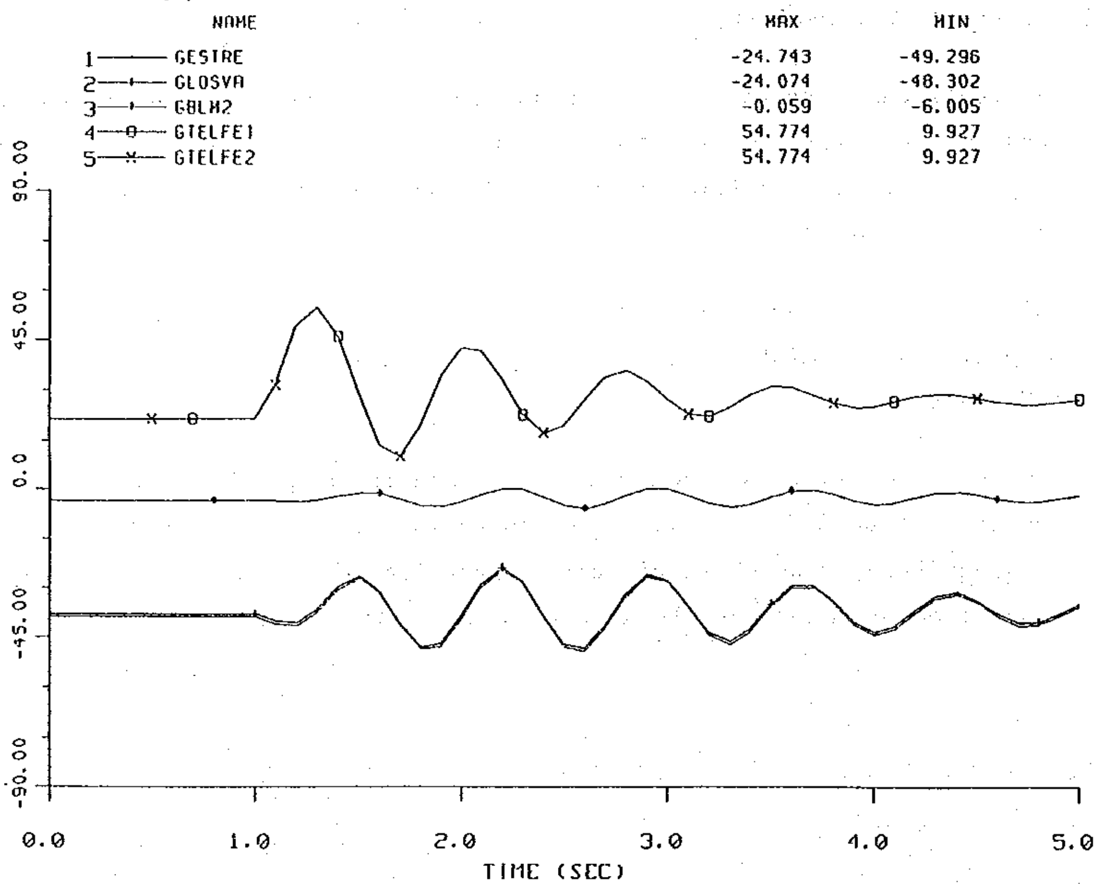
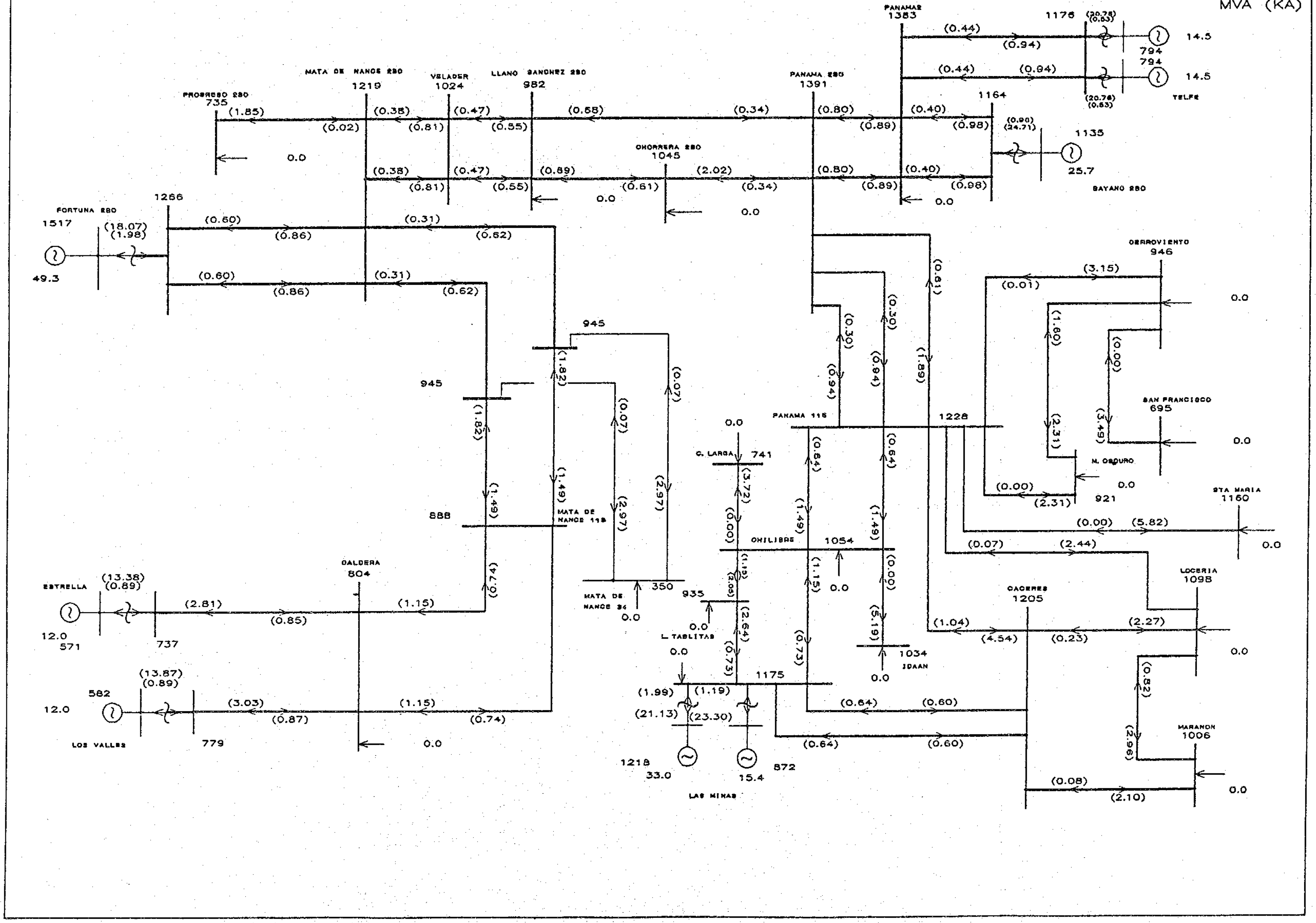


Fig. 8.3.2 (5) Expected Short Circuit Capacity

MVA (KA)



CHAPTER 9 IMPLEMENTATION SCHEDULE

CHAPTER 9 IMPLEMETATION SCHEDULE

9.1 SCOPE OF IMPLEMENTATION SCHEDULE

Fig. 9.1.1. shows the implementation schedule of the proposed 150 MW coal-fired power station to be constructed on the Telfers island site.

This schedule covers activities to be performed during the period from submission of this feasibility study report to the commissioning of the power station, including loan procedure for financing the construction, application to the Panama Canal Commission through DEPAT for authorization of land utilization, selection of consulting firm for preparing the tender documents, bidding and selection of contractor, execution of construction works and tests.

9.2 WORK TO BE PERFORMED PRIOR TO STARTING THE CONSTRUCTION

It is appropriate for the project to be executed on a full turn-key base, taking into account the availability of IRHE's engineering staff. For this purpose, IRHE will have to get a consulting firm to conduct all the engineering services.

After receiving the feasibility study report, IRHE will have to promptly prepare a "Project Planning Report" for loan application, which include general explanation and annual disbursement schedule of the project. In parallel with this, IRHE must apply for the authorization of land utilization in the project area including the power plant site and the sea area fronting the coal unloading jetty. About 12 months will be necessary for going through these formalities and arriving at the opening of letters of credit. After that, review of the feasibility study, preparation of tender documents, bidding and selection of contractor will be carried out by a consulting firm. It will take about 23 months to perform these engineering services.

9.3 CONSTRUCTION SCHEDULE

Within about 35 months from submission of the feasibility study report, the contract will be awarded to contractor to start land reclamation, foundation works, design and manufacture of the equipment and materials.

After obtaining the export licenses from authorities concerned, the equipment and materials will be shipped and unloaded on the piers of Christobal Harbour and Coco Solo Harbour, then transported to the site by trucks and trailers.

The installation of electrical and mechanical equipment will be started after lift-up of the boiler drum. After completion of the installation work, initial firing, tests and trial run will be conducted in sequence to arrive at commissioning.

It will take 31 months from the award of contract to the commissioning of the No.1 unit, and then 3 months latter the No.2 unit will enter service. With the completion of acceptance test to be conducted prior to the commissioing, the final payment will be made.

Coal must be imported and storaged in the coal storage yard prior to the initial firing. The construction of transmission line and substation must be completed before initial power receiving.

The main events in the implementation schedule are shown below.

- Submission of Feasibility Study Report	March 1987
- Start of definite study and preparation of tender documents	April 1988
- Submission of offers	July 1989
- Start of civil works	March 1990
- Start of structural works	September 1990
- Boiler drum lift-up	July 1991
- Initial power receiving	February 1992
- Commissioning of the No.1 unit	October 1992
- Commissioning of the No.2 unit	January 1993

Fig. 9.1.1 Implementation Schedule of Coal-Fired Power Plant

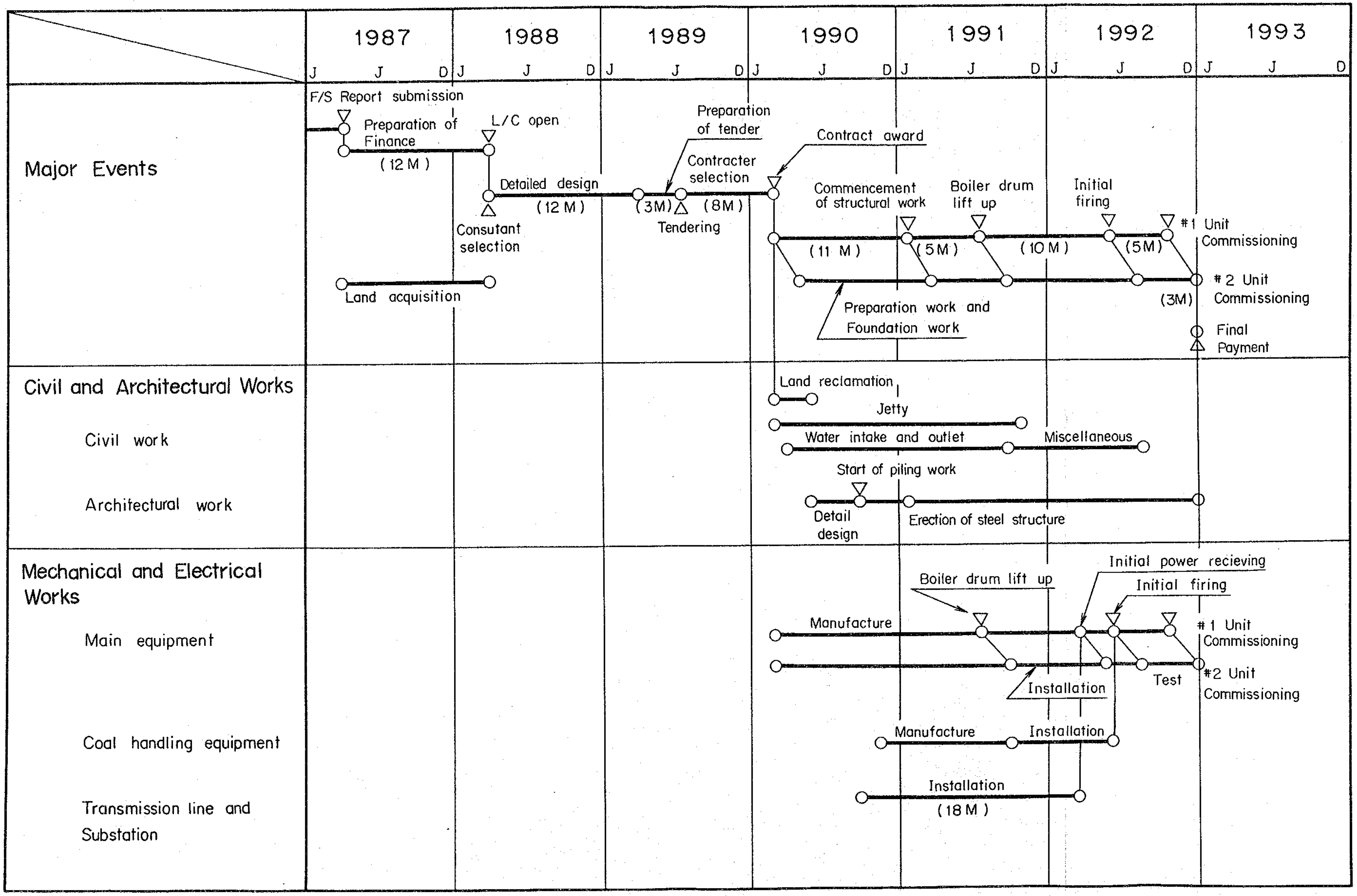
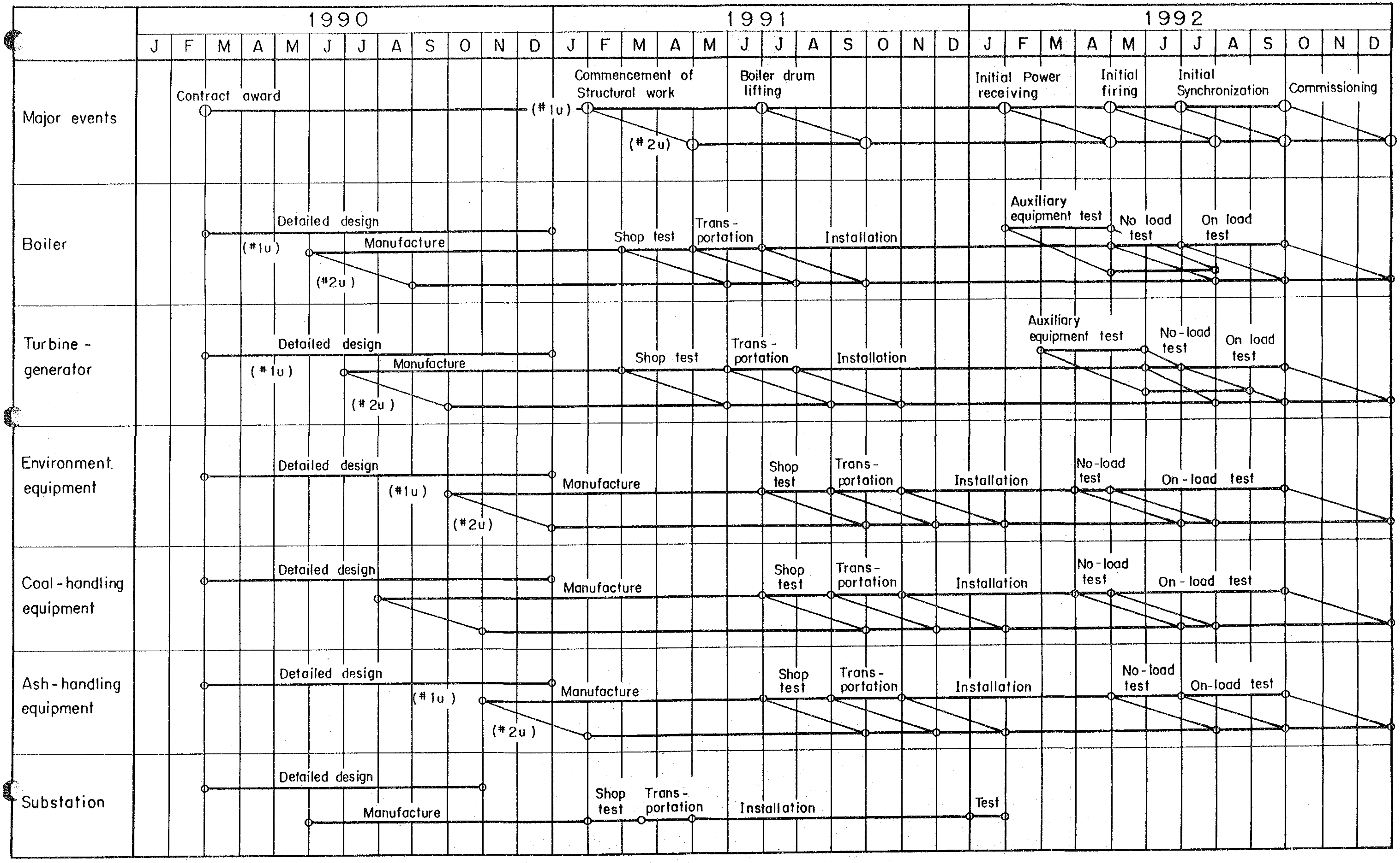


Fig. 9.1.2 Detailed Constraction Schedule



CHAPTER 10 CONSTRUCTION COST ESTIMATE

CHAPTER 10 CONSTRUCTION COST ESTIMATE

10.1 BREAK-DOWN OF THE CONSTRUCTION COST

The construction cost was firstly estimated at prices in August 1986 when JICA study team conducted field investigations in Panama, then the price escalation during the construction period was estimated and added to the former. The following shows the composition of the total construction cost:

- Total construction cost
  - Direct cost
    - Power station
    - Transmission line and substation
  - Indirect cost
    - Physical contingency
    - Administration cost
    - Engineering fee
  - Price escalation
  - Interest during construction
  - Import tax

The construction cost was divided into foreign currency portion and local currency portion. The foreign currency portion includes costs of imported equipment and materials, ocean freight and insurance, and salaries for foreign engineers and personnel, while the local currency portion includes costs of inland transportation, locally available construction materials such as cement, aggregates, etc. as well as salaries and wages for local personnel and workers.

10.2 CONDITIONS FOR COST ESTIMATE

(1) Limit of cost estimate

The estimated construction cost covers the proposed coal-fired power station and transmission line and substation described in Chapter 7. The limit of cost estimate is as follows:

a) Access road, construction offices and spare parts, etc. are included but welfare facilities such as staff housing, playground, etc. are not included.

b) Fuel expense necessary for trial run is not included because such expense is covered by charge of electricity generated by this test operation.

c) Water charge is included but electricity charge is not included because electricity needed for construction work will be supplied by IRHE free of charge.

d) Expense incurred for loan procedure is not included.

e) The receiving point of power generated by the proposed coal-fired power station is Panama II substation. IRHE plans to commission this substation in 1992 in connection with both the proposed coal-fired power plant project and the Changuinola hydro power development project. Therefore, the equipment cost of 230 kV switchyard to be jointly used by these two projects was divided into the cost allocated to the proposed coal-fired power plant project and the cost allocated to the said hydro power project, the latter cost being indicated separately as a reference data.

f) Installation cost of raw water pipeline of about 2 km from Mount Hope water treatment plant to the power station is included.

g) Upon obtaining authorization of the Panama Canal Commission, the land included in the canal zone can be used free of charge for the project as described in Chapter 4. However, cost necessary to acquire land located in the other area is included.

(2) Physical contingency

Physical contingency is to cover unforeseen additional works and unavoidable design modification of equipment. For both the civil works and the mechanical and electrical equipment an amount of 5% of their respective direct cost was included as physical contingency.

(3) Administration cost

An amount of 1.5% of the direct construction cost was included as IRHE's administration cost. This cost is to cover expenses of its office on the plant site, personnel expenses for supervision, liaison work and shop test conducted abroad, and training expense of its personnel.

(4) Engineering fee

Engineering fee was estimated at 2.5% of the direct construction cost. This cost is to cover personnel expense, royalty, travelling expense, communication charge of consultant employed by IRHE for designing and construction supervision.

(5) Price escalation

Price escalation was estimated at 2.0% per annum for foreign currency portion and 3.5% per annum for local currency portion.

(6) Interest rate

Interest rate was estimated at 10% for foreign currency portion and 8% for local currency portion to calculate interest during construction.

(7) Import tax

35% import tax to be uniformly levied on the imported equipment and materials was separately counted up as local currency portion.

(8) Annual disbursement

It was estimated that the construction cost be disbursed annually under the following conditions:

a) Imported equipment and materials

- 20% of the CIF price upon signing the contract.
- 60% of the CIF price upon shipment of the equipment and materials.
- 20% of the CIF price to be released upon completion of the project.

b) Civil and structural works

- 20% of the contract price upon signing the contract.
- 70% of the contract price according to works done.
- 10% of the contract price to be released upon completion of the project.

c) Administration cost and engineering fee

- According to work done (Man-month basis).

d) Import tax

- 100% upon unloading the imported equipment and materials.

10.3 RESULT OF ESTIMATE

The result of the construction cost estimate based on the above-mentioned conditions is as follows:

	(Millions of Balboas)
Total construction cost	209.79
Import tax	35.09
Total	244.88

Detail of the above construction cost is given in Table 10.3(1), and its annual disbursement is shown in Tables 10.3(2) to 10.3(4).

Note: The cost of 230 kV switchyard equipment of the Panama II substation not directly connected to the proposed coal-fired power plant project is as follows (Refer to section 10.2(1).e)):

	(Millions of Balboas)
Cost at 1986 prices	3.80
Foreign currency portion	3.11
Local currency portion	0.69
Import tax	1.09
Total	4.89