2.5.4 Financial Status and Accounting

(1) General

The total assets of the power station is 2,762.6 billion ZL, the capital is 2,556.5 billion ZL and the liabilities is 366.4 billion ZL (5 billion yen). (Refer to Tables 2.5-5 through -9).

The accounting of the power station is completely independent; the expenses incurred by the operation of the power plant of a wholesale power industry are covered by the income from the tariff sold to the Power Network Company with some profit retained. The revenue was 1,083.2 billion ZL, expenses were 902.5 billion ZL, and a profit was 180.7 billion ZL in 1990. The ratio of profit to the total sale was 17%, but this high percentage was thought to be caused tentatively by the interim measure of the review of tariff system through introduction of market principle. It is planned to modify the tariff system after 1991 to squeeze the profit according to the following formula.

Proper profit rate = (total expenses - fuel cost) x 7%

The largest problem with the current tariff system of wholesaling electricity is lack of the system of return for the investment. Since the investments for renewal of facility and environmental measures are possible within the profit in the current tariff system, it is impossible to make a long term borrowing for the large investment. Therefore, the problem with the tariff system is how to make the capital costs (interest and amortization) of proper investment reflected on the tariff on a long-term basis.

(2) Composition of Generating Cost

1) Basic Principle

The tariff of electric power wholesaled from Kozienice Power Station to the Power Network Company covers and includes the following cost. (However, subsidy is provided to the transaction of the Power Network Company as referred to before.)

1. The tariff is divided to the variable cost (kWh portion of tariff) and the fixed cost (kW portion of tariff).

2. The variable cost corresponds to the fuel cost, and it is the sum calculated by multiplying the unit cost per MWh by the amount of energy supplied. As of January, 1991, the fuel cost unit price is set at 116,840 ZL/MWh (1,600 yen/MWh*). As the amount of energy supplied in that month was 816,041 MWh, the variable cost income calculated as follows;

   116,840 ZL/MWh x 816,041 MWh = 95,341 million ZL
   (approximately 1.3 billion yen).

3. The fixed cost consists of other expenses and the sum corresponding to profit. The detail is given below. As of January, 1991, the fixed cost for 8 units of 200 MW units was 35,446 million ZL, and 2 units of 500 MW units was 22,096 ZL, and the total was 57,540 ZL (approximately 800 million yen)

4. The whole wholesale revenue on a kWh basis is calculated as follows;

   152,881 million ZL ÷ 816,041 MWh = 187 ZL/kWh
   (2.25 yen/kWh)

   Payment of the tariff from the power station to the Power Network Company is made as follows;

---

* The calculation was done based on the foreign currency exchange rates of 1 US$ = 9,500 ZL (fixed exchange rate at this time), and 1 US$ = 130 yen (the average exchange rate at this time).

Advanced payment: on 6th day of each month
Settlement of Account: on the last day of each month

2) Actual Composition of Generating Cost (Based on accounting at the end of '90 business year)

1. Fuel Cost

Table for the detailed tariff calculation is formulated by the government based on calorific value, sulphur content and ash content and the coal cost is calculated by this table.

However, it is required to modify the table corresponding to the inflation, and this modification is performed every month in recent years. The trend of correction factors in recent years is given in Table 2.5-10.

According to these modification indices, the tariff in March, '91 is 2.05 time as high as that in June, '90.

The total fuel cost in '90 was 539.4 billion ZL; coal was 398.5 billion ZL, oil 7.4 billion ZL, and transportation 133.4 billion ZL.

The total calorific value of the coal purchased in '90 was 87,070.3 TJ. The average cost of coal per calorific value is 4,557 ZL/TJ. The calorific value per weight was 4,734 kcal/kg (19,819 KJ/kg), which is very low value. According to the above data, the total weight of the coal purchased in '90 was 4.3 million tons, and the unit price per weight of coal purchased in '90, was 90,568 ZL/t (1,240 yen/t).

2. Labor Expense

When we look at the labor expenses in '90, we obtain the following figure.

The total labor cost is 5,357 million ZL, and the labor cost per capita of employee is 1,561 ZL (approximately 210,000 yen). As classified the labor expense in engineers and workers, the engineers earn 17.75 million ZL (approximately 240,000 yen) and workers earn 15.03 ZL (approximately 200,000 yen). Difference between the above two categories is thought to be not so much.

As for the wages of the employees in each job category, the wage of engineer in the operating section is the highest, being 24.19 million ZL (approximately 330,000 yen). The lowest is in the welfare section, where engineers earn 14.44 million ZL (approximately 200,000 yen) and workers earn 10.20 million ZL (approximately 150,000 yen).

The escalation rate of labor cost was 523.2% of the previous year. (3.14 million ZL per person in '89).

The detail of labor costs in '90 in Kozienice Power Station is given in Table 2.5-11.

3) Depreciation Cost

Criteria of depreciation are presented in Table 2.5-12.

4) Repairing Cost

Repairing cost is recovered according to the plan and the actual expenditure.

The expenditure in '90 was 192.7 billion ZL (2.7 billion yen).

In Japan, the repairing cost is approximately 2% of the construction cost depending upon the age of the facility. For example 3 billion yen of the repairing cost for a generating plant of 600 MW scale with the construction cost of approximately

150 billion yen. Compared with the Japanese case, the repairing cost for the power station is thought to be large taking into account the difference of labor cost and price level. This is assumed to be due to the age of the facility, and also to be related to the insufficient investment for renewal of facilities and the low plant capacity factor.

Of the total repairing cost of 192.7 billion ZL, 91.6 billion ZL (48% of the total) is cost for the contracting works, the repairing works considerably depend on outside contractors. The remaining part of the repairing cost is spent inside the Power Station; 63.4 billion ZL (33% of the total), is material costs and 31.3 billion ZL (16% of the total) is labor costs.

Table 2.5-1 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 2.5-2 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 2.5-3 Personnels of Kozienice Power Station

Section	Engineer	Worker	Total
Operation	72	402	474
Repair	215	915	1,130
Research and Development Management	69	225	294
Ash Treatment and Railway	49	550	599
General Affairs	22	56	78
Engineering	16	23	39
Personnel Affairs Training Economic Analysis	23	23	46
Welfare	38	174	212
Accounting	43	0	43
(Sub-Total)	(547)	(2,368)	(2,915)
Heat Supply Section	190	328	518
Total	737	2,696	3,433

Table 2.5-4 Energy Generation and Capacity Factor of Power Station

Year	Energy Generation (MWh)	Capacity Factor (%)
1986	10,127.271	44.4
1987	11,050,941	48.5
1988	9,974,419	43.8
1989	9,920,510	43.6
1990	8,374,632	36.7

Table 2.5-5 Breakdown of Generating Cost

1990 Base		
Fuel Cost	539.3 billion ZL	50%
Material Cost	4.4	
Wage	30.7	3%
Repair Cost	192.7	18%
Depreciation	71.3	7%
Other Production Costs	22	2%
Interest	0	
Other Expenses	43.1	3%
(Total)	(903.5 billion ZL)	
Profit* (20% of the cost)	180.7	17%
Sales Income	1,084.2	

* It is being studied to squeeze the profit to (total cost - fuel cost) x 7%.

Rise of retail price in May and October, 1991 is included in the contract.

Table 2.5-6 Disposition of Profit

		In million ZL	
Total Profit		* 221,667	A
Profit from Power Generation		209,662	
Profit from Heat Supply		12,005	
Un-approved Expenditures		2,426	B
(Promotional expenses and gifts		1,501)	
Income not subjected to Taxation		18,346	C
(Installation of Environmental Equipment		15,558)	
Income subjected to Taxation	A + B - C	205,747	D
Corporate Tax	D x 40%	82,299	
Tax Exemption, etc.		Δ 32	
Corporate Tax Paid		82,266	E
Stock Dividend	8% of Open Stocks (owned by Government)	27,584	F
Tax on Excess Wages		28,714	G
Retained Earnings by Power Station	A-(E+F+G)	83,102	H
Bonus		5,734	I
Contribution to Social Insurance		2,580	J
Contribution to Residence Loan		20,000	K
Contribution to Welfare Loan		7,475	L
(Crew Fund)			
Final Retained Earnings	H-(I+J+K+L)	47,312	
(Company Fund)			

Table 2.5-7 Balance Sheet

(Asset)	(in million ZL)
1. Fixed Assets	2,762,577
Fixed Assets	2,564,267
Investment	197,004
Stocks (Radom Bank)	1,306
2. Liquid Assets	233,589
Cash	31,898
Account Receivable	81,180
Stored Articles	120,511
(Materials)	108,550)
Total	2,996,166

(Liabilities and Capital)	
1. Capital	2,556,566
Open Capital	927,822
Power Statio Capital	1,628,744
2. Liabilities	366,369
Construction Liabilities	260,777
Liquid Liabilities	105,592
3. Reserve, etc.	73,231
Reduction by Financial Operations	▵ 21
Surplus	73,252
Total	2,996,166

Table 2.5-8 Statement of Fixed Asset Depreciation (After Revaluation)

(in million ZL)

	Asset Item	Acquired Value	Depreciation
01	Building	1,136,064	200,479
02	Pipeline	51,562	14,508
03	Water Facility	149,677	31,694
04	Other Buildings	582,416	182,996
05	Boiler	750,789	394,829
06	Turbine	688,198	380,053
07	Others	23,531	3,234
08	Equipments	162,188	145,638
09	Current Switcher	66,133	40,711
10	Current Adjuster	134,056	87,843
11	Transformer	128,011	84,326
12	Others	727,347	495,669
13	Railway	42,117	21,026
14	Other Fixed Assets	12,629	7,626
15	Total Fixed Assets	4,654,900	2,090,633
16	Total Production Facilities	4,497,239	2,067,907
17	Heat Supply Facilities	62,800	12,536
18	Boiler	21,248	1,847
19	Heat Unit	41,552	10,668
20	Substation Facility, 110 kV and above	1,179	-
21	Welfare Facilities	3,551	116
22	Assets not subject to Depreciation	393,044	297,422
23	Assets already depreciated	282,610	282,610
25	Increase in Fixed Asset - Investment Profit	144,251	675
26	Legal Limit of Depreciation		76,198
31	Average Price of Fixed Assets		1,809,473
32	Average Price of depreciated Fixed Assets		1,619,466
33	Average Depreciation Rate		4.20%

Table 2.5-9 Change of Energy Production Costs

No. 1

Period	Cost									単位 100万ZL
	Fuel	Materials	Salaries	Repairing	Depreciation	other Production Costs	Interest	Remaining Costs	Total Cost	
	02	04	05	06	07	08	09	10	01	
1986	13,608	113	663	3,781	1,541	207	127	978	21,018	
1987	19,748	186	751	5,566	1,796	706	59	1,291	30,103	
1988	30,416	256	1,255	9,098	2,579	1,129	25	2,323	47,081	
1989	53,570	591	5,287	32,013	3,448	3,980	――	6,417	105,306	
1990	539,380	4,379	30,701	192,712	71,278	21,989	――	43,106	903,545	
1	47,064	727	1,495	19,018	6,158	2,156	――	4,198	80,816	
2	26,813	597	1,711	19,033	5,498	2,040	――	3,110	58,802	
3	30,275	305	1,818	18,256	5,806	2,081	――	3,735	62,276	
4	35,199	75	1,791	18,261	5,794	2,024	――	2,382	65,526	
5	43,952	259	2,009	18,275	5,796	1,975	――	3,151	75,417	
6	36,056	232	1,980	18,240	5,773	2,020	――	2,695	66,996	
7	33,715	376	2,456	12,247	5,790	2,117	――	3,154	59,855	
8	35,319	374	2,762	11,540	5,816	2,285	――	2,757	60,853	
9	48,189	130	2,674	16,858	5,776	2,248	――	3,587	79,462	
10	75,995	282	2,701	16,832	5,308	2,243	――	4,830	108,191	
11	58,853	440	2,734	16,785	7,830	2,196	――	3,081	91,919	
12	67,950	582	6,570	7,367	5,933	-1,396	――	6,426	93,432	
1991										
1	83,124	596	2,886	35,019	16,605	7,556	――	4,849	150,635	

Change of Energy Production Costs

No. 2

Period		Unitary Energy Cost			Unitary Power Cost	Net Production (MWh)	Fixed Asset
		Fuel	Remaining	Total			
		12	13	11	14	03	11
1986		1,344	731	2,075	3	10,127,271	49,114
1987		1,787	937	2,724	4	11,050,941	49,157
1988		3,049	1,671	4,720	6	9,974,419	100,774
1989		5,400	5,215	10,615	20	9,920,510	100,928
1990		64,406	43,484	107,890	140	8,374,632	1,499,849
	1	50,303	36,075	86,378	13	935,609	1,496,788
	2	51,058	39,086	90,144	12	525,148	1,496,788
	3	50,029	52,880	102,909	12	605,154	1,496,274
	4	52,443	45,184	97,627	12	671,185	1,497,288
	5	59,508	42,601	102,109	12	738,582	1,497,752
	6	64,044	54,956	119,000	12	562,987	1,499,986
	7	64,436	49,959	114,395	10	523,229	1,501,486
	8	68,156	49,273	117,429	10	518,210	1,501,594
	9	73,136	47,463	120,599	12	658,896	1,501,586
	10	70,238	29,758	99,996	12	1,081,958	1,503,626
	11	78,164	43,916	122,080	13	752,941	1,503,977
	12	84,860	31,823	116,683	10	800,733	1,505,520
1991							
	1	101,744	82,633	184,377	26	816,992	4,117,229

Change of Energy Production Costs

No. 3

		Self Cost of Sales			Value of Sales			
		Total	Power	El. Energy	Total	Power	El. Energy	
		12	13	14	15			
1986		21,002	7,404	13,598	21,648	7,698	13,950	
1987		30,081	10,348	19,733	31,347	10,962	20,385	
1988		47,047	16,653	30,394	47,954	16,419	31,535	
1989		105,248	51,712	53,536	110,351	54,550	55,801	
1990		902,882	363,888	538,994	1,083,221	518,948	564,273	
	1	80,809	33,782	47,027	99,787	49,977	49,810	
	2	58,688	31,909	26,779	72,713	44,769	27,944	
	3	62,196	31,957	30,239	76,858	44,653	32,205	
	4	65,470	30,296	35,174	77,342	41,609	35,733	
	5	75,392	31,456	43,936	79,165	34,556	44,609	
	6	66,967	30,933	36,034	67,093	29,942	37,151	
	7	59,826	26,124	33,702	72,255	37,733	34,522	
	8	60,832	25,525	35,307	71,299	37,104	34,195	
	9	79,415	31,252	48,163	88,487	38,500	49,987	
	10	108,123	32,169	75,954	126,067	43,979	82,088	
	11	91,842	33,044	58,798	114,526	46,063	68,463	
	12	93,322	25,441	67,881	137,629	70,063	67,566	
1991								
	1	150,464	67,401	83,063	153,749	58,403	95,346	

Table 2.5-10 Trend of Correction Factors of Coal Charge System Table

90.6 - 90.12	1.55
90.12 - 91. 1	1.20
91. 1 - 91. 2	1.05
91. 2 - 91. 3	1.05

Table 2.5-12 Criteria of Depreciation

(Figures in parentheses are Japanese values)

	Rate of Depreciation	Period of Depreciation
Machinery	5 ~ 6 %	17 ~ 20 years (15 years)
Environmental Equipment	8.5 ~ 10 %	10 ~ 12 years (7 years)
Measuring Instrument	17 ~ 20 %	5 ~ 6 years (7 years)
Building	2.5 %	40 years (30 years)
Foundations (River structures, etc.)	4 %	25 years (50 years)

Table 2.5-11 Labor Costs of Kozienice Power Station (1990)

(Annual Income in 10,000 ZL)

	Engineer			Workers, etc.			Total		
	Number of Personnels	Unit Price	Total	Number of Personnels	Unit Price	Total	Number of Personnels	Unit Price	Total
Operation	71.5	2,419	172,944	402	1,790	719,544	473.5	1,885	892,488
Repair	215	1,755	377,301	914.5	1,499	1,370,946	1,129.5	1,548	1,748,247
Research, Development and Control	69	1,778	122,701	225	1,503	338,210	294	1,567	460,911
Ash Treatment, Railway, etc.	49	1,932	94,684	549.5	1,561	857,800	598.5	1,591	952,484
General Affairs	22	1,594	35,066	56	1,414	79,174	78	1,465	114,240
Engineering	16	1,738	27,807	23	1,658	38,127	39	1,691	65.934
Personnel Affairs/ Training/Economics	23.5	1,699	39,916	22.5	1,165	23,371	46	1,463	67.287
Welfare	38	1,444	54,869	173.5	1,029	178,568	211.5	1,104	233,437
Accounting	43	1,463	62,908				43	1,463	62,908
Heat Supply	190	1,668	316,973	328	1,347	441,907	518	1,465	758,880
Total	737	1,775	1,308,169	2,694	1,503	4,051,648	3,431	1,561	5,356,816

Chapter 3. Descriptions of FGD Project Site

CHAPTER 3 DESCRIPTION OF DeSOx SYSTEM PROJECT SITE

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Chapter 3 Descriptions of DeSOx System Project Site

3.1 Location

The Kozienice Power Plant is located at 51°-40'N and 21°-28'E in Radom Prefecture in southeast of Republic of Poland. It is on the left shore of the Vistula River flowing south to north across Poland and 12 km north of the city of Kozienice.

3.2 Access

The main road No. 723 is running from Warsaw, the capital of Poland, to the Kozienice Power Plant. The distance from Warsaw to Kozienice Power Plant is about 75 km. The road is a two-lane road with good surface condition.

Coal, chemicals and other materials used at the Kozienice Power Plant are being carried to the plant by the railway which was used for carrying materials at construction of the power plant. Railroad tracks lead to appropriate points within the plant site. It is judged that the railway can be used effectively for carrying materials and equipments at construction of the Flue Gas Desulphuriser (FGD). Major ports in Poland are Danzing, Gdynia and Stettin facing on the Baltic Sea.

3.3 Climate

3.3.1 Outline

The weather in Poland is generally unstable under the influence of the oceanic climate of Europe in the west and the continental climate in the east, and is cold except summer. The weather data, attached hereto, are those obtained at the Kozienice Power Plant (temperature and precipitation) and Radom Meteorological Station (wind).

3.3.2 Temperature

According to the weather data of last ten years (1981-1990), the average daily maximum temperature, the average temperature and the average daily minimum temperature are 11.4, 8.0 and 4.6°C, respectively. The average monthly maximum temperature is the highest in August at 22.2°C, and the average monthly minimum temperature is the lowest in January at -4.1°C. The maximum monthly change in the average temperature is 6.1°C. The highest and lowest temperatures in the last ten years were 32.8°C occurring in August and -31.3°C occurring in January, respectively.

The temperature data are shown in Table 3.3-1 and Fig. 3.3-1.

3.3.3 Precipitation

The average annual precipitation in the last ten years is 479 mm. Precipitation is occurring much during the five months from May to September, and relatively less from October to April. The days with precipitation vary through the year, and no specific tendency is present. The maximum daily precipitation in the last ten years is 34.7 mm which occurred in May. The precipitation data are shown in Table 3.3-2 and Fig. 3.3-2.

3.3.4 Wind

The Distribution Diagram of Wind Direction and Speed shown in Fig. 3.3-3 was prepared from weather data obtained at the Radom Meteorological Station. According to the figure, prevailing winds are in the direction of SW-NW. The occurrence of winds below 2.0 m/s and 5.0 m/s is 5 and 89%, respectively. The occurrence of winds of 5.0 m/s and faster is 11%.

A frequency table of wind direction and speed at the Radom Meteorological Station is shown in Table 3.3-3.

Table 3.3-1 Monthly Temperature

MONTHLY AVERAGE TEMPERATURE AT KOZIENICE P.S.

UNIT(°C)

YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	AVERAGE
JAN.	-2.2	-2.3	3.0	0.3	-9.6	-1.6	-12.9	0.7	2.1	1.7	-2.1
FEB.	0.3	-2.6	-2.7	-1.8	-9.7	-9.6	-0.9	0.5	4.1	5.1	-1.7
MAR.	5.5	3.1	3.7	0.7	2.0	1.9	-2.7	0.4	5.3	6.7	2.7
APR.	7.3	4.9	9.2	7.9	7.9	8.5	7.0	6.0	8.6	7.9	7.5
MAY	15.3	13.4	15.4	13.2	14.0	13.2	11.4	13.7	12.8	12.5	13.5
JUNE	18.4	15.1	16.5	14.2	14.2	15.9	15.2	15.6	15.0	16.1	15.6
JUL.	19.6	17.7	18.3	15.3	16.5	17.1	17.6	18.5	17.1	16.3	17.4
AUG.	18.4	18.7	17.6	17.6	18.1	17.2	15.2	17.1	17.4	17.2	17.5
SEPT.	15.7	15.1	14.5	13.8	12.2	11.0	12.4	13.2	14.0	10.9	13.3
OCT.	10.4	8.8	9.2	10.6	8.3	8.0	8.2	7.4	10.5	9.2	9.1
NOV.	4.3	4.9	2.2	2.4	0.5	5.4	4.2	0.0	1.6	4.7	3.0
DEC.	-2.1	1.1	-1.0	-1.4	2.3	-0.4	0.3	1.0	1.5	-0.2	0.1

MONTHLY MAXIMUM TEMPERATURE AT KOZIENICE P.S.

UNIT(°C)

YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	AVERAGE
JAN.	-0.2	-0.3	4.8	2.0	-6.7	0.1	-10.0	2.4	3.7	3.5	-0.1
FEB.	2.3	-0.5	-0.7	-0.1	-6.9	-6.7	1.5	2.1	6.5	7.9	0.5
MAR.	8.4	6.2	6.4	3.8	4.1	5.2	0.3	2.7	8.8	10.3	5.6
APR.	11.3	8.6	13.9	12.3	12.0	12.9	10.2	11.1	12.3	12.3	11.7
MAY	19.7	18.3	20.4	17.4	19.0	18.3	15.8	19.0	17.8	18.3	18.4
JUNE	22.3	19.6	21.4	17.3	17.3	20.8	19.7	19.7	19.3	21.4	19.9
JUL.	24.2	22.6	23.0	18.9	20.5	21.7	22.2	23.1	22.2	19.9	21.8
AUG.	22.6	24.0	23.4	23.1	22.5	21.4	19.2	21.6	22.2	22.4	22.2
SEPT.	19.8	20.3	18.4	16.6	15.7	14.0	16.5	16.8	18.5	13.8	17.0
OCT.	13.1	12.8	12.5	13.8	11.0	12.3	12.2	12.3	13.4	13.9	12.7
NOV.	5.9	7.6	4.3	5.2	2.2	7.9	5.9	2.4	3.6	6.4	5.1
DEC.	0.0	2.5	1.3	0.1	4.1	1.3	1.8	2.5	3.3	1.2	1.8

MONTHLY MINIMUM TEMPERATURE AT KOZIENICE P.S.

UNIT(°C)

YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	AVERAGE
JAN.	-4.3	-4.4	1.3	-1.3	-12.6	-3.2	-15.9	-1.0	0.5	-0.2	-4.1
FEB.	-1.8	-4.7	-4.6	-3.6	-12.5	-12.5	-3.3	-1.1	1.7	2.3	-4.0
MAR.	2.5	0.0	1.1	-2.4	-0.2	-1.4	-5.7	-1.9	1.8	3.2	-0.3
APR.	3.3	1.1	4.6	3.5	3.8	4.1	3.8	1.0	4.9	3.5	3.4
MAY	11.0	8.5	10.5	9.0	9.0	8.1	7.0	8.4	7.8	6.8	8.6
JUNE	14.5	10.6	11.7	11.2	11.1	10.9	10.8	11.5	10.8	10.8	11.4
JUL.	14.9	12.8	13.5	11.7	12.4	12.4	13.0	13.8	12.0	12.7	12.9
AUG.	14.2	13.5	11.8	12.2	13.7	13.1	11.2	12.5	12.7	12.1	12.7
SEPT.	11.6	9.8	10.7	11.0	8.8	8.0	8.4	9.7	9.5	8.1	9.5
OCT.	7.6	4.9	6.0	7.4	5.5	3.6	4.2	2.5	7.7	4.6	5.4
NOV.	2.7	2.2	0.1	-0.4	-1.3	3.0	2.5	-2.3	-0.5	3.1	0.9
DEC.	-4.3	-0.3	-3.3	-2.9	0.4	-2.1	-1.1	-0.6	-0.2	-1.5	-1.6

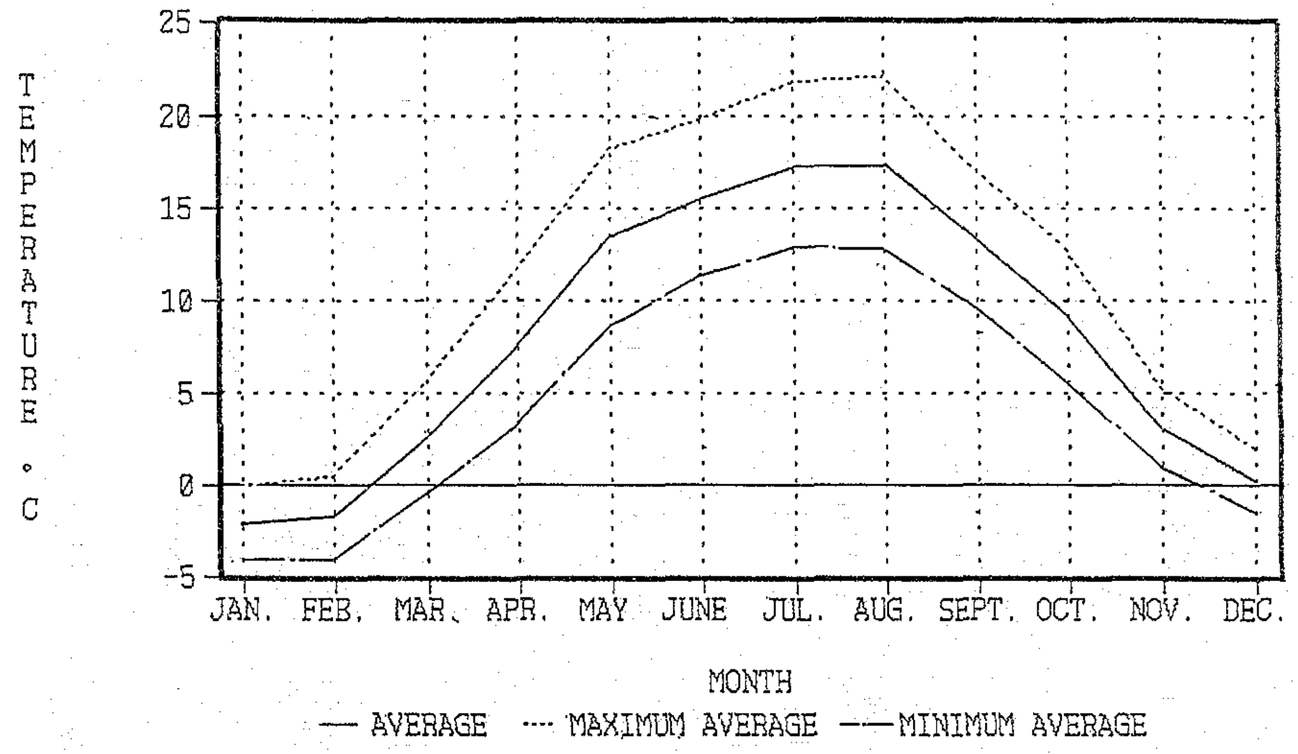


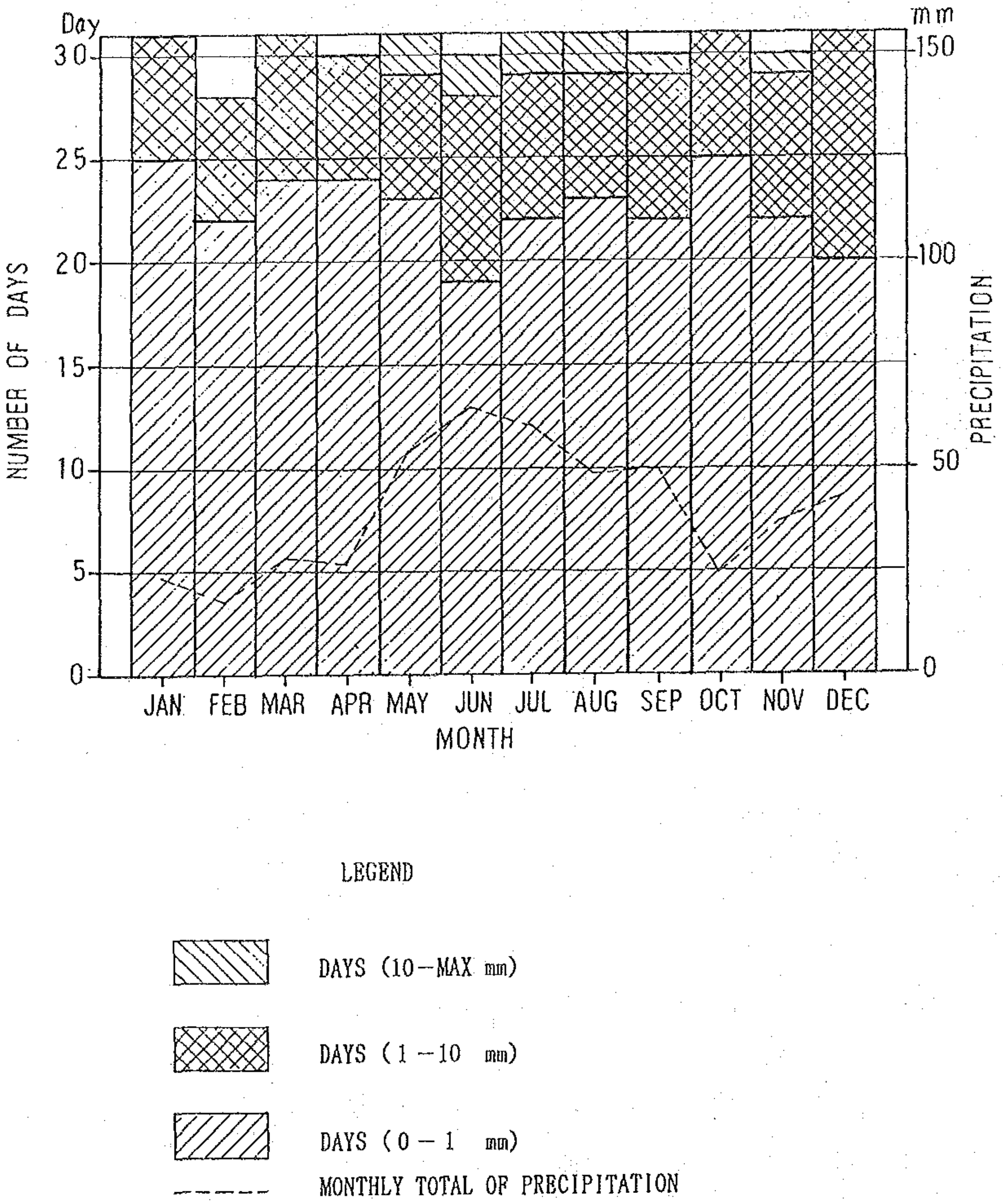
Fig. 3.3-1 MONTHLY TEMPERATURE AT COZIENICE P.S FROM 1981 TO 1990

Table 3.3-2 Monthly Rainfall at KOZIENICE P.P.

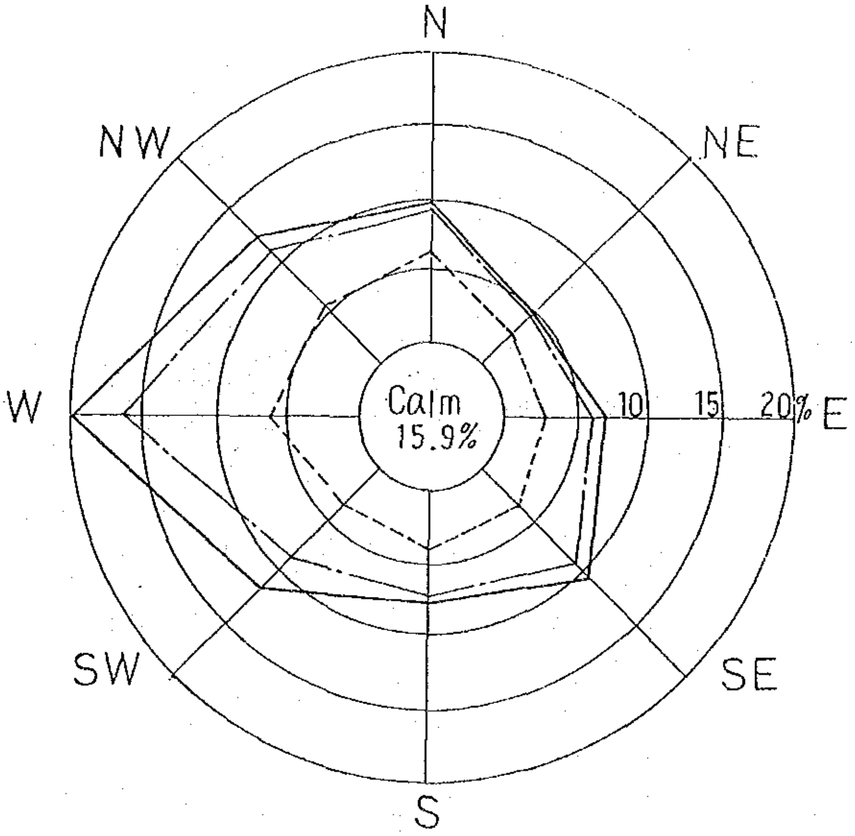
(unit : mm)

Month / Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1981	24.8	12.7	35.4	9.3	54.0	79.8	43.1	62.3	47.7	50.7	50.8	53.6	524.2
1982	26.1	7.8	6.9	28.0	39.1	42.2	38.2	41.6	26.5	56.1	23.2	75.7	411.4
1983	43.3	23.2	47.5	40.7	91.0	32.7	56.1	30.1	42.8	18.5	21.9	34.0	481.8
1984	29.8	9.5	22.4	4.9	92.1	72.5	67.0	18.3	60.8	18.8	24.5	12.4	433.0
1985	18.0	24.1	28.3	30.5	45.4	104.0	64.0	62.7	39.2	18.8	19.4	68.9	523.3
1986	35.6	5.3	11.7	25.2	60.8	40.4	69.5	68.7	62.9	29.9	19.6	26.8	456.4
1987	21.6	11.6	37.5	35.0	55.4	86.0	50.7	64.0	40.6	19.8	37.5	61.7	521.4
1988	21.0	42.1	30.2	8.3	53.0	57.0	77.7	59.7	31.2	5.9	54.6	50.4	491.1
1989	11.2	24.1	26.5	37.2	34.9	99.1	58.6	34.9	41.9	17.7	61.7	24.6	472.4
1990	6.0	16.3	34.6	48.0	13.4	35.8	77.5	46.5	106.3	9.6	55.7	21.7	471.4
Total	237.4	176.7	281.0	267.1	539.1	649.5	602.4	488.8	499.9	245.8	368.9	429.8	4,786.4
Average	23.7	17.7	28.1	26.7	53.9	64.9	60.2	48.9	50.0	24.6	36.9	43.0	478.6

Fig. 3.3-2 Precipitation and days



RADOM Meteorological Station



LEGEND

Center	0.0−0.09m/s
————————	0.1−Max m/s
———·———	0.1−4.9 m/s
--------	0.1−1.9 m/s

Fig.3.3-3 Distribution Diagram of Wind Direction and Speed

Table 3.3-3　Anual Percentage Distribution of Wind Direction and Speed

(RADOM Meteorological Station)

(unit : %)

Speed (m/s) \ Direction	N	NE	E	SE	S	SW	W	NW	C	Total
0.1 ～ 1.9	6.3	2.9	2.8	3.6	4.0	3.5	6.2	5.6		34.9
0.1 ～ 4.9	9.4	4.7	6.1	9.3	7.2	8.8	16.3	11.2		73.0
0.1 ～ Max.	9.9	4.9	7.0	10.5	7.7	11.8	19.8	12.5		84.1
Total	9.9	4.9	7.0	10.5	7.7	11.8	19.8	12.5	15.9	100.0

3.4 Topography

The Kozienice Power Plant and its surrounding are part of a vast flat area, of 105 to 110 m above sea level, facing the Vistula River.

The areas around the power plant are planted with pine trees, and vegetables are grown in surrounding farms.

In addition to rail tracks for carrying materials necessary for operation and maintenance of the power plant, power cables, water supply and discharge pipes and other utility facilities are existing overhead or underground the FGD project site between the powerhouse and the coal yard. Furthermore, the power transmission line from the roof of the powerhouse to the switchyard is passing above the FGD project site.

A topographical map of the area and a power plant layout are shown in Figs. 3.3-4 and 3.3-5, respectively.

3.5 Geology

According to the results of structure drillings conducted in the past, the geology of the site of the Kozienice Power Plant consists of sand and gravel soil of river accumulation from quaternary period and an underlying tertiary strata compounded by sand, lignite, clay and varwed clay. The depth of quaternary strata amounts to approx. 20m.

Soil profile roughly indicate a fine sand layer, medium grained sand layer, coarse grained sand layer and gravel sand layer in that order from surface, and the Plant's Main Building is constructed on the medium and coarse grained sand layers as its supporting base.

The natural underground water level around the Kozienice Power Plant used to depend on the water level of the Vistula River, and it is being affected much by the Main Building drainage system.

Structure drillings spacing, of which data have been obtained, is as shown in Fig. 3.5-1. The data are insufficient for the planned FGD project site, and additional structure drillings are necessary at the stage of working for execution.

Structure drillings spacing and soil profiles are shown in Fig. 3.5-1. In addition, data of laboratory test are given in Table 3.5-1.

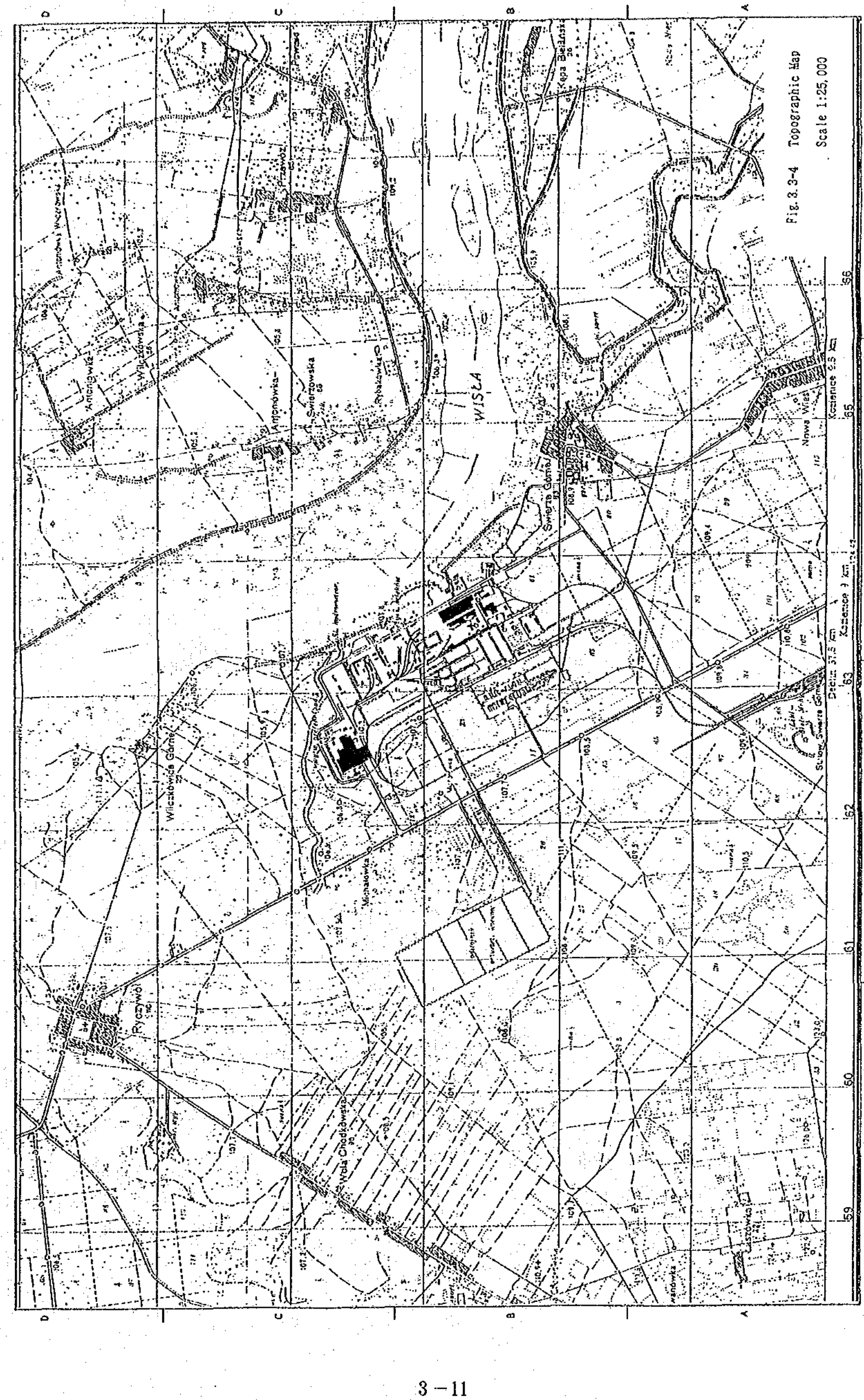


Fig. 3.3-4 Topographic Map
Scale 1:25,000

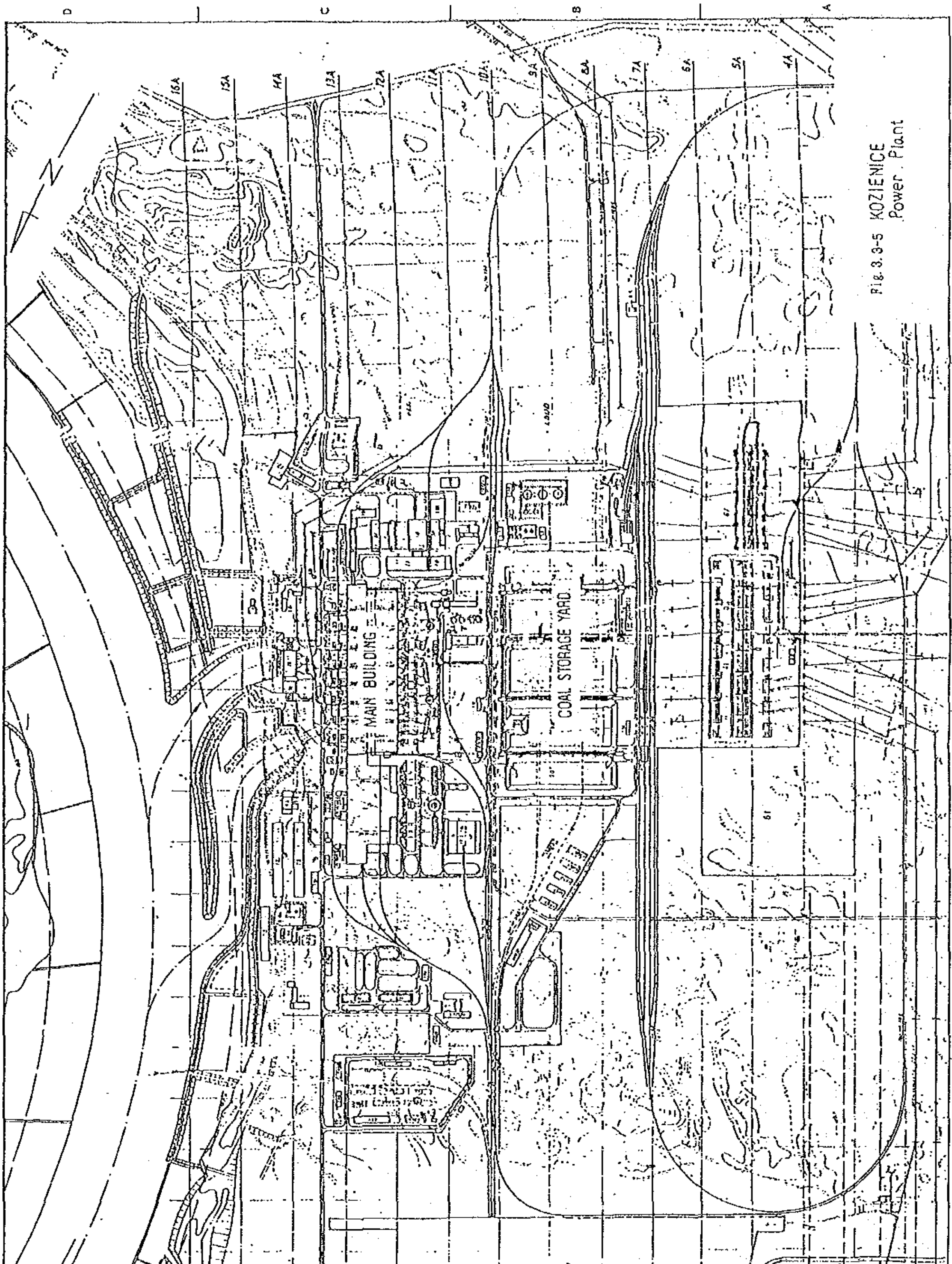


Fig.3.3-5 KOZIENICE Power Plant

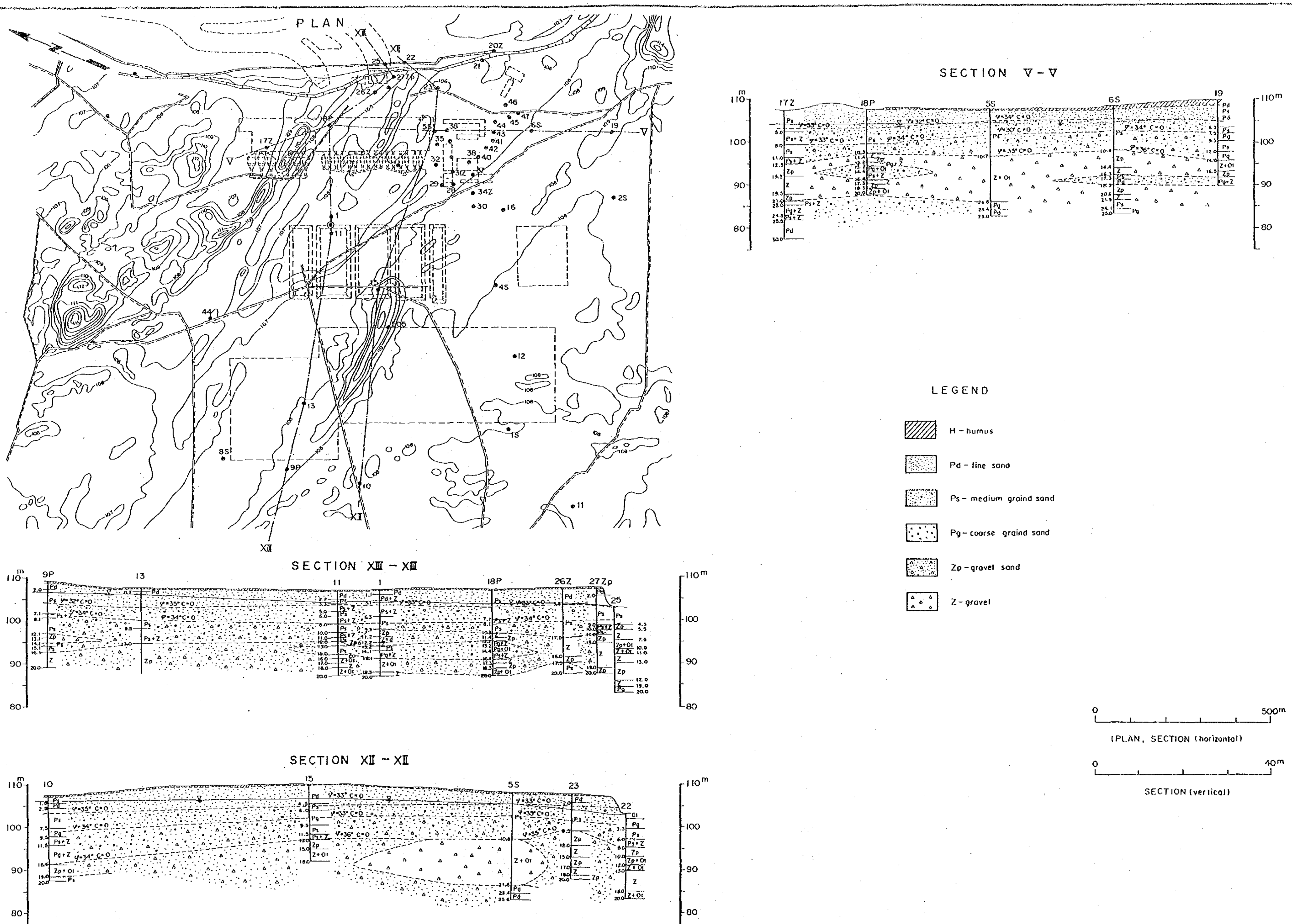


Fig. 3.5-1 Sketch of structure drillings spacing and soil profiles

Table 3.5-1 Data of Laboratory Test

Item	Unit	Range of Measured Values	Average Value
I. Geophisical Behaviours of the Sandy Soil			
1. Angle of internal friction	-	30° ~ 35°	34°
2. Cohesion	MPa		0°
3. Bulk density	t/m^3	1.46 ~ 1.99	1.73
4. Original bulk modulus	MPa	13.0 ~ 17.0	14.0
5. Secondary bulk modulus	MPa	19.5 ~ 24.0	24.0
6. Filtration coefficient	m/24 hours	17 ~ 30	25
II. Geophisical Behaviours of the Gravel Soil			
1. Angle of internal friction	-	34° ~ 37°	35°
2. Bulk density	t/m^3	1.67 ~ 2.26	1.92
3. Filtration coefficient	m/24 hours	25 ~ 45	35

Chapter 4. Selection of the Optimum DeSOx System

CHAPTER 4 SELECTION OF THE OPTIMUM DeSOx SYSTEM

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Chapter 4 Selection of the Optimum DeSOx System

4.1 Emission Standards Applied to the Kozienice Power Station

Emission Standards and Ambient Air Quality Standards in Poland are legislated in 1990 in which regulations are designated according to kinds of fuel used and firing method as shown in Table 4.1-1.

Emission Standards are classified into existing plants and newly built plants and Ambient Air Quality Standards are classified into general area and special protected area. These Standards will be regulated more stringently from the beginning of 1998.

Moreover, local authorities of Poland are allowed to set stricter regulation than figures set by the Central Government in order to preserve ambient air quality in local area.

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 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 as shown in Attachment 4.1-1.

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 in order to reduce the SOx emission to the target value requires studies of the selection of the optimum DeSOx system from various kinds of DeSOx system and combination of the power generation plants and installed DeSOx units including numbers and capacity of the DeSOx plants.

Therefore, the selection of the optimum DeSOx system will be done according to the following manner.

(1) Selection of possible DeSOx system for the Kozienice power station and general technical comparison of each system.

(2) Determination of conditions for the study of combination of the power plants and installed DeSOx plants, and of the selection of the optimum DeSOx system.

(3) The study of the combination of the power plants and installed DeSOx system according to conditions determined in item (2).

(4) Based on the optimum combination determined in item (3). case studies on selected DeSOx systems in item (1) will be made and overall technical and economical evaluation is to be carried out on selected DeSOx systems referring to the general technical evaluation done in item.

(5) Finally, the optimum DeSOx system for the power plants will be selected according to the studies of the above.

In Fig. 4.1-1, a flow chart of this procedure is shown.

Table 4.1-1 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 lignite coal.				• In column for SOx, figures of upper side show values valid by the end of 1997, and bottom side show from 1998.					

Agreement on Pollutants Emission Between Radom Prefecture and Kozienice Power Plant

Decision

By the Radom Prefecture concerning the protection of air against pollution.

I. This decision determines the type and amount of pollutants that can be introduced into the air by the Kozienice Power Plant. This decision is valid until December 31, 1997.

1. Pollutants introduced into the air from individual power generating units and from stack No. 1 shall not exceed the following values:

a) Boiler OP - 650 - Unit No. 1 - 200 MW

	Maximum [kg/h]	Annual [t/year]
- Sulphur dioxide	1,119	5,550
- Nitrogen dioxide	512	3,102
- Dust	514	3,115
- Carbon oxide	228	1,382

b) Boiler OP - 650 - Unit No. 2 - 200 MW

[Values same as above]

c) Boiler OP - 650 - Unit No. 3 - 200 MW

[Values same as above]

d) The total amount of pollutants introduced into the air by stack No. 1 (height 200 meters, outlet diameter 6.7 m) shall be as follows:

	Maximum [kg/h]	Annual [t/year]
- Sulphur dioxide	3,357	16,650
- Nitrogen dioxide	1,536	9,306
- Dust	1,542	9,345
- Carbon oxide	684	4,146

2. Pollutants introduced into the air from individual power generating units and from stack No. 2 shall not exceed the following values:

a) Boiler OS-650 - Unit No. 4 - 200 MW

	Maximum [kg/h]	Annual [t/year]
- Sulphur dioxide	1,119	5,550
- Nitrogen dioxide	512	3,102
- Dust	514	3,115
- Carbon oxide	228	1,382

b) Boiler OS-650 - Unit No. 5 - 200 MW

[Values same as above]

c) Boiler OS-650 - Unit No. 6 - 200 MW

[Values same as above]

d) Boiler OS-650 - Unit No. 7 - 200 MW

[Values same as above]

e) Boiler OS-650 - Unit No. 8 - 200 MW

[Values same as above]

f) The total amount of pollutants introduced into the air by stack No. 2 (height 200 m, outlet diameter 7.9 m) shall be as follows:

	Maximum [kg/h]	Annual [t/year]
- Sulphur dioxide	5,595	27,750
- Nitrogen dioxide	2,560	15,510
- Dust	2,570	15,575
- Carbon oxide	1,140	6,910

3. Pollutants introduced into the air from individual power generating units connected to stack No. 3 shall not exceed the following values:

a) Boiler AP - 1650 - Unit No. 9 - 500 MW

	Maximum [kg/h]	Annual [t/year]
- Sulphur dioxide	2,851	9,050
- Nitrogen dioxide	1,149	4,457
- Dust	1,310	5,082
- Carbon Oxide	581	2,254

b) Boiler AP - 1650 - Unit No. 10 - 500 MW

[Values same as above]

c) The total amount of pollutants introduced into the air by stack No. 3 (height 300 m, outlet diameter 9.3 m) shall be as follows:

	Maximum [kg/h]	Annual [t/year]
- Sulphur dioxide	5,702	18,100
- Nitrogen dioxide	2,298	8,914
- Dust	2,620	10,164
- Carbon oxide	1,162	4,508

4. The following emission values will be applicable to the Kozienice Power Plant until December 31, 1997.

	Maximum [kg/h]	Annual [t/year]
- Sulphur dioxide	14,654	62,500
- Nitrogen dioxide	6,394	33,730
- Dust	6,732	35,084
- Carbon oxide	2,986	15,564

5. The following amounts of pollutants generated in the process of fuel combustion are permitted:

a) Boiler OP - 650

- Sulphur dioxide	566 g/GJ
- Nitrogen dioxide	259 g/GJ
- Dust	260 g/GJ

b) Boiler AP - 1650

- Sulphur dioxide	566 g/GJ
- Nitrogen dioxide	228 g/GJ
- Dust	260 g/GJ

II. The following emission values shall be applicable to the Kozienice Power Plant after January 1, 1998

- Sulphur dioxide	7,995 kg/h
- Nitrogen dioxide	4,402 kg/h
- Carbon oxide	2,986 kg/h
- Dust	3,366 kg/h

III. The Kozienice Power Plant is obliged to:

1. Install a desulphurisation system by December 31, 1997

2. Complete modernization of power generating equipment by December 31, 1997 (in order to meet dust and nitrogen dioxide emission standards which come in force on January 1, 1998)

3. Submit to the Radom Prefecture a schedule of activities aimed at dust and nitrogen dioxide reduction. This schedule should be submitted by June 30, 1992.

IV. The Radom Prefecture reserves the right to impose on the Kozienice Power Plant other obligations concerned with air protection.

V. The permissible pollution values specified in part II of this decision shall be binding for the Kozienice Power Plant until December 31, 1999.

Rationale

An analysis of air pollution conducted by Energoprojekt on the basis of coal parameters and ESP efficiency (97.5%) showed that the permissible sulphur dioxide emission values are dramatically exceeded on a large area.

Nitrogen dioxide emission values are exceeded by at least 30% on specially protected areas.

Consequently, further analyses were carried out in order to establish emission values which do not exceed allowable concentration levels.

The total amount of pollution after 1998 must not exceed the following values:

- sulphur dioxide	7,995 kg/h
- Nitrogen dioxide	4,402 kg/h
- Dust	3,366 kg/h

These values imply that the present emission levels should be reduced by:

- 70% in the case of sulphur dioxide
- approximately 45% in the case of nitrogen dioxide
- approximately 55% in the case of dust

The order to achieve these valuer it will be necessary to modernize boilers (mill-furnace systems) and electrostatic precipitators, as well as to install a DeSOx system.

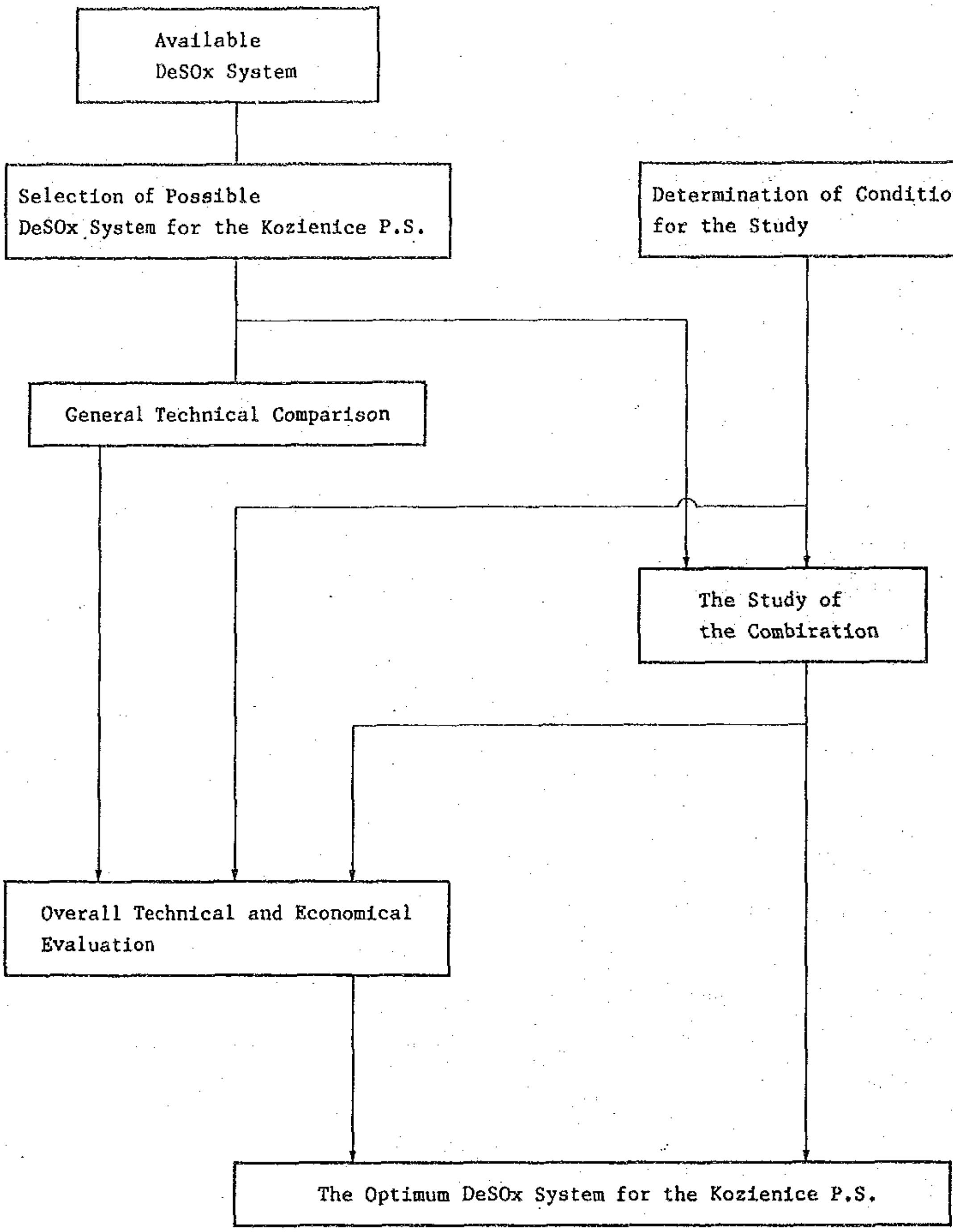


Fig.4.1-1 SELECTION FLOW OF THE OPTIMUM DeSOx SYSTEM

4.2 Selection and Technical Comparison of FGD Methods to be Evaluated

4.2.1 Selection of FGD Methods to be Evaluated

A large variety of FGD methods are being used, but many of them are similar in their principles. Such methods are categorized also in a variety of ways, but they are generally categorized into wet, semi-dry and dry methods depending on the use of water in their absorption process. FGD methods classified in such manners are shown in Fig. 4.2-1.

Judging from the current trends of FGD technologies in the world, the limestone method, where limestone slurry is used as the absorbent, is popular among the wet methods, and being employed at many utility plants.

The spraydryer method corresponds to the semi-dry method. This method has not been employed in Japan at coal fired power plants although it has been employed at many plants in Europe and the USA.

Among the dry methods, the activated carbon method which uses activated carbon as absorbent, the coal ash using method which partly uses coal ash as absorbent, and the simplified FGD method where absorbent is blown into the furnace or duct have been employed at utility plants, and more data are getting to be available.

From such wet, semi-dry and dry FGD methods, the following seven methods were selected, based on their experience at coal fired utility power plants, development status etc., as methods which can be applicable to 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 method>

(4) Activated carbon method
(5) Coal ash using method
(6) Simplified FGD method - Dry absorbent injection into furnace method
(7) Simple FGD method - Dry absorbent injection into duct method

These selected seven methods are outlined and their technologies are compared generally below. In Section 4.5, in addition, their technologies and economy are compared in considerations of conditions specific to the Kozienice Power Plant, and a method most appropriate for the Kozienice Power Plant is selected from the seven methods.

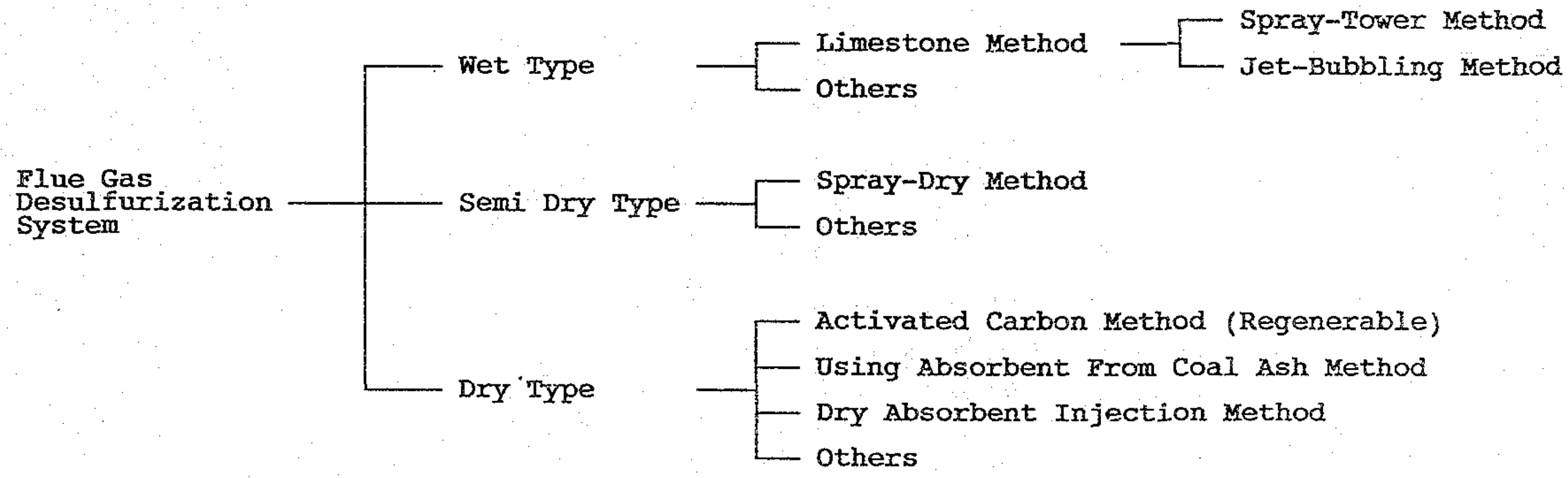


Fig. 4.2-1 FLUE GAS DESULFURIZATION SYSTEM

4.2.2 Technical Comparison of Evaluated FGD Methods

The following technical items, which are considered important, are described for each evaluated FGD method for general comparison:

(1) Basic principles of the process
(2) Reactions
(3) Desulphurisation performance
(4) Dust removal performance
(5) Technical levels
(6) Experience at utility plants
(7) Reliability
(8) Byproducts
(9) Utilities
(10) Waste water
(11) Stack lining and Exhaust gas reheating
(12) Operability
(13) Maintenability

Table 4.2-1 shows results of general technical comparison of the FGD methods evaluated in this study.

In addition, basic processes of such FGD methods are outlined in pages which follow.

(1) Wet type limestone-gypsum method - Spray tower method

Limestone ($CaCO_3$) slurry is sprayed to flue gas in a spray tower to absorb sulphur oxides (SOx) of the flue gas for desulphurisation. The limestone slurry thus sprayed reacts with absorbed sulphur oxides and forms calcium sulphite ($CaSO_3$). Calcium sulphite thus formed is oxidized further and discharged in the form of gypsum ($CaSO_4$).

Major reactions which occur in this method are as follows:

[Absorption]

$$CaCO3 + SO2 + \frac{1}{2}H_2O \rightarrow CaSO_3 \cdot \frac{1}{2}H_2O + CO_2$$

[Oxidation]

$$CaSO_3 \cdot \frac{1}{2}H_2O + \frac{1}{2}O_2 + 1\frac{1}{2}H_2O \rightarrow CaSO_4 \cdot 2H_2O$$

The flow of these reactions is shown in Fig. 4.2-2.

The process flow of this method is shown in Fig. 4.2-3. This method consists of a draft system, a limestone slurry preparation system, an absorbing system, a gypsum recovery system, etc.

a. Draft system

The flue gas from boiler is pressurized by a boost-up fan (BUF), subjected to heat exchange at a gas-gas heater (GGH) with treated gas from FGD outlet, and enters the spraying absorber. Here, the flue gas temperature is lowered to the saturation temperature by spraying part of the absorber circulating liquid. The cooled flue gas is then uniformly dispersed and rectified in the absorber, comes into contact, face to face, with slurry at the absorbing portion, where sulphur oxides in the flue gas are absorbed and dust in the flue gas is removed by the scrubbing in the absorber.

After the desulphurisation, mist included in the flue gas are removed at the mist eliminator which is existing at the upper part of the spraying tower.

After removal of sulphur oxides and dust, the treated flue gas is led again to the gas-gas heater, where it is heated by flue gas from boiler, and then discharged from the stack.

b. Limestone slurry preparation system

Limestone (powder), used as absorbent is stored in a limestone powder silo. The limestone powder is fed to a limestone slurry tank through a limestone metering feeder. Water is also added to the limestone slurry tank at a specified rate. Limestone powder and water are made into limestone slurry, and the limestone slurry is kept in the limestone slurry tank. Necessary amounts of limestone slurry are pumped from the tank by limestone slurry pumps to a circulation tanks existing at the bottom of the absorber. Waste water of gypsum dehydration is usually used for preparing the limestone slurry.

c. Absorbing system

The absorbing system, where the mixed slurry of limestone and reaction products is sprayed in the absorber, is the most important system on the desulphurisation and the dust removal efficiency of the FGD. The mixed slurry sprayed in the absorber falls while absorbing and removing sulphur oxides and dust of the flue gas and the slurry is stored in the circulation tank existing at the bottom of the absorber. Limestone slurry is added to the tank to maintain the desulphurisation performance of the mixed slurry, and the mixed slurry is sprayed again in the absorber tower for desulphurisation. The air is blown into the absorber circulation tank to oxidize calcium sulphite into gypsum (calcium sulphate).

d. Gypsum recovery system

When gypsum is to be recovered as a byproduct, the gypsum slurry from the absorption system is dehydrated by dehydrators to obtain gypsum in this system. Waste water from dehydrators is usually used again as make-up water for the desulphurization process.

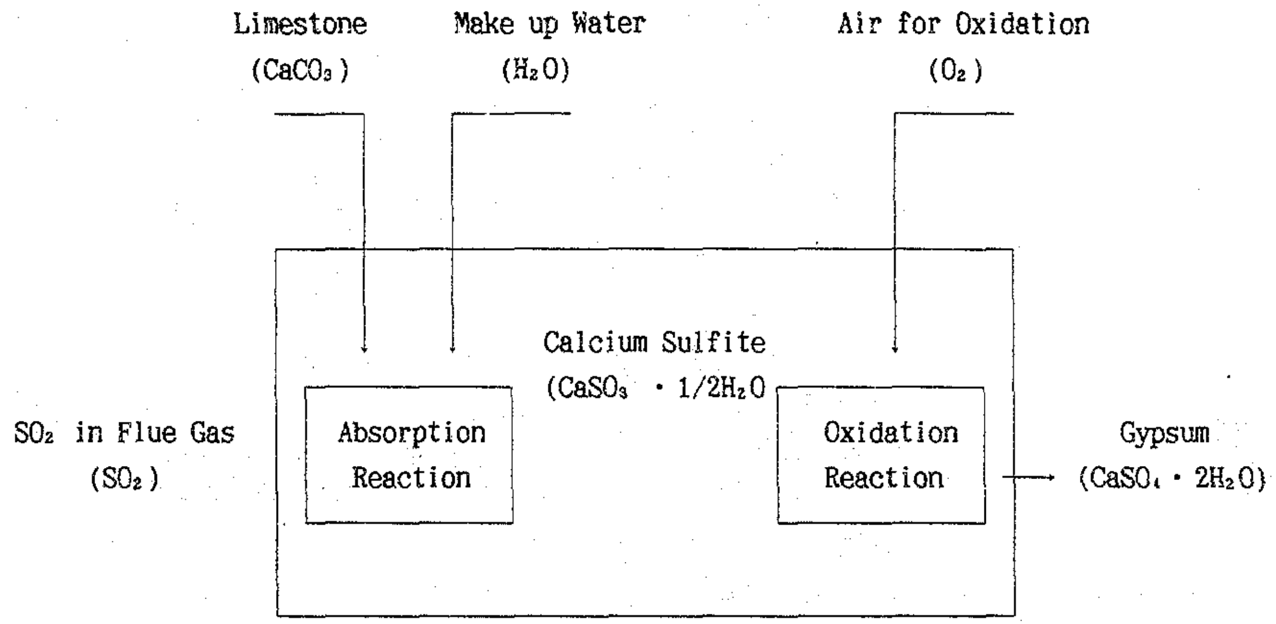
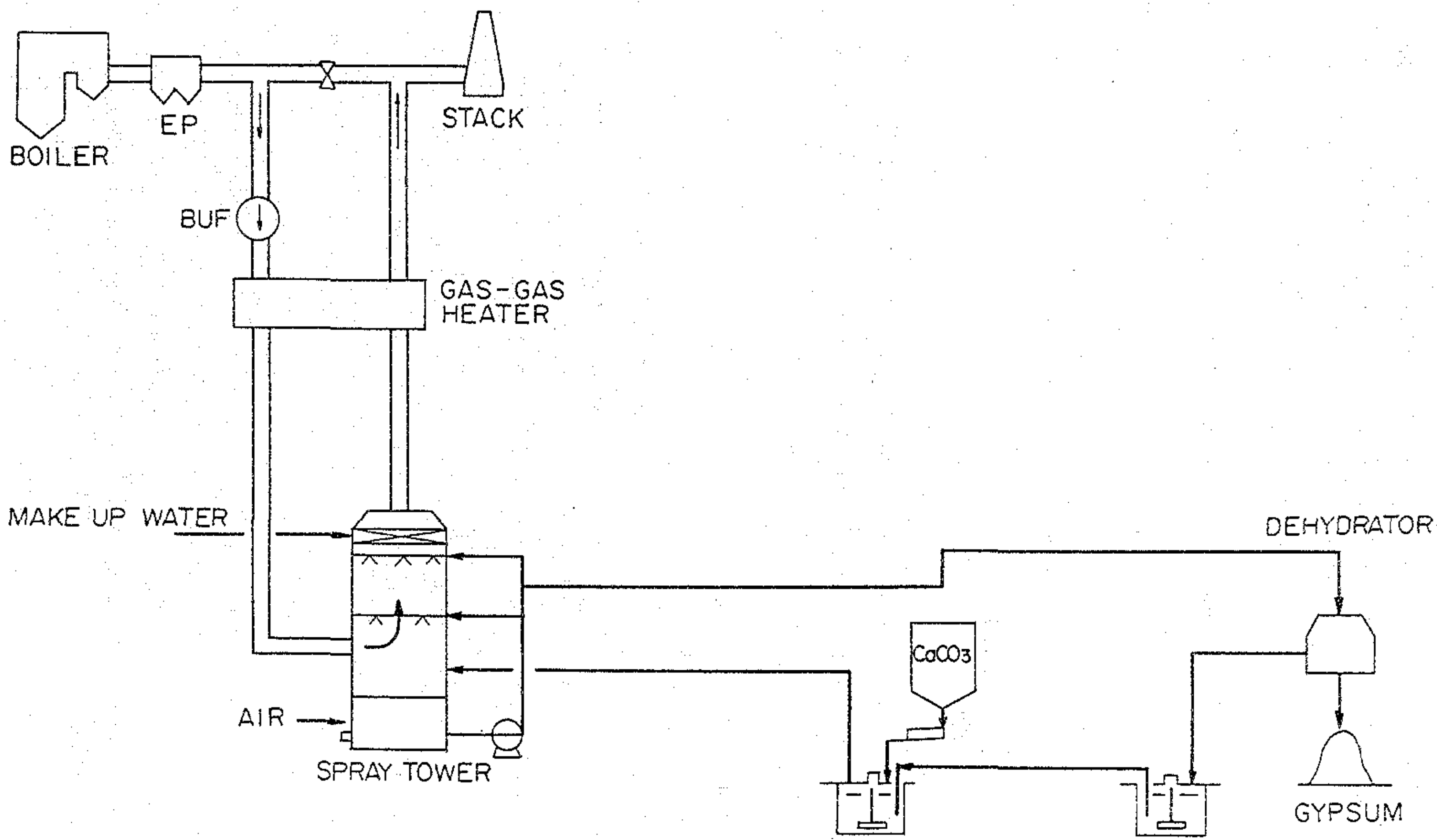


Fig. 4.2-2 Reaction Scheme of Wet Limestone - Gypsum Process
(Spray Tower Method)



PROCESS FLOW OF WET LIMESTONE-GYPSUM PROCESS
(SPRAY TOWER METHOD)

Fig. 4.2 − 3

(2) Wet type limestone gypsum method - Jet bubbling method

In this method, the flue gas and the air for oxidation are blown into an absorption liquid of limestone slurry in a jet bubbling reactor (JBR). Sulphur oxides included in flue gas are absorbed and oxidized in this way, and gypsum is recovered as a by-product.

The major reaction which occurs in this method is as follows:

[Absorption and oxidation]

$$SO_2 + CaCO_3 + \frac{1}{2}O_2 + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O + CO_2$$

The flow of this reaction is shown in Fig. 4.2-4.

The process flow of this method is shown in Fig. 4.2-5. This method consists of a draft system, an absorbing system, a limestone slurry preparation system, a gypsum recovery system, etc.

a. Draft and absorbing system

The flue gas from boiler is pressurized by a boost-up fan (BUF), subjected to heat exchange at a gas-gas heater (GGH) with treated gas from FGD outlet, and part of the makeup water is sprayed to lower the flue gas temperature to the saturation temperature.

The flue gas of saturation temperature is led to the JBR and blown into the absorption liquid through sparger pipes, and sulphur oxides and dust are absorbed and removed from the flue gas.

Mists included in the flue gas at desulphurisation are removed at a subsequent mist eliminator. After desulphurisation and dust removal, the treated flue gas is led again to the gas-gas heater, where it is heated by flue gas from boiler, and then discharged from the stack.

b. Limestone slurry preparation system

Limestone (powder), used as absorbent is stored in a limestone powder silo. The limestone powder is fed to a limestone slurry tank through a limestone metering feeder. Water is also added to the limestone slurry tank at a specified rate. Limestone powder and water are made into limestone slurry, and the limestone slurry is kept in the limestone slurry tank. Necessary amounts of limestone slurry are pumped by limestone slurry pumps and fed to the JBR. Usually, waste water of gypsum dehydration is used as water for making the limestone slurry.

c. Gypsum recovery system

When gypsum is to be recovered as a byproduct, the gypsum slurry from the JBR is dehydrated by dehydrators to obtain gypsum in this system. Waste water from dehydrators is usually used again as make-up water for the desulphurisation process.

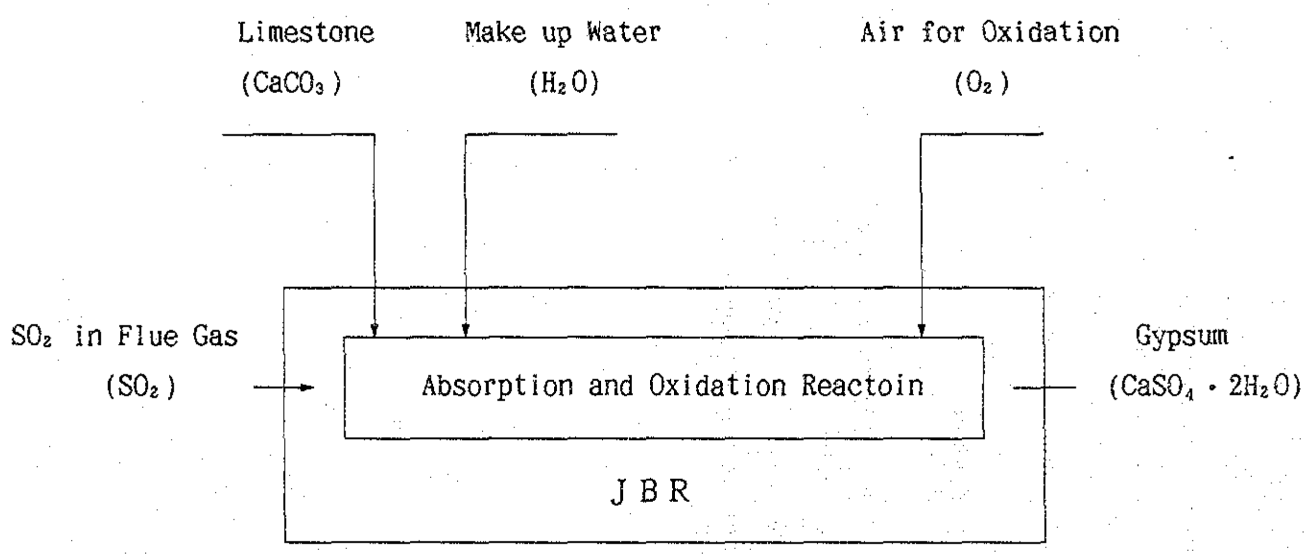
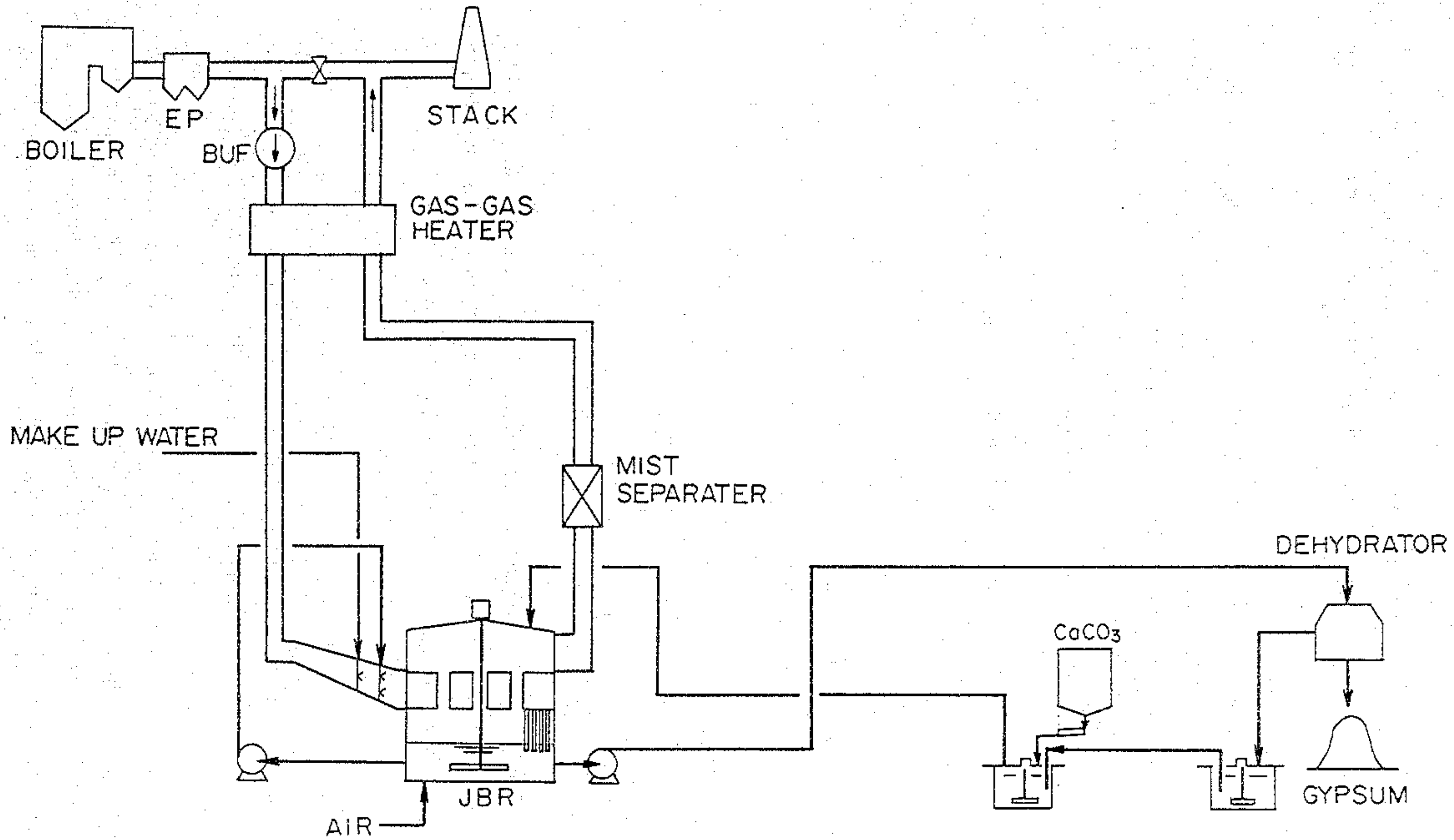


Fig. 4.2-4 Reaction Scheme of Wet Limestone - Gypsum Process (Jet - Bubbling Method)



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

Fig. 4.2 - 5

(3) Spray dryer method

In the spray dryer method, slaked lime slurry is sprayed in the form of very fine droplet in flue gas in a spray dryer absorber (SDA) to absorb sulphur oxides of the flue gas.

Water in the slurry evaporates by the heat of the hot flue gas. Sulphur oxides in flue gas reacts, at the same time, with slaked lime ($Ca(OH)_2$) of the slurry, resulting a dry powder mixture of calcium sulphite ($CaSO_3$) and gypsum ($CaSO_4$), which falls on the bottom of SDA or is collected and removed by a subsequent dust collector.

Major reactions which occur in this method are as follows:

[Absorption]

$$Ca(OH)_2 + SO_2 + \frac{1}{2}H_2O \rightarrow CaSO_3 \cdot \frac{1}{2}H_2O + H_2O$$

[Oxidation]

$$CaSO_3 \cdot \frac{1}{2}H_2O + \frac{1}{2}O_2 + 1\frac{1}{2}H_2O \rightarrow CaSO_4 \cdot 2H_2O$$

The flow of these reactions is shown in Fig. 4.2-6.

The process flow of this method is shown in Fig. 4.2-7. This method consists of a draft system, a slaked lime slurry preparation system, a slurry spraying system, a dust recirculation system, etc.

a. Draft system

The flue gas from boiler is led to SDA usually by an induced draft fan (IDF). The absorbent is sprayed in the SDA and sulphur oxides are removed. The temperature of the flue gas in the SDA is adjusted to an optimal operating temperature range by the amount of concentration-adjusted slaked lime slurry sprayed in the SDA. The temperature of flue gas for optimal operation is controlled to be higher than the saturation temperature by 10 to

20°C so that the flue gas can be in a dry state. The reaction products generated in the flue gas are partly removed by the cyclone separation effect of the SDA. The rest of the reaction products is carried to a subsequent dust collector, where the dust including the reaction products are removed to achieve a level of concentration which meets regulations, and the treated flue gas is discharged from the stack.

b. Slaked lime slurry preparation system

Slaked lime or quick lime, used as absorbent, is stored in a storage silo, and fed to a slaked lime slurry tank through a slaked lime metering feeder. Water is also added to the tank at a specified rate to make supplied slaked lime into slurry and store it in the slurry form.

c. Slurry spraying system

The slurry spraying system sprays the absorbent slurry in the SDA. The absorbent slurry is a mixture of the slaked lime slurry and part of the reaction products fallen to the bottom of the SDA and collected at the subsequent dust collector.

The absorbent slurry must be sprayed in the form of very fine droplet, and rotary atomizers are used for that purpose in large scale systems.

d. Dust recirculation system

The dust recirculation system removes the reaction products fallen to the bottom of the SDA and collected at the subsequent dust collector, and recirculates part of the reaction products to the absorbent slurry to improve the utilization rate of slaked lime used in the method.

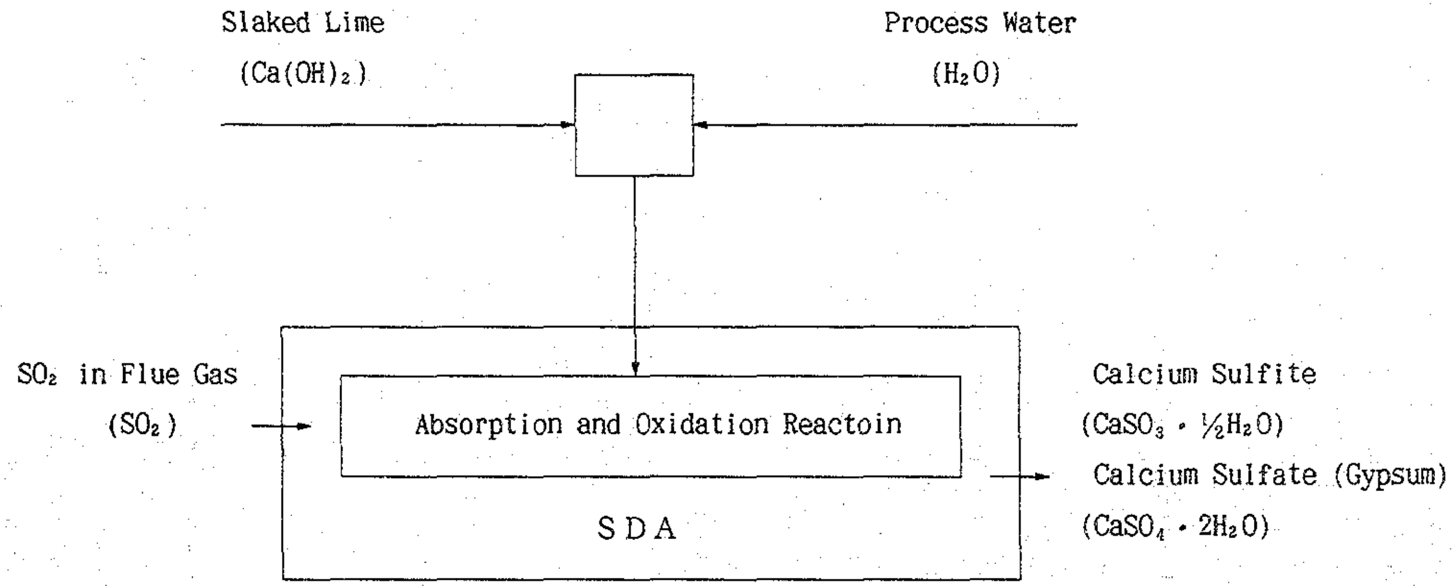


Fig. 4.2-6 Reaction Scheme of Spray Dryer

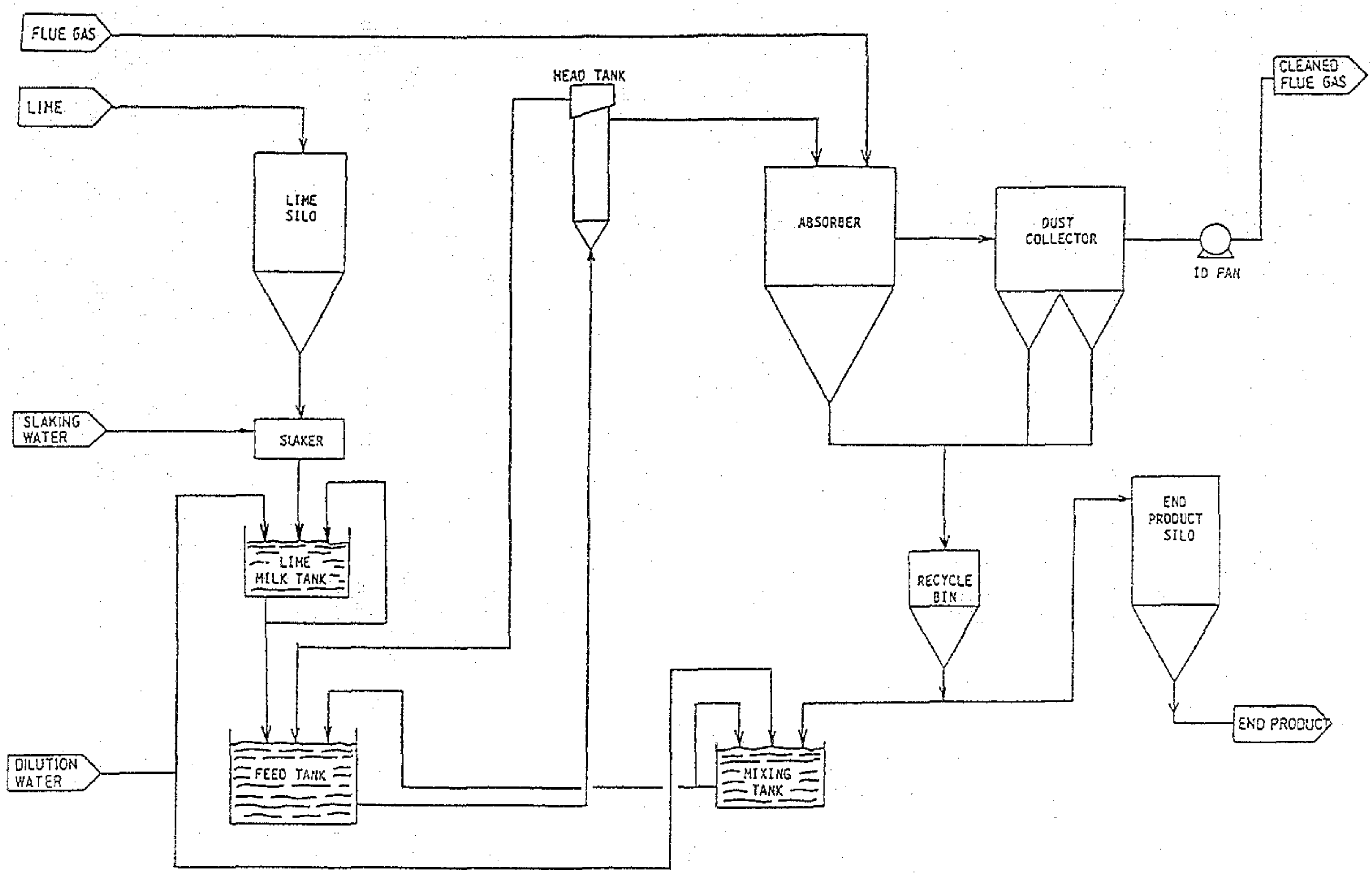


Fig. 4.2-7 PROCESS FLOW OF SPRAY DRYER

(4) Activated carbon method

In the activated carbon method, activated carbon used as absorbent is filled in an moving bed type absorber in which activated carbon moves by gravitation. Flue gas is passed through the absorber for absorption of sulphur oxides.

As the absorption efficiency of the absorbent deteriorates gradually, the absorbent is continuously heated for regeneration in a desorber. Sulphuric acid or sulphur is recovered as a byproduct.

The absorption and regeneration reactions which occur in this method are as follows:

[Absorption]

$$SO_2 + \frac{1}{2}O_2 + H_2O \rightarrow H_2SO_4$$

[Regeneration]

$$H_2SO_4 \rightarrow H_2O + SO_3$$
$$SO_3 + \frac{1}{2}C \rightarrow SO_2 + \frac{1}{2}CO_2$$

The flow of the absorbing reaction is shown in Fig. 4.2-8.

The process flow of this method is shown in Fig. 4.2-9. This method consists of a draft system, an absorption system, a regeneration system, a by-product recovery system, etc.

a. Draft system

The flue gas is passed through the moving bed type absorber, which is filled with activated carbon and in which the absorbent moves by gravitation, so that sulphur oxides of the flue gas is absorbed.

b. Absorption system

The absorbent (activated carbon) is fed to the top of the absorber and then the absorbent is flowed down by gravity from the top of the absorber to the bottom of it.

During the moving action, the flue gas from boiler is passed horizontally through the moving bed (cross-flow contact) and sulphur oxides are absorbed. The used absorbent is regenerated in the desorber, and then fed to the absorber again.

c. Regeneration system (Desorption system)

The used absorbent (activated carbon) from the absorber, which absorbed sulphur oxides, is regenerated in the desorber for reuse. In regeneration, the used absorbent is heated to about 400°C to free SO_2-rich gas from the used absorbent at the desorber.

d. Recovery system

The recovery system recovers by-product from the SO_2-rich gas freed in the regeneration system. The by-product is recovered in the form of sulphuric acid or elemental sulphur.

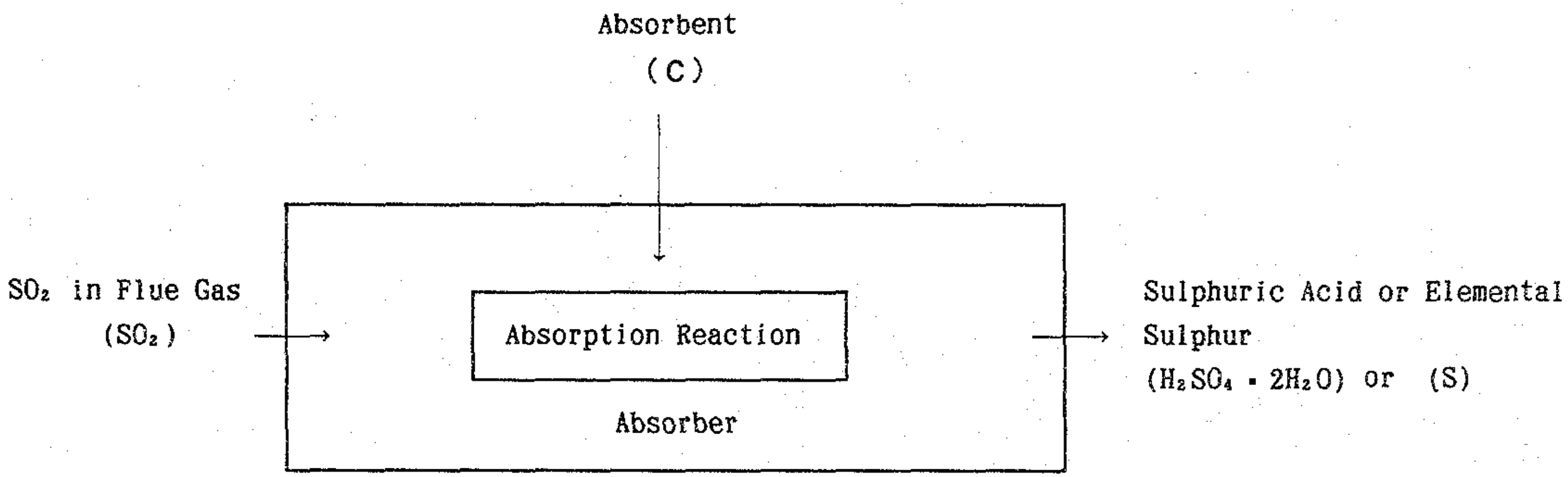


Fig.4.2-8 Reaction Scheme of Activated Carbon

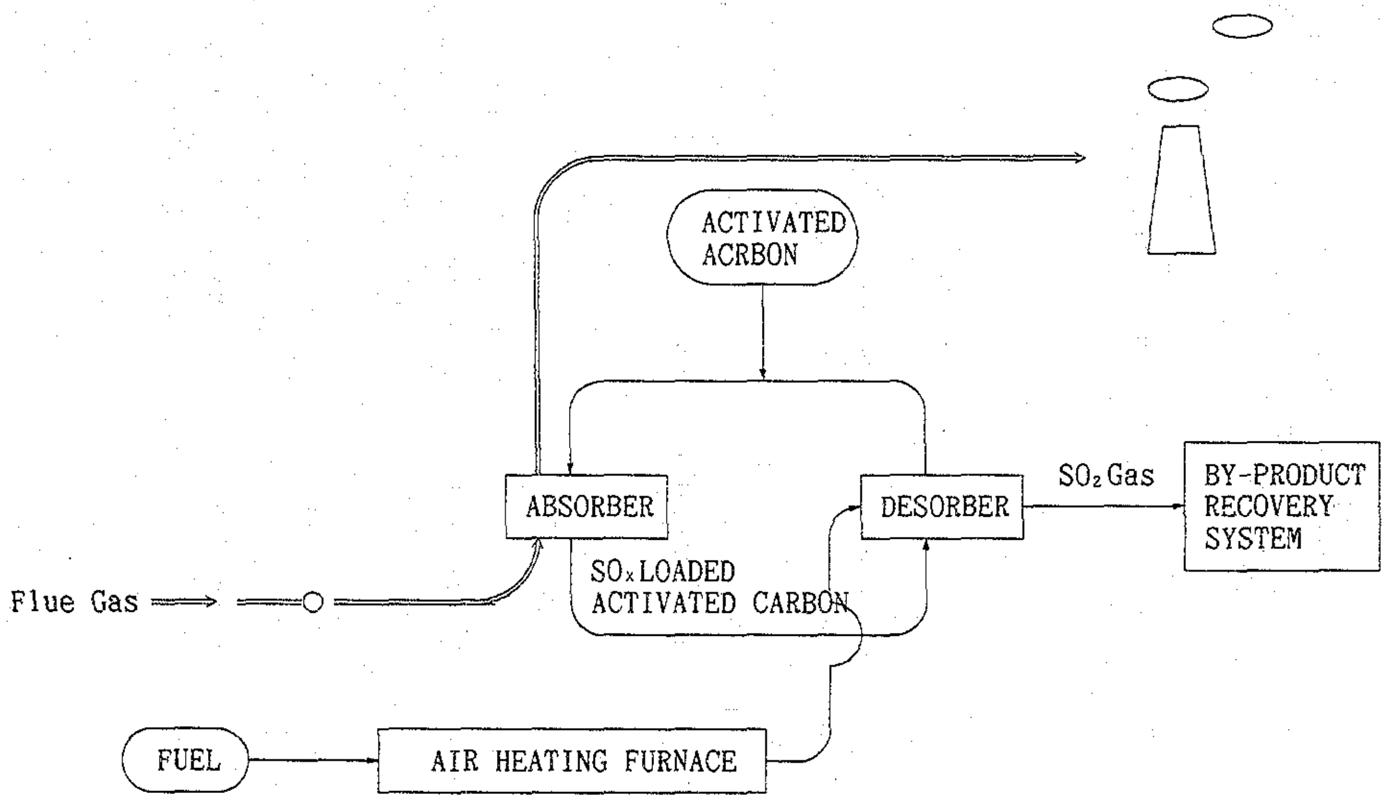


Fig. 4.2-9 PROCESS FLOW OF ACTIVATED CARBON

(5) Coal ash-using dry FGD method

In the coal ash using method, an absorbent made of coal ash, slaked lime and used absorbent or gypsum is filled in moving bed type absorbers in which the absorbent pellets move by gravitation. Flue gas is passed through the absorbers for absorption of sulphur oxides.

After absorption of sulphur oxides, the spent absorbent is partly used as the source of gypsum which is one of the raw materials of the fresh absorbent, and the rest is removed from the system.

The major reaction which occurs in this method is as follows:

[Absorption]

$$CaO + SO_2 + \frac{1}{2}O_2 \rightarrow CaSO_4$$

The flow of this reaction is shown in Fig. 4.2-10.

The process flow of this method is shown in Fig. 4.2-11. This method consists of a draft system, an absorption system, an absorbent production system, a spent absorbent recovery and storage system, etc.

a. Draft system

The absorber consists of a preabsorber and a main absorber. The flue gas from boiler is led to the preabsorber, where dust and part of sulphur oxides are removed by the absorbent, and then led to the main absorber for desulphurisation. In this method, the flue gas from boiler is treated by a dry process. Thus, the temperature of the flue gas is not lowered in the process, and no reheating of the treated flue gas is necessary. The treated flue gas is induced by a fan, and discharged from the stack.

b. Absorption system

The absorbent is fed to the top of the main absorber. The flue gas from boiler is passed horizontally through the moving bed (cross-flow contact) while the absorbent goes down from the top of the main absorber to the bottom by gravitation, and sulphur oxides are absorbed. The absorbent coming out of the main absorber is fed to the top of the preabsorber, and contacted again to the flue gas from boiler. In the preabsorber, the absorbent removes dust and part of sulphur oxides, thus improving the utilization rate of calcium contained in the absorbent is improved.

c. Absorbent production system

This system produces the absorbent pellets using coal ash, slaked lime and gypsum as raw materials.

Powders of raw materials from respective storage tanks are mixed uniformly in a mixer, and mixed further with water into a clay form in a kneader. The mix is then extruded with an extruder into a cylindrical form, and cured in a steam curing unit.

The wet cylindrical pieces are dried in hot dry air to form pores in the pieces to make them active for desulphurisation, and used as the absorbent pellets. The absorbent pellets thus produced are stored in a absorbent storage silo, and supplied to the absorber.

d. Spent absorbent recovery and storage system

In spent absorbent from absorber contains calcium in the form of gypsum. The spent absorbent, therefore, is stored in spent absorbent storage silo and partly reused as the source of gypsum for production of the fresh absorbent. The rest of spent absorbent is removed from the system along with the collected dust.

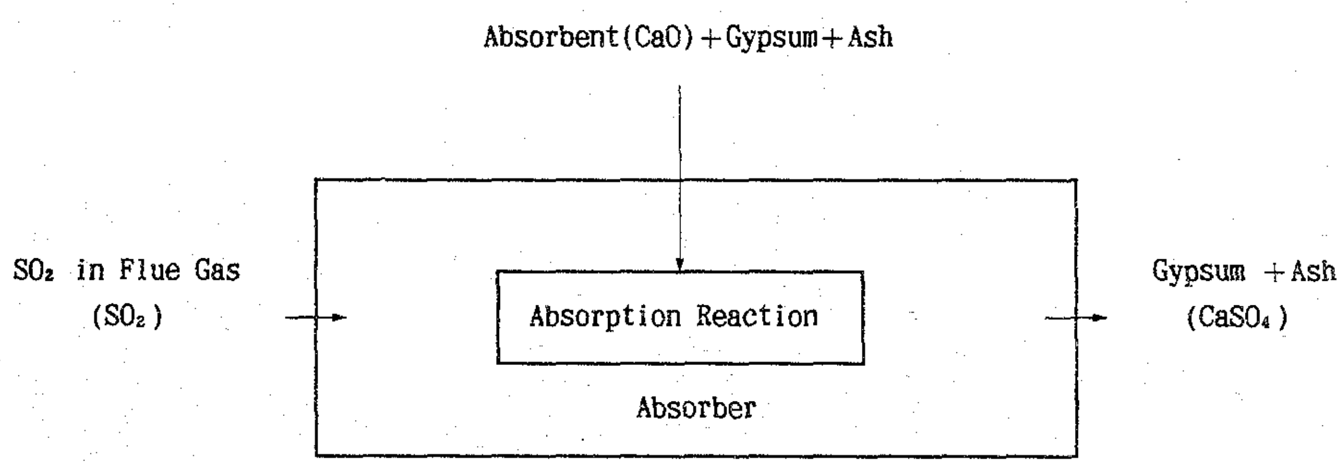


Fig.4.2-10 Reaction Scheme of Coal Ash Using dry FGD Method

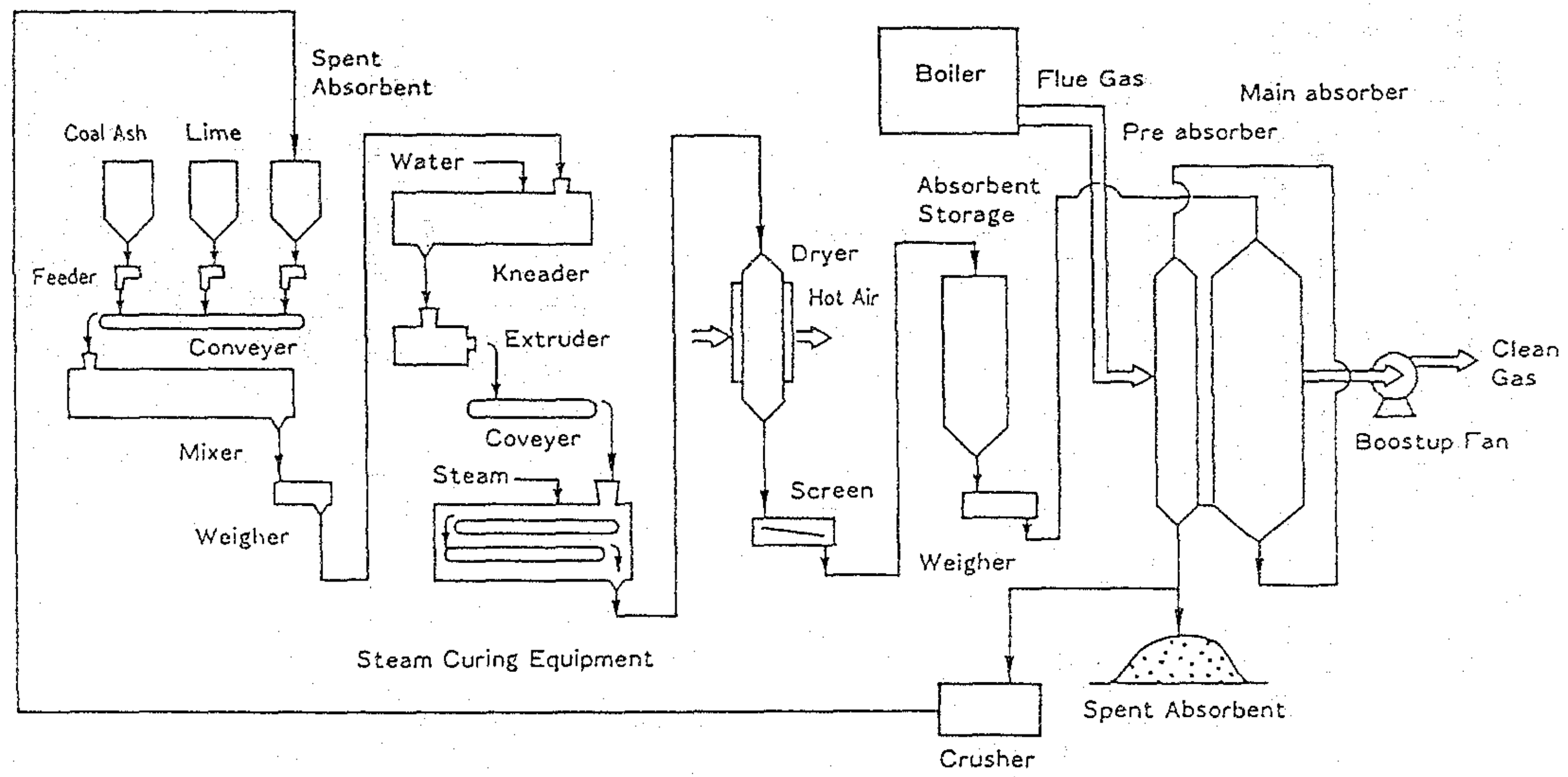


Fig. 4. 2-11 PROCESS FLOW OF DRY FGD SYSTEM USING ABSORBENT MADE FROM CAL ASH AND LIME

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

In this simplified FGD method, limestone ($CaCO_3$) is blown into the high temperature region (about 1,100°C) of furnace to decarbonate limestone and partly absorb sulphur oxides at the same time. In addition, water is sprayed in a reactor, installed at a low temperature region downstream of the air preheater, for further desulphurisation when it is necessary to get better DeSOx efficiency. The byproduct along with dust is collected at following dust collector.

Desulphurising reactions occur in the furnace and the reactor when water spray tower is applied. Reactions which occur in the furnace and water spray tower are as follows:

[Reactions in furnace]

$$CaCO_3 \rightarrow CaO + CO_2$$
$$CaO + SO_2 + \frac{1}{2}O_2 \rightarrow CaSO_4$$

[Reactions in reactor]

$$CaO + SO_2 + \frac{1}{2}H_2O \rightarrow CaSO_3 \cdot \frac{1}{2}H_2O$$
$$CaO + SO_2 + \frac{1}{2}O_2 + \frac{1}{2}H_2O \rightarrow CaSO_4 \cdot 2H_2O$$
$$SO_2 + H_2O \rightarrow H_2SO_3$$
$$CaO + H_2SO_3 \rightarrow CaSO_3 \cdot \frac{1}{2}H_2O + \frac{1}{2}H_2O$$

The process flow of this method is shown in Fig. 4.2-12.

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

In this simplifiied FGD method, an absorbent of slaked lime ($Ca(OH)_2$) is blown into the duct at a low temperature region following the air preheater. In addition, water is sprayed in a subsequent reactor for furhter desulphurisation when it is necessary to get better DeSOx efficiency. Slaked lime is used as absorbent because of its high reactivity. The byproduct along with dust is collected at following dust collector.

Reactions which occur in this method are as follows:

[Reactions in duct]

$$Ca(OH)_2 + SO_2 \rightarrow CaSO_3 \cdot \tfrac{1}{2}H_2O + \tfrac{1}{2}H_2O$$
$$Ca(OH)_2 + SO_2 + \tfrac{1}{2}O_2 + H_2O \rightarrow CaSO_4 \cdot 2H_2O$$

[Reactions in reactor]

$$SO_2 + H_2O \rightarrow H_2SO_3$$
$$Ca(OH)_2 + H_2SO_3 \rightarrow CaSO_3 \cdot \tfrac{1}{2}H_2O + 3/2\ H_2O$$

The process flow of this method is shown in Fig. 4.2-13.

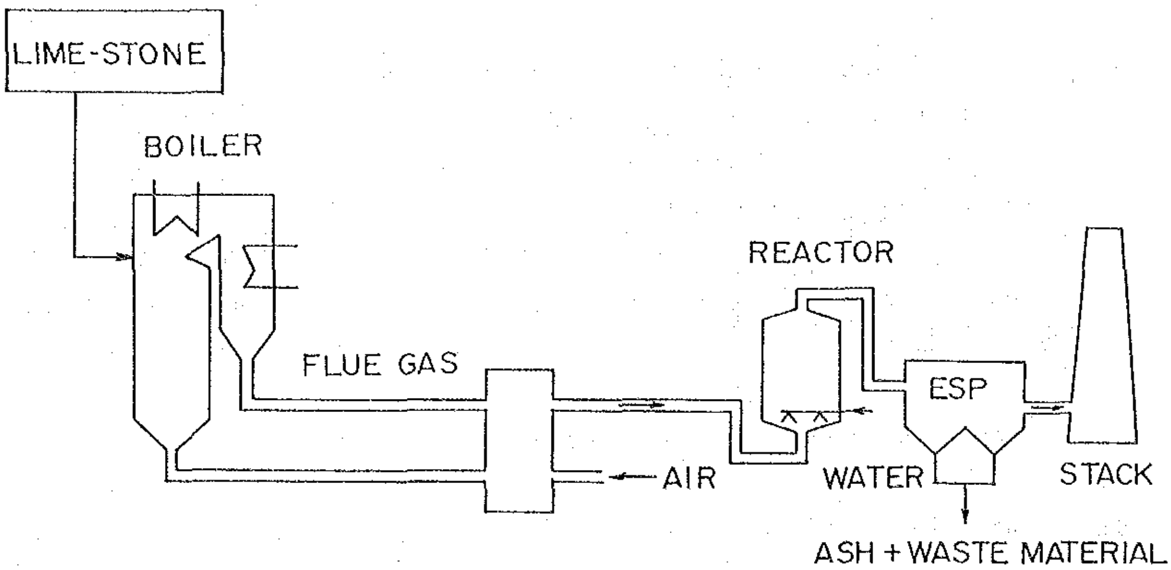


Fig. 4.2-12 PROCESS FLOW OF
Dry Absorbent Furnace Injection System

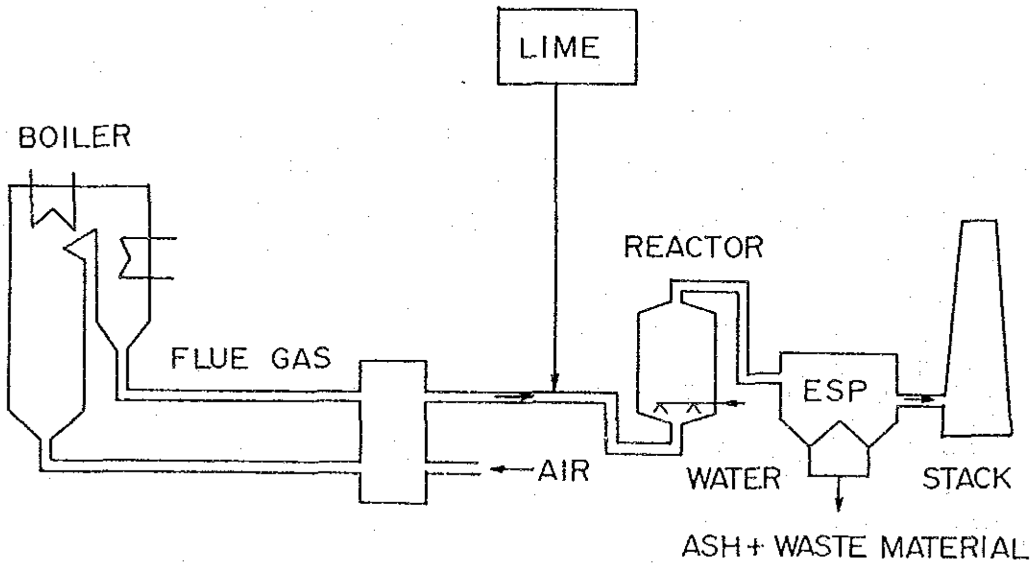


Fig. 4.2-13 PROCESS FLOW OF
Dry Absorbent Duct Injection System

Table 4.2-1 (1) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

	Item	Wet Type		Semi-Dry Type	Dry Type			
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
1.	Process Description	Limestone ($CaCO_3$) is conveyed as slurry to absorber and sprayed into flue gas stream. Sulphur oxides (SOx) present in flue gas is absorbed as calcium sulfite ($CaSO_3$). Then, byproduct gypsum is produced by further oxidization and dewatering.	Limestone is conveyed as slurry to jet-bubbling reactor (JBR). Flue gas and air is injected into the JBR to form bubbling layer. Through the bubbling layer, SOx absorbing and oxidization are carried out. Then, byproduct gypsum is produced by dewatering.	In spray dryer method, slaked lime ($Ca(OH)_2$) slurry is atomized as fine droplets. The droplets are mixed with flue gas in a drying chamber, then the droplets are dried to powder and SOx is reacted with alkaline matter simultaneously. Powder is collected at the bottom of the spray dryer and at following dust collector.	Flue gas pass through absorbent in gravity moving bed type absorber and SOx in flue gas absorbed in activated carbon. Activated carbon deteriorated in absorption performance is regenerated by heating in desorber. As by-product, sulphuric acid or elemental sulphur can be recovered.	Flue gas pass through absorbent in gravity moving layer type absorber and SOx in flue gas absorbed in absorbent. Absorbent is dry solid type which made of fly ash, slaked lime and gypsum as raw materials. A part of used SOx absorbed absorbent is crushed to make gypsum source as absorbent material and rest of absorbent is discharged out of the system.	Decarbonizing and a part of desulphurisation are carried out simultaneously by injection of $CaCO_3$ into boiler furnace. When absorber for water spray is installed at low flue gas temperature region after air preheater, SOx absorption reaction is further proceeded. Compound of $CaCO_3$ and Sulphur oxides forms dry powder, then collected and discharged at dust collector.	$Ca(OH)_2$ for desulphurisation is injected into duct at low flue gas temperature region after air preheater. When absorber for water spray is installed after $Ca(OH)_2$ injection, SOx absorption reaction is further proceeded. Compound of sulphur oxides forms dry powder, then collected and discharged at dust collector.
2.	Reaction Formula	(1) Absorbing Process $CaCO_3+SO_2+1/2H_2O$ $\rightarrow CaSO_3 \cdot 1/2H_2O+CO_2$	(1) Absorption and Oxidation Process $SO_2+CaCO_3+\frac{1}{2}O_2+2H_2O$ $\rightarrow CaSO_4 \cdot +2H_2O+CO_2$	(1) Absorption Process $Ca(OH)_2+SO_2+\frac{1}{2}H_2O$ $\rightarrow CaSO_3 \cdot \frac{1}{2}H_2O+H_2O$	(1) Absorption process $SO_2+\frac{1}{2}O_2+H_2$ $\rightarrow H_2SO_4$	(1) Absorption Process $CaO+SO_2+1/2O_2$ $\rightarrow CaSO_4$	(1) Reaction in Furnace $CaCO_3 \rightarrow CaO+CO_2$ $CaO+SO_2 \rightarrow 1/2O_2+CaSO_4$	(1) Reaction in Dust $Ca(OH)_2+SO_2 \rightarrow$ $CaSO_3 \cdot 1/2H_2O+1/2H_2O$ $Ca(OH)_2+SO_2+1/2H_2O+$ H_2O $\rightarrow CaSO_4 \cdot 2H_2O$

Table 4.2-1 (2) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

	Item	Wet Type		Semi-Dry Type	Dry Type			
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
2.	Reaction Formula	(2) Oxidizing Process $CaSO_3 \cdot 1/2H_2O + 1/2O_2 + 3/2H_2O \rightarrow CaSO_4 \cdot 2H_2O$		(2) Oxidation Process $CaSO_3 \cdot \frac{1}{2}H_2O + \frac{1}{2}O_2 + 1\frac{1}{2}H_2O \rightarrow + SO_2 + 1/2H_2O + \rightarrow CaSO_4 \cdot 2H_2O$	(2) Desorption Process $H_2SO_4 \rightarrow H_2O + SO_3$ $SO_3 + \frac{1}{2}C \rightarrow SO_2 + \frac{1}{2}CO_2$ (3) Byproduct Process The reaction formula is shown in the section of "Byproduct".		(2) Reaction in absorber $CaO + SO_2 + 1/2H_2O \rightarrow CaSO_3 \cdot 1/2H_2O$ $CaO + SO_2 + 1/2O_2 + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O$ $SO_2 + H_2O \rightarrow H_2SO_3$ $CaO + H_2SO_3 \rightarrow CaSO_3 \cdot 1/2H_2O + 1/2H_2O$	(2) Reaction in absorber $SO_2 + H_2O \rightarrow H_2SO_3$ $Ca(OH)_2 + H_2SO_3 \rightarrow CaSO_3 \cdot 1/2H_2O + 3/2H_2O$
3.	SO_x Removal Efficiency	Approx. 90% DeSOx Eff. can be increased by increment of liquid and gas ratio (L/G). Cheeper limestone compared with other adsorbents can be used.	Approx. 90% Higher DeSOx Eff. can be obtained by increment of the sparger pipe submergence depth in the absorbent of the Jet Bubbling Reactor (JBR). Limestone can be used as absorbent.	Approx. 80 ~ 90% Up to around 1,000 ppm inlet SO_2, DeSOx Eff. can be the same as the Wet limestone-gypsum method. Slaked lime ($Ca(OH)_2$) is used as absorbent which has higher reaction characteristics and higher price.	Approx. 90% By the absorption function of activated carbon, DeSOx Eff. can be as the same as Wet limestone-gypsum method. DeSOx Eff. differs according to space velocity (SV) and recirculation amount of activated carbon.	Approx. 90% DeSOx Eff. differs with Ca/S and Space Velocity (SV). The smaller SV value gives the more DeSOx Eff. Increment of Ca/S makes higher DeSOx Eff. but Ca utilization factor will be less. The higher Ca/S ratio is the less calcium utilization rate of absorbent.	Approx. 40 ~ 70% (In case of no water spray tower 30~40%) Higher DeSOx Eff. compared with other simplified DeSOx systems can be obtained. Limestone can be used because it is injected into high temperature furnace. However, twice as much of absorbent is required as Wet limestone-gypsum method.	Approx. 40 ~ 70% (In case of no water spray tower 30~40%) The same level of DeSOx Eff. as the absorbent injection into furnace can be performed. Absorbent is injected into duct with less temperature than furnace, therefore slaked lime of higher reaction rate is used.

Table 4.2-1 (3) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

	Item	Wet Type		Semi-Dry Type	Dry Type			
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
3.	SO_x Removal Efficiency				The smaller SV is the higher DeSOx Eff. Increment of activated carbon circulation amount makes higher DeSOx Eff., however, make up amount of activated carbon is increased.		Water injection after the furnace is required to get better Eff. DeSOx Eff. relay on boiler load and flue gas tempera-ture. When no water injection by spray tower is performed, DeSOx Eff. is to be about 30~40%.	Water injection is required to get better Eff. DeSOx Eff. relay on boiler load and flue gas temperature. When no water in-jection by spray tower is performed, DeSOx Eff. is to be about 30~40%.
4.	Dust Removal Efficiency	Approx. 90% Dust removal is performed by inertia impingement of dust with spray drops. Dust removal Eff. is determined by L/G, particle size, and spray drops size. High dust removal Eff. can be obtained.	Approx. 90% Dust removal is performed in JBR. High dust removal Eff. can be obtained by turbulent gas and liquid contact through JBR.	Approx. 90% (With dust collector) Dust collector installed after spray dryer performs dust removal. The system including dust collector offers the same level of dust removal as the wet type.	Approx. 90% Moving bed absorption tower has the function of dust removal. The faster cir-culating speed is the less dust removal Eff. Dust removal Eff. is the same level as the wet type.	Approx. 90% Absorbent has the function of dust collection as well as SOx removal. The more absorbent moving speed and dust load at the inlet are the more dust load at the outlet. Dust removal Eff. can be the same as the wet type.	Approx. 90% (With dust collector) Dust removal is performed by dust collector installed after DeSOx reactor. The system including dust collector offers the same level of dust removal as the wet type.	Approx. 90% (With dust collector)

Table 4.2-1 (4) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

	Item	Wet Type		Semi-Dry Type	Dry Type			
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
5.	Technical Maturity	It has been recognized as a proven technology for commercial use.	The same description as left.	It has been recognized as a proven technology for commercial use as the same as the wet type.	Tests in demonstration plants were finished and several commercial plants have been operating.	Test in a demonstration plant was finished. One commercial plant has been in operation since Apr. 1991.	Tests in pilot plants and demonstration plants have been conducting. One commercial plant has been operating.	
6.	(1) Operational experience in commercial plants	About 36% of DeSOx system in the world consists of Wet limestone-gypsum method. When share of another type of wet DeSOx system namely wet limestone-sludge disposal method is added, it would be 85%.		The share of spray dryer system in the world is only about 8%, however this system have been popular in Europe and the United States.	This system using activated carbon were researched and developed as a simultaneous DeSOx-DeNOx in the later half of 1960's.	This system was materialized during a research for coal ash effective utilization. It was proved in the research that a solid of coal ash, lime, and gypsum has the function of SOx adsorption.	Share of this simplified DeSOx system which injects absorbent into furnace or duct is about 2% in the world. Numbers of commercial plants with this system are limited and present (Apr. 1991) status of this system is that research and development are promoted by sponsors of industries and manufacturing firms in the United States, Canada, and Europe including EPRI, EPA, and DOE of the United States of America.	
		At the present, wet spray tower DeSOx system is the most experienced system and it has been recognized as the most proven technology.	There is CT-121 model of JBR for commercial use. There are fifteen (15) commercial plants including one plant under construction.	This system has been evaluated as the same proven technology as the wet type.	After that, demonstration tests at coal-fired power plants were carried out and now several commercial plants have been operating.	One of Japanese private electric power companies, Hokkaido Electric Power Co., Ltd. is the leading developer of this system.	Only one commercial plant which reports good operational experience is the one called LIFAC (Limestone Injection with an Activation Reactor) applied to the No. 4 unit (265MW) of Inkoo coal-fired power plant of IVO in Finland.	

Table 4.2-1 (5) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

Item		Wet Type		Semi-Dry Type	Dry Type			
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
6.	(1) Operational experience in commercial plants	Latest model of in-situ oxidation single tower with 500MW equivalent capacity is in operation. As the latest model of this system, a single tower in situ forced oxidation DeSOx system for 1,000MW coal-fired plant was put into operation in June 1990. (2x500MW equivalent DeSOx system).	As a commercial plant for a coal-fired power plant, 2 units of 200MW soot-separation two-tower, DeSOx system has been operating since 1984. A pilot test of a soot-mixed, single-tower improved CT-121 with 1,500 m^3N/h flue gas volume was finished in 1988. At the present, this system for 700MW coal-fired power plant is under construction (as of April, 1991).	The reason why spray dryer method has not been applied so widely as the wet type is that disposal problem with by-product and higher running cost with expensive slaked lime consumption.	Numbers of commercial plants are limited and there is no experience in a large scale coal-fired power plant.	A half treating capacity of 350MW power plant in Tomoto-Azuma Power Station of Hokkaido Electric Power Co., Ltd. has been in operation as a commercial plant since March 1991. After completion of 1,000m^3N/h pilot plant test and 50,000m^3N/h demonstration plant test.	Research and development history of No. 4 unit of Inkoo power plant are as follows: a) Full scale lime injection and half scale activation reactor to the flue gas volume of No.4 unit were installed as research purpose which put into operation in January, 1986. b) The other half scale of activation reactor was installed as a commercial plant and renovation of the limestone injection system was carried out and the system was pout into operation in January, 1988. c) The activation reactor installed research purpose was replaced with new one that is the same model as the one installed as commercial plant and the system was put into operation in January 1990. It is generally said that this system is suitable for a plant which is not required high DeSOx Eff. as it is the simplified DeSOx system.	

Table 4.2-1 (6) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

Item		Wet Type		Semi-Dry Type	Dry Type			
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
6.	(2) Operational experience in commercial <u>coal-fired</u> 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.	3 Plants There are 3 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.	1 Plant There is one 265MW equivalent commercial plant for a coal-fired power plant.	1 Plant* Many cases of pilot plant and demonstration plant tests have been conducting, however supply experience to coal-fired power plant is not many. The biggest scale in a coal-fired power plant is 137MW equivalent.
7.	Reliability	Measures for corrosion and erosion with DeSOx and dust removal of flue gas and with handling of absorbent and by-product gypsum are required. Measure for scaling in the absorbing tower is required.		Major problems with this system are erosion and plugging of absorbent atomizer installed in the absorber.	Several commercial DeSOx plants with this method have been operating but there is no big scale application to coal-fired power plant, more over, operation experiences of	Reliability on long term operation will be given by the scale up (13 times) commercial plant (644,000 m^3N/h) from the demonstration plant (50,000 m^3N/h) because	Simplified DeSOx process by absorbent injection has limited application to commercial plants and operational experience of commercial plants are short, therefore the reliability on long term operation of this system will be proved by the further experience in the future.	

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

Table 4.2-1 (7) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

Item		Wet Type		Semi-Dry Type	Dry Type			
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
7.	Reliability	This system has enough reliability for the above problems because a lot of renovation were carried out in design, structure, material of each part of system during the long history from the development stage to the present. Maintenance carried out at a periodical inspection of a power generation plant has proved continuous operation without problem for one year.	As the operation results of the soot separation CT-121 (200MW) and the good test results of the soot mixing CT-121 (1,500 m^3N/h), it is believed that the reliability would be comparative to the spray tower method. An operational experience with a big scale of this system will be given by 700 MW equivalent DeSOx system which is under construction (as of Apr. 1991).	There are two types of atomizing method, one is rotary atomizer and the other one is two-fluid nozzle. Rotary atomizer is usually adopted to more than 250MW class boilers as the atomizer gives good atomizing efficiency hence residence time in the absorber can be shortened and less nozzle plugging than the two-fluid nozzle. Rotary atomizer rotates at about 11,000 rpm, therefore periodical inspection and adjustment for atomizing nozzles and cleaning of scale at rotary desk are required.	commercial plants are rather short (as of Apr. 1991). In processes of recovering elemental sulphur or sulphuric acid as by-product, there are many chemical reaction processes which makes complicated equipment arrangement, therefore maintenance and by-product recovering system is more complicated than the wet type.	the operation period of the commercial plant is very short (1 month, as of Apr. 1991). This system uses the absorbent made from coal ash, slaked lime and gypsum.	As weak points of this system, followings can be considered. a) low DeSOx efficiency b) Influence to fouling and slugging of boiler furnace c) Unknown factors when it is scaled up to large scale plant d) Increase of dust lead to existing ESP (in case of existing ESP is used as dust collector for DeSOx system) There are still some items to be proved like the above, therefore the reliability of this system at the present is far less than the wet type or the spray dryer processes.	

Table 4.2-1 (8) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

Item		Wet Type		Semi-Dry Type	Dry Type			
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
7.	Reliability			In case of rotary atomizing nozzles, inspection and adjustment in every three-month and replacement in every year are required. This system is simple because which has less interiors in the absorber than the wet type and has no big size pumps like slurry circulation pumps in the wet spray tower method. Therefore, when the spray dryer DeSOx system has one stand-by atomizer, it gives the same level of reliability as the wet type.	Therefore, reliability of this system on long term continuous operation of 500MW class at the present is less than the wet type and the spray dryer.	This system requires pelletizers to produce pellet absorbent and the maximum size of this pelletizer in the market at the present is about 3 ton/h, therefore when DeSOx system is designed for a big power plant, numbers of pelletizer stream will be bigger and numbers of related facilities will be increased. As for inspection and maintenance of the absorbent production system, a simplified inspection and maintenance in every three-month is required as well as a periodical inspection and maintenance in every year. Therefore, re-liability of this system at the moment is re-cognized less than the wet type.		

Table 4.2-1 (9) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

Item	Wet Type		Semi-Dry Type	Dry Type			
	Limestone-Gypsum Method						
	(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
8. By-product (1) Kinds of by-product	Gypsum ($CaSO_4 \cdot 2H_2O$)		Compound of flyash and re-action product (Flyash+$CaSO_3$+ $CaSO_4$+$Ca(OH)_2$)	Elemental sulphur or sulphuric acid (H_2SO_4 or S)	Used absorbent (Flyash+$CaSO_4$+ CaO)	Compound of flyash and reaction product (Flyash +$CaSO_3$ + $CaSO_4$ + $Ca(OH)_2$)	
(2) Disposal of by-product	High quality of gypsum is re-covered as by-product and it can be used as cement raw material and gypsum wall board. In the United States, non-recovering of by-product is rather popular because there are many places for land reclaiming, cost reduction of DeSOx system can be achieved without by-product recovering system and a lot amount of by-product is recovered with high sulphur coal. Countries other than the Unite States, by-product has been recovered as commercial gypsum, because there are limited areas for disposal and land re-clamation, and gypsum has value for commercial use.		By-product from the spray dryer system which is compound of flyash and reaction product can be handled with usual ash handling system because physical characteristics of the by-product is dry small particles that has fluidity very like flyash. Research and development of effective use of by-product are under way.	SO_2-rich gas (SO_2 concentration 20 to 25 vol.%) produced by heating of SO_2 adsorbed activated carbon at desorber is sent to by-product recovery system to recover the by-product. As by-product, elemental sulphur or sulphuric acid can be selected. Process of each case is as follows.	By-product as used absorbent is comparatively stable solid in chemical and physical characteristics that contains about 50% of gypsum ($CaSO_4$). A part of by-product is used as alternatives of gypsum for absorbent pro-duction after it is crushed into small particles, and rest of by-product is dis-charged outside the DeSOx system.	By-product of this system has similar characteristics as the spray dryer method since the reaction mechanism of the system is close to the spray dryer system, therefore disposal of by-product is nearly the same as the by-product of the spray dryer process. According to the test results report from No. 4 unit of Inkoo power plant of IVO in Finland, by-product of LIFAC has stability and self hardening characteristics, therefore there is a possibility to use it as road bed material and construction material.	

Table 4.2-1 (10) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

Item		Wet Type		Semi-Dry Type	Dry Type			
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
8.	(2) Disposal of by-product				a) Sulphuric acid recovery After dust and impurities are removed from the SO_2-rich gas, the gas is oxidized in a converter to form SO_3. The SO_3 is then absorbed in an absorber to form sulphuric acid. $SO_2+\frac{1}{2}O_2 \rightarrow SO_3$ $SO_3+H_2O \rightarrow H_2SO_4$ b) Elemental sulphur recovery SO_2-rich gas is reduced to H_2S in a reduction claus using a carbon-bonaceous reduction agent. H_2S and SO_2 is converted to elemental sulphur in a claus unit. $C+SO_2 \rightarrow S+SO_2$ $C+CO_2 \rightarrow 2CO$ $C+H_2O \rightarrow CO+H$ $H_2+S \rightarrow H_2S$ $CO+S \rightarrow COS$ $COS+H_2O \rightarrow H_2S+CO_2$ $H_2S+\frac{1}{2}SO_2 \rightarrow 1\frac{1}{2}S+H_2O$ The carbonyl sulphide (COS) which is generated secondarily in the reduction column, is hydrolyzed in the claus unit and eventually elemental sulphur is obtained.	By-product discharged outside the system is handled with the same manner as coal flyash. Effective use of by-product is under development.		

Table 4.2-1 (11) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

	Item	Wet Type		Semi-Dry Type		Dry Type		
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
9.	Utilities (1) Absorbent	Limestone $CaCO_3$ Limestone which is lower price is used as absorbent. Usually, lime-stone is procured as powder phase, and it is used as a slurry phase. Usually, limestone powder passed the 325 mesh is more than 95%.		Slaked Lime $Ca(OH)_2$ Slaked lime is used as absorbent which has higher re-action characteristics than limestone. Usually, powdered quick lime (CaO) or slaked lime $Ca(OH)_2$ is received as absorbent material. CaO or $Ca(OH)_2$ is slaked by slaking system and used as slurry phase. Slaking is carried out with water and with heating at about 80°C in order to get buter slaking reaction.	Activated Carbon Expensive activated carbon is used as absorbent. Activated carbon that loss SOx absorbing ability is regenerated by regenerator continuously. Activated carbon has chemical-loss at a process of reaction and powdered-loss at a process of drying re-generation. Usually, make up of activated carbon is 1.5% per quantity of circulation at moving bed absorption tower.	Absorbent made from flyash, slaked lime and used absorbent (gypsum) Flyash, slaked lime and used absorbent (gypsum) are mixed in dry condition after that these are kneaded with water. Pasted kneading raw material is formed at type of pellet (6mmφx3~10mm long). After that the pellet is trans-ferred to steam curing equipment, and it is cured with steam (about 100°C). As the result, hydration reaction on flyash, slaked lime and used absorbent gives necessary hardness to absorbent. After that, the pellet is dried with hot air and it is changed to final shape of absorbent.	Limestone $CaCO_3$ Limestone can be used as absorbent. In order to obtain 70% DeSOx Eff., this system needs about twice as much limestone as the wet type.	Slaked Lime $Ca(OH)_2$ Slaked lime is used as absorbent in order to obtain higher reaction rate. In order to get 70% DeSOx Eff., this system needs quantity of slaked lime as the same as Spray Dryer Method with 90% Eff.
		Density of limestone slurry which is sprayed into the absorber is about 15%. In case of insitu forced oxidation (IFO), the system can be designed with excess feeding ratio of absorbent at about 1.02. (In case of applying separate oxidation tower, it would be about 1.05.)	Density of limestone feeding to absorber is about 25%. Density of limestone in mother liquid of absorber is less than 0.2%. The system can be designed with excess feeding ratio of absorbent at about 1.01 which is less than spray tower method.					

Table 4.2-1 (12) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

	Item	Wet Type		Semi-Dry Type		Dry Type		
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
9.	(1) Absorbent			In order to get the same level of DeSOx efficiency as wet limestone/gypsum method (Approx. 90%), it is necessary to feed absorbent with excess feeding ratio of about 1.3~1.5, therefore a lot amount of more expensive absorbent than limestone is required.		Absorbent consists of 1/3 flyash, 1/3 staked lime and 1/3 used absorbent (gypsum). The system is usually designed with excess feeding ratio of absorbent at about 1.25.		
	(2) Water	Following make up water is required. a) Evaporating water at absorption tower. b) Surface moisture of by-produced gypsum c) Crystallization water of by-produced gypsum d) Blow off water to control liquid quality in the system. Waste water discharged from gypsum recovering process can be recycled as dissolving water of absorbent and etc.		Spray Dryer Method needs a lot of water as the same as the Wet Type Method because almost all of droplet of absorbent-slurry sprayed to spray dryer evaporate and goes out through stack.	In by-product recovering process, cooling water is required for desorption gas cooling.	In absorbent producing process, water is necessary for kneading flyash, slaked lime, and used absorbent. The quantity of water is about 1/10 of Wet Type method.	Since almost all of water sprayed to absorber evaporate and goes out through stack, this method needs a lot of water as the same as the Wet Type Method.	

Table 4.2-1 (13) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

Item		Wet Type: Limestone-Gypsum Method (1) Spray Tower Method	Wet Type: Limestone-Gypsum Method (2) Jet-Bubbling Method	Semi-Dry Type (3) Spray Dryer Method	(4) Activated Carbon Method	Dry Type (5) Coal Ash Using Method	Dry Type (6) Dry Absorbent Injection into Furnace Method	Dry Type (7) Dry Absorbent Injection into Duct Method
9.	(3) Steam	When flue gas after FGD is reheated by Gas/Gas heater (GGH), steam for soot blowing is required. In case of other reheating equipment are used, following steam is required. a) After-burner type • atomizing steam b) Steam heater type • heating steam		Steam is required for absorbent slurry in a slaking system. Steam for flue gas reheating is not necessary, because flue gas is kept under dry condition. In order to protect visible white plume from a stack, sometime flue gas reheating system is adopted.	Flue gas reheating is not required, because of its process, flue gas temperature is not lowered.	Steam is required for curing and drying of absorbent in production process. Flue gas reheating is not required, because of its process, flue gas temperature is not lowered.	Steam for reheating equipment is not necessary for the same reason as Spray Dryer Method.	
	(4) Electricity	Spray Tower Method needs power for boost up fan and absorbent-slurry circulating pump as major consumer.	Jet-Bubbling Method doesn't need absorbent-slurry circulating pump. Draft loss of JBR is larger than spray tower method. Therefore, power consumption of boost up fan is larger than spray tower method.	Power consumption of Spray Dryer Method is about 70% of Wet Type. Because spray dryer has a few internal equipment and this method doesn't have large size equipment like slurry circulating pumps.	Power consumption is about 30% of Wet Type Method, because absorber is moving bed type and this method requires no large size equipment.	Since this system has dry absorption process, there is no slurry circulation pump. It is possible to reduce power for fans with less absorber draft loss by choosing appropriate space velocity (SV) value.	These systems are simplified and less auxiliary equipped systems compared with others, therefore power consumption of these systems are about 18 to 20 % of the spray tower method.	

Table 4.2-1 (14) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

	Item	Wet Type		Semi-Dry Type		Dry Type		
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
9.	(4) Electricity	This system consume more power than other systems because of power consumption of above equipments.	Total power consumption is less than the spray tower method.			In absorbent production process, rather many number of equipments are equipped, however most of them are small size equipments. Therefore, power consumption of this system is about 60% of the spray tower method.		
	(5) Others	In case of insulation of waste water treatment system, chemical is needed. When flue gas is heated up by after burner not GGH, fuel for after burner is required.			Deteriorated activated carbon is regenerated at regeneration tower continuously, fuel for heating for this regeneration process is required.			

Table 4.2-1 (15) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

	Item	Wet Type		Semi-Dry Type		Dry Type		
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
10.	Waste Water	Limestone-Gypsum Method usually produce waste water in by-product recovering process. Quantity of waste water depends on reacted slurry amount extracted from absorber. Quantity of bleeding of reacted slurry is controlled so as to settle the density of chlorine which affect the DeSOx efficiency and the corrosion resistibility of the desulphurisation system. Waste water contains dust, volatile matters such as fluorine, chlorine and COD which is produced in gypsum formation process.		No waste water is generated because water in injected absorbent slurry is evaporated and then the reacted product is exhausted in the form of dried particles.	No waste water is generated in the process of absorbing because the system is dry moving bed type, however the by-product recovering process generate waste water.	No water is required for absorption process, therefore no waste water is generated in the process. A small amount of water is used in absorbent production process, however all of water is evaporated during production process then no waste water is produced.	No waste water is generated because the reacted product is exhausted in the form of dried particles as the same as the spray dryer method.	
11.	Stack Lining and Treated Gas Reheating	The treated gas after absorber is moisture saturated gas with the temperature of approx. 50°C and contains a small amount of mist. Therefore, when the gas is exhausted to the stack without any appropriate countermeasures, it will condensate in the stack and will cause corrosion, furthermore the moisture saturated gas with mist will be exhausted from the stack with high speed, as a consequence the mist will be separated in the atmosphere and will fall in the vicinity of the stack.		The flue gas and reacted product are completely dried because the gas temperature at the spray dryer exit is kept 10~20°C higher than the dew point.	The lining work for the ducts and the stack and the flew gas reheating are unnecessary because there is no temperature drop in the system.		It is said that the lining work for ducts and stack is unnecessary because the same chemical reaction is performed as the same as spray dryer system. Flue gas reheating is also unnecessary because the system is dry type. However, Unit No. 4 of Inkoo Power Station in Finland which adopts LIFAC System has a steam gas heater downstream the absorber to reheat the flue gas up to 75°C in order to protect the ESP and the stack from corrosion which would be able to occur since the system applies water spray tower to get better DeSOx Eff.	

Table 4.2-1 (16) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

	Item	Wet Type		Semi-Dry Type		Dry Type		
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
11.	Stack Lining and Treated Gas Reheating	The Mist will corrode the outer wall of the stack and auxiliary machines nearby due to its strong acid (pH ≑ 2). Therefore, anti-corrosion lining to absorber outlet ducts and stack and reheating of the treated gas up to 80°C to protect stack lining and to prevent the fall of the mist to the surroundings are necessary.		SO_3 is removed by the chemical reaction which is per-formed inside the spray dryer. From above reasons, lining work for the ducts and the stack to protect from the cor-rosion by the sulphuric acid mist is un-necessary and flue gas re-heating is also unnecessary.				
12.	Operational Characteristics (1) Load Change Characteristics	The system responds well to normal load change of boiler maintaining designed DeSOx efficiency. Time constant of DeSOx performance of absorbent slurry to inlet SOx amount is large, therefore the system can follow load change at step like.		For normal load change of boiler, the system offer the same level of load response as the wet lime-stone-gypsum method, however there is a limitation on lowest temperature of SDA inlet flue gas temperature at which the system can be put into operation (or absorbent injection) in order to keep SDA outlet temperature well above the saturate temperature of flue gas. Late absorbent injection at plant start up and early stop of the injection at plant shut down are required for the reason of the above.	The same description as Limestone-Gypsum Method.		The system responds to boiler load by controlling absorbent feed rate into the furnace or flue gas duct and water spray flow rate into the reactor when water spray tower is applied. SO_2 removal ratio depends much on gas temperature of the absorbent injection area and/or the reactor and is very sensitive to these gas temperature. SO_2 removal efficiency changes by the boiler load and the flue gas temperature. Therefore, these system suit for a continuous load operation plant with a constant load, but not good for a plant which will be operated frequent load increase/decrease or start-up/shut-down.	

Table 4.2-1 (17) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

	Item	Wet Type		Semi-Dry Type		Dry Type		
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
12.	Operational Characteristics (1) Load Change Characteristics			Therefore, DeSOx performance cannot be performed during these periods which may result in temporary over emission on regulated figure when it is regulated-based on concentration of SOx in flue gas.				
	(2) Operability	The system is simple with not many components in each process, therefore the operation is easy. Almost immediately after the FGD operation, flue gas can be introduced to the system.		In normal load operation, the operability is nearly the same as the limestone-gypsum method. But, in starting-up/shutting-down operation, it is severe due to limitation on the spray dryer outlet gas temperature.	The operation on absorbing process and draft system is easy and immediately after the FGD operation, flue gas can be introduced to the system. But, the operability on by-product recovery process and regeneration of activated carbon process are worse than that of limestone-gpysum method, because this process is composed with many equipments and about 20 hours are required to warm up these processes.	The operation on absorbing process and draft system is easy and immediately after the FGD operation, flue gas can be introduced to the system. But, the operability on absorbent producing process are worse than that of limestone-gypsum method, because this process is composed of many equipments.	It is required some effort to find out the most suitable control conditions such as absorbent injection flow rate, water spray flow rate into the reactor and reactor outlet gas temperature control in several operation conditions, since the SO_2 removal efficiency changes by the boiler load and the flue gas temperature. The system can be influenced sensitively to load change and operation conditions such as in-service burner stage, type of coal, etc.	

Table 4.2-1 (18) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

No.	Item	Wet Type		Semi-Dry Type	Dry Type			
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
13.	Maintenability	It is necessary to take measures to prevent corrosion and abrasion due to SO_2 and dust removal of flue gas and handling of absorbent or by-product. Anticorrosion and antiabrasion materials are selected in accordance with the property of process liquid and/or chemical. For towers and basins resin lining is applied, for pipes rubber lining, etc. and for pumps in slurry process anticorrosion stainless materials or rubber lining, etc. are used. But, it is necessary to repair these materials because it is impossible to secure the perfect anticorrosion and/or antiabrasion materials. Further, the cleaning of towers, basins and pipes in the absorbent slurry process and gypsum slurry process are necessary to eliminate scale coating.		For major parts of spray dryer, ordinary mild steel can be used and no lining is necessary. Major problems in maintenance of this system are abrasion and clogging of spray nozzle of rotary atomizers. Rotary disk which is rotating at about 11,000 r.p.m. are equipped to the rotary atomizer. In order to overcome this abrasion problem, cleaning, inspection and adjustment of nozzles in every three months and replacement of nozzles in every year are necessary.	Dry type absorber is employed for these system, therefore ordinal mild steel can be used and no lining for corrosion protection is required.		The maintenance is easy than that of limestone-gypsum method and spray dryer method due to simple system. It is necessary to pay attention regarding an abrasion and/or clogging of the spray nozzles.	
					In a process which produces sulphur or sulphuric acid as a by-product, the system configuration is complicated and special materials considering chemicals are used. Therefore, the maintainability is worse than that of lime-stone-gypsum method.	For scale up of absorbent pro-duction system, it is necessary to increase number of extruders because maximum capacity of extruders in the market at the present is limited. Therefore, this fact makes less maintenability of the system. Solid type absorbent is used in the system, therefore number of transportation equipment are increased which requires man-power for maintenance.		

Table 4.2-1 (19) Comparison of Various Flue Gas Desulphurisation System (1 Unit Base)

Item		Wet Type		Semi-Dry Type		Dry Type		
		Limestone-Gypsum Method						
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray Dryer Method	(4) Activated Carbon Method	(5) Coal Ash Using Method	(6) Dry Absorbent Injection into Furnace Method	(7) Dry Absorbent Injection into Duct Method
13.	Maintenability			In comparison with wet lime-stone-gypsum method, this system has less interiors in SDA and there is no big size pumps like in wet limestone-gypsum method which makes equipment composition simple, therefore maintenability is better than that of wet limestone gypsum method.		For the maintenance of this absorbent production system, simplified in-spection in every several months concentrated on the transportation equipments other than periodical inspection in ever year is required. Therefore, maintainability of the system is less than that of wet limestone-gypsum method.		
14.	Others			At the present, 14 meters in diameter SDA standard module is used for 200 to 500MW class commercial power plants. For large amount of flue gas treatment, numbers of module are increased. When it comes to 500MW power plant, number of module would be three.			When water spray tower after absorbent injection is applied, a diameter of the tower would be about 10 meters for 200MW class power plant. Area of 12 meters in diameter is required considering attached auxiliaries and maintenance space, etc.	

4.3 Study Conditions of the Optimum DeSOx System Selection

In order to reduce SOx emission amount from the power plant to target value by means of installation of the optimum DeSOx system selected from seven possible DESOx system reviewed item 4.2, it is necessary to make a study that to which power plants of unit No. 1 to No. 10, the selected optimum DeSOx system is to be installed.

Study conditions which are particular to the Kozienice power station are determined in this section. These study conditions are to be used for the study of the optimum combination of power plants and installed DeSOx plants, and for the study of the selection of the optimum DeSOx system.

Determination of the study conditions are made by discussions with related organizations of Poland and collections of information at the field survey of the feasibility study on Desulphurisation system for the Kozienice power station.

4.3.1 Power Plant Operation Practice

a. Plant Utilization Factor

i) 200 MW Plants 57% (Equivalent to 5,000 hours operation at rated output)

ii) 500 MW Plants 57% (Equivalent to 5,000 hours operation at rated output)

Plant utilization factors of the plants at the present are shown below.

i) 200 MW Plants 56% (Average of 8 plants from 1985 to 1990)

ii) 500 MW Plants 31% (Average of 2 plants from 1985 to 1990)

According to the information from the power station these figures will be changed up to 57%.

Therefore, plant utilization factors of both 200 MW plants and 500 MW plants are set at 57% for the study which is equivalent to 5,000 hours operation at the rated output.

Note: Plant Utilization Factor = $\frac{\text{Annual Generating Power (MWh)}}{\text{Rated Output)MW)} \times 8,760 \text{ hrs}} \times 100$ [%]

b. Plant Thermal Efficiency

i) 200 MW Plants 36.7% (Average of 1990's figures of 8 plants from the power station)

ii) 500 MW Plants 36.1% (Average of 1990's figures of 2 plants from the power station)

c. Minimum Continuous Operation Load

i)	200 MW Plants	140 MW
ii)	500 MW Plants	250 MW

d. Power Plant Periodical Inspection

A 60 days-full-scale inspection is carried out in every four years and a year when there is no full-scale inspection 28 days-simplified inspection is carried out.

e. Rate of Power Plant Failure

Power plant failure of unit No. 1 to No. 8 in recent five years is about 2%.

According to the information from the power station, that of unit No. 9 and No. 10 (500 MW plants) is little bit higher than unit No. 1 to No. 8 (200 MW plants).

Note: Rate of plant failure $= \dfrac{\text{Idle time by failure}}{\text{Operating time + Idle time by failure}} \times 100\ [\%]$

f. SO_2 Emission Amount and Regulation

According to calculations by the power station, emission amounts of SO_2, NO_2 and dust at hourly maximum and average of 5,000 hours operation a year at rated load from 200 MW plants and 500 MW plants are shown in Table 4.3-1.

Maximum SO_2 emission amounts from each 200 MW plant and 500 MW plant at the present are shown below.

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

Kozienice power plant has a obligation to install as DeSOx system by December 31, 1997.

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 which is stricter regulation than previous figure of 14,654 kg/h by December 31, 1997 which is the total value of regulated SO_2 emission from each boiler.

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

i) 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 by December 31, 1991.)

ii) 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.)

Table 4.3-1 Pollutant Emission from the Boilers of Cozienice Power Station

Items		Unit	Emission from Boilers			Emission from Power Station	
			OP-650 (200 MW)	AP-1650 (500 MW)		OP-650 x (8) AP-1650 x (2) 3000 hrs/year	OP-650 x (8) AP-1650 x (2) 5000 hrs/year
				3000 hrs/year	5000 hrs/year		
SO_2	Max.	kg/h	2,035	5,184	5,184	26,648	26,648
	Ave.	kg/h	1,114	1,766	2,957	12,444	14,826
NO_2	Max.	kg/h	640	1,435	1,435	7,990	7,990
	Ave.	kg/h	350	489	818	3,778	4,436
Dust	Max.	kg/h	590	1,504	1,504	7,728	7,728
	Ave.	kg/h	323	512	858	3,608	4,300