Chapter 6. Conceptual Design of DeSOx System

CHAPTER 6 CONCEPTUAL DESIGN OF DeSOx SYSTEM

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Chapter 6 Conceptual Design of DeSOx System

6.1 Basic Plan for DeSOx System

A basic plan is prepared for conceptual design of DeSOx system for the Kozienice Power Plant based on the results of the "Selection of the optimum DeSOx system" and information and data collected during Site Surveys.

Design conditions for the conceptual design of DeSOx system basically same as the conditions for the optimum FGD selection described in 4.3. Major parameters of basic plan and design conditions for the conceptual design are shown below.

(1) Coal Properties

a.	Heating value (LHV)	4,460 kcal/kg
b.	Total moisture	10.7 %
c.	Moisture content	8.4 %
d.	Sulphur content	0.96 %
e.	Ash	27.85 %

(2) FGD System

a. Method

Wet-type limestone-gypsum method (Single-tower in-situ oxidation spray tower method)

b. Capacity and Number of Units

500 MW equivalent, 3 units

c. Desulphurisation Efficiency

89%

d. Combination of FGD Units

2 FGD Units for Nos. 4, 5, 6, 7 and 8 Plants (200 MW x 5)
1 FGD Unit for No. 9 Plant (500 MW)

(3) Design Conditions of FGD Units

Design conditions of FGD Units are shown in Table 6.1-1.

Two FGD Units (No. 1 and No. 2) installed for Nos. 4-8 power generation plants and one FGD Unit (No. 3) installed for No. 9 power generation Plant are different a little only in the inlet gas condition. Design conditions, however, are represented by those of the FGD to be installed for No. 9 power generation Plant. Items different in conditions are shown below.

a. Inlet Gas Volume

The inlet gas volume of the FGD Unit for No. 9 power generation Plant (2,078,000 m^3N/h-wet) is a little greater (1.8 %) than those of the FGD Units for Nos. 4-8 power generation Plants (2,042,500 m^3N/h-wet), but the case of No. 9 power generation Plant is used as the planned inlet gas volume for FGD.

b. Inlet Gas Temperature

The inlet gas temperature of the FGD Unit for No. 9 power generation Plant (130°C) is higher by 16°C than those of the FGD Units for Nos. 4-8 power generation Plants (114°C), but the case of No. 9 power generation Plant is used as the planned inlet gas temperature for FGD.

c. Byproduct production

The byproduct production is different by about 1% among the FGD Units, but the case of the FGD Unit for No. 9 power generation Plant is used as a design condition.

(4) Planned Performance of FGD Units

Planned performance of the FGD Unit is shown in Table 6.1-2.

(5) Absorbent (limestone) Characteristics

The limestone characteristics are planned as shown below. Limestone of such characteristics is generally used for FGDs of wet-type limestone-gypsum method and can be obtained by the Kozienice Power Plant.

a.	Purity	$CaCO_3$	94% or more
b.	Grain size	Passing 325-mesh	95% or more

(6) Water for Desulphurisation

All water for desulfurisation including make-up water, cooling water, etc. is obtained from the Wisla River. Table 6.1-3 shows planned water qualities for DeSOx system which have been set based on the results of analysis of Wisla River water obtained at the Power Plant.

(7) Air

The Power Plant has no extra capacity for supplying compressed air, and it appears difficult to obtain compressed air from the Power Plant. It is therefore planned that all air for oxidation, pneumatic control and other purposes is to be supplied by the new system to be installed in the DeSOx system.

(8) Electric Facility

It is planned to supply electric power from the 220-kV overhead power line for the No. 4 starting transformer, running above the space for FGD installation. The power line will be T-branched to a new transformer to be installed for supply of power of 6 kV. Switchgears will be installed in a new electric room which is to be located in the ZRE Building which will undergo reconstruction.

(9) Control Systems

A new control room will be located in the ZRE Building to be reconstructed. An independent control desk for each unit will be provided in the control room, and operations and monitoring will basically be conducted by CRT (cathode-ray tube) operations. Control equipment will employ the latest version of digital control.

(10) Disposal of Byproduct

Coal used at the Kozienice Power Plant is high in chlorine concentration and there is no market for commercial gypsum . Thus, byproduct gypsum will be mixed with wastewater of desulphurisation and coal ash, and the mixture will be transported by a conveyer system.

(11) Byproduct Disposal Area

The byproduct disposal area will have impermeable construction using water-proofing sheet. the impermeable sheet will, however, be used for minimum number of byproduct disposal area which keep byproduct for a period necessary for stabilization of byproduct. In this study, it is planned for two years period.

Table 6.1-1 Design Condition of FGD Unit

	Item	Unit	Design Condition
1.	Capacity of FGD	-	500 MW
2.	FGD Process	-	Wet-Limestone-Gypsum
3.	Gas Flow Rate	m^3N/h, wet	2,078,000
4.	Inlet Flue Gas Temperature	°C	130
5.	Inlet Flue Gas Composition		
	H_2O	vol%	15.4
	O_2	vol%	6.0
	SO_2	ppm	940
	HF	mg/m^3N, dry	24
	HCl	mg/m^3N, dry	579
	SO_3	ppm	5
6.	SO_2 Removal Efficiency	%	89
7.	Dust Concentration		
	Outlet of the Existing EP	mg/m^3N, dry	300
8.	Absorbent	-	Limestone
	Purity	%	94% or more
	Grain Size	mesh	325 mesh pass 95% or more
9.	Gypsum		To be discarded with fly ash
10.	Outlet Flue Gas Temperature at the Inlet of the Stack	°C	90
11.	Cl Concentration in Make-up Water	ppm	237

Table 6.1-2 Design Performance of FGD Unit

	Item	Unit	Design Performance
1.	Capacity of FGD	-	500 MW
2.	Gas Flow Rate	m^3N/h, wet	2,078,000
3.	Inlet Gas Condition		
	Temperature	°C	130
	SO_2	ppm	940 (5,184 kg/h)
	SO_3	ppm	5
	Dust Load	mg/m^3N, dry	300
4.	Outlet Gas Condition		
	Temperature	°C	90
	SO_2	ppm	103 (571 kg/h)
	SO_3	ppm	2
	Dust Load	mg/m^3N, dry	50
5.	SO_2, Removal Efficiency	%	89
6.	Ca/S (Consumed Ca/Inlet SO_2)	-	1.11
7.	Draft Loss of FGD Plant	mmAq	305
8.	Gypsum Slurry	t/h	39.4
	Fly Ash Consumption	t/h	63
	Gypsum Ash Waste	t/h	102.4

Table 6.1-3 Design River Water Analysis

Item	Unit	Anaysis
Temperature	°C	5 ~ 29
pH	-	7.6 ~ 8.4
Alkarinity	mvol/l	3.3
Hardness	°dH	18.4
Fe	mg/l	0.31
Cl	mg/l	237
Solved Matter	mg/l	764
SS	mg/l	39
DO	mg/l O_2	8.5
COD	mg/l	11.4
BOD	mg/l	7.0
Ammonia	mg/l	0.7

Note: The above quality is determined by taking the maximum values from the sample analysis of river water.

6.2 Plan for Overall FGD Layout

An overall FGD layout is shown in Fig. 6.2-1.

The FGDs were arranged in the space between the coal yard and NOs. 2 and 3 Stacks in consideration of the items described below for achieving an economical layout with minimum equipment replacing or relocation.

(1) The following facilities are existing in the space for FGD system, but they were taken into account in the FGD arrangement because their moving is difficult.

  a. Coal conveyer and foreign material in coal removal facility

  b. High-voltage overhead power lines running over the space for installation

  (Equipment to be installed below the high-voltage power lines are installed at distances required from high-voltage power lines.)

  c. Cables and cable tranches buried between Nos. 2 and 3 Stacks and along the road on the side of the Coal Yard.

(2) Existing Facilities to be Transferred or Eliminated

  a. Railway tracks being used for receiving chemicals for the demineralizer

  b. Pipes for ash transportation

  c. Other smaller pipings and cables, etc.

(3) Existing Facilities to be Reconstructed

  a. Existing common ducts for connection of FGDs

  b. No. 2 Stack lining

c. ZRE Building for the control room and electrical room for FGDs

(4) Considerations for More Stringent Regulation on SOx Emission in the Future

One way to cope with more stringent regulation on SOx emission in the future is to install another FGD for No. 10 power generation Plant. For that reason, the layout for the FGD system to be installed this time must also plan for possible installation of an FGD for No. 10 power generation Plant.

(5) Indoor Equipment

The following equipment are planned to install indoors as a measure for coping with freezing in winter and for prevention of noises as well.

a. Absorber slurry recirculation pumps

b. Facility for mixing the byproduct and flyash

c. Oxidation air blowers and air compressors (These are to be installed in one building as equipment common to three FGD units.)

d. Intake pumps of water for FGD system

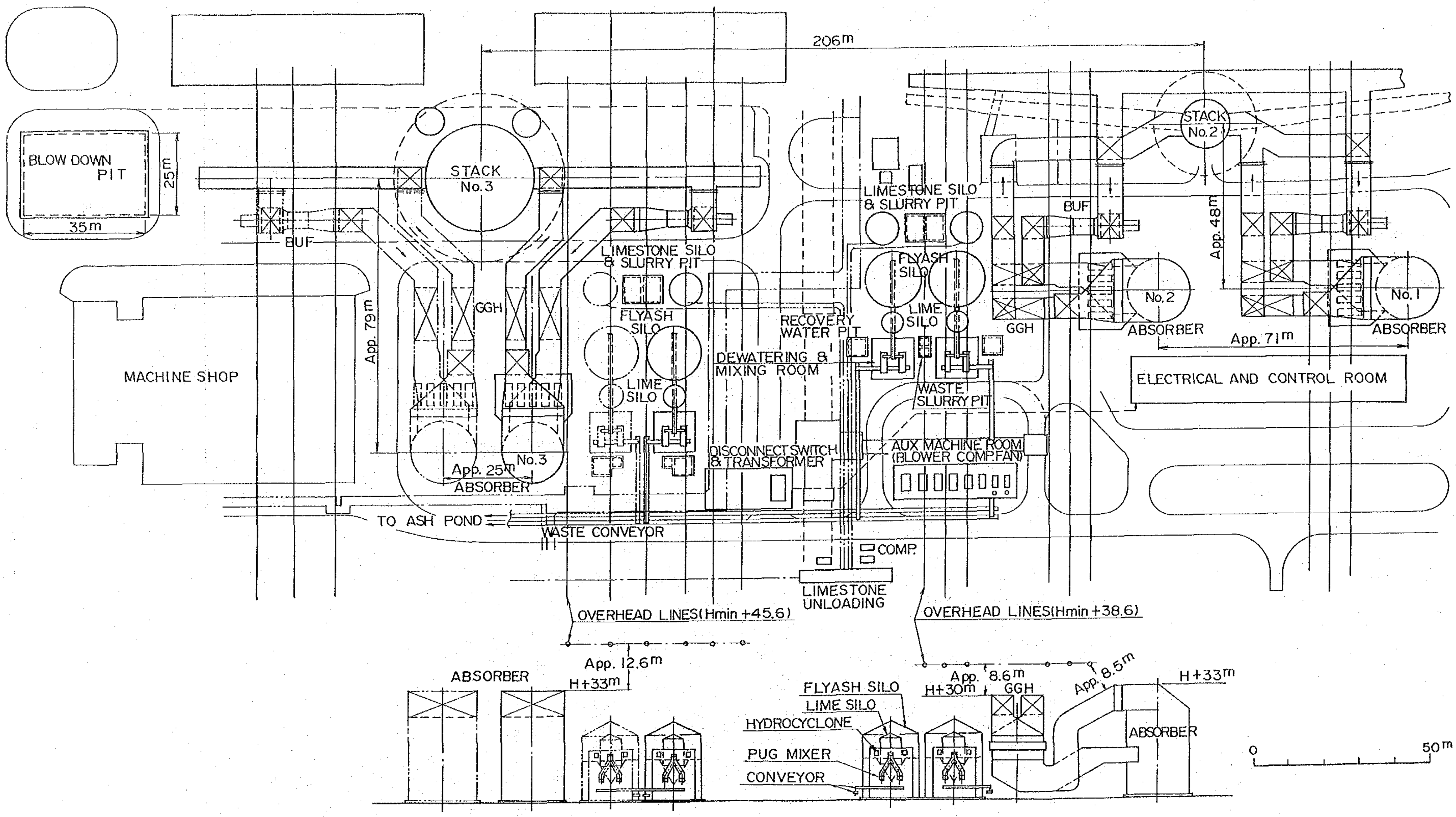
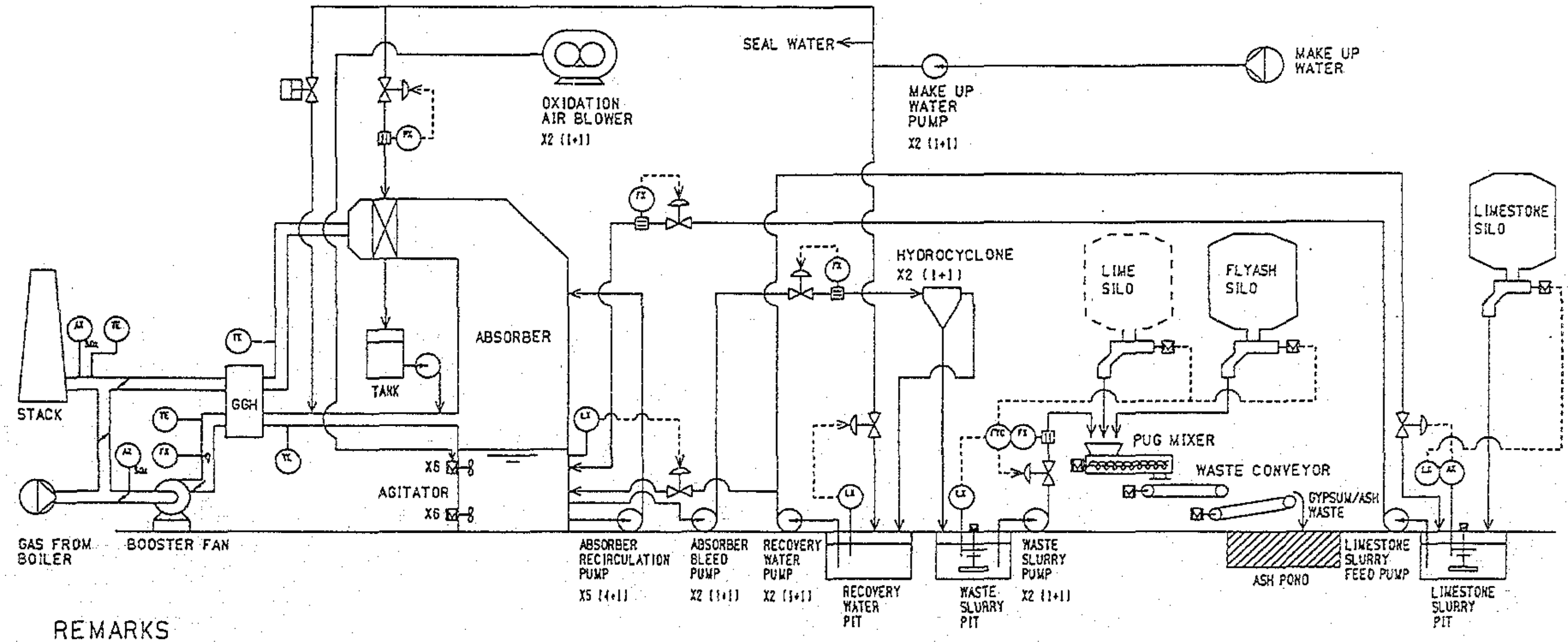


Fig. 6.2-1 General Layout of Three (3) 500 MW FGD Units

6.3 System Diagram of DeSOx System and Specifications of Major Equipment

Fig. 6.3-1 shows a system diagram of the FGD system.

Specifications of major equipment are shown in Table 6.3-1.



REMARKS

AX : ANALYSIS TRANSMITTER

FX : FLOW RATE TRANSMITTER

LX : LEVEL TRANSMITTER

TE : TEMPERATURE DETECTOR

Fig. 6.3-1 Flow Diagram of 500 MW FGD Unit

Table 6.3-1 Specification of Major Equipment for 500 MW FGD Unit

Equipment	Specification
1. Absorbing System	
1) Absorber	
Number	1
Type	Spray Tower
Dia. x Height	ϕ18.8 m x 32.3 m H
Capacity	2,078,000 m^3N/h
2) Absorber Upper Recir. Pump	
Number	1
Type	Centrifugal
Capacity	123 m^3/min
Head	28 m
Motor	810 kW
3) Absorber Middle Recir. Pump	
Number	1
Type	Centrifugal
Capacity	123 m^3/min
Head	26 m
Motor	760 kW
4) Absorber Lower Recir. Pump	
Number	1
Type	Centrifugal
Capacity	123 m^3/min
Head	25 m
Motor	720 kW
5) Absorber Prescrubbing Recir. Pump	
Number	1 + 1 stand-by
Type	Centrifugal
Capacity	72 m^3/min
Head	21 m
Motor	360 kW

Equipment	Specification
6) Absorber Bleed Pump	
Number	1 + 1 stand-by
Type	Centrifugal
Capacity	2.4 m^3/min
Head	38 m
Motor	37 kW
7) Agitator for Absorber Recir. Tank	
Number	6
Type	Propeller
Motor	30 kW
8) Oxidation Agitator on Absorber	
Number	6
Type	Propeller
Motor	30 kW
9) Oxidation Air Blower	
Number	3 + 1 stand-by for 3 x 500 MW
Type	Roots
Capacity	90 m^3/min
Head	0.8 kg/cm^2-g
Motor	180 kW
2. Gypsum Dewatering & Mixing System	
1) Hydrocyclone	
Number	2 sets
Capacity (as slurry)	39,400 kg/h
2) Pug Mixer	
Number	1 + 1 stand-by
Type	Mixer
Capacity (as slurry)	3 m^3
Motor	75 kW
3) Recovery Water Pit	
Number	1
Type	Concrete pit
Capacity (Net)	57 m^3

Equipment	Specification
4) Waste Slurry Pit	
Number	1
Type	Concrete pit
Capacity	16 m^3
5) Waste Slurry Pump	
Number	1 + 1 stand-by
Type	Centrifugal
Capacity	0.9 m^3/min
Head	15 m
Motor	5.5 kW
6) Recovery Water Pump	
Number	1 + 1 stand-by
Type	Centrifugal
Capacity	1.1 m^3/min
Head	26 m
Motor	11 kW
7) Fly Ash Silo	
Number	1
Type	Cylindrical, Vertical
Capacity	1,800 m^3 (1 day)
Accessary	Weigh Feeder, Conveyor
8) Lime Silo*	
Number	1
Type	Cylindrical Vertical
Capacity	280 m^3
Accessary	Weigh Feeder, Conveyor
9) Waste Conveyor	(Transport Gypsum/Ash Waste) to Ash Pond)
Number	2 Trains
Type	Belt Conveyor
Capacity	330 t/h
Length	3 km

* Necessity of lime addition in order to facilitate hydration of gypsum/ash waste shall be confirmed by a test using sample ash and gypsum at later stage.

Equipment	Specification
3. Limestone Preparation System	
1) Limestone Silo	
Number	1
Type	Cylindrical
Capacity	630 m^3 (for 3 days)
Accessary	Weigh Feeder
2) Limestone Slurry Pit	
Number	1
Type	Concrete Pit
Capacity (Net)	172 m^3
3) Limestone Slurry Feed Pump	
Number	1 + 1 stand-by
Type	Centrifugal
Capacity	1.2 m^3/min
Head	20 m
Motor	11 kW
4. Drafting System	
1) Boost Up Fan	
Number	1
Type	Axial Flow
Capacity	56,300 m^3/min
Head	390 mmAq
Motor	4,700 kW
2) Reheating Equipment	
Number	1
Type	Regenerative Type GGH
Capacity	2,078,000 m^3N/h

Equipment	Specification
3) Scavenging Fan	
Number	1
Motor	150 kW
Gas leakage	
untreated -> treated	1.0%
treated -> untreated	5.0%
Dust leakage	10 mg/m^3N
5. Common Equipment	
1) Make up Water Pump	
Number	1 + 1 stand-by for 3 x 500 MW
Type	Centrifugal
Capacity	1.5 m^3/min
Head	70 m
Motor	37 kW
2) Air Compressor	
Number	1 + 1 stand-by for 3 x 500 MW
Type	Rotary Screw
Capacity	1,020 m^3N/h
Head	7 kg/cm^2 g
Motor	132 kW
3) Seal Air Fan	
Number	1 + 1 stand-by for 3 x 500 MW
Type	Roots Blower
Capacity	190 m^3/min
Head	700 mm H_2O
Motor	55 kW
6. Electrical Equipment	(Number of electrical equipment is for 3 FGD Plants.)
1) FGD Transformer	
Number	1
Number of windings	2
Rated voltage	220 kV/6.3 kV
Capacity	27 MVA

Equipment	Specification
2) Disconnecting Switch	
Number	2 sets
Rated voltage	220 kV
3) Switchgears	
Rated voltage (M/C / P/C / MCC)	6.3/0.4/0.4 kV
4) Battery	
Number	3 sets
Rated voltage	110 V
Capacity	500 AH (10hours rate)
5) Charger	
Number	3
Type	Thyristor rectifier
Capacity	50 kVA
7. C&I Equipment	(Number of C&I equipment is for 3 FGD Plants.)
1) Control Desk	
Number	4 (1 for each FGD Plant and 1 for common)
Type	Steel plated desk type
CRT (Cathode Ray Tube)	1 CRT for each desk
2) Controller	
Type	Self-standing steel plated digital controller
3) Relay Panels	
Type	Self standing steel plated hard-wired type

Equipment	Specification
4) CVCF	
Number	3
Type	Thyristor inverter type
Capacity	25 kVA

CVCF: constant voltage constant frequency equipment

6.4 DeSOx System Material Balance

In Fig. 6.4-1, material balance for one 500 MW FGD system which is installed to No. 9 power generation plant, and in Fig. 6.4-2, these for two 500 MW FGD systems which are installed to No. 4 to No. 8 power generation plants.

These material balances are made based on the case that high chlorine content in coal of 0.46 % which makes chlorine content in FGD absorbing slurry of 39,000 ppm.

In this feasibility study, the FGD system was designed based on the case using this high chlorine content of coal.

However, it is preferable to operate the system with low chlorine content in the system as much as possible because of chlorine contents in the system at 39,000 ppm is rather heavy duty on materials and absorbing reaction of the system.

The Kozienice Power Plant has used several kinds of coal. Chlorine contents of major consumption brand of Piast, Zahrze, and Murcki are 0.46%, 0.27%, and 0.04%, respectively. A weighted mean figure of these chlorine contents is 0.28% calculated from receiving amount in 1990.

FGD units will be installed to 1,500 MW equivalent generator output out of 2,600 MW total output of the power plant.

There would be a method to reduce chlorine content in the FGD system using low chlorine content coals in the boilers with FGD units and high chlorine content coals in the boilers without FGD units.

In Fig. 6.4-3 and Fig. 6.4-4, by means of the above method, for example, material balances of suppressed chlorine content in the system to 20,000 ppm are shown.

Moreover, judged from passed experience, it is recommended to operate the FGD system with chlorine content in the system lower than 15,000 ppm.

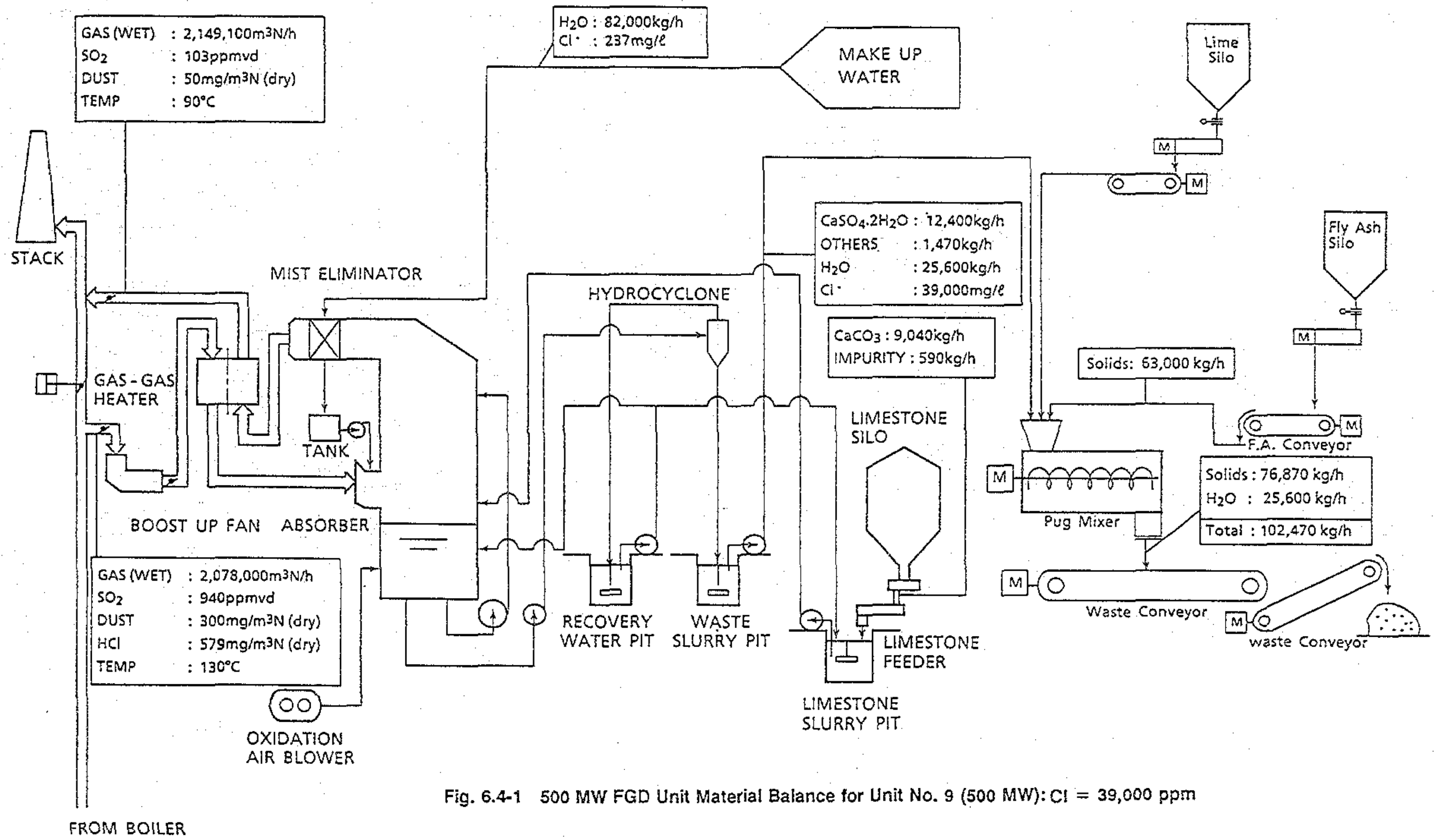


Fig. 6.4-1 500 MW FGD Unit Material Balance for Unit No. 9 (500 MW): Cl = 39,000 ppm

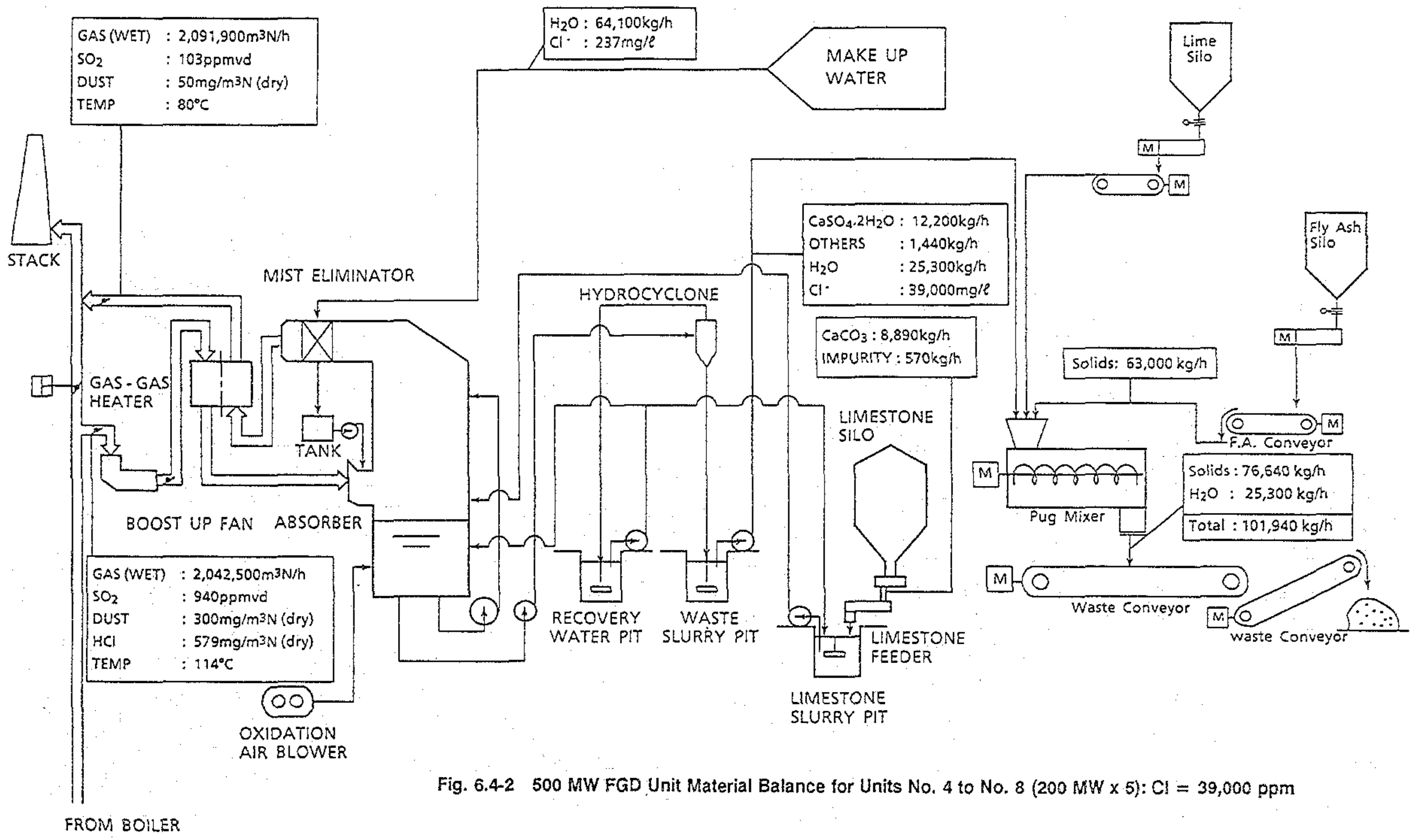


Fig. 6.4-2 500 MW FGD Unit Material Balance for Units No. 4 to No. 8 (200 MW x 5): Cl = 39,000 ppm

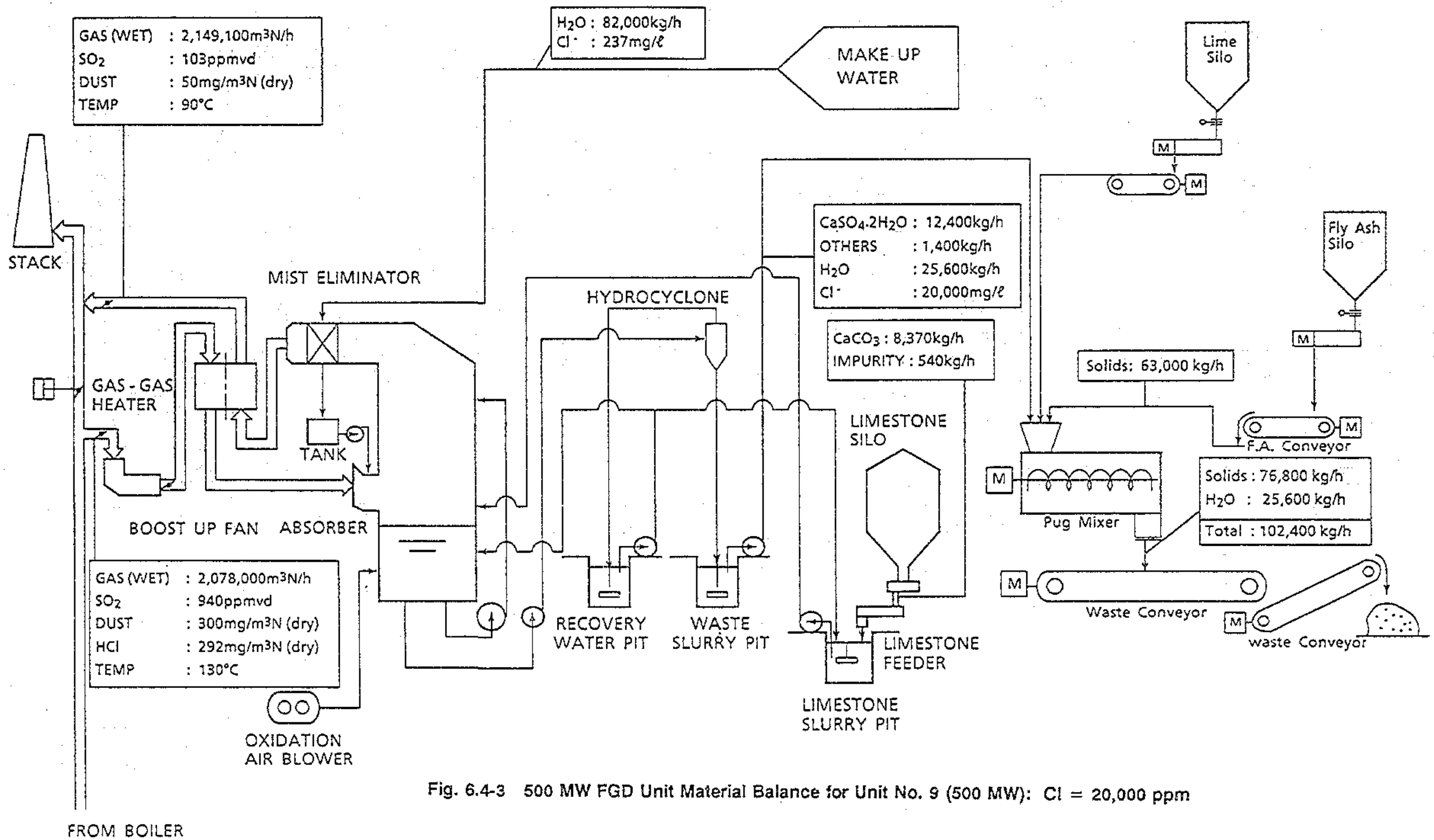


Fig. 6.4-3 500 MW FGD Unit Material Balance for Unit No. 9 (500 MW): Cl = 20,000 ppm

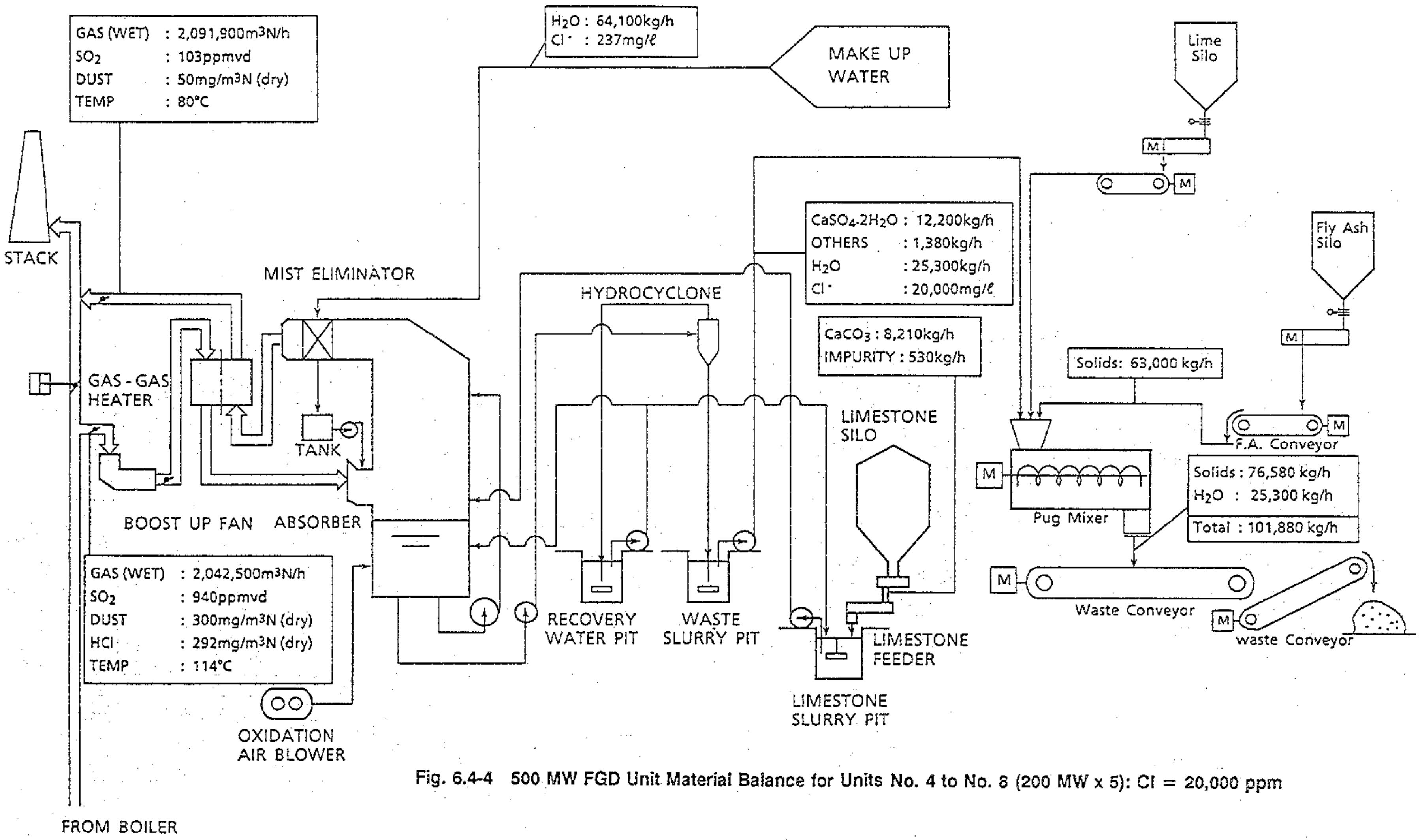


Fig. 6.4-4 500 MW FGD Unit Material Balance for Units No. 4 to No. 8 (200 MW x 5): Cl = 20,000 ppm

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 forced oxidation system (single tower IFO system). The single tower IFO system has a multi-functional absorber which combines the functions of prescrubbing, 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 more for 500-MW 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 a little because of simplified internal structure.

- Number of spray stages in operation can be changed.

  For low load operation and change of S (%) in coal, number of spray stages operation can be changed. Therefore, economical FGD operation can be achieved.

In this study, the spray tower which has much experiences and above mentioned features is selected for the FGD absorber based on the meeting at the Kozienice Power Plant.

(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 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 (89%), FGD outlet dust concentration (50 mg/m^3N) 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 and dust removal efficiency.

The absorber sizing is determined by full consideration of abovementioned condition. In addition, following specific condition is also considered.

Generally, mist eliminator is equipped on top of the absorber. But, in this project, the mist eliminator will be equipped at the absorber outlet duct in order to keep separation between top of the absorber and overhead lines (400 kV: 7.7 m or more, 220 kV: 6.5 m or more).

Hence, the absorber will be designed as following diameter and height.

Absorber diameter : 18.8 m
Absorber height : 32.3 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) affect SO_x removal efficiency because of that the substances inhibit dissolution of limestone and deteriorate limestone activity.

From the results of coal analysis, the chlorine content of coal is very high while the fluorine content of that is similar to 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 4% taking account of the deterioration of limestone activity by high chlorine content in coal.

c. Liquid Gas Ratio (L/G)

In the spray tower absorber, SO_x and dust removal performances are greatly influenced by the amount of absorbent slurry recirculation.

In this study, design L/G will be 3.4 ℓ/m^3N at each absorbing spray stage and 2.0 ℓ/m^3N at gas cooling spray stage for SOx removal efficiency of 89% and FGD outlet dust concentration of 50 mg/m^3N.

d. Chlorine Concentration in the Absorber

If chlorine (Cl) concentration is kept high, quantity of bleed water from absorber can be reduced. On the other hand, it is necessary to consider the material of FGD system from a view point of corrosion.

In this study, chlorine concentration in the absorber is designed to be maximum 40,000 mg/ℓ described in Chapter 4 "Handling of Byproduct and Waste Water" from the view points of minimization of the waste water quantity and the material corrosion.

The chlorine concentration in the absorber i.e., 40,000 mg/ℓ is applied to the FGD units for "Drax Power Plant" of National Power Company in the United Kingdom.

The plant consists of six 660 MW coal fired boilers. The FGD units will be retrofitted to all boilers, each of which has a capacity of 660 MW treating flue gas by single tower IFO system. The FGD units will be commenced commercial operation from 1993 to 1996 (No. 1 FGD unit: Sep. 1993).

For the Kozienice FGD units, the maximum design chlorine concentration i.e., 40,000 mg/ℓ presupposes optimum selection of FGD material (lining material).

The lining material under the design condition is shown in Fig. 6.5-3.

(4) Absorber Structure

Outline of the absorber is shown in Fig. 6.5-4. The number of spray stages will be designed to be a total of four (4) stages i.e., one (1) for gas cooling portion and three (3) for absorbing portion, in order to get design L/G.

Each spray stage at absorbing portion has one (1) recirculation pump. Spray stage at gas cooling portion has two (2) recirculation pumps, one of them is used to ordinary while the other is in stand-by.

Six (6) agitators for absorbent slurry mixing and six (6) oxidation agitators will be equipped at the absorber recirculation tank.

Oxidation air is injected into the absorber recirculation tank through the oxidation agitators.

The mist eliminator will be equipped at the absorber outlet duct as mentioned before.

(5) Specification of the Absorber

- Type : Spray Tower (Single Tower)
- Oxidation: In si-tu Forced Oxidation (IFO)
- Number : One (1) for each FGD unit
- Size : Diameter ϕ 18.8 m x Height 32.3 m
- Capacity : 2,078,000 m^3N/h

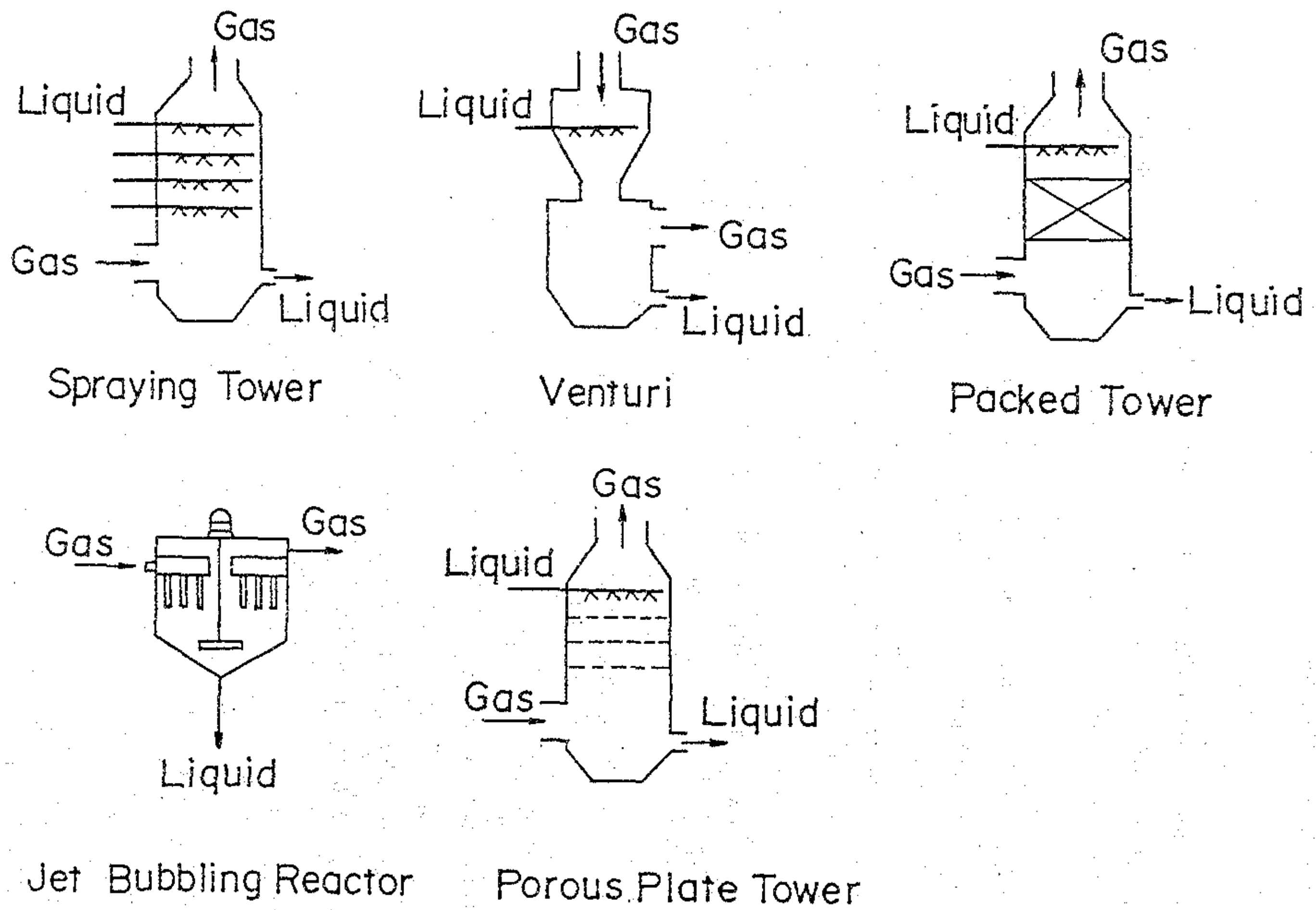
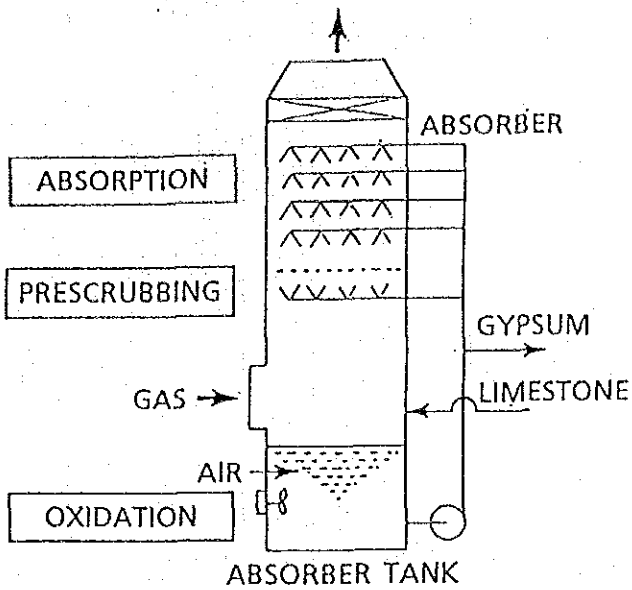
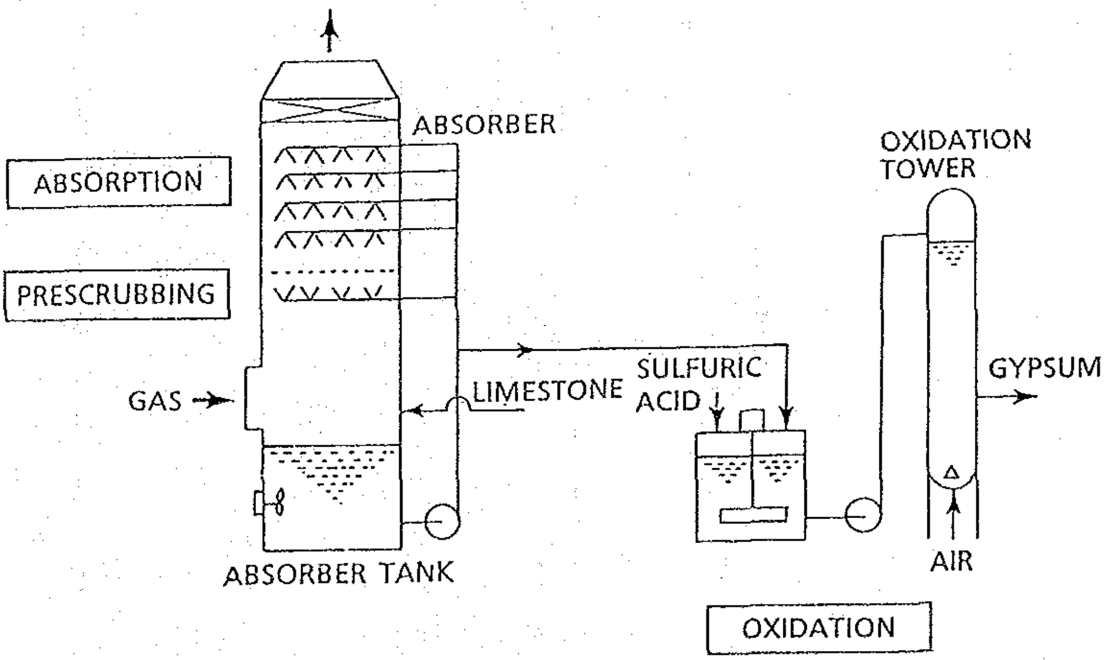


Fig. 6.5-1 Typical Absorber Shemes Employed for FGD

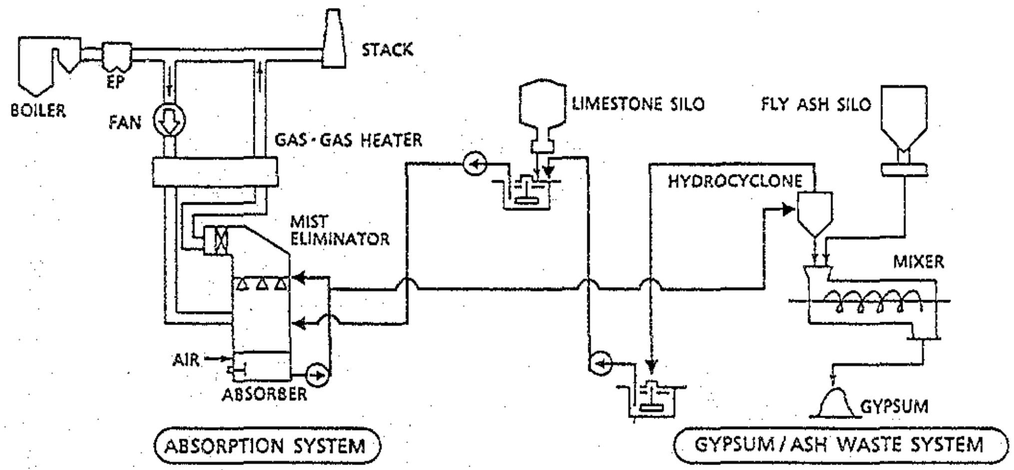


In situ forced oxidation (IFO) system



External forced oxidation (EFO) system

Fig. 6.5-2 Comparison of Oxidation System



FLOW SHEET

NO.	PORTION	LINING MATERIAL
1	FLUE GGH~ ABSORBER INLET	HEAT RESISTANT GLASS FLAKE RESIN
	ABSORBER OUTLET ~GGH INLET	GLASS FLAKE RESIN
2	ABSORBER GAS INLET TANK UPPER ZONE	HEAT RESISTANT GLASS FLAKE RESIN
	SPRAY ZONE	RUBBER
	MIST ELIMINATOR	GLASS FLAKE RESIN
3	TANK	GLASS FLAKE RESIN OR RUBBER
4	PIT	RESIN MORTAR
5	SLURRY PIPING	RUBBER

Fig. 6.5-3 STANDARD LINING MATERIAL FOR WET LIMESTONE GYPSUM FGD SYSTEM

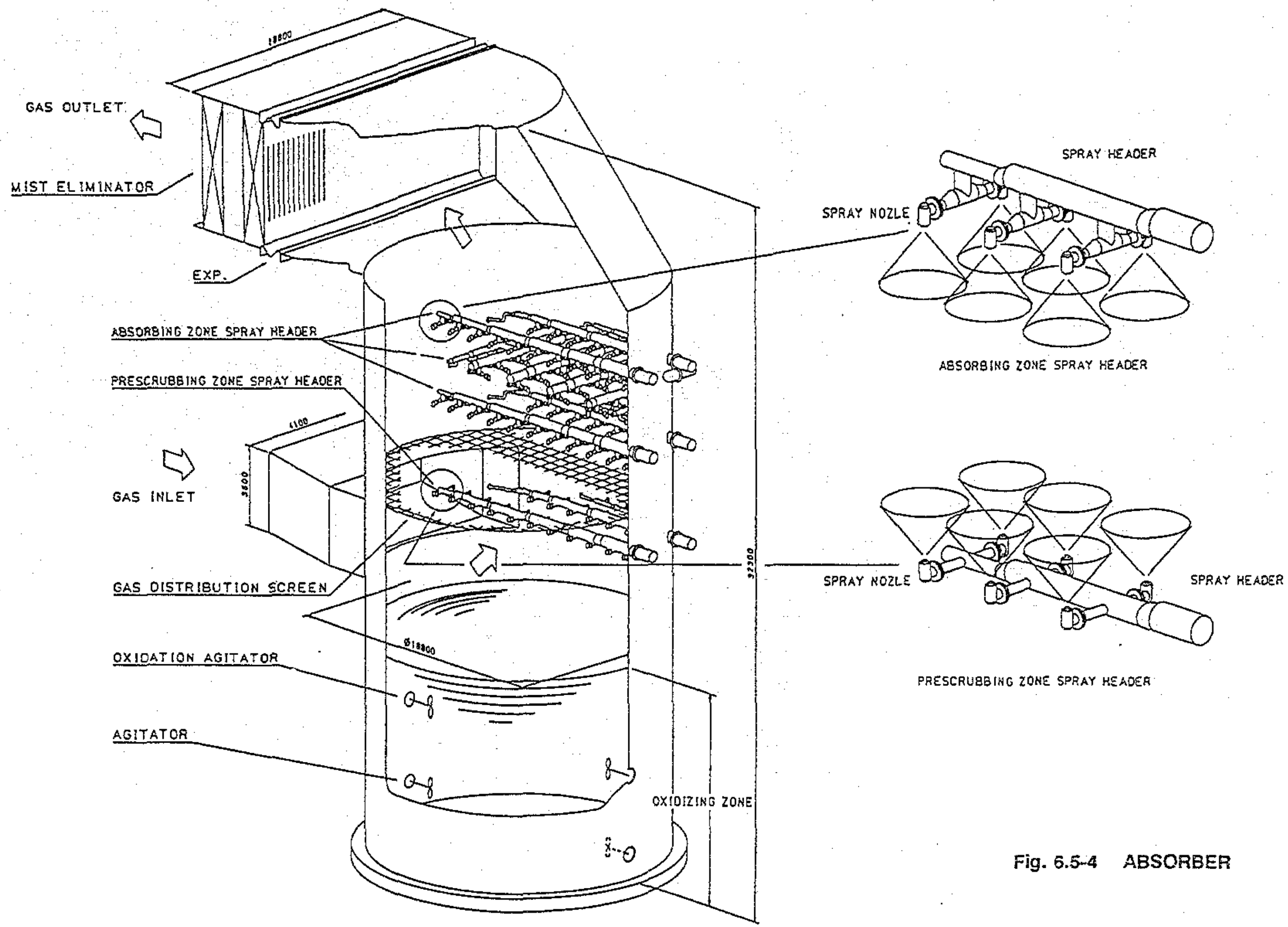


Fig. 6.5-4 ABSORBER

6.5.2 Boost Up Fan (BUF)

(1) Fan Position

The corrosive and abrasive environment of Boost Up Fan (BUF) depends on the BUF position, so that the construction and performance of BUF to be mounted 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 adopted for this project.

Features of each fan position are as follows:

- A position

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

  While it is necessary to consider measures against abrasion 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 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 fan due to reduction of actual gas quantity.

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 lesser leakage of absorber untreated gas towards the stack side.

- C position

As C position fan is located in the spot where the temperature is the lowest (about 50°C), the fan capacity can be the smallest. If sulphuric acid mist is in the gas, corrosive environment will be created, so that use of ultra high class stainless steel is required for the fan material. Consequently, the cost of this fan is the highest and there is a little experience.

When regenerative rotating type GGH is adopted, the untreated gas leakage will be the same as B position fan.

- 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.

Japanese Power Companies have no experience of adopting D position fan.

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 6.5-1 shows comparison of each location of the fans.

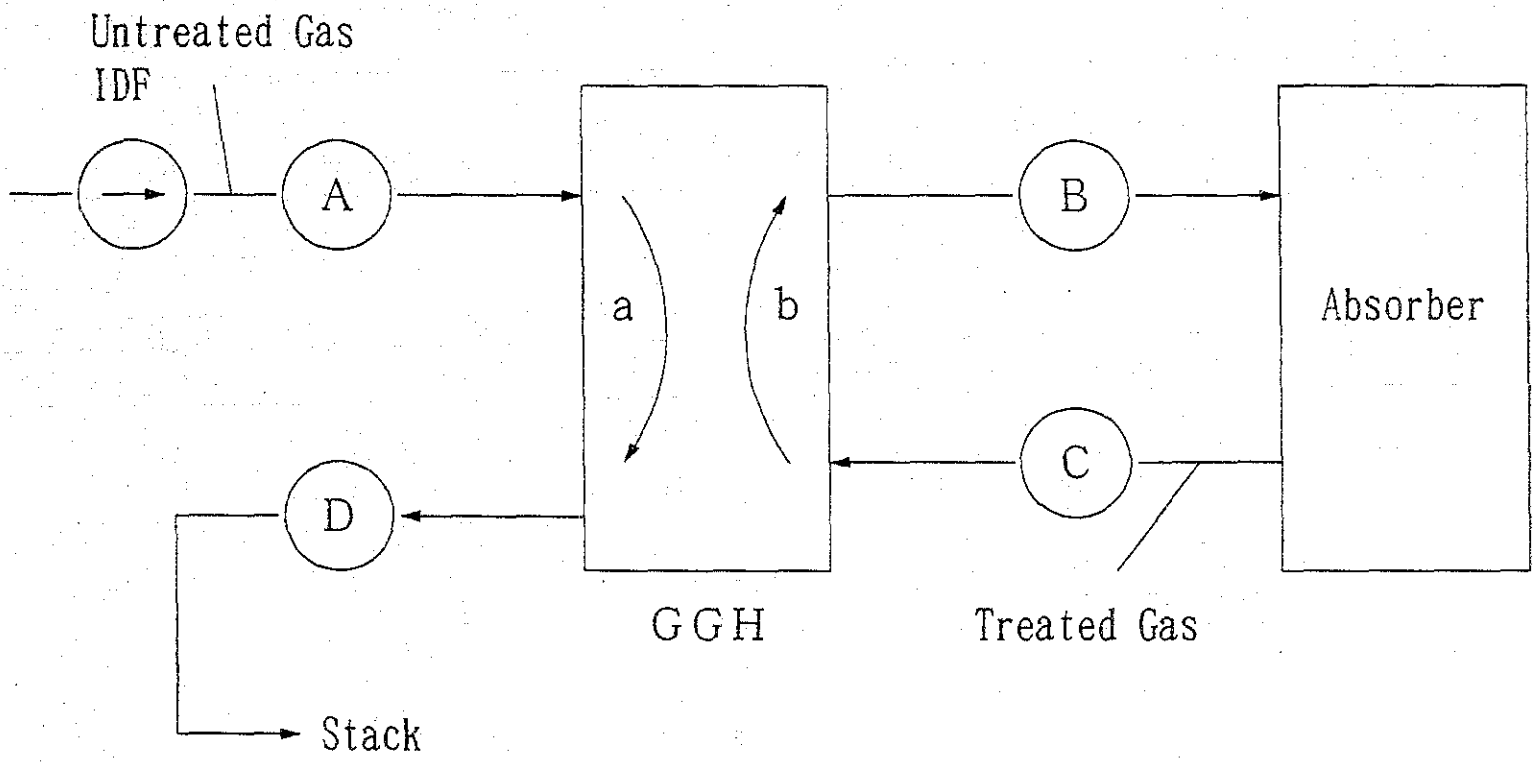


Fig. 6.5-5 Position of BUF and Gas Flow

Table 6.5-1 Comparison of Fan Positions

Fan Position		A	B	C	D
Gas temperature (°C)		114 - 130	80 - 100	45 - 50	80 - 90
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 (%)		5	1.5	1.5	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

(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 material, and both centrifugal and axial fans can be mounted there.

Table 6.5-2 shows comparison of the fan types of this case.

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

- 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 are applied to the Kozienice Power Plant.

Table 6.5-2 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 Abrasion	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

(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.

- Fan Position: A position
- Number : One (1) for each FGD unit
- Fan Type : Axial Fan
- Capacity : Flue gas flow rate 56,300 m^3/min
  Static pressure 390 mmAq
  Motor power 4,700 kW

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 Heater (GGH)
  - Regenerative Rotating Type
  - Non-Leak Type
- After-Burner

The regenerative rotating type Gas-to-Gas Heater (GGH) which has wider experiences and a high reliability with a cheeper operating cost will be adopted for this project.

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 down stream of 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 6.5-3 shows the comparison of both methods.

The GGH method which does not require liquid fuel and saves water consumption will be adopted for this project.

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 6.5-4.

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 emission standards.

Taking account of the emission standards for the case of the Kozienice Power Plant, no application of the non-leak type GGH is required, so that the regenerative rotating type GGH will be adopted for the Kozienice Power Plant.

Table 6.5-3 Comparison of Flue Gas Reheating System

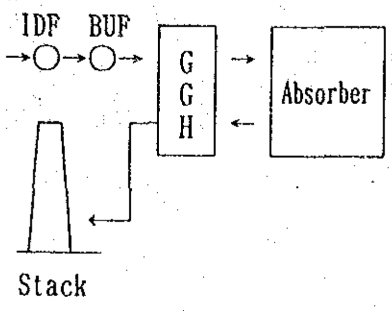
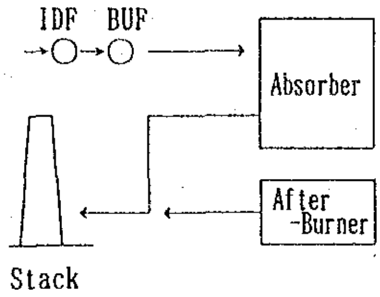
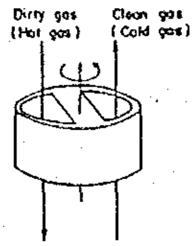
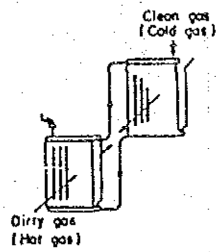
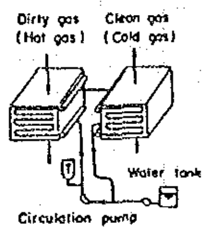
	Item	Gas-to-Gas Heater (GGH)	After-Burner
1.	Outline of the system		
2.	Flue gas reheating method	Heat exchange is conducted between the absorber inlet gas (hot gas side) and the absorber outlet gas (cold gas side), thereby the absorber outlet gas is reheated.	The absorber outlet gas is directly heated 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 6.5-4 Comparison of Gas-to-Gas Heater (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

(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 study, the flue gas temperature at the GGH outlet will be set from 80 to 90°C where problems such as corrosion will not be severe.

Besides, the GGHs which have the same specifications will be employed to all FGD units taking maintainability account. In this case, GGH outlet temperature of the FGDs for the No. 4 to No. 8 power generation units will be 80°C and that of the FGD for the 500 MW No. 9 unit will be 90°C.

Table 6.5-5 shows the anticipated performance data of the GGHs.

The case 1 shows the gas balance under the 500 MW unit gas condition and the case 2 shows the gas balance equipped with the case 1 GGH under the 200 MW units gas condition.

Where, the GGH inlet gas temperature is included the temperature rising (4°C) in the BUF.

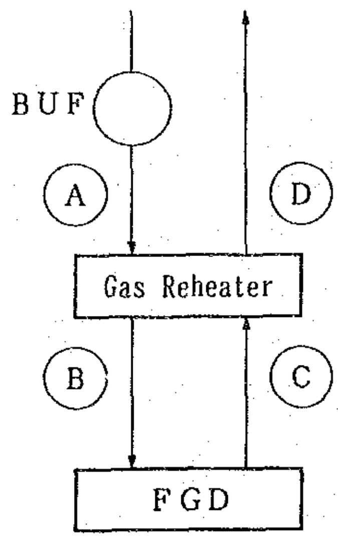
Table 6.5-5 GAS REHEATER PERFORMANCE DATA

CASE 1

Item \ Location	A	B	C	D
1. Gas Flow Rate (Wet) (m^3N/h)	2,078,000	2,169,200	2,240,300	2,149,100
2. Gas Temp. (℃)	134	86	44	90

CASE 2

Item \ Location	A	B	C	D
1. Gas Flow Rate (Wet) (m^3N/h)	2,042,500	2,131,100	2,180,500	2,091,900
2. Gas Temp. (℃)	118	79.5	43	80



6.5.4 Limestone Storage and Handling System

Limestone is used as absorbent in FGD process. It is normally of fine powder in practical application. Therefore, the limestone storage and handling system shall be designed on the basis of powder's characteristics. In addition, reactivity of the limestone is an important item for FGD design.

Taking account of these items, the system will be designed as follows.

(1) Limestone Properties and Receiving Method

Limestone properties will be determined as follows taking account of analysis results of the limestone obtained through the investigation at 2nd stage and the design values which are generally used for FGD system in Japan.

- Purity : $CaCO_3$ 94% or more
- Particle Size: 325 mesh pass through 95% or more

The reactivity of the obtained limestone is better than that of the limestone which are generally used for FGD systems in Japan. Therefore, there will be no problem in the system design.

Fig. 6.5-6 shows the limestone reactivity.

In addition, powdered limestone with abovementioned features is to be procured from cement factories located near the Kozienice Power Plant. Hence, the limestone as powder will be received by railway wagons and/or truck lorries.

(2) Limestone Consumption in the FGD System

Limestone consumption in each FGD unit will be as follows:

Limestone consumption for one (1) 500 MW FGD at rated load: 9.6 t/h

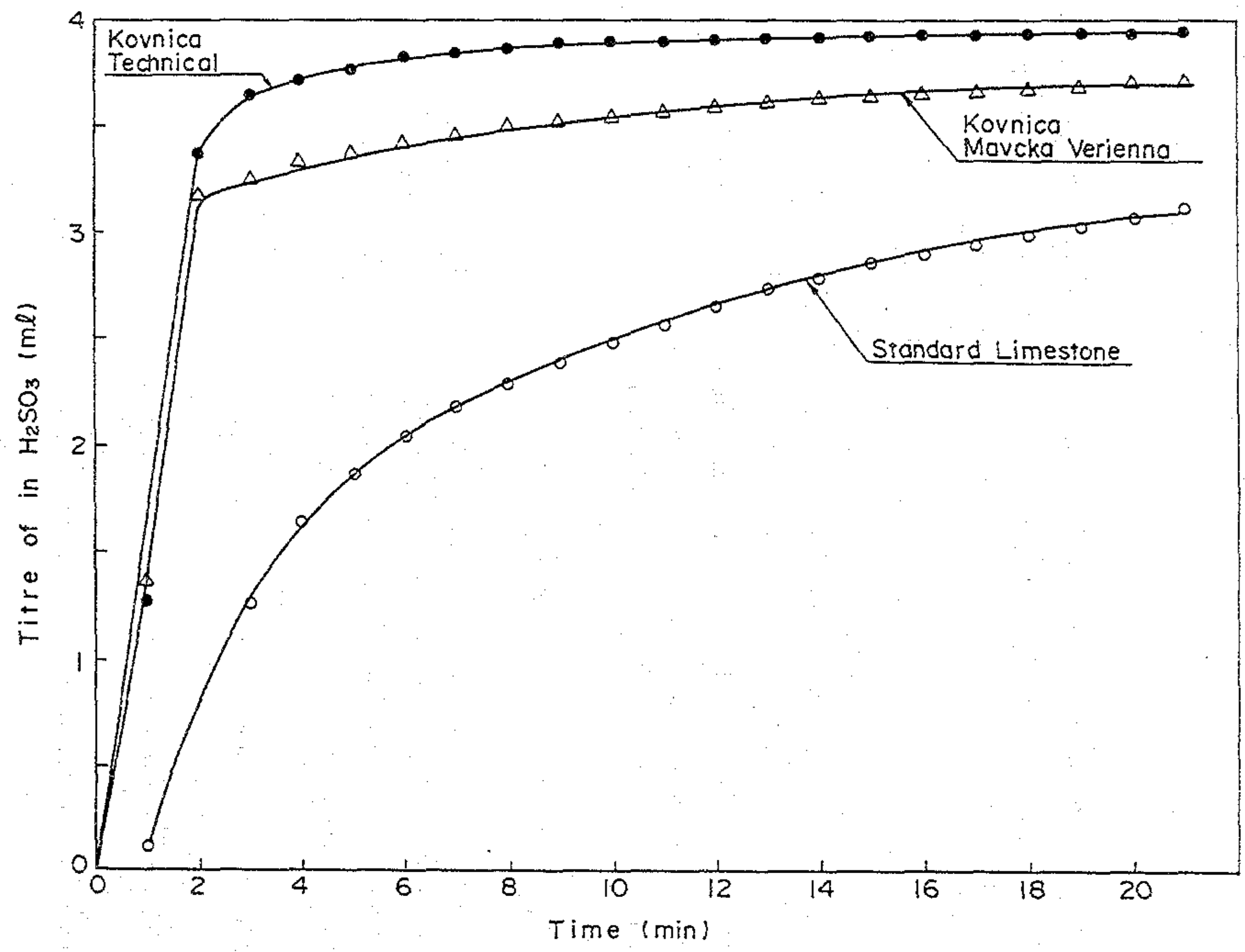


Fig. 6.5-6 STANDARD LIMESTONE REACTIVITY

(3) System Description

Limestone as powder phase will be carried by railway wagons or truck lorries depending on the source of supply and the received limestone is stored in the limestone silos.

Each silo has the airslide equipment for fluidization and the feeder for limestone discharge. Limestone is fed by the feeder into the limestone slurry pit where the limestone is dissolved in water, then pumped to the absorber.

The limestone silo is installed for each FGD unit. The storage capacity of each silo will be equivalent to three (3) days, i.e., 630 m^3.

6.5.5 Byproduct Handling System

(1) Method of Handling the Byproduct

As for the method of handling the byproduct, the gypsum slurry will be mixed with flyash and disposed to the byproduct disposal area because of the following reasons.

- There is little market for gypsum board around the Kozienice Power Plant and gypsum price at cement factories is low.

- Coals used at the Kozienice Power Plant contain high levels of chlorine.

  No waste water treatment technology for treating, on commercial base, waste water containing such a high level of chlorine is yet to be available.

  With the use of this method, chlorine will be fixed in minerals which are generated by reactions of flyash and gypsum.

(2) Proportions of Mixing

Approximate proportions of mixing for each FGD unit will be as follows:

- Fly ash 63 t/h
- Gypsum 14 t/h
- Water 26 t/h

Annual amounts of flyash required for byproduct handling will be calculated as follows with the above mentioned mixing amounts and 57% plant utilization factor (equivalent to 5,000 hours operation at rated output).

63 t/h × 5,000 h × 3 units = 945,000 t/year · 3 units

The flyash production and effective use amount at the Kozienice Power Plant are shown below.

	1987	1988	1989	1990
Flyash production (A)	1,539,936	1,255,534	1,272,468	934,427
Effective use (B)	228,155	234,699	227,606	155,393
Ash disposal (A-B)	1,311,781	1,020,835	1,044,862	779,034
Plant utilization factor				
200 MW Units	59%	54%	55%	52%
500 MW Units	40%	36%	33%	19.5%

From the past data of flyash production, effective use, plant utilization factor, etc., flyash amount for byproduct handling is to be secured without the data in 1990 when the plant utilization factors were the lowest.

According to the information from the power station, plant utilization factor for each power generating units will be changed up to 57%.

Therefore, the present amount of flyash effective use is to be achieved after the FGD installation.

In order to minimize the amount of waste water, the maximum chlorine concentration in the absorber will be designed as 40,000 mg/ℓ (39,000 mg/ℓ in the material balance) as mentioned in the absorber design, so that the amount of waste water will be approx. 26 t/h at the maximum.

Mixing amounts given above are approximate figures at this stage, and there is a possibility that the lime addition is required in some cases, so that sample tests are to be carried out in a detailed design stage using actual ash to get more reliable values.

(3) System Description

The gypsum slurry extracted from the absorber is concentrated in the hydrocyclones to get the slurry concentration at 35%.

The overflow liquid of the hydroclones is reused as make-up water for the absorber and as dissolving solution for the limestone slurry.

The 35% solids hydrocyclone underflow sludge is once stored in an agitated waste slurry tank then pumped to a pug mixer where flyash and lime (if necessary) are added to increase density of the landfill waste 70-75% solids.

The pug mixer discharges the waste onto enclosed waste conveyors which transport the waste to the by product disposal area.

While the byproduct handling system will be installed for each FGD Unit (unit-to-unit method), the waste conveyors will be designed of common use for three (3) FGD units and as two (2) trains taking redundancy into account.

Each flyash silo is designed to be compact with one(1) day storage capacity i.e. approx. 1,800 m^3.

(4) Byproduct Disposal Area

A part of the ash disposal area will be used for the byproduct disposal area where the impermeable sheet will be applied to a bottom and sides to prevent permeation of hazardous substances which contain high level of chlorine into ground by rainfall or snowfall.

There are possible materials for the impermeable sheet such as vinyl chloride, synthetic rubber, polyethylene and so on.

In this case, 1.5 mm thickness high-density polyethylene sheet will be applied taking account of durability during operation and workability at construction.

Annual amount of byproduct mixed with flyash is to be approx. 1,500,000 m^3, so that amount of that for 12 years operation is to be approx. 18,000,000 m^3 (1,500,000 m^3 x 12 years).

The byproduct disposal area will be required approx. 810,000 m^2 (900 m x 900 m). Fig. 6.5-7 shows outline of the byproduct and ash disposal area.

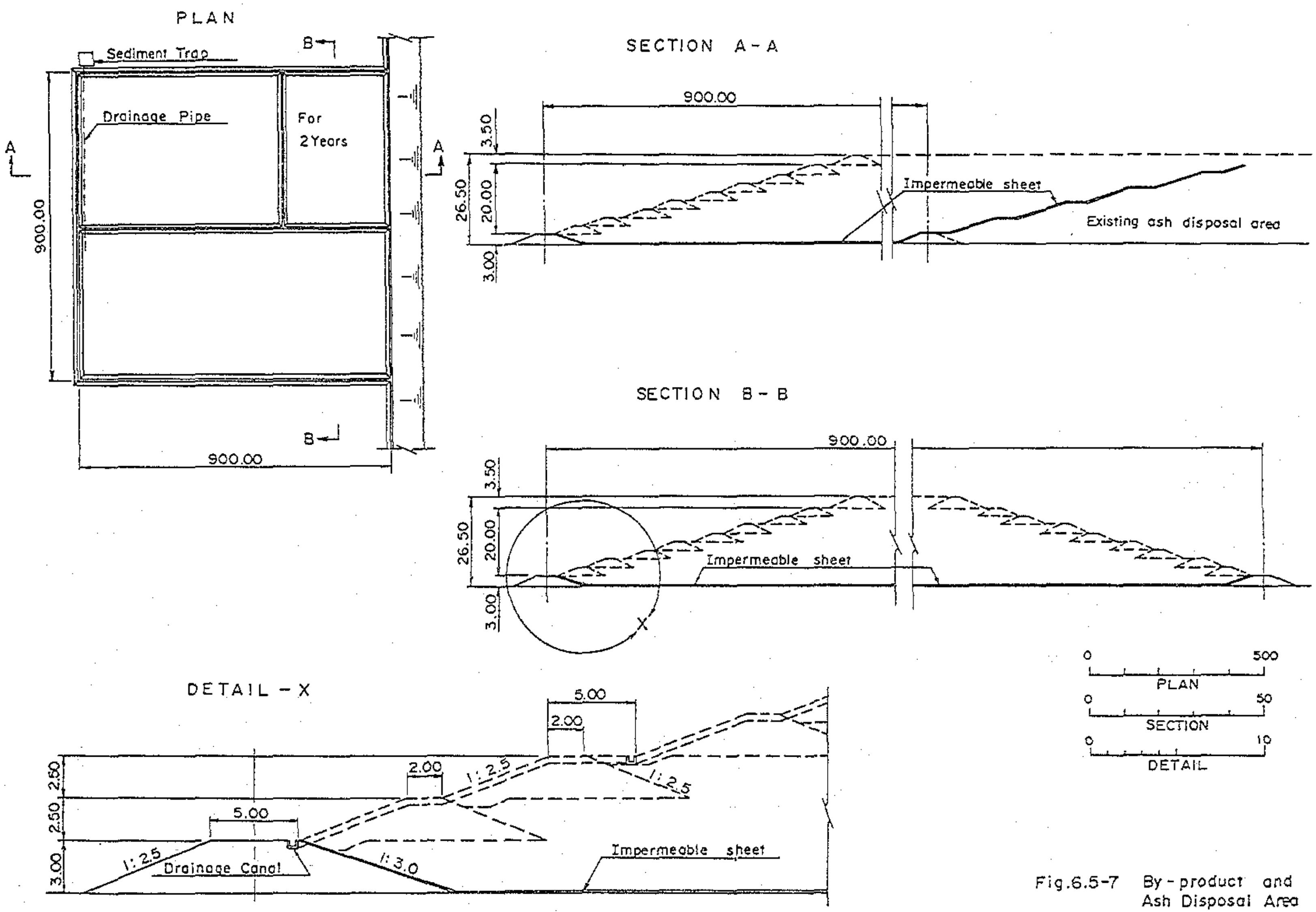


Fig.6.5-7 By-product and Ash Disposal Area

6.5.6 Water Acquisition and Supply System

The water required for FGD system is used as make-up for the absorber, preparation of limestone slurry and cooling for each equipment.

The water for the FGD system will be taken from Wisla river. The water acquisition and supply system will be equipped.

(1) Required water quantity for FGD System

Following water quantity for each FGD unit will be required.

- Process water : 82 t/h
  (make-up and limestone slurry preparation)

- Cooling water : 20 t/h

In order to minimize the quantity of cooling water, air cooled type bearing will be applied to the BUF.

The cooling water will be used for following items.

- GGH : 10 t/h
- Motor for BUF : 2 t/h
- Oxidation Air Blower : 2 t/h
- Air Compressor : 6 t/h

(2) Water Acquisition Scheme

According to the water quality of Wisla river shown in Table 4.3-10, there is a little difference between inlet side and outlet side. It is considered that 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 culvert so that the power generating units can be operated without troubles by the water acquisition.

Fig. 6.5-7 shows the water acquisition scheme (location of the water pumping station).

(3) System Description

Two (2) make-up water pumps will be designed of common use for three (3) FGD units. 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 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. 6.5-8 shows the water acquisition and supply system.

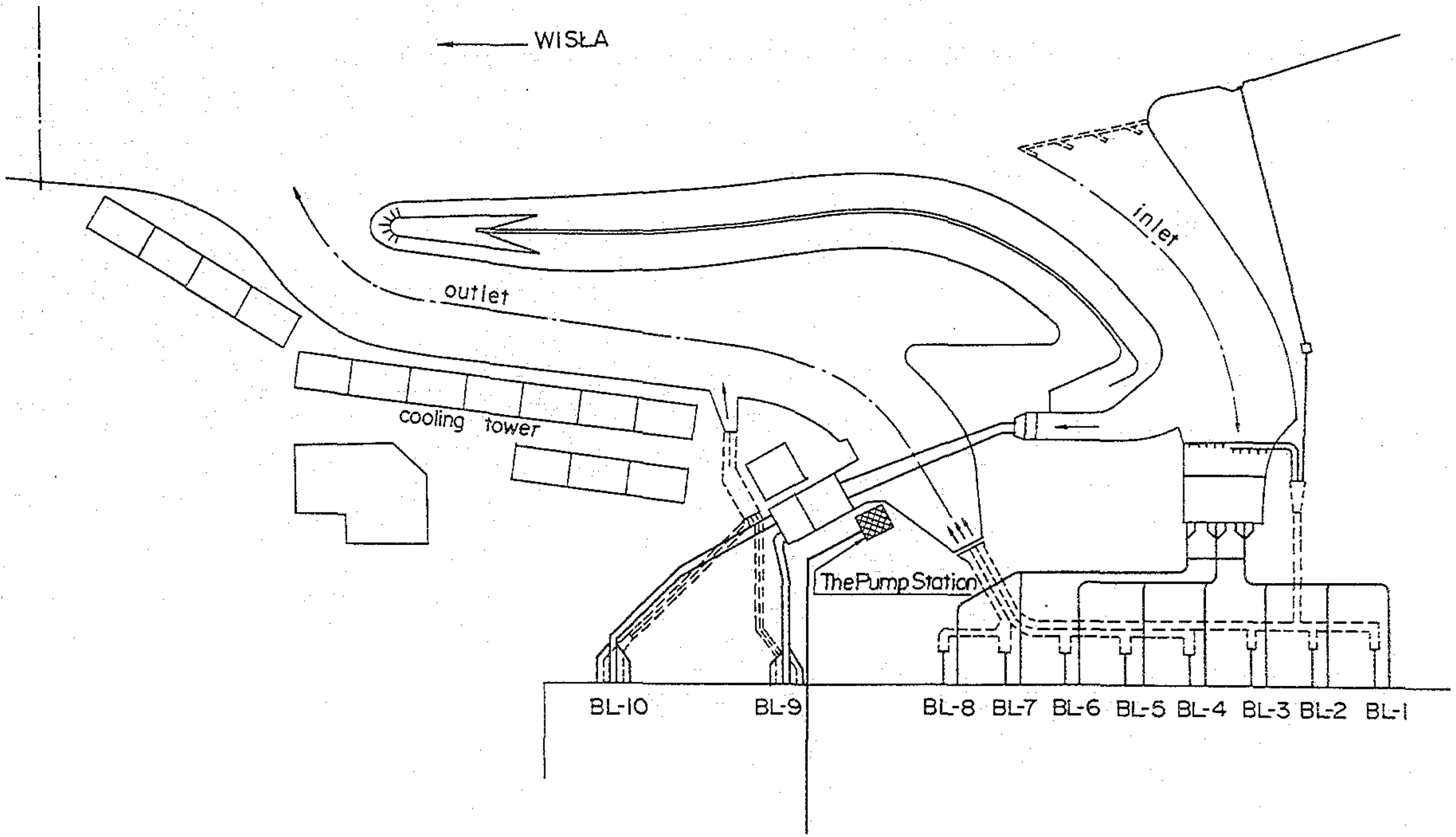


Fig. 6.5-8 Location of The Pump Station

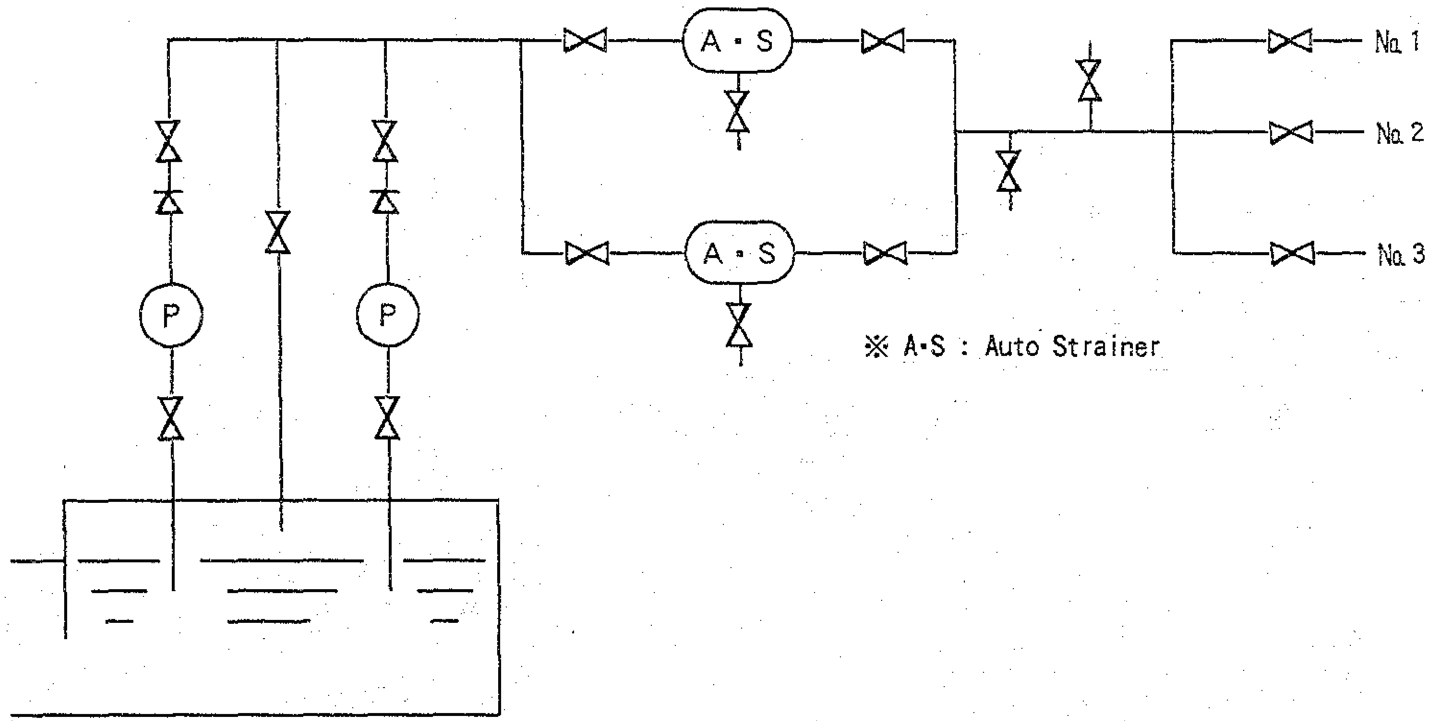


Fig. 6. 5-9 Flow Diagram of Raw Water System

6.5.7 Air Supply System

The air required for the FGD System is followings:

- Oxidation air
- Control air
- Service air
- Others (Seal air for GGHs and dampers)

The air supply system for the FGD system will be independent of that for the power generating units because of following reasons.

- No modification is required.

- There is no effect on the FGD operation and safety stoppage when the air supply system for the power generating units fails.

(1) Oxidation Air Supply System

The oxidation air required for each FGD unit will be 4,570 m^3N/h.

Four (4) oxidation blowers will be installed for three (3) FGD units. One (1) of the four (4) oxidation blowers will be for stand-by.

The capacity of the oxidation blower is designed to be 90 m^3/min and 0.8 kg/cm^2 from the required air flow and pressure.

(2) Control and Service Air Supply System

Following control air and service air will be required for each FGD unit.

- Control Air : 150 m^3N/h
- Service Air : 190 m^3N/h

The service air is mainly used for airslide equipment of silos, so that dehumidifiers dryers will be required for air drying. Besides, the dehumidifiers will be required for the control air supply system. Therefore, the control and service air will be supplied from common sources (compressors).

Two (2) compressors will be installed for three (3) FGD units. One (1) of the two (2) compressors is used to supply the control and service air, while the other is in stand-by.

The capacity of the compressor is designed to be 1,020 m^3N/h and 7 kg/cm^2-g from the required air flow and pressure.

(3) Seal Air Supply System

As for GGHs and dampers seal air sources, two (2) seal air fans will be installed for three (3) FGD units. One (1) of the two (2) fans is ordinary used, the other is for stand-by.

The capacity of the fan is designed to be 190 m^3/min. and 700 mmH_2O.

6.5.8 Electrical Equipment

Electrical equipment was examination from the viewpoints of economy, reliability and operability, and it is formulated into the power supply system shown in Fig. 6.5-10 (One Line Diagram). The power is taken from the 220 kV overhead lines for the existing No. 4 Starting Transformer. The power is received by a 27-MVA FGD transformer via disconnecting switches and supplied to each FGD. Four lines of metal-clad busbars, three for respective FGDs and one for common, are provided for operability.

(1) Methods of getting and supplying power

Four methods of getting and supplying power as itemized below, are considerable.

a. To get and supply power from existing house transformers or starting transformers

b. To install a transformer for FGDs at generator output in parallel with existing house transformers

c. To add switchgears at Switch Yard to get electricity and further install a transformer for FGDs for supplying

d. To get electricity from the overhead line for the existing starting transformer primary by T-branching, and install a transformer for FGDs for supplying.

Each of these cases is shown in Fig. 6.5-11 and discussed below.

(Case A)

Existing house transformers have no capacity for supplying additional power. In addition, getting electricity from existing starting transformer is not realistic considering the high load which occurs at starting the plant and backing up house transformers.

(Case B)

This method requires remodeling and addition of IPBs (Isolated Phase Buses), and is not economical. In addition, power must be get from more than one generator, which is not realistic for operation.

(Case C)

The power source is independent in this method, and it is favorable without operational restrictions. The method, however, requires addition of switchgears, which is not economical.

(Case D)

This method shares the existing switchgears of the starting transformer, and is much economical in comparison with Case C. In addition, it involves less remodeling of existing equipment.

The method of Case d is employed according to discussions given above. The power is get, by T-branching, from the overhead lines which are supplying power to No. 4 starting transformer from the 220 kV Switch Yard. The point of getting electricity is close to the Electrical Room (in the ZRE Building), and it is favorable also.

Power is supplied to the Electrical Room as shown in Fig. 6.5-12. A transformer for FGDs is installed near the point of T-branching for getting electricity from the overhead lines, and power is then supplied from the transformer to each metal-clad switchgear existing in the Electrical Room.

(2) One Line Diagram

Fig. 6.5-10 (1/3) shows a one line diagram of the whole system.

The metal-clad busbar has been divided into four circuits, i.e., those for No. 1 FGD, No. 2 FGD, No. 3 FGD and for common equipment.

Each metal-clad busbar is provided with bus ties so that it is backed up by existing metal-clad busbars PR4-A and PR4-B.

The criteria stipulated by Kozienice Power Plant as below are considered for one line diagrams.

a. Standard voltage of bus bars

M/C 6.3 kV, P/C 400 V, MCC 400 V

b. Standard voltage of auxiliary machines

M/C 6.0 kV, P/C 380 V, MCC 220/380 V

c. Classification of auxiliary machines

M/C	160 kW and more
P/C	more than 50 kW and less than 160 kW
MCC	50 kW and less

(3) FGD transformer capacity

The capacity of the transformer for FGDs was calculated to be 27 MVA as given below.

[Conditions]

• Estimated rated power consumption of each FGD	6.6 MW
• Allowance for transformer capacity	10%
• Power factor	0.8%

[Calculation]

6.6 MW × 1.1 ÷ 0.8 = 9 MVA
9 MVA × 3 Units = 27 MVA

(4) Confirmation of Interrupting Capacity and Voltage Drop

The short-circuit current in metal-clad switchgears and voltage drop at start of the largest auxiliary equipment in the power supply system are confirmed below to show that the power supply system is appropriate in design.

a. Confirmation of short-circuit current

The short circuit current of a metal-clad incoming breaker (point A shown in the following figure) and feeder breakers (point B shown in the following figure) are calculated. In calculations, the following conditions are assumed.

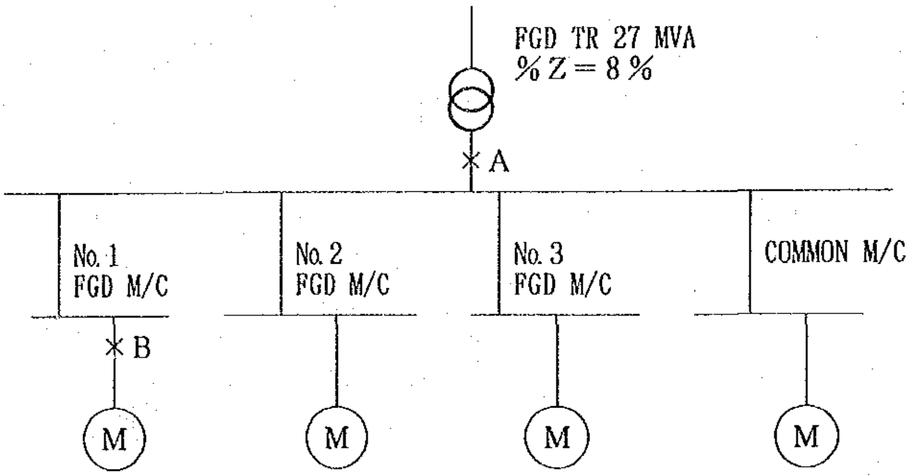
i. Percent impedance of FGD transformer is 8%

ii. The impedance on the Switch Yard side is ignored.

iii. Motor load capacity is 90% of total rated load, i.e., 6.6 MW × 0.9 ÷ 0.8 (power factor) × 3 = 22 MVA

iv. Motor contribution impedance is 25%.

[Calculation]



Fault current at Point A

$$\frac{27\ \text{MVA} \times 100}{\sqrt{3} \times 6.3\ \text{kV} \times 8\%} = 30.9\ \text{kA} \quad \cdots\cdots\cdots \quad \text{(i)}$$

Fault current at Point B

(Fault current at Point B)

= (Fault current at Point A) + (Current due to motor contribution)

Current due to motor contribution is given by;

$$\frac{22\ \text{MVA} \times 100}{\sqrt{3} \times 6.3\ \text{kV} \times 25\%} = 8.1\ \text{kA}$$

Thus, the fault current at Point B is;

30.9 + 8.1 = 39.0 kA . . . . (ii)

Results (i) and (ii) are well below 48 kA, the interrupting current of metal-clad switchgears being employed at the Kozienice Power Plant, and they pose no problem.

b. 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)
- cosϕ' : Power factor at starting the equipment largest in capacity (BUF), which is assumed to be 0.15
- cosϕ" : Mean power factor of other equipment, which is assumed to be 0.85
- %Z : Transformer impedance, which is assumed to be 8 (%)
- R/X : R-to-X ratio of transformer, which is assumed to be 0.1
- P : Power of the equipment largest in capacity = 4.7 kW (BUF)
- ycosϕ : 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:

$$e=\frac{8}{27}[0.1\times\{(27-\frac{4.7}{0.85}+\frac{4.7}{0.85}\times 6.5\times 0.15\}+$$

$$\{27-\frac{4.7}{0.85}\times 0.53+\frac{4.7}{0.85}\times 6.5\times 0.99\}]$$

$$=\frac{8}{27}(0.1\times 23.64+46.96)$$

$$=14.6(\%)$$

The result of calculation indicates that the voltage drop in the metal-clad busbar which would occur when the largest auxiliary equipment of BUF is started under full load is 14.6%. The voltage drop of 14.6% meets the criterion (15%) of the Kozienice Power Plant. Thus, there is no problem as to voltage drop also.

(5) Electric Equipment Layout

Fig. 6.5-12 shows the electric equipment layout including the point of getting the power, positions of FGD transformer and Electrical Room, and the main cable route. Fig. 6.5-13 shows the layout of panels in Electrical and Control Room.

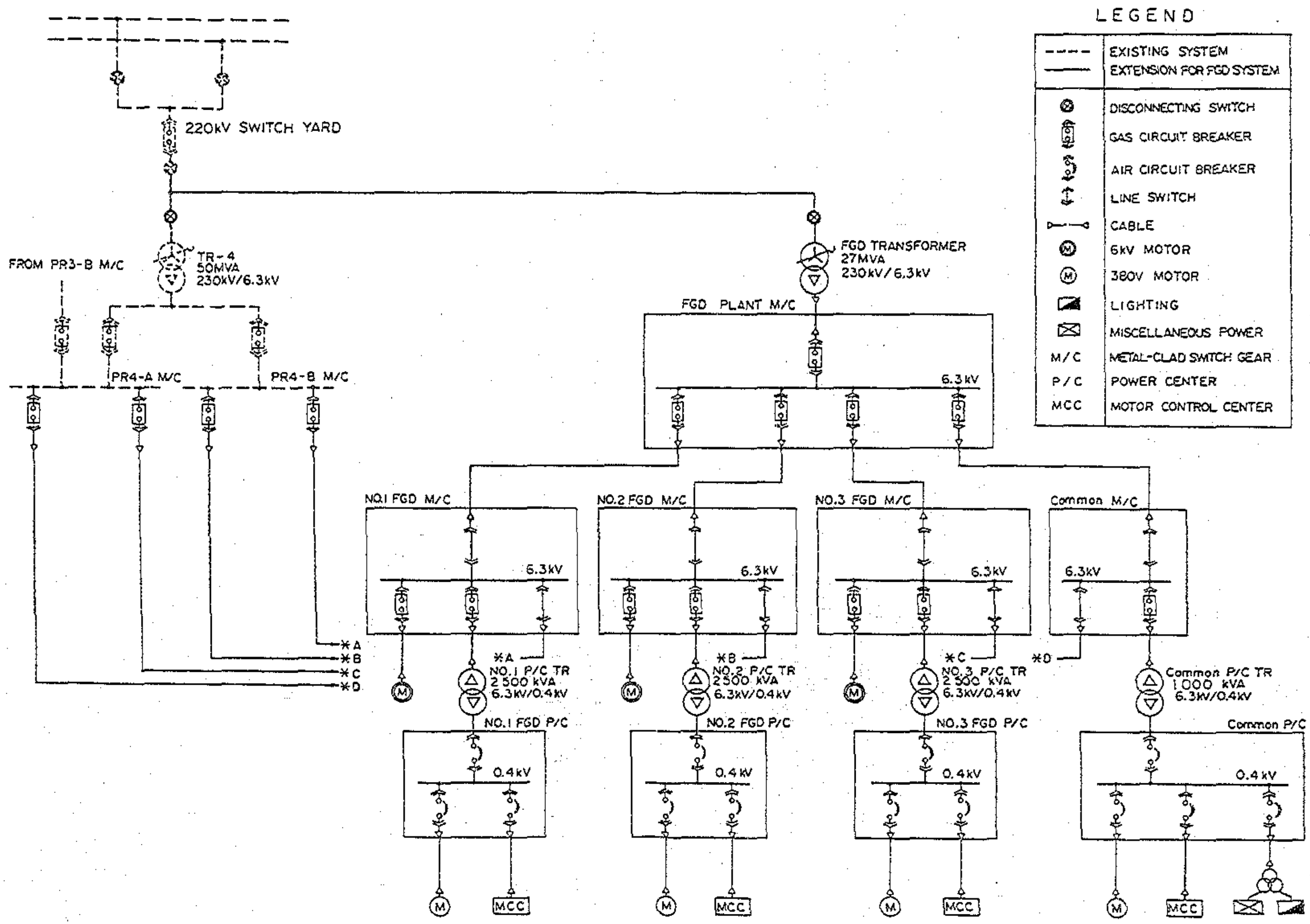
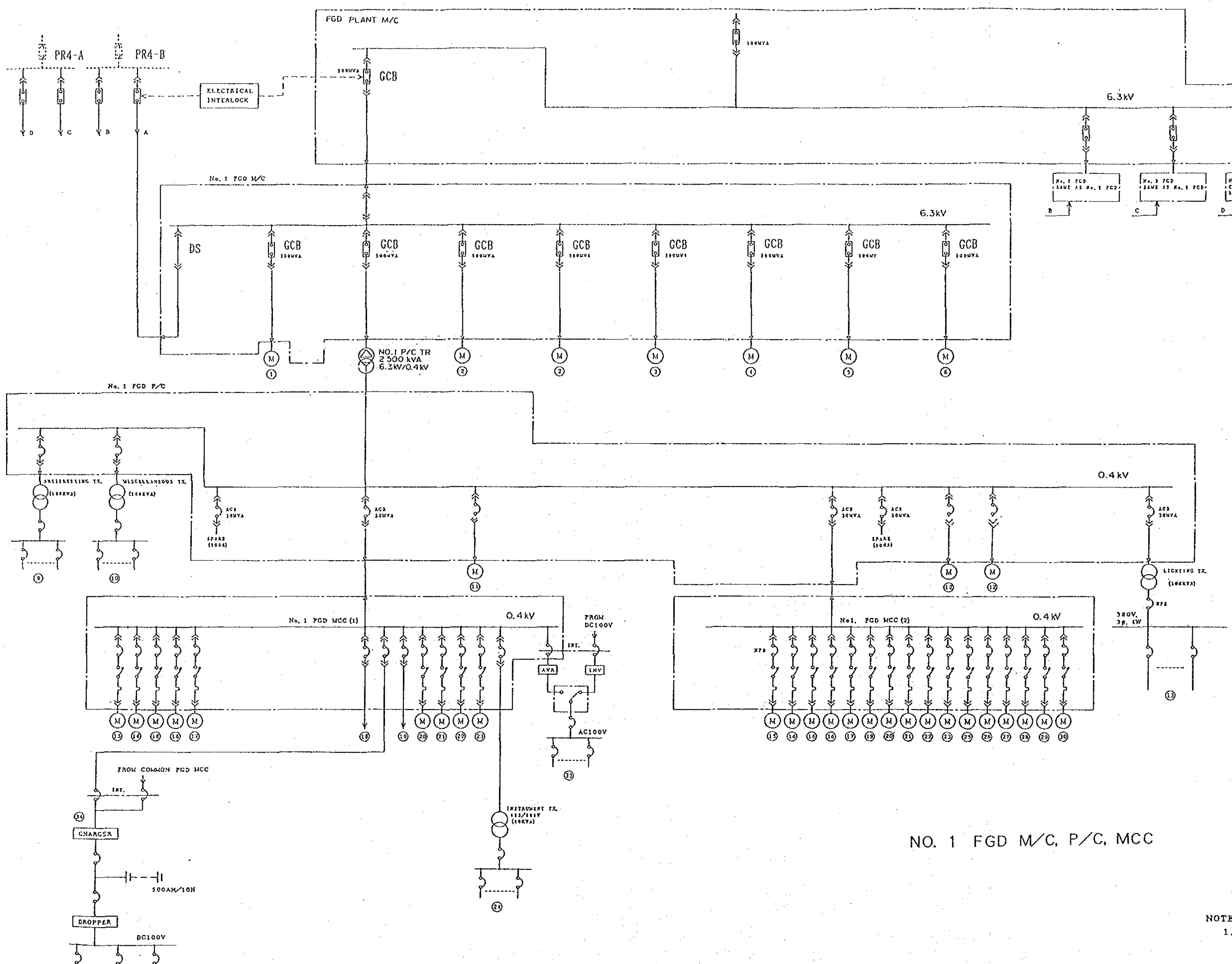


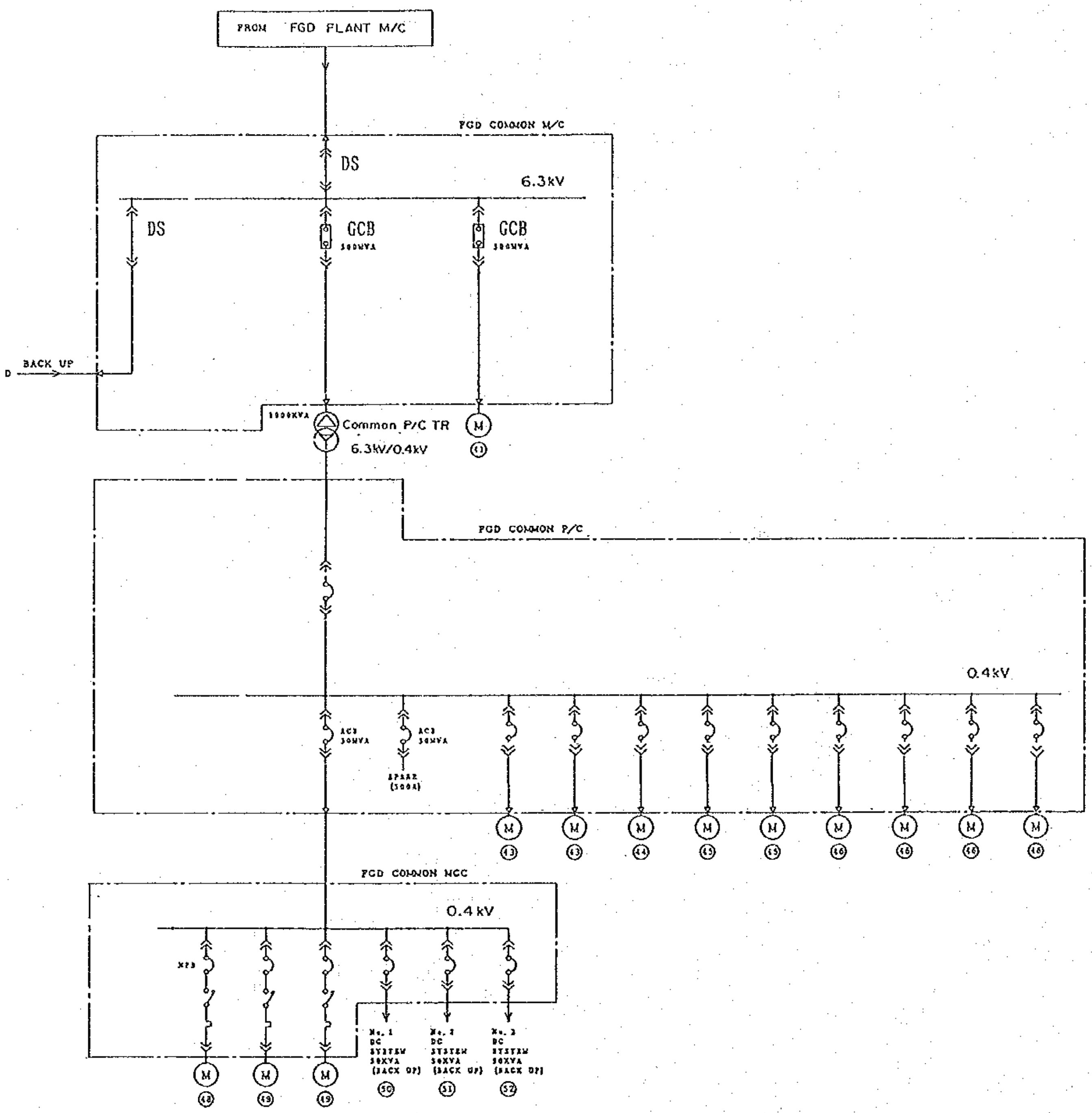
Fig. 6.5-10 ONE LINE DIAGRAM (1/3) GENERAL SCHEME



NO.	SERVICE	Q'TY/UNIT	RATED OUTPUT (KW)	VOLTAGE (V)
1	BOOST UP FAN	1	4700	6000
2	ABSORBER RECIRCULATION PUMP	1 (1)	360	6000
3	ABSORBER RECIRCULATION PUMP (LOWER)	1	720	6000
4	ABSORBER RECIRCULATION PUMP (MIDDLE)	1	760	6000
5	ABSORBER RECIRCULATION PUMP (UPPER)	1	810	6000
6	OXIDATION AIR BLOWER	1	180	6000
7				
8				
9	ANTIFREEZING	1	100KVA	380
10	MISCELLANEOUS	1	100KVA	380
11	SCAVENGING FAN	1	150	380
12	PUG MIXER	1 (1)	75	380
13	LIGHTING	1	300KVA	380
14				
15	ABSORBER AGITATOR	1 (1)	37	380
16	OXIDATION AGITATOR	6	30	380
17	M/E WASH WATER PUMP	1 (1)	3. 7	380
18	GAS GAS HEATER	1	30	380
19	RECOVERY WATER PUMP	1 (1)	11	380
20	WASTE SLURRY PUMP	1 (1)	5. 5	380
21	LIMESTONE SLURRY FEED PUMP	1 (1)	11	380
22	F-A WEIGH FEEDER	1 (1)	3. 7	380
23	LIME WEIGH FEEDER	1 (1)	3. 7	380
24	INSTRUMENT	1	40KVA	380
25	RECOVERY WATER TANK AGITATOR	1	5. 5	380
26	WASTE SLURRY TANK AGITATOR	1	2. 2	380
27	LIMESTONE SLURRY TANK AGITATOR	1	2. 2	380
28	LIMESTONE FEEDER	1	3. 7	380
29	F-A & LIME CONVEYOR	1	3. 7	380
30	WASTE CONVEYOR 1	1	11	380
31				
32				
33	CVCF	1	25KVA	380
34	CHARGER	1	50KVA	380

NOTE ;
1. Q'ty in bracket show the quantity of stand-by equipment.
e. g: 1 (1) —prescrubbing pump
1 pumps are normally running
(1) pump is stand-by

Fig.6.5—10 ONE LINE DIAGRAM (2/3)



NO.	SERVICE	Q'TY/UNIT	RATED OUTPUT (kW)	VOLTAGE (V)
41	OXIDATION AIR BLOWER	1	180	6000
42				
43	AIR COMPRESSOR	1 (1)	132	380
44	BLOW DOWN TANK AGITATOR	1	55	380
45	SEAL AIR FAN	1 (1)	55	380
46	WASTE CONVEYOR 2	2 (2)	90	380
47				
48	BLOW DOWN TANK TRANSFER PUMP	1	30	380
49	MAKE UP WATER PUMP	1 (1)	37	380
50	CHARGER (No. 1 UNIT)	1	50KVA	380
51	CHARGER (No. 2 UNIT)	1	50KVA	380
52	CHARGER (No. 3 UNIT)	1	50KVA	380

NOTE :

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

   e. g: 1 (1) –prescrubbing pump
   1 pumps are normally running
   (1) pump is stand-by

COMMON FGD M/C, P/C, MCC

Fig.6.5–10 ONE LINE DIAGRAM (3/3)

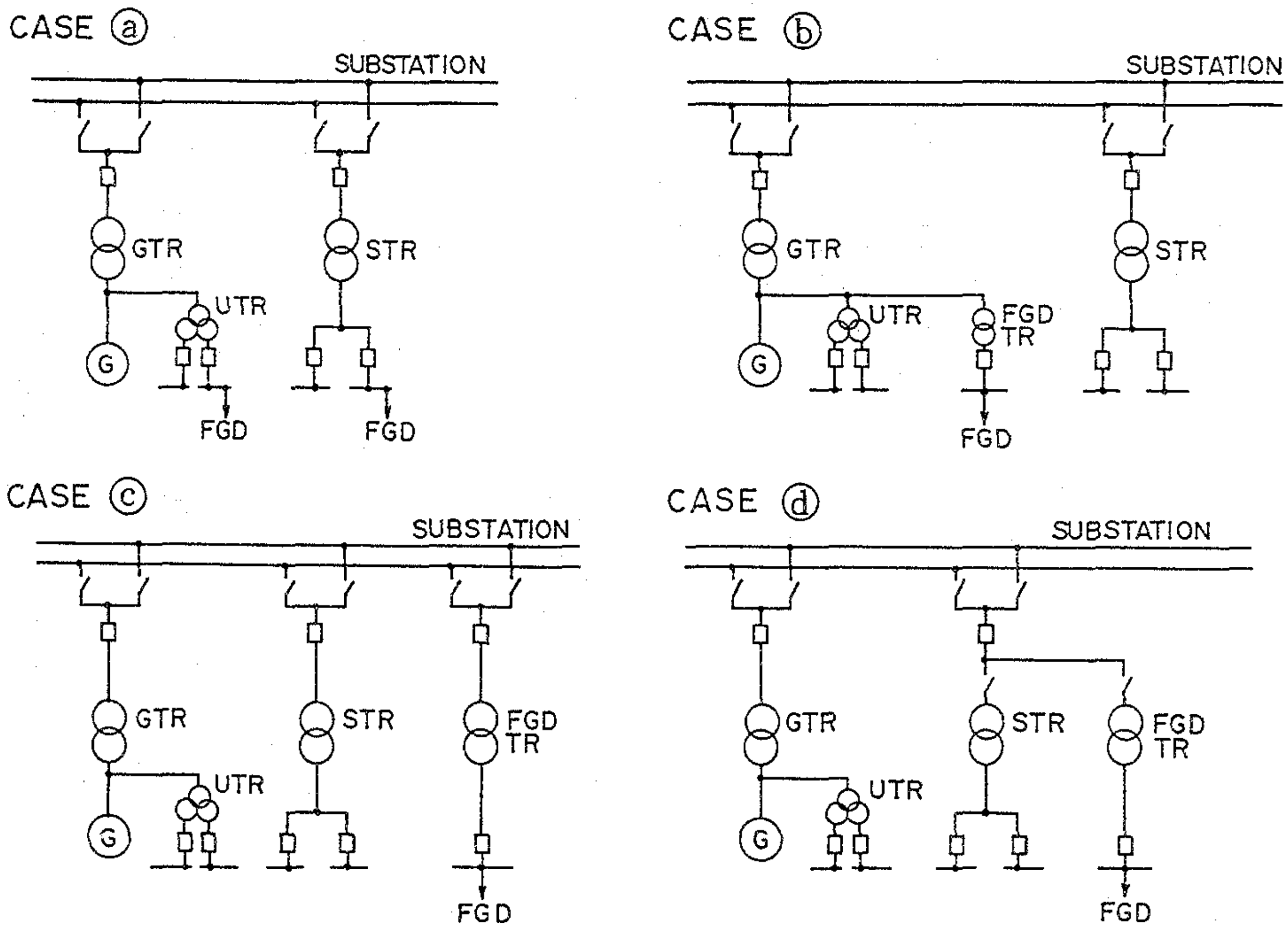


Fig.6.5-11 ELECTRIC POWER SOURCE FOR FGD PLANT

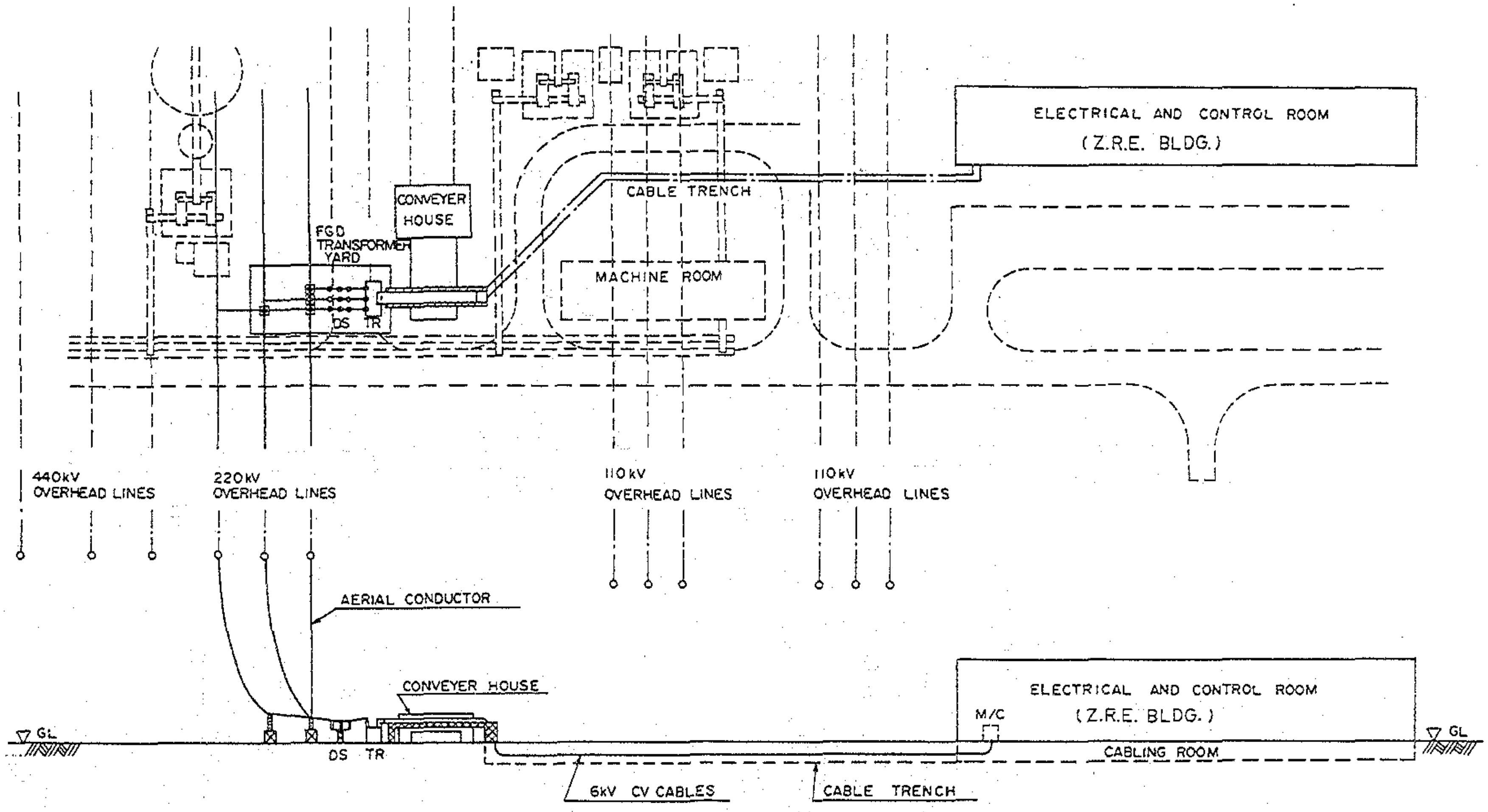


Fig. 6.5-12 LOCATION OF ELECTRICAL EQUIPMENT

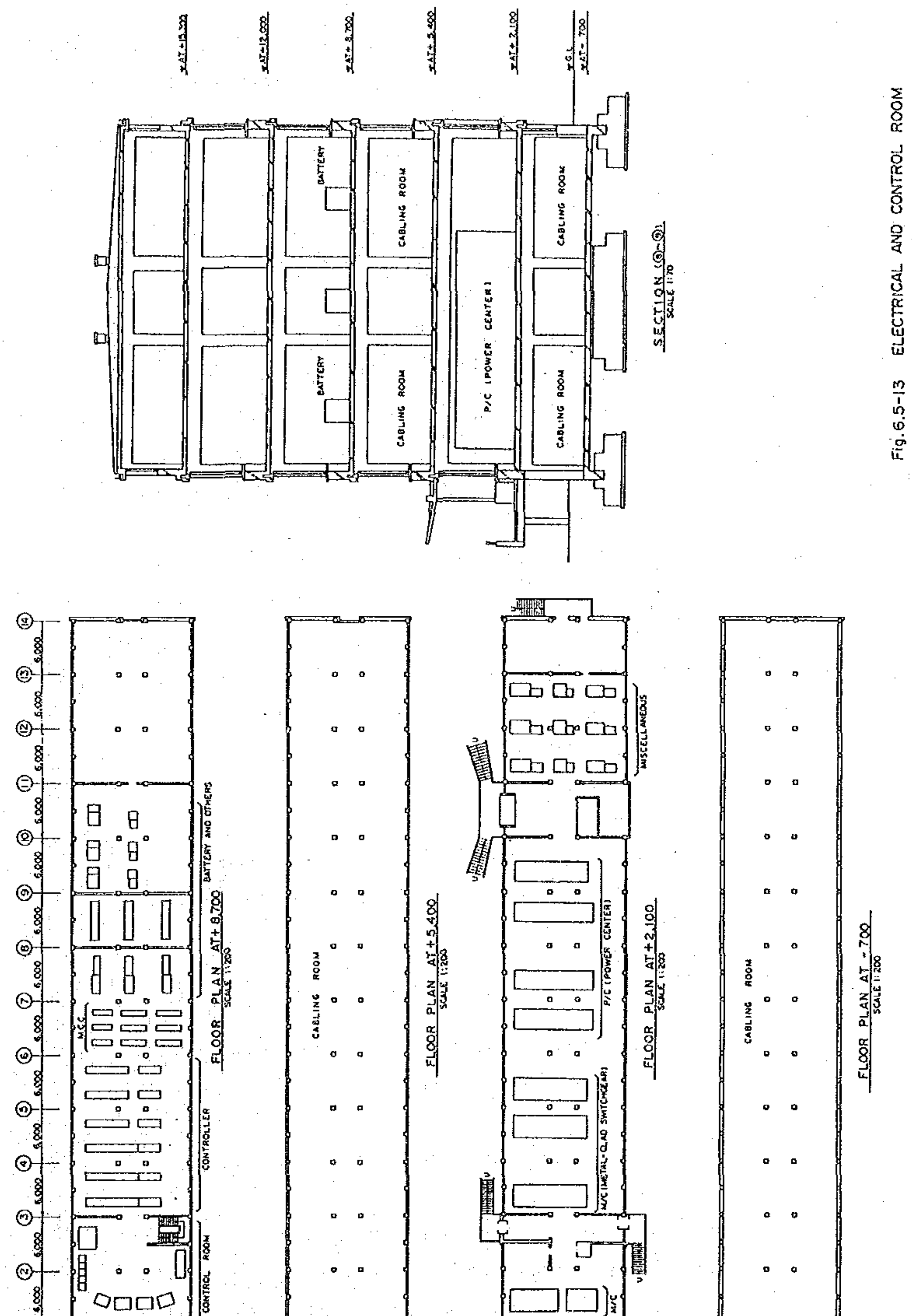


Fig.6.5-13 ELECTRICAL AND CONTROL ROOM

6.5.9 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 the Kozienice Power Plant. 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 three 500 MW class FGDs for Kozienice Power Plant.

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 execute 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. 6.5-14. Functions of each equipment are described below.

a. Operation desks

All operations and monitoring of FGDs are basically executed from operation desks. Four independent operation desks are used for respective FGDs and for common equipment. Each operation desk is provided with one CRT for starting and stopping of the whole FGD and each auxiliary equipment, status monitoring, display of system diagram, display of warning and alarms, etc. Each CRT has a CPU (Central Processing Unit). The function of each CRT is interchangeable with one another.

Each operation desk is provided with an emergency plant stop button and a bypass damper open button so that such operations can be executed manually in case of emergency. In addition, the operation desk is provided with necessary instruments such as indicators and recorders.

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 warning. 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 concentration	Absorbent solvent (recovered water) and limestone are mixed at a constant rate so that the slurry remains at a constant concentration.
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 concentration, 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.
Gypsum processing system	Control of ash mixing	Coal ash is mixed in proportion to the gypsum flow rate at the gypsum slurry pump outlet so that byproduct gypsum slurry and coal ash are mixed at constant ratios.

(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). Nos. 1 and 2 FGDs take care of five power plants of Nos. 4 to 8 commonly, and it is possible that the gas volumes at FGD inlets get below the minimum flow of BUF when many power plants stop. It is therefore necessary to consider interlocks which open bypass dampers in such cases.

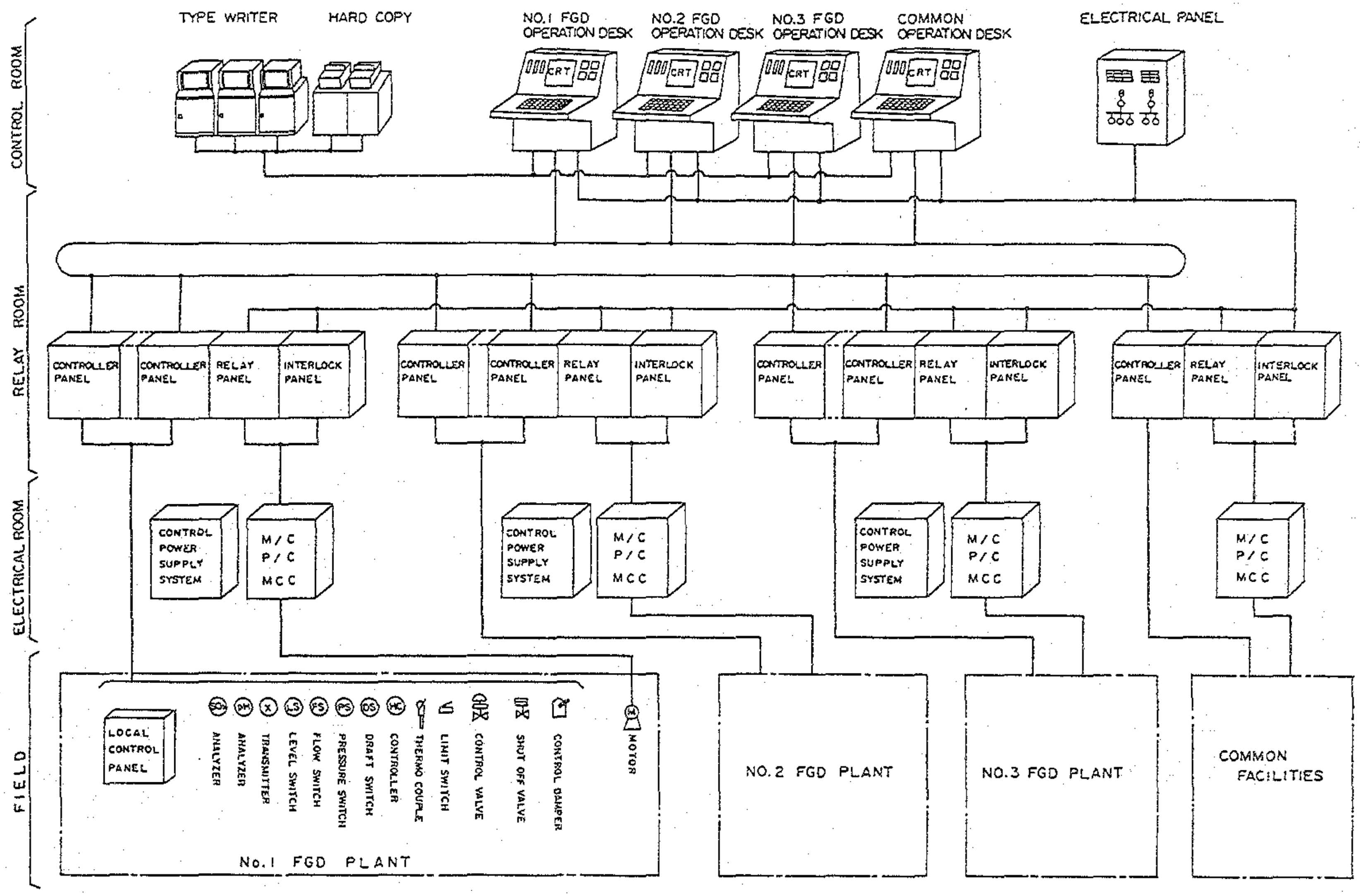


Fig. 6.5-14 CONFIGURATION OF FGD CONTROL SYSTEM

6.5.10 Related Buildings

For each 500 MW DeSOx System, one Dewatering and Mixing Room and one Absorber Recirculation Pump Room are required as related buildings. Also for 500 MW x 3 Unit, one Auxiliary Machine Room to house oxidation blowers, seal air fans and compressors is required. The above buildings, which need not large span, are designed as reinforced concrete structure taking into consideration of economy.

The plans and sections of each building are shown on Fig. 6.6-15.

The other works required in related buildings are reconstruction of Z.R.E. building where electrical and control panels are installed. (refer to Clause 6.5.10)

6.5.11 Foundation (including Loading Data)

The required foundations are following main 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;-

• Absorber	5,000 ton x 3 units
• G.G.H.	800 ton x 3 units
• B.U.F.	500 ton x 3 units
• Limestone Silo	800 ton x 3 units
• Flyash Silo	2,200 ton x 3 units
• Lime Silo	400 ton x 3 units
• Limestone slurry pit	280 ton x 3 units
• Recovery Water Pit	120 ton x 3 units
• Waste Slurry Pit	30 ton x 3 units
• Transformer	130 ton x 1 unit

The geological data of Kozienice Power Plant, which are described in Chapter 3, shows that comparative hard sand layer expands upto ground surface homogeneously. Taking account of structure calculation of existing stack and surrounding equipment foundations and building foundation, the sand layers (average measured value 34°) to be somewhat lower from ground surface are selected as supporting base. At detail design stage, it is necessary to execute structure drillings, etc. at DeSOx area and confirm geological data.

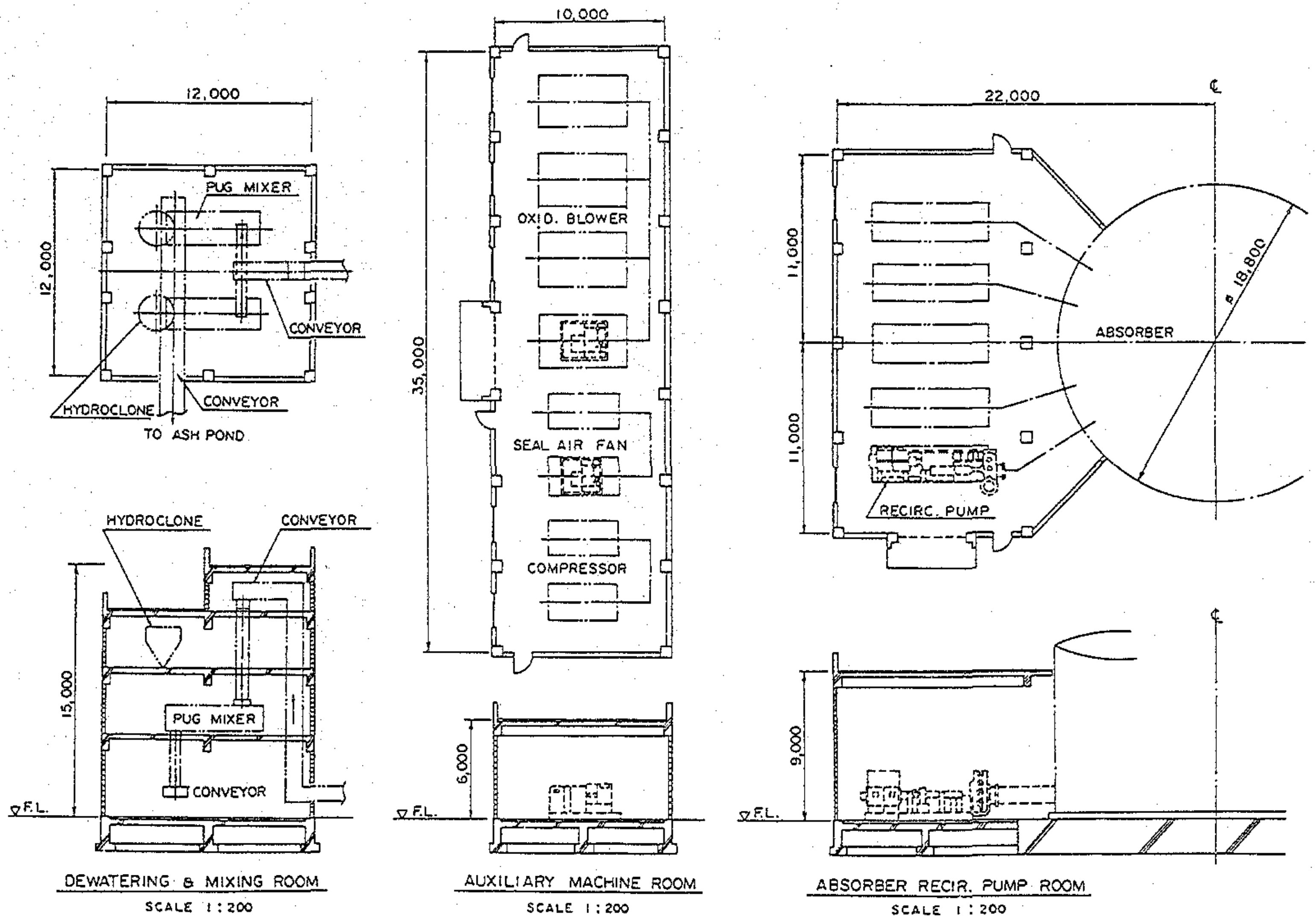


Fig. 6.5-15 RELATED BUILDINGS

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 transfer are described below.

6.6.1 Reconstruction

(1) Ducts

The existing collecting ducts must be reconstructed for connection of FGDs with existing facilities. Stacks and stack inlet ducts of the Kozienice Power Plant are of common collecting type. In addition, the existing stack inlet ducts are made of bricks, making it difficult to change system configurations at the time of reconstruction. It is planned therefore to install new common ducts of carbon steel also for the purpose of shortening the period when power plants are being stopped during the duct work.

Figs. 6.6-1 and 6.6-2 show new common ducts and the duct work for the FGDs.

Dampers are provided in the duct system at inlets and outlets of FGDs so that FGDs can be connected to and disconnected from the duct system in a flexible manner at such times as maintenance servicing and scheduled stopping of the FGDs. In addition, a bypass duct is provided not to affect boilers in case an FGD trips. Furthermore, a bypass damper is provided to the bypass duct for economical operation by preventing flue gas recirculation.

The bypass damper instantaneously and fully opens when an FGD trips to lead the flue gas directly to a Stack through the bypass duct. Pressure changes in the flue gas system can thus be minimized and boilers are protected from effects of tripping of FGDs.

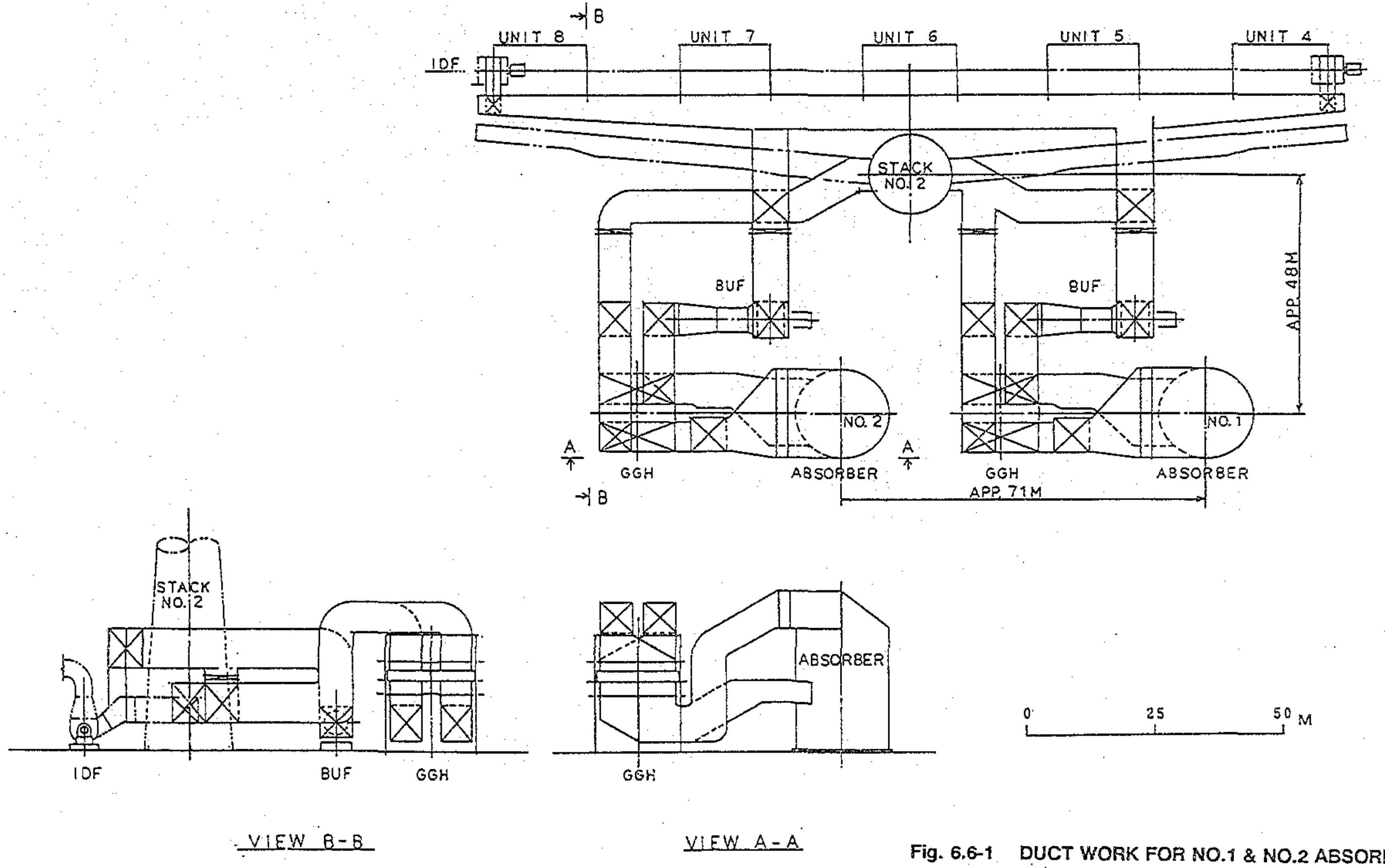
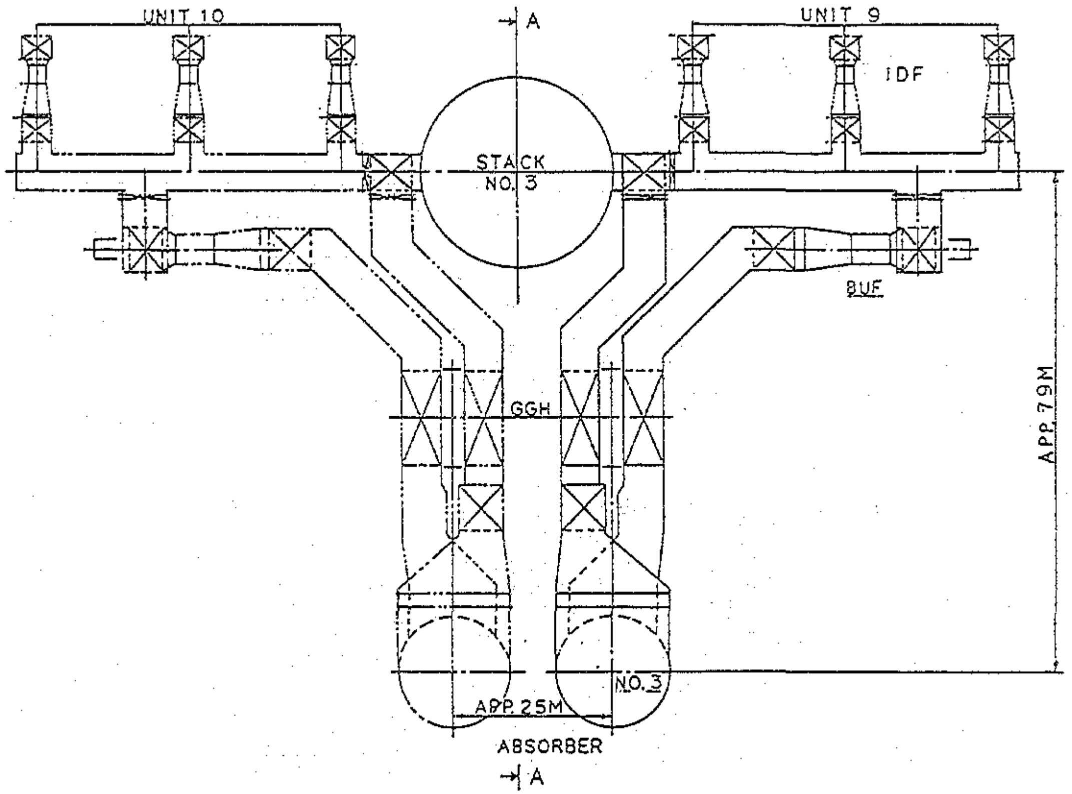
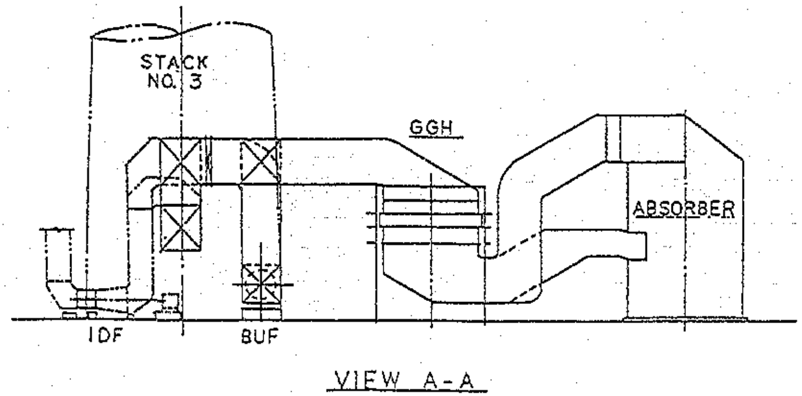


Fig. 6.6-1 DUCT WORK FOR NO.1 & NO.2 ABSORBER





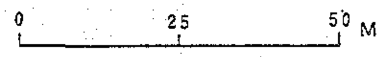


Fig. 6.6-2 DUCT WORK FOR NO.3 ABSORBER

(2) No. 2 Stack Lining

No. 3 Stack has been lined with acid-resistant bricks, but No. 2 Stack has been lined not with acid-resistant bricks but with ordinary bricks. Under the condition where the flue gas temperature is on the order of 80 to 90°C at stack inlet, the inner surface of a stack must be protected with acid-resistant materials. It is thus planned to provide acid-resistant lining on inner surface of No. 2 Stack.

The inner surface of No. 2 Stack is consisting of ring-shaped bricks supported, heightwise, at 17 points, 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 (Nos. 4 to 8 Plants must be stopped during the lining work.)

(3) ZRE Building

The Electrical Room and the Control Room for FGDs are to be housed in the existing ZRE Building. Four floors of the building (FL-700, +2,100, +5,400, +8,700) are to be used for the rooms. The arrangement of electric panels has been planned so that remodeling only involves wall partitioning and no works on columns and beams.

Panel layouts in the Electrical Room and Control Room are shown in Fig. 6.6-13.

(4) Electrical Equipment

a. Electrical interconnection for getting power for FGDs from existing house power system

- Point of Interconnection

  Primary side of 220 kV overhead lines for existing starting transformer (TR-4)

- Method of Connection

  T-branching in the overhead lines

- Power Capacity Requirement

  27 MVA

A new disconnecting switch is required between the point of T-branching and the starting transformer (TR-4).

b. Linking of metal-clad busbars of FGDs to existing ones

- Point of linking

  PR-4A and B metal-clad busbars which are existing

- Method of linking

  Existing busbars are extended and breakers for linking are installed.

(5) 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)
vii. Primary breaker signals of the existing TR-4 starting transformer (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

8 t/h on average, 20 t/h maximum

(2) Coal Ash Transport Piping

A piping for transporting flyash (dry powder) is required for its mixing in byproducts (gypsum and waste water). Fly ash is distributed from the ash remover system of existing ESPs to three fly ash silos for FGDs. The configuration of distribution system must be designed considering operational schedule of ESPs and FGDs.

a. Point of interconnection

At ash removers of existing ESPs

b. Ash requirement

About 200 t/h

6.6.3 Facilities to Be Removed

(1) Railway Track being Used for Receiving Water-treating Chemicals

The railway track being used for receiving water-treating chemicals (about 450 m) is crossing the space for FGD installation, and must be removed. A possible alternative measure for transportation of chemicals is to extend chemical receiving pipings to the railway track near the Coal Yard or to use trucks for transportation.

(2) Railway Track for Maintenance

The railway track for maintenance (about 200 m) is crossing the space for FGD installation, and must be removed.

6.6.4 Facilities to Be Transferred

(1) Ash Flowing Piping

The ash flowing piping for Nos. 4 to 8 Plants (about 350 m) is on the space for FGD installation, and must be transferred. It is judged to be better to use the same route as the current route for Nos. 1 to 3 Plants.

(2) Other Underground and Overhead Pipings and Cables

Other underground and overhead pipings and cables for the powerhouse, ZRE Building, coal storage facilities, coal handling facilities and machine shop are present in the space for FGD installation, and they must be transferred taking the FGD layout and uses of such pipings and cables fully into consideration.

Chapter 7. Project Implementation Programme

CHAPTER 7 PROJECT IMPLEMENTATION PROGRAMME

Contents

List of Tables

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 for starting operation of FGDs on January 1, 1998, it is necessary to begin the civil work for FGD system around October 1994 and equipment installation around June 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:

(1)	Completion of the Feasibility Study	End of Dec. 1991
(2)	Preparation of Financial Source	End of Jan. 1993
(3)	Selection of Consultant	End of Apr. 1993
(4)	Detailed Design and Preparation of Tender Documents	End of Nov. 1993
(5)	Completion of Tender Evaluation	End of May 1994
(6)	Contract Award	End of May 1994
(7)	Commencement of Civil Work	Beginning of Oct. 1994
(8)	Erection Start	Beginning of Jun. 1995
(9)	Trial Operation Start	Beginning of Sep. 1996
(10)	Taking Over	End of Oct. 1997
(11)	Commercial Operation Start	1st of Jan. 1998

7.2 Construction Schedule

A planned schedule for construction of FGD system for Kozienice Power Plant is shown in Table 7.2-2 (1) and 7.2-2 (2). Items described below were taken into account in studying the construction schedule.

(1) All FGD systems must be available for commercial operation on January 1, 1998.

(2) The time of completion of each of the three FGD units is to be different by about 5 months to lower the peak work load to the extent possible.

(3) The reconstruction work on the common ducts of existing power plants are to be made during the summer, when power demand is low, so that the time of stopping power plants is as short as possible.

It would be noted that the time during which power plants are to be stopped for reconstruction of common ducts for connection with FGD system is about 1.5 months.

(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 execute the acid-resistant lining of No. 2 Stack during the summer when power demand is low so that the work proceeds in parallel with the reconstruction work on the common ducts for FGD system and power plants.

The period for the lining is assumed for three months.

Table 7.1-1 KOZIENICE POWER PLANT FGD SYSTEM IMPLEMENTATION SCHEDULE

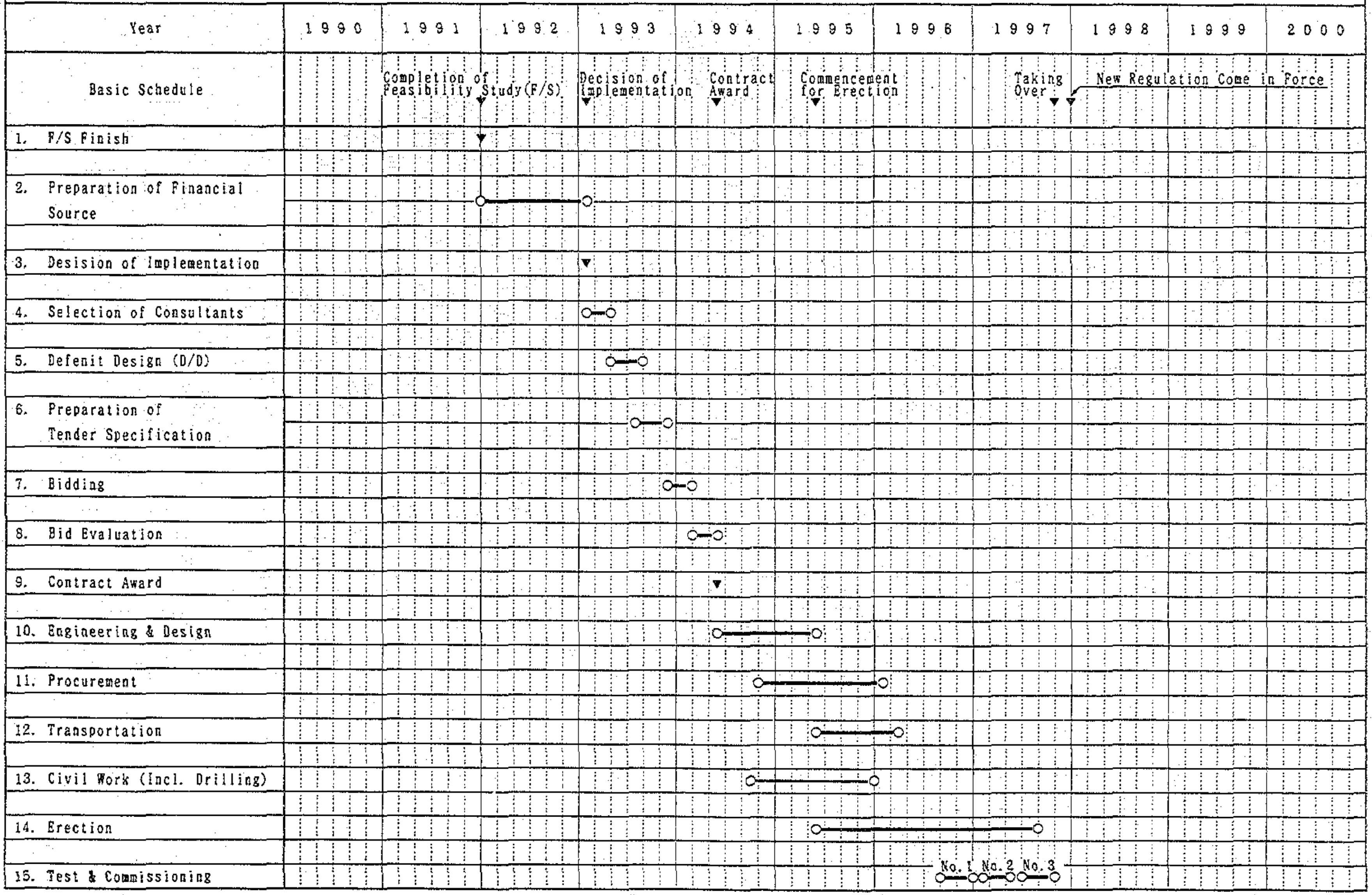
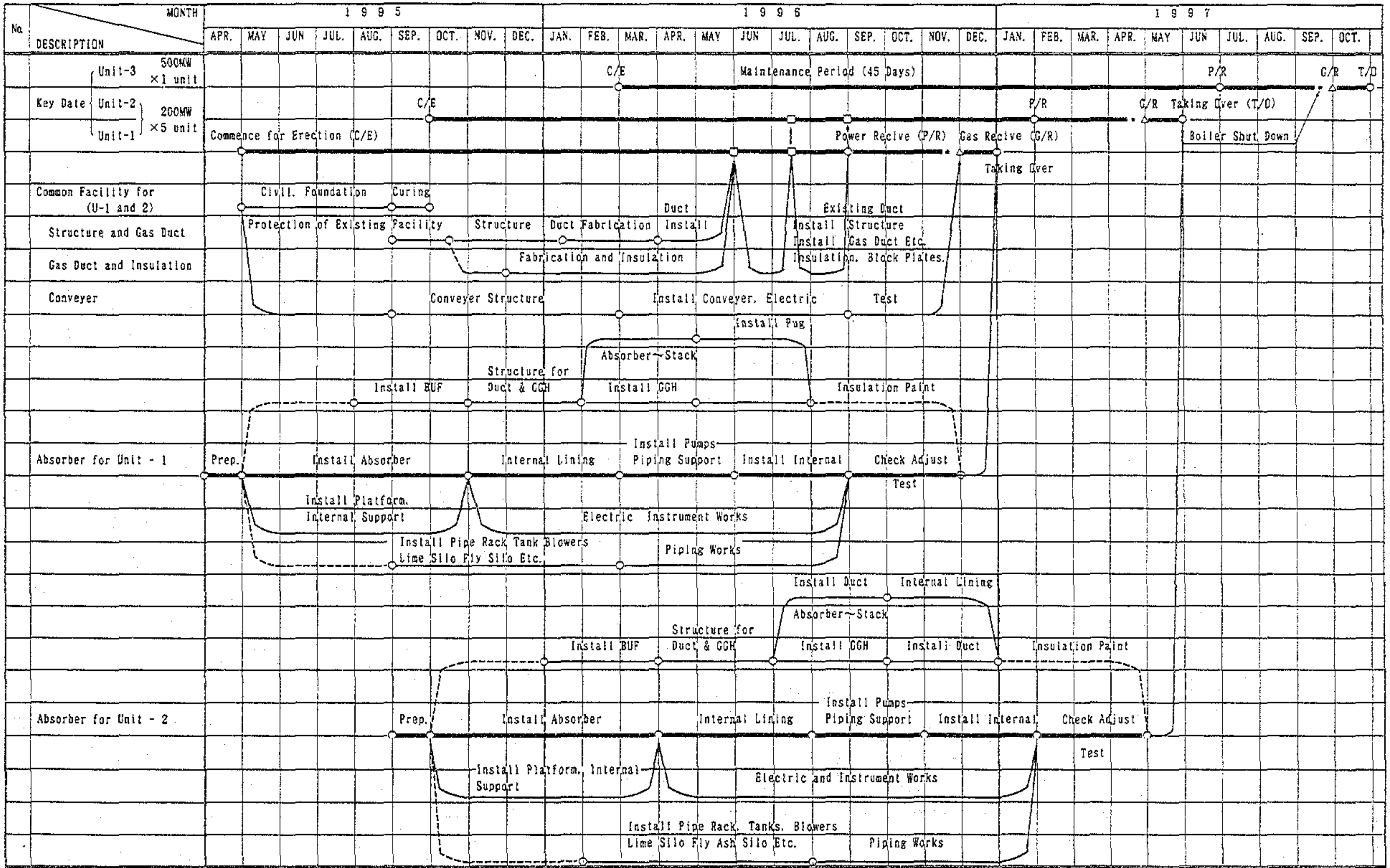
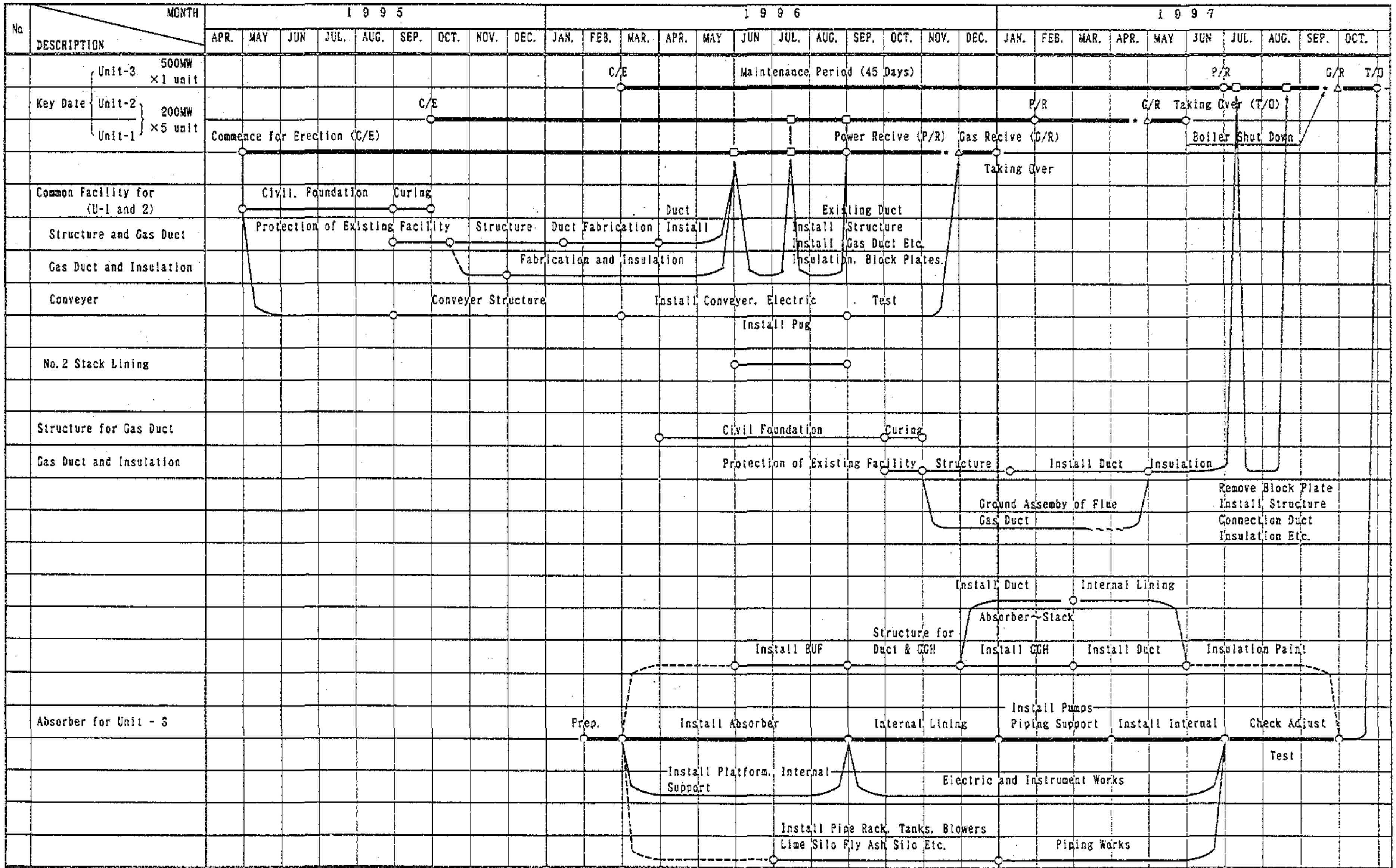


Table 7.2-1 (1) 500MW FGD Plant ×3 Units Construction Schedule



Remarks
(1) 3 days Boiler shut down work of each unit will be required before hot gas recive to remove block plates inside flue gas duct.
(2) connection change of the existing common duct and new one between IDF outlet and stack will be done during low load demand season.

Table 7.2-1 (2) 500MW FGD Plant ×3 Units Construction Schedule



Remarks

(1) 3 days Boiler shut down work of each unit will be required before hot gas recive to remove block plates inside flue gas duct.
(2) Connection change of the existing common duct and new one between IDF outlet and stack will be done during low load demand season.
(3) Approximately 3 months plant shut down of No.4 to No.8 will be required by No.2 stack lining.

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 the three 500 MW class FGD units 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 three 500 MW class FGD units is shown below. Estimated costs of respective equipment are shown in Table 8.1-1.

	$x\ 10^6$ ZL	$x\ 10^3$ U$
(1) DeSOx System and Associated Equipment	1,130,833	119,035
(2) Transportation	43,890	4,620
(3) Construction	92,369	9,723
(4) Civil Work	112,575	11,850
(5) Modification of Existing Facilities	12,350	1,300
(6) Spare Parts	22,686	2,388
(7) Start-up and Commissioning	22,686	2,388
(8) Import Tax	94,212	9,917
[Direct Construction Cost] (1)~(8)	[1,531,601]	[161,221]
(9) Engineering Fee [5% of Direct Const. Cost]	76,580	8,061
(10) Contingency [5% of Direct Const. Cost]	76,580	8,061
(11) Administration fee [5% of Direct Const. Cost]	76,580	8,061
[Total Construction Cost] (1)~(11)	[1,761,341]	[185,404]
[Construction Cost per kW]	[1,174 x 10^3ZL/kW]	[123.6 U$/kW]

Table 8.1-1 500 MW x 3 FGD Plants Construction Cost

Unit: x 10^3U$

	Item	Foreign Portion	Local Portion	Total
1	Absorber System	15,840	18,326	34,166
2	Limestone Slurry Supply System	0	3,549	3,549
3	Gypsum Dewatering & Ash Mixing System	2,192	15,047	17,239
4	Draft System	30,250	9,993	40,243
5	Miscellaneous	0	1,971	1,971
6	Air Supply System	0	662	662
7	Electrical System	0	8,636	8,636
8	Control System	12,569	0	12,569
[9]	[Equipment Cost]	60,851	58,184	119,035
10	Transportation	0	4,620	4,620
11	Construction	0	9,723	9,723
12	Civil Work	3,705	8,145	11,850
13	Modification of Existing Facilities	0	1,300	1,300
14	Spare Parts	1,554	834	2,388
15	Start-up & Commissioning	0	2,388	2,388
16	Import Tax	0	9,917	9,917
[17]	[Direct Construction Cost]	66,110	95,111	161,221
18	Engineering Fee	8,061	0	8,061
19	Contingency	1,612	6,449	8,061
20	Administration Fee	0	8,061	8,061
[21]	[Total Construction]	75,783	109,621	185,404

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 March 1, 1991

(2) Exchange Rates

1) 1 ZL = 0.014 yen
2) 1 U$ = 9,500 ZL
3) 1 U$ = 135 yen

8.3 Scope of Estimation

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

Fig. 8.3-1 shows the scope of estimation of equipment and common facilities of 500 MW class FGD unit. It would be noted that the scope of estimation covers items given below.

(1) FGD Main Unit

a. Absorber system
b. Limestone slurry supply system
c. Gypsum dewatering and ash-mixing system
d. Draft system
e. Miscellaneous
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 of flyash handling system
c. Reconstruction of electrical facilities and instrumentation
d. Relocation of ash transfer piping
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
c. Acid-resistant lining of No. 2 Stack
d. Water-proofing of byproduct disposal area (corresponding to the volume of byproduct to be disposed over a period of 2 years)
e. Foundation of byproduct transport conveyer
f. Water-intake pump station
g. Reconstruction of ZRE Building

(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 1991 is shown below. A breakdown of the operation cost is given in Table 8.5-1.

	$\times 10^3$ ZL	U$
a. Utilities Cost	40,220,680	4,233,756
b. Labor Cost	1,111,824	117,034
c. Maintenance Cost	76,579,975	8,061,050
[Total]	[117,912,479]	[12,411,840]

(2) Conditions for Estimation of O&M Costs

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

a) Labor cost and utility costs are based on those prevailing in 1991.

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

c) Capacity Factor

The capacity factor of FGD system is assumed to be 57% corresponding to 5,000 hours of operation at 100% generator output.

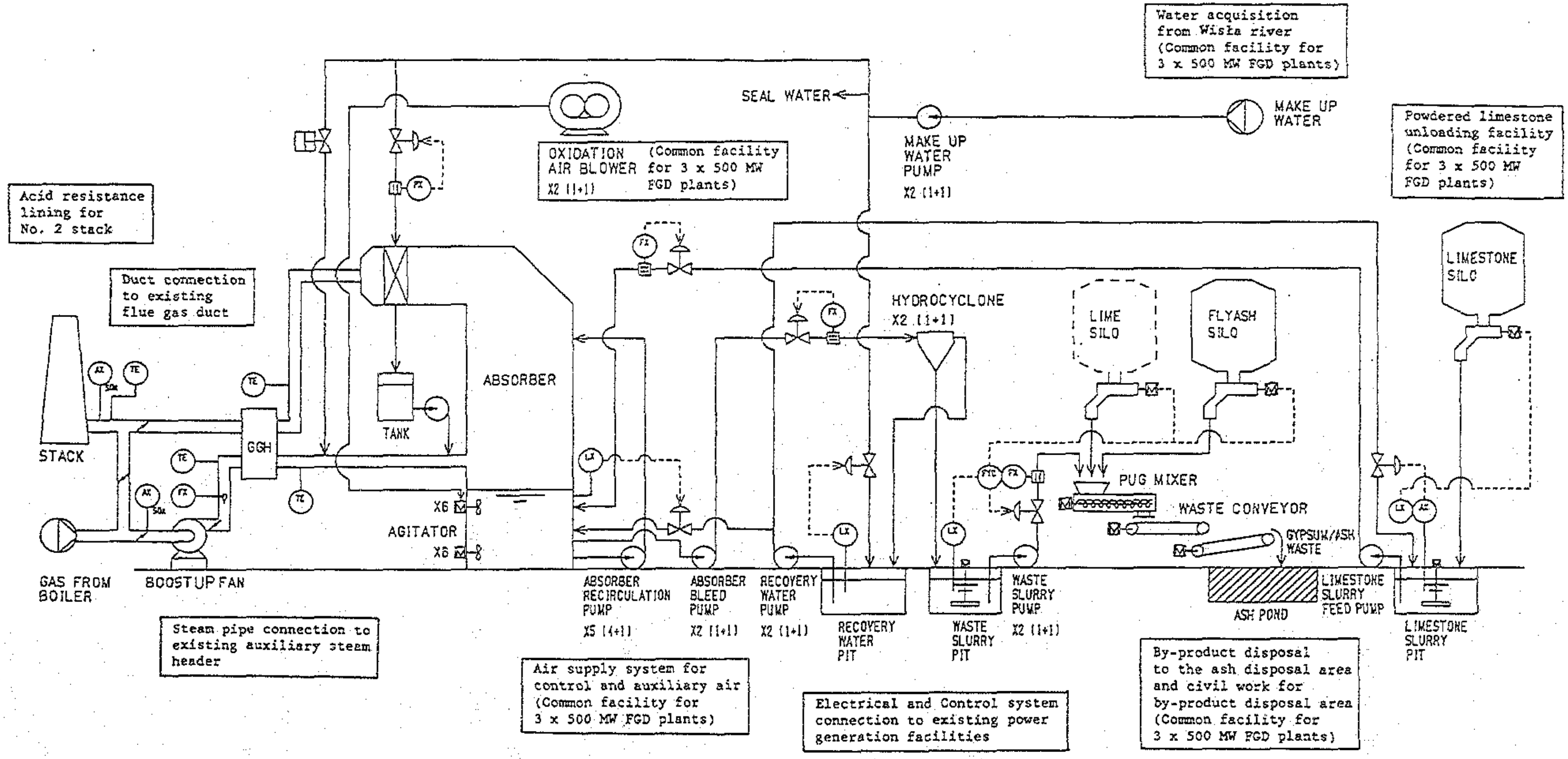

Fig. 8.3-1 Supply Limit of One 500 MW FGD Plant

Table 8.5-1 Operation Cost for Three (3) FGD Plants

Item	Quantity (Per Year)	Unit Price (Zℓ/Unit)	Annual Cost ($\times 10^3$ Zℓ/Year)
1. $CaCO_3$ (94%)	142,750 (Tonns)	130,000	18,557,500
2. Electric Power	99,000 (MWh)	200,000	19,800,000
3. Make-up Water	1,051,000 (Tonns)	180	189,180
4. Cooling Water	300,000 (Tonns)	180	54,000
5. Steam	30,000 (Tonns)	54,000	1,620,000
[Sub-total]			[40,220,680]
6. Labor Cost	37 (man-year)	-	1,111,824
7. Maintenace Cost	-	-	76,579,975
[Grand total]			[117,912,479]
8. Cost/kWh	15.72 (Zℓ/kWh)		

Note 1. All of prices are based on 1991 prices.

2. Carolific value of coal is to be 4,460 kcal/kg (LHV).

3. Sulphur content of coal is to be 0.96%.

4. Capacity factor is assumed to be 57% (5,000 hr. operation at full load).

5. Maintenance Cost: 5% 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 Units are started and stopped linked usually with start and stop of power generation plants. When one FGD Unit is existing for one power plant (unit-to-unit desulphurisation system), the FGD is started in the initial phase of starting the power plant when light oil is burned at the power plant, and the FGD Unit starts its service just before heavy oil is used as fuel when the SOx emission rises. The FGD Unit is stopped following boiler purging.

The FGD Units are started in the sequence of the absorbing systems, the drafting systems and the gypsum processing systems. The FGD Units are stopped, on the other hand, in the sequence of the drafting systems, absorbing systems and the gypsum processing systems. Fig. 9.1-1 shows starting and stopping timings of the unit-to-unit FGD Unit.

For the case of the Kozienice Power Plant, No. 3 FGD Unit is operated in the unit-to-unit scheme, but Nos. 1 and 2 FGD Units are started and put into service when the gas volume at FGD inlets are above certain levels (above minimum flow rates of BUFs) because they are common for Nos. 4 to 8 power plants.

As for stopping, regulations on volume of emission applies to the Kozienice Power Plant but no regulation on concentration applies. Thus, it is possible, at the Kozienice Power Plant, to stop FGD Units during low load operations.

9.1.1 Start Up Procedures

(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. In addition, check that bearing cooling water has been secured for absorber recirculation pumps.

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 prescrubbing 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 scheduled 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.

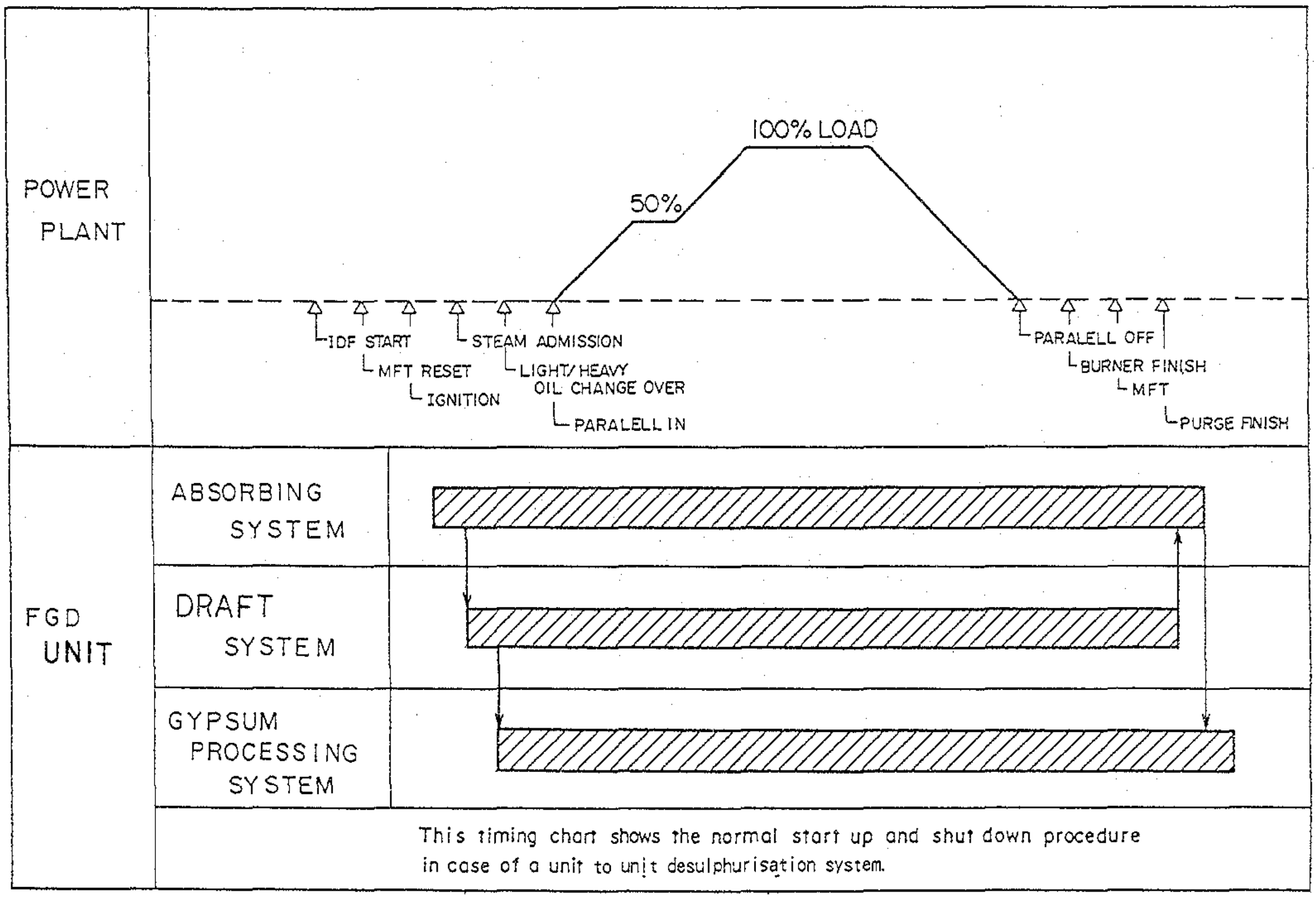


Fig.9.1-1 FGD UNIT START UP SHUT DOWN TIMING CHART

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

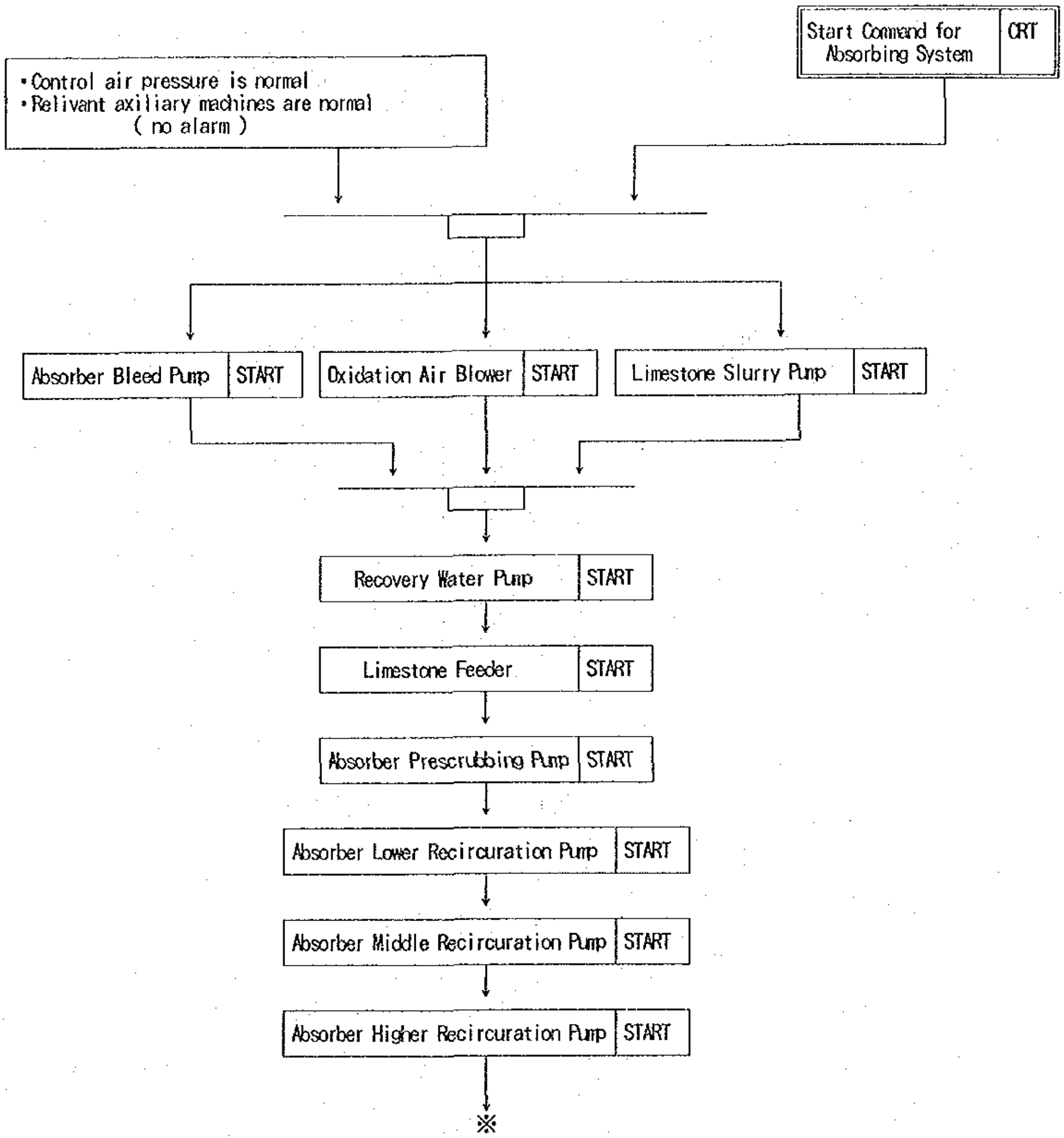


Fig. 9. 1-2 FLOW CHART OF START UP PROCEDURE (2/2)

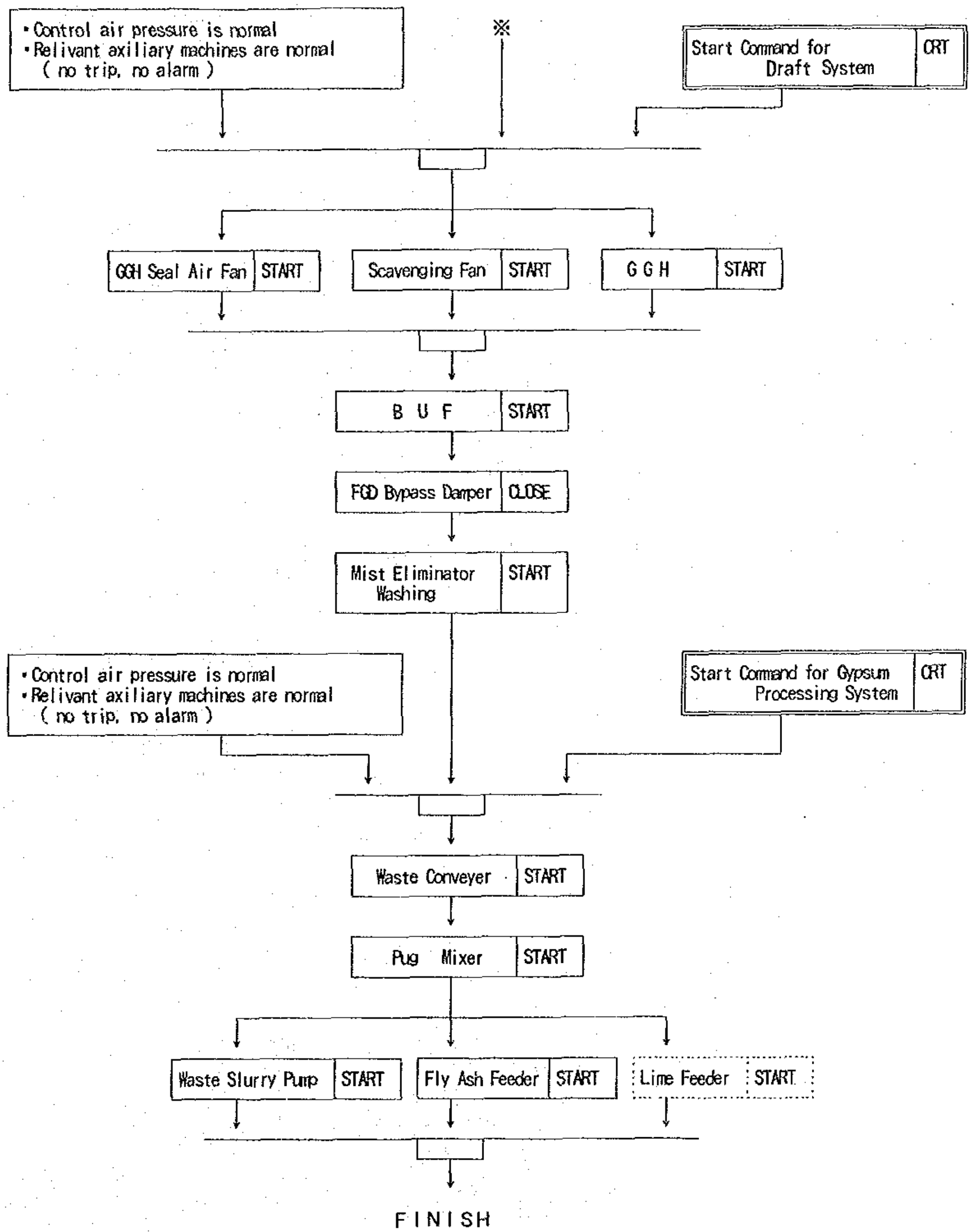
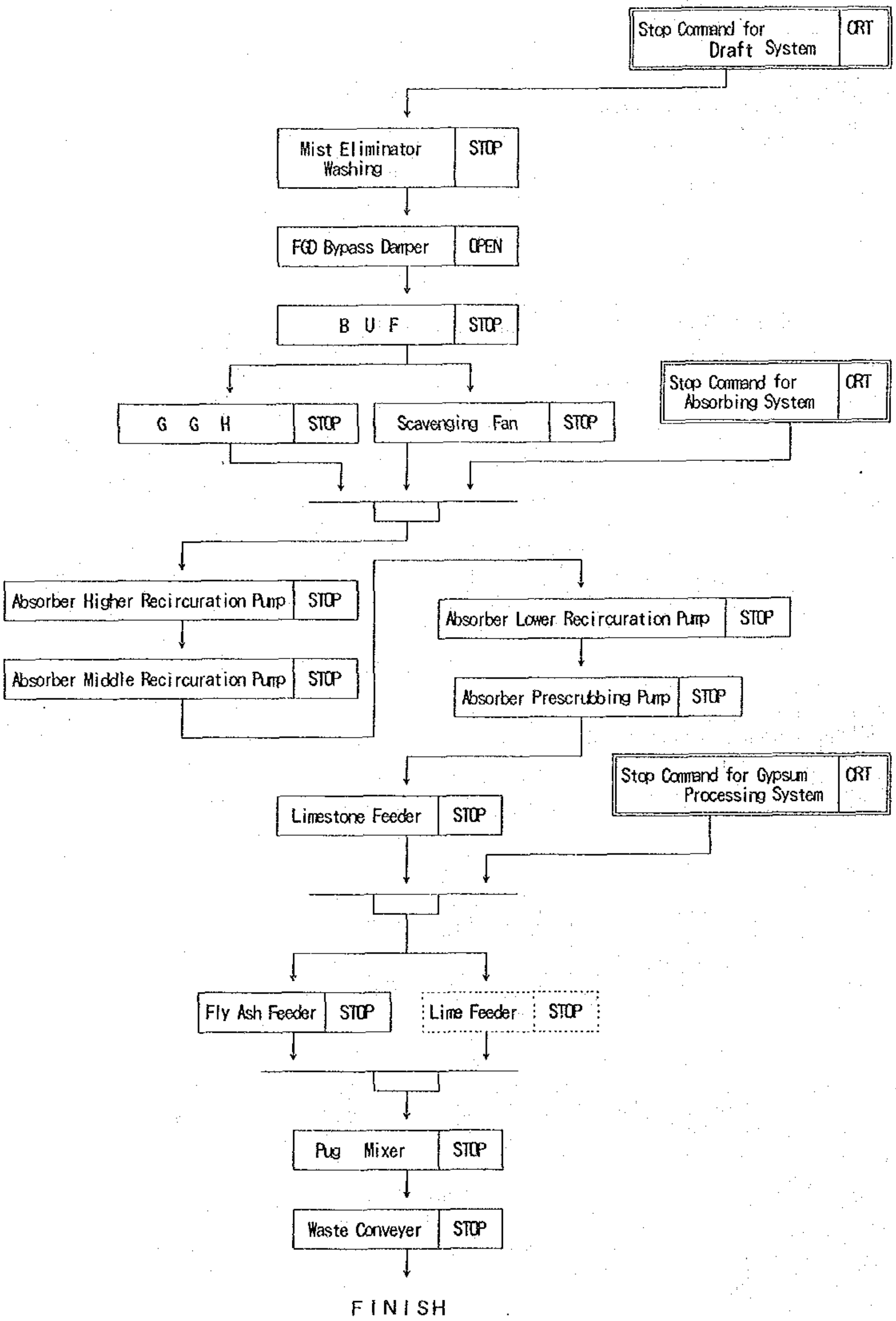


Fig. 9. 1-3 FLOW CHART OF SHUT DOWN PROCEDURE (SHORT TERM STOP MODE)



9.1.3 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 silo, a limestone slurry pit and limestone slurry feed pumps and an absorbing and oxidizing section consisting of an absorber, absorber recirculation pumps and oxidizing air blowers.

Limestone discharged from a limestone silo mixed and stirred with recovery water or make-up water to become limestone slurry. The limestone slurry is adjusted to be constant in concentration. The slurry is sent to the absorber by limestone slurry feed pumps via flow regulator valves.

In the absorber, the slurry staying at the bottom is pumped up by absorber 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 sulphur oxides and remove dust as well from the flue gas in the process of coming down.

Limestone produces calcium sulphite upon absorption of sulphur oxides, and calcium sulphite turns to gypsum when oxidized by the oxidizing air being blown at the lower part of the absorber.

In this absorption process, the two largest factors which determine the desulphurisation performance of operation 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 desulphurisation and dedusting 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 for the inlet gas conditions and required efficiencies is 3.4 L/m^3N for each spraying stage and 2.0 L/m^3N for cooling stage. The number of recirculation pumps to be operated at the rated operation of 500 MW is four; one for each stage of upper, middle and lower stages and one for the cooling stage, and such pumps must be of capacity which meets the required L/G ratio. At low load operations, it is better to operate a fewer number of pumps, still meeting the L/G ratio, for saving the power consumption.

Spray nozzles may clog, however, when a 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.

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 deterioration in efficiency.

c. Control and Monitoring of pH Value of Slurry Circulating in Absorber

The desulphurisation performance depends much on the pH value of slurry circulating in the absorber. The desulphurisation efficiency deteriorates when the pH value is low. When the pH value is high, the desulphurisation efficiency is higher, but not without adverse effects 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 soot-mixed single-tower internal oxidation system being employed for the system and operated in the range of 5.4 to 5.6. In addition, inlet and outlet SO_2 concentrations are monitored, and the pH value is controlled in a manner of achieving a certain desulphurisation efficiency. The pH value of circulating slurry is controlled by the volume of limestone slurry which is supplied through a control valve of limestone slurry supply line.

d. Monitoring of Gas Temperature in Absorber

An emergency spraying is started, for protection of absorber and flue gas duct 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 reduction in the volume of slurry spraying, and it is necessary to assure an adequate number of absorber recirculation pumps in operation and monitor the volume 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, and sends the gas to a stack, consists of a BUF, gas-to-gas heater (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. The flue gas is subjected to desulphurisation and de-dusting in the absorber. The gas is now clean but cool. Thus, it is sent to the GGH after its mists are eliminated by a mist eliminator at absorber outlet. In the GGH, the clean gas is reheated through heat exchange with dirty gas to

80°C or higher for prevention of corrosion of ducts and the stack, and the reheated clean gas is returned to stack inlet.

b. Draft Control and Monitoring

The draft pressure of the draft system is usually controlled by opening of the damper at BUF outlet. The draft is corrected for pressure losses in the system based on the gas volume at BUF inlet, and controlled in a manner where the pressure difference before and after the bypass damper is constant. The pressure loss 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 Gas-to-Gas Heater

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.

In a GGH of regenerative rotating type, the gas leakage of some extent is unavoidable due to its construction. It is therefore necessary for such GGH to keep the gas-to-gas heater seal air fan and the scavenging fan operating all the time for the purpose of specifically preventing the dirty gas from leaking into clean gas.

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 Processing System

a. Outline

The gypsum processing system is a system where gypsum slurry generated by reaction of limestone with sulphur dioxide in the absorber is collected, mixed with flyash, and disposed. The system is composed of a dewatering section consisting of absorber bleed pumps, hydrocyclones and a waste slurry pit and a gypsum disposal section consisting of waste slurry pumps, a flyash silo, (a lime silo), bug mixers and waste conveyers.

b. Operation of Dewatering Section

Both absorber bleed pump and hydrocyclone are operated continuously. The supply of slurry to the hydrocyclone is adjusted by the regulation valves. The slurry of about 15% is concentrated by the hydrocyclone to about 35% by dehydration. Water coming from dehydration is collected in a recovery water pit, and reused in the absorber or in the limestone supply pit as make-up water.

c. Operation of Gypsum Disposal System

The waste slurry pump operates continuously to supply gypsum slurry to the bug mixer continuously. The flyash silo discharges flyash at a certain rate corresponding to the flow of gypsum slurry at the waste slurry pump outlet so that the ratio of water to solid in the mixture is 1 to 3.

The bug mixer operates continuously while mixing such gypsum slurry and flyash, and the mixture is discharged to the conveyer as waste. The waste thus discharged is transported on the continuously operating conveyer to the ash disposal area, where the waste is disposed.

It is known to be effective to mix lime to make the mixture of gypsum slurry and flyash more stable, but the effectiveness must be confirmed by experiments to prepare for possible mixing of lime in the mixture.

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				
Desulphurization 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			