6.5 Conceptual Design of FGD Equipment

The conceptual design of the FGD system is made as follows on the basis of the basic plan, overall layout plan, system flow diagram and material balance.

6.5.1 Absorber System

The majority of up-to-date wet limestone-gypsum FGD have been designed as soot-mixing, single tower, in si-tu (internal) forced oxidation system (single tower IFO system). The single tower IFO system has a multi-functional absorber which combines the functions of prescribing, absorbing and also include oxidizing function.

The absorber applied to the single tower IFO system is either "Spray Tower" or "Jet Bubbling Reactor" described at Chapter 4.

In this section, the conceptual design of absorber for spray tower method is described as follows.

(1) Absorber Type

In order to achieve high SO_x removal and dust removal performances, a consideration should be given to provide sufficient contact between flue gas and absorbent liquid in an absorber.

A variety of methods of gas-liquid contact are available as listed below.

- By liquid spraying (Spray Tower, Venturi Scrubber)
- By gas dispersion in liquid (Jet Bubbling Reactor)
- By packed material (Packed Tower)
- Other method (Porous Plate Tower)

Typical absorber schemes employed for FGD systems are shown in Fig. 6.5-1. The spray tower has been employed for 500-MW or more class FGD absorber and has much operational experiences. The spray tower has following features compared with other absorber schemes.

- Pressure loss in the absorber is small.

  Power consumption of a Boost Up Fan (BUF) can be reduced due to small pressure loss in the absorber.

- Internal Structure is simple.

  Scaling in the absorber is little because of simplified internal structure.

- Operation number of spray stages can be changed during FGD operation.

  For low load operation and change of sulphur contents in coal, operation number of spray stages can be changed easily during FGD operation. Therefore, economical FGD operation can be achieved.

In this study, the spray tower which has much experiences and above mentioned features is selected as the FGD absorbers for the conceptual design of the FGD systems for Melnik Power Station.

(2) Oxidation System

There are two kinds of oxidation system in order to oxidize calcium sulphite ($CaSO_3$) produced by reaction of sulphur oxides with absorbent.

One is "In si-tu (Internal) forced oxidation (IFO) system" in which oxidation air is injected into an absorber recirculation tank, and another one is "External forced oxidation (EFO) system" in which oxidation is performed by a subsequent oxidation tower.

These oxidation systems are shown in Fig. 6.5-2. Recent design of oxidation system is directed toward IFO system.

Features of IFO system are followings.

- Less space and cost is required compared with EFO system due to no installation of oxidation tower.

- Limestone excess ratio can be reduced and there is no need for sulfuric acid (H_2SO_4) in addition for oxidation.

In this study, IFO system in which oxidizing function is integrated in the absorber is selected taking less cost and space requirement into account.

(3) Absorber Design

Major factors related to SO_x and dust removal performances of the spray tower absorber are followings.

• Gas velocity in the absorber	.....	SO_x removal performance
• Absorber height	......	ditto
• Limestone excess ratio	......	ditto
• Liquid gas ratio (L/G)	......	SO_x and dust removal performances
• Solubility acidic gas (HCl, HF)	......	SO_x removal performance
• Inlet SO_2 concentration	......	ditto
• Inlet dust concentration	......	Dust removal performance

Absorber design will be carried out taking account of planned SO_x removal efficiency (90%) with FGD outlet dust concentration of about less than 40 mg/m^{3}N and above mentioned factors.

Absorber design and related these factors are described as follows.

a. Absorber diameter and height

Liquid-gas contact in the absorber is shown as follows:

$$\text{Liquid-gas contact} \propto \frac{\text{Gas volume}}{\text{Gas velocity in the Absorber}} \times \text{Absorber Height}$$

If the gas velocity is high, the absorber height must be higher in order to keep optimum liquid-gas contact. On the other hand, if the gas velocity is low, the absorber diameter must be increased while the absorber height can be reduced.

The gas velocity must be selected so that no entrainment occurs in the mist eliminator under the maximum design gas volume. Then, the absorber diameter is determined.

The absorber height is determined taking account of number of spray stages and absorbent residence time in the absorber (storage capacity in the absorber recirculation tank). Where, the number of spray stages are determined by design L/G to achieve planned SO_x removal efficiency.

The absorber sizing is determined by full consideration of these conditions. Hence, the absorber will be designed with following diameter and height.

[Part II]

Absorber diameter : 8.0 m

Absorber height : 22.5 m

[Part III]

Absorber diameter : 18.1 m

Absorber height : 24.8 m

b. Limestone excess ratio

Limestone and SO_2 do not react stoichiometrically in actual equipment.

Thus, it is necessary to maintain limestone a little more excessively compared with that necessary for SO_2 absorption.

Substances included in the flue gas such as chlorine (exists as HCl) and fluorine (exists as HF) SO_x removal efficiency because of that the substances hinder the reaction of SO_2 and limestone.

From the results of coal analysis, the both chlorine and fluorine contents of coal are very high than usual FGD design value.

Therefore, limestone excess ratio must be increased compared with usual design value in order to achieve planned SO_x removal efficiency.

In case of the single tower IFO system, generally, limestone excess ratio is designed to be Approx. 2%.

In this study, the design limestone excess ratio will be 6% taking account of the hindrance of limestone reaction by high chlorine and fluorine contents in coal.

c. Liquid-to-gas (L/G) ratio

In the spraying tower method, the spraying flow rate of absorbent slurry recirculation much affect the SOx and dust removal performances.

The L/G ratio at absorption section is set in this plan to 17.1 ℓ/m^3_N for Part II and 16.1 ℓ/m^3_N for Part III to attain the planned deSOx efficiency of 90% in the absorber of FGD.

In addition, dust removal efficiency of at least 90% is expected with the introduction of those L/G ratio. The regulatory limit of 100 mg/m^3_N is being met already with existing ESPs, however, and no specific attention is given as to the dust removal performance of FGDs.

d. Chlorine concentration in absorption system

The volume of deSOx waste water can be reduced if the chlorine concentration is kept high in the absorption system. When the chlorine concentration is high, however, it becomes necessary to consider corrosion resistance for FGD reactor inner materials.

In this plan, the chlorine concentration in absorption system is set to be less than 10,000 mg/ℓ in consideration of both deSOx waste water which must be reduced to the possible extent and corrosion resistance of the reactor inner materials as discussed in Chapter 4 in relation to the study of methods of byproduct and waste water treatment. Many FGDs of single-tower in-situ oxidation spraying tower method with in-system chlorine concentration of 10,000 mg/ℓ have also been used in Japan.

The selection of lining materials for FGD for the design condition of less than 10,000 mg/ℓ in in-system chlorine concentration is shown in Fig. 6.5-3.

e. Method of waste water treatment

The waste water used as blow water in FGD is discharged following removal of heavy metals by the processes of coagulation, sedimentation and neutralization.

The water to be discharged after such treatment must fully meet water quality standards for rivers as shown in Table 6.5-1.

(4) Absorber Configuration

The outline of the absorbers configuration is shown in Fig. 6.5-4.

To achieve the planned L/G ratio, the number of spraying stages of the absorber is set to be four; one stage in the gas cooling section and three stages in the absorbing section. As for recirculation pumps for circulation of absorbent slurry, one recirculation pump is provided for each spraying stage in the absorbing section and two recirculation pumps (one for regular use and the other for stand-by are provided for the gas cooling section.

Absorber slurry mixing agitators and oxidation agitators are installed to circulation tanks at the bottom part of the absorber. Their numbers are two and three for Part II and six and eight for Part III, respectively. The air for oxidation is blown into circulation tank through each oxidation agitator.

As described before, the mist eliminator is installed to absorber outlet duct.

(5) Specification of the Absorber

[Part II]

- Type : Spray Tower (Single Tower)
- Oxidation: In si-tu Forced Oxidation (IFO)
- Number : One (1) for each FGD unit, altogether four (4)
- Size : Diameter ϕ 8.0 m x Height 22.5 m
- Capacity : 440,000 m^3N/h x 4 units

[Part III]

- Type : Spray Tower (Single Tower)
- Oxidation: In si-tu Forced Oxidation (IFO)
- Number : One (1) for FGD unit of Part III
- Size : Diameter ϕ 18.1 m x Height 24.8 m
- Capacity : 2,300,000 m^3N/h

Table 6.5-1 Planning Discharged Water Quality from Waste Water Treatment

	Item	Unit	Value
1	Discharged Water Rate	t/h	9
2	COD	mg/ℓ	30
3	Cl^-	mg/ℓ	10,000
4	F^-	mg/ℓ	55
5	pH	-	5.8 ~ 8.6

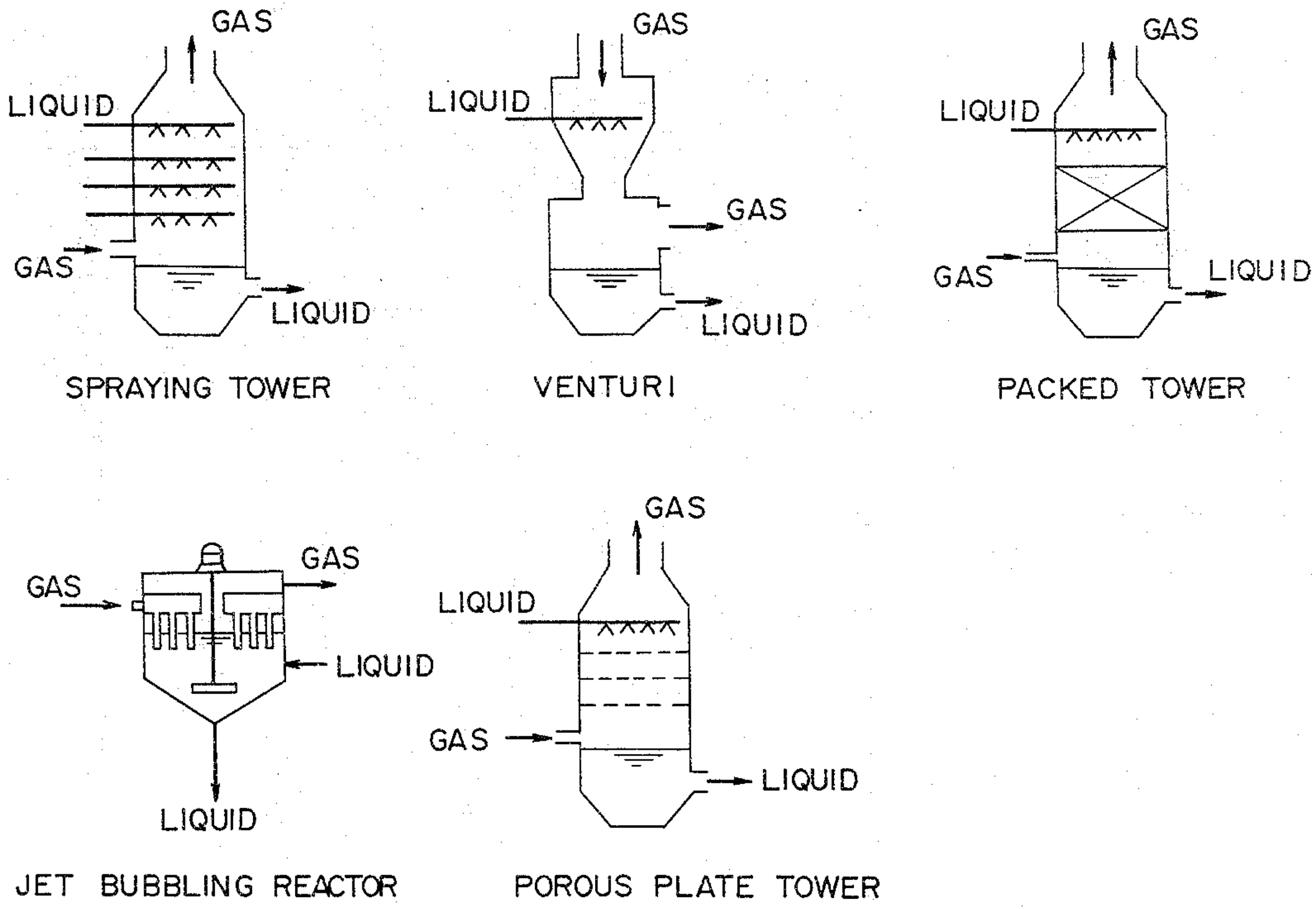
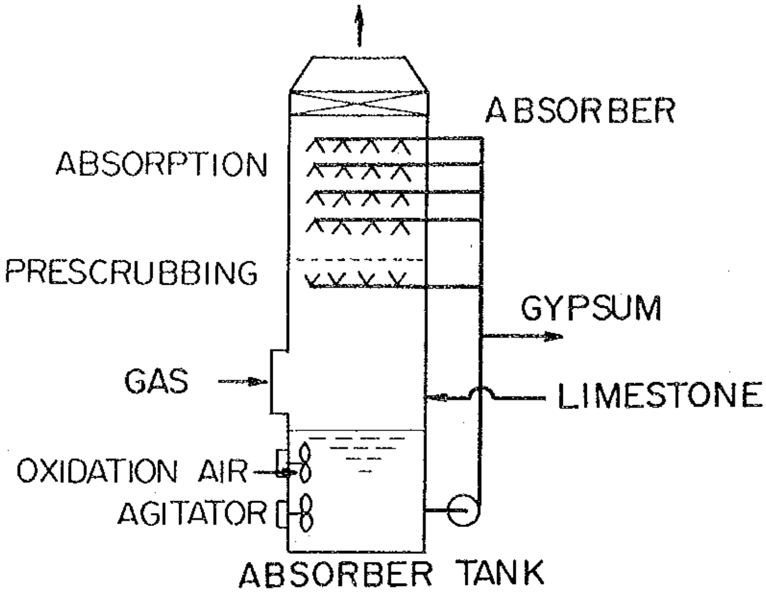
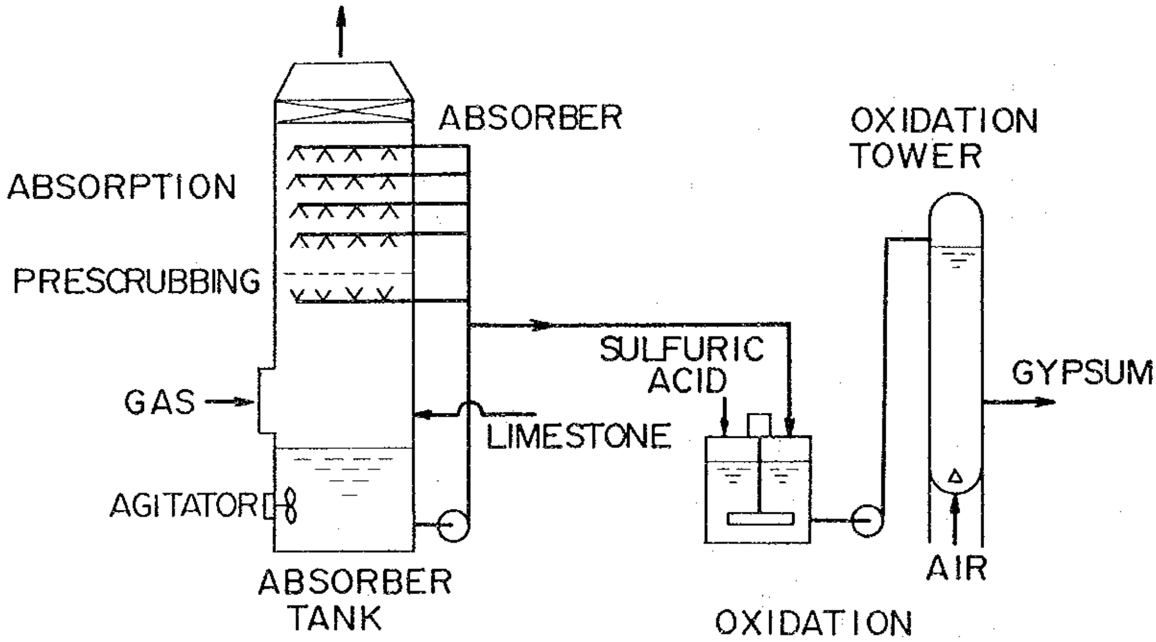


Fig. 6.5 - 1
TYPICAL ABSORBER SCHEMES EMPLOYED FOR WET FGD

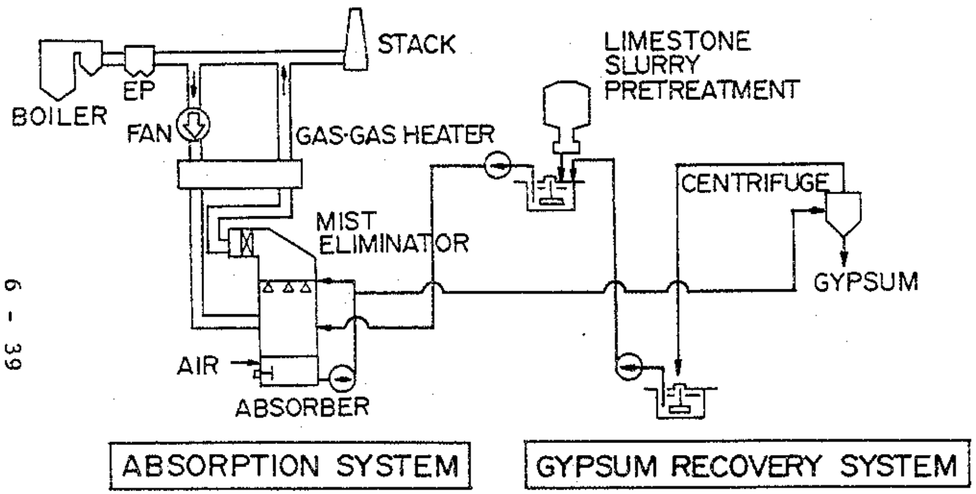


IN SITU (INTERNAL) FORCED OXIDATION (IFO) SYSTEM



EXTERNAL FORCED OXIDATION (EFO) SYSTEM

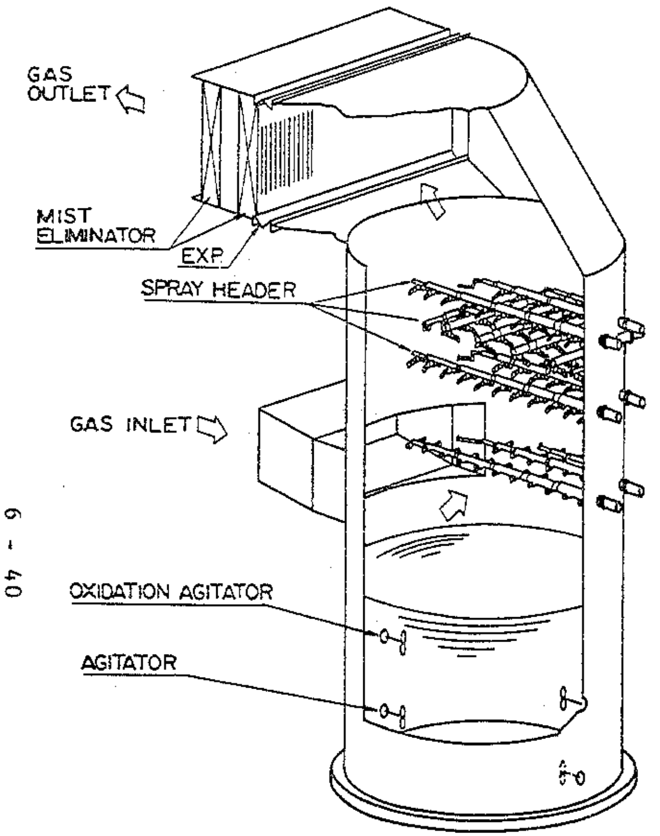
Fig. 6.5-2
COMPARISON OF OXIDATION SYSTEM OF SPRAY TOWER SYSTEM



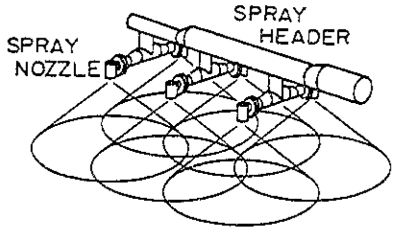
FLOW SHEET

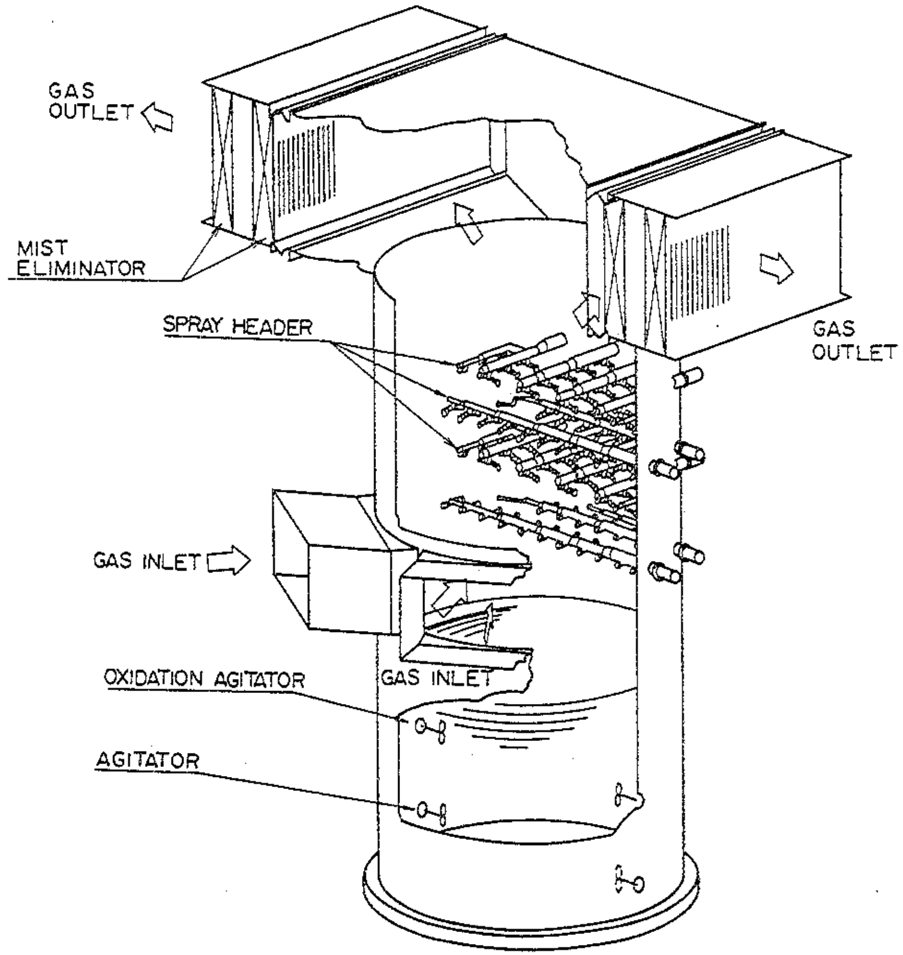
NO.	PORTION	LINING MATERIAL
1.	FLUE	
	• GGH ~ ABSORBER INLET	HEAT RESISTANT GLASS
	• ABSORBER OUTLET ~ GGH INLET	GLASS FLAKE RESIN
2.	ABSORBER	
	• GAS INLET TANK UPPER ZONE	HEAT RESISTANT GLASS FLAKE RESIN
	• SPRAY ZONE	INNER PIPE: GLASS FLAKE RESIN TOWER CASING: STAINLESS LINING
	• MIST ELIMINATOR	GLASS FLAKE RESIN
3.	TANK	GLASS FLAKE RESIN
4.	PIT	RESIN MORTAR
5.	SLURRY PIPING	FRP PIPE OR STAINLESS STEEL

Fig.6.5-3 LINING MATERIAL FOR FGD SYSTEM



PART Ⅱ





PART Ⅲ

Fig.6.5-4 ABSORBER BIRD'S EYE VIEW

6.5.2 Boost Up Fan (BUF)

(1) Fan Position

The corrosive and erosive conditions of Boost Up Fan (BUF) depends on the BUF installation position, so that the construction and performance of BUF to be installed may differ at each position.

There are four (4) positions for BUF with regenerative rotating type GGH shown as Fig. 6.5-5, namely:

- "A" position
- "B" position
- "C" position
- "D" position

Since the gas conditions are the same as those of IDF, so that A position fan which has wider experiences and a high reliability will be applied for this FGD design.

Features of each fan position are as follows:

a. "A" Position

As the gas temperature at "A" position is high, the fan capacity will be the highest due to treating larger actual gas volume, but there is no problem of corrosion.

While it is necessary to consider measures against erosion under high inlet dust condition, inexpensive carbon steel can be used as the material for fan.

The "A" position which is generally used to FGD fan and has wider experiences.

When regenerative rotating type GGH is adopted, there may be a leakage of absorber untreated gas toward the stack (toward "a" direction in the Fig. 6.5-5).

b. "B" Position

As the gas temperature is 40 ~ 50°C lower than that at "A" position, the fan capacity may be smaller than that of "A" position fan due to reduction of actual gas volume.

Gas temperature is near the dew point and SO_3 and hydrogen acid (HCl, HF) contained in the flue gas are condensed creating an environment of sulphuric acid and hydrogen acid corrosion, so that for fan material, high class stainless steel is required.

There is a little experience in application of FGD fan.

In case regenerative rotating type GGH is used:

As absorber treated gas will recycle (toward "b" direction in the Fig. 6.5-5) to absorber untreated gas side, there will be less leakage of absorber untreated gas towards the stack side.

c. "C" Position

The gas temperature is the lowest (45-50°C) at "C" position. The actual gas volume is therefore the smallest, and the BUF capacity can be the lowest at "C" position among the positions of "A" through "D", and the power consumption is also the lowest. As the gas temperature is the lowest, however, the small amount of sulfuric acid mist contained in the flue gas causes a highly corrosive condition, and the cost of BUF is the highest because highest grade stainless steel must be used as the BUF materials.

The behavior of gas leakage for the case of using regenerative rotary GGH is the same as that for the case of "B" Position.

d. "D" Position

Gas temperature of "D" position fan is nearly the same as that of "B" position fan. Less corrosive substances exist in the flue gas compared with the case of "B" position fan.

Humidity of the gas is relatively high compared with "A" position fan, so that measures against corrosion are to be required.

Up to now, there is no experience of "D" position fan application in the world.

In addition, "D" position fan will be located to the place nearest to the stack and fan-generated noise will be emitted from the stack.

In case of adopting regenerative rotating type GGH, untreated gas leakage will be as much as that at "A" position.

Table 6.5-2 shows comparison of each location of the fans.

(2) Fan Type

As mentioned above, since the gas conditions at "A" position are not in corrosive atmosphere, no special material is required for fan parts, and both centrifugal and axial fans can be installed there.

Table 6.5-3 shows comparison of the fan types of this case.

The axial fan will be applied to this case taking the followings into account:

- The BUF is the equipment which has the largest power consumption among associated equipment of FGD system. Power consumption of the axial fan will be smaller than that of the centrifugal fan.

- While a centrifugal fan has simpler structure and maintenance and inspection are easier compared with an axial fan, the axial type IDFs have been already applied to Melnik Power Station.

(3) BUF Design

The BUF is designed to be following specification taking the margin for treated flue gas volume and pressure loss of the equipment into account.

[Part II]

- Fan Position: "A" position
- Number : One (1) for each FGD unit, altogether four (4)
- Fan Type : Axial Fan
- Capacity : Flue gas flow rate 13,700 m^3/min
  Static pressure 270 mmAq
  Motor power 700 kW

[Part III]

- Fan Position: "A" position
- Number : Two (2) for FGD unit
- Fan Type : Axial Fan
- Capacity : Flue gas flow rate 34,200 m^3/min
  Static pressure 290 mmAq
  Motor power 1,570 kW

Table 6.5-2 Comparison of Fan Positions

Fan Position		A	B	C	D
Gas temperature (°C)		170 - 190	120 - 160	50 - 60	100
Fan capacity		100 (Base)	90	80	90
	Corrosion	No problem	Measures against SO_3 and halogen acid (HCl, HF) corrosion are necessary	Measures against corrosive mist are necessary	Measures against corrosion are to be required
	Abrasion	No problem, unless dust concentration is high	Same as the left	No problem, since absorber outlet dust concentration is low	Same as the left
	Dust accumulation	Little accumulation due to high temperature of gas	Dust may accumulate due to SO_3 condensation	Little dust existence, but moist dust may accumulate	No problem
Noise at stack outlet		None	None	Little	Large
Untreated gas leakage ratio with regenerative rotating type GGH (%)		4.5	1.5	1.5	4.5
Material for fan		Carbon steel	High class stainless steel	Ultra high class stainless steel	High class stainless steel is to be applied
Experience in Japanese Power Companies		Many	A few	A few	None

Table 6.5-3 Comparison of Fan Types

Type	Axial	Centrifugal
Structure	Complicated	Simplified
Performance	Higher efficiency in a wide range than that of centrifugal fan	Lower efficiency at a partial load than that of axial fan
Resistance to Erosion	Less resistible in case of high dust concentration	Relatively resistible concerning to high dust concentration
Maintenance and Inspection	Since the complicated structure, maintenance and inspection need more time and skill than the case of centrifugal fan	Since the simplified structure, maintenance and inspection are easier than the case of axial fan
Experience	Many	Many
Power Consumption	Smaller power consumption than that of centrifugal fan	Larger power consumption than that of axial fan

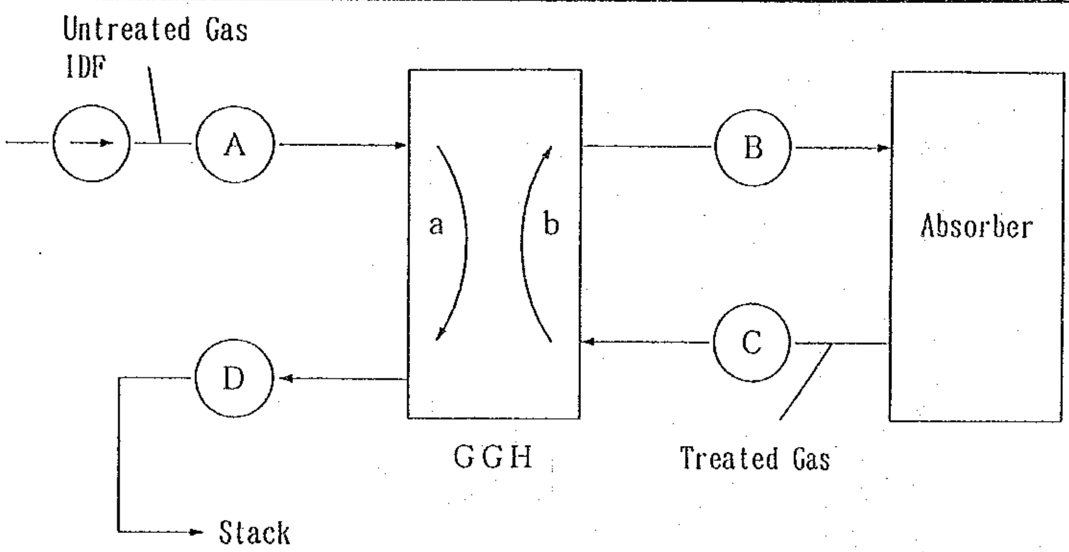


Fig. 6.5-5 Position of BUF and Gas Flow

6.5.3 Flue Gas Reheating System

(1) Purpose of Flue Gas Reheating

The flue gas treated by the absorber will be reheated up for the following reasons.

a. Prevention of Stack and Duct Corrosion

The low temperature gas at the absorber outlet contains corrosive mist, although it is very small amount. The flue gas is reheated in order to protect the stack and the ducts against corrosion and prevent the dust and mist accumulation on the inside wall of stack and duct.

b. Improvement of Diffusion Efficiency of Stack Gas Discharging into the Atmosphere

With the flue gas heated, the effective height of a stack can be increased because gas velocity and buoyancy are increased, so the diffusion efficiency of stack gas discharging into the atmosphere can be improved compared with the case of no flue gas reheating.

(2) Comparison of Reheating System

The following methods are available in the flue gas reheating system.

- Gas to Gas Heat Exchanger (GGH)
  - Regenerative Rotating Type
  - Non-Leak Type
- After-Burner

The regenerative rotating type Gas to Gas Heat Exchanger (GGH) which has wider experiences and a high reliability with a cheeper operating cost will be applied for this FGD design.

In the GGH method, heat exchange is conducted between the absorber inlet gas (hot gas) and the absorber outlet gas (cold gas), thereby the absorber outlet gas is reheated. The heat exchange process of this method contrary decreases the temperature of the absorber inlet gas, so that the make-up water amount for the absorber is decreased due to reduction of water vaporizing in the absorber.

With the After-Burner method, the treated gas by the absorber is directly heated by the hot gas generated by the liquid fuel burning in the After-Burner installed downstream the absorber. The absorber inlet gas temperature is higher than the case of GGH. Therefore, the make-up water amount for the absorber is increased due to increase of water vaporizing in the absorber.

Table 6.5-4 shows the comparison of both methods.

The GGH method which does not require liquid fuel and saves water consumption will be applied for this FGD design.

Besides, the GGH method is divided into two types; one is regenerative rotating type GGH in which heat exchange is conducted by means of rotating heating element, and the other is non-leak type GGH in which heat exchange takes place via heat pipes or with thermal media circulating in the reheating system.

Comparison of both GGH types are shown in Table 6.5-5.

The regenerative rotating type GGH has been mostly used for FGD system, in this type, leakage of gas and dust through the sealed sections between casing and rotor is unavoidable.

In the non-leak GGH, there is no leakage of gas and dust because the inlet gas line (untreated gas side) and outlet gas line (treated gas side) are completely separated each other. Although, the actual adoption of the non-leak type is costly in comparison with the regenerative rotating type.

The non-leak type is to be applied for the cases of strict SO_2 emission regulation.

Taking into account of the SO_2 emission regulation for the case of Melnik Power Station, no application of the non-leak type GGH is required, so that the regenerative rotating type GGH will be applied for this FGD design.

(3) GGH Performance

The higher the flue gas temperature at the outlet of GGH, the more effective it is in preventing the corrosion of duct and stack, and in effecting the diffusion of exhaust gas into the atmosphere. However, this requires a larger GGH and increases the cost.

In this plan, the gas temperature at stack inlet is set to be 100°C at which condition may introduce less problem of corrosion of duct or stack, and the gas temperature at GGH outlet is set to be 90°C for Part II and 100°C for Part III. It is planned, in addition, to use heat exchange elements, baskets, etc. of same specifications for Part II and Part III for the purpose of efficient maintenance.

The planned GGH performance and gas balance are shown in Table 6.5-6.

It should be noted that the GGH inlet gas temperature is included the temperature rising (4°C) at BUF.

Table 6.5-4 Comparison of Flue Gas Reheating System

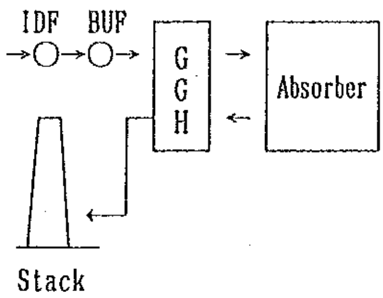
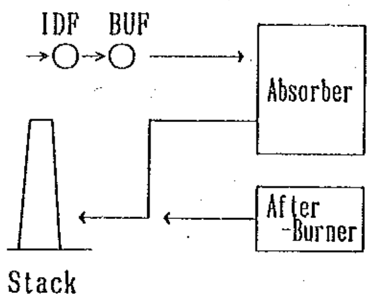
	Item	Gas to Gas Heat Exchanger (GGH)	After-Burner
1.	Outline of the system		
2.	Flue gas reheating method	Heat exchange is conducted between the absorber inlet gas (hot gas side) and the absorber outlet gas (cold gas side), thereby the absorber outlet gas is reheated.	The absorber outlet gas is directly heated by the hot gas generated by the liquid fuel burning in the After-Burner.
3.	Feature of the system	• Make-up water amount for the absorber can be decreased. • No fuel for flue gas reheating is required.	• Larger make-up water amount for the absorber is required. • Fuel for flue gas reheating is required. • Careful operation is required to prevent from flameout of the burner.
4.	Experience	Many The current flue gas reheating system has been designed as GGH	A few

Table 6.5-5 Comparison of Gas to Gas Heat Exchanger (GGH) Types

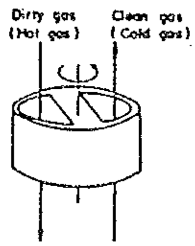
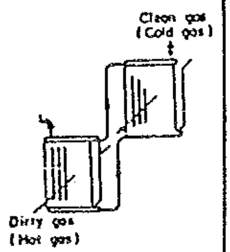
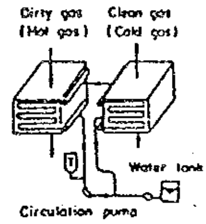
	Item	Regenerative Rotating Type	Non-Leak Type	
			Separate Type Heat Pipe	Thermal Media Circulation
1.	Mechanism	 Heat exchange is conducted by the rotating heating element.	 Heat exchange is conducted by the heat pipe. (Natural recirculation)	 Heat exchange is conducted by the forced recirculation of thermal media.
2.	Gas and dust leakage	Yes	None	None
3.	Power source	Required	Not required	Required
4.	Measures against corrosion during shut down	Not required	Required	Required
5.	Cost	Base	Higher	Higher
6.	Experience	Many	A few	A few

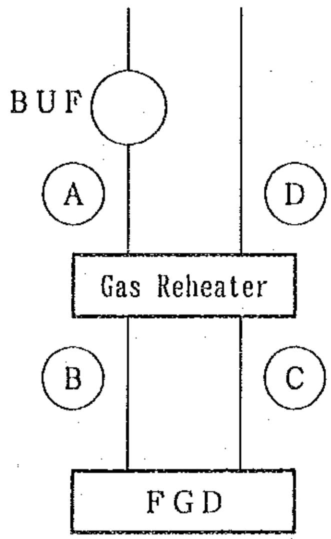
Table 6.5-6 GAS REHEATER PERFORMANCE DATA

[Part II]

Item \ Location	A	B	C	D
1. Gas Flow Rate (Wet) (m^3N/h)	416,800	406,800	439,900	449,900
2. Gas Temp. (℃)	190	158	57	90

[Part III]

Item \ Location	A	B	C	D
1. Gas Flow Rate (Wet) (m^3N/h)	2,206,000	2,152,000	2,282,000	2,336,000
2. Gas Temp. (℃)	170	126	55	100



6.5.4 Pretreatment, Storage and Supplying Equipment of Absorbent

Fine limestone powder is used as absorbent in the wet-type limestone-gypsum method. The pretreatment, storage and supplying equipment must be designed to be optimum, including the pulverizing mill, in consideration of required powder characteristics. In addition, the reactivity of limestone is also an important item for the design of FGDs.

In consideration of the above, the designs of the pretreatment, storage and supplying equipment are planned as described below.

(1) Characteristics and Method of Receiving Limestone

Limestone characteristics are set to be as follows in consideration of specifications of usable limestone obtained during the site surveys and those employed in designing FGDs in Japan.

a. Limestone purity: ≥96% $CaCO_3$ (corresponding to Rank III in Czechoslovak Standards)

b. Limestone grain size: 22.5-80 mm

In addition, block limestone meeting the above-mentioned characteristics is available from the Certovy Sohody mine near the Melnik Power Station, and it is assumed to receive such block limestone by railroad.

(2) Limestone Consumption at FGDs

The limestone consumption per one FGD Unit is roughly as follows:

Limestone consumption at Part II

2.33 t/h (at rated load of 110 MW)
9.32 t/h (in total for 4 FGDs)

Limestone consumption at Part III
12.44 t/h (at rated load of 500 MW)

(3) Equipment Configuration and Capacities

Received limestone is stored in a limestone storage yard. The limestone storage yard must have a feeder for disbursing to supply limestone to the crusher and mill room.

Flow diagram of limestone pretreatment system is shown in Fig. 6.5-6.

Two crushers, one for regular use and the other for stand-by, and three mills, two for regular use and the third for stand-by, are installed, and they are operated common for both Part II and Part III.

Crushed limestone from the crusher is made into powder by wet-type mill, and fed to a hydrocyclone for classification. Powder of oversized particles is fed back to the mill. Normal limestone powder is made into limestone slurry of 30% density, and supplied to the slurry tank.

Limestone slurry adjusted as to its density to 20% in the slurry tank and sent to the absorber as the absorbent.

The limestone storage yard is common to all FGDs and has a capacity for storing 7 days of use (3,700 tons) in consideration of troubles in delivery that might happen.

(4) Limestone Crusher and Mill Specifications

[Crusher]

Type	:	Hammer crusher
Quantity	:	2
Capacity	:	24.0 t/h/unit
Grain size after crushing	:	Not more than 20 mm

[Mill]

Type	:	Wet-type tube mill
Quantity	:	3
Capacity	:	13.7 t/h/unit
Particle size after milling	:	95% pass on 325 mesh (Not more than 43 μm)

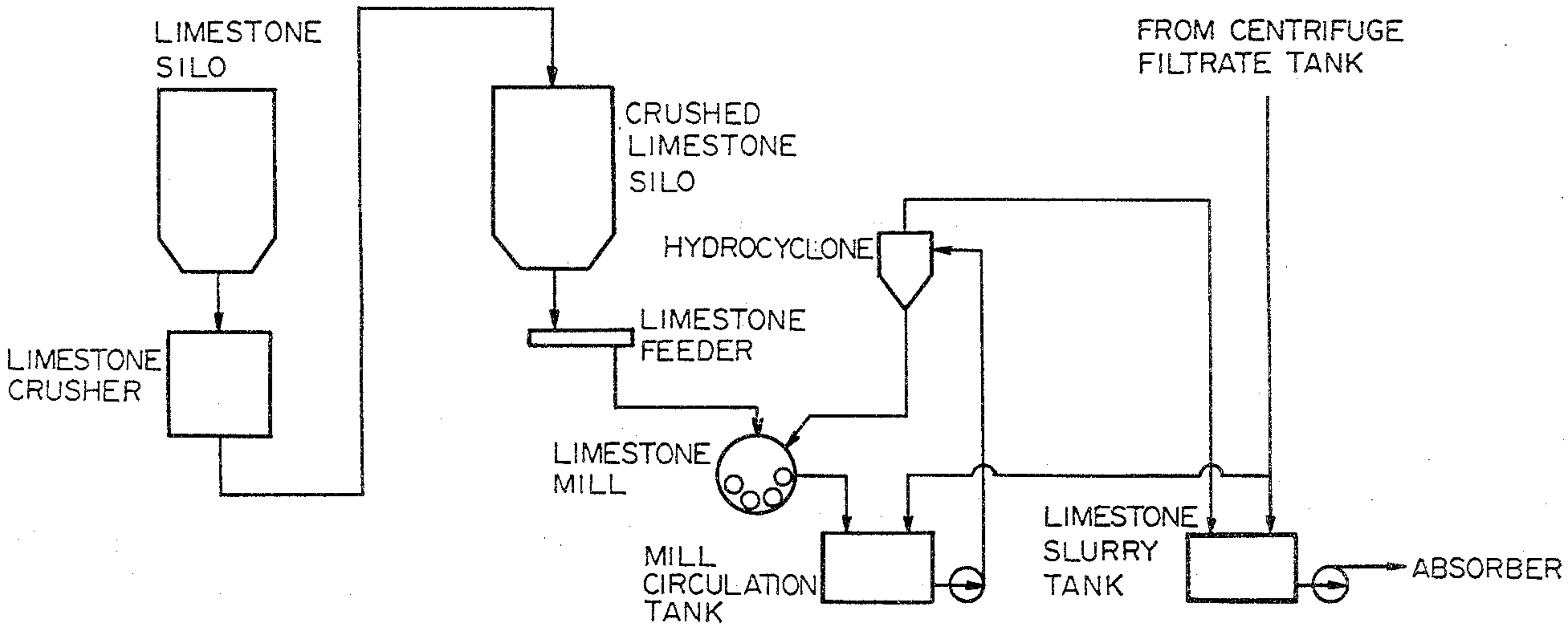


Fig. 6.5-6 FLOW DIAGRAM OF LIMESTONE PRE-TREATMENT SYSTEM

6.5.5 Byproduct Treatment System

(1) Methods of Byproduct Treatment

A common gypsum storage silos of the two units are set to store 6,000 tons of gypsum in consideration of same qualities of gypsum from Part II or Past III. Of all gypsum from Part II and Part III, 100,000 tons of gypsum (10% free water contain), or 110-day equivalent of gypsum production at 38 t/h, is shipped on belt conveyer to the gypsum board factory being planned to be built adjacent to the Power Station.

The rest of gypsum is transported regularly on railroad to an old coal mine which is prepared as a byproduct and ash disposal area and disposed so that it is fixed into solid material.

(2) Method of Storing Byproduct

It is assumed that the gypsum board factory prepares an extra gypsum storage house in consideration of the year of the periodical inspection of Part III because gypsum generation from FGDs at the Power Station in such year decreases extremely, and the shortage from the planned amount of annual gypsum delivery to the factory is anticipated when sulphur contents in coal is below 1.3%.

The gypsum storage silo to be built at the Power Station therefore takes only the allowance for shipping by trains, and it is set to have a capacity of 6,000 tons (3,000 tons x 2 units).

(3) Equipment Configuration and Capacities

Gypsum slurry extracted from the absorber is condensed to 10% of water concentration using centrifuges. Water coming from centrifuges is recovered as process water and used for dissolving limestone and make up for the absorber. The blow water is mixed with process blow water when the chlorine concentration in the blow water exceeds 10,000 mg/ℓ, and sent to waste water treatment system.

Condensed gypsum, on the other hand, is kept temporarily at the gypsum storage silo in the Power Plant and shipped as necessary,.

Byproduct treatment equipment are common to both Part II and Part III and arranged in the same building. Dedicated centrifuges are used for Part II and Part III respectively, and one standby centrifuge is installed for each of Part II and Part III.

(4) Byproduct Disposal Yard

Water-shielding sheet is applied to the bottom and sides of the byproduct disposal yard to prevent chlorine from seeping into the ground after rain and snow falls. The material of water-shielding sheet can be PVC, synthetic resin, polyethylene, etc. but high-density polyethylene sheet (1.5 mm thick) is to be used in consideration of durability and ease of application.

The amount of byproduct to be disposed in about 44 thousand cubic meters annually, and the capacity of byproduct disposal yard required for 12.5 years of disposal is about 0.55 million cubic meters. The area required for byproduct disposal is about 55 thousand square meters (235 m x 235 m) when the height of disposal is 15 m.

A conceptual drawing of the byproduct disposal area is shown in Fig. 6.5-7.

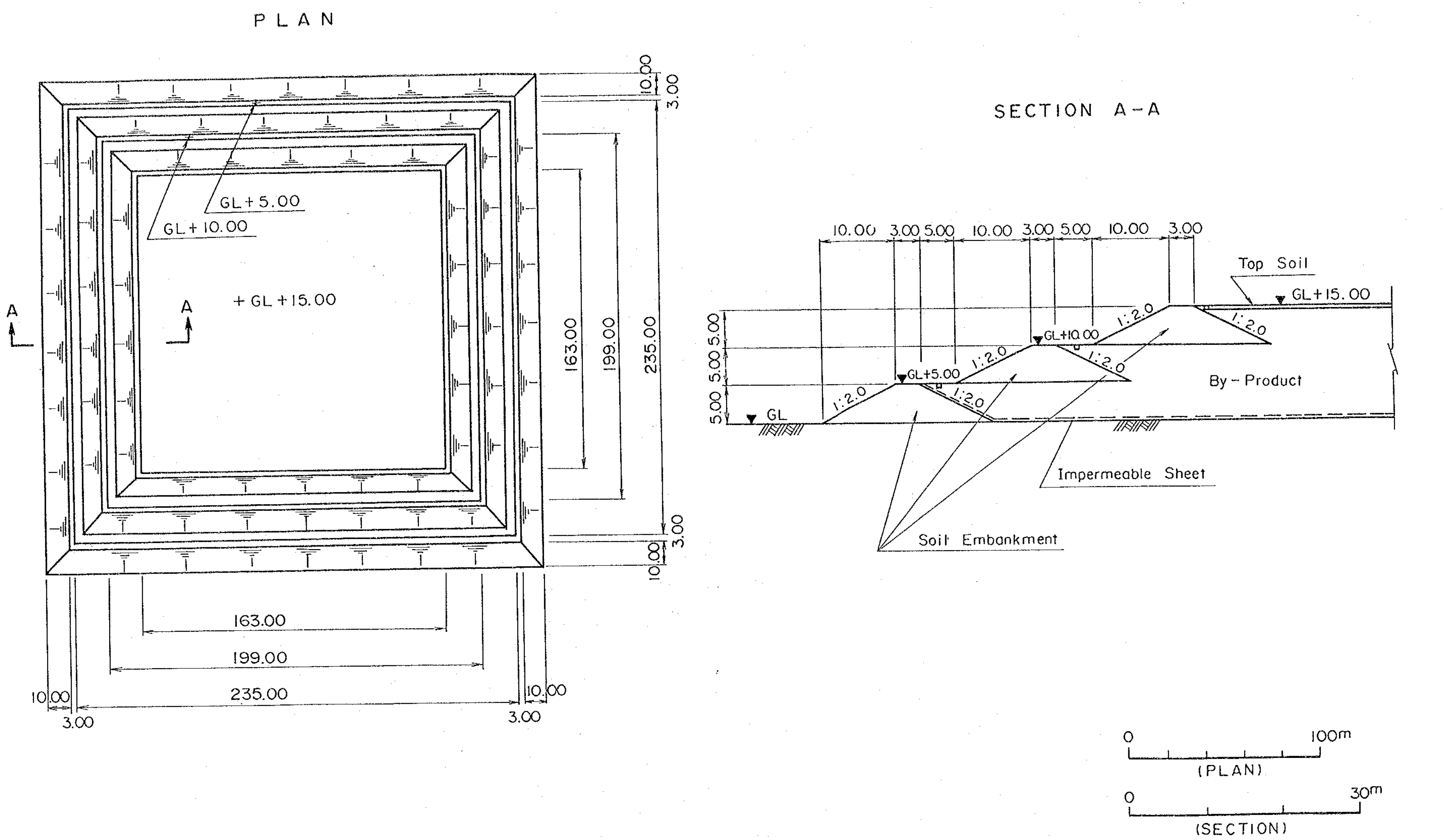


Fig. 6.5 - 7 BY-PRODUCT DISPOSAL AREA

6.5.6 Waste Water Treatment System

Waste water blow from the process water is made continuously or intermittently to keep the chlorine concentration in absorber below the certain level (10,000 pm) and the water is sent eventually to the waste water treatment system.

The amount of water is

0.7 t/h x 4 units = 2.8 t/h for Part II, and
3.5 t/h for Part III, and

the total amount of waste water is 6.3 t/h. The treatment capacity is set to be 9.0 t/h with a safety margin.

The waste water treatment facility processes waste water to make the level of heavy metals which affect water qualities of rivers to the level below the river water quality standards employing the coagulation-sedimentation method. As for the chlorine level, the chlorine level at discharge port will be below 30 mg/ℓ at the highest because of mixing with turbine condenser cooling water, and it fully meets the river water quality standards.

The sludge resulting from coagulation and sedimentation and containing heavy metals is mixed with coal at the coal yard or on coal conveyer on the way to the coal yard, and disposed by burning in the boiler. Such impurities partly reach the FGD again but most of them are collected at ESP, and no concentration in the deSOx process occurs.

A flow diagram of the waste water treatment facility is shown in Fig. 6.5-8.

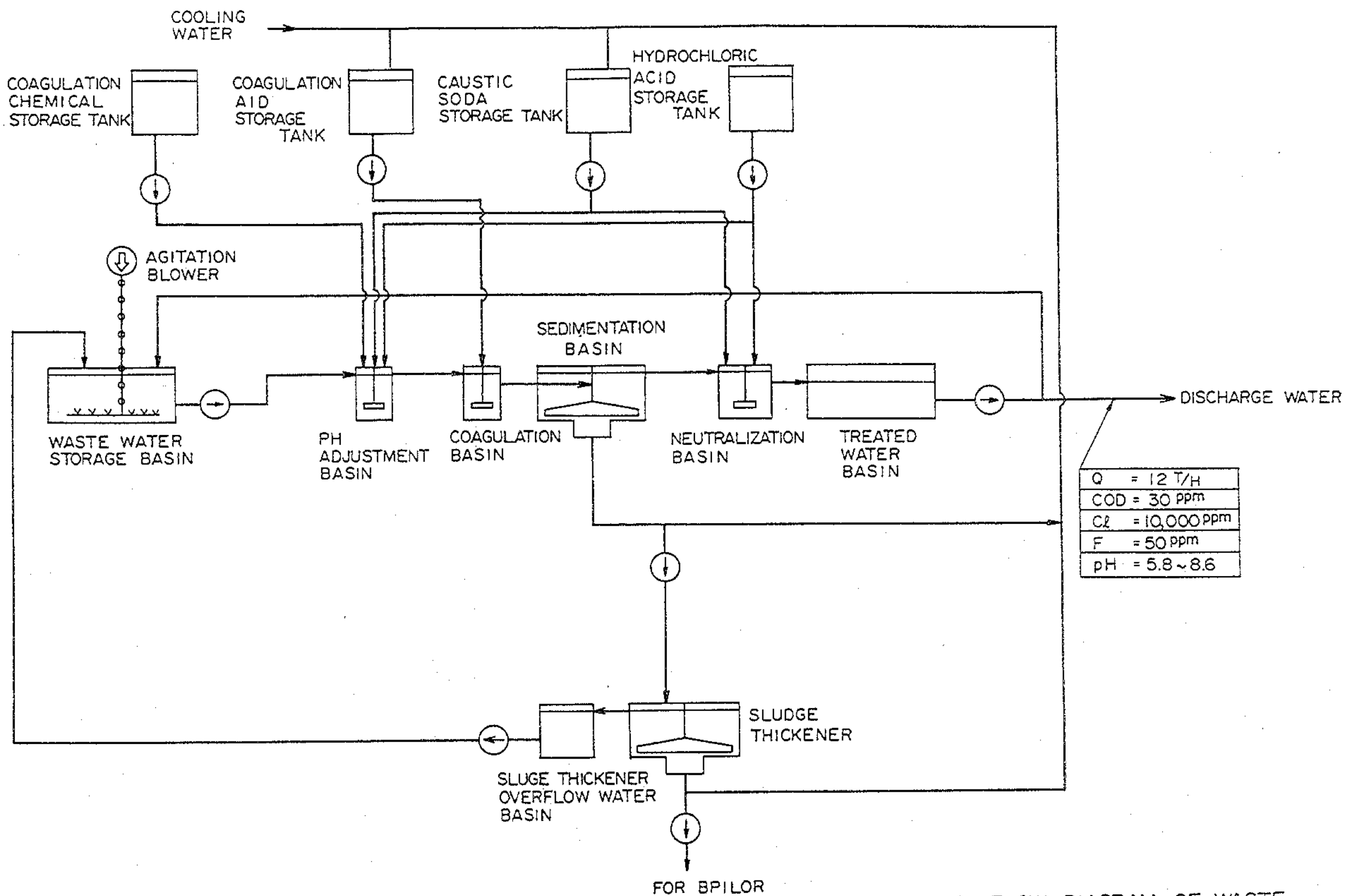


Fig.6.5-8 FLOW DIAGRAM OF WASTE WATER TREATMENT

6.5.7 Water Acquisition and Supply System

Water is used in FGD as make up (replenishment) water for absorber and process water such as limestone slurry preparation. It is planned to get water for such purposes from the Labe River installing new water intake and other facilities for FGDs.

(1) Water Requirement of FGDs

Water requirement of FGDs in terms of deSOx process water is as follows:

- 252 t/h (from material balance)

  Part II: 127 t/h (for 4 Units)
  Part III: 125 t/h

As for cooling of auxiliary equipment, air-cooling method is employed for all purposes including cooling of bearings of rotary equipment such as BUFs, and no cooling water is used in the system configuration.

(2) Water Acquisition Scheme

According to the water quality of Labe river shown in Table 4.3-8, there is little difference between inlet side and outlet side. It is therefore considered no trouble is to be caused by either side of acquisition from a view point of water quality.

The water for FGD system will be acquired from the outlet side of the Part II turbine condenser cooling water, so that the power generating units can be operated without troubles by the water acquisition.

The water acquisition point (location of the water pumping station) is shown in Fig. 6.5-11.

(3) System Description

Two (2) make-up water pumps will be designed for FGD units of Part II and Part III respectively. One (1) of the two (2) pumps is used to supply the water for the FGD units, while the other is in stand-by.

While the acquired water is relatively clean, the automatic cleaning strainers (approx. 20 mesh) will be installed in order to eliminate suspended solid from the water. The strainers will be designed as two (2) trains respectively for Part II and Part III, taking maintainability into account.

The pumping station is designed to be indoor type for anti-freezing. The water is pressurized at the pumping station and delivered through a pipe line connected with each FGD water supply network.

Fig. 6.5-9 shows the water acquisition and supply system.

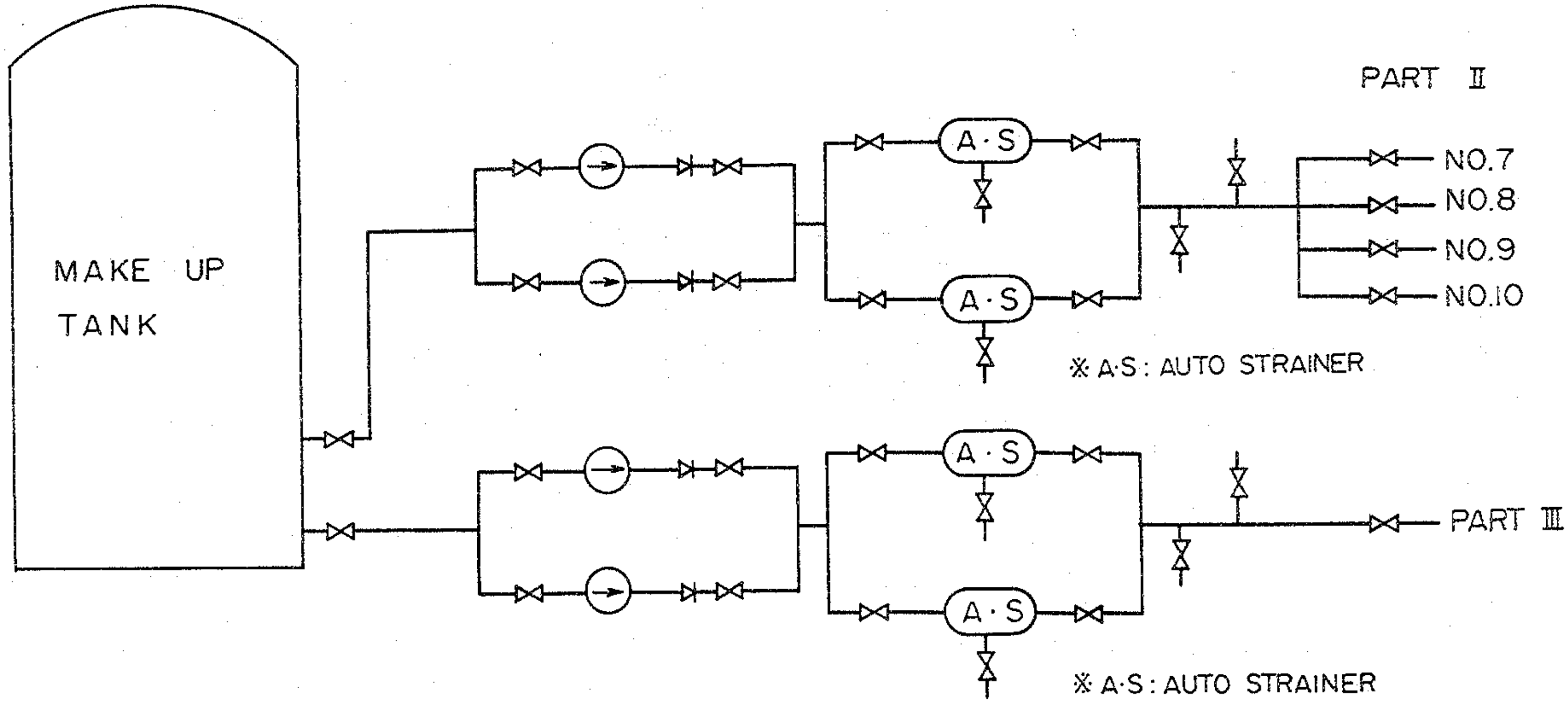


Fig.6.5-9 FLOW DIAGRAM OF RAW WATER SYSTEM

6.5.8 Air Supplying Facilities

The air required for FGD systems are followings:

- Air for oxidation
- Air for control
- Air for sealing

Air supplying facilities are planned to be installed as new air sources independent of the power plants in consideration for reducing the number of remodeling on existing facilities and for preventing the adverse affect on power generation.

(1) Oxidation Air Supplying Equipment

The amount of air required for oxidation in circulation tanks at the bottom of absorber is as follows:

- Part II : 7,880 m^3N/h (1,970 m^3N/h per Unit)
- Part III : 10,600 m^3N/h

The oxidation air blower is a relatively large equipment, and for the case of Part II, three such blowers, one each for two FGDs and one for stand-by, are planned to be installed in consideration of the time of FGD installation which is different between that for Nos. 7 and 8 power plants and Nos. 9 and 10 power plants.

For Part III, on the other hand, two blowers, one for regular use and the other for stand-by, are planned to be installed.

Specifications of blowers for oxidation air are as follows in consideration of necessary air volume and pressure:

- Part II : 22 m^3/min, 0.6 kg/cm^2-g x 3 units
- Part III : 220 m^3/min, 0.6 kg/cm^2-g x 2 units

(2) Control Air Supplying Equipment

The amount of air required for control of FGDs is roughly as follows:

- Part II : 100 m^3N/h (25 m^3N/h per unit)
- Part III : 150 m^3N/h

The control air equipment is also a relatively large equipment as in the case of the oxidation air blower, and for the case of Part II, three such equipment, one each for two FGDs and one for stand-by, are planned to be installed in consideration of the time of FGD installation which is different between that for Nos. 7 and 8 power plants and Nos. 9 and 10 power plants.

For Part III, two such equipment, one for regular use and the other for stand-by, are planned to be installed.

Specifications of blowers for control air are as follows in consideration of necessary air volume and pressure:

- Part II : 50 m^3N/h, 7 kg/cm^2-g x 3 units
- Part III : 150 m^3N/h, 7 kg/cm^2-g x 2 units

(3) Sealing Air Supplying Equipment

In addition to the air supplying equipment mentioned above, sealing air funs are to be installed as sealing air sources for GGH and damper, BUF shafts and GGH soot blowers.

Specification of sealing air funs are as follows in consideration of necessary air volume and pressure:

- Part II : 152 m^3N/h, 600 mmAq x 1 unit
- Part III : 122 m^3N/h, 600 mmAq x 1 unit

6.5.9 Electrical Equipment

Electrical equipment is examined from the viewpoints of economy, reliability and operability, and it is formulated to be the power supply system shown in Fig. 6.5-10 (One Line Diagram).

(1) Methods of Receiving and Supplying Electric Power

Electric power is obtained from the secondary 110-kV bus bar of the main transformer of Part II. The power is received by two FGD transformers of 35 MVA via circuit breakers and supplied to each FGD. As for the FGD transformers, each transformer has the capacity to supply electricity to all auxiliary equipment of all FGD units of Part II and Part III in consideration for transformer maintenance and unexpected accident on a transformer.

For supply of electricity to the electrical room, electric power is supplied through underground cable pit to each metal-clad switchgear (which are referred to, hereinafter, as M/C) of the electrical room via FGD transformer installed adjacent to control and electrical rooms.

(2) One Line Diagram

The M/C bus bar consists of three segments of M/C for Part III, M/C for Nos. 7 and 8 of Part II and M/C for Nos. 9 and 10 of Part II in consideration of operability. It should be noted that M/C for Nos. 7 and 8 of Part II and M/C for Nos. 9 and 10 of Part II are kept linked during regular operation. In addition, M/C bus bars are connected via switchgears so that they can back up the others each other.

Standards employed at Melnik Power Station described below are taken into account, and general standards of Japan are also taken into account for uncertain cases.

a. Standard voltage of bus bars

M/C 6.3 kV, P/C 415 V, MCC 415 V

b. Standard voltage of auxiliary equipment

M/C 6.0 kV, P/C 400 V, MCC 400 V

c. Capacity classification of auxiliary equipment

M/C ≥ 200 kW
P/C ≥ 75 kW, < 200 kW
MCC < 75 kW

Capacities of above-mentioned auxiliary equipment, power center (P/C) transformers, batteries and switchgears will be reviewed at the time of detail design.

(3) Capacity of FGD Transformer

The capacity of FGD transformer was set to be 35 MVA in consideration of capacities of all auxiliary equipment for Part II and Part III, total capacity and allowance for the transformer.

(4) Confirmation of Interrupting Capacity and Voltage Drops

The short-circuit current in M/C switchgears and voltage drop at the time of the largest auxiliary equipment start in the power supply system are confirmed by followings.

a. Confirmation of short-circuit current

The short-circuit currents of the receiving M/C circuit breaker (Point A in the figure) and the feeder circuit breaker (Point B in the figure) are calculated assuming the state where all auxiliary equipment of Part II and Part III are receiving electricity from one FGD transformer. Formulas for calculation are shown in Table 6.5-7. The following conditions are taken into account in calculation:

i. Percent impedance of FGD transformer is 10%.

ii. The impedance on the switchyard side is ignored.

iii. Motor load capacity is 90% of total rated load.

iv. The motor contribution impedance is 25%.

b. Confirmation of voltage drop

The voltage drop in bus bar associated with start of the largest M/C auxiliary equipment (BUF of Part III) is confirmed.

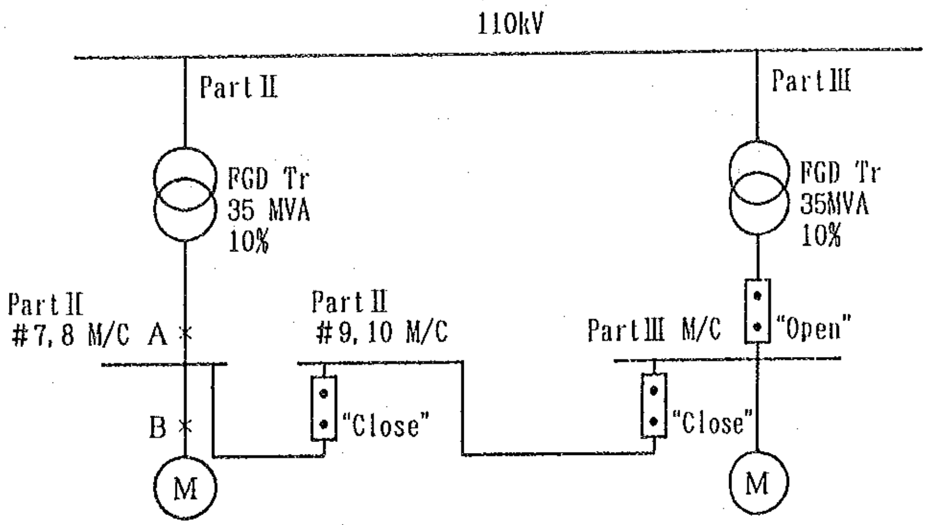
Calculations are made using the formula shown in Table 6.5-8.

The voltage drop in the M/C bus bar associated with starting of the largest equipment of BUF is 9.9% according to the calculation, and it meets the criterion value (15%) which is usually applied.

(5) Electrical Equipment Layout

Fig. 6.5-12 shows the location of electrical equipment including the point of receiving power, positions of FGD transformer and the main cable route. The layout of panels in the control and electrical room are shown in Fig. 6.5-14.

Table 6.5-7 Calculation for the Confirmation of Short-Circuit Current



Fault current at Point A

$$\frac{35\ MVA \times 100}{\sqrt{3} \times 6.3\ kV \times 10\%} = 32.0\ kA \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (i)$$

Fault current at Point B

(Fault current at Point B)
= (Fault current at Point A) + (Current due to motor contribution)
With 10% redundancy of Transformer and motor load factor of 90% is assumed, motor contribution is;

$$\frac{35\ MWA}{(1+0.1)} \times 0.9 = 28.6\ MVA$$

Thus I_M is;

$$\frac{28.6\ MVA \times 100}{\sqrt{3} \times 6.3\ kV \times 25\%} = 10.5\ kA$$

Thus, the fault current at Point B is;

$I_B = I_A + I_M$

$= 32.0\ kA + 10.5\ kA$

$= 42.5\ kA$

Result (ii) is above 40 kA, the additional 63 kA interrupting metal-clad switchgears should be installed.

Table 6.5-8 Calculation for the Confirmation of Voltage Drop

The voltage drop of the metal-clad busbar at the start of BUF, the largest auxiliary equipment is calculated for confirmation. Calculation is made by using a formula given below.

[Calculation]

$$\varepsilon=\frac{\%Z}{H}\left[\frac{R}{X}\left\{\left(H-\frac{P}{y\cos\phi}\right)\cos\phi''+\frac{P}{y\cos\phi'}K\cdot\cos\phi'\right\}+\left\{\left(H-\frac{P}{y\cos\phi}\right)\sin\phi''+\frac{P}{y\cos\phi'}K\cdot\sin\phi'\right\}\right]$$

- ε : Voltage drop (%)
- H : Transformer capacity (MVA)
- $\cos\phi'$: Power factor at starting the equipment largest in capacity (BUF), which is assumed to be 0.15
- $\cos\phi''$: Mean power factor of other equipment, which is assumed to be 0.85
- %Z : Transformer impedance, which is assumed to be 10 (%)
- R/X : R-to-X ratio of transformer, which is assumed to be 0.1
- P : Power of the equipment largest in capacity = 1.9 kW (BUF)
- $y\cos\phi$: Efficiency x power factor of the equipment largest in capacity (BUF), which is assumed to be 0.85
- K : Ratio of rated current to starting current of the equipment largest in capacity (BUF), which is assumed to be 6.5

The voltage drop is thus calculated as follows:

$$\varepsilon=\frac{10}{35}\left[0.1\times\left\{\left(35-\frac{1.9}{0.85}\right)\times0.85+\frac{1.9}{0.85}\times6.5\times0.15\right\}+\left\{35-\frac{1.9}{0.85}\times0.53+\frac{1.9}{0.85}\times6.5\times0.99\right\}\right]$$

$$=9.9\ (\%)$$

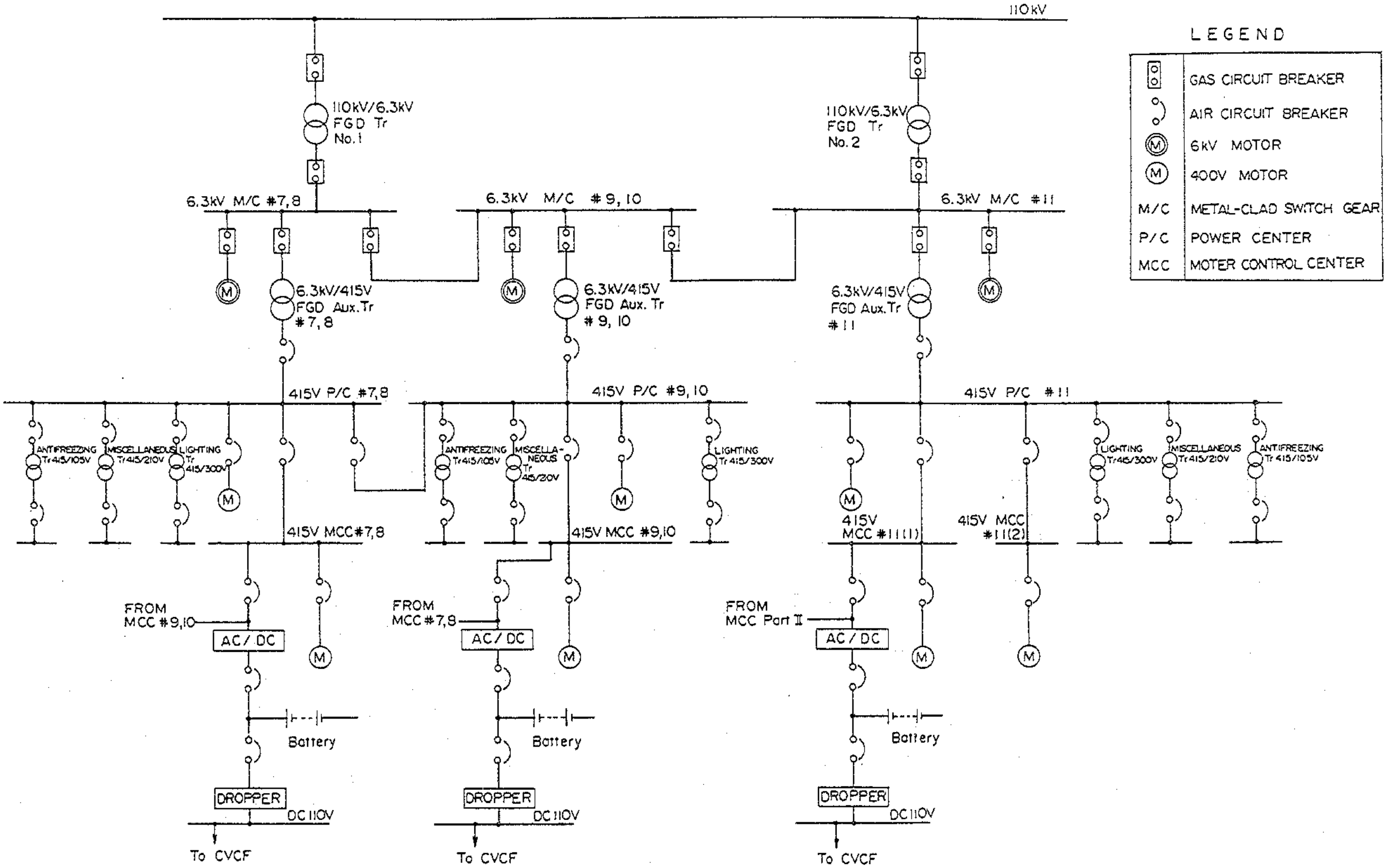
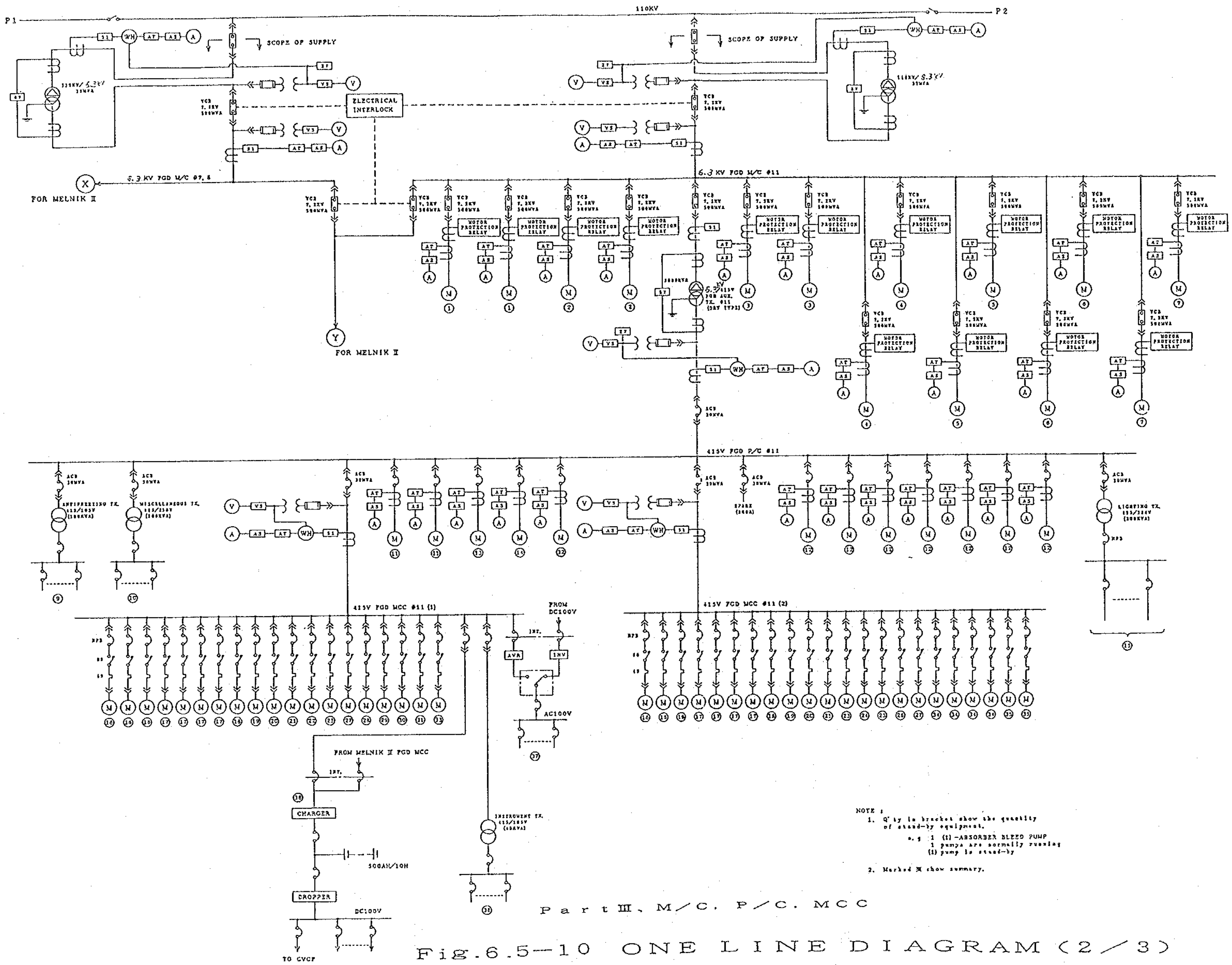


Fig. 6.5-10 ONE LINE DIAGRAM (1/3)

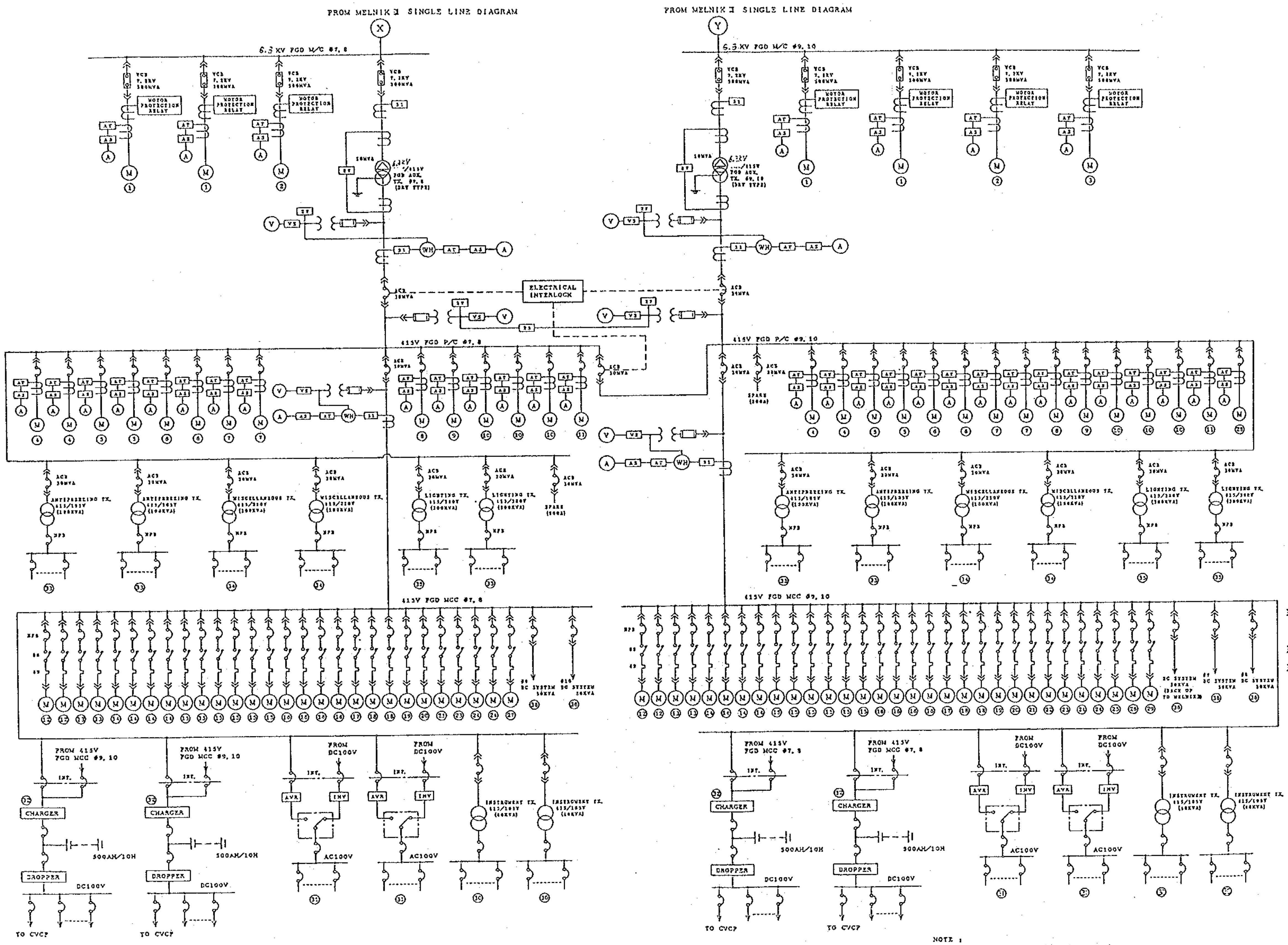


NOTE :
1. Q'ty in bracket show the quantity of stand-by equipment.
e.g 1 (1) -ABSORBER BLEED PUMP
1 pumps are normally running
(1) pump is stand-by
2. Marked ※ show summary.

Part III, M/C, P/C, MCC

Fig.6.5-10 ONE LINE DIAGRAM (2/3)

NO.	SERVICE	Q'TY	VOLTAGE (V)
1	BOOST UP FAN	2	6000
2	ABSORBER RECIRCULATION PUMP (1ST)	2	6000
3	ABSORBER RECIRCULATION PUMP (2ND)	2	6000
4	ABSORBER RECIRCULATION PUMP (3RD)	2	6000
5	ABSORBER RECIRCULATION PUMP (4TH)	2	6000
6	OXIDATION AIR BLOWER	1 (1)	6000
7	BALL MILL (1SET IS COMMON)	1 (1)	6000
8			
9	ANTIFREEZING	1	400
10	MISCELLANEOUS	1	400
11	AIR COMPRESSOR	1 (1)	400
12	CENTRIFUGE	6 (1)	400
13	RECLAIMER (COMMON FOR MELNIK II & I)	1	400
14	SLURRY HOLDING TANK AGITATOR	1	400
15	LIGHTING	1	400
16	ABSORBER AGITATOR	6	400
17	OXIDATION AGITATOR	8	400
18	ABSORBER BLEED PUMP	1 (1)	400
19	GAS GAS HEATER	2	400
20	SEALING AIR FAN	2	400
21	MAKE-UP WATER PUMP	1 (1)	400
22	ABSORBER AREA DRAINPIT PUMP	1	400
23	ABSORBER AREA DRAINPIT AGITATOR	1	400
24	SLURRY HOLDING TANK TRANSFER PUMP	1	400
25	CENTRIFUGE FILTRATE PUMP	1 (1)	400
26	CENTRIFUGE FILTRATE TANK AGITATOR	1	400
27	BLOW DOWN PUMP	1 (1)	400
28	BLOW DOWN TANK AGITATOR	1	400
29	LIMESTONE FEEDER	1	400
30	LIMESTONE SLURRY TANK AGITATOR	1	400
※ 31	LIMESTONE STORAGE	1	400
※ 32	LIMESTONE CRUSHING	1	400
※ 33	LIMESTONE UNLODING	1	400
34	GYPSUM CONVEYOR (1)	4	400
35	GYPSUM CONVEYOR (2) (COMMON FOR MELNIK II & I)	2	400
36	INSTRUMENT	1	400
37	CVCF	1	400
38	CHARGER	1	400



NO.	SERVICE	Q'TY	VOLTAGE (V)
1	BOOST UP FAN	4	6000
2	OXIDATION AIR BLOWER	1 (1)	6000
3	BALL MILL	1	6000
4	ABSORBER RECIRCULATION PUMP (1ST)	4	400
5	ABSORBER RECIRCULATION PUMP (2ND)	4	400
6	ABSORBER RECIRCULATION PUMP (3RD)	4	400
7	ABSORBER RECIRCULATION PUMP (4TH)	4	400
8	SLURRY HOLDING TANK AGITATOR	1 (1)	400
9	SLURRY HOLDING TANK TRANSFER PUMP	1 (1)	400
10	CENTRIFUGE	5 (1)	400
11	AIR COMPRESSOR	1 (1)	400
12	GAS GAS HEATER	4	400
13	SEALING AIR FAN	4	400
14	ABSORBER AGITATOR	8	400
15	OXIDATION AGITATOR	12	400
16	ABSORBER BLEED PUMP	4 (4)	400
17	ABSORBER AREA DRAINPIT AGITATOR	2	400
18	ABSORBER AREA DRAINPIT PUMP	4	400
19	MAKE-UP WATER PUMP	1 (1)	400
20	CENTRIFUGE FILTRATE TANK AGITATOR	1 (1)	400
21	CENTRIFUGE FILTRATE PUMP	1 (1)	400
22	BLOW DOWN TANK AGITATOR	1	400
23	BLOW DOWN PUMP	1 (1)	400
24	GYPSUM CONVEYOR (1)	4	400
25	LIMESTONE FEEDER	1	400
※ 26	LIMESTONE STORAGE	1	400
27	LIMESTONE SLURRY TANK AGITATOR	1	400
※ 28	LIMESTONE CRUSHING	1	400
※ 29	LIMESTONE UNLODING	1	400
30	INSTRUMENTATION DISTRIBUTION BOARD	4	400
31	CVCP	4	400
32	CHARGER	4	400
33	ANTIFREEZING	4	400
34	MISCELLANEOUS	4	400
35	LIGHTING	4	400
36	DC SYSTEM BACK UP	5	400

NOTE :

1. Q'ty in bracket show the quantity of stand-by equipment.

   e.g 1 (1) —MAKE-UP WATER PUMP
   1 pumps are normally running
   1 pump is stand-by

2. Marked ※ show summary.

Part Ⅱ、M/C、P/C、MCC

Fig.6.5—10 ONE LINE DIAGRAM (3/3)

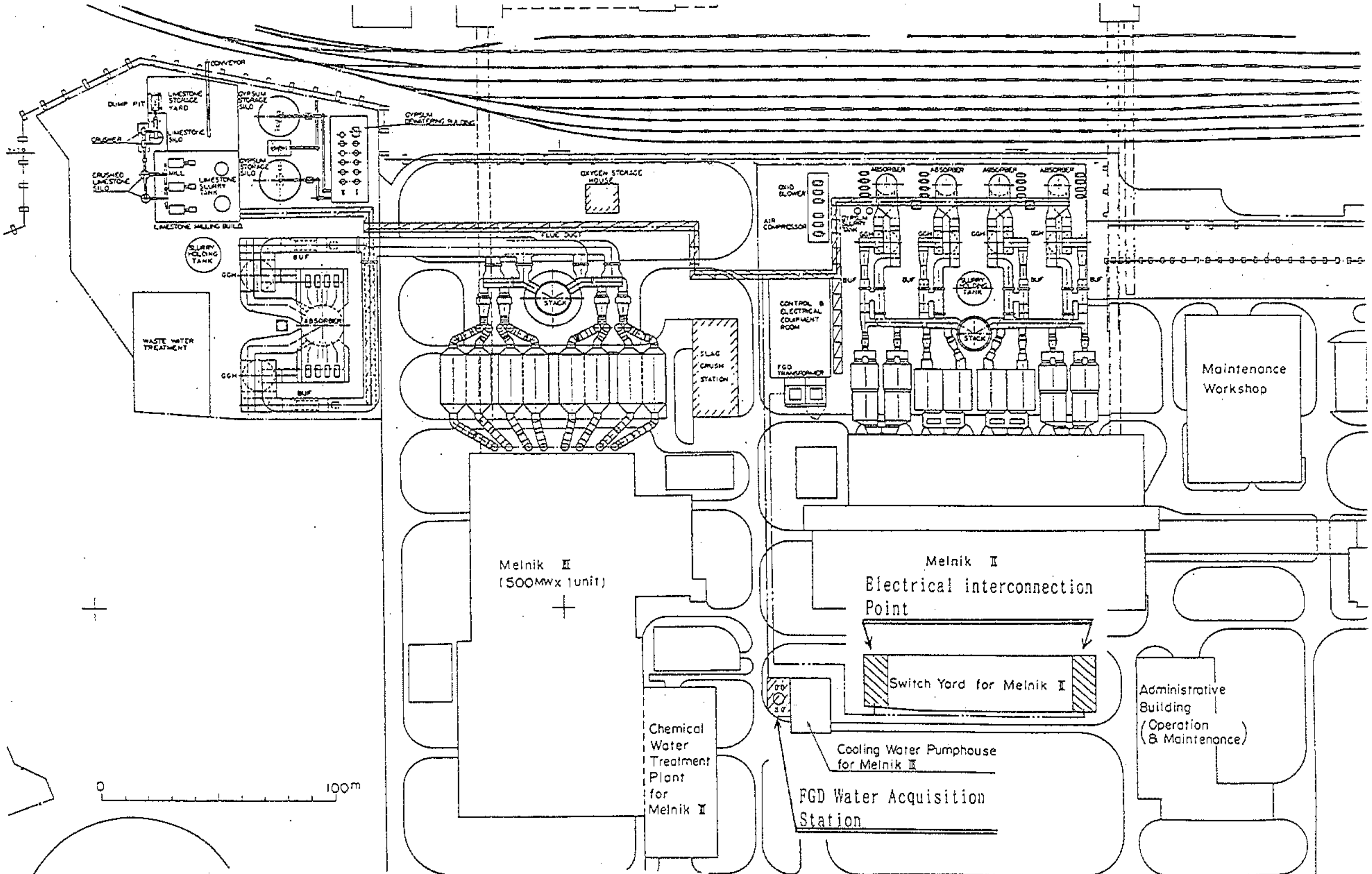


Fig.6.5-11 LOCATION OF ELECTRICAL EQUIPMENT AND RAW WATER ACQUISITION

6.5.10 Control Equipment

The progress which have been made recently in the field of control equipment has been remarkable, and automatic control systems are being employed not only for operation of power generating plants but also for operation of flue gas desulphurisation system. The level of control of flue gas desulphurisation systems especially of wet-type limestone-gypsum method in Japan is the highest level in the world realizing high operability and reliability.

The latest digital control system which is the same level as the current Japanese system is to be used also for the flue gas desulphurisation system of Melnik Power Station. It is the control system therefore which fully automates remote operations and monitoring and start up, shut down and ordinary operations being made in the Control Room. It is a high-reliability system which realizes easy operation through CRTs (Cathode-ray Tubes).

(1) Basic Policies for Automation

The operation of FGDs is to be automated for the purposes itemized below in addition to making it possible to operate the 500 MW class FGD and the four (4) 110 MW class FGDs for Melnik Power Station.

a. To reduce the number of operators necessary for operation of FGDs

b. To centralize operations, monitoring and control of FGDs for easy operation

c. To improve the operational reliability

Basic policies to be employed for achieving purposes stated above in planning the automated control are as follows;

a. Ordinary operations are made in automatic mode.

b. Start up and shut down operations are basically made automatically. They are to be conducted sequentially, however, by instructions to be given by operators at some breakpoints.

c. The following operations are basically automated:

   i. Operations which might require emergency operations

   ii. Operations where mistakes are likely to occur

   iii. Operations to be made according to certain patterns

   iv. Operations of auxiliary equipment which is to be started, stopped or adjusted according to load changes

In addition, the following operabilities are to be included as basic policies in organizing the automated system:

a. It must be possible basically to conduct all start up, shut down and ordinary operations from the operation desk through CRTs in the Control Room.

b. Monitoring of the operating statuses of the whole plant and information processing must also be realized by CRTs

(2) Configuration of the Control System

Control system hardware consists of operation desks and their peripherals mainly installed in the Control Room, controller and relay panels installed in the Relay Room, and local control devices in the field. The system configuration is outlined in Fig. 6.5-12. Functions of each equipment are described below.

a. Operation Desks

All operations and monitoring of FGDs are conducted basically from operation desks. One operation desk is installed independently for each of the five (5) FGDs, and common equipment is housed in the operation desk for the FGD of Part III. Each operation desk is equipped with one CRT for starting and stopping of the whole FGD or respective auxiliary equipment, monitoring of conditions, displaying of system diagrams and alarms, etc. Each

CRT must have its own built-in CPU (Central Processing Unit). In addition, CRTs must allow to switch functions from one to the other.

The operation desk must be set with an emergency plant shutdown button and a bypass damper opening button so that such operation can be performed manually at a time of emergency. In addition, the operation desk must be provided with necessary indication lamps and instruments such as recorder.

b. Printers

Printers consist of data logger typewriters which print out data necessary for operation management of the FGD, event typewriters which record device statuses (starting, stopping, alarms, etc. of auxiliary equipment), hardcopy printers which copy the CRT screen, etc.

c. Electric Panel

An electric panel is installed in the Control Room for operation and monitoring of the power supply system for FGDs. This electric panel allows to execute remote operations of the power supply system such as power receiving, stopping and busbar linking. The electric panel is provided with voltmeters, ammeters, power meters, alarm devices, protection relays, etc. necessary for monitoring.

d. Controller Panels

The controller panel is the main portion for controlling starting, stopping and controlling each process of the FGD, and provided with such functions as input/output processing, modulating, sequence control and alarming. The controller is provided for each system or function. In addition, critical hardwares such as CPUs, power supply units, data transmission units, and analogue data input modules for important control objects are provided in dual.

e. Engineering Console

The engineering console is a tool for execution of adjustment, etc. of the controller, and consists of a CRT, CPU, memory devices (such as hard disks), etc.

f. Relay Panels

These panels house interlocking circuits for protection of FGDs and auxiliary equipment. Each circuit is made up of hard-wired logics of solenoid relays.

g. Local Control Devices

Local control devices include auxiliary equipment control panels, control valves, damper control drives, transmitters, and sensors, detectors and other local measuring instruments installed in the field.

h. Control Power Supply Panel

Control equipment requires a power source which is high in reliability. The control power supply must be non-interruptible and provide power small in voltage and frequency fluctuations. The control power supply panel therefore supplies power through CVCF (constant-voltage constant-frequency) units and it is backed up with batteries against power failures.

(3) Outline of Process Control

Major process control items of respective systems of the FGD are given and described in the table below.

System	Process Control Item	Description
Draft System	Draft Control	BUF outlet damper opening is controlled, according to the gas flow at BUF inlet, so that the differential draft pressure at bypass damper remains constant.
Absorbent supply system	Absorbent slurry density	Absorbent solvent (recovered water) and limestone are mixed at a constant rate so that the slurry remains at a constant density.
Absorption and oxidation system	pH of slurry circulating in absorber	The pH value is controlled by adjusting the supply of the absorbent slurry of constant density, which is prepared by the absorbent supply system.
	Concentration of slurry circulating in absorber	The concentration of slurry is controlled by adjusting the amount of slurry bleeding from absorber.
	Control of absorber level	The level is controlled by adjusting the amount of make-up water and the amount of slurry bleeding from absorber.
Byproduct recovery system	Free water in byproduct	The system adjusts the time of dewatering so that free water in byproduct (gypsum) is below a certain level.

(4) Protective Interlocks

Protective interlocks are configured according to the following basic policies for protection of existing power plants and the new FGDs:

a. When the FGD trips, the bypass damper is opened to let power plants continue to operate. In addition, the load is decreased as necessary.

b. When the draft pressure at FGD inlet duct is abnormally high or low, the bypass damper is opened, further the draft system of the

FGD is forced to trip if the abnormal draft pressure is still continued after that.

c. When all IDFs connected to an FGD stop or trip, the FGD is also stopped (forced to trip).

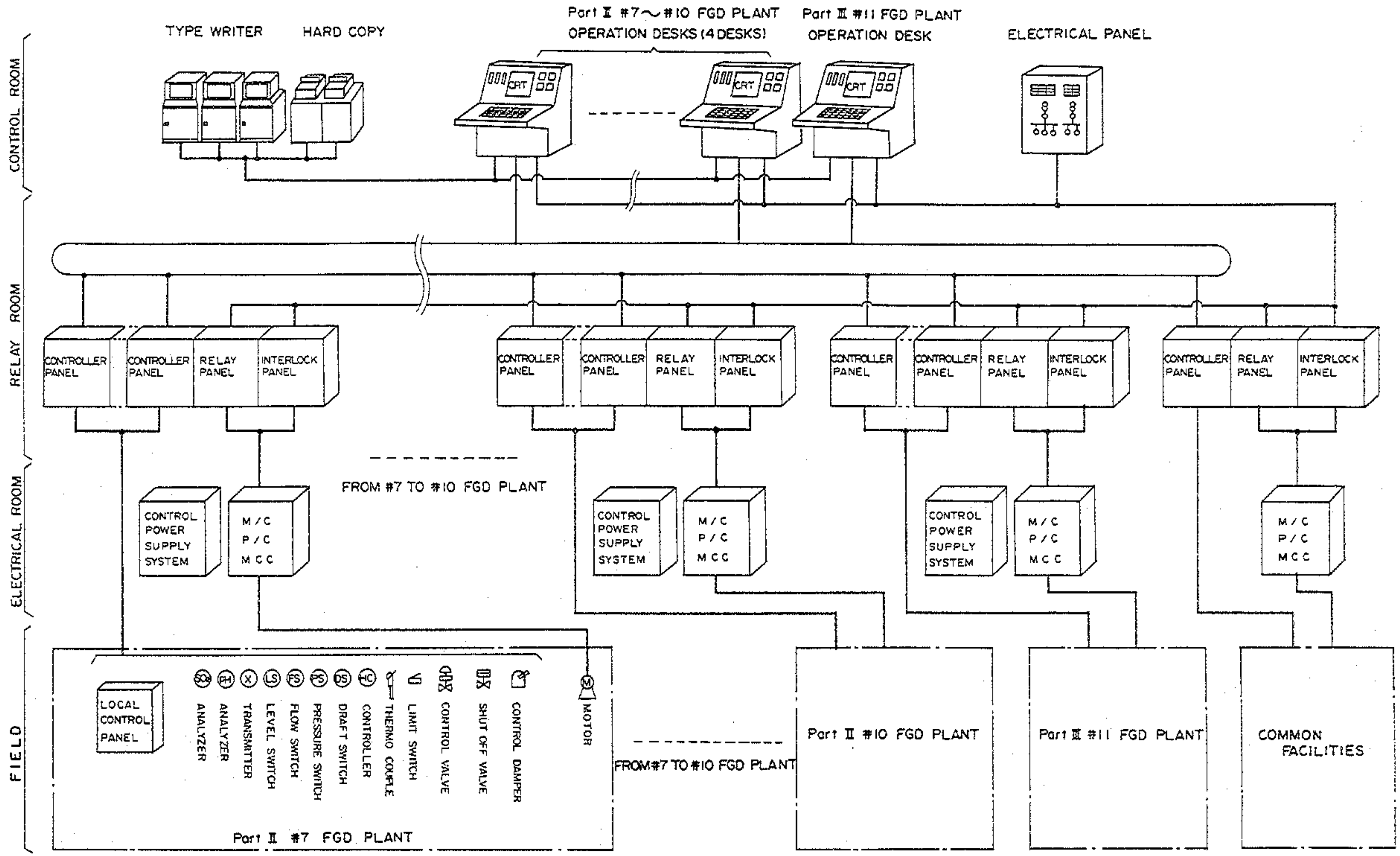


Fig. 6.5-12 CONFIGURATION OF FGD CONTROL SYSTEM

6.5.11 Related Buildings

As related buildings, two Gypsum Silos, one Gypsum Dewatering Building, one Auxiliary Machine Room, one Control & Electrical Equipment Room, one Limestone Milling Building and six Absorber Recirculation Pump Room (four for Part II and two for Part III) are required. The location and plan and section of each building are shown in Fig. 6.2-1 "General Layout" and Figs. 6.5-13 and 14 "Related Buildings".

- Gypsum Silo

  Two Gypsum Silo are arranged near railway track in the FGD installation area of Part III. The effective stock weight of each silo is 3,000 tons and structure type of silo shell is reinforced concrete.

- Gypsum Dewatering Building

  Eleven (11) gypsum centrifuges are installed on the second floor and conveyor sending dewatered gypsum to silos is arranged on the first floor. On the ground floor, the oxidation air blowers and the air compressors for Part III are installed. This building is arranged near gypsum silos for short length of gypsum discharging conveyor.

- Auxiliary Machine Room

  This building, which houses the oxidation air blowers and the air compressors, is arranged in the FGD installation area of Part II.

- Control and Electrical Room

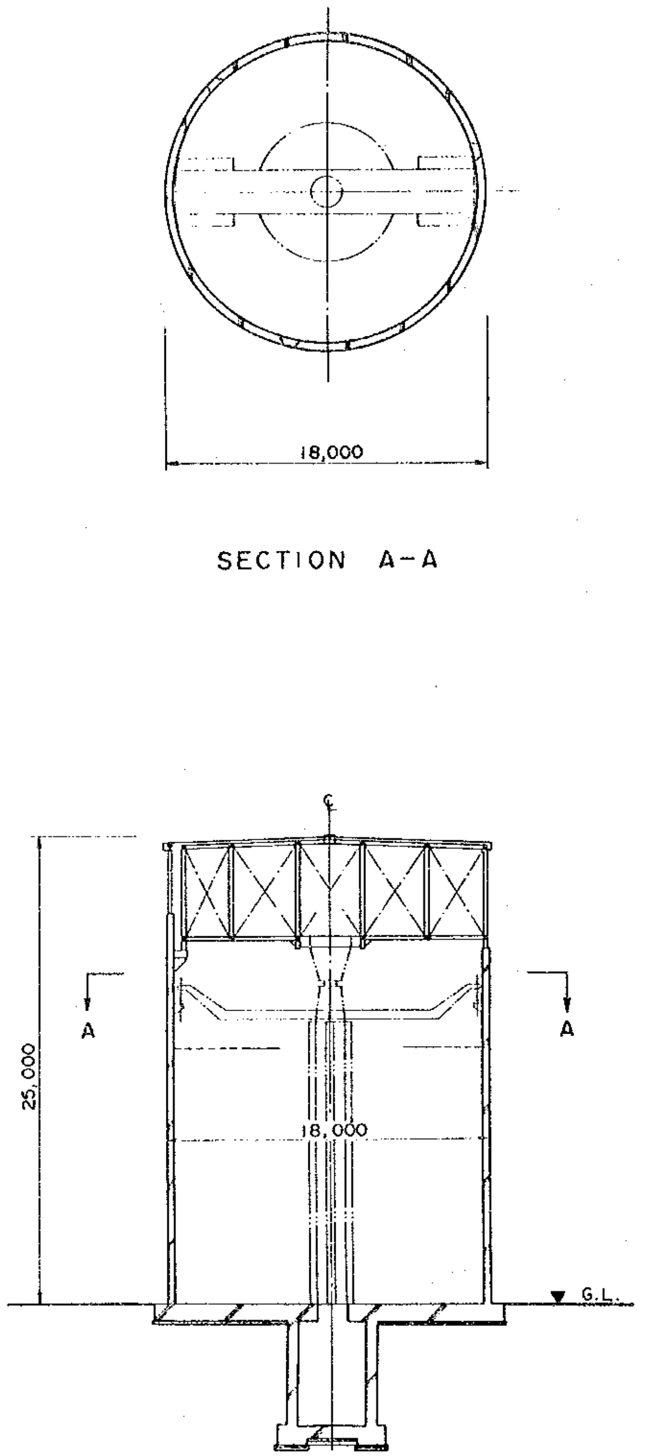
  This building, which houses control boards and electrical boards for Part II and III, is arranged nearby Part III in the FGD installation area of Part II.

- Limestone Milling Building

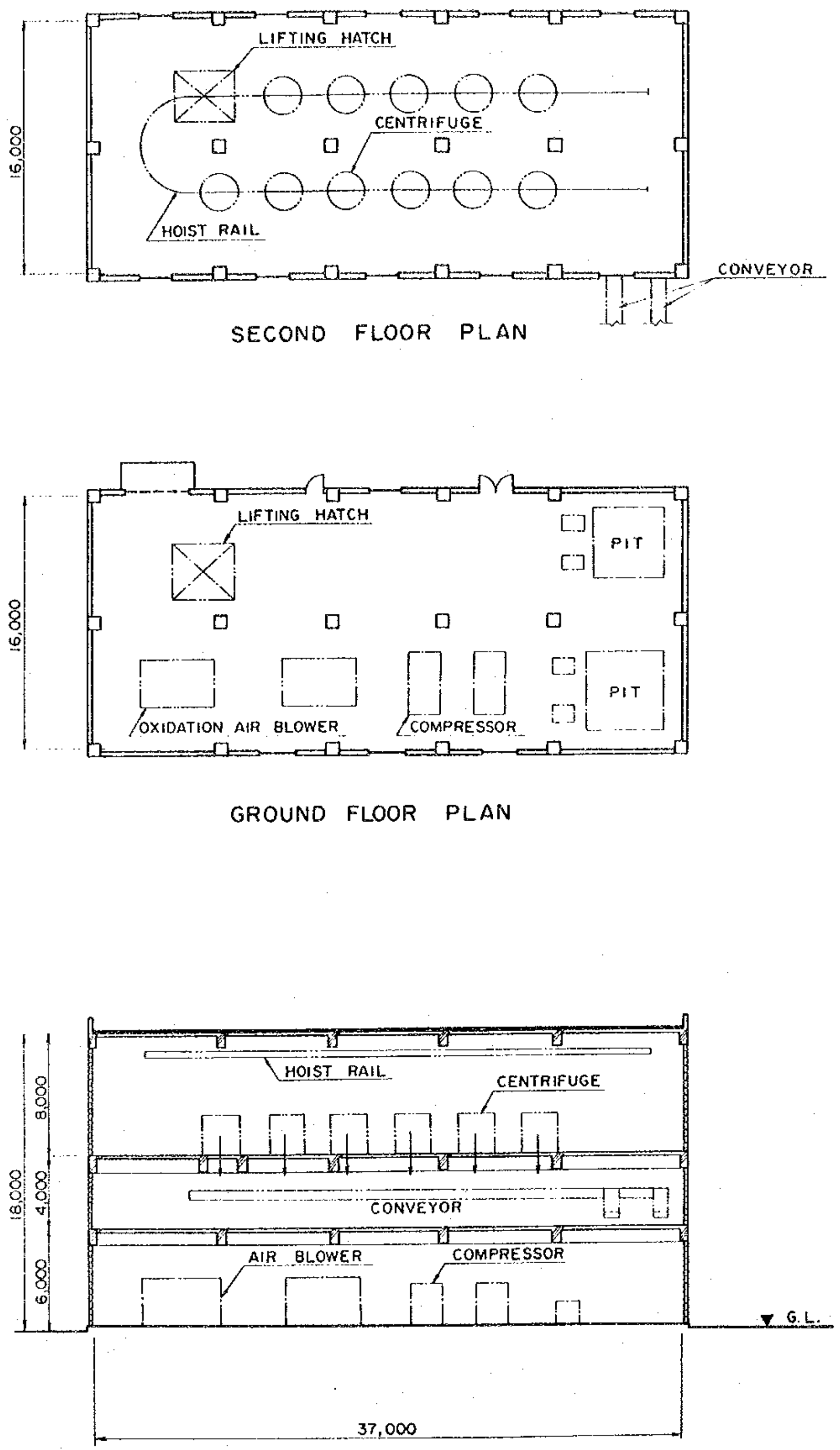
  This building, which houses three limestone mills and two slurry tanks, is arranged in the FGD installation area of Part III.

- Absorber Recirculation Pump Room

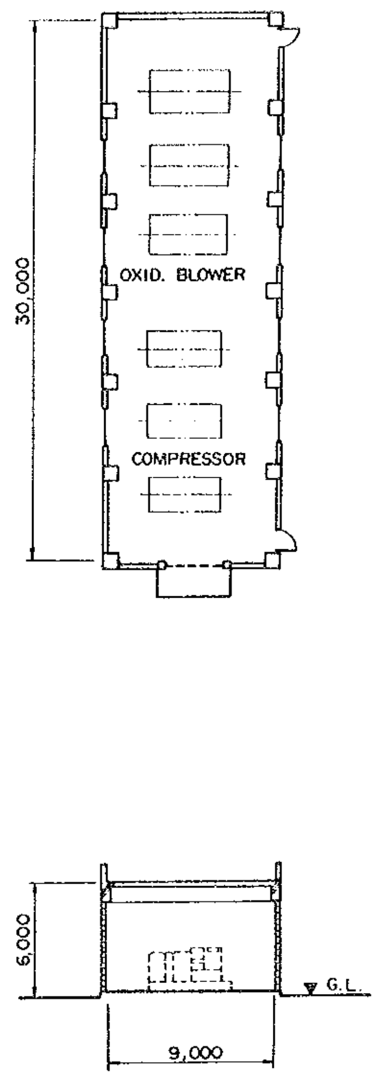
  Six buildings, which house absorber recirculation pumps, are arranged beside each absorber of Parts II and III.



GYPSUM SILO
SCALE 1 : 200



GYPSUM DEWATERING BUILDING
SCALE 1 : 200



AUXILIARY MACHINE ROOM
SCALE 1 : 200

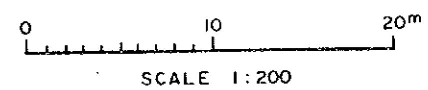


Fig.6.5-13
RELATED BUILDINGS (1/2)

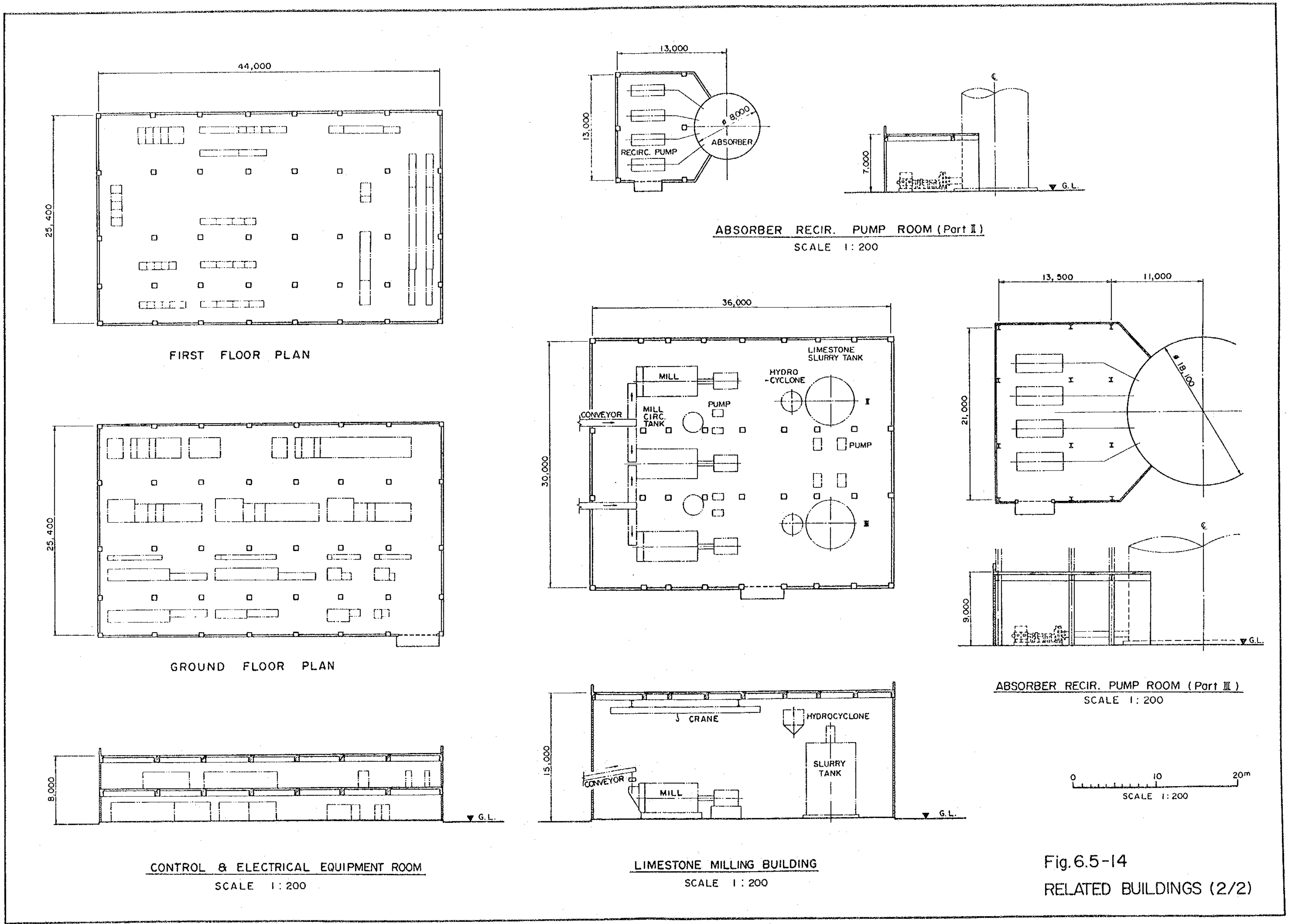


Fig. 6.5-14

RELATED BUILDINGS (2/2)

6.5.12 Foundation (Including Loading Data)

The required foundations are the following major equipment foundations and pits, duct supporting foundations, by-product conveyor foundations and cable trenches.

The loading data of main equipments and pits are as follows;-

[Part II]

• Absorber	1,000 ton x 4 units
• G.G.H.	400 ton x 4 units
• B.U.F.	120 ton x 4 units
• Slurry Holding Tank	2,200 ton x 1 unit
• Absorber Drain Pit	45 ton x 2 units

[Part III]

• Absorber	3,500 ton x 1 unit
• G.G.H.	600 ton x 2 units
• B.U.F.	200 ton x 2 units
• Slurry Holding Tank	2,900 ton x 1 unit
• Absorber Drain Pit	50 ton x 1 unit

[Common]

• Limestone Silo	700 ton x 1 unit
• Crushed Limestone Silo (II)	280 ton x 1 unit
• Crushed Limestone Silo (III)	350 ton x 1 unit
• Dump Pit	150 ton x 1 unit
• Transformer	70 ton x 2 units

The geological data of Melnik Power Station, which are described in Chapter 3, shows that comparative hard sand layer expands nearly upto ground surface. The above equipment load is planned to be supported on this sand layer through direct foundation.

At the time of definite design stage, it is necessary to execute structure drillings, etc. at Parts II and III areas and to confirm geological data.

6.6 Reconstruction of Existing Facilities

For installation of the FGDs, it is necessary to remove and transfer equipment existing in the installation space and reconstruct existing equipment which will connect with FGD plants.

Basic plans for such reconstruction, removal and relocation are described below.

6.6.1 Remodeling

(1) Duct

Reconstruction of existing collection duct is necessary to connect FGDs to existing power plant facilities.

For the case of Part II, common collecting method has been applied to the stack and the stack inlet duct, and it is planned to make remodeling of the common collecting duct inclusive of the closing damper to shorten the shutdown period of power plants to the extent possible during installation of FGDs.

Newly installed common ducts and duct works for FGDs are shown in Figs. 6.6-1 and 6.6-2, respectively.

The system configuration of ducts include dampers at inlet and outlet of each FGD for both Part II and Part III so that any FGDs can flexibly be separated from or connected to the flue gas system at maintenance or scheduled shutdown of FGDs. In addition, it is planned to use the collecting duct as a bypass duct so that operation failure of FGD will not affect the boilers. In addition, a bypass damper is installed to the bypass duct to prevent recirculation of flue gas for economical operation.

The bypass damper fully opens automatically, as soon as an FGD trips, to let the flue gas flow directly to the stack through the bypass duct, and thus keeps pressure variations low in the flue gas system to prevent such trips from affecting the boilers.

(2) Stack Lining

The flue gas temperature at stack inlet of Parts II and III is about 180°C at present, and is decreased till about 100°C after DeSOx installation. It is therefore planned to provide acid-resistant lining on inner surface of stacks due to harder corrosive condition with the lower flue gas temperature.

The inner surface of stack is consisting of ring-shaped bricks supported, heightwise, at 11 points (for Part II stack) and at 13 points (for Part III stack), and following considerations are required in the work of acid-resistant lining:

a. Adhesion of lining material to existing bricks and method of lining

b. Review of structural calculation for additional load

c. Shortening of the lining period (power plants of Parts II and III must be stopped during the lining work.)

(3) Electrical equipment

Electric power for FGD is obtained from existing auxiliary power system.

• Point of connection

Secondary 110-kV bus bar of the existing main transformer of Part II

• Method of connection

to the bus bar through a circuit breaker

• Required power source capacity

35 MVA

It is planned to install two 35-MVA FGD transformers so that they can back up each other, and thus no backing up by linking to existing M/C bus bar is required.

(4) Instrumentation

At least the following signal lines must be remodeled for connection between existing power plants and the FGD system:

a. Signals from Existing Power Plants to the FGD System

i. Generator output
ii. Gas volume at IDF outlet
iii. IDF control damper opening
iv. MFT signals
v. FDF breaker signals (both ON and OFF signals)
vi. IDF breaker signals (both ON and OFF signals)

b. Signals from the FGD System to Existing Power Plants

i. BUF breaker signals (both ON and OFF signals)
ii. FGD bypass damper signals (both Open and Close signals)
iii. SO_2 concentration at FGD inlet
iv. SO_2 concentration at FGD outlet
v. SO_2 concentration at Stack outlet

6.6.2 Other Interconnections

(1) Steam Piping

Steam pipings are required for GGH soot blowers, for prevention of freezing and for equipment warming

a. Point of Interconnection

At the common auxiliary steam header

b. Steam Pressure

15 kg/cm^2

c. Steam Requirement

4.5 t/h on average, 28 t/h maximum

6.6.3 Facilities to be Removed and Relocated

(1) Material Warehouse and Coal Train Defreezing Tunnel

The material warehouse and the coal train defreezing tunnel, existing at the FGD installation area for Part II, are removed and relocated. In moving the coal train defreezing tunnel, a full consideration is to be given also to rerouting of flue gas duct for supplying flue gas from boiler for defreezing.

(2) Ash-slurry Transportation Piping and Hot-water Supply Piping

The rack (about 470 m in overall length), supporting the ash-slurry transportation piping of Part III and the hot-water piping of Part I supplying hot-water to the city of Melnik, running through the FGD installation area is to be removed and rerouted. The route after moving must be the shortest route running around the space for installation of FGDs.

(3) Other Underground and Overhead Pipings and Power Cables

Other underground and overhead pipings and power cables such as those to the powerhouse, coal yard, coal conveyers and material warehouse are crossing the FGD installation area, and they must be moved paying full attention to the position of installation of FGDs and uses of such pipings and cables.

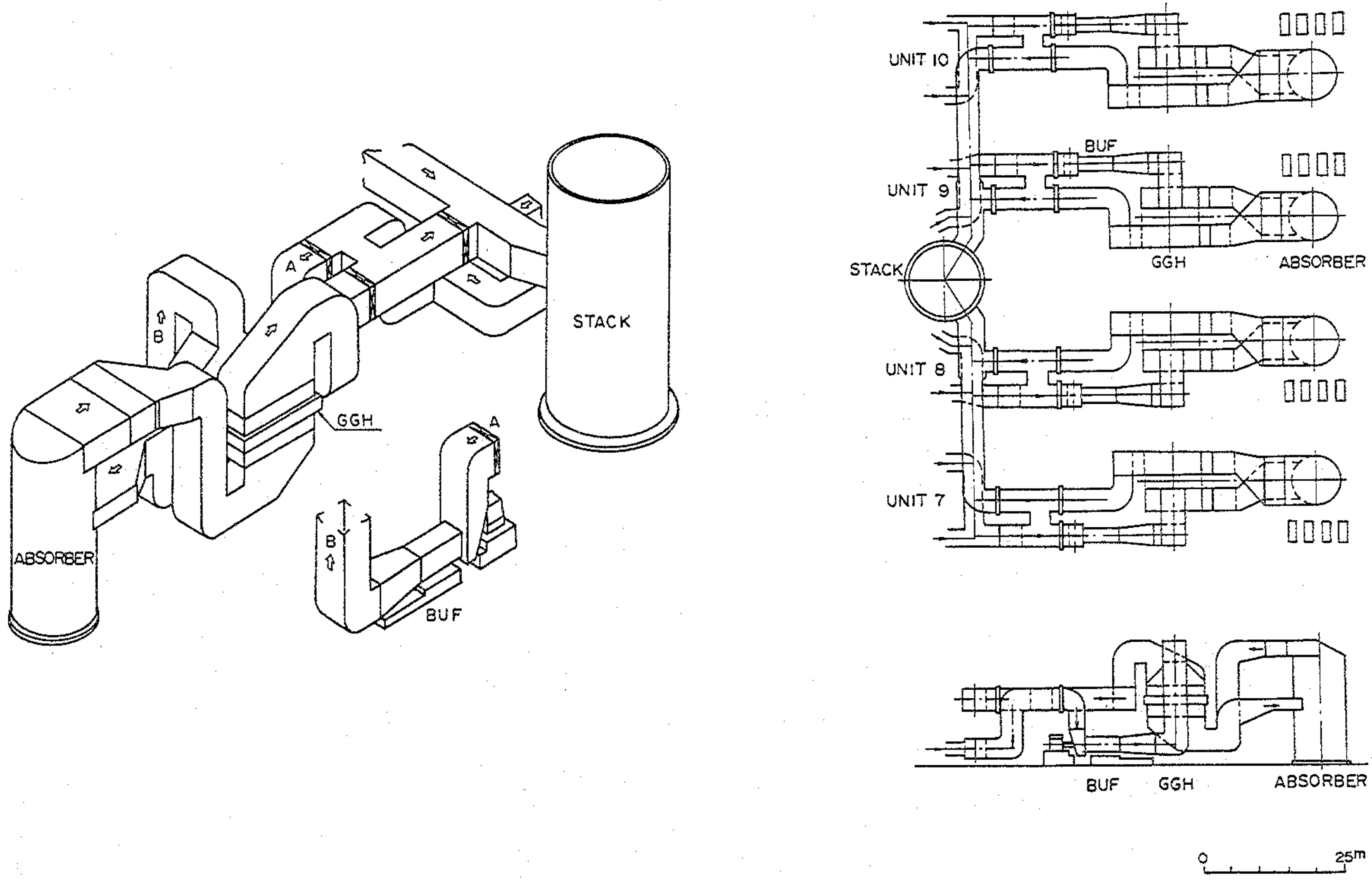


Fig. 6.6-1 PART II DUCT WORK ARRANGEMENT

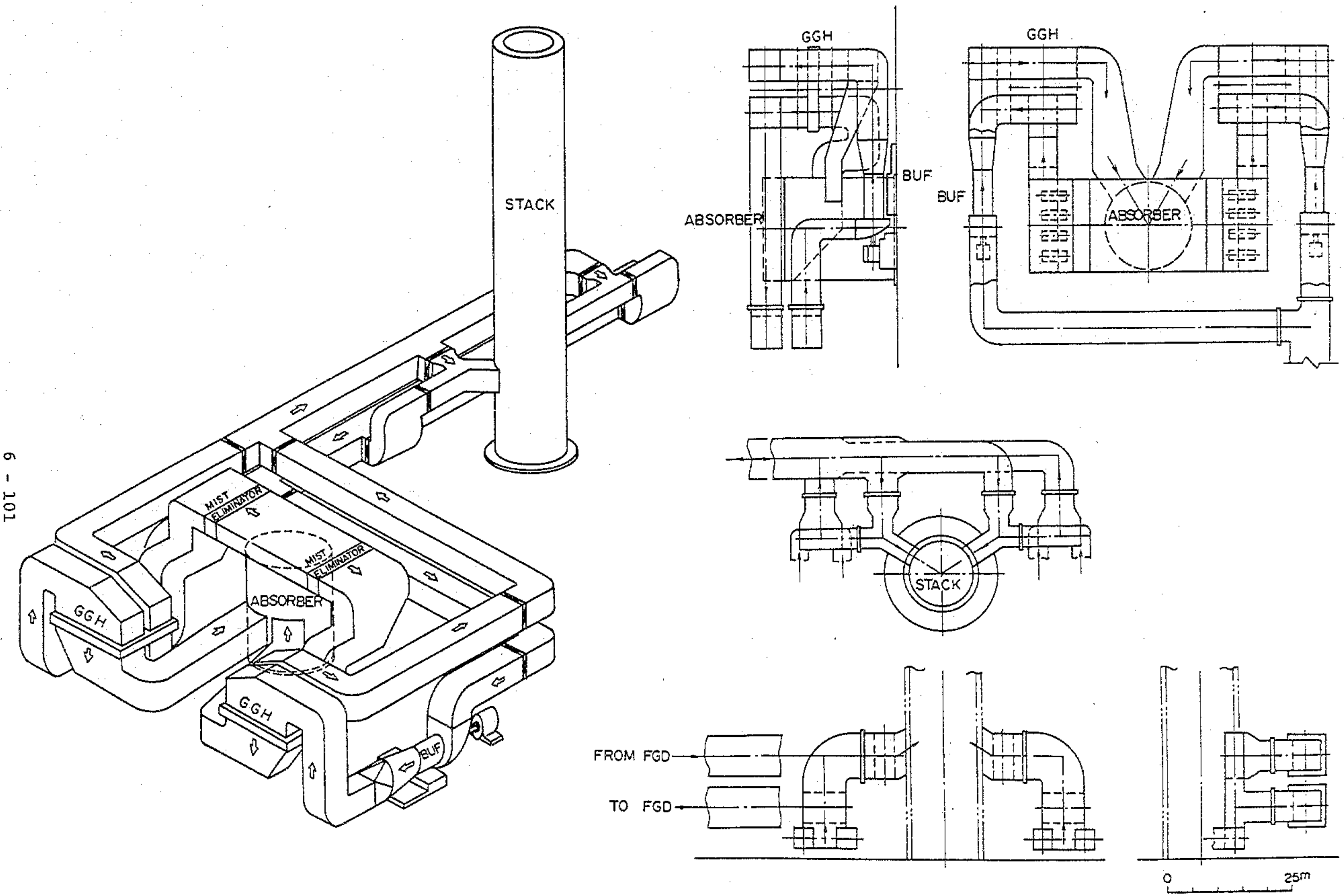


Fig. 6.6-2 PART III DUCT WORK ARRANGEMENT

Chapter 7　Project Implementation Programme

CHAPTER 7 PROJECT IMPLEMENTATION PROGRAMME

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Chapter 7 Project Implementation Programme

7.1 Plan for the Implementation Programme

A plan for the project implementation programme is shown in Table 7.1-1.

In order to start the commercial operation of FGDs of Part III and Units Nos. 9 & 10 of Part II on October 1, 1996, it is necessary to start the civil work for FGD system in the beginning of September 1994 and equipment installation in the beginning of May 1995.

In addition to that, there are other works such as preparation of tender document, evaluation of bidders and contract award for construction, and the plan is to be proceeded in the following schedule:

		Part III and Units Nos. 9 and 10 of Part II	Units Nos. 7 and 8 of Part II
(1)	Completion of the Feasibility Study	End of Dec. 1992	Same as left
(2)	Preparation of Financial Source	End of Jan. 1993	Same as left
(3)	Selection of Consultant	End of Mar. 1993	Same as left
(4)	Detailed Design and Preparation of Tender Documents	End of Nov. 1993	Same as left
(5)	Completion of Tender Evaluation	End of Apr. 1994	Same as left
(6)	Contract Award	End of Apr. 1994	Same as left
(7)	Commencement of Civil Work	Beginning of Sep. 1994	Beginning of Sep. 1996
(8)	Erection Start	Beginning of May 1995	Beginning of May 1997
(9)	Trial Operation Start	Beginning of Aug. 1996	Beginning of Aug. 1998
(10)	Taking Over	End of Sep. 1996	End of Sep. 1998
(11)	Commercial Operation Start	1st of Oct. 1996	1st of Oct. 1998

7.2 Construction Schedule

A planned schedule for construction of FGDs for Part III and units Nos. 9 and 10 of Part II is shown in Table 7.2-1 (1) and that for units Nos. 7 and 8 of Part II is shown in Table 7.2-1 (2). The construction schedules were prepared in consideration of the following:

(1) FGD system of Part III and those for units Nos. 9 and 10 of Part II must be available in commercial operation by October 1, 1996.

(2) In consideration of the start of operation of FGDs for units Nos. 7 and 8 of Part II, which is planned to be just two years after the start of other FGDs, it is planned to improve the overall economy by delaying the purchase of equipment for units Nos. 7 and 8 other than common equipment of Part II to the extent possible. In addition, it is planned to reduce the highest work loads of construction as much as possible.

(3) The reconstruction work of the existing duct of Part III is planned to be executed during the time of periodical inspection in 1995. In addition, the connecting work is scheduled so that the period of plant shutdown is as short as possible.

It should be noted that the power plant must be shutdown for about 1.5 months for the reconstruction work of the existing duct for connection of FGD at Part III.

As for Part II, the reconstruction of duct for connection of FGDs does not affect the operation of power plants much because installation of FGDs is to be carried out while the power plants are shutdown for their retrofit for cogeneration.

(4) The construction work proceeds in winter at a rate which is expected in summer.

Reconsideration is required if working efficiency lowers during the very cold period.

(5) It is planned to conduct the acid-resistant lining of stacks during the summer when power demand is low, or the shutdown time in 1995 in case of Part III, so that the work proceeds in parallel with the works for connection of FGDs to existing duct.

It should be noted that the power plant must be shutdown for 3 months with stack lining work.

Table 7.1-1 Schedule of Project Imprementation for DeSOx Installation of Melnik P.S.

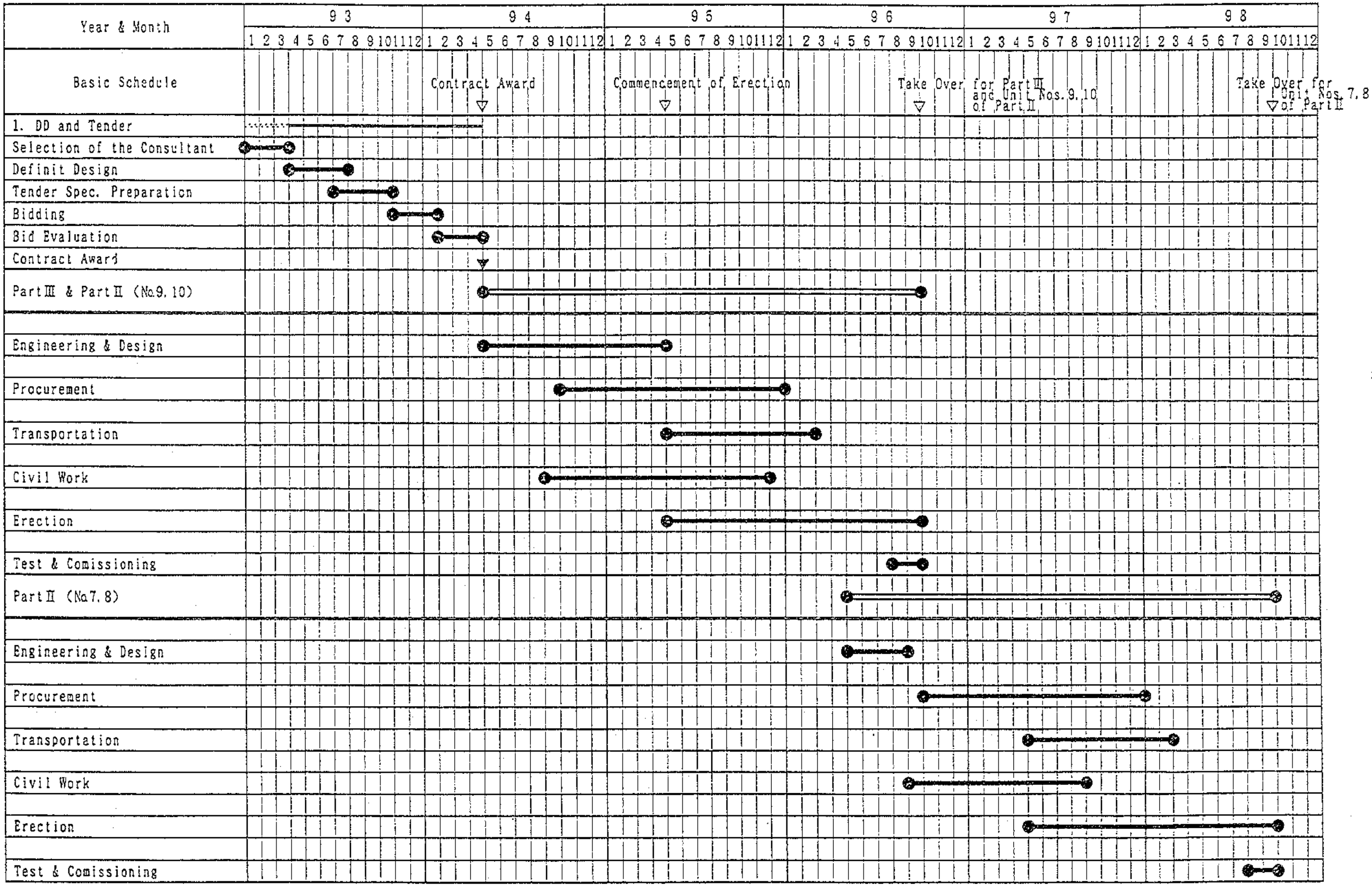


Table 7.2-1 (1) Unit No.11 FGD Plant and Common Facility Construction Schedule

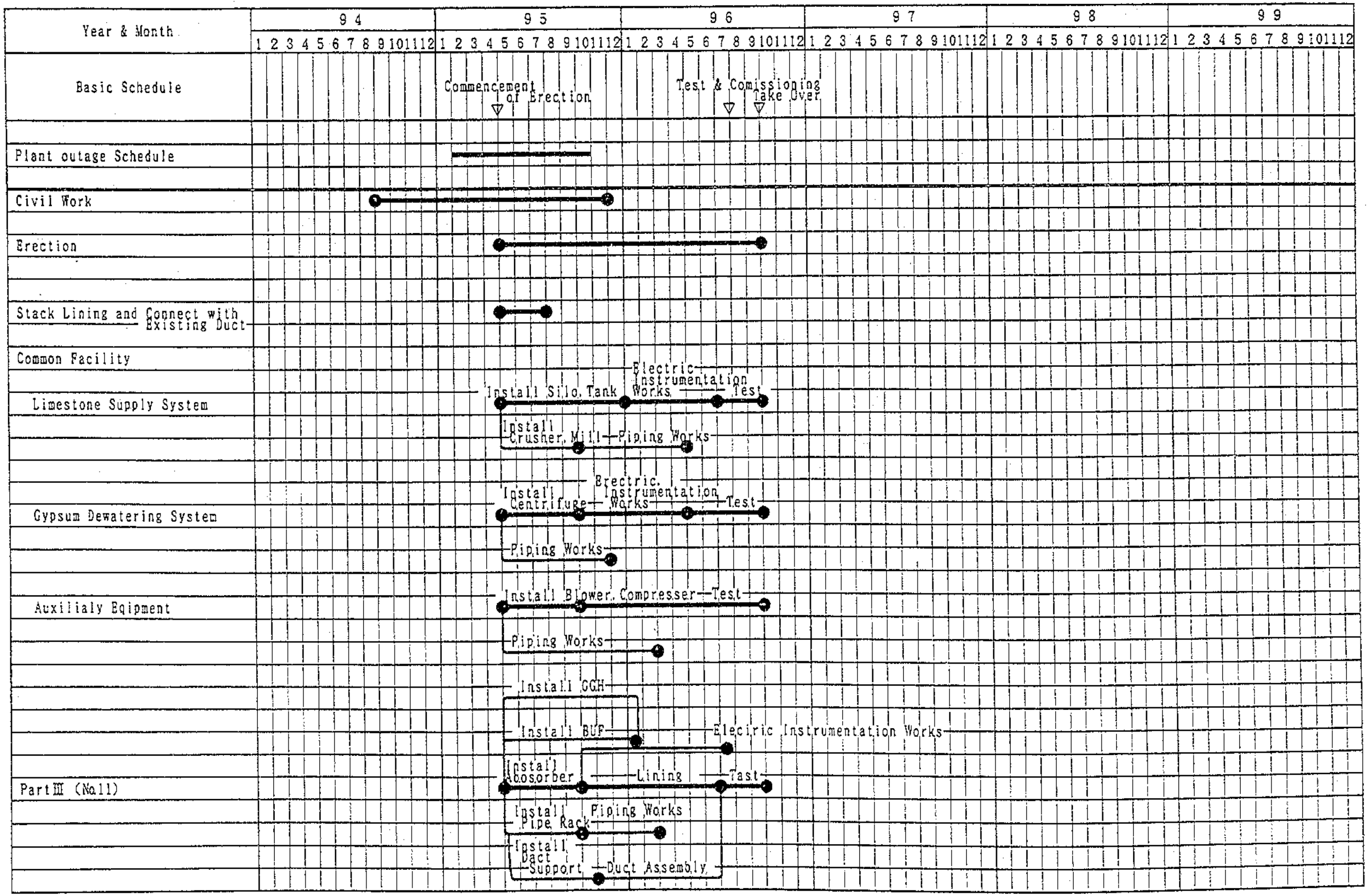
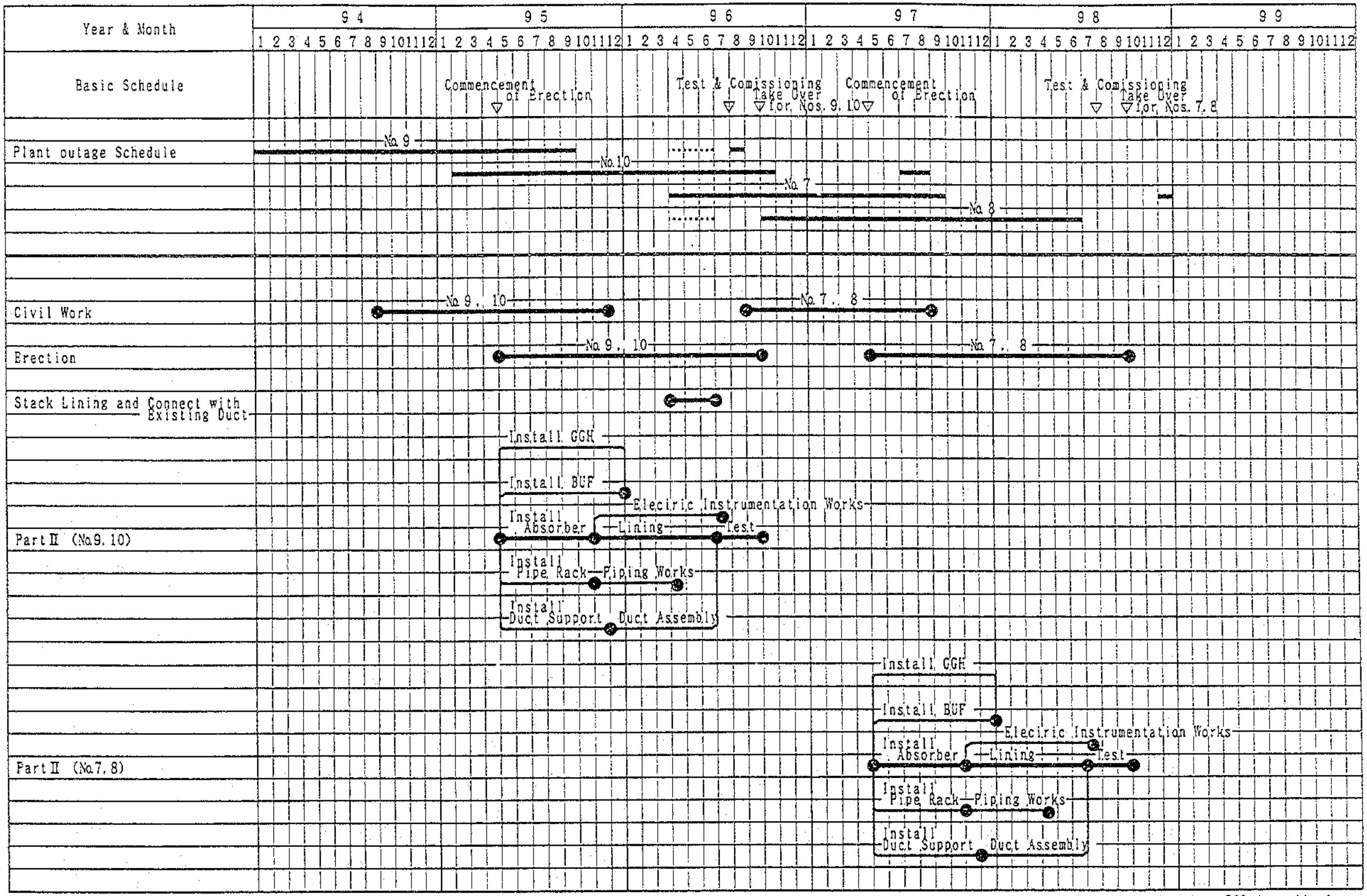


Table 7.2-1 (2) Units Nos. 7, 8 and Units Nos. 9, 10 Construction Schedule



Note : Dotted line described in the plant outage schedule means required outage related to FGD installation.

Chapter 8 Construction Cost and Operation and Maintenance Cost

CHAPTER 8 CONSTRUCTION COST AND O&M COST

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Chapter 8 Construction Cost and Operation and Maintenance Cost

The construction cost and operation and maintenance cost of 500 MW class FGD units for Part III and 4 x 110 MW class FGD units (with the capacity of 80% flue gas treatment) for Part II estimated based on the conceptual design of FGD system described in Chapter 6 are shown below.

8.1 Estimated Construction Cost

An estimated amount of construction cost for FGD units for Part II and Part III are shown below respectively. Estimated costs of respective equipment are shown in Table 8.1-1.

[Part II]

	x 10^3 kčs	x 10^3 US$
(1) DeSOx System and Associated Equipment	1,865,455	67,151
(2) Transportation	55,921	2,013
(3) Construction	187,209	6,739
(4) Civil Work	318,164	11,453
(5) Modification of Existing Facilities	140,317	5,051
(6) Spare Parts	37,364	1,345
(7) Start-up and Commissioning	38,003	1,368
(8) Import Tax	134,955	4,858
[Direct Construction Cost] (1)~(8)	[2,777,388]	[99,978]
(9) Engineering Fee [5% of Direct Const. Cost]	138,900	5,000
(10) Contingency [5% of Direct Const. Cost]	138,900	5,000
(11) Administration fee [5% of Direct Const. Cost]	138,900	5,000
[Total Construction Cost] (1)~(11)	[3,194,088]	[114,978]
[Construction Cost per kW]	[7,259 kčs/kW]	[261.3 US$/kW]

[Part III]

	x 10^3 kčs	x 10^3 US$
(1) DeSOx System and Associated Equipment	1,949,239	70,167
(2) Transportation	58,505	2,106
(3) Construction	195,627	7,042
(4) Civil Work	360,890	12,991
(5) Modification of Existing Facilities	15,112	544
(6) Spare Parts	39,086	1,407
(7) Start-up and Commissioning	39,725	1,430
(8) Import Tax	133,677	4,812
[Direct Construction Cost] (1)~(8)	[2,791,861]	[100,499]
(9) Engineering Fee [5% of Direct Const. Cost]	139,595	5,025
(10) Contingency [5% of Direct Const. Cost]	139,595	5,025
(11) Administration fee [5% of Direct Const. Cost]	139,595	5,025
[Total Construction Cost] (1)~(11)	[3,210,646]	[115,574]
[Construction Cost per kW]	[6,421 kčs/kW]	[231.1 US$/kW]

Table 8.1-1 (1) FGD Plants Construction Cost for Part II

Unit: x 10^3US$

	Item	Foreign Portion	Local Portion	Total
1	Absorber System	4,423	9,600	14,023
2	Limestone Slurry Supply System	31	3,133	3,164
3	Gypsum Dewatering & Recovery System	1,446	4,213	5,659
4	Draft System	12,258	11,154	23,412
5	Miscellaneous	39	1,010	1,049
6	Air Supply System	0	241	241
7	Electrical System	0	5,449	5,449
8	Control System	14,154	0	14,154
[9]	[Equipment Cost]	32,351	34,800	67,151
10	Transportation	0	2,013	2,013
11	Construction	1,368	5,371	6,739
12	Civil Work	1,391	10,062	11,453
13	Modification of Existing Facilities	0	5,051	5,051
14	Spare Parts	1,345	0	1,345
15	Start-up & Commissioning	1,368	0	1,368
16	Import Tax	0	4,858	4,858
[17]	[Direct Construction Cost]	37,823	62,155	99,978
18	Engineering Fee	5,000	0	5,000
19	Contingency	1,891	3,109	5,000
20	Administration Fee	0	5,000	5,000
[21]	[Total Construction]	44,714	70,264	114,978

Note (1) Spare Parts : Equipment Cost x 2%
(2) Import Tax : Foreign Portion x 15%
(3) Engineering Fee : Direct Construction Cost x 5%
(4) Contingency : Direct Construction Cost x 5%
(5) Administration Fee: Direct Construction Cost x 5%

Table 8.1-1 (2) FGD Plants Construction Cost for Part III

Unit: x 10^3US$

	Item	Foreign Portion	Local Portion	Total
1	Absorber System	5,293	9,911	15,204
2	Limestone Slurry Supply System	47	2,791	2,838
3	Gypsum Dewatering & Recovery System	1,578	4,804	6,382
4	Draft System	17,357	13,447	30,804
5	Miscellaneous	47	878	925
6	Air Supply System	0	233	233
7	Electrical System	0	6,016	6,016
8	Control System	7,765	0	7,765
[9]	[Equipment Cost]	32,087	38,080	70,167
10	Transportation	0	2,106	2,106
11	Construction	1,430	5,612	7,042
12	Civil Work	1,966	11,025	12,991
13	Modification of Existing Facilities	0	544	544
14	Spare Parts	1,407	0	1,407
15	Start-up & Commissioning	1,430	0	1,430
16	Import Tax	0	4,812	4,812
[17]	[Direct Construction Cost]	38,320	62,179	100,499
18	Engineering Fee	5,025	0	5,025
19	Contingency	1,916	3,109	5,025
20	Administration Fee	0	5,025	5,025
[21]	[Total Construction]	45,261	70,313	115,574

Note (1) Spare Parts : Equipment Cost x 2%
(2) Import Tax : Foreign Portion x 15%
(3) Engineering Fee : Direct Construction Cost x 5%
(4) Contingency : Direct Construction Cost x 5%
(5) Administration Fee: Direct Construction Cost x 5%

8.2 Conditions for Estimation of Construction Cost

(1) Time of Estimation July 31, 1992

(2) Exchange Rates

1) 1 Kčs = 4.634 yen
2) 1 US$ = 27.76 Kčs
3) 1 US$ = 128.7 yen

8.3 Scope of Estimation

The scope of estimation of the direct construction cost covers the items given below and includes equipment cost of the main units and associated equipment of the 500 MW class FGD unit for Part III and 4 x 110 MW class FGD units for Part II, installation and adjustment, trial operation, reconstruction of existing facilities, civil works, construction works, spare parts, transportation and import tax.

The scope of estimation of equipment and common facilities of FGD units cover items given below.

(1) FGD Main Unit

a. Absorber system
b. Limestone pre-treatment and slurry supply system
c. Gypsum dewatering and temporary storage system
d. Draft system
e. Miscellaneous (Related equipment)
f. Air supply system
g. Electrical system
h. Control system

(2) Reconstruction of Existing Facilities

a. Reconstruction of IDF outlet common duct (the cost is included in that of the draft system)
b. Reconstruction and remodeling of electrical facilities and instrumentation
c. Relocation of ash slurry transportation piping and district heating supply piping
d. Relocation of coal train defreezing tunnel and warehouse
e. Removal of railway tracks
f. Transfer of other underground and overhead pipings and cables, etc.

(3) Civil and Architectural Works

a. Foundation of FGD system
b. Ancillary buildings (Control and Electrical room, limestone storage and pretreatment house, gypsum storage silo, gypsum dewatering, air supply room and so on)
c. Foundation of ancillary buildings
d. Acid-resistant lining of Stack
e. Water-proofing of byproduct disposal area (corresponding to the volume of byproduct from Part II to be disposed over a period of 12.5 years)
f. Foundation of byproduct transport conveyer
g. Water acquisition station
h. Waste water treatment system

(4) Spare Parts

(5) Transportation Cost

(6) Import Tax

8.4 Engineering Fee

The engineering fee to be paid to consultant is estimated to be 5% of the direct construction cost on the basis of the scope of work itemized below.

(1) Preparation of Tender Documents
(2) Tendering Procedure
(3) Bid Evaluation
(4) Review of Approval Drawings and Documents
(5) Supervision of Construction Work
(6) Witness of the Taking over and Performance Tests

8.5 Operation and Maintenance Costs (O&M Costs)

(1) Annual O&M Costs

An annual O&M costs estimated based on unit labor and utility costs of 1992 is shown below. A breakdown of the operation cost is given in Table 8.5-1.

[Part II]

	$x\ 10^3$ kčs	US$
a. Utilities Cost	24,711,000	889,525
b. Labor Cost	2,275,000	81,893
c. Maintenance Cost	95,823,000	3,449,352
d. By-products Treatment Cost	9,175,000	330,274
[Total]	[131,984,000]	[4,751,044]

[Part III]

	$x\ 10^3$ kčs	US$
a. Utilities Cost	22,186,000	798,632
b. Labor Cost	1,553,000	55,904
c. Maintenance Cost	96,319,000	3,467,207
[Total]	[120,058,000]	[4,321,743]

(2) Conditions for Estimation of O&M Costs

Conditions applied to estimation of O&M costs are as follows:

a) Labors cost and utility costs are based on those prevailing in 1992.

b) Labors cost and utility costs were calculated from unit costs, in Czechoslovakia, obtained during field surveys.

c) Capacity Factor

The capacity factor of FGD system is assumed to be;

Part II : 58% corresponding to 5,081 hours of operation at rated load

Part III : 51% corresponding to 4,468 hours of operation at rated load.

Table 8.5-1 Operation Cost for FGD Plants

Part II

Item	Quantity (Per Year)	Unit Price (kčs/Unit)	Annual Cost ($\times 10^3$ kčs/Year)
1. $CaCO_3$ (96%)	46,526 (Tonns)	130	6,048
2. Electric Power	30,486 (MWh)	477	14,542
3. Make-up Water	574,153 (Tonns)	0.54	310
4. By-product Disposal	77,756	118	9,175
5. Steam	30,486 (Tonns)	125	3,811
[Sub-total]			[33,886]
6. Labor Cost	30.5 (man-year)	-	2,275
7. Maintenace Cost	-	-	95,823
[Grand total]			[131,984]
8. Cost/kWh	0.059 (kčs/kWh)		

Part III

Item	Quantity (Per Year)	Unit Price (kčs/Unit)	Annual Cost ($\times 10^3$ kčs/Year)
1. $CaCO_3$ (96%)	54,713 (Tonns)	130	7,113
2. Electric Power	30,163 (MWh)	436	13,151
3. Make-up Water	455,736 (Tonns)	0.54	246
4. Steam	13,404 (Tonns)	125	1,676
[Sub-total]			[22,186]
5. Labor Cost	20.5 (man-year)	-	1,553
6. Maintenace Cost	-	-	96,319
[Grand total]			[120,058]
7. Cost/kWh	0.0537 (kčs/kWh)		

Note 1. All of prices are based on July, 1992.
2. Carolific value of coal is to be 3,620 kcal/kg (Air Dry base).
3. Sulphur content of coal is to be 1.5% (Dry base).
4. Capacity factor is assumed to be 58% for Part II (5,081 hr. operation at full load) and 51% for Part III (4,468 hr. operation at full load).
5. Maintenance Cost: 3% of Direct Construction Cost

Chapter 9 Operation and Maintenance

CHAPTER 9 OPERATION AND MAINTENANCE

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Chapter 9 Operation and Maintenance

9.1 Methods of Operation

The FGD is started and stopped linked usually with start and stop of its power plant. When one FGD Unit is existing for one power plant (unit-to-unit FGD system), the FGD is started in the initial phase of starting the power plant, and the FGD starts its service before switching the fuel to coal. The FGD is stopped following boiler purging. The FGD system is started in the sequence of the absorbing system, the drafting system and the gypsum processing system. The FGD system is stopped, on the other hand, in the sequence of the drafting system, absorbing system and the gypsum processing system.

Fig. 9.1-1 shows starting and stopping timings of the unit-to-unit FGD system.

9.1.1 Start Up Procedure

(1) Preparations before Starting

a. Confirm that absorbent, make-up water and other utilities are available for operation.

b. Check each tank or pit to confirm that its liquid level is as specified. In addition, check pumps to confirm that priming and bleeding have been completed for them.

c. Check bearings of GGH, BUF, etc. to confirm that lubricating oil has been supplied to them.

d. Confirm that pH meters, SO_2 meters, level gauges and other meters have been calibrated.

e. Check valves and dampers of each system to confirm that they have been opened or closed forming the system properly.

f. Confirm that the power source for auxiliary equipment is in good order.

(2) Start Up Procedure

The FGD Units are started remotely from the Control Room. The FGD Units are started system by system sequentially by operating on the CRT of the Operation Desk. The starting flow chart is shown in Fig. 9.1-2.

9.1.2 Shut Down Procedure

The FGD Units are stopped system by system, from the Control Room, sequentially by operating on the CRT as in the case of starting. A stop mode is either a short-term stop mode or a long-term stop mode. In the short-term stop mode, all pumps of the slurry system other than absorber recirculation pumps and prescribing pumps are kept operated, for circulation, for prevention of clogging in pipings. In the long-term stop mode, all auxiliary equipment is stopped, and all pumps are subjected to replacement with clean water for prevention of slurry sedimentation and adhesion. At stopping for the periodical inspection, in addition, all liquid within the system is blown out.

A flow chart of the short-term stop mode is shown in Fig. 9.1-3.

9.1.3 Functions of Each System and Procedures of Ordinary Operation

(1) Absorbing System

a. Outline

The absorbing system is the main system of the FGD, and it is composed of a limestone slurry supplying section consisting of a limestone silos, linestone crushur, wet-type limestone mill, hydrocyclone, limestone slurry tank and limestone slurry supply pumps, and an absorbing and oxidizing section consisting of an absorber, absorber circulation pumps, oxidizing air blowers, etc.

Limestone discharged from a limestone silo is made into powder by crusher and wet-type limestone mill, classified by hydrocyclone and mixed and stirred with recovery water and replenishing water in limestone slurry tank to become limestone slurry. The limestone slurry is adjusted to a certain concentration. The slurry is sent to the absorber by slurry supply pumps via flow regulator valves.

In the absorber, the slurry staying at the bottom is pumped up by recirculation pumps and sprayed from upper part of the absorber to come down again to be recirculated. The sprays of slurry make contact with flue gas moving in the opposite direction and absorb SO_2 and remove dust as well from the flue gas in the process of coming down. Limestone produces calcium sulfite upon absorption of SO_2, and calcium sulfite turns to gypsum when oxidized by the oxidizing air being blown at the lower part of the absorber.

The two largest factors which determine the deSOx performance of operation in this absorption process are the ratio of circulating slurry volume to flue gas volume and the pH value of the slurry being circulated.

b. Volume of slurry circulated in absorber and the number of recirculation pumps in operation

For achieving required SO_2 and dust removal efficiencies, it is necessary to spray a volume of slurry which meets a necessary liquid-to-gas (L/G) ratio. The L/G ratio designed in this plan is 17.1 ℓ/m^3N for Part II and 16.1 ℓ/m^3N for Part III at absorbing section.

The number of recirculation pumps to be operated at the rated load operation is 4 in total; one each at the upper, middle and lower stages and one at the cooling stage, for both Part II and Part III.

The number of recirculation pumps in operation, however, can be reduced at the partial load operations, within the range where the above-mentioned L/G ratio is met, for reduction of auxiliary power. When the load is increasing, in addition, it is necessary to start recirculation pumps in advance to increase the volume of circulation ahead of the load curve for prevention of a transient lowering in efficiency.

Spray nozzles may clog, however, when the pump of a same stage is kept stopped for an extended period of time, and it is necessary to switch pumps to be stopped from time to time.

c. Control and monitoring of pH value of slurry circulating in absorber

The deSOx performance depends much on the pH value of slurry circulating in the absorber. The deSOx efficiency is lower when the pH value is low. When the pH value is high, the deSOx efficiency is higher, but not without adverse affects such as increase of limestone which remains without making the reaction. The pH value of slurry circulating in absorber is usually targeted at 5.5 for the single-tower in-situ oxidation system being employed for the system and in the range of 5.4 to 5.6 in actual operation. In addition, inlet and outlet SO_2 concentrations are monitored, and the pH value is controlled in a manner of achieving a required deSOx efficiency. The pH value of circulating slurry is controlled by adjusting the flow of limestone slurry by a regulation valve existing in the limestone slurry supply line.

d. Monitoring of gas temperature in absorber

An emergency spraying is started, for protection of absorber and stack lining, when the gas temperature gets high. If the gas temperature still rises, it is necessary to stop the BUF to cut off the gas flow. One of the possible causes of such temperature rise is lowering of the slurry spraying quantity, and it is necessary to assure an adequate number of slurry recirculation pumps in operation and monitor the quantity of slurry being sprayed.

In addition, it is effective, for preventing the emergency spraying valve from sticking and spray nozzles from clogging, to open and close the valve for testing periodically.

(2) Draft System

a. Outline

The draft system, which leads untreated flue gas to the absorber, reheats the flue gas after it is treated in the absorber, and sends the gas to a stack, consists of a BUF, GGH, bypass damper and ducts which link such components.

The BUF sends untreated, i.e., dirty flue gas from IDF outlet to the absorber through the GGH. (At Part II, the flue gas branches into two; the flue gas goes to BUF in one branch and to stack through bypass damper in the other branch.) The flue gas which is subjected to desulfurization and dust removing in the absorber goes from the outlet of absorber to the mist eliminator where mists are eliminated. After mist eliminator, the gas is sent to the GGH where it is reheated, by heat exchange with high temperature untreated gas, mainly for prevention of corrosion of ducts and stack. After the gas is heated again to over 90°C in Part II and over 100°C in Part III, the gas is returned to stack inlet. In Part II, the treated gas is mixed with untreated gas coming through the bypass line so that the gas temperature is over 100°C at stack inlet.

b. Draft control and monitoring

The draft system is usually controlled by opening of the damper at BUF inlet. At part III, corrections are made for pressure losses in the system using the gas volume at BUF inlet as a base, and the draft is controlled so that the pressure difference between before and after the bypass damper is constant. At Part II, the gas quantity sucked by BUF is controlled so that the concentration of SO_2 is below the predetermined level at the point of mixing of treated and untreated gases.

The pressure loss in the system increases when the mist eliminator or GGH gets clogged, and it is necessary to always pay attention to the pressure difference between inlet and outlet of the FGD.

c. Operation of GGH

What to be noted in operation of the GGH are staining and clogging due to mist and dust deposits, which follow a rise in differential pressure between GGH inlet and outlet, and a deterioration in heat transferring effects. It is therefore necessary to keep monitoring the differential pressure and carry out soot blowing periodically.

d. FGD Bypass Damper

The FGD bypass damper is fully opened, when it is impossible or unnecessary to operate the FGD, to let the power plant operate without the FGD. It is effective to test this damper for closing and opening periodically to ensure that the damper works without fail at emergency.

(3) Gypsum Recovery System

a. Outline

The gypsum processing system is a system where gypsum slurry generated by reaction of limestone with SO_2 in the absorber and extracted from absorber is dehydrated, stored and discharged for use or disposal. The system is composed of a dewatering section consisting of bleed pumps and centrifuges and a discharging section consisting of gypsum silos, reclaimers and gypsum conveyors.

b. Operation of dewatering section

Both bleed pumps and centrifuges are operated continuously. The supply of slurry to centrifuge is adjusted by the regulation valve. The slurry of about 20% in concentration is concentrated by the centrifuge to about 90% by dehydration. Water coming from centrifuge is collected in a recovery tank, and reused in the absorber or in the limestone supply tank as making up water.

c. Operation of discharging section

As of July 1992, it is planned to utilize about 100,000 tons of gypsum (water-containing gypsum) annually at a nearby gypsum board factory, and to dispose the rest. The same conveyor is used at discharging gypsum from gypsum silos for both utilization and disposal.

9.1.4 Performance Management

It is desirable to practice performance management in routine operations. One way to do so is to prepare and keep an operation log sheet having performance items and items necessary for judging operating conditions. The log sheet, when kept well, will be helpful for finding signs of troubles and taking measures against them.

Table 9.1-1 shows an example of the form of operation log sheet.

Table 9.1-1 Format of Operation Log Sheet

		Unit	1	2	3	---
Generator Output		MW				
Treated Gas Volume		m^3N				
SO_2 Density	DeSOx Inlet	ppm				
	DeSOx Outlet	ppm				
	Stack Inlet	ppm				
DeSOx Efficiency		%				
Gas Temperature	DeSOx Inlet	°C				
	DeSOx Outlet	°C				
Draft Pressure Difference (GGH)	Untreated Gas Side	mmAq				
	Treated Gas Side	mmAq				
pH in Absorber						

		Unit	Hourly	Daily	Monthly
Power Consumption		MWh			
Limestone Consumption		Ton			
Utility Consumption	Water	Ton			
	Air	m^3N			
	Steam	Ton			
	Chemicals	Ton			

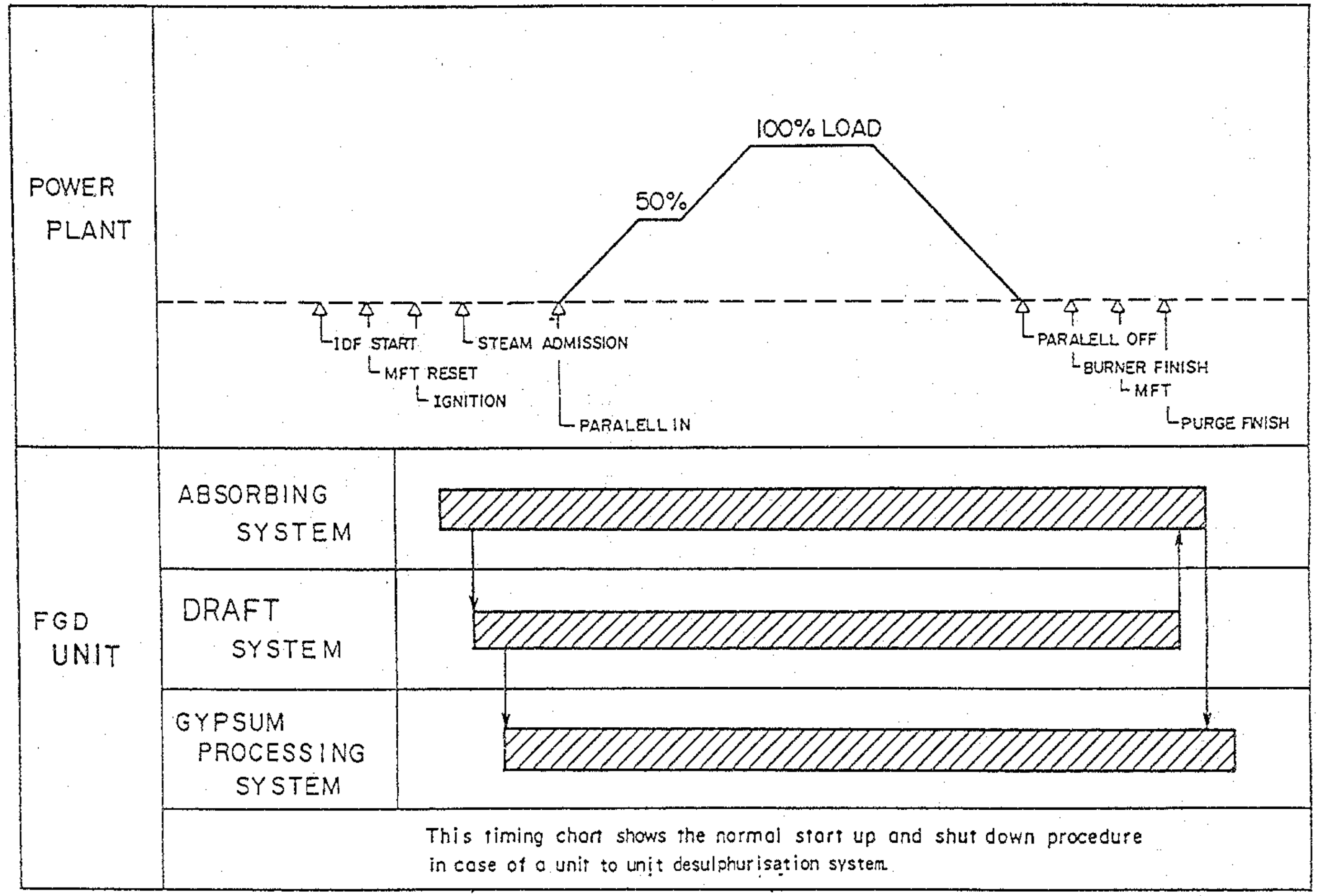

Fig.9.1-1 FGD UNIT START UP SHUT DOWN TIMING CHART

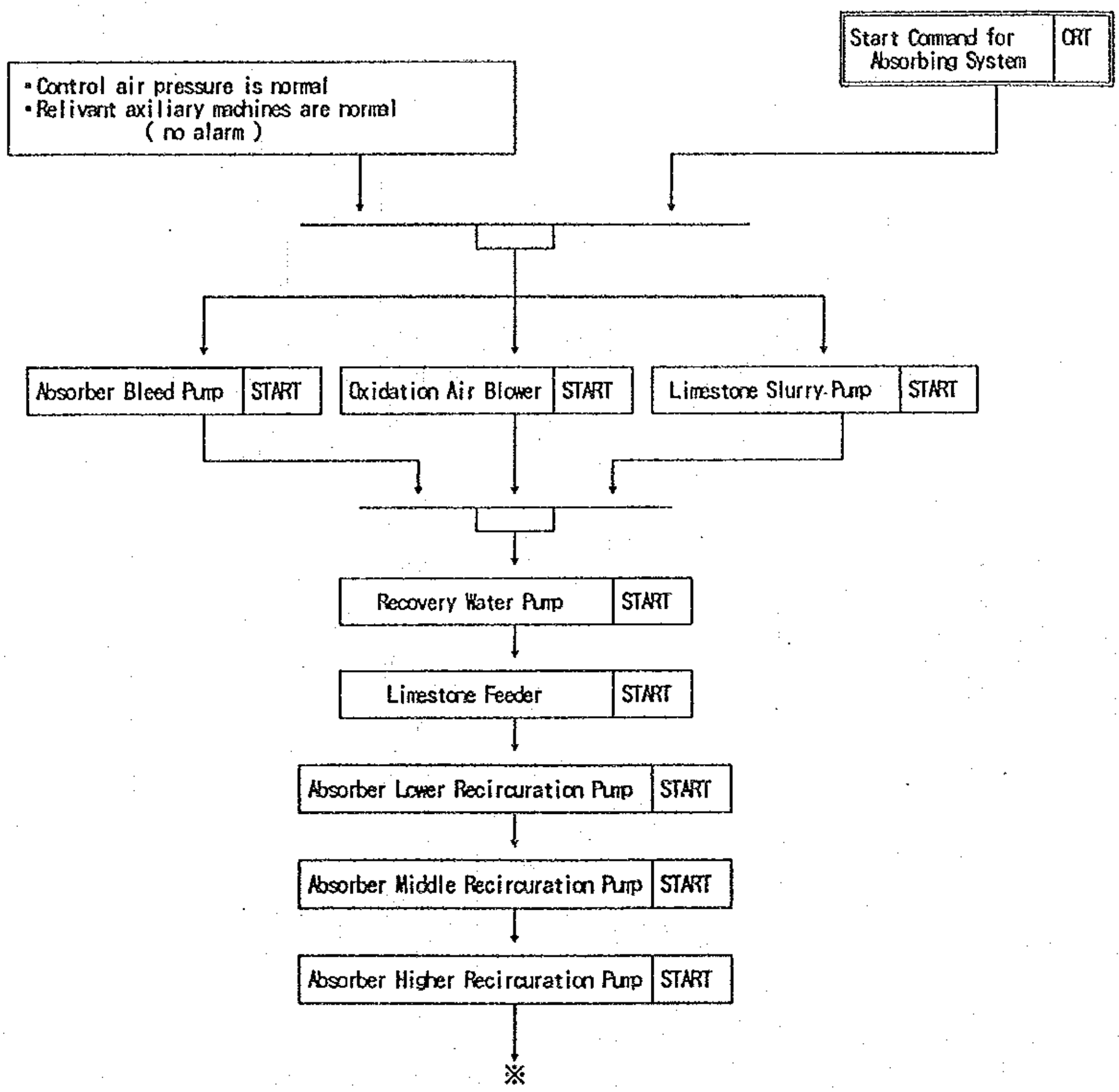

Fig. 9. 1−2 FLOW CHART OF START UP PROCEDURE (1/2)

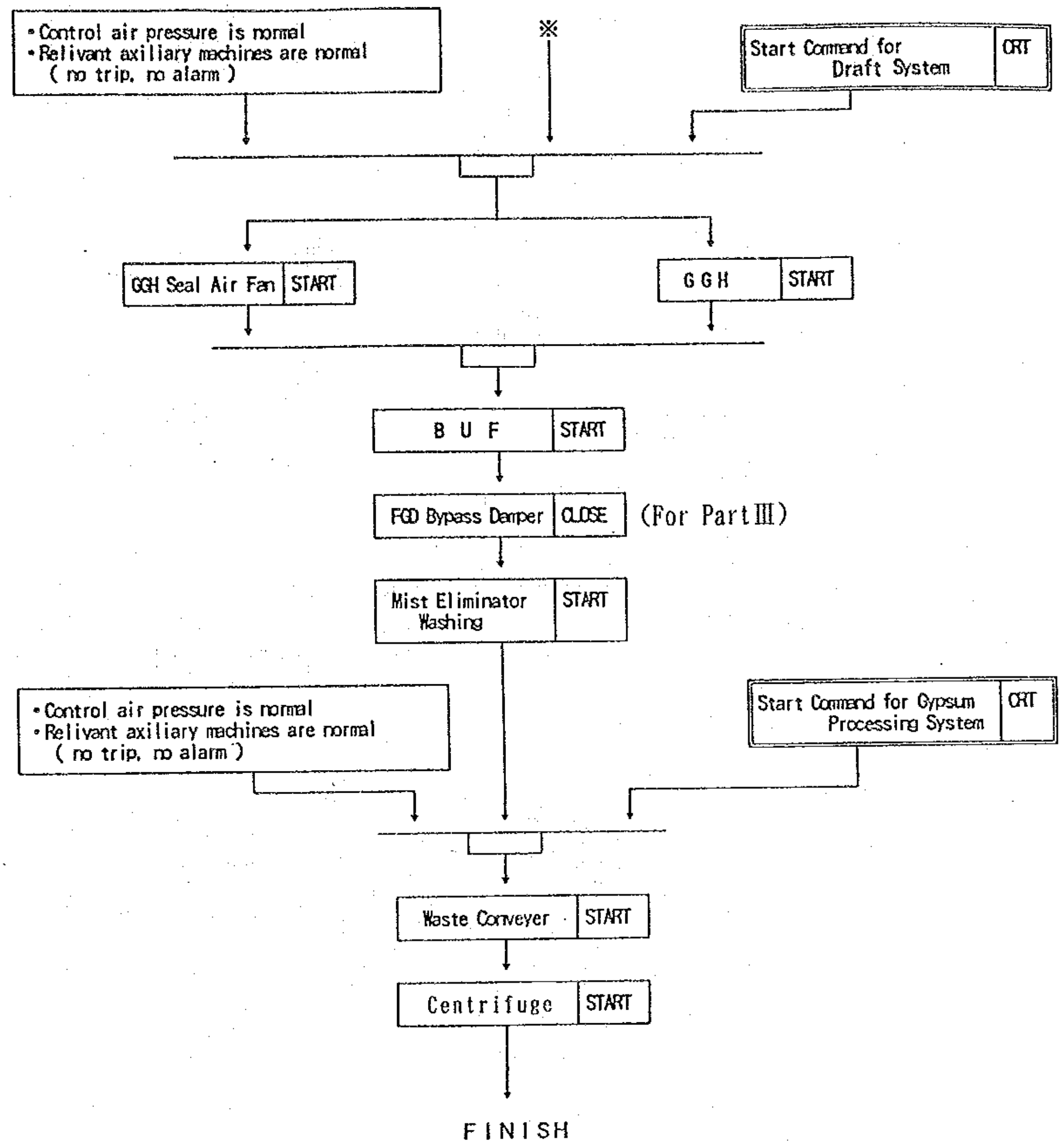

Fig. 9. 1-2 FLOW CHART OF START UP PROCEDURE (2/2)

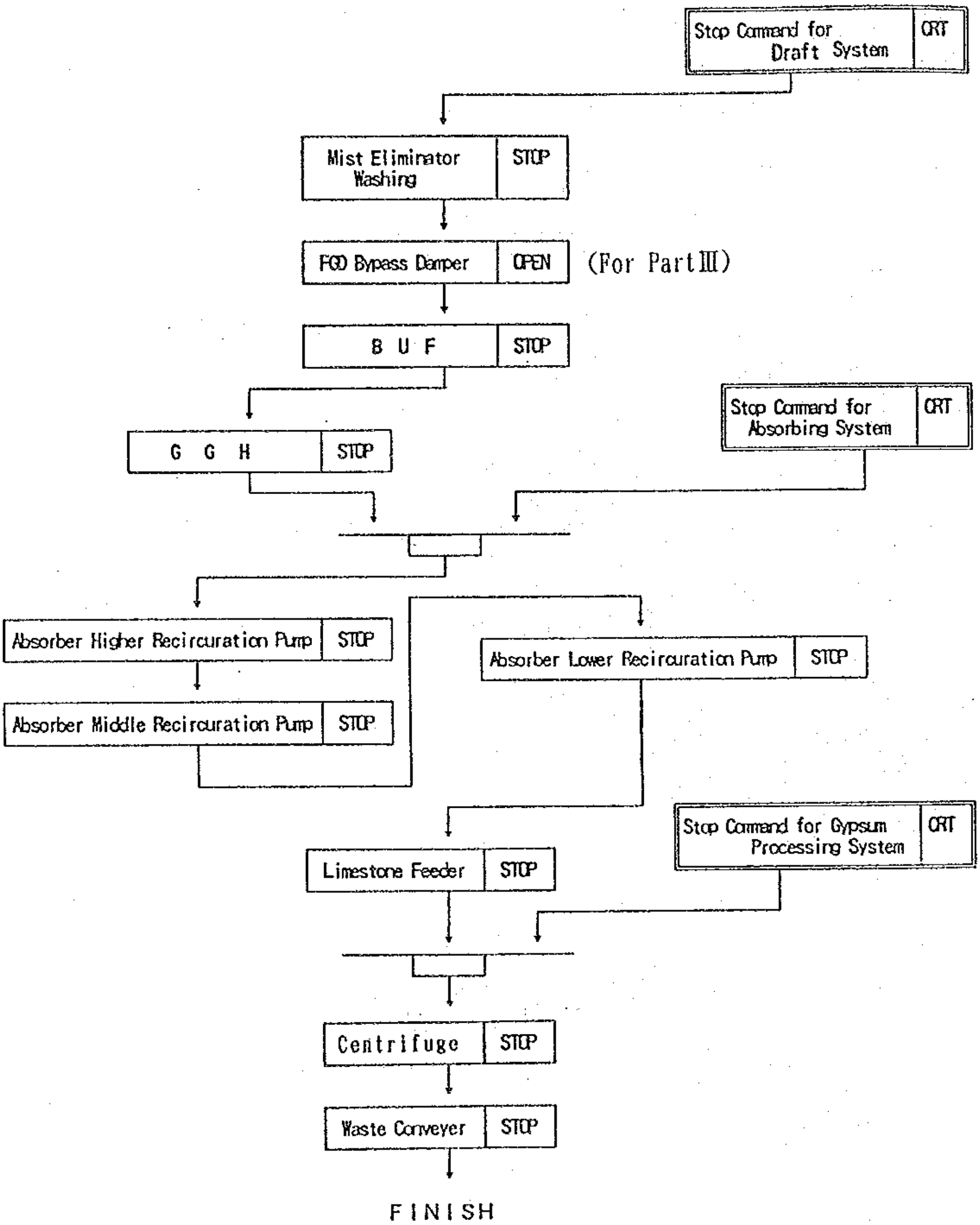

Fig. 9. 1-3 FLOW CHART OF SHUT DOWN PROCEDURE
(SHORT TERM STOP MODE)

9.2 Maintenance Procedures

In addition to keeping monitoring the operating condition in the control room, it is desirable to patrol, at each shift, the field to check for equipment troubles. For patrolling, it is desirable to prepare a check sheet considering the route of equipment inspection, inspection frequency, points of inspection, points of special observation, etc., and patrol the field according to the check sheet. Table 9.2-1 shows an example of check sheet.

The FGD must be stopped once a year for periodical inspection. In the FGD, especially, gypsum sedimentation and clogging possibly occur in the tower, tanks, pumps and pipings, and it is necessary to remove and clear such sedimentation and clogging in addition to overhauling of each equipment.

9.2.1 Maintenance during Ordinary Operations

As for maintenance during ordinary operations, it is desirable not only to monitor operating conditions in the control room but also to patrol the field at each shift to keep operations of each equipment checked. In addition, it is necessary to carry out, at definite intervals such as once a week or once a month, operation tests of auxiliary equipment which do not normally operate and calibration of pH meters and SO_2 meters.

Points to be specifically noted in monitoring of ordinary operations and patrolling are as follows:

(1) Scaling and clogging in pipings. Attention must be paid to the fact that limestone which does not undergo the reaction increases and scaling tends to occur easily especially when the pH value of the absorbent slurry is high.

(2) Special attention must be paied to clogging in spray nozzles and pipings in the absorber. Clogged spray nozzles and pipings causes deterioration in deSOx performance. In addition, the amount of absorbent slurry being circulated in the absorber decreases also. It is therefore necessary to carefully monitor the amount of absorbent slurry being circulated.

(3) Attention must be paied to scale deposits in the mist eliminator existing at the absorber outlet. The draft pressure loss increases as scale deposits increase in the mist eliminator causing a greater load on the BUF. It is therefore necessary to keep an eye on the pressure difference between absorber inlet and outlet, and take actions such as washing the mist eliminator more often when clogging is anticipated.

(4) Be careful about shaft vibrations in the BUF. Possible causes of shaft vibrations are the BUF blades which were worn due to dust in the flue gas and dust deposits on the BUF blades.

Table 9.2-2 shows major maintenance items to be executed periodically and their periods and descriptions as well.

9.2.2 Maintenance at Periodical Inspection

Each FGD must be stopped once a year to overhaul its equipment. At such periodical inspection, the FGD must be stopped, and dampers at absorber inlet and outlet must be closed to cut off the FGD completely from the boiler. Table 9.3-3 gives standard maintenance items of periodical inspection and their descriptions.

Each unit is tested and adjusted after inspection and repairs, if any. When individual tests are over, a trial operation is carried out in steps of system tests and total FGD plant test. The inspected FGD is put into service following the last interlock test in which the FGD is tested linking with the boiler.

Table 9.2-1 FGD System Check List

No.		Name	Spare	Set Value	1	2	3
1	Absorber	Absorber					
2		FGD Make-Up Water Pump					
3		Absorber Lower Recirculation Pump					
4		Absorber Upper Recirculation Pump					
5		Absorber Bleed Pump					
6		GGH Inlet Mist Eliminator Recovery Pump					
7		Absorber Mist Eliminator					
8		GGH Inlet Mist Eliminator					
9		Absorber Agitator					
10		GGH Inlet Mist Eliminator Recovery Pit Agitator					
11	Draught	Boost Up Fan (BUF)					
12		BUF Variable Speed Joint					
13		BUF Cooling Oil Pump					
14		BUF Cooling Oil Pressure (kg/cm^2)		3.0			
15		BUF Control Oil Pump					
16		BUF Control Oil Pressure (kg/cm^2)		9.0			
17		GGH					
18		FGD Inlet Damper					
19		FGD Outlet Damper					
20		Duct					
21	Absorbent	Limestone Mill					
22		Limestone Crusher					
23		Limestone Feeder					
24		Limestone Slurry Service Pump					
25		Limestone Conveyor					
26	Gypsum Production	Oxidizing Gypsum Tank					
27		Centrifuge Filtrate Pump					
28		Centrifuge					
29		Gypsum Dehydrator Oil Pump					
30		Oxidizing Air Compressor					
31		Gypsum Dehydrator Vent Gas Fan					
32		Oxidizing Tower Service Pump					
33	Gypsum Production	Naturalization Tank Service Pump					
34		Gypsum Conveyor					
35		Blow Down Pump					
36		Gypsum Dehydrator Service Pump					
37		FGD Sulfuric Acid Pump					
38		Oxidizing Tower Service Tank Agitator					
39		Oxidizing Tower Atomizer					
40		Neutralization Tank Agitator					
41		Gypsum Dehydrator Service Tank Agitator					
42		Gypsum Dehydrator Discharge Liquid Pit Agitator					
43	Others	Make Up Water Tank					
44		Caustic Soda Pump					
45		GGH Washing Water Pump					
46		GGH Washing Water Drain Pump					
47		Emergency Blow Down Tank Feed Pump					
48		Absorption System Drain Pump					
49		Gypsum System Drain Pump					
50		FGD Reagent Yard Drain Pump					
51		GGH Washing Water Pit Agitator					
52		FGD Emergency Blow Down Tank Agitator					
53		Absorption System drain Pit Agitator					
54		Gypsum System Drain Pit Agitator					
55		FGD Control Air Compressor					
56		FGD Shaft Sealing Fan					
57		Process Pipes					
58		Make-Up Water Pipes					
59		Waste Water Treatment System					
60		Control Air Pipes					
61		Service Air Pipes					
62		Service Water Pipes					
63		Sealing Water Flow					
64		M/C, P/C, C/C, Switch Gears					

Table 9.2-2 Inspection Items of Periodic Maintenance

Item	Inspection Frequency	Description of Inspection	Ramarks
1) Inspection and calibration of pH meter	Once per 2 weeks	a. Removal of scales, and washing b. Calibration c. Adjustment of sample flow d. Addition of reagents	Provide an automatic washer for prevention of scaling
2) Inspection and cleaning of gas flow meter	Once per 3 months	a. Removal of gypsum, dust, etc., and cleaning b. Replace damaged parts (which are worn, corroded, etc.) c. Inspect and adjust the purging air and washing water functions	Provide a purging device for prevention of clogging
3) Inspection and cleaning of limestone silo level gauge	Once per 3 months	a. Cleaning b. Calibration	
4) Purging of gas draft detection tubes	Once per month	a. Purging and cleaning of detection piping b. Adjustment of flow rate of the air purging equipment	
5) Inspection and calibration of slurry concentration meter	Once per month	a. Removal of scaling, and cleaning b. Calibration	
6) Inspection and calibration of SO_2 meter	Once per week	a. Removal of clogging in sampling mechanism, and cleaning b. Replacement of consumables c. Replacement of malfunctioning components d. Confirmation of remaining standard gas for calibration and replace if not remaining much e. Calibration	
7) Inspection and cleaning of level gauge	Once per month	a. Purge the detection piping for cleaning b. Adjust the volume of water for purging	Provide a water purging device for prevention of scaling
8) Bypass damper Open/Close test	Once per 2 weeks	a. Operate the bypass damper actually to make sure that it will open without fail in case of emergency	The bypass damper is kept closed during ordinary operation
9) Absorber emergency spraying valve Open/Close test	Once per 2 weeks	a. Operate the emergency spraying valve actually for a short time to make sure that it will operate without fail in case of emergency	The emergency spraying valve is kept closed during ordinary operation

Table 9.2-3 Maintenance Items of Periodical Inspection

(1/3)

Item	Description
1. Mechanical Equipment	
(1) Absorber, tanks and pits	a. Drain, and open manholes. b. Inspect inside (for deposits, damage, cracks, wears, erosion, deformation, etc.) and repair. c. Clean inside. d. Replace gaskets of manholes, etc. e. Inspect and repair internal equipment. f. Inspect and repair the lining. g. Inspect and clean nozzles.
(2) Pumps	a. Disassemble, inspect and clean. b. Inspect and clean strainers. c. Replace bearings. d. Replace gaskets such as packings, O rings and oil seals. e. Change the grease.
(3) Ducts	a. Open manholes. b. Inspect inside (for deposits, damages, cracks, wears, erosions, deformation, etc.) and repair. c. Remove ash (Wash with water as necessary). d. Inspect and clean expansions.
(4) Dampers	a. Inspect and clean. b. Change the grease.
(5) Boost-up fans	a. Overhaul the casing. b. Overhaul the blades. c. Unlock and inspect couplings. d. Overhaul bearings (Replace them as necessary). e. Overhaul hydraulic units. f. Drain oil tanks, and clean inside. g. Change the lubricant. h. Replace packings, seals and other gaskets. i. Inspect each component for wears, damages, cracks, etc., and repair it as necessary.
(6) GGH	a. Inspect elements of each layer for ash deposits and damages. b. Wash elements with water. c. Disengage and inspect each element. d. Inspect inside (including baskets, seals and rack gears). e. Overhaul and clean the lubrication unit. f. Replace gaskets of the lubrication system. g. Overhaul the drive unit. h. Overhaul the air motor. i. Overhaul the soot blower.

Item	Description
(7) Pipings (of absorbent slurry and gypsum system)	a. Disconnect pipings and inspect inside. b. Check orifice dimensions. c. Clean strainers.
(8) Pneumatic drives and valves	a. Disassemble pneumatic drives and valves, and replace O rings, packings, bushes, etc., as necessary. b. Inspect seat surfaces at linkages between valve unit and shaft. c. Add grease. d. Inspect, adjust and clean each component.
(9) Motor-operated valves	a. Inspect outside, adjust and clean. b. Inspect the valve, coupling of shaft and seat surfaces. c. Adjust actuator limit switches.
(10) Conveyers	a. Clean the points of inspection b. Inspect the chute, belt, roller, scraper, belt cleaner, skirt rubber, etc. for wears and erosions. c. Change the grease.
(11) Oxidizing air blowers	a. Overhaul the air blower and its lubrication system. b. Inspect the drive shaft of the step-up gear for flaws, wears and tooth bearing. c. Change the grease.
(12) Silos	a. Inspect and clean inside. b. Overhaul discharging unit. c. Replace packings. d. Change the grease.
(13) Wet-type mill	a. Overhaul and cleaning. b. Inspection and replacement of bearings of driving units. c. Change the lubricating oil. d. Inspection of wears in mill balls and replacement of mill balls.
(14) Other machines	a. Overhaul and clean each machine. b. Inspect bearings and replace them as necessary. c. Replace packings, O rings, seals and other gaskets. d. Change the lubricating grease.

Item	Description
2. Electrical Equipment	
(1) Switchgears	a. Inspect inside and clean. b. Check insulations. c. Check sliding portions for wears, deformation and damages. Lubricate as necessary. d. Check contacts for wears. e. Retighten terminal bolts and nuts. f. check relay operations.
(2) Transformers	a. Inspect and clean each part. b. Check for loose bolts, and retighten them. c. Check insulation.
(3) Motors	a. Overhaul and clean the motor. b. Replace bearings. c. Check insulation.
(4) Batteries	a. Inspect outside, and clean. b. Check the electrolyte level, voltage and measure the specific gravity of electrolyte.
(5) Panels and others	a. Inspect and clean inside. b. Retighten terminal bolts. c. Check insulation
3. Control and Instrumentation Equipment	
(1) Indicating recorders	a. Change consumables. b. Make calibrations.
(2) Transmitters, detectors and analyzers	a. Inspect and clean. b. Make calibrations. c. Carry out maintenance items which are made during ordinary operation.
(3) Controllers	a. Inspect inside the panel, and clean. b. Check terminals and plug-in connectors. c. Check the power supply unit. d. Carry out control tuning.

Chapter 10 Analysis and Evaluation on Socio-economic Impact

CHAPTER 10 ANALYSIS AND EVALUATION ON SOCIO-ECONOMIC IMPACT

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Chapter 10 Analysis and Evaluation on Socio-economic Impact

10.1. Analysis on the Impact on Electricity Tariff

10.1.1 Methodology and Basic Condition

(1) Methodology

When investment is made, such cost shall be recovered together with fair return and operation and maintenance cost which is necessary to enable such investment to be recovered.

Especially in case of electric power industry, this principle should be observed from the view point of sound corporate management.

In this project, as DeSOx system generates no profit, recovery of profit is not required and the level of electricity tariff shall be so established that investment cost and operation and maintenance cost shall be recovered through such electricity tariff.

Cost related to investment includes depreciation cost and interest to be repaid, and operation and maintenance cost includes personnel cost, repair cost, industrial chemicals related to operation of DeSOx system.

Tariff applicable to the project is calculated as follows.

$$\text{Tariff} = \frac{\text{Total Annual Cost}}{\text{Annual Net Generation}}$$

(2) Calculation of Construction, Operation and Maintenance Costs

1) Financing

Because, as stated above, this project will produce no profit, its financing cost must be obtained at the lowest interest rates possible. It is accordingly believed necessary to acquire the foreign currency portion of the funds from overseas governmental fund.

The domestic portion of the funds, on the other hand, ought to be procured on the premise of being available at interest of 10 percent to 15 percent. This is based on the following factors: (1) the interest of the long-term loan that CEZ has from National Bank is 15 percent to 17 percent (average on the balance); (2) in anticipation of the expansion and saturation of the domestic credit market and the subsidence of inflation, interest is likely to go down.

CEZ, furthermore, has its own capital for environmental measures and for building nuclear power plants (the after-tax profit for 1991 was kčs 10.4 billion. It is therefore, necessary to study the possibility of lowering the financing cost by using part of this profit.

2) Calculation of Total Construction Cost

Total Construction Cost would be calculated as follows.

(i) Interest

Interest would be calculated by application of above mentioned interest to disbursement of construction cost calculated in Chapter 8.

(ii) Import Tax

Import Tax shall be added to the local portion. Total Construction Cost is construction cost plus above (i) and (ii). Inflation during construction shall be disregarded.

Total Construction Cost is shown in Table 10.1-1 and 10.1-2.

3) Calculation of Costs

The operation period should be 25 years.

The depreciation amount is to be calculated by the straight-line method with zero residual value, on the assumption that the depreciation period for a chemical plant is 12.5 years.

The interest rate on the loan is to be computed on the assumption that the interest rate will remain constant during the loan period.

(For overseas governmental fund, which is to be repaid in 25 years, the grace period is to be 7 years. The repayment period for domestically procured loans is to be 10 years after the completion of the project.)

For operation and maintenance cost, the cost calculated in Chapter 8 shall be also adopted without inflation as same as in case of calculation of the total construction cost.

Repair cost is assumed to be 3% of total Construction Cost which enables to operate De-SOx system for 25 years.

Fine imposed on the power station shall be borne by the power station itself, therefore such fine shall not be regarded as the cost of the desulphurisation project.

In this calculation no corporate tax is payable because amount of income is same as that of expense.

(3) Basic Condition of the Power Station

Conditions assumed in Chapter 4 shall be also adopted during the whole period assumed here without any change. Additional cost necessitated to maintain such level shall be recovered through the tariff applicable to the power station itself, this means that such additional cost has no effect on the tariff of this project.

10.1.2 Evaluation of the Impact on Energy Tariff

Additional tariff in each year attributable to installation of the DeSox system, based on the premises mentioned above and estimation of maximum and minimum total construction costs, are shown in the Table 10.1-3 to Table 10.1-6.

According to this calculation, the increase in tariff is strongly recommended since 0.28-0.36 kčs/kWh (Part II, maximum) and 0.26-0.32 kčs/kWh (Part III, maximum) additional cost is incurred.

Table 10.1-1 Total Construction Cost [Part II]

(1,000 US$)

Interest for Local Loan / Interest for Foreign Loan		5.0%			8.0%		
		Local Portion	Foreign Portion	Total	Local Portion	Foreign Portion	Total
10.0%	C.C.	70,264	44,714	114,978	70,264	44,714	114,978
	I.D.C.	12,955.39	4,294.84	17,250.23	12,955.39	7,047.25	20,002.64
	Total	83,219.39	49,008.84	132,228.23	83,219.39	51,761.25	134,980.64
15.0%	C.C.	70,264	44,714	114,978	70,264	44,714	114,978
	I.D.C.	20,156.08	4,294.84	24,450.92	20,156.08	7,047.25	27,203.33
	Total	90,420.08	49,008.84	139,428.92	90,420.08	51,761.25	142,181.33

Note:

C.C. : Construction Cost
I.D.C. : Interest during Construction

Table 10.1-2 Total Construction Cost [Part III]

(1,000 US$)

Interest for Local Loan \ Interest for Foreign Loan		5.0%			8.0%		
		Local Portion	Foreign Portion	Total	Local Portion	Foreign Portion	Total
10.0%	C.C.	70,313	45,261	115,574	70,313	45,261	115,574
	I.D.C.	9,295.38	3,176.78	12,472.16	9,295.38	5,144.80	14,440.18
	Total	79,608.38	48,437.78	128,046.16	79,608.38	50,405.80	130,014.18
15.0%	C.C.	70,313	45,261	115,574	70,313	45,261	115,574
	I.D.C.	14,164.55	3,176.78	17,341.33	14,164.55	5,144.80	19,309.35
	Total	84,477.55	48,437.78	132,915.33	84,477.55	50,405.80	134,883.35

Note:

C.C. : Construction Cost
I.D.C. : Interest during Construction

Table 10.1-3 Calculation of Tariff
[Part II, Case of Maximum Construction Cost]

(USD 1000)

Year after Completion 9810	Depreciation	Interest	Utility Cost	Personnel Cost	Repair Cost	Disposal Cost	Total	Tariff (Yen/KWh)	Tariff (KCS/KWh)	Tariff (c/KWh)
1	5572.622	5943.578	444.763	40.947	1750.54	165.137	13917.585	0.40	0.08	0.31
2	5572.622	5283.180	444.763	40.947	1750.54	165.137	13257.188	0.38	0.08	0.30
3	11374.506	10885.916	889.525	81.893	3449.34	330.274	27011.454	1.55	0.33	1.21
4	11374.506	13440.464	889.525	81.893	3449.34	330.274	29566.003	1.70	0.36	1.32
5	11374.506	11854.113	889.525	81.893	3449.34	330.274	27979.651	1.61	0.34	1.25
6	11374.506	10267.762	889.525	81.893	3449.34	330.274	26393.300	1.52	0.32	1.18
7	11374.506	8681.411	889.525	81.893	3449.34	330.274	24806.949	1.43	0.30	1.11
8	11374.506	7095.060	889.525	81.893	3449.34	330.274	23220.598	1.34	0.28	1.04
9	11374.506	5508.708	889.525	81.893	3449.34	330.274	21634.247	1.24	0.26	0.97
10	11374.506	3922.357	889.525	81.893	3449.34	330.274	20047.895	1.15	0.24	0.90
11	11374.506	2996.404	889.525	81.893	3449.34	330.274	19121.942	1.10	0.23	0.86
12	11374.506	2070.450	889.525	81.893	3449.34	330.274	18195.988	1.05	0.22	0.81
13	8588.195	1840.400	889.525	81.893	3449.34	330.274	15179.627	0.87	0.18	0.68
14	5801.885	1610.350	889.525	81.893	3449.34	330.274	12163.266	0.70	0.15	0.54
15	2900.942	1380.300	889.525	81.893	3449.34	330.274	9032.274	0.52	0.11	0.40
16	0.000	1150.250	889.525	81.893	3449.34	330.274	5901.282	0.34	0.07	0.26
17	0.000	920.200	889.525	81.893	3449.34	330.274	5671.232	0.33	0.07	0.25
18	0.000	690.150	889.525	81.893	3449.34	330.274	5441.182	0.31	0.07	0.24
19	0.000	460.100	889.525	81.893	3449.34	330.274	5211.132	0.30	0.06	0.23
20	0.000	230.050	889.525	81.893	3449.34	330.274	4981.082	0.29	0.06	0.22
21	0.000	0.000	889.525	81.893	3449.34	330.274	4751.032	0.27	0.06	0.21
22	0.000	0.000	889.525	81.893	3449.34	330.274	4751.032	0.27	0.06	0.21
23	0.000	0.000	889.525	81.893	3449.34	330.274	4751.032	0.27	0.06	0.21
24	0.000	0.000	889.525	81.893	3449.34	330.274	4751.032	0.27	0.06	0.21
25	0.000	0.000	889.525	81.893	3449.34	330.274	4751.032	0.27	0.06	0.21
26	0.000	0.000	444.763	40.947	1698.30	165.137	2349.646	0.07	0.01	0.05
27	0.000	0.000	444.763	40.947	1698.30	165.137	2349.646	0.07	0.01	0.05

Annual Operation Hour	5081
Annual Load Factor	58
Auxirialy Loss	
Annual Net Generation(KWh)	2235640000

Table 10.1-4 Calculation of Tariff
[Part II, Case of Minimum Construction Cost]

(USD 1000)

Year after Completion 9810	Depreciation	Interest	Utility Cost	Personnel Cost	Repair Cost	Disposal Cost	Total	Tariff (Yen/KWh)	Tariff (KCS/KWh)	Tariff (c/KWh)
1	5251.146	3702.110	444.763	40.947	1750.54	165.137	11354.642	0.33	0.07	0.25
2	5251.146	3290.765	444.763	40.947	1750.54	165.137	10943.297	0.31	0.07	0.24
3	10578.259	6667.054	889.525	81.893	3449.34	330.274	21996.345	1.27	0.27	0.98
4	10578.259	8149.167	889.525	81.893	3449.34	330.274	23478.457	1.35	0.28	1.05
5	10578.259	7180.837	889.525	81.893	3449.34	330.274	22510.128	1.30	0.27	1.01
6	10578.259	6212.507	889.525	81.893	3449.34	330.274	21541.798	1.24	0.26	0.96
7	10578.259	5244.178	889.525	81.893	3449.34	330.274	20573.469	1.18	0.25	0.92
8	10578.259	4275.848	889.525	81.893	3449.34	330.274	19605.139	1.13	0.24	0.88
9	10578.259	3307.519	889.525	81.893	3449.34	330.274	18636.809	1.07	0.23	0.83
10	10578.259	2339.189	889.525	81.893	3449.34	330.274	17668.480	1.02	0.21	0.79
11	10578.259	1782.205	889.525	81.893	3449.34	330.274	17111.496	0.98	0.21	0.77
12	10578.259	1225.221	889.525	81.893	3449.34	330.274	16554.512	0.95	0.20	0.74
13	7952.686	1089.085	889.525	81.893	3449.34	330.274	13792.803	0.79	0.17	0.62
14	5327.113	952.950	889.525	81.893	3449.34	330.274	11031.094	0.63	0.13	0.49
15	2663.556	816.814	889.525	81.893	3449.34	330.274	8231.402	0.47	0.10	0.37
16	0.000	680.678	889.525	81.893	3449.34	330.274	5431.710	0.31	0.07	0.24
17	0.000	544.543	889.525	81.893	3449.34	330.274	5295.575	0.30	0.06	0.24
18	0.000	408.407	889.525	81.893	3449.34	330.274	5159.439	0.30	0.06	0.23
19	0.000	272.271	889.525	81.893	3449.34	330.274	5023.303	0.29	0.06	0.22
20	0.000	136.136	889.525	81.893	3449.34	330.274	4887.168	0.28	0.06	0.22
21	0.000	0.000	889.525	81.893	3449.34	330.274	4751.032	0.27	0.06	0.21
22	0.000	0.000	889.525	81.893	3449.34	330.274	4751.032	0.27	0.06	0.21
23	0.000	0.000	889.525	81.893	3449.34	330.274	4751.032	0.27	0.06	0.21
24	0.000	0.000	889.525	81.893	3449.34	330.274	4751.032	0.27	0.06	0.21
25	0.000	0.000	889.525	81.893	3449.34	330.274	4751.032	0.27	0.06	0.21
26	0.000	0.000	444.763	40.947	1698.80	165.137	2349.646	0.07	0.01	0.05
27	0.000	0.000	444.763	40.947	1698.80	165.137	2349.646	0.07	0.01	0.05

Annual Operation Hour	5081
Annual Load Factor	58
Auxirialy Loss	
Annual Net Generation(KWh)	2235640000

Table 10.1-5 Calculation of Tariff
[Part III, Case of Maximum Construction Cost]

(USD 1000)

Year after Completion	Depreciation	Interest	Utility Cost	Personnel Cost	Repair Cost	Fuel Cost	Total	Tariff (Yen/KWh)	Tariff (KCS/KWh)	Tariff (c/KWh)
1	10790.669	11404.470	798.632	55.904	3467.22	0.000	26516.894	1.53	0.32	1.19
2	10790.669	10137.306	798.632	55.904	3467.22	0.000	25249.731	1.45	0.31	1.13
3	10790.669	8870.143	798.632	55.904	3467.22	0.000	23982.568	1.38	0.29	1.07
4	10790.669	11411.418	798.632	55.904	3467.22	0.000	26523.843	1.53	0.32	1.19
5	10790.669	9920.229	798.632	55.904	3467.22	0.000	25032.654	1.44	0.30	1.12
6	10790.669	8429.040	798.632	55.904	3467.22	0.000	23541.465	1.36	0.28	1.05
7	10790.669	6937.851	798.632	55.904	3467.22	0.000	22050.276	1.27	0.27	0.99
8	10790.669	5446.662	798.632	55.904	3467.22	0.000	20559.087	1.19	0.25	0.92
9	10790.669	3955.473	798.632	55.904	3467.22	0.000	19067.897	1.10	0.23	0.85
10	10790.669	2464.284	798.632	55.904	3467.22	0.000	17576.708	1.01	0.21	0.79
11	10790.669	2240.258	798.632	55.904	3467.22	0.000	17352.683	1.00	0.21	0.78
12	10790.669	2016.232	798.632	55.904	3467.22	0.000	17128.657	0.99	0.21	0.77
13	5395.334	1792.206	798.632	55.904	3467.22	0.000	11509.297	0.66	0.14	0.52
14	0.000	1568.181	798.632	55.904	3467.22	0.000	5889.937	0.34	0.07	0.26
15	0.000	1344.155	798.632	55.904	3467.22	0.000	5665.911	0.33	0.07	0.25
16	0.000	1120.129	798.632	55.904	3467.22	0.000	5441.885	0.31	0.07	0.24
17	0.000	896.103	798.632	55.904	3467.22	0.000	5217.859	0.30	0.06	0.23
18	0.000	672.077	798.632	55.904	3467.22	0.000	4993.833	0.29	0.06	0.22
19	0.000	448.052	798.632	55.904	3467.22	0.000	4769.808	0.27	0.06	0.21
20	0.000	224.026	798.632	55.904	3467.22	0.000	4545.782	0.26	0.05	0.20
21	0.000	0.000	798.632	55.904	3467.22	0.000	4321.756	0.25	0.05	0.19
22	0.000	0.000	798.632	55.904	3467.22	0.000	4321.756	0.25	0.05	0.19
23	0.000	0.000	798.632	55.904	3467.22	0.000	4321.756	0.25	0.05	0.19
24	0.000	0.000	798.632	55.904	3467.22	0.000	4321.756	0.25	0.05	0.19
25	0.000	0.000	798.632	55.904	3467.22	0.000	4321.756	0.25	0.05	0.19

Annual Operation Hour	4468
Annual Load Factor	51
Auxiriary Loss	
Annual Net Generation(KWh)	2234000000

Depreciation	Straight Method
Residual Value	0
Term (Year)	12.5
Total Value	134883.357

Table 10.1-6 Calculation of Tariff

[Part III, Case of Minimum Construction Cost]

(USD 1000)

Year after Completion	Depreciation	Interest	Utility Cost	Personnel Cost	Repair Cost	Fuel Cost	Total	Tariff (Yen/KWh)	Tariff (KCS/KWh)	Tariff (c/KWh)
1	10243.692	7164.754	798.632	55.904	3467.22	0.000	21730.202	1.25	0.26	0.97
2	10243.692	6368.670	798.632	55.904	3467.22	0.000	20934.119	1.21	0.25	0.94
3	10243.692	5572.587	798.632	55.904	3467.22	0.000	20138.035	1.16	0.24	0.90
4	10243.692	7063.842	798.632	55.904	3467.22	0.000	21629.291	1.25	0.26	0.97
5	10243.692	6133.209	798.632	55.904	3467.22	0.000	20698.657	1.19	0.25	0.93
6	10243.692	5202.576	798.632	55.904	3467.22	0.000	19768.024	1.14	0.24	0.88
7	10243.692	4271.943	798.632	55.904	3467.22	0.000	18837.391	1.08	0.23	0.84
8	10243.692	3341.309	798.632	55.904	3467.22	0.000	17906.758	1.03	0.22	0.80
9	10243.692	2410.676	798.632	55.904	3467.22	0.000	16976.125	0.98	0.21	0.76
10	10243.692	1480.043	798.632	55.904	3467.22	0.000	16045.492	0.92	0.19	0.72
11	10243.692	1345.494	798.632	55.904	3467.22	0.000	15910.942	0.92	0.19	0.71
12	10243.692	1210.944	798.632	55.904	3467.22	0.000	15776.393	0.91	0.19	0.71
13	5121.846	1076.395	798.632	55.904	3467.22	0.000	10519.997	0.61	0.13	0.47
14	0.000	941.846	798.632	55.904	3467.22	0.000	5263.602	0.30	0.06	0.24
15	0.000	807.296	798.632	55.904	3467.22	0.000	5129.052	0.30	0.06	0.23
16	0.000	672.747	798.632	55.904	3467.22	0.000	4994.503	0.29	0.06	0.22
17	0.000	538.198	798.632	55.904	3467.22	0.000	4859.954	0.28	0.06	0.22
18	0.000	403.648	798.632	55.904	3467.22	0.000	4725.404	0.27	0.06	0.21
19	0.000	269.099	798.632	55.904	3467.22	0.000	4590.855	0.26	0.06	0.21
20	0.000	134.549	798.632	55.904	3467.22	0.000	4456.305	0.26	0.05	0.20
21	0.000	0.000	798.632	55.904	3467.22	0.000	4321.756	0.25	0.05	0.19
22	0.000	0.000	798.632	55.904	3467.22	0.000	4321.756	0.25	0.05	0.19
23	0.000	0.000	798.632	55.904	3467.22	0.000	4321.756	0.25	0.05	0.19
24	0.000	0.000	798.632	55.904	3467.22	0.000	4321.756	0.25	0.05	0.19
25	0.000	0.000	798.632	55.904	3467.22	0.000	4321.756	0.25	0.05	0.19

Annual Operation Hour	4468
Annual Load Factor	51
Auxiriary Loss	
Annual Net Generation(KWh)	2234000000

Depreciation	Straight Method
Residual Value	0
Term (Year)	12.5
Total Value	128046.155

10.2 Economic Evaluation

10.2.1 Methodology and Basic Condition

(1) Methodology

In general, economic evaluation of a development project is designed to measure its socio-economic impact on the country as a whole by comparing two cases; the project is implemented and the project is not implemented.

The economic evaluation employs indices such as net present value of the project, benefit/cost ratio and economic internal rate of return which are calculated from benefits and costs of the project using the "Discounted Cash Flow method".

To determine benefits and costs of a project, market prices obtained should be converted to real benefits and costs, since these are generally distorted due to taxes, government subsidies, import control, import duties, public charges, minimum wages, and other government intervention and monopolistic pricing.

The World Bank and other international financing organizations employ international market prices to estimate real project costs and benefits. The method of economic evaluation employed by the World Bank and other international financing organizations may be summarized as shown in Fig. 10.2-1.

Phase 1: To exclude items to be transferred to national income from market prices.

Phase 2: To convert market prices for trade goods, non-trade goods, skilled labor, unskilled labor and other items to real (border) prices.

Phase 3: To determine the internal rate of return on the basis of real benefits and costs, and compare it with opportunity cost of capital in the country.

Phase 4: To carry out a socio-economic evaluation considering national saving and income distribution.

For this project, economic evaluation up to Phase 3 is carried out (See Fig. 10.2-1).

In economic evaluation of power development projects, it is more realistic to measure and compare benefits and costs of the project using the long-term marginal cost method or the tariff system method, if benefits can be accounted for.

However, if benefits cannot be easily accounted for and the project is incorporated in a long range electric power development program which is a part of a national socio-economic development policy to satisfy future power demand (i.e., if the project is not implemented, other means of power supply is to be substituted for it.), the alternative plant approach will be employed to measure and evaluate economic costs of the proposed project and the alternative project.

In this case, the power station is already in operation. If this project would not be realized, either new investment for a new power station which would substitute electric energy to be reduced in order for Melnik Power Station to observe the regulation, or additional investment on the Melnik Power Station for observance of the regulation would be required.

As a realistic plan, construction of a new power station or reconstruction of the existing power station is required. In comparison with construction of a new power station, reconstruction of a existing power station necessitates less investment. Consequently, in this study economical evaluation will be made based on the reconstruction.

(2) Conversion into International Market Price

Conversion of the construction cost shown in Chapter 8 into international market price shall be made based on the following conditions.

1) Exclusion of Import Tax and Interest during Construction

15% import tax included in the local portion of the construction cost shown in Chapter 8 shall be excluded when economic cost is calculated. Interest during construction shall be also excluded.

2) Conversion of Local Portion into International Market Price

Foreign exchange rate of July, 1992 shall be adoped in this study in order to convert local portion denominated in local currency into international market price or vise versa correctly.

1US$ = ¥128.65
1US$ = kčs27.76
1US$ = DM1.4740

(3) Reconstruction of Thermal Power Plants

The natural-gas power plant (gas-combined cycle) is chosen as the reconstruction of the thermal power plants, which would be benefit on the economic evaluation of this project since it is the least expensive and can meet emission standards of the New Clean Air Act.

The reconstruction of the thermal plant into the natural-gas plant assumes that both would have the same power output and electricity yield.

Followings are the basic conditions for this reconstruction.

Total Construction Cost	612.66 x 10^6 kčs (2,891 Million Yen)
Plant life (inil. construction)	25 years
Construction Period	4 years

. Repair Cost

Part II per 1 unit	3.53×10^6 kčs	less than the existing power station
Part III	16.04×10^6 kčs	less than the existing power station

. Personnel Cost

Part II per 1 unit	0.04×10^6 kčs	less than the existing power station
Part III	0.2×10^6 kčs	less than the existing power station

. Fuel Cost

Part II per 1 unit	680.53×10^6 kčs	more than the existing power station
Part III	$2,643.48 \times 10^6$ kčs	more than the existing power station

(4) Other Basic Conditions

Other basic conditions for this economical evaluation are as follows.

1) Operation and Maintenance Cost for this project

Assumption for calculation of tariff is also applicable to here.

2) Plant life of DeSOx system 25 years

Judging from experience in Japan, we judged that stable and continuous operation during 25 years is possible as long as appropriate maintenance is made.

3) Discount rate 10%