THE REPUBLIC OF POLAND

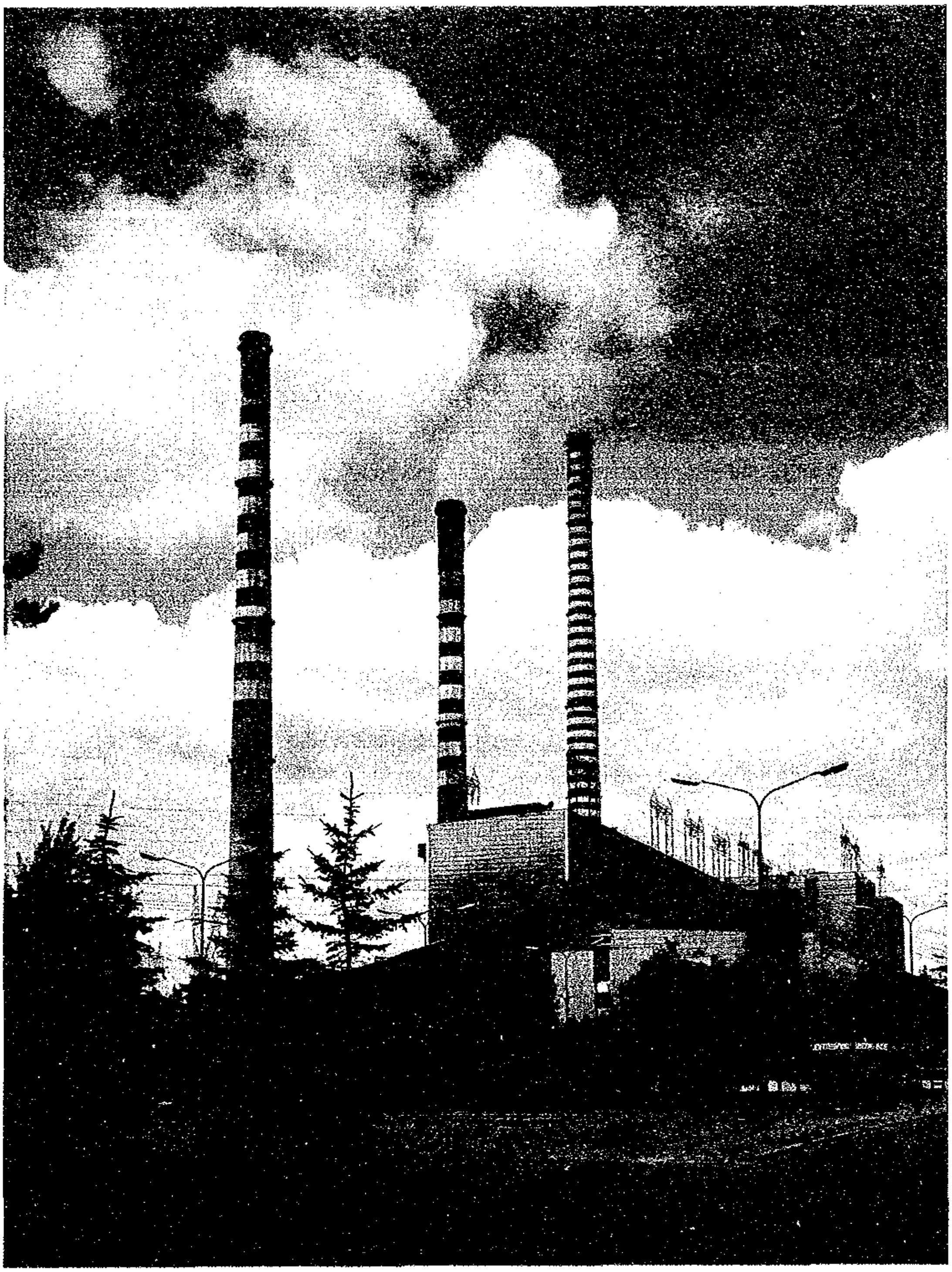
FEASIBILITY STUDY
ON
FLUE GAS DESULPHURISATION
FOR
THE KOZIENICE POWER PLANT

FINAL REPORT

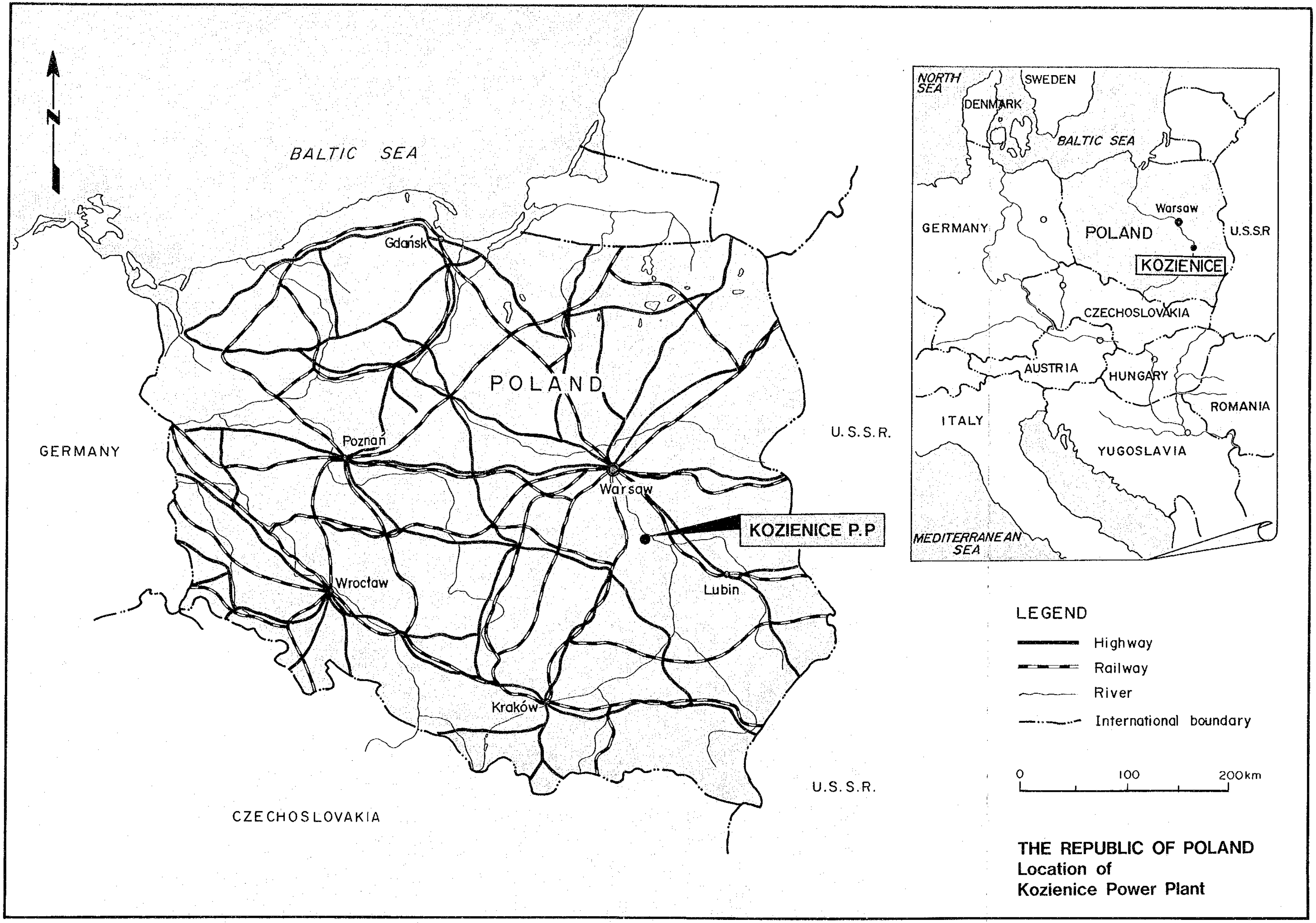
SUMMARY

DECEMBER 1991

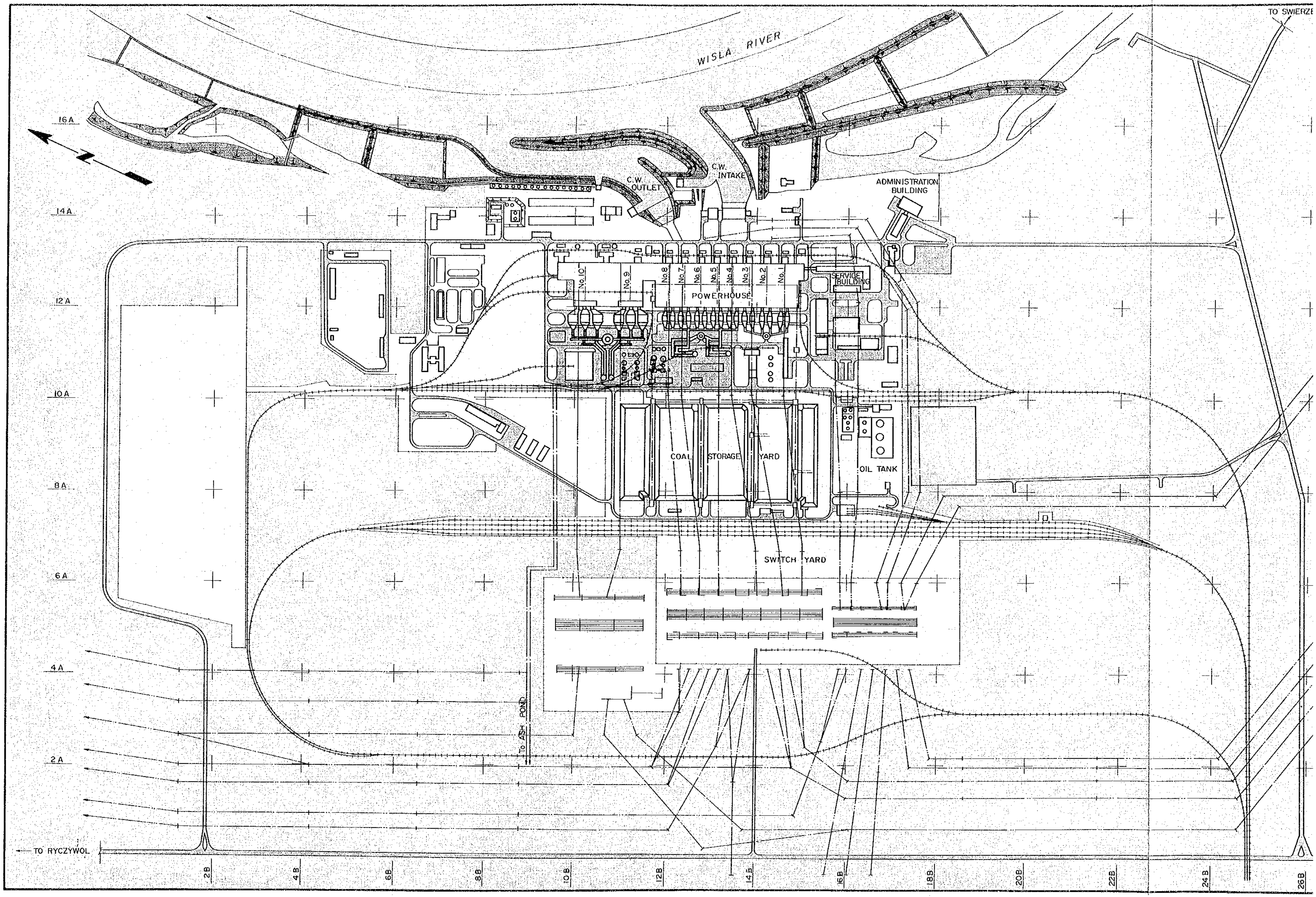
JAPAN INTERNATIONAL COOPERATION AGENCY



THE KOZIENICE POWER PLANT



THE REPUBLIC OF POLAND
Location of
Kozienice Power Plant


WISLA RIVER
TO SWIERZE
16A
14A
12A
10A
8A
6A
4A
2A
C.W. OUTLET
C.W. INTAKE
ADMINISTRATION BUILDING
SERVICE BUILDING
POWERHOUSE
No.10
No.9
No.8
No.7
No.6
No.5
No.4
No.3
No.2
No.1
COAL STORAGE YARD
OIL TANK
SWITCH YARD
TO ASH POND
TO RYCZYWOL
2B
4B
6B
8B
10B
12B
14B
16B
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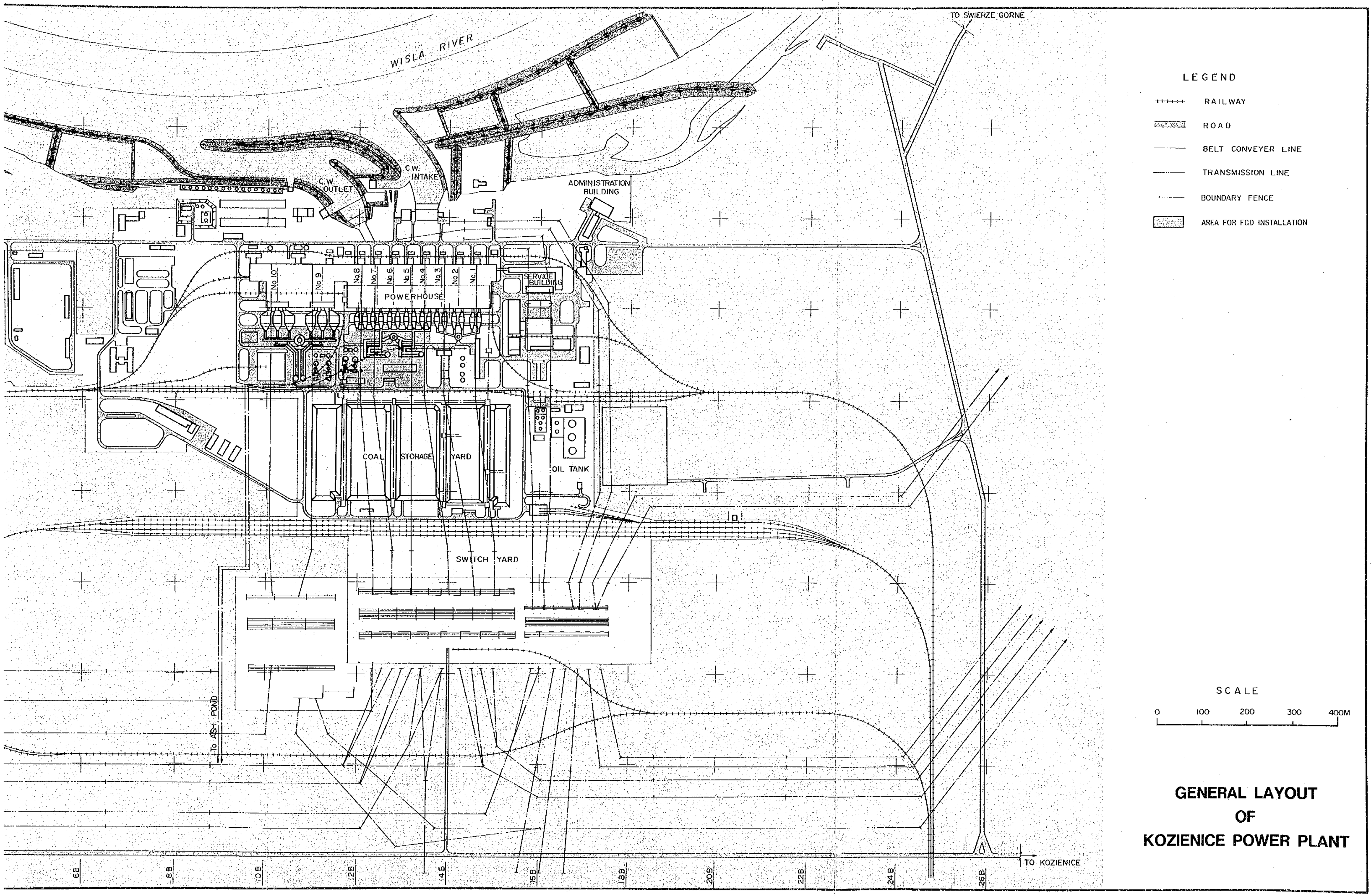
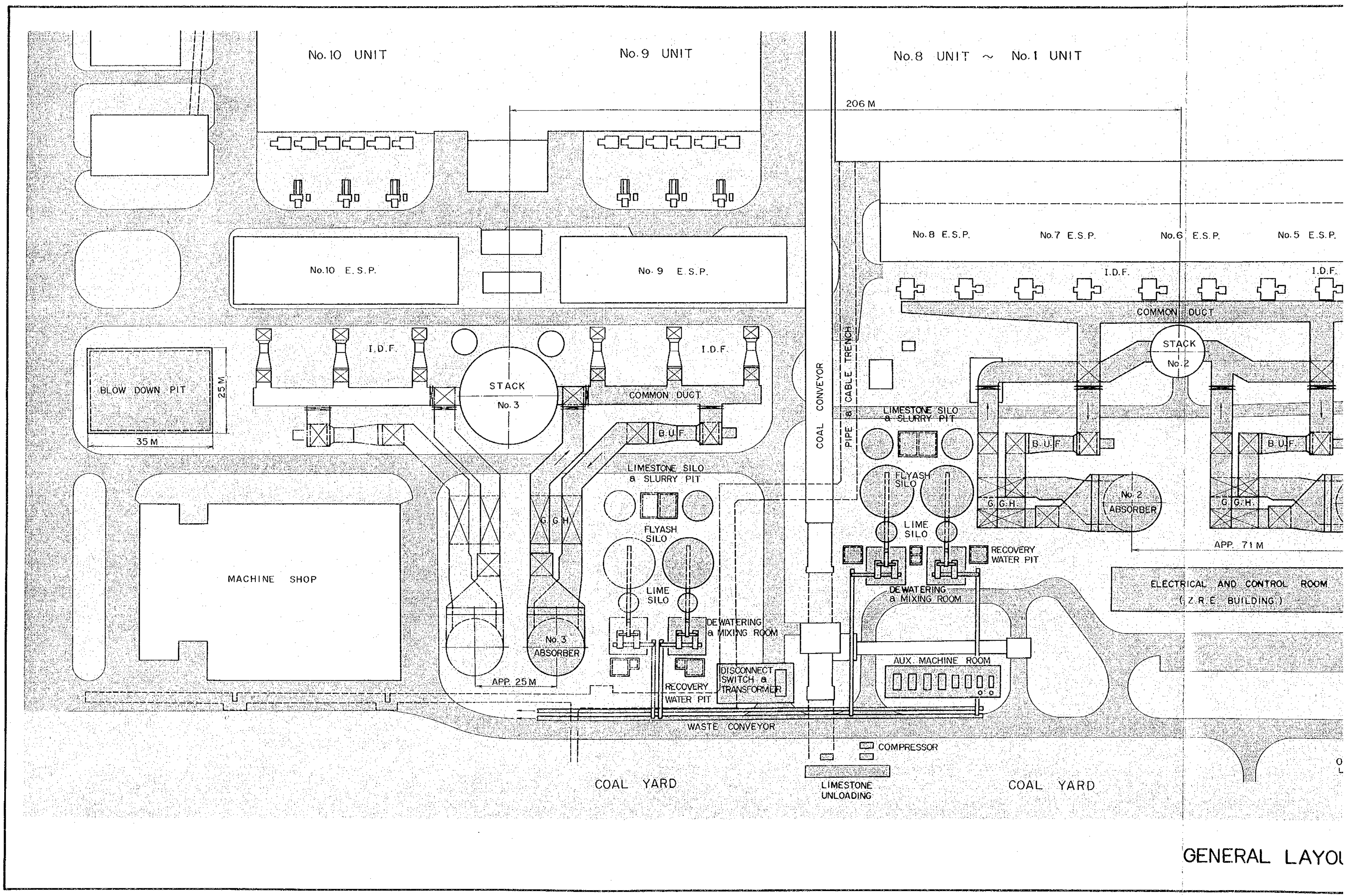
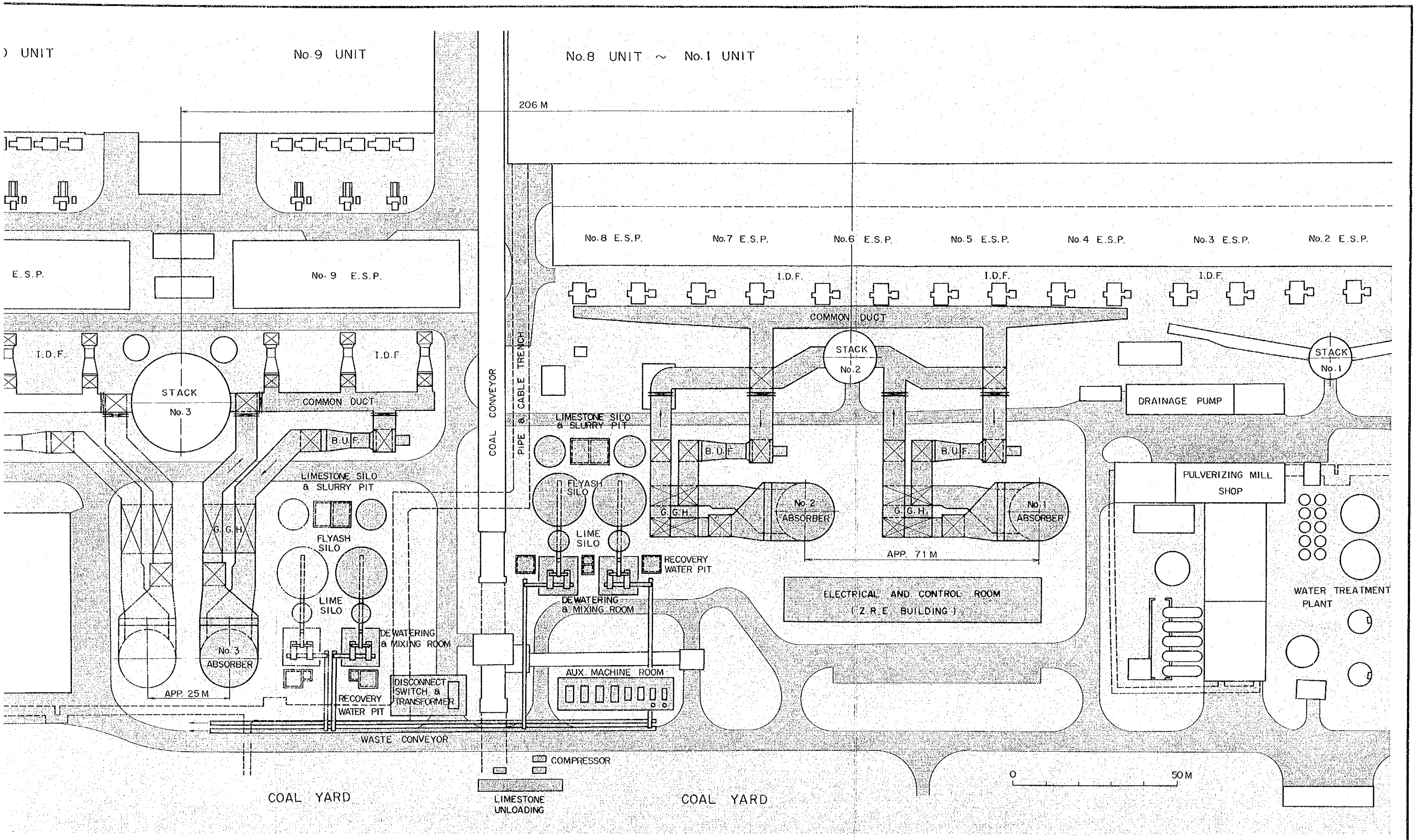
22B
24B
26B



GENERAL LAYOUT OF KOZIENICE POWER PLANT



GENERAL LAYOU



GENERAL LAYOUT OF THREE (3) 500 MW FGD UNITS

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Outline of the Study

Study items of the Investigation of the Feasibility Study on Flue Gas Desulphurisation of the Kozienice Power Plant of the Republic of Poland were as follows:

<u>1st Stage</u>

(1) Collection and analysis of data related to the Feasibility Study

(2) Determination of the level of sulphur oxide emission of the Power Plant, and environmental assessment based on the level of sulphur oxide emission of the Power Plant

(3) Technical evaluations and economic comparison for selection of the optimum flue gas desulphurisation method and equipment for the Power Plant

<u>2nd Stage</u>

(1) Additional investigation of the 1st stage field survey

(2) Conceptual design of DeSOx system

(3) Project implementation programme

<u>3rd Stage</u>

(1) Calculation of new tariff necessitated by introduction of DeSOx system

(2) Benefit from introduction of DeSOx system

(3) Socioeconomic effects by introduction of DeSOx system

The Kozienice Power Plant has made the agreement with Radom Prefecture to reduce the hourly maximum sulphur oxide emission of 26,648 kg/h at present to

7,995 kg/h by the end of 1997. It has reached a conclusion that it is most appropriate, to meet the agreement, to install three 500-MW class flue gas desulphurisers (FGD Units) of wet type limestone-gypsum method, which achieves the desulphurisation efficiency of 89%, to treat the flue gas from power plants corresponding to 1,500 MW of the 2,600 MW total output of the Power Plant.

Another conclusion, as to the power generation plants for which FGDs are installed, is that it is most suitable to install two FGD Units of the efficiency and capacity described above for Unit No. 4 through Unit No. 8 (200-MW x 5) power plants which are all using the No. 2 Stack and one FGD Unit of the same type for No. 9 (500-MW) power generation plant which is using the No. 3 Stack.

Based on the above study conclusion of the optimum DeSOx system and combination of DeSOx system installed and power generation plants, a conceptual design of DeSOx system was carried out at the 2nd stage with further data and information collection by doing 2nd stage field survey.

Furthermore, a study on the project implementation programme was made as the 2nd stage study.

The study suggests that it is necessary to make an order of the DeSOx equipment by around the end of May in 1994 and to start the erection by around the end of May in 1995 in order to put into DeSOx system commercial operation from the 1st of January, 1998.

An estimation of the project cost as of the 1st of March, 1991 was 185,404,000 US$.

If the figure is converted into unit cost per kW, it is 123.6 U$/kW.

Diffusions of sulphur oxides emissions of the Power Plant after installation of FGD Units were calculated as a part of the environmental assessment, and it reached a conclusion that the sulphur oxide level at the point of maximum sulphur oxide concentration would be well below the environmental standard to be applied to the environment of the neighborhood of the Kozienice Power Plant.

Tariff is calculated based on the annual cost including interest during construction. As a result of this calculation, 33 to 41 ZL/kWh additional burden in tariff is estimated.

For the economic evaluation, reconstruction of boilers into natural gas firing which has the same reduction of SO_2 effect as this project was chosen.

According to this economic evaluation, this project is much superior to the partial reconstruction of the boilers into natural gas firing which has the same SO_2 reduction effect in terms of cost.

Following are analysis on introduction of DeSOx system in Polish power plants based on above analyses.

(1) Economic extension and increase in employment attributable to increase in investment.

(2) Absorbable effect on energy tariff

(3) Increase in export

Poland is already industrialized. In this project, local procurement shall be extended as much as possible so that technology can be absorbed aggressively. As a consequence, Poland will be able to export DeSOx equipments to neighbor countries by taking advantage of both its comparatively cheap labor cost and such technology.

What described in respective chapters are outlined below.

1. Socioeconomic Background and Current Status of Electric Utility Industry

Social reforms based on liberalization, privatization and open policies and economic assistance of western countries based on the agreement of G24 are going on in Poland, but the economic outlook of Poland is still severe due to inflation coming from the vicious cycle of rises in consumer prices and salaries and stagnant industrial production.

The Republic of Poland is the biggest coal-producing country in Europe, but it is not enough to meet her energy demands because of the cold weather and her highly energy-consuming industrial structure including her low energy utilization efficiency as represented by her energy consumption per unit GNP which is twice as high as that in western countries, and she is an importer of primary energy.

The Ministry of Industry proposed, in August 1990, a scenario, on long-term prospect of energy supply and demand, of 1) Promotion of electrification, 2) Reduction of dependence on coal and brown coal shifting to petroleum and natural gas and 3) Use of atomic energy from year 2000, in view of promotion of energy saving and in harmony with environmental protection, based on the "Directions of Energy Policies for 1990 to 2010" which was formulated with cooperation of the World Bank, OECD-IEA and the Government of France.

As for the electric utility system in the Republic of Poland, the direct governmental control is being reviewed to reorganize it to have completely independent generation and distribution sectors. The organization would mediate with an electric power network company and be based completely on market principles, but such reorganization is yet to occur.

The Kozienice Power Plant, which is located at 75 km south of Warsaw, is a large-scale coal fired power station having a generation capacity of 2600 MW, which corresponds to about 10% of the total generation capacity of whole Poland. With 3,400 employees, the Power Plant is managed by the self-supporting system where necessary costs are covered by the income from the wholesale of electricity. The income was about one trillion ZL (about 15 billion yen) in 1990, and the unit electricity rate is on the order of 187 ZL (2.55 yen) per kWh.

In Table 1-1, history of Kozienice Power Plant and in Table 1-2, specification of major equipment of the Power Plant are shown.

The policy of environmental protection is being promoted in the Republic of Poland. Environmental standards have been set in addition to regulations on sulphur oxide and other emissions for the purpose of achieving targeted reduction of nationwide levels of sulphur oxide and other emissions, and it is becoming necessary for the Kozienice Power Plant to take actions for meeting such standards and regulations.

In Table 1-3, Emission and Ambient Air Quality Standards in Poland legislated in 1990 is shown.

2. Description of DeSOx System Project Site

The Kozienice Power Plant, located on the left shore of the Vistula (Wisla) River, is 12 km north of the city of Kozienice and 75 km south of Warsaw, and roads and railways from the two cities to the Power Plant are in good order.

The weather in the Republic of Poland is generally unstable under the influence of the oceanic climate of western Europe and the continental climate of eastern Europe, and is cold except the summer. The precipitation is low with an annual precipitation of about 500 mm.

It is said that about 90% of the land is flat, and the Power Plant is located in a vast flat area of forests and farms.

The geology around the Power Plant consists of a quaternary river deposit and an underlying tertiary layer.

Table 1-1 **History of Kozienice Power Station**

Phase	Unit Number	Output	Start of Construction	Date of Commissioning
I	1	200MW	1970.3.1	1972.10.18
	2	200MW		1973. 3.10
	3	200MW		1973. 6.20
	4	200MW		1973.10.08
	5	200MW		1973.12.10
	6	200MW		1974. 5.28
II	7	200MW	1972.8.1	1974.10.18
	8	200MW		1974.12.24
III	9	500MW	1974.7.1	1978.12. 4
	10	500MW		1979.11.30

Table 1-2 Outline of Kozienice Power Station

Item	Outline of Facilities	
1. Major Equipment	No. 1 - No. 8 Units	No. 9, 10 Units
(1) Unit Output	200 MW	500 MW
(2) Boiler		
Type	Drum type, natural circulation type	Drum type, forced circulation type
Maximum Evaporation	650 T/H	1,650 T/H
Firing System	Front firing system	Corner firing system
Fuel System	Pulverized coal (Hard coal)	Pulverized coal (Hard coal)
Mill Type	Ball mill	Roller mill
(3) Turbine		
Type	Tandem, reheat, condenser, 3-casing type	Tandem, reheat, condenser, 4-casing type
Speed	3,000 rpm	3,000 rpm
Main Steam Pressure	130 kg/cm^2g	166 kg/cm^2g
Main Steam Temperature	535 °C	535 °C
Reheat Steam Temperature	535 °C	535 °C
(4) Generator		
Capacity	235.2 MVA	588 MVA
Voltage/Frequency	15.75 kV/50 Hz	20 kV/50 Hz
Cooling System	Stator: water Rotor: hydrogen	Stator: water Rotor: hydrogen
(5) Environmental Facility	Electrostatic precipitator	Electrostatic precipitator
(6) Stack	1 stack each for No. 1 - No. 3 units and No. 4 - No. 8 units 200 m high	1 stack for No. 9, 10 units 300 m high
2. Condenser Cooling Water	Taken from Vistula River to the north of plant.	
3. Coal Yard	Outdoor storage system, 5 piles used by all units, transported to coal yard by rail.	
4. Ash Disposal Site	Ash slurry transported by pipeline to a site 3 km to the west of the plant.	

Table 1-3 Emission and Ambient Air Quality Standards in Poland

	Emission Standards (g/GJ) (Ministries of Environment, Natural Resources, and Forest)				Ambient Air Quality Standards ($\mu g/m^3$) (Ministries of Environment, Natural Resources, and Forest)					
	Existing Plants		New Plants		General Area			Special Protected Area		
	1990 ~ 1997	1998 ~	1990 ~ 1997	1998 ~	30 Min. Value	24 Hrs. Value	Annual Ave.	30 Min. Value	24 Hrs. Value	Annual Ave.
SOx	1,240	870	870	200	600	200	32	250	75	11
(SO_2)	1,540	1,070	1,070	200	440	150	32	150	75	11
NOx	330	170	170	170	500	150	50	150	50	30
(NO_2)	225	150	150	150						
Dust	260	130	130	130	250	120	50	85	60	40
(SPM)	195	95	95	95						
Remarks	• Figures are classified into 13 categories according to kinds of fuel used and Firing method. • Figures of upper side are those for firing bituminous coal and of bottom side are those for ligunite coal.				• In column for SOx, figures of upper side show values valid by the end of 1997, and bottom side show from 1998.					

3. Selection of the Optimum DeSOx System

The Kozienice Power Plant is located close to a nature conservation area and other protected area and designated as a special regulated area. Because of that the discussion for setting stricter regulations has been made between the local authority of Radom prefecture and the Power Plant.

As a result, both parties have made mutual consent on these figures and made agreement in August 1991.

These agreed figures consist of two stages, namely figures for those valid by the end of 1997 and for those valid from the beginning of 1998.

According to the agreement, SO_2 emission from the Power Plant will be reduced to 30% of the present maximum SO_2 emission amount from January of 1998 by installing DeSOx system.

Therefore, selection of optimum DeSOx system for the Kozienice Power Plant is made in this report in accordance with the agreement.

The selection of the optimum DeSOx system is made according to a flow sheet showing in Fig. 3-1.

Seven FGD methods, listed below, which would be possibly applicable to the Kozienice Power Plant were selected and their technologies were compared for the purpose of selecting the most suitable FGD method for the Kozienice Power Plant.

<Wet methods>

(1) Limestone-gypsum method - Spray tower method
(2) Limestone-gypsum method - Jet bubbling method

<Semi-dry methods>

(3) Spray dryer method

<Dry methods>

(4) Activated carbon method

(5) Coal ash-using dry FGD method

(6) Simple FGD method - Dry absorbent injection into furnace

(7) Simple FGD method - Dry absorbent injection into duct

Process flow sheets of these seven methods are shown in Fig. 3-2 to 8.

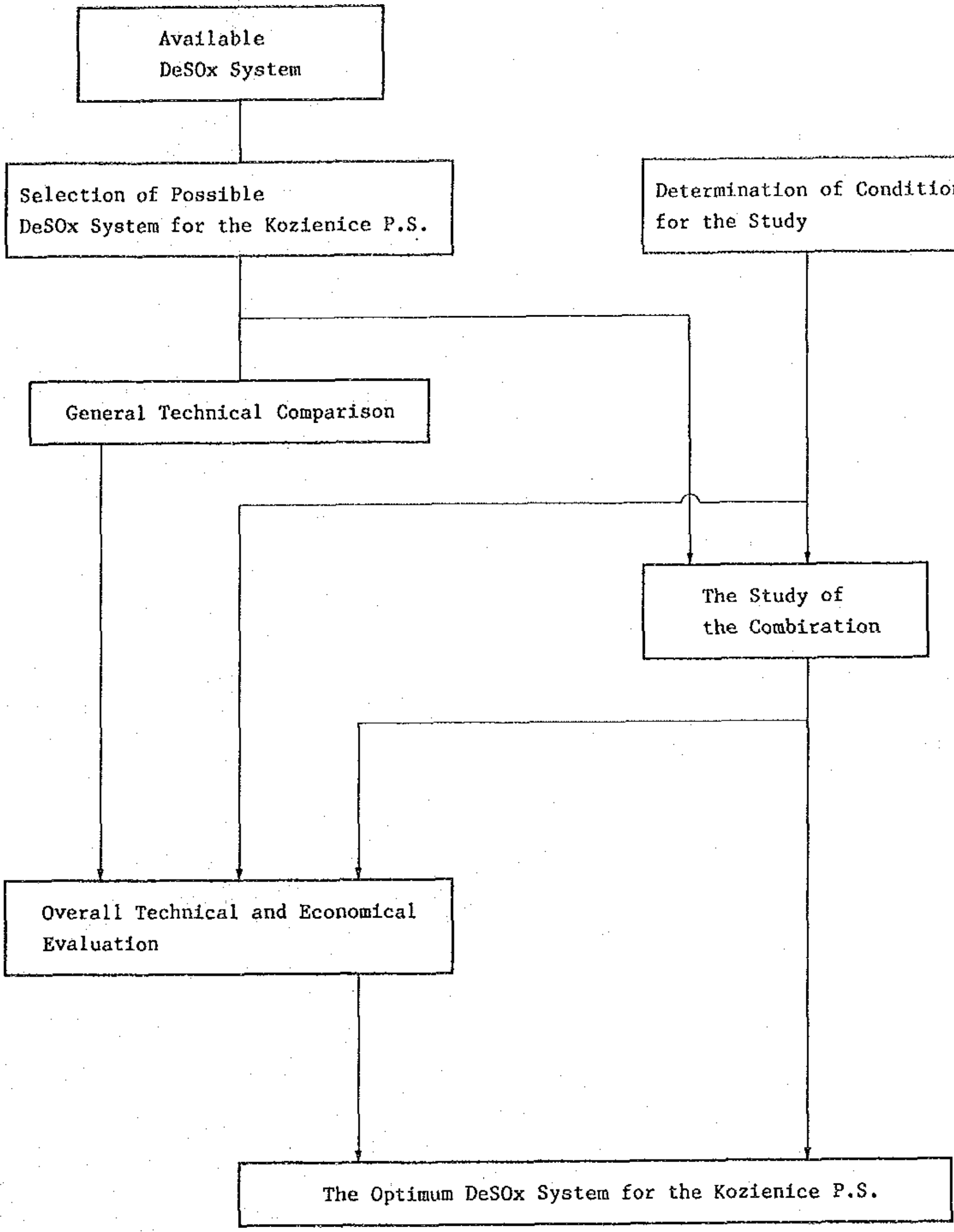


Fig. 3-1 Selection Flow of the Optimum DeSOx System

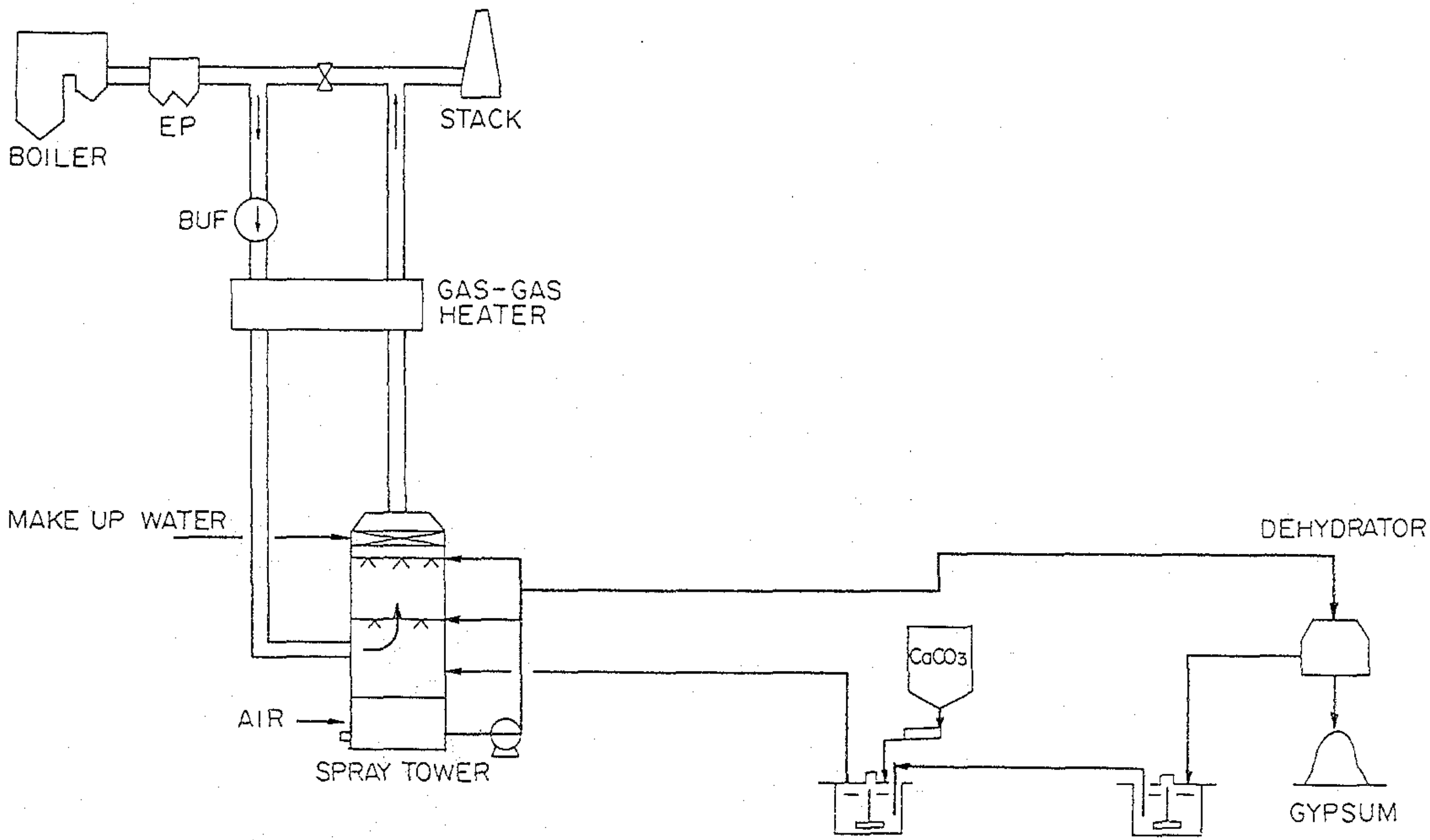


Fig. 3-2 PROCESS FLOW OF WET LIMESTONE - GYPSUM PROCESS
(SPRAY TOWER METHOD)

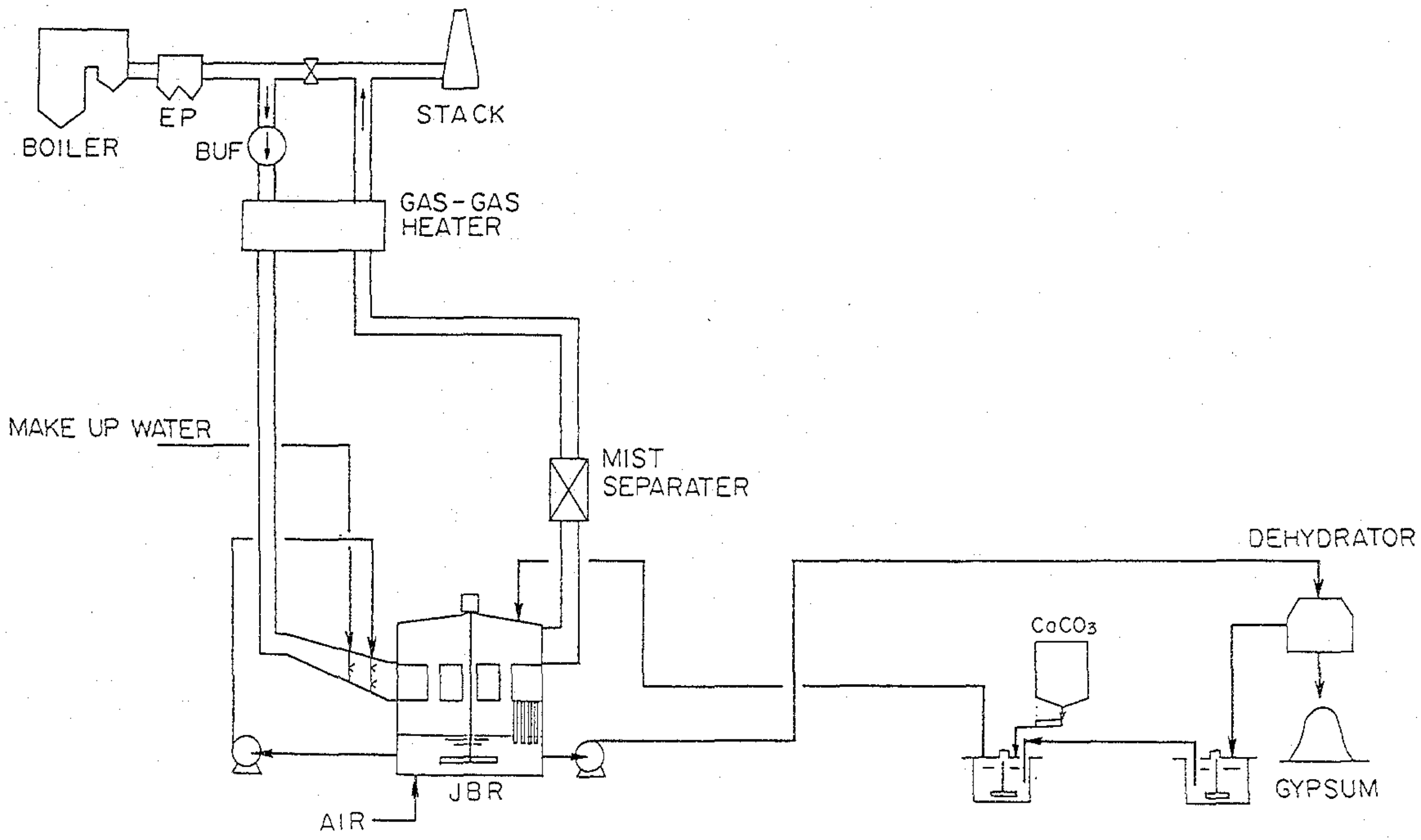


Fig. 3-3 PROCESS FLOW OF WET LIMESTONE-GYPSUM PROCESS
(JET-BUBBLING METHOD)

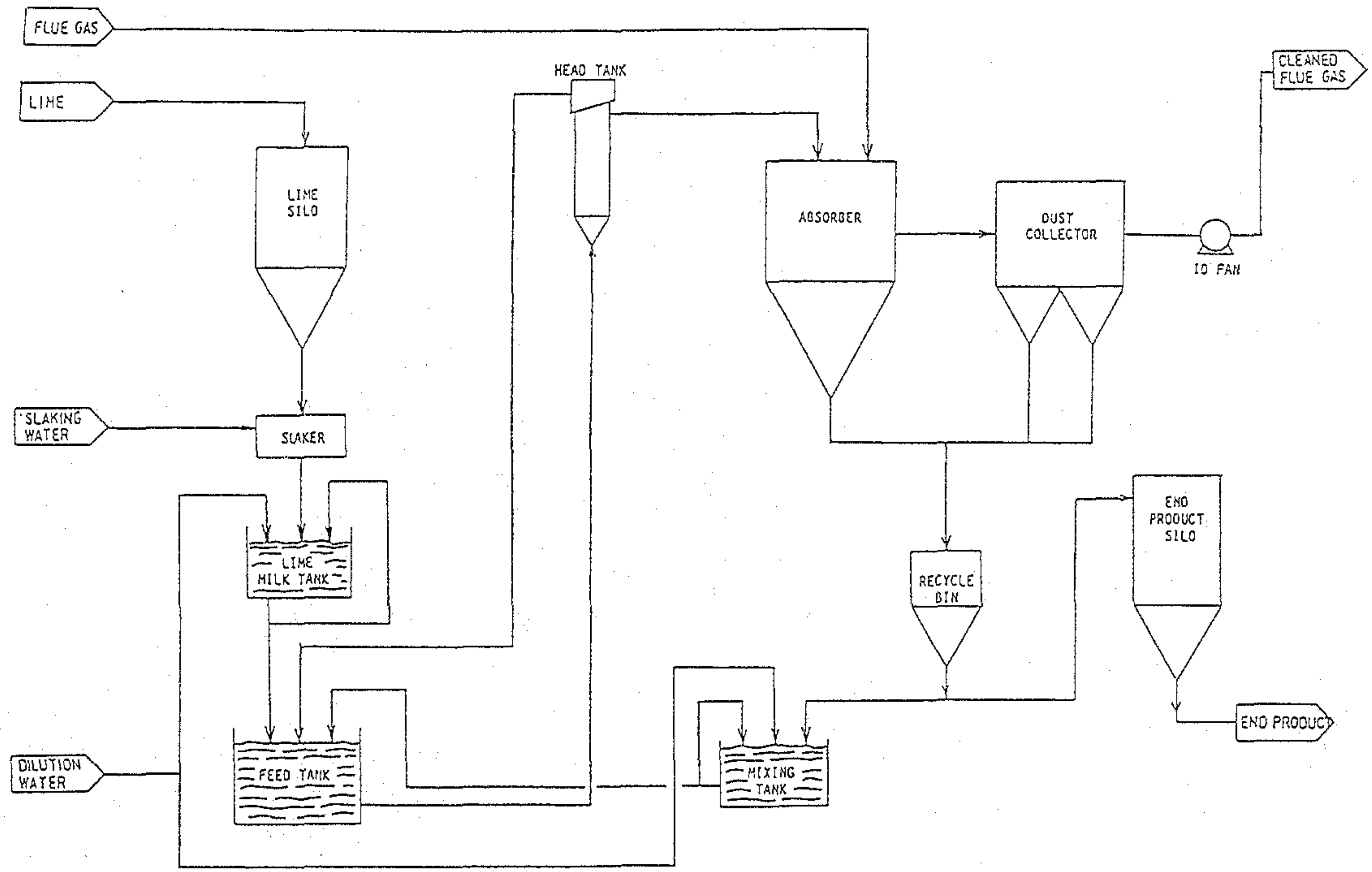


Fig. 3-4 Process Flow of Spray Dryer

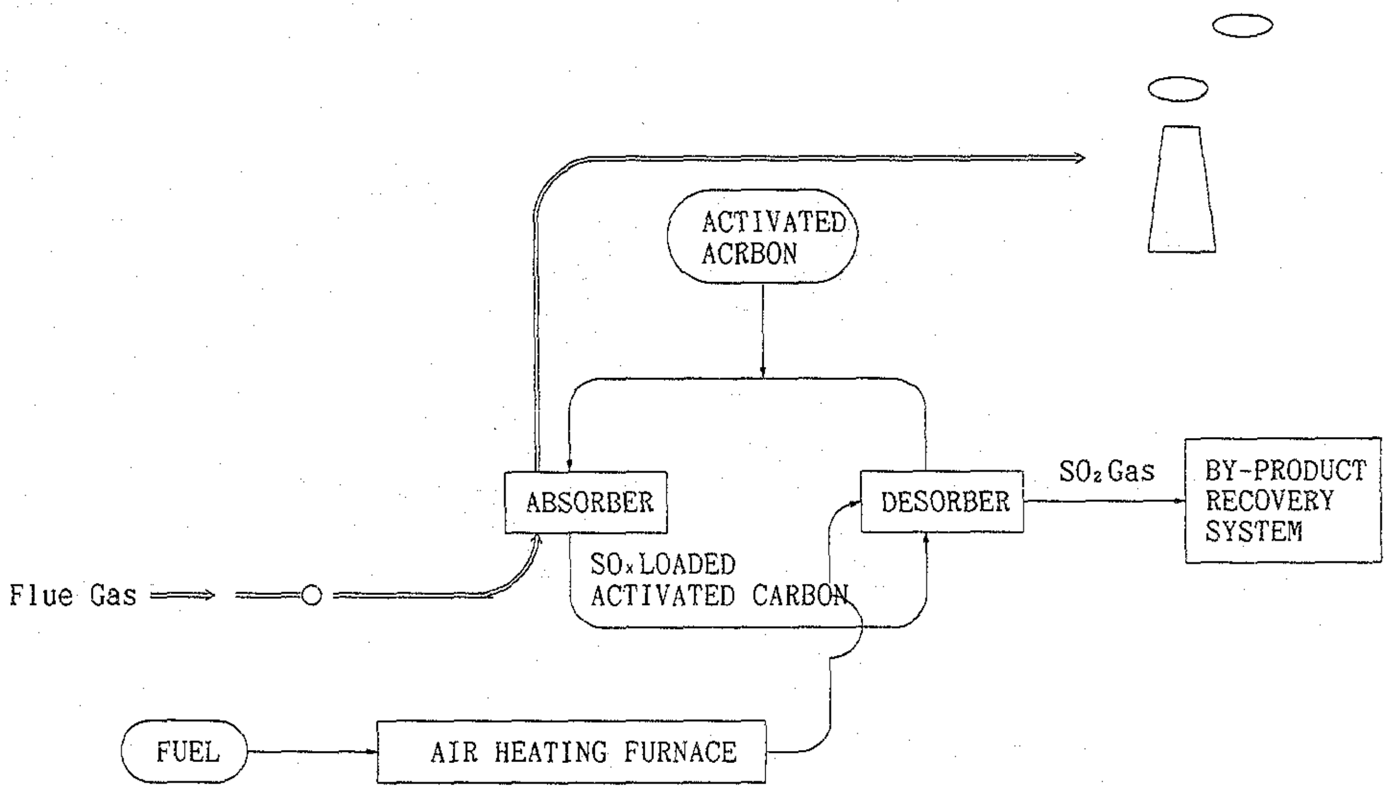


Fig. 3-5 Process Flow of Activated Carbon

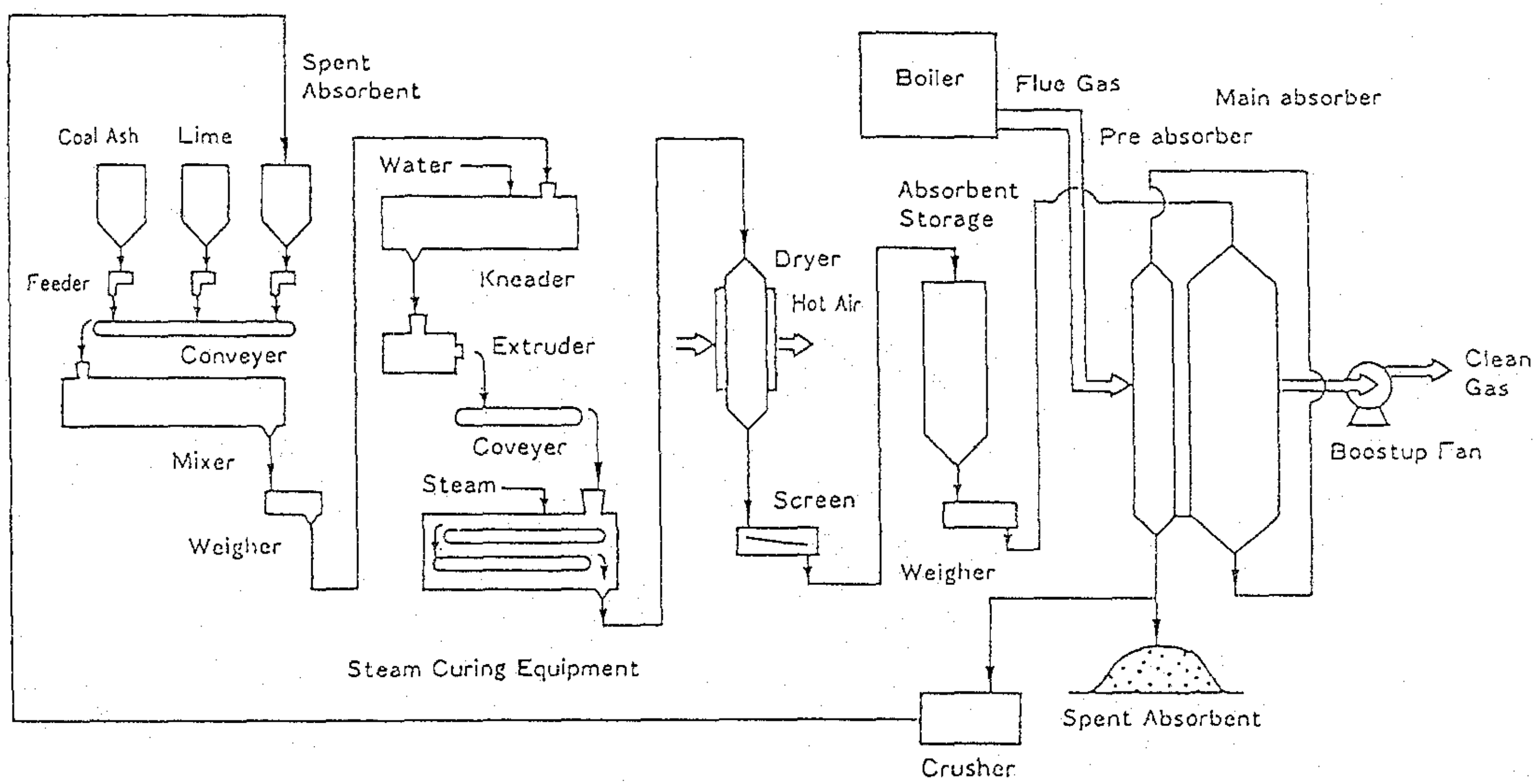


Fig. 3-6 PROCESS FLOW OF COAL ASH USING DRY FGD METHOD

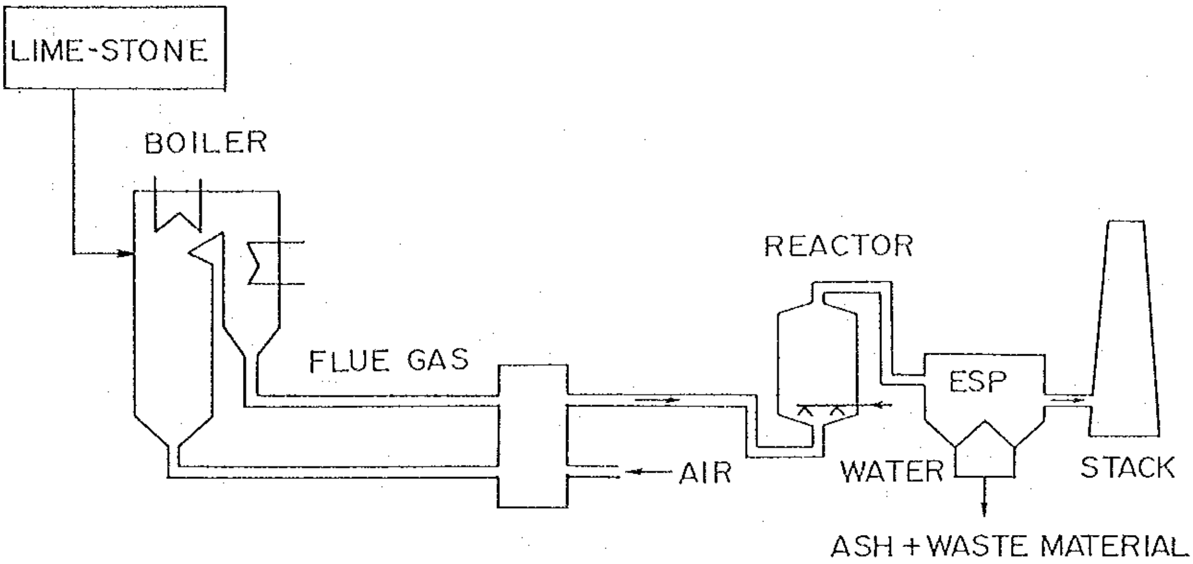


Fig. 3-7 PROCESS FLOW OF Dry Absorbent Furnace Injection System

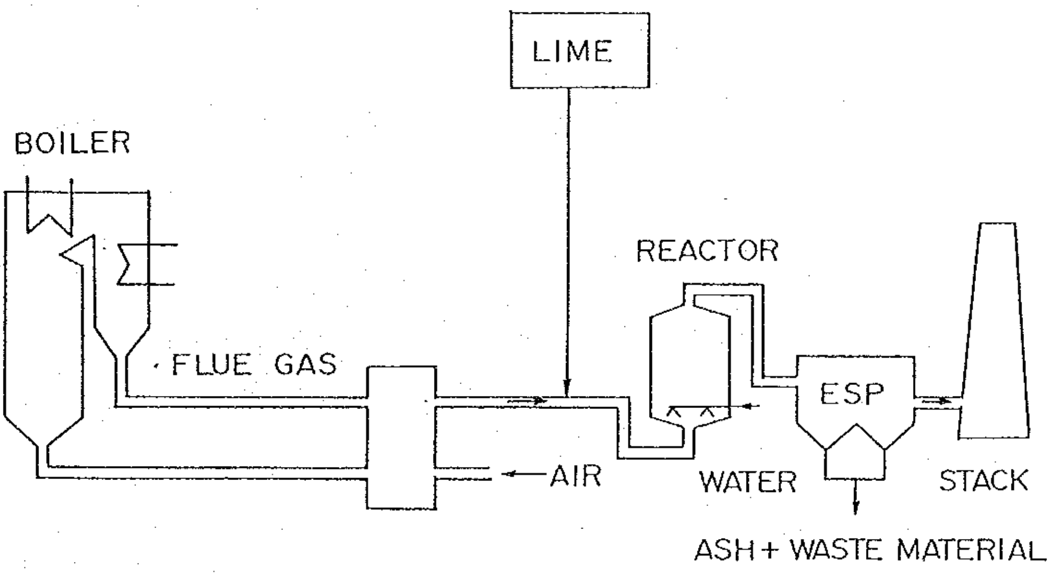


Fig. 3-8 PROCESS FLOW OF Dry Absorbent Duct Injection System

Conditions for the study on these methods are as follows.

(1) Plant Utilization Factor

a.	200 MW Plants	57% (Equivalent to 5,000 hours operation at rated output)
b.	500 MW Plants	57% (Equivalent to 5,000 hours operation at rated output)

(2) Plant Thermal Efficiency

a.	200 MW Plants	36.7% (Average of 1990's figures of 8 plants from the power station)
b.	500 MW Plants	36.1% (Average of 1990's figures of 2 plants from the power station)

(3) Minimum Continuous Operation Load

a.	200 MW Plants	140 MW
b.	500 MW Plants	250 MW

(4) SO_2 Emission Amount and Regulation

As for SO_2 emission regulation from January 1, 1998 it will be 7,995 kg/h regulated as the total emission from the power plant.

SO_2 emission amounts from each boiler for this study are determined as follows:

a. Boiler without FGD

200 MW plant	1,119 kg/h
500 MW plant	2,851 kg/h

(Above figures are the same as those for agreed emission amount by December 31, 1991.)

b. Boiler with FGD

200 MW plant	2,035 kg/h
500 MW plant	5,184 kg/h

(Above figures are the same as those of maximum SO_2 emission at the present.)

(5) Operation range of DeSOx system

50 to 100% of rated output

(6) Response to Power Plant Load Change

Response rate of DeSOx system to power plant load change is set at 2% of rated output per minute at a range of 50% to 100% rated output.

(7) Water Source for DeSOx System

Water for DeSOx system will be taken from Vistula River which water quality is usable for DeSOx system.

(8) Inlet and Outlet Conditions of FGD

In Table 3-1, inlet and outlet conditions of FGD is shown.

(9) Coal Properties

In Table 3-2, coal properties for the study is shown.

Analysis results of coals which were obtained during the first site survey are shown in Table 3-3.

Table 3-1 FGD Inlet and Outlet Gas Conditions

Item	Unit	FGD Inlet		FGD Outlet		Remarks
		200 MW	500 MW	200 MW	500 MW	
Treated Capacity	%	*1	*1			"*1" Will be determined based on the study of FGD capacity and efficiency along with the units to be equipped with the FGD's.
Flue Gas from Boiler	m^3N/h	817,000	2,078,000			
Flue Gas Temp.	°C	114	130	80*2	90*2	"*2" Shows value with reheating system.
SO_2 from Boiler	kg/h	2,035	5,184			
SO_2 Concentration	ppm	940	940			
Dust Load				It will be settled by a dust removal efficiency of applied system.		
: Design Value	mg/m^3N	300	300			
: Current Value	mg/m^3N	275 ~ 335	511 ~ 572			
Excess O_2	%	6.0	6.0			"*3" Value are presumed based on EPDC's experiences.
HCl	mg/m^3N	579	579			
HF	mg/m^3N	24	24			
SO_3*3	ppm	5	5			

Table 3-2 Coal Property

Item	Unit	Value	Remarks
(1) As Received Base			
. Total Moisture	%	10.7	
. Moisture	%	8.4	
. Heating Value	kcal/kg	4,460	(LHV)
. Sulphur Content	%	0.96	
. Ash Content	%	27.85	
(2) Proximate Analysis			
. Inherent Moisture	%	2.5	
. Ash Content	%	30.4	
. Volatile Matter	%	26.1	
. Fixed Carbon	%	41.0	
(3) Ultimate Analysis			
. Carbon	%	54.9	
. Hydrogen	%	3.7	
. Nitrogen	%	0.9	
. Oxygen	%	8.2	
. Sulphur	%	1.1	
. Ash Content	%	31.2	

Table 3-3 Coal Analysis by EPDC

Sampling Date: March 12th, 1991

Item	Unit	Mine					
		ZABRZE	PIAST	WESOLA	MURCK	PIACIV	Sample from Coal Yard
Total Moisture (AR)	%	6.44	14.2	8.42	11.0	12.5	10.5
Lower Heating Value (AD)	kcal/kg	5,250	5,730	4,870	4,900	5,430	5,860
Proximate Analysis (AD)							4.0
Inherent Moisture	%	2.5	6.6	4.4	4.7	6.1	4.0
Ash	%	32.2	16.8	31.0	29.0	22.0	20.9
Volotile Matter	%	24.9	30.4	25.7	28.4	29.5	28.9
Fixed Carbon	%	40.4	46.2	38.9	37.9	42.4	46.2
Fuel Ratio	-	1.6	1.5	1.5	1.3	1.4	1.6
Ultimate Analysis (Dry)							
Carbon	%	54.8	62.4	52.2	53.5	58.1	62.2
Hydrogen	%	3.56	4.02	3.52	3.71	3.88	3.96
Total Sulphur	%	0.88	1.37	0.89	0.90	1.17	0.84
Nitrogen	%	0.89	0.88	0.88	0.94	0.86	0.98
Fluorine	%	0.016	0.015	0.019	0.02	0.016	0.02
Chlorine	%	0.27	0.46	0.14	0.04	0.30	0.16
Boron	%	0.004	0.009	0.005	0.006	0.008	0.004
Total	%	60.42	69.15	57.66	59.12	64.33	68.16

Note: AR: As Received Base, AD: Air Dry Base

(10) Electrostatic Precipitator (ESP) Inlet and Outlet Dust Load

a.	200 MW plants inlet	:	30.7 g/m^3N, Dry
b.	500 MW plants inlet	:	30.7 g/m^3N, Dry
c.	ESP outlet dust for DeSOx design	:	300 mg/m^3N, Dry

(11) Powdered Limestone Property

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

(12) Area for DeSOx System Installation

In Fig. 3-9, a ground plane of usable space for DeSOx system installation is shown.

(13) Unit Price of Utilities

In Table 3-4, unit prices of utilities as of 1991 which are used for the economic comparison of each DeSOx system are shown.

The exchange rates between Poland zloty, Japanese yen, and American dollar as of March 1991 are as follows.

1 ZL = 0.014 Yen
1 U$ = 9,500 zl
1 U$ = 135 Yen

(14) Unit Price of By-products

a.	Gypsum	35,000 to 45,000 ZL/ton
b.	Sulphuric Acid	1,100 ZL/kg

(15) Deterioration Rate and Interest

a.	Deterioration Rate	:	12 years (with no value at the end)
b.	Interest Rate	:	5%

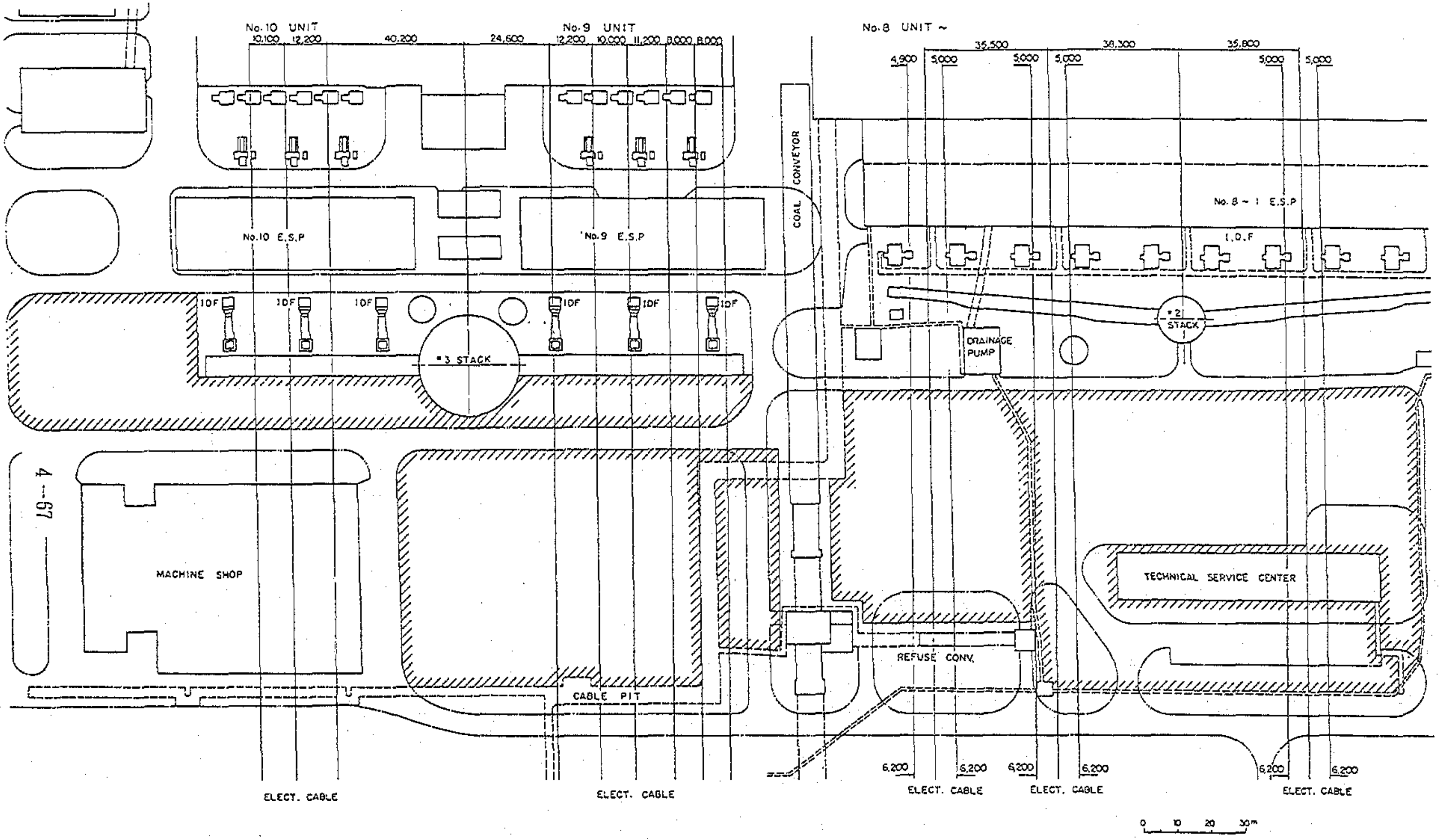


Fig. 3-9 Available Space for FGD Installation

Table 3-4 A Unit Price of Utilities

Item	Unit	Value	Remarks
(1) Limestone ($CaCO_3$)	Zl/ton	130,000	• 94% or more as $CaCO_3$ • 95% or more 325 mesh pass
(2) Lime (CaO)	Zl/ton	325,000	90% passed on 0.04 mm's mesh
(3) Slaked Lime ($Ca(OH)_2$)	Zl/ton	420,000	
(4) Activated Carbon	Zl/ton	9,500,000	
(5) Caustic Soda ($NaOH$)	Zl/kg	2,130	based on 100% concentration
(6) Sulphuric Acid (H_2SO_4)	Zl/kg	1,300	based on 100% concentration
(7) Auxiliary Steam	Zl/ton	54,000	17 ata and 220°C
(8) Auxiliary Power	Zl/kwh	200	
(9) Law Water	Zl/ton	180	river water

* These are the prices in March, 1991.

Comparison for combination between power generation plants and FGD units is shown in Table 3-5 (1) and (2).

Before the study of the above, simplified FGD methods are excluded from FGD methods to be examined and compared by the following reasons:

The DeSOx efficiency of the simplified FGD methods are on the order of 30 to 40% when absorbent is blown into the furnace or duct. To meet the emission standards of the Kozienice Power Plant, however, the DeSOx efficiency of 70% is required even when an FGD Unit is installed to each power generation unit by the "unit-to-unit" method. To attain a DeSOx efficiency of over 70% while using a simplified FGD method, it would be necessary to further install a DeSOx tower (water spraying reaction tower) between the existing boiler house and the dust collector. The size of a DeSOx tower is about 12 m in diameter, and no space for such installation is available, at the Kozienice Power Plant, between the existing boiler house and the dust collector

Table 3-6 (1) and (2), technical comparison of various FGD system is shown and in Table 3-7, cost comparison of those for three 500 MW class FGD is shown.

It reached a conclusion after examination that the optimum FGD method for the Kozienice Power Plant is either of the wet type limestone-gypsum methods and the most suitable combination is to install two 500-MW equivalent FGD Units of 89% in desulphurisation (DeSOx) efficiency to treat the flue gas of No. 4 through No. 8, (200-MW x 5) power plants of 1,000 MW in total generating capacity and one FGD Unit of same capacity and efficiency to treat flue gas of No. 9, (500-MW) power plant. The conclusion therefore was that it is the best to install three FGD Units same in type and capacity.

The wet type limestone-gypsum methods include the two methods of the spray tower method and the jet bubbling method. Differences were little between the two methods in their technical and economic comparisons made in the current stage of the Feasibility Study, and either method can be applicable to the Kozienice Power Plant.

Differences are little between the spray tower method and the jet bubbling method in their basic principles of flue gas desulphurisation. The only difference is in the method of contacting the absorbing liquid and flue gas for absorption of sulphur oxides (SOx). Such contact is achieved by spraying the absorbing liquid by slurry circulation pumps in the spray tower method and by blowing flue gas into the absorbing liquid by desulphuriser fans in the jet bubbling method.

In Fig. 3-10 to 13, layouts and process flow sheets of these two systems are shown.

It was concluded in this Feasibility Study that either of the spray tower method and the jet bubbling method can be applicable to the Kozienice Power Plant. In order to carry out a conceptual design of the most suitable FGD method, it has been decided to proceed with the study on the assumption of the use of the spray tower method which has been employed more for 500-MW class FGD Units and much operational experiences have been accumulated.

Table 3-5 (1) Combination of DeSOx Plants Installation

Coal Calorific Value: 4,460 kcal/kg
Sulphur content: 0.96 %

	Stack No.1			Stack No. 2					Stack No. 3		Total SO_2 Emission	Evaluation	
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10		Cost	Space, etc.
Case A				(200MW)	(200MW)	(200MW)	(200MW)	(200MW)	(500MW)	(500MW)		△	△
Flue Gas through DeSOx (%)	-	-	-	100	100	100	100	100	100	100			
DeSOx Eff. (%)	-	-	-	78	78	78	78	78	78	78			
SO_2 Emission (kg/h)	1,119	1,119	1,119	448	448	448	448	448	1,140	1,140	7,877		
Case B				(172MW)	(172MW)	(172MW)	(172MW)	(172MW)	(430MW)	(430MW)		X	△
Flue Gas through DeSOx (%)	-	-	-	86	86	86	86	87	86	86			
DeSOx Eff. (%)	-	-	-	90	90	90	90	90	90	90			
SO_2 Emission (kg/h)	1,119	1,119	1,119	460	460	460	460	442	1,172	1,172	7,983		
Case C						(200MW)	(200MW)	(200MW)	(500MW)	(500MW)		△	o
Flue Gas through DeSOx (%)	-	-	-	-	-	100	100	100	100	100			
DeSOx Eff. (%)	-	-	-	-	-	54	90	90	90	90			
SO_2 Emission (kg/h)	1,119	1,119	1,119	1,119	1,119	937	204	204	519	519	7,978		
Case D						(120MW)	(200MW)	(200MW)	(500MW)	(500MW)		△	o
Flue Gas through DeSOx (%)	-	-	-	-	-	60	100	100	100	100			
DeSOx Eff. (%)	-	-	-	-	-	90	90	90	90	90			
SO_2 Emission (kg/h)	1,119	1,119	1,119	1,119	1,119	937	204	204	519	519	7,978		
Case E						(200MW)	(200MW)	(200MW)	(500MW)	(500MW)		o	o
Flue Gas through DeSOx (%)	-	-	-	-	-	100	100	100	100	100			
DeSOx Eff. (%)	-	-	-	-	-	78	78	78	90	90			
SO_2 Emission (kg/h)	1,119	1,119	1,119	1,119	1,119	448	448	448	519	519	7,977		

Note 1. Regulation on SO_2 Emission: 7,995 kg/h
2. SO_2 amount from boilers:
- Plants without FGD 1,119 kg/h (200 MW plants), 2,851 kg/h (500 MW plants)
- Plants with FGD 2,035 kg/h (200 MW plants), 5,164 kg/h (500 MW plants)

3. Figures in ( ) are capacity of DeSOx plants in MW equivalent

⊚ Excellent
o Good
△ Fair
X Bad

Table 3-5 (2) Combination of DeSOx Plants Installation

Coal Calorific Value: 4,460 kcal/kg
Sulphur content: 0.96 %

	Stack No.1			Stack No. 2					Stack No. 3		Total SO_2 Emission	Evaluation	
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10		Cost	Space, etc.
Case F							(600MW)		(500MW)	(500MW)		○	○
Flue Gas through DeSOx (%)	-	-	-	-	-		100		100	100			
DeSOx Eff. (%)	-	-	-	-	-		78		90	90			
SO_2 Emission (kg/h)	1,119	1,119	1,119	1,119	1,119		1,344		519	519	7,977		
Case G						(200MW)	(200MW)	(200MW)	(500MW)	(500MW)		△	○
Flue Gas through DeSOx (%)	-	-	-	-	-	100	100	100	100	100			
DeSOx Eff. (%)	-	-	-	-	-	90	90	90	90	76			
SO_2 Emission (kg/h)	1,119	1,119	1,119	1,119	1,119	204	204	204	519	1,245	7,971		
Case H						(200MW)	(200MW)	(200MW)	(500MW)	(500MW)		△	○
Flue Gas through DeSOx (%)	-	-	-	-	-	100	100	100	100	84			
DeSOx Eff. (%)	-	-	-	-	-	90	90	90	90	90			
SO_2 Emission (kg/h)	1,119	1,119	1,119	1,119	1,119	204	204	204	519	1,266	7,992		
Case I							(600MW)		(500MW)	(500MW)		△	○
Flue Gas through DeSOx (%)	-	-	-	-	-		100		100	84			
DeSOx Eff. (%)	-	-	-	-	-		90		90	90			
SO_2 Emission (kg/h)	1,119	1,119	1,119	1,119	1,119		611		519	1,266	7,991		
Case J							(500MW)		(500MW)	(500MW)		◎	◎
Flue Gas through DeSOx (%)	-	-	-	-	-		100		100	100			
DeSOx Eff. (%)	-	-	-	-	-		92		92	92			
SO_2 Emission (kg/h)	1,119	1,119	1,119	1,119	1,119	1,018	407		415	415	7,850		
Case K					(500MW)		(500MW)		(500MW)	(500MW)		◎	◎
Flue Gas through DeSOx (%)	-	-	-		100		100		100	-			
DeSOx Eff. (%)	-	-	-		89		89		89	-			
SO_2 Emission (kg/h)	1,119	1,119	1,119		560		560		571	2.851	7,899		

Note 1. Regulation on SO_2 Emission: 7,995 kg/h
2. SO_2 amount from boilers:
- Plants without FGD 1,119 kg/h (200 MW plants), 2,851 kg/h (500 MW plants)
- Plants with FGD 2,035 kg/h (200 MW plants), 5,184 kg/h (500 MW plants)

3. Figures in ( ) are capacity of DeSOx plants in MW equivalent

◎ Excellent
○ Good
△ Fair
X Bad

Table 3-6 (1) Technical Comparison of Various Flue Gas Desulphurisation System (Based on Application to Kozienice P.S.)

	Item	Wet Type		Semi-Dry Type	Dry Type	
		Limestone-Gypsum Method		Spray Dryer Method	Activated Carbon Method	DeSOx Method Using Flyash as a part of Absorbent
		Spray Tower Method	Jet-Bubbling Method			
1.	SOx Removal Efficiency (Eff. at practical operation range)	Ca. 90	Ca. 90	Ca. 80 ~ 90	Ca. 90	Ca. 90
2.	Dust Removal Efficiency	Ca. 90	Ca. 90	Ca. 90 (Combination with dust collector after SDA)	Ca. 90	Ca. 90
3.	Technical Maturity	It has been recognized as a proven technology for commercial use.	Same as the left	Same as the left	Tests in demonstration plants were finished and several commercial plants have been operating.	Test in a demonstration plant was finished and a commercial plant has been operating.
4.	Operational experience in commercial coal-fired plants	305 Plants* Many plants including big scale plants of 350MW, 500MW and 700MW class for coal-fired power plants have been installed and in operation.	7 Plants* • As of July 1991, there are seven applications to coal fired power plants. • As the biggest plants in operation, there are two 250MW plants. • At the present, 700MW equivalent plant is being constructed and will be in operation in June 1995.	53 Plants* • There are 53 applications including big scale plants of 350MW and 500MW class to coal-fired power plants. • Application of the spray dryer system is popular especially in Europe and the United States of America.	4 Plants • There are 4 applications to coal-fired power plants. • The biggest application of 130MW equivalent plant is under operation. • A plant for a 350MW fludized bed combustion boiler is under planning which is scheduled to be in operation in July 1995.	1 Plant • As a commercial plant, there is a 175MW equivalent plant for a half of 350MW coal-fired power plant. • DeSOx plant was put into operation in March 1991.

* Figures in FGD handbook published by IEA in May 1987 (Including planned plants as of May 1987)

Table 3-6 (2) Technical Comparison of Various Flue Gas Desulphurisation System (Based on Application to Kozienice P.S.)

	Item	Wet Type		Semi-Dry Type	Dry Type	
		Limestone-Gypsum Method		Spray Dryer Method	Activated Carbon Method	DeSOx Method Using Flyash as a part of Absorbent
		Spray Tower Method	Jet-Bubbling Method			
5.	Reliability	• It has been recognized as a proven technology. • Reliability is very high.	• It has been recognized as a proven technology. • Reliability is similar to that of spray tower method.	• It has been recognized as a proven technology. • High reliability similar to spray tower method has been recognized.	• It has been recognized as a level of proven technology which can be applied to commercial plant, however operational experience is shorter than those of wet-limestone/gypsum and spray dryer methods.	Same as the left.
6.	Operational Characteristics	Excellent	Excellent	Good (There is a limitation on operation at low flue gas temperature.)	Good (Warm-up time at start up is rather long.)	Good (Absorbent production process is complicated.)
7.	Maintainability	Good	Good	Good	Good	Good
8.	By-Product	Commercial gypsum can be recovered, however there is no market for gypsum board around the power plant and gypsum price at cement factories is low, therefore no gypsum recovery is more economical.	Same as the left	Calcium sulfite+Flyash • Research for effective use is under way. • In case of Kozienice power plant, evaluation was made based on disposal to the ash pond.	Sulphuric acid or elemental sulphur • In case of Kozienice power plant, evaluation was made based on sulphuric acid recovery.	Used absorbent • Research for effective use is under say. • In case of Kozienice power plant, evaluation was made based on disposal to the ash pond by slurry transportation similar to existing ash disposal system.

Table 3-6 (3) Technical Comparison of Various Flue Gas Desulphurisation System (Based on Application to Kozienice P.S.)

		Wet Type		Semi-Dry Type	Dry Type	
		Limestone-Gypsum Method		Spray Dryer Method	Activated Carbon Method	DeSOx Method Using Flyash as a part of Absorbent
		Spray Tower Method	Jet-Bubbling Method			
9.	Utility					
	(1) Absorbent	Limestone ($CaCO_3$) • About 25 t/h of limestone is necessary. • Limestone can be supplied by cement factories near the power plant.	Limestone ($CaCO_3$) Same as the left	Slaked lime [$Ca(OH)_2$] • About 37 t/h of slaked lime is necessary. • There is no factory to supply such amount of slaked lime to the power plant.	Activated Carbon • About 4 t/h or 20,000 t/year of activated carbon is necessary. • At the present (July 1991), it is very difficult to obtain activated carbon at the power plant because production amount of activated carbon in Poland is about 1,500 t/year.	Flyash+Gypsum+$Ca(OH)_2$ (Each of them is about 1/3) • About 19 t/h of slaked lime is necessary. • There is no factory to supply such amount of slaked lime to the power plant.
	(2) Water (River water)	270 t/h	270 t/h	184 t/h	70 t/h	315 t/h
	(3) Steam	6 t/h	6 t/h	-	0.6 t/h	84 t/h
	(4) Electricity	19,800 kW	19,800 kW	12,900 kW	14,000 kW	14,700 kW
10.	Waste Water	None Disposal to ash pond as a compound of Gypsum, flyash, and waste water.	None Same as the left	None	6 t/h Waste water treatment system is required.	None

Table 3-6 (4) Technical Comparison of Various Flue Gas Desulphurisation System (Based on Application to Kozienice P.S.)

	Item	Wet Type		Semi-Dry Type	Dry Type	
		Limestone-Gypsum Method		Spray Dryer Method	Activated Carbon Method	DeSOx Method Using Flyash as a part of Absorbent
		Spray Tower Method	Jet-Bubbling Method			
11.	Stack Lining or Flue Gas Reheating	Required	Required	Not necessary	Not necessary	Not necessary
12.	Reconstruction of Existing Power Plant	• Reconstruction of duct between IDF outlet and stack inlet. • Other small items	Same as the left	Same as the left	Same as the left	Same as the left
13.	Installation Space	Available space for FGD installation can be used for 3 units of 500MW equivalent.	Same as the left	• It is difficult to install within the available space. • It is necessary to remove existing maintenance service building and renew a building for FGD control room.	Same as the left	Same as the left
14.	Overall Evaluation	Applicable	Applicable	• Difficult to be installed within the available space. • Difficult to obtain slaked lime.	Same as the left • Difficult to obtain activated carbon.	Same as the left • Difficult to obtain slaked lime.

Table 3-7 Cost Comparison of Various Flue Gas Desulphurisation System (Based on Application to Kozienice P.S.)

	Item	Wet Type		Semi-Dry Type	Dry Type		Remarks
		Limestone-Gypsum Method					
		Spray Tower Method	Jet-Bubbling Method	Spray Dryer Method	Activated Carbon Method	DeSOx Method Using Flyash as a part of Absorbent	
1.	Estimated Conditions						
	Reheat & Stack Lining	Yes	Yes	None	None	None	
	By-products Recovery	None	None	None	Yes	None	
	Groundwater Protection Measures at Ash Pond	Yes	Yes	Yes	None	None	
	SOx Removal Efficiency	89%	89%	89%	89%	89%	
	DeSOx Plant Size	500MW x 3	500MW x 3	500MW x 3	500MW x 3	500MW x 3	
2.	Capital Cost						Annual Payment for Investment (A)
	Annual Payment for Investment	100% (Base)	100%	80%	110%	105%	= Investment x Levelizing Factor
3.	Running Cost						Annual Running Cost (B)
	Annual Running Cost	100% (Base)	100%	225%	250%	190%	= Running Cost - By-products Sale
	Total Annual Cost	100% (Base)	100%	105%	140%	120%	Total Annual Cost = A + B

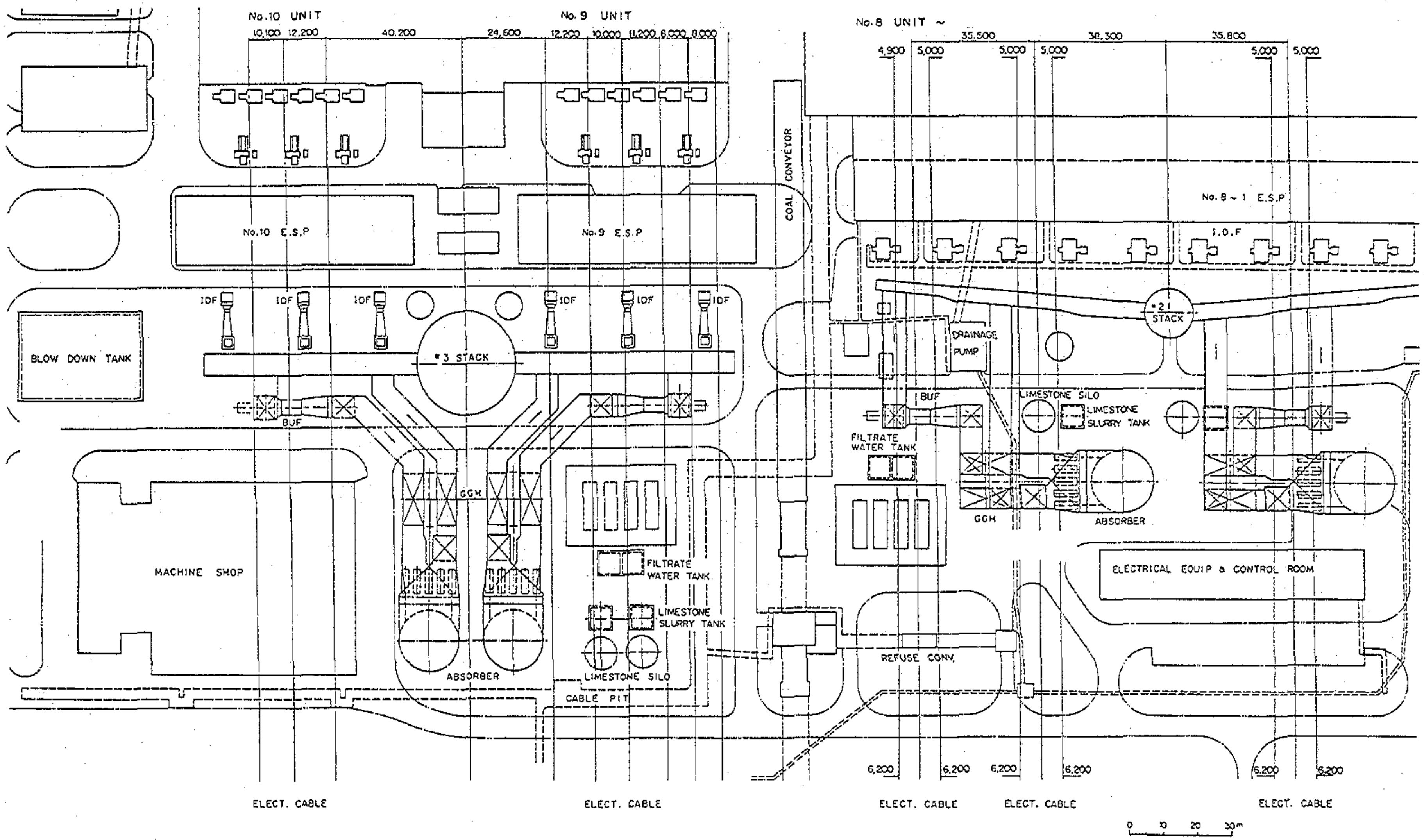


Fig. 3-10 500 MW THREE (3) FGD GENERAL LAYOUT WET LIMESTONE-GYPSUM METHOD (SPRAY TOWER)

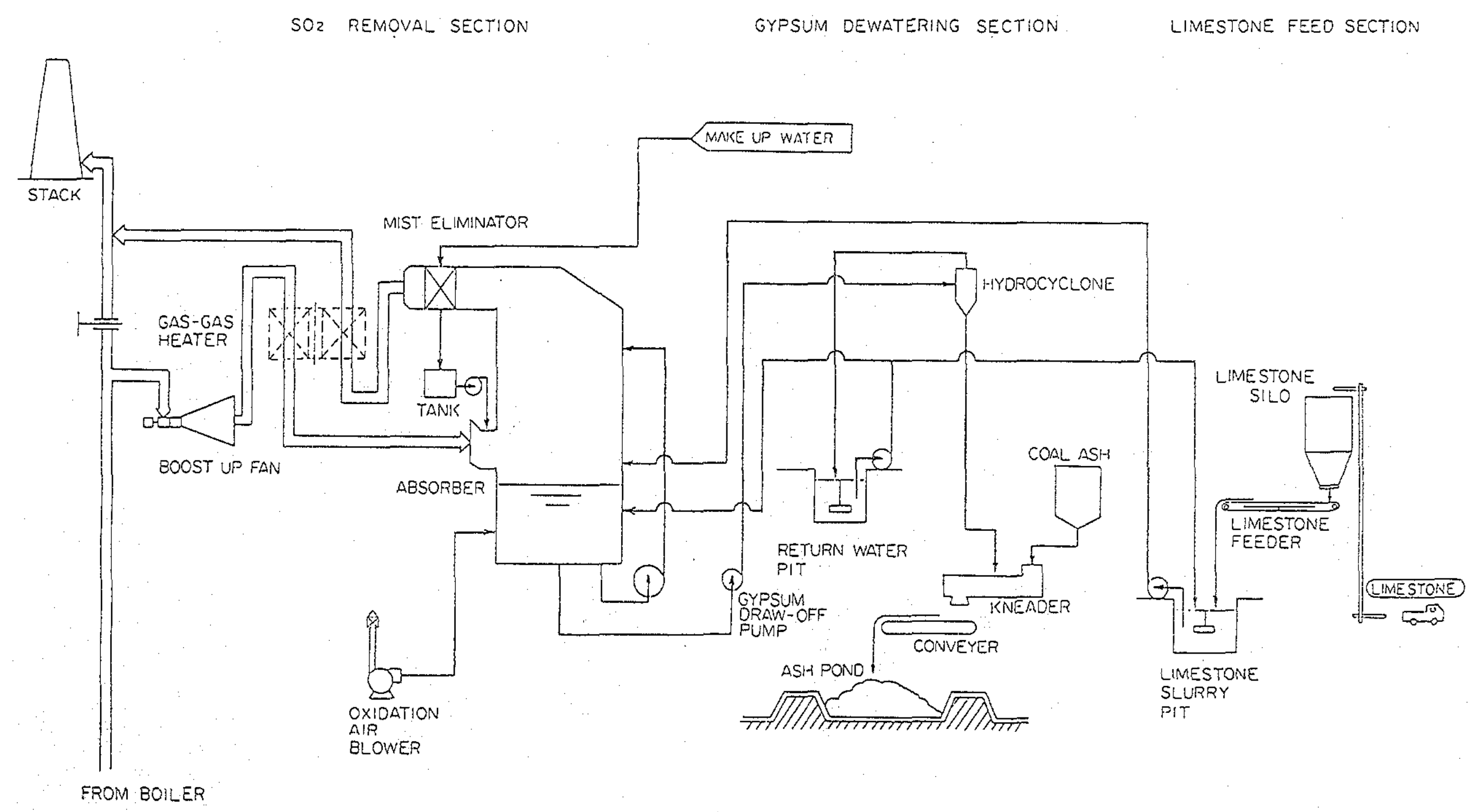


Fig. 3-11 Wet Limestone/Gypsum Method Process Flow Sheet (Spray Tower Reactor)

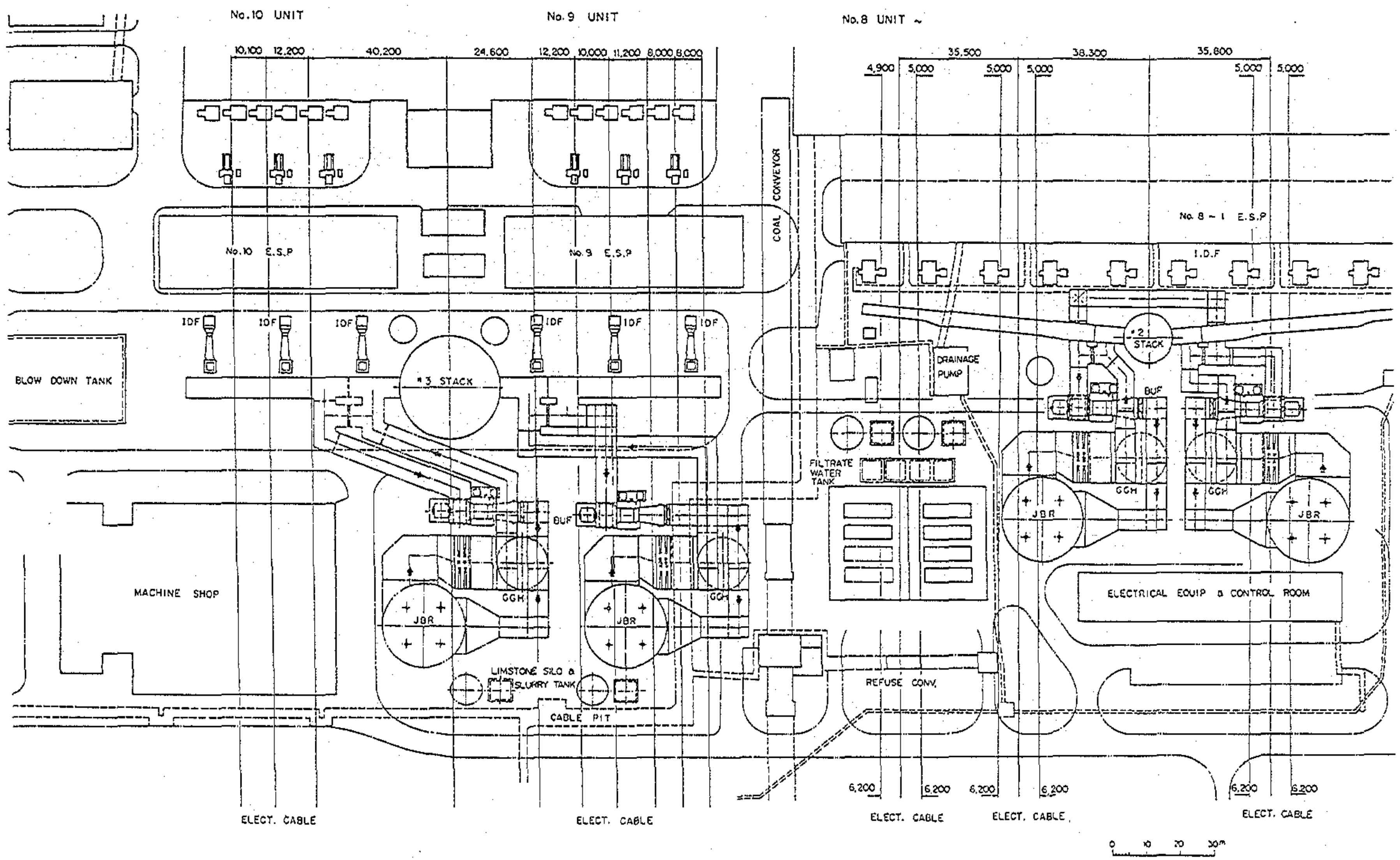


Fig. 3-12 500 MW THREE (3) FGD GENERAL LAYOUT
WET LIMESTONE-GYPSUM METHOD
(JET-BUBBLING REACTOR)

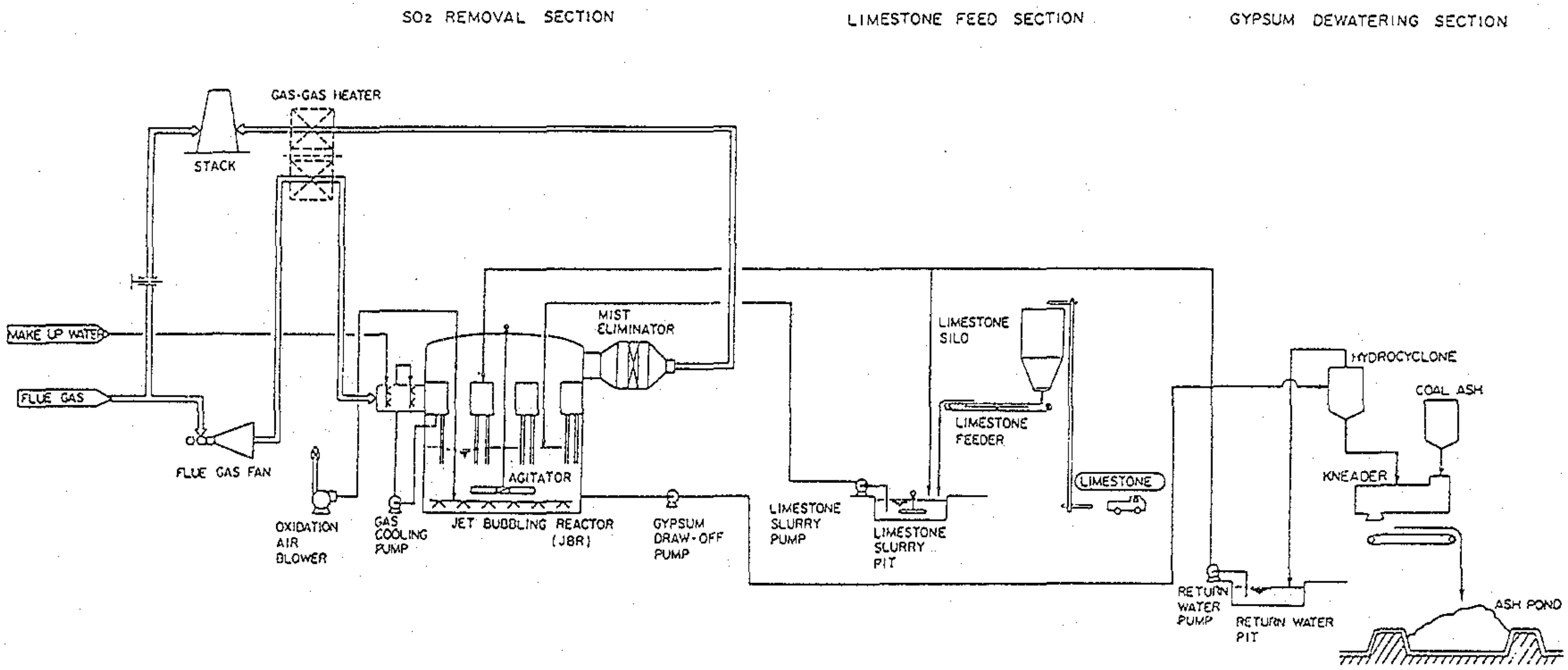


Fig. 3- 13　Wet Limestone/Gypsum Method Process Flow Sheet (Jet Bubbling Reactor)

4. Environmental Assessment

The maximum ground level concentrations of SO_2 before and after installation of the FGD Units are compared by hourly ground level concentration of SO_2 and the annual mean of hourly ground level concentration determined from diffusion formulas.

In Table 4-1, the results of calculation is shown.

The hourly ground level concentrations of SO_2 before and after installation of FGD Units of the most suitable combination thus obtained were 0.092 $mg/m^3 \cdot SO_2$ and 0.058 $mg/m^3 \cdot SO_2$, and their annual means were 0.015 $mg/m^3 \cdot SO_2$ and 0.009 $mg/m^3 \cdot SO_2$, respectively.

Furthermore, dust in flue gas can be reduced by installation of the wet type FGD Units.

The predicted present hourly ground concentration of 0.042 mg/m^3 dust would be 0.024 mg/m^3 dust with the installation of the wet type DeSOx system.

It is assumed that the employment of such wet type FGD Units would improve the environment much to levels where the SO_2 and dust emission of the Power Plant little affect the natural environment and human life.

Table 4-1 Result of Calculation

(Short-Term; Hourly Average) Wind Velocity 6.0 m/s

Case	Item	Cmax (mg/m^3)				Xmax (km)				He (m)		
		No. 1	No. 2	No. 3	Total	No. 1	No. 2	No. 3	Total	No. 1	No. 2	No. 3
Case I	SO_2	0.034	0.040	0.024	0.092	19.8	24.2	32.5	25.0	403.0	479.0	620.7
	SPM	0.015	0.018	0.011	0.042							
Case II	SO_2	0.034	0.029	0.005	0.066	19.8	22.8	27.5	21.5	403.0	455.9	536.0
	SPM	0.015	0.011	0.002	0.028							
Case III	SO_2	0.034	0.011	0.017	0.058	19.8	20.4	30.0	22.9	403.0	412.3	579.0
	SPM	0.015	0.002	0.007	0.024							

(Long-Term; Annual Average)

Case	Item	Cmax (mg/m^3)				Xmax (km)				Direction
		No. 1	No. 2	No. 3	Total	No. 1	No. 2	No. 3	Total	
Case I	SO_2	0.004	0.006	0.005	0.015	-	-	-	-	(E)
	SPM	0.002	0.003	0.002	0.007					
Case II	SO_2	0.004	0.004	0.001	0.010	-	-	-	-	(E)
	SPM	0.002	0.002	0.000	0.004					
Case III	SO_2	0.004	0.001	0.003	0.009	-	-	-	-	(E)
	SPM	0.002	0.000	0.001	0.004					

Note: Case I = Present (Before Dec.31,1997), Case II = Combination Case-J, Case III = Combination Case-K

5. Conceptual Design of DeSOx System

A conceptual design of the DeSOx system was carried out based on the study result of the selection of the optimum DeSOx system for the Kozienice Power Plant.

There is a little difference in inlet flue gas conditions between two FGD Units (No. 1 and No. 2) installed to No. 4 to No. 8 power generation plants and one FGD Unit (No. 3) installed to No. 9 power generation plant.

In this study, the conditions for No. 3 FGD Unit have been selected as the representative.

In Table 5-1 and 5-2, design conditions and planned performance of the FGD Units are shown respectively.

A general layout of the FGD Units is shown in Fig. 5-1.

In this layout, it is planned to be able to install another FGD Unit to No. 10 power generation plant in the future, if it would become necessary.

In Fig. 5-2 and in Table 5-3, a flow diagram and specifications of major equipment of the FGD Units are shown respectively.

In Fig. 5-3, material balance for No. 1 and No. 2 FGD Units and in Fig. 5-4 that for No. 3 FGD Unit are shown.

In these material balances, the case using high chlorine content coal is represented.

However, it is recommended to reduce chlorine content in coal by purchasing low chlorine content coals and/or blending low chlorine content coals with high chlorine content coals and so on.

In Fig. 5-5 and 5-6, material balances of 20,000 ppm chlorine content in the FGD Units are shown.

Table 5-1 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 5-2 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

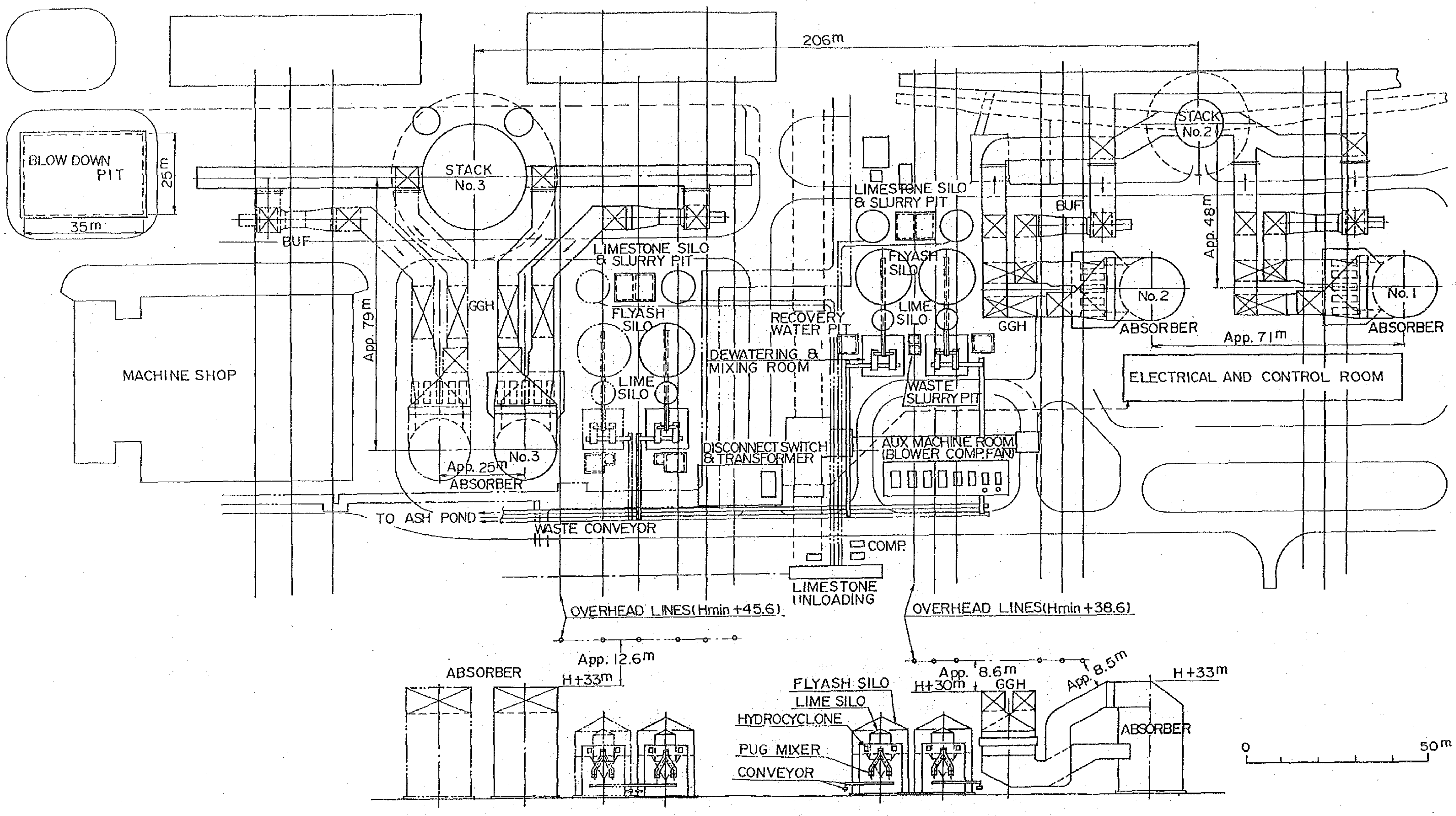
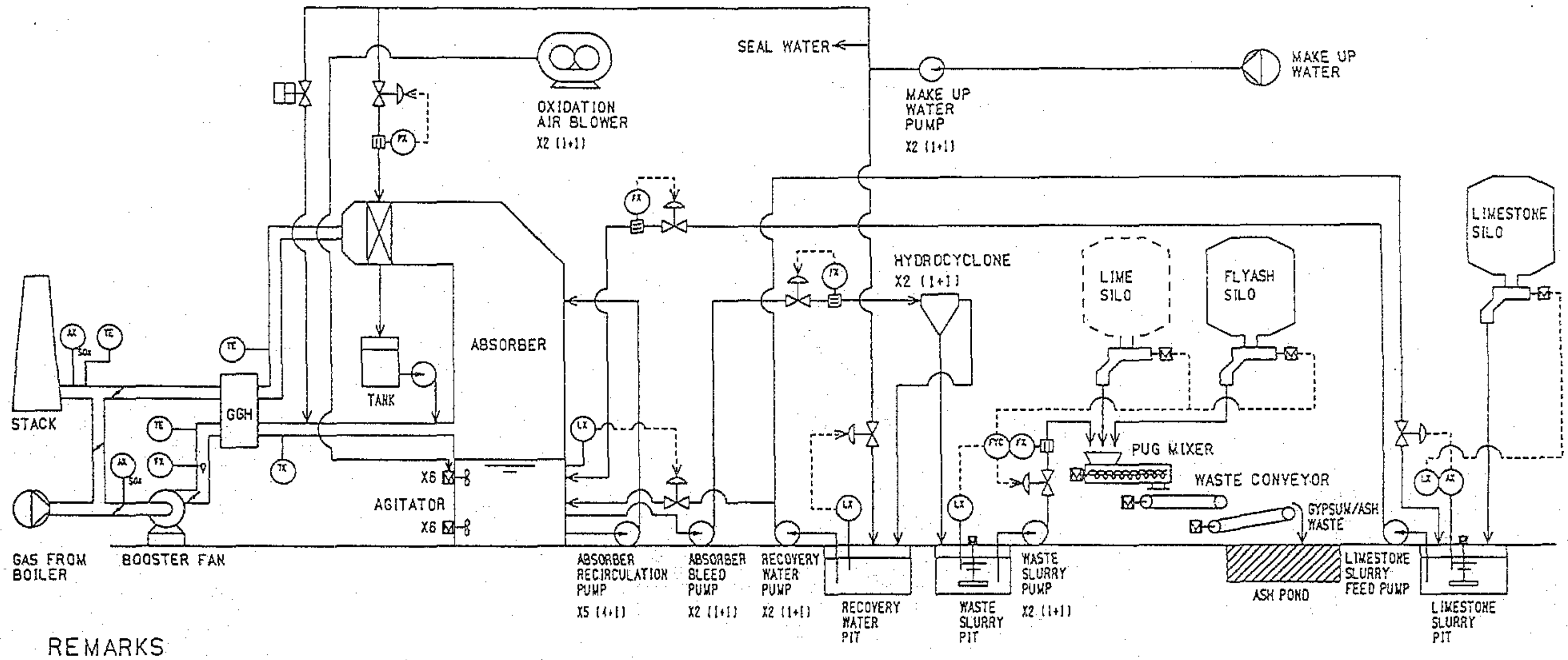


Fig. 5-1 General Layout of Three (3) 500MW FGD Units



REMARKS

AX : ANALYSIS TRANSMITTER

FX : FLOW RATE TRANSMITTER

LX : LEVEL TRANSMITTER

TE : TEMPERATURE DETECTOR

Fig. 5-2 Flow Diagram of 500 MW FGD Unit

Table 5-3 Specification of Major Equipment for 500 MW FGD Unit

Equipment	Specification
1. Absorbing System	
1) Absorber	
Number	1
Type	Spray Tower
Dia. × Height	ϕ18.8 m × 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

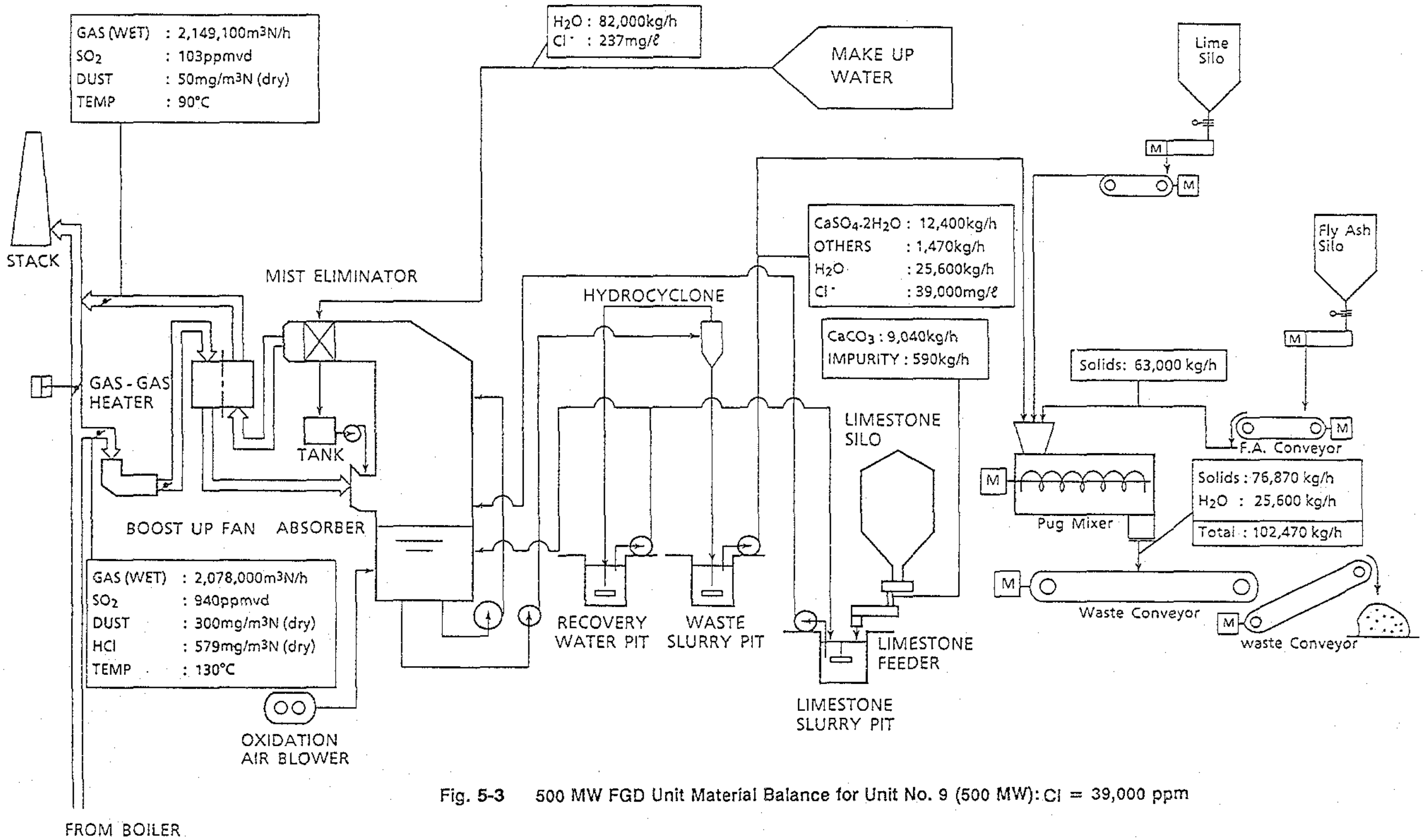


Fig. 5-3 500 MW FGD Unit Material Balance for Unit No. 9 (500 MW): Cl = 39,000 ppm

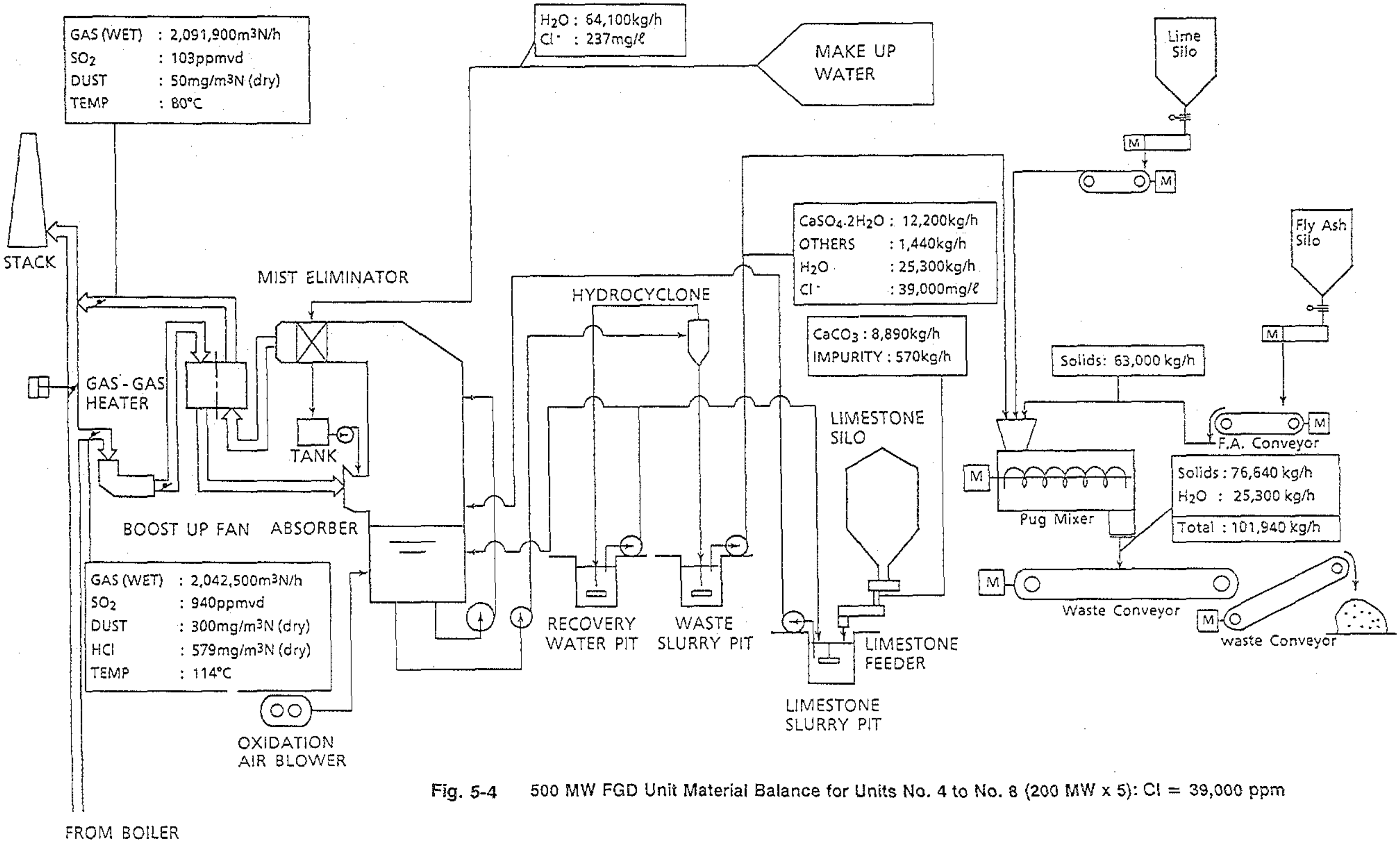


Fig. 5-4 500 MW FGD Unit Material Balance for Units No. 4 to No. 8 (200 MW x 5): Cl = 39,000 ppm

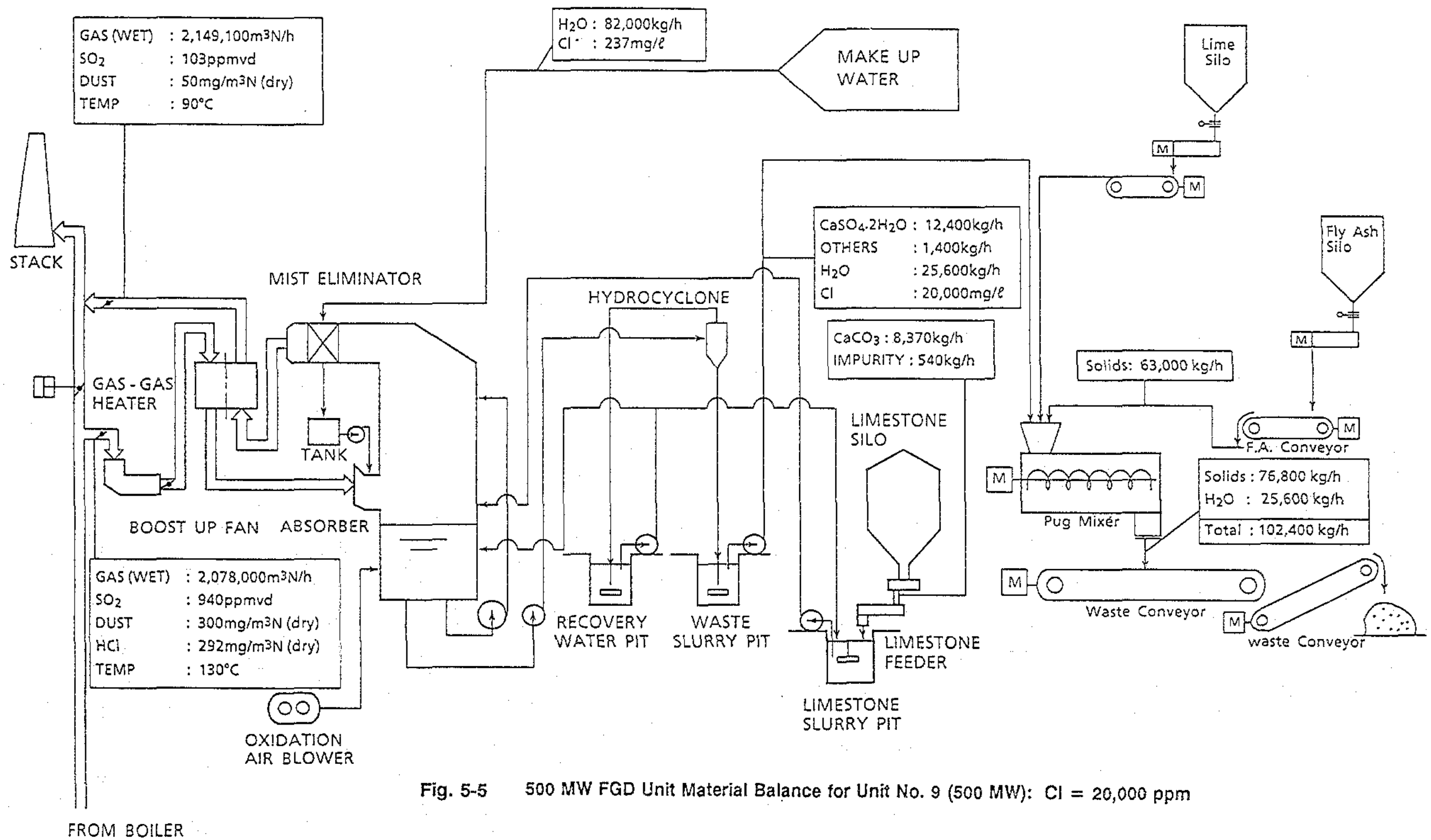


Fig. 5-5 500 MW FGD Unit Material Balance for Unit No. 9 (500 MW): Cl = 20,000 ppm

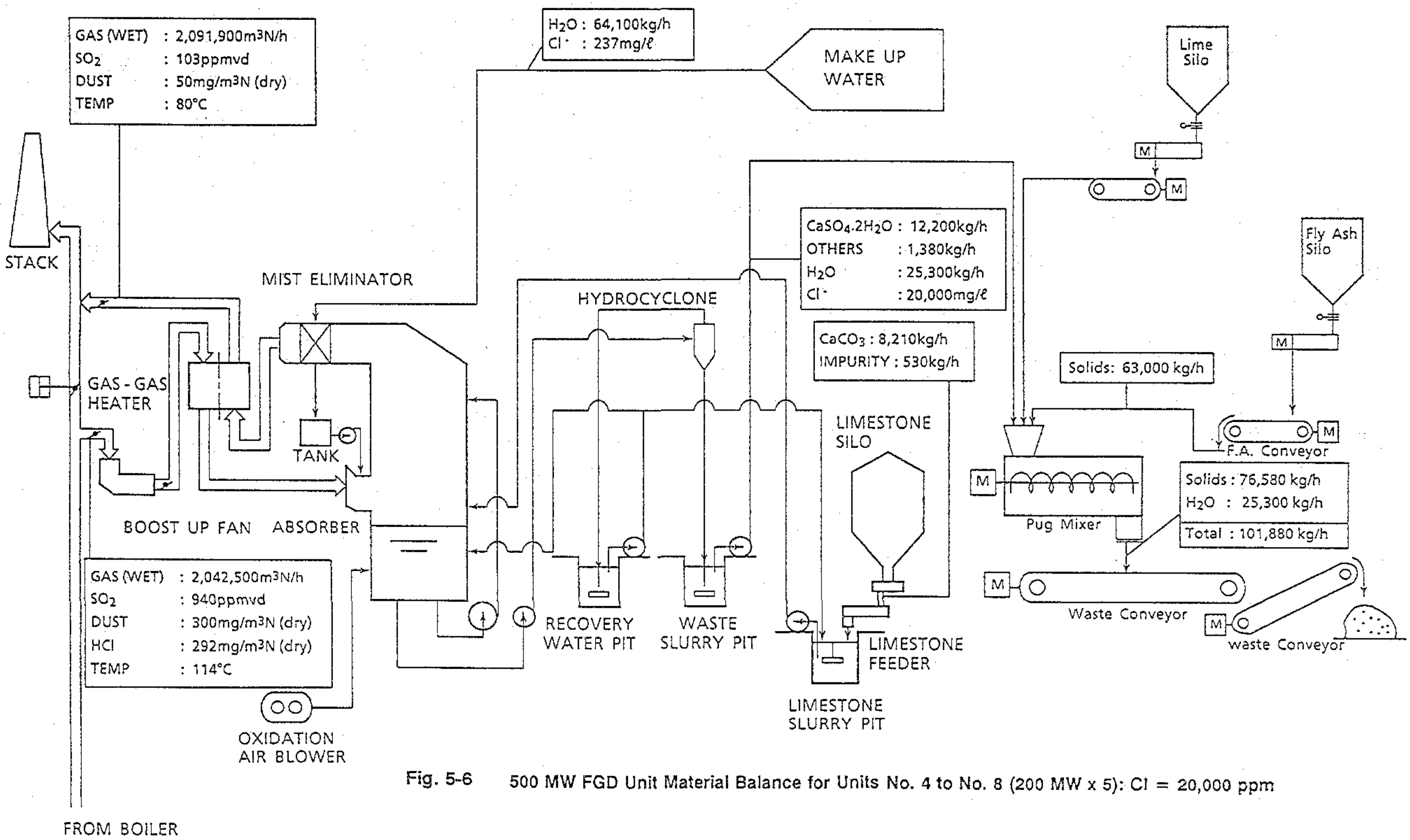


Fig. 5-6 500 MW FGD Unit Material Balance for Units No. 4 to No. 8 (200 MW x 5): Cl = 20,000 ppm

Outlines of major equipment are as follows.

(1)	Absorber	:	Single tamer, in-situ oxidation, spray tower method (General view of the absorber is shown in Fig. 5-7 and selection list of lining material including for the absorber is shown in Fig. 5-8.)
(2)	Boost Up Fan (BUF)	:	Axial fan, fixed blade, A position (Between IDF and Gas/Gas Heater)
(3)	Flue Gas Reheating System	:	It is installed for the purpose of preventing corrosion of stacks and flue gas ducts and of improving an effect of flue gas dispersion from stacks. Regenerative rotating type Gas/Gas heater (GGH) which has good reliability and economics is selected for flue gas reheating system.
(4)	By-product Handling Facility	:	By-product gypsum and waste water in it are mixed with flyash then conveyed to the disposal area adjacent to the ash disposal area.
(5)	Electric Equipment	:	Electric equipment is powered by a newly installed DeSOx transformer which is connected with the primary side of the existing No. 4 starting transformer over head line by T-branch connection.
(6)	Control Equipment	:	The latest model of digital controller is selected as the control equipment.

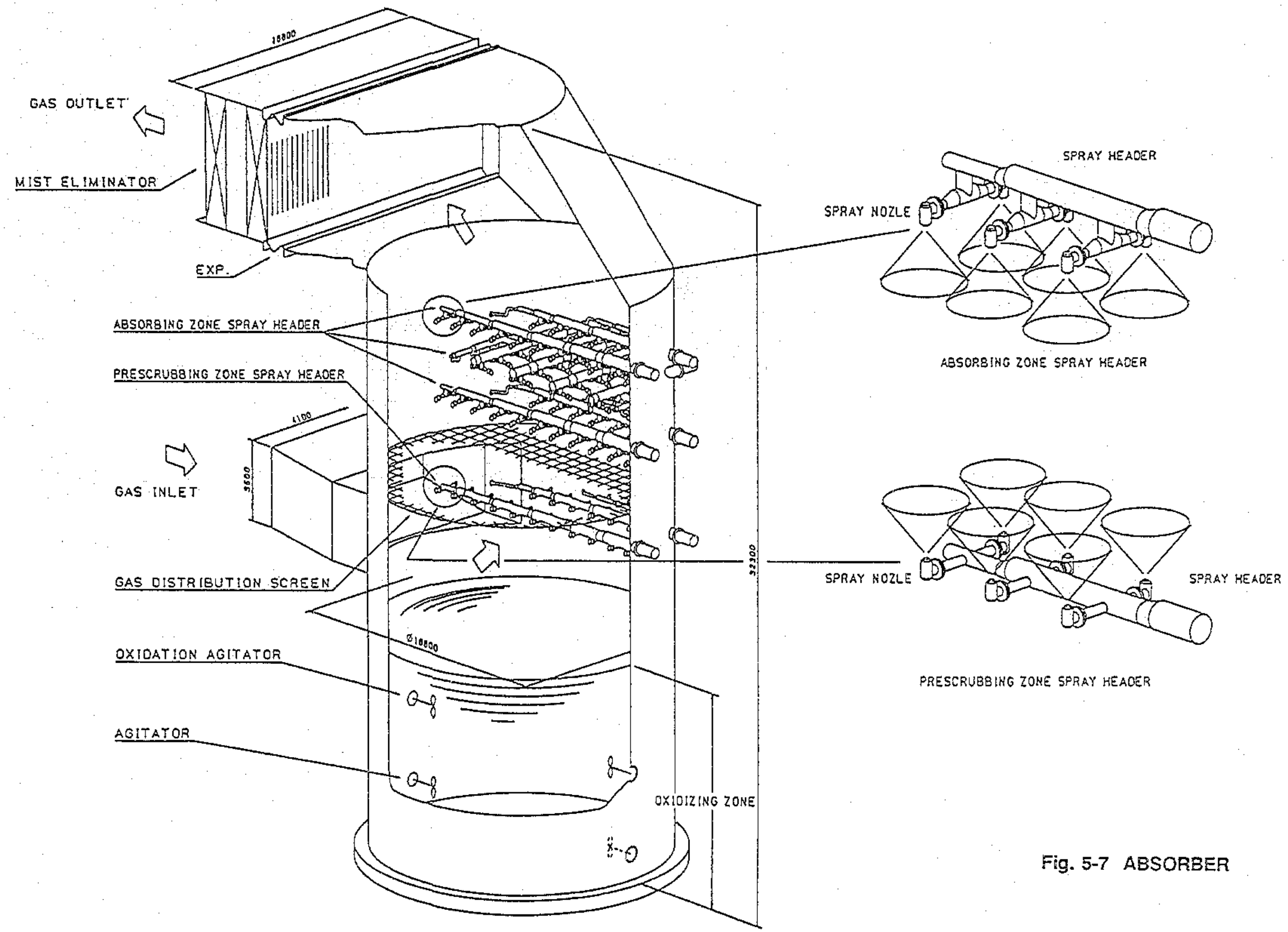
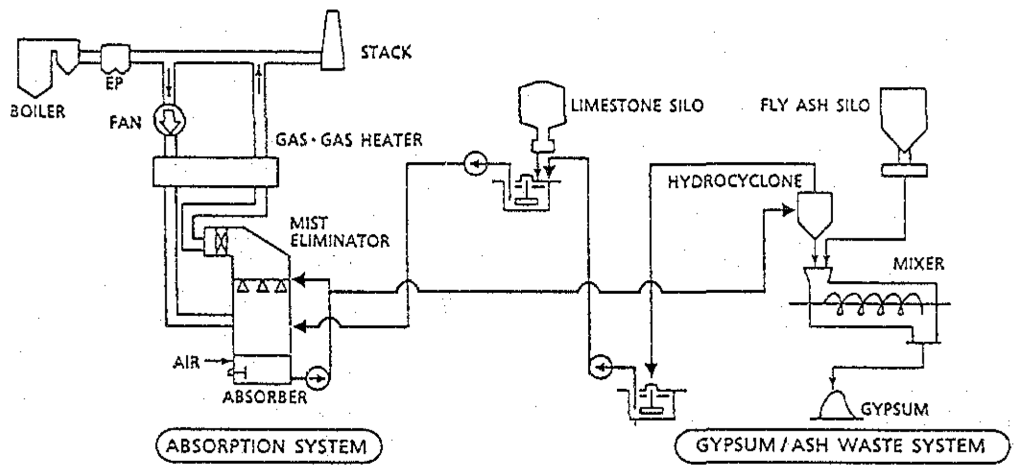


Fig. 5-7 ABSORBER



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. 5-8 STANDARD LINING MATERIAL FOR WET LIMESTONE GYPSUM FGD SYSTEM

Major facilities which are necessary to be reconstructed or remodeled due to DeSOx system installation are as follows.

(1) Flue gas common ducts at stack inlet

(2) Inner material of No. 2 stack for acid resistance lining

(3) Z.R.E. building for electrical and control room

(4) Rail way track for receiving chemical for demineralizer

(5) Rail way track for maintenance

(6) A part of flyash transportation piping