renewal of turbines and generators are planned to begin in 1994 for retrofit to cogeneration.

(2) Additional Examination on the Aspect of Technical Comparison

a. The sulfur content of coal for the Melnik Power Station was set to be 1.5% based on past data for this Study. The FGDs of wet type limestone-gypsum method are more flexible and can be upgraded as to their performance with some equipment remodeling even when the regulations become stricter or coal characteristics change in the future.

b. The by-product (gypsum) of the wet type FGD can be utilized more and more as a raw material for boards and cement. All gypsum from Part II was assumed to be disposed as a prerequisite for the method in this Study as in the case of the spray dryer method. There is a possibility, however, of a greater marketability for gypsum in the future, and gypsum from Part II still has a chance for effective utilization.

As for the by-product generated from the spray dryer method, on the other hand, many research and development activities are going on, but there is no promising perspective yet for effective utilization.

4.5.5 Optimum FGDs for Melnik Power Station

According to comprehensive judgment from the results of examinations given above, the best DeSOx method for the Melnik Power Station is the wet type limestone-gypsum method for both Part II and Part III.

Fig. 4.5-9 shows the summarization of evaluation flow till this selection result on the examinations.

Table 4.5-1 (1) Technical Comparison of Various Flue Gas Desulphurisation System (Based on Application to the Melnik P.S.)

	Item	Wet Type		Semi-Dry Type	Dry Type
		Limestone-Gypsum Process			
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray-Dryer Method	(4) Activated Coke Method
1.	SOx Removal Efficiency (Eff. at practical operation range)	90 or more	90 or more	ca. 60 ~ 90	90 or more
2.	Dust Removal Efficiency	ca. 90	ca. 90	ca. 90 (Combination with dust collector after SDA)	ca. 90
3.	Technical Maturity	It has been recognized as a proven technology for commercial use.	Same as the left	Same as the left	Tests in demonstration plants were finished and several commercial plants have been operating.
4.	Operational experience in commercial coal-fired plants	193 Units* Many plants including big scale plants of 350MW, 500MW and 700MW class for coal-fired power plants have been installed and in operation.	25 Units • As of July 1992, there are 25 applications to coal fired power plants. • As the biggest plants in operation, there are two 350MW plants. • A 700MW equivalent plant is currently under construction and the number of units are now 26 units including those under construction.	87 Units* • There are 87 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 Units • There are 3 applications to coal-fired power plants. • The biggest plant currently operation is of 130 MW equivalent. • The low temp. DeNox application, having technical concepts similar to those of dry FGD, is under construction for a 350 MW Fluidized Bed Combustion (FBC) Boiler and its operation is scheduled to start in July 1995.

* Figures in IEA Coal Research, "FGD installations on coal-fired plants" published by IEA in April 1990 (including under construction units as of April 1990).

** For Part II, by product, utilities and waste water are totals four 110 MW units.

Table 4.5-1 (2) Technical Comparison of Various Flue Gas Desulphurisation System (Based on Application to the Melnik P.S.)

	Item	Wet Type		Semi-Dry Type	Dry Type
		Limestone-Gypsum Process			
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray-Dryer Method	(4) Activated Coke Method
5.	Reliability	• It has been recognized as a proven technology. • Reliability is very high.	• It has been recognized as a proven technology. • Reliability is similar to that of spray tower method.	• It has been recognized as a proven technology. • High reliability similar to spray tower method has been recognized.	• It has been recognized as a level of proven technology which can be applied to commercial plant, however operational experience is shorter than those of wet-Limestone/gypsum and spray dryer methods.
6.	Operational Characteristics	Excellent	Excellent	Good (There is a limitation on operation at low flue gas temperature.)	Fair (Warm-up time at start up is rather long. In addition, care must be paid to activated coke which tends to remain in the adsorption tower when the flue gas temperature is high.)
7.	Maintainability	Good	Good	Good	Good
8.	By-Product	Marketable gypsum obtained is about 15.3 ton/h (3.8 ton/h x 4 units) at Part II and about 26.0 ton/h at Part III, which amounts to about 170,000 ton per year. The construction of a gypsum board factory is being planned near the Melnik Power Station. In the comparison, it was assumed that about 92,000 tons of gypsum from Part III is used at the factory every year from 1996 and about 78,000 tons of gypsum from Part II is to be disposed at the ash disposal area every year, for the time being, without having no useful ways to use.		Sulphurous gypsum + Fly ash + slaked line Studies are uner way to utilize the byproduct. For the purpose of comparison for the Melnik Power Station, it is assumed that the byproduct is disposed to the disposal area.	Sulphuric acid For the purpose of comparison for the Melnik P.S., it is assumed that the byproduct is recovered in the form of sulphuric acid.

Table 4.5-1 (3) Technical Comparison of Various Flue Gas Desulphurisation System (Based on Application to the Melnik P.S.)

		Wet Type		Semi-Dry Type	Dry Type
		Limestone-Gypsum Process			
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray-Dryer Method	(4) Activated Coke Method
9.	Utility				
	(1) Absorbent or Adsorbent	Limestone ($CaCO_3$)	Limestone ($CaCO_3$)	Lime [CaO]	Activated Coke
		• About 9.2 t/h and 12.2 t/h of limestone is required for Part II and Part III, respectively. Limestone is domestically available to purchase.	Same as the left	• About 7.8 t/h and 10.4 t/h of lime is required for Part II and Part III, respectively. Lime is domestically available.	• About 1.2 t/h and 1.6 t/h of activated coke is required for Part II and Part III, respectively (Annual requirement is about 12,900 t.) Activated coke of that amount is not currently available in Czechoslovakia, and all requirement must be imported from Germany.
	(2) Water (from the Labe River)	Part II 113 t/h Part III 102 t/h	Same as the left	Part II 106 t/h Part III 107 t/h	Part II 2.6 t/h Part III 3.4 t/h
	(3) Steam	Part II 6 t/h Part III 3 t/h	Same as the left	-	Part II 0.5 t/h Part III 0.5 t/h
	(4) Electricity	Part II ca.6,000 kW Part III ca.6,800 kW	Part II ca.6,500 kW Part III ca.7,600 kW	Part II ca.6,000 kW Part III ca.7,300 kW	Part II ca.5,100 kW Part III ca.6,600 kW
10.	Waste Water	Part II ca.4 t/h Part III ca.5 t/h	Same as the left. Same as the left	None	ca.8 t/h

Table 4.5-1 (4) Technical Comparison of Various Flue Gas Desulphurisation System (Based on Application to the Melnik P.S.)

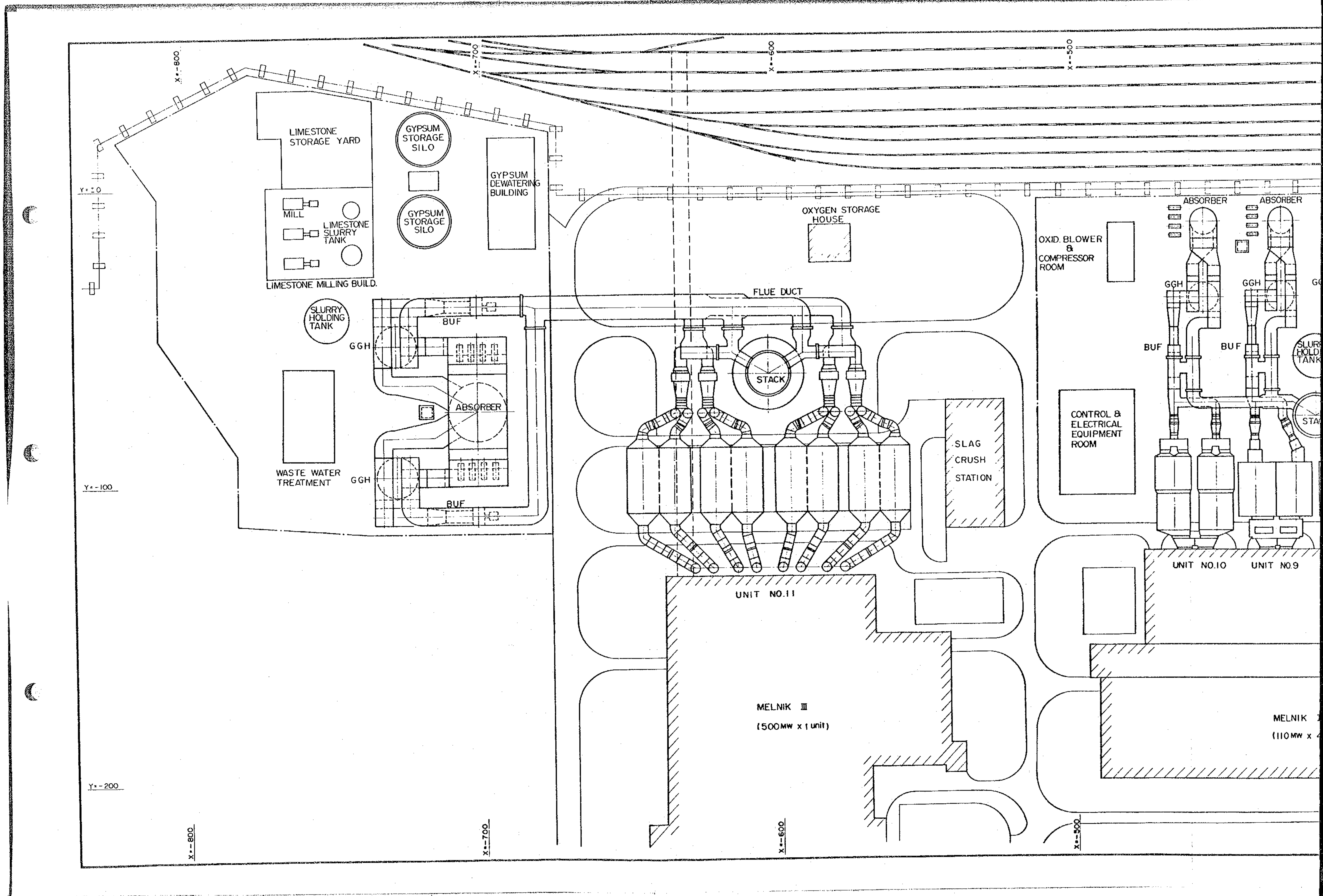
Item		Wet Type		Semi-Dry Type	Dry Type
		Limestone-Gypsum Process			
		(1) Spray Tower Method	(2) Jet-Bubbling Method	(3) Spray-Dryer Method	(4) Activated Coke Method
11.	Stack Lining or Flue Gas Reheating	Required	Required	Not necessary	Not necessary
12.	Retrofit of Existing Facilities	• Retrofit of duct between IDF outlet and stack inlet. ∘ Other small items	Same as the left	Same as the left	Same as the left
13.	Installation Space	Part II: FGD can be installed by removing the coal train defreezing tunnel and the warehouse. Part III: FGD can be installed in a space available for FGD installation.	Same as the left	Same as the left	Same as the left
14.	Overall Evaluation	Applicable	Applicable	Applicable	Difficulty is apprehended in supply of activated coke.

Table 4.5-2 (1/2) Cost Comparison of Various Flue Gas Desulphurisation System (Based on Application to Melnik P.S. Part II)

	Item	Wet Type		Semi-Dry Type	Dry Type	Remarks
		Limestone-Gypsum Process		Spray Dryer Method	Activated Carbon Method	
		Spray Tower Method	Jet-Bubbling Method			
1.	Estimated Conditions					
	Reheat & Stack Lining	Yes	Yes	None	None	
	By-products Recovery	[None]	[None]	None	Yes	[None] shows the remaining some possibility of By-products Recovery.
	Groundwater Protection Measures at Ash Pond	Yes	Yes	Yes	None	
	Ratio of Treated Gas Flow	82.5% (78%)	82.5% (78%)	82.5%	82.5%	Figure in ( ) shows the value with the consideration of GGH leakage.
	SOx Removal Efficiency in Reactor	85% (90%)	85% (90%)	85%	85%	
	Total SOx Removal Efficiency	70%	70%	70%	70%	
	DeSOx Plant Size	110MW x 4	110MW x 4	110MW x 4	110MW x 4	
2.	Capital Cost Annual Payment for Investment	100% (Base)	102%	87%	118%	Annual Payment for Investment (A) = Investment x Levelizing Factor
3.	Running Cost Annual Running Cost	100% (Base) (176)	104% (180)	193% (399)	734% (727)	Annual Running Cost (B) = Running Cost - By-products Sale. Figure in ( ) is based on the assumption of absorbent price corrected by the international market price.
	Total Annual Cost	100% (Base) (100)	102% (102)	96% (107)	171% (160)	Total Annual Cost = A + B

Table 4.5-2 (2/2) Cost Comparison of Various Flue Gas Desulphurisation System (Based on Application to Melnik P.S. Part III)

	Item	Wet Type		Semi-Dry Type	Dry Type	Remarks	
		Limestone-Gypsum Process					
		Spray Tower Method	Jet-Bubbling Method	Spray Dryer Method	Activated Carbon Method		
1.	Estimated Conditions						
	Reheat & Stack Lining	Yes	Yes	None	None		
	By-products Recovery	Yes	Yes	None	Yes		
	Groundwater Protection Measures at Ash Pond	Yes	Yes	Yes	None		
	SOx Removal Efficiency	85%	85%	85%	85%	100% Treated Gas Flow	
	DeSOx Plant Size	500MW × 1	500MW × 1	500MW × 1	500MW × 1		
2.	Capital Cost					Annual Payment for Investment (A) = Investment × Levelizing Factor	
	Annual Payment for Investment	100% (Base)	101%	89%	119%		
3.	Running Cost						
	Annual Running Cost	100% (Base) (241)	108% (248)	332% (711)	1,325% (1,327)	Annual Running Cost (B) = Running Cost - By-products Sale	Figure in ( ) is based on the assuption of absorbent price corrected by the international market price.
	Total Annual Cost	100% (Base) (100)	101% (101)	102% (114)	186% (172)	Total Annual Cost = A + B	


X=-800
X=-700
X=-600
X=-500
Y=0
Y=-100
Y=-200
LIMESTONE STORAGE YARD
GYPSUM STORAGE SILO
GYPSUM STORAGE SILO
GYPSUM DEWATERING BUILDING
MILL
LIMESTONE SLURRY TANK
LIMESTONE MILLING BUILD.
OXYGEN STORAGE HOUSE
ABSORBER
ABSORBER
OXID. BLOWER & COMPRESSOR ROOM
GGH
GGH
FLUE DUCT
SLURRY HOLDING TANK
BUF
GGH
STACK
BUF
BUF
ABSORBER
CONTROL & ELECTRICAL EQUIPMENT ROOM
WASTE WATER TREATMENT
GGH
SLAG CRUSH STATION
BUF
UNIT NO.10
UNIT NO.9
UNIT NO.11
MELNIK III
(500MW x 1 unit)
MELNIK
(110MW x

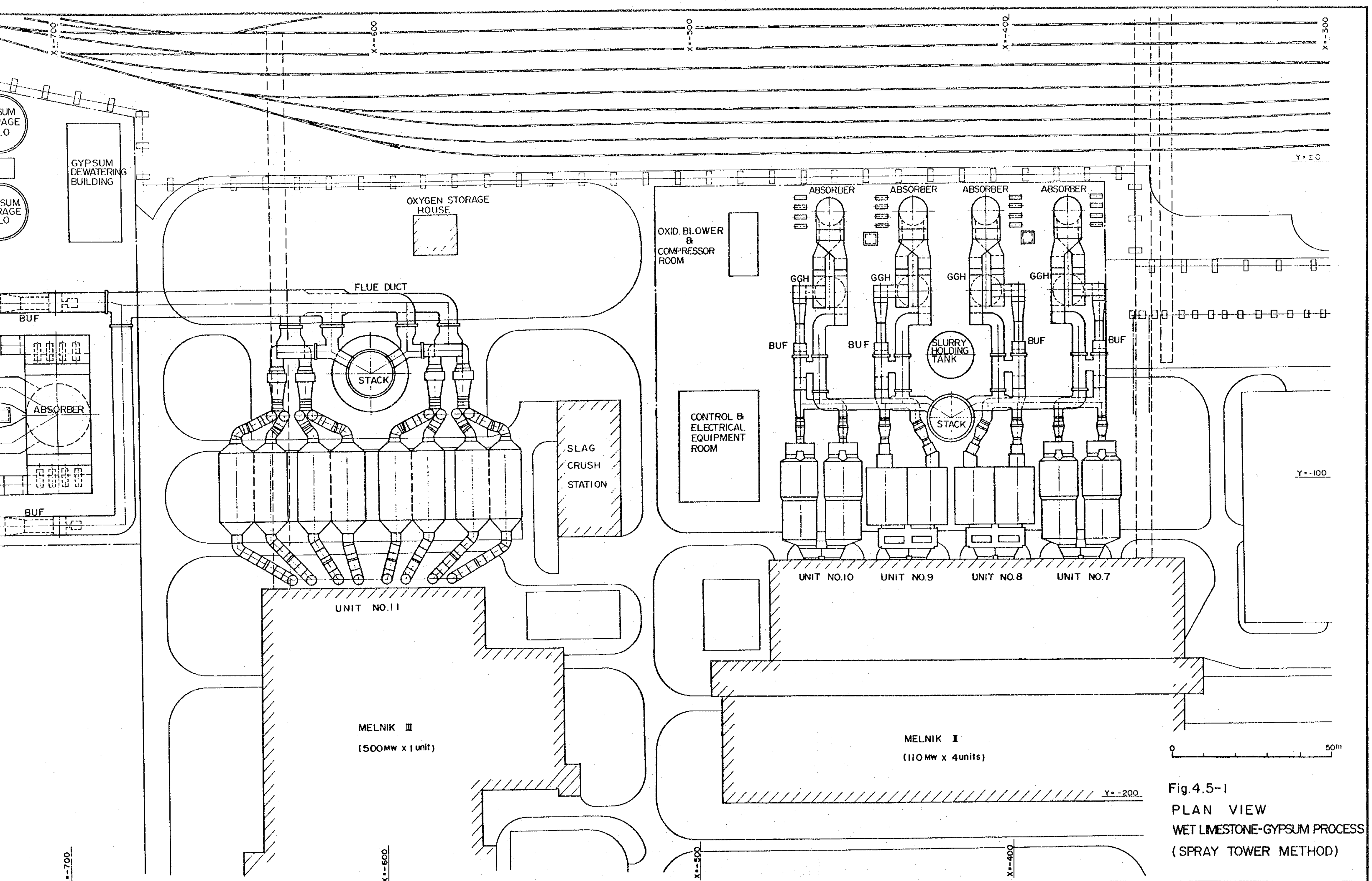
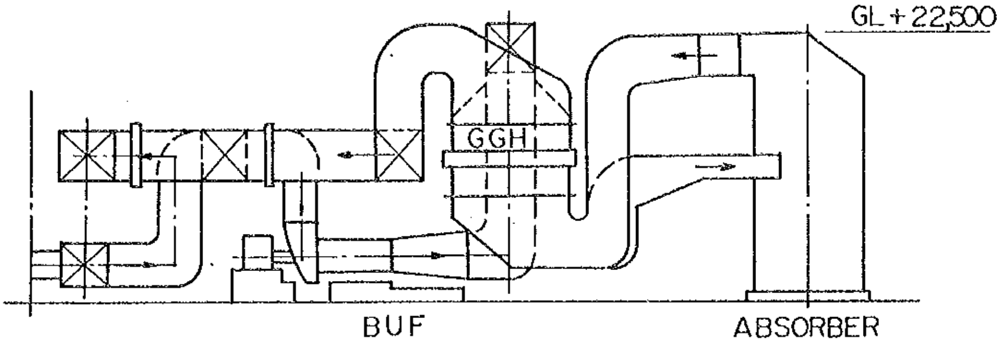
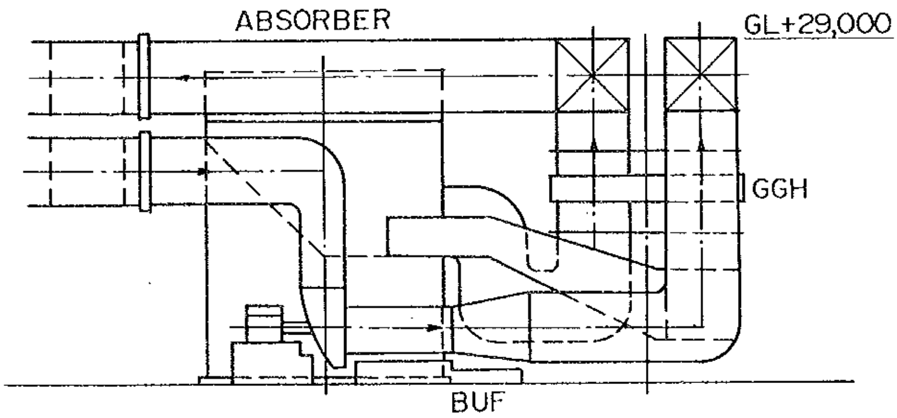


Fig.4.5-1
PLAN VIEW
WET LIMESTONE-GYPSUM PROCESS
(SPRAY TOWER METHOD)

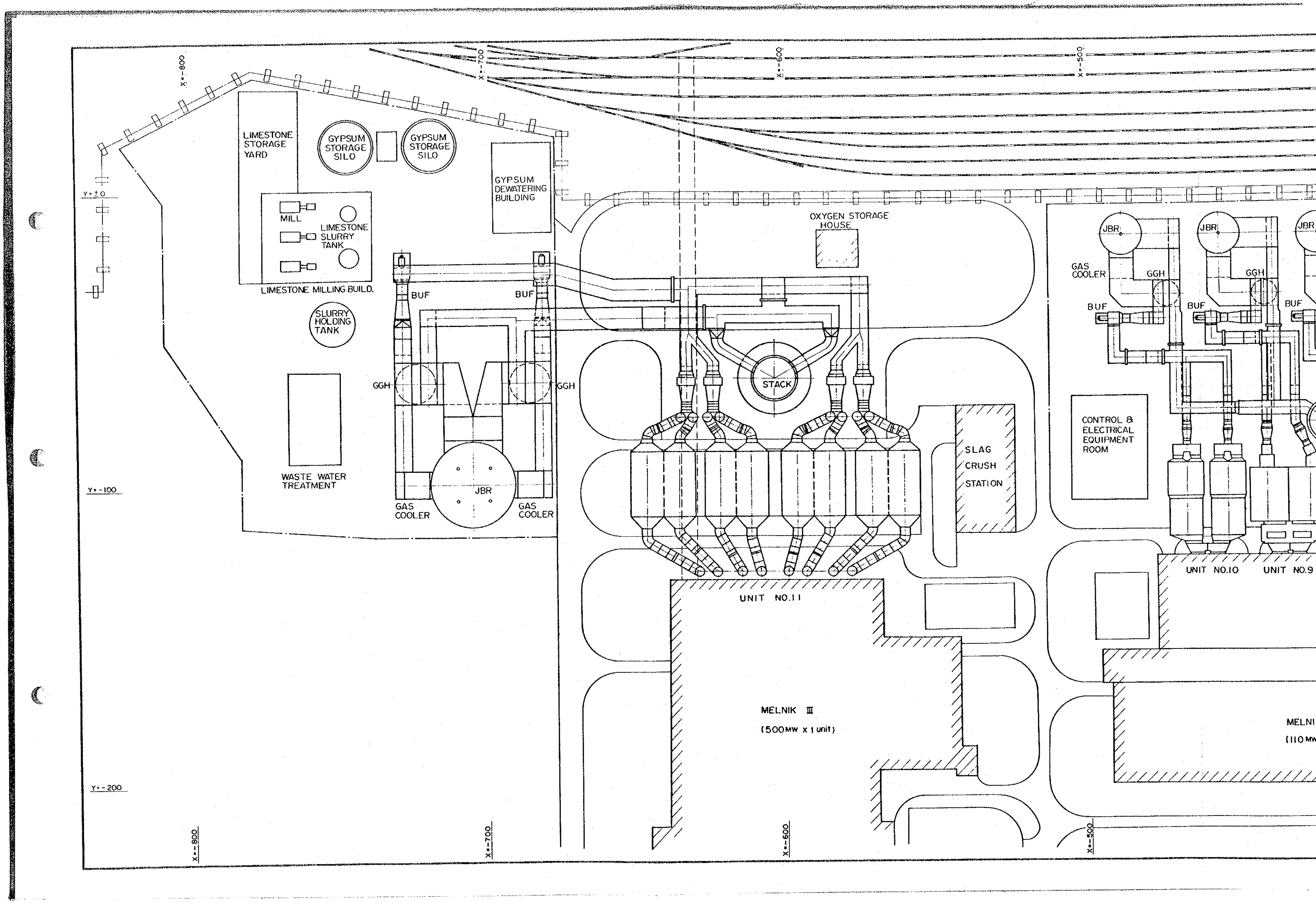


PART Ⅱ



PART Ⅲ

Fig. 4.5-2 SIDE VIEW
(SPRAY TOWER METHOD)



X=-800
X=-700
X=-600
X=-500
Y=±0
Y=-100
Y=-200
LIMESTONE STORAGE YARD
GYPSUM STORAGE SILO
GYPSUM STORAGE SILO
GYPSUM DEWATERING BUILDING
MILL
LIMESTONE SLURRY TANK
LIMESTONE MILLING BUILD.
SLURRY HOLDING TANK
WASTE WATER TREATMENT
BUF
BUF
GGH
GGH
JBR
GAS COOLER
GAS COOLER
OXYGEN STORAGE HOUSE
STACK
SLAG CRUSH STATION
UNIT NO.11
MELNIK III
(500MW x 1 unit)
JBR
JBR
JBR
GAS COOLER
GGH
GGH
BUF
BUF
BUF
CONTROL & ELECTRICAL EQUIPMENT ROOM
UNIT NO.10
UNIT NO.9
MELNI
(110 MW

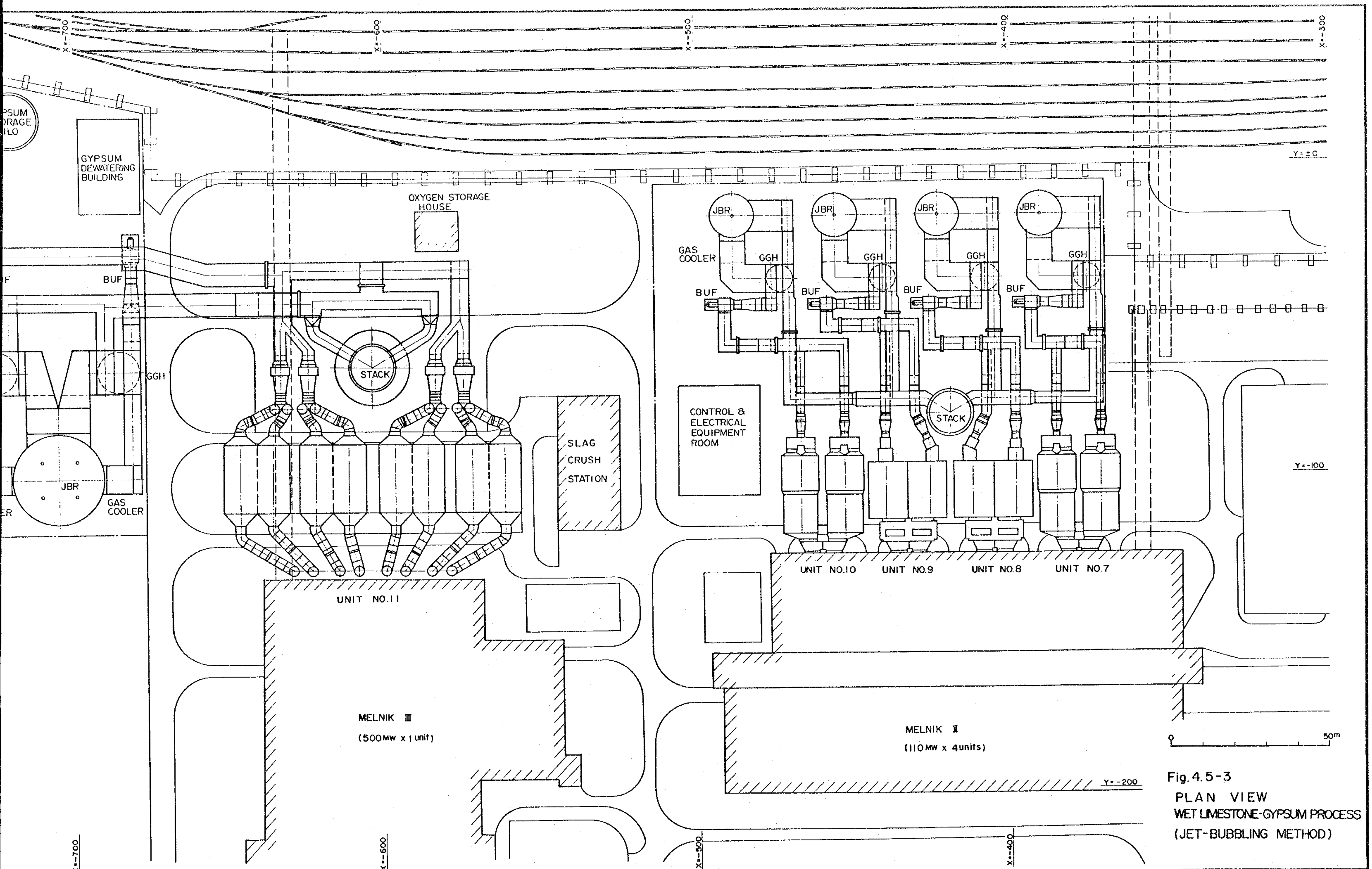
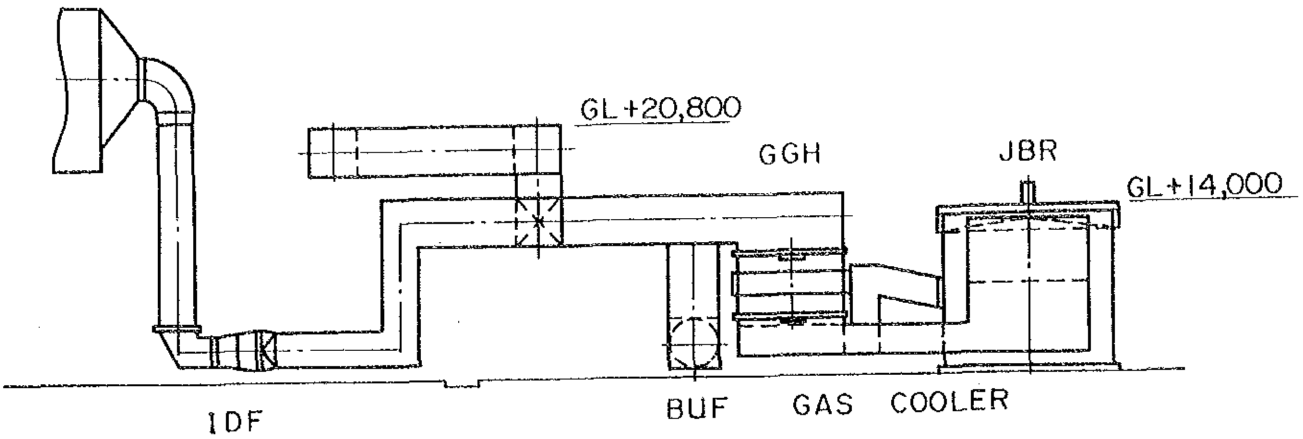
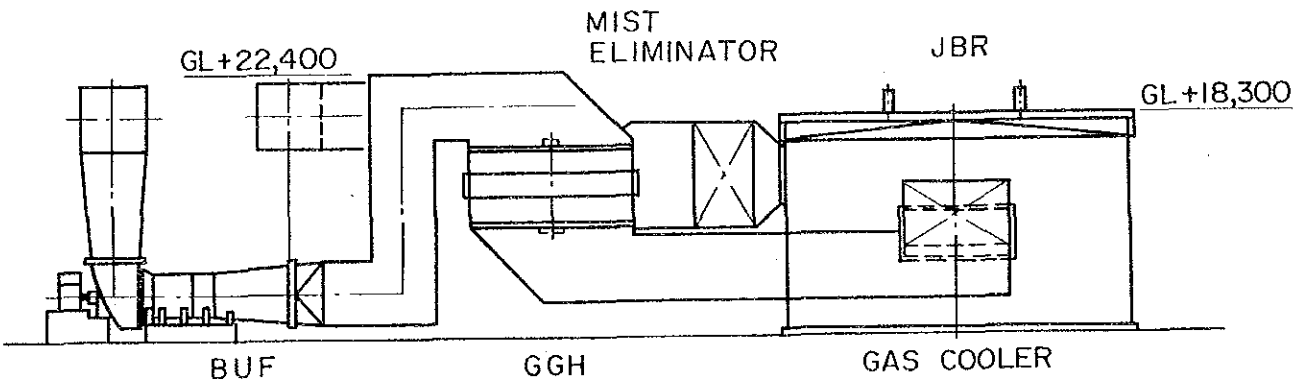


Fig. 4.5-3
PLAN VIEW
WET LIMESTONE-GYPSUM PROCESS
(JET-BUBBLING METHOD)



PART II



PART III

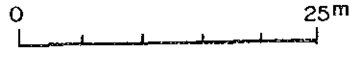
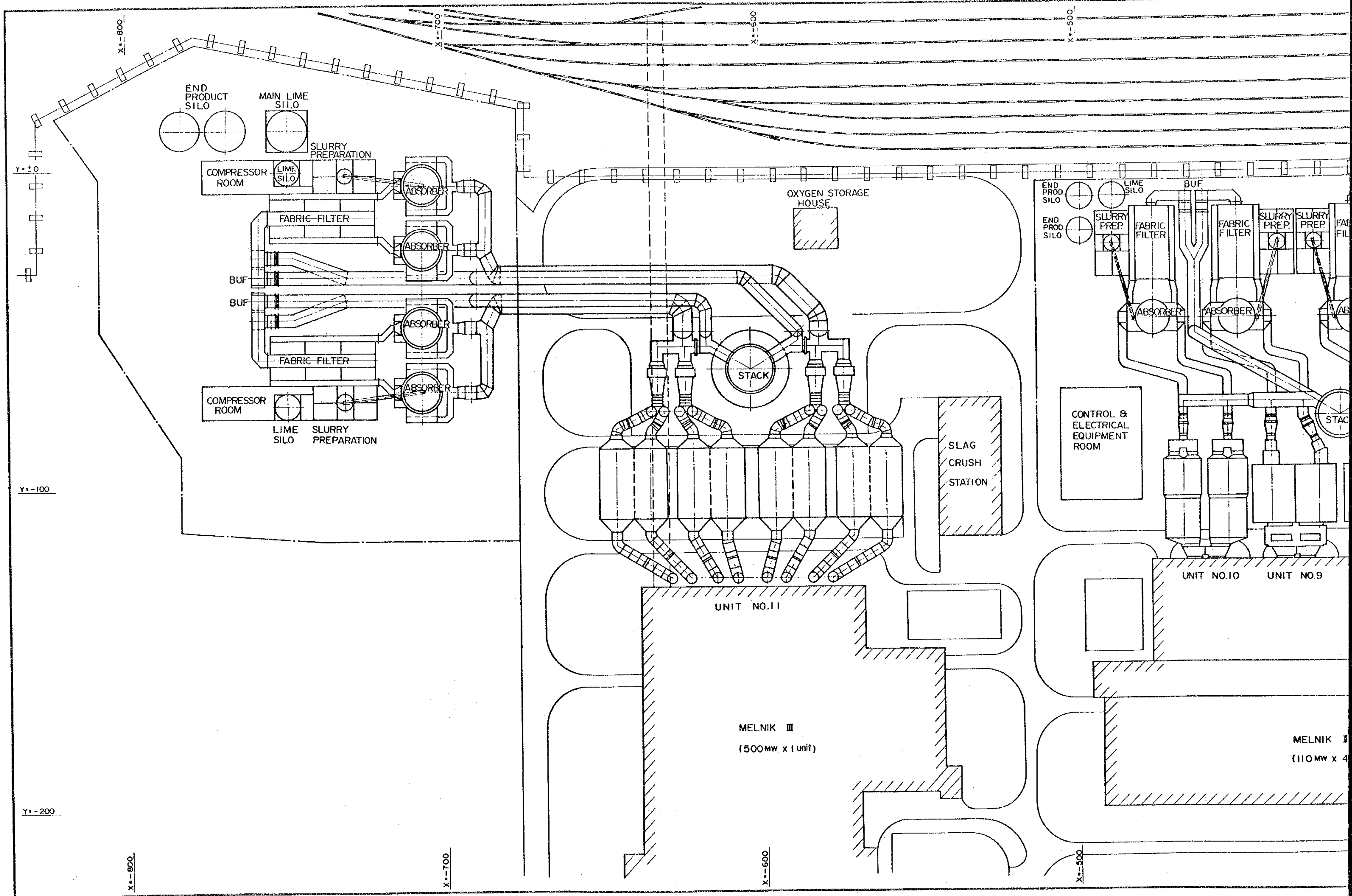


Fig. 4.5-4 SIDE VIEW
(JET BUBBLING METHOD)



X=-800
X=-700
X=-600
X=-500
Y=±0
Y=-100
Y=-200
END PRODUCT SILO
MAIN LIME SILO
SLURRY PREPARATION
COMPRESSOR ROOM
LIME SILO
ABSORBER
FABRIC FILTER
BUF
LIME SILO
SLURRY PREPARATION
OXYGEN STORAGE HOUSE
STACK
SLAG CRUSH STATION
UNIT NO.11
MELNIK III
(500MW x 1 unit)
END PROD. SILO
LIME SILO
SLURRY PREP.
FABRIC FILTER
CONTROL & ELECTRICAL EQUIPMENT ROOM
UNIT NO.10
UNIT NO.9

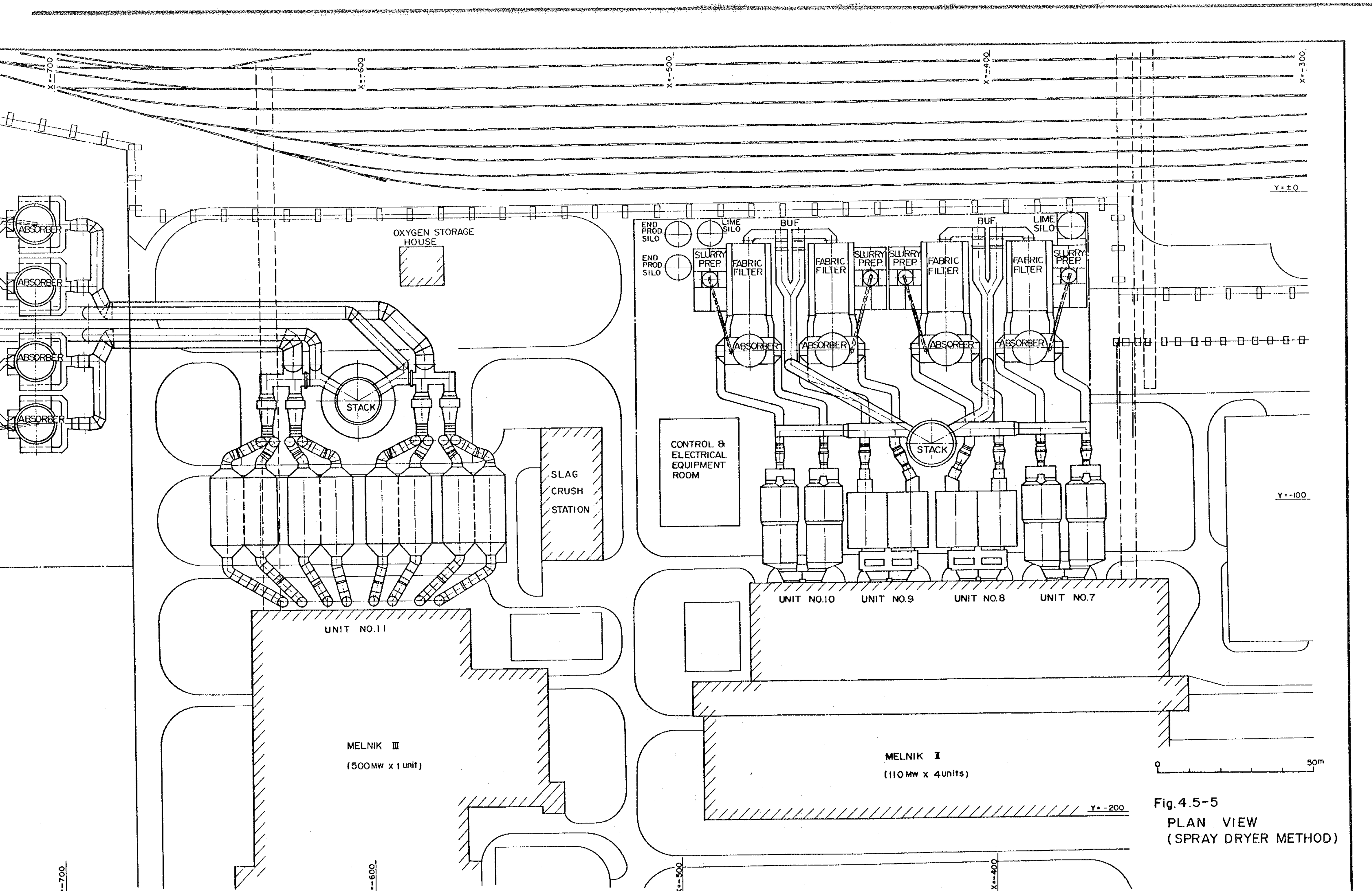
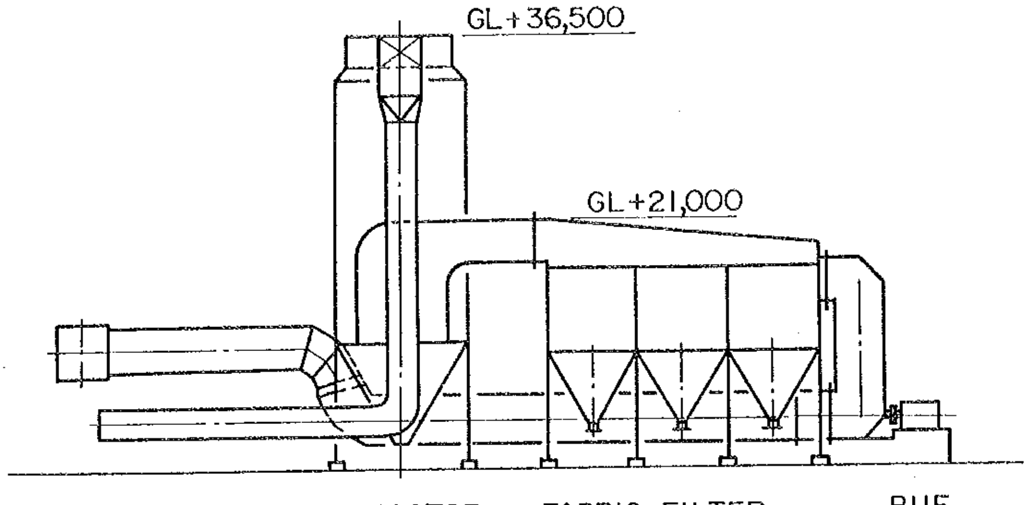
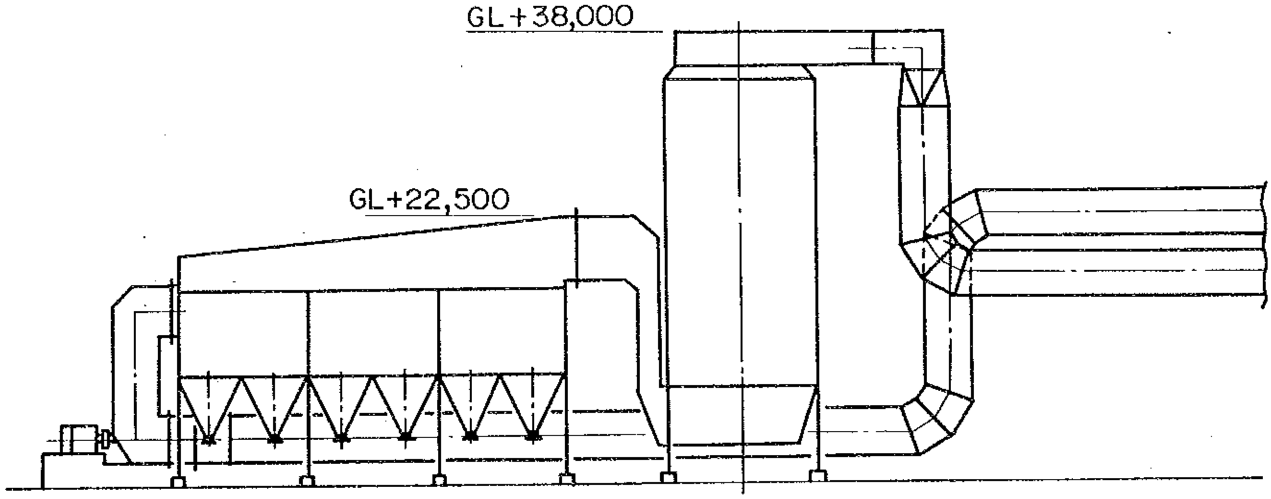


Fig.4.5-5
PLAN VIEW
(SPRAY DRYER METHOD)



PART II



PART III

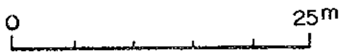
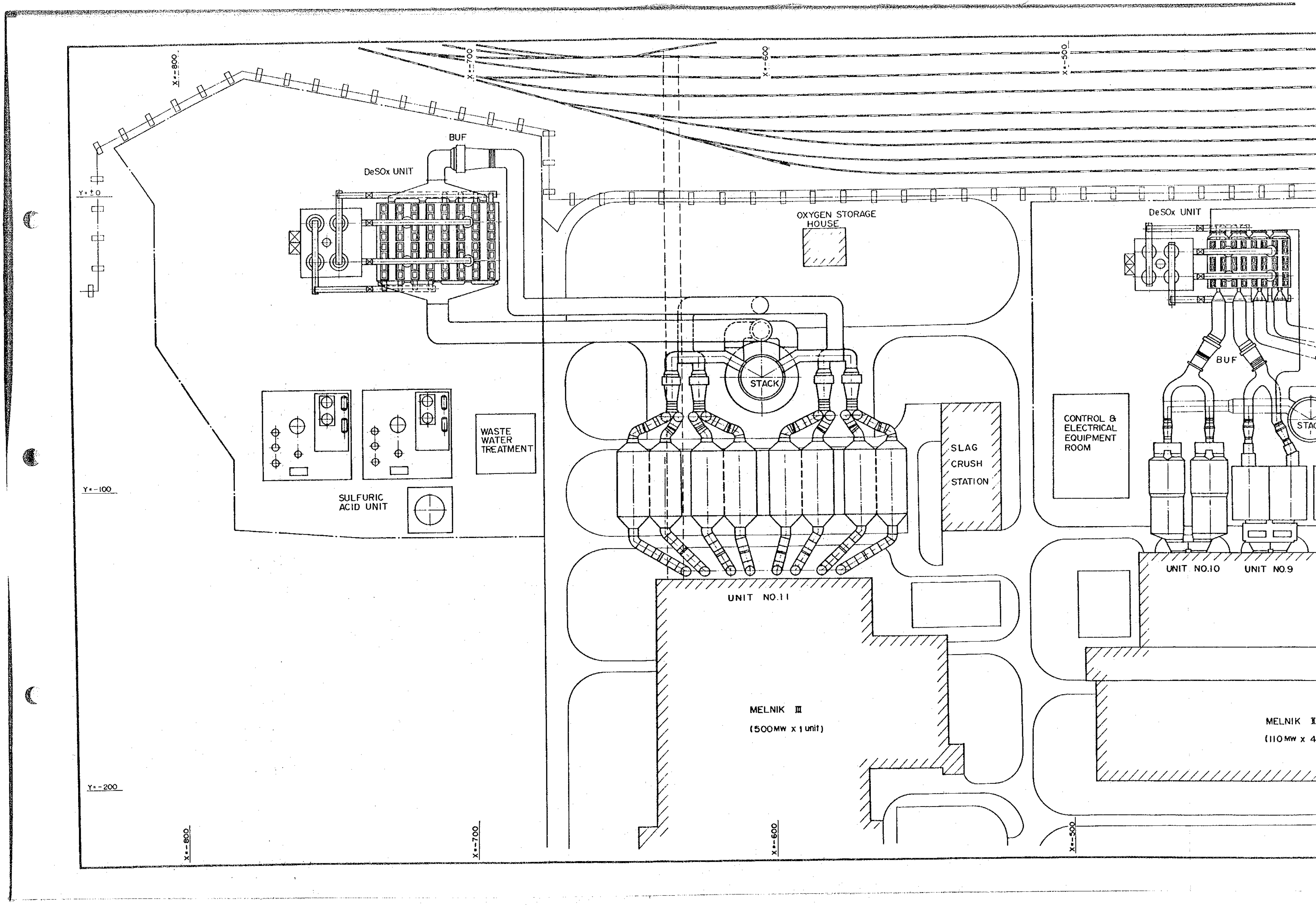


Fig 4.5-6 SIDE VIEW

(SPRAY DRYER METHOD)


X=-800
X=-700
X=-600
X=-500
Y=±0
Y=-100
Y=-200
BUF
DeSOx UNIT
OXYGEN STORAGE HOUSE
STACK
WASTE WATER TREATMENT
SULFURIC ACID UNIT
SLAG CRUSH STATION
CONTROL & ELECTRICAL EQUIPMENT ROOM
UNIT NO.11
UNIT NO.10
UNIT NO.9
MELNIK III
(500MW x 1 unit)
MELNIK

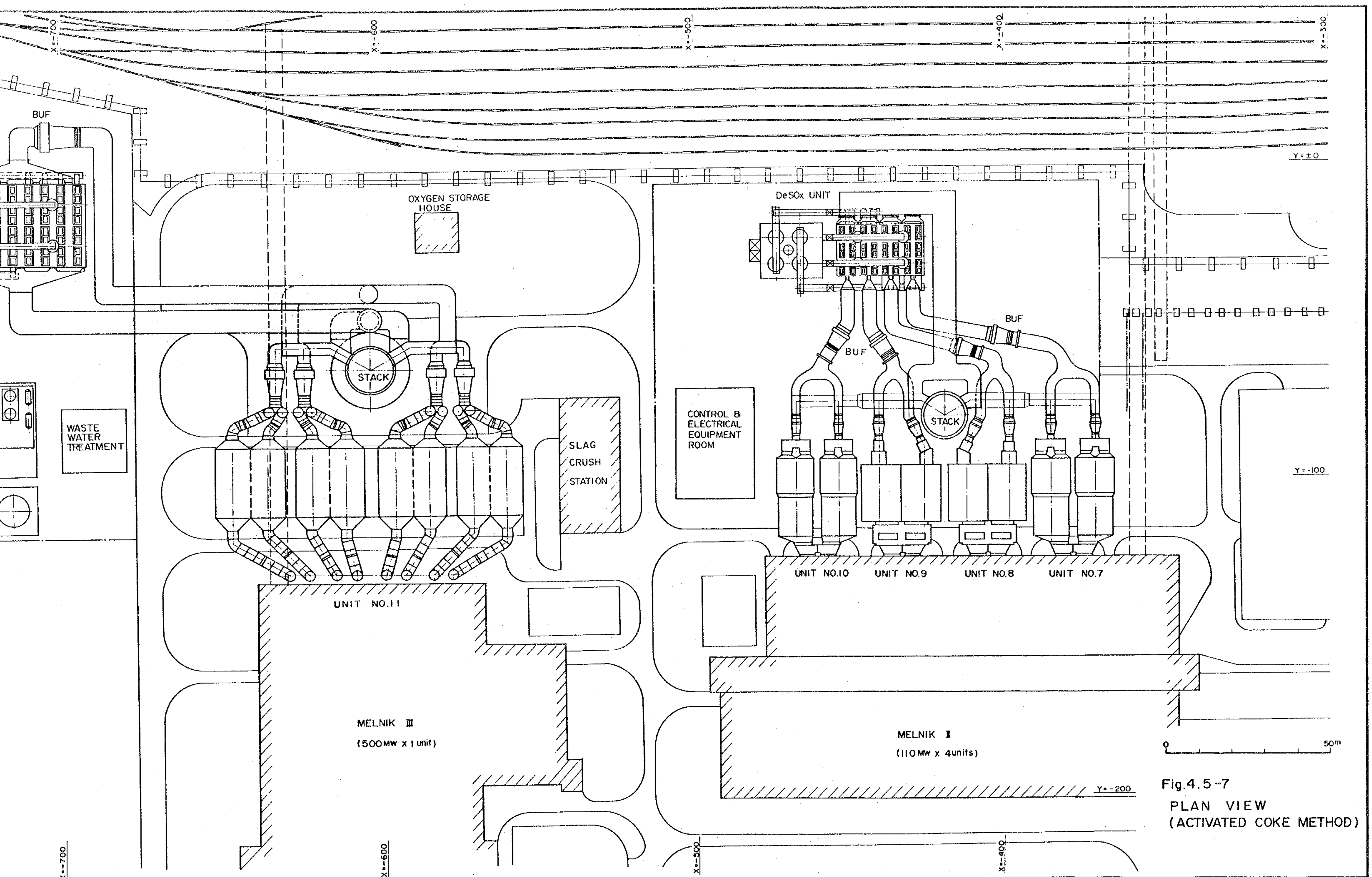


Fig.4.5-7
PLAN VIEW
(ACTIVATED COKE METHOD)

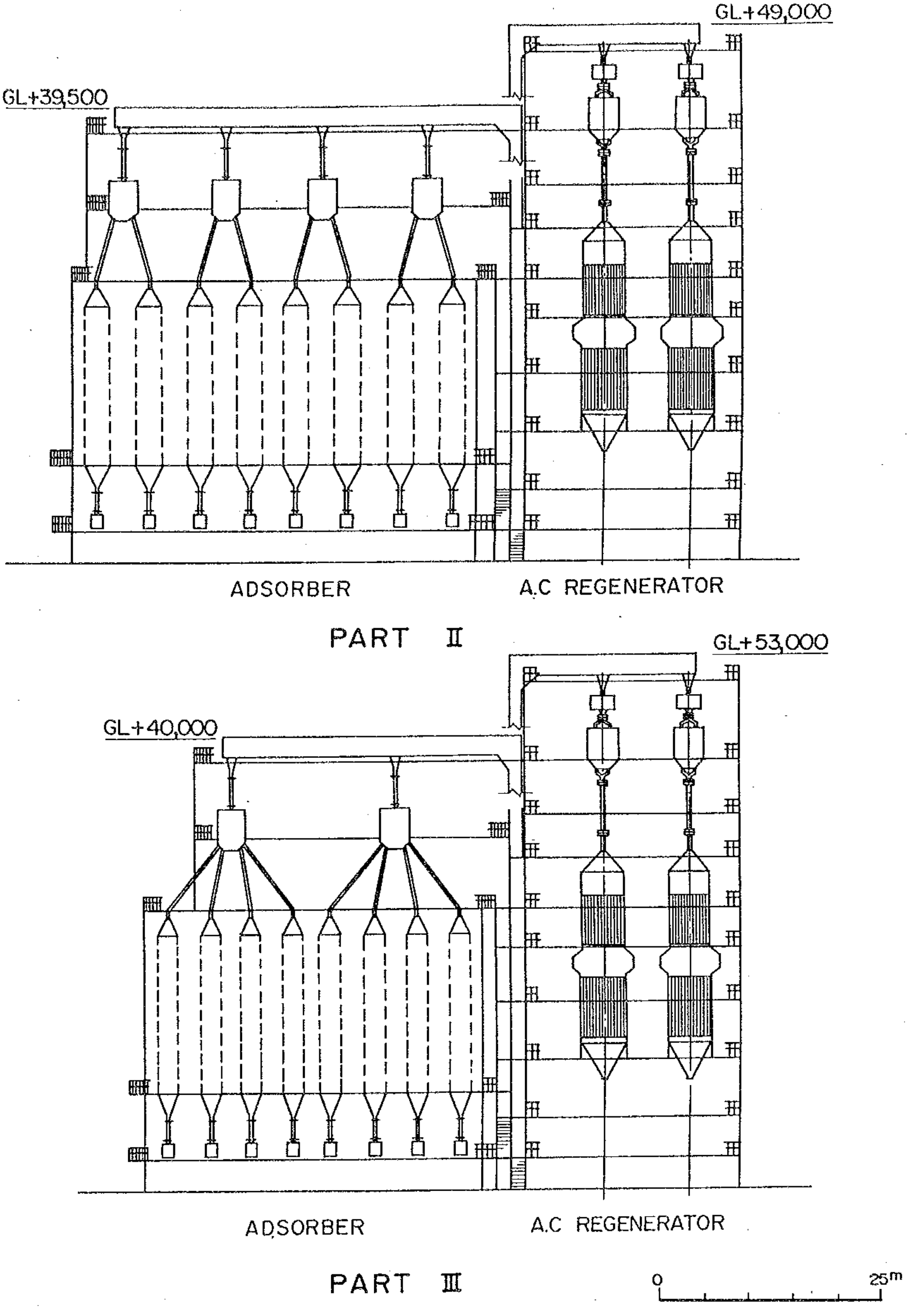
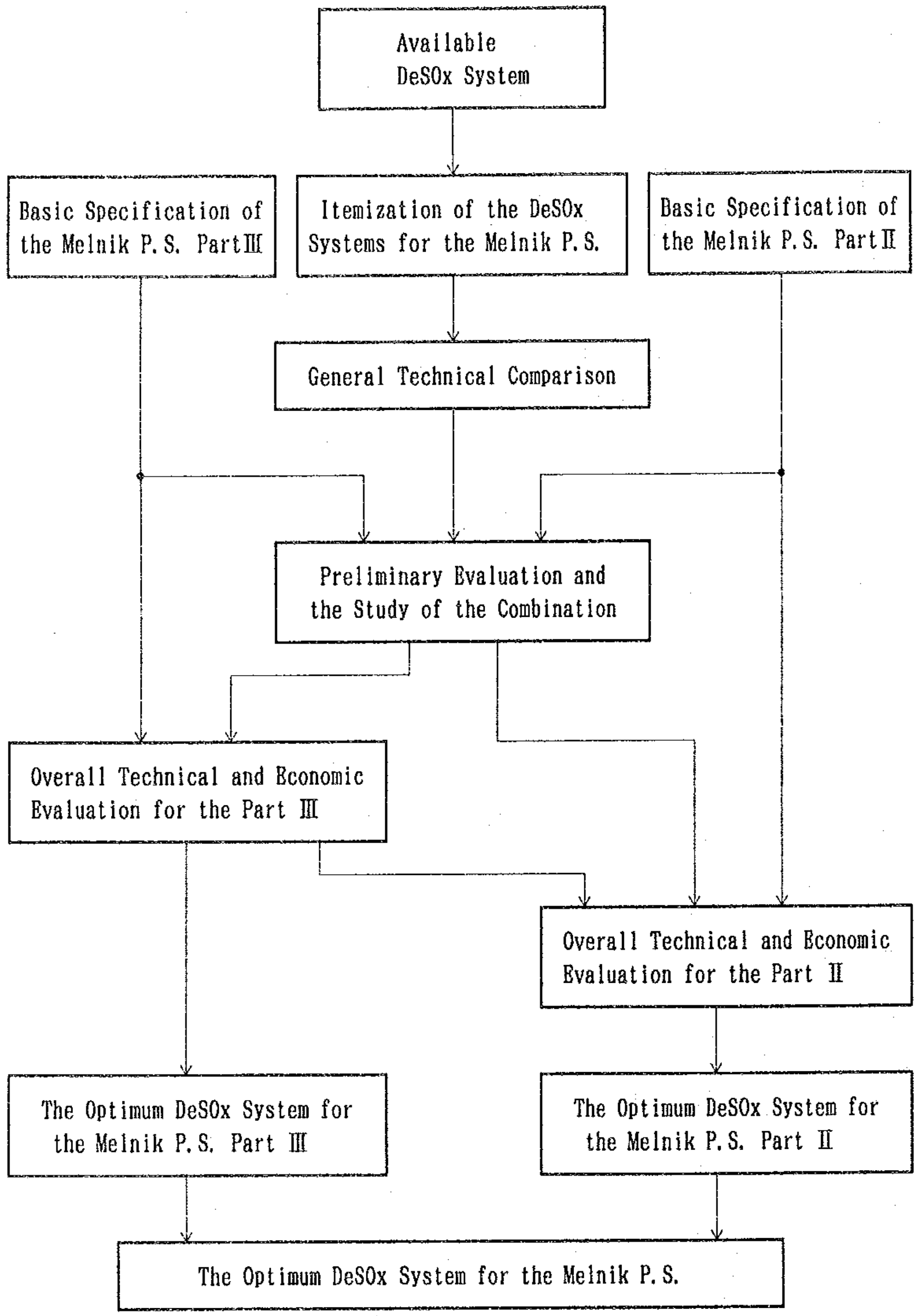


Fig. 4.5-8 SIDE VIEW
(ACTIVATED COKE METHOD)



Evaluation (Summarized Table)	FGD Method					
Article 4.2	Limestone-Gypsum Method (Spray Tower & JBR)	Spray-Dryer Method	Activated Coke Method (Regenerable)	Limestone Injection into Furnace Method	Slaked Lime Injection into Fluegas Duct	Electron Beam Method
Table 4.2-1	↓	↓	↓	↓	↓	
	○	○	○	○	○	
Article 4.4	↓	↓	↓			
	○	○	○			
Table 4.5-1 Table 4.5-2(2) Table 4.5-1 Table 4.5-2(1)	↓	↓				
	○	○				
Article 4.5-4	↓					
	○					
Article 4.5-5	○					

Fig. 4.5-9 Summarization of Evaluation Flow

4.6 Results of Selection for the Optimum FGDs

4.6.1 FGD Method and Number of Units to be Installed

(1) Optimum FGD Method

According to the results of examinations given in Section 4.5, it is concluded that optimum FGD method for the Melnik Power Station is the wet type limestone-gypsum method for both Part II and Part III.

The wet type limestone-gypsum method has its two varieties of the spraying tower method and jet bubbling method. Differences are little between such two methods in technical and economic comparisons, and either method can be applicable to the Melnik Power Station.

The two wet methods are different only in the way how the flue gas and the absorbent liquid come into contact for absorption of SO_2. In the spraying tower method, the absorbent liquid is sprayed using slurry circulation pumps for that purpose, while, in the jet bubbling method, the flue gas is injected into the absorbent liquid in absorbing tower using DeSOx fans.

(2) Combinations of FGDs

Conclusions reached as to optimum combinations of power plants and FGDs are as follows:

For Part II:

To install one FGD unit, of 82.5% in flue gas treatment rate and 85% in deSOx efficiency (taking into account the flue gas leakage to by-pass line, 80% in flue gas treatment rate and 87.5% in deSOx efficiency is considered) and 70% in total deSOx efficiency, to each of the 110 MW power units

For Part III:

To install one wet type limestone-gypsum FGD unit, of entire flue gas treatment and 85% in total deSOx efficiency, to the 500 MW power unit

In other words, the conclusion is that it is the best, for the power plants of 940 MW in total, to install one 500 MW equivalent FGD of 85% in total deSOx efficiency for the 500 MW power plant and four 110 MW equivalent FGDs of 70% in total deSOx efficiency for the 440 MW power plant.

4.6.2 Conceptual Design Specifications

The conclusion reached by technical and economic examinations is that either the spraying tower method or the jet bubbling method is applicable to both Part II and Part III. For the purpose of this Study, however, the spraying tower method is selected for conceptual design on the ground that the method has been employed for a greater number of power plants and has much operational experiences.

Specifications for conceptual design of FGD units to be carried out in the Second Stage Study are as follows:

(1) Part II

a.	FGD method	Wet type limestone-gypsum process - spraying tower method
b.	Treatment capacity and number of units	88 MW (110 MW x 80%) equivalent FGD, 4 units
c.	Combination	One FGD unit for each of Unit Nos. 7, 8, 9 and 10
d.	DeSOx efficiency	More than 70%
e.	Handling of by-product	To be disposed to the disposal area
f.	Flue gas reheating	To be reheated
g.	Layout plan	See Fig. 4.5-1.

(2) Part III

a. FGD method	Wet type limestone-gypsum process - spraying tower method
b. Treatment capacity and number of units	500 MW class FGD, 1 unit
c. DeSOx efficiency	More than 85%
d. Handling of by-product	To be supplied to a nearby gypsum board factory
e. Flue gas reheating	To be reheated
f. Layout plan	See Fig. 4.5-1.

4.6.3 Handling of By-product and Waste Water

The coal used at the Melnik Power Station is high in chlorine and fluorine contents. The chlorine content is 0.015% (as dry base) at maximum, and the fluorine content is 0.076% (as dry base) at maximum. The hydrogen chloride (HCl) and hydrogen fluoride (HF) concentrations in flue gas estimated from these values are 24.8 and 121.3 mg/m^3N (as O_2 = 6% & dry base), respectively. The volume of waste water (including that contained in gypsum) to be treated, derived for maintaining the chlorine concentration in the FGD system at 10,000 mg/ℓ for prevention of corrosion is about 4 t/h for Part II and 5 t/h for Part III.

4.6.4 By-product Disposal Area

The current ash disposal area nearby the Power Station will be full in 1998, and, to install FGDs as a measure for SOx emission reduction from 1996, it becomes necessary to construct a by-product disposal area before preparing another ash disposal area.

The by-product disposal area must have a in-permeable construction to prevent chlorine and fluorine components of by-product from getting out of the disposal area. The by-product disposal area, in addition, must have a "management type" pool to retain water from the disposal area. Water-shielding sheet will be used for making the disposal area in-permeable, but it should be planned to apply the water-shielding sheet only to a minimum possible part of the disposal area necessary for the period during which the by-product stabilizes.

As for making other part non-permeable, tests shall be conducted in reference to reports saying that the by-product itself shows a high non-permeable character once it gets stable. Other parts of the disposal area can be made into a non-permeable construction using such by-product if the by-product of the Melnik Power Station shows a high non-permeable character in such tests. The ash disposal area currently in use is scheduled to be full in 1998, and it will be necessary to prepare a new ash disposal area for further disposal. It is therefore necessary to plan a by-product disposal area in good coordination with the plan for the current and new ash disposal areas.

Chapter 5 Environmental Assessment

CHAPTER 5 ENVIRONMENTAL ASSESSMENT

Contents

List of Tables

List of Figures

Chapter 5 Environmental Assessment

5.1 Environmental Assessment Method

Environmental effects by the FGDs contribution are estimated in this chapter, by the method of environmental assessment, based on the "Selection of Optimum FGD System" to be employed at the Melnik Power Station as a measure for reduction of sulfur oxides emitted from the plants. In addition, effects of the FGDs on natural and living environment are evaluated by analyzing and comparing environmental values before installation of FGDs, environmental standards and estimated environmental values after installation of FGDs.

The methodology for environmental impact assessment is shown in Fig. 5.1-1.

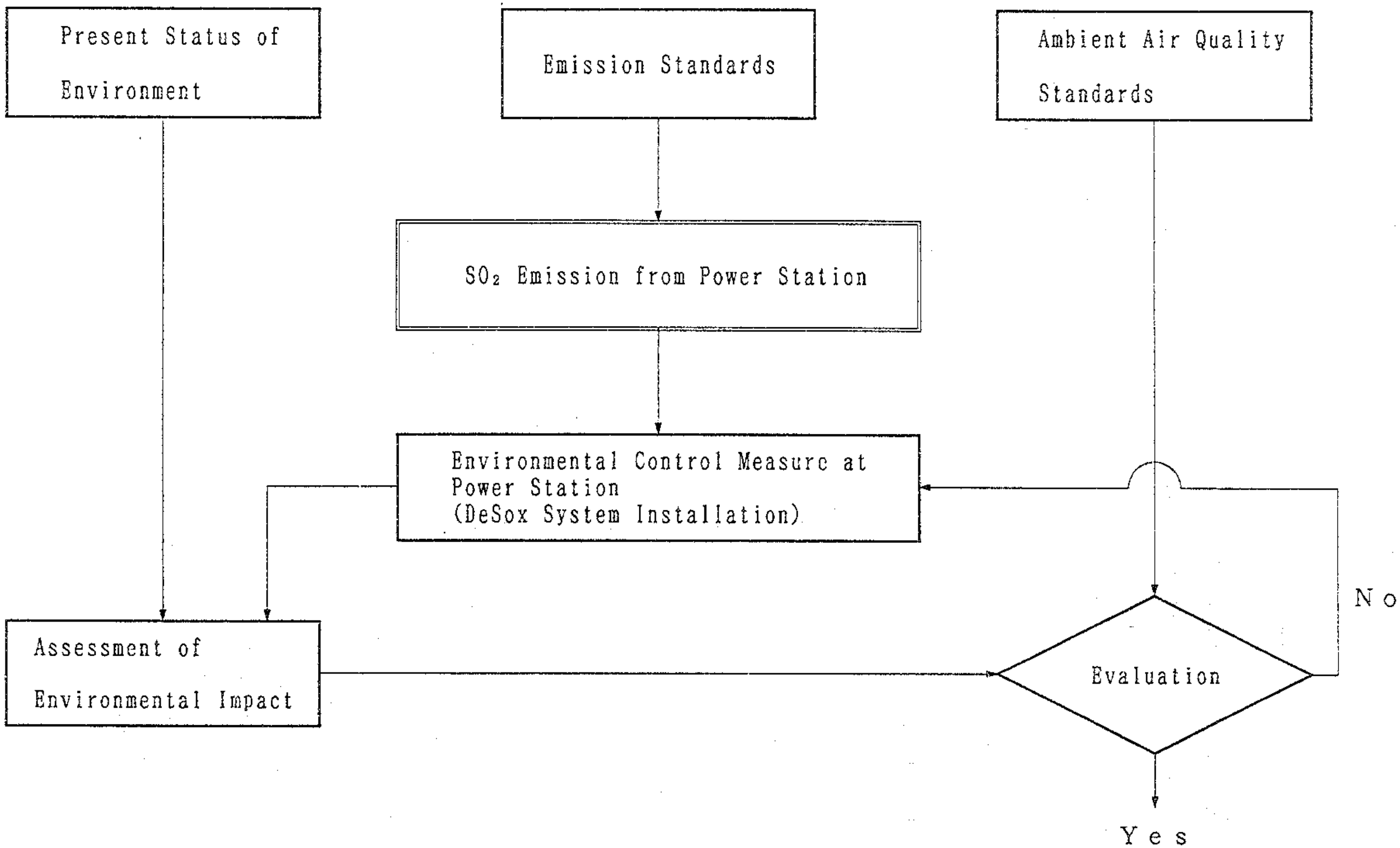


Fig. 5.1-1 METHODOLOGY FOR EMVIRONMENTAL IMPACT ASSESSMENT

5.2 Basic Data

Pollutants emitted to the ambient air from a source are mixed, diluted and transferred, before reaching the ground, through diffusions which depend on the weather and the topography of the area. It is therefore necessary to collect and analyze the basic data itemized below for prediction and evaluation of the air pollution. Such data were collected during the site survey.

(1) Data on the Source of Pollution

1) Location of the source

2) Kinds and amounts of pollutants

3) Discharging conditions (stack height and inner diameter, exhaust gas temperature, discharging rate, etc.)

(2) Data on the Weather

1) Wind directions and speeds

2) Vertical distribution of atmospheric temperature

Detailed weather data are very important for estimation of diffusion of air pollution. Weather data (1984 ~ 1990) around the Melnik Power Station obtained during the survey were only those collected at one observatory in Tisice (about 17 km southeast of the Power Plant). The weather data are scarce in frequency of observation (3 hours of observation a day), and problems remain as to the accuracy of data analysis. No upper air data were available, and they were estimated from ground air data to use them for estimation.

Data of atmospheric temperature, precipitation and wind direction and speed are shown in Table 3.3-1 and Fig. 3.3-1, Table 3.3-1 and Fig. 3-3-3 and Table 3.3-2 and Fig. 3.3-4, respectively.

(3) Current State of air Pollution Around the Power Station

The state of air pollution around the Melnik Power Station had been monitored from 1988 to 1991, and the data are shown in Tables 5.2-1.

According to the results of measurements made during the last four years, the annual mean concentration of daily means was in the range of 0.080 to 0.165 mg/m^3. The concentration in 1991 is 0.03 to 0.06 mg/m^3, and the environment seems to be improving fairly in comparison with the conditions in 1988 and 1989.

The concentration is low in summer and about 5 times as high in winter. Such high concentrations in winter seem to be coming from coal burned for heating, etc.

Table 5.2-1 Annual Average SO_2 Concentration Measured in the Observatory Stations around the Melnik Power Station (1988 - 1991) (1/2)

(Unit: $\mu g/m^3$)

Monitoring Point (Month)			1	2	3	4	5	6	7	8	9	10	11	12	Ave.
HOSTKA	NE-10km	1988	-	-	-	109	129	64	77	63	43	54	296	427	140
		1989	203	173	164	91	88	47	41	93	110	131	42	91	107
		1990	74	63	50	24	32	28	20	20	57	143	58	45	51
		1991	87	125	74	33	28	45	27	18	17				(50)
ROUDNIOE SAD	W-10km	1988	-	-	-	150	117	60	50	55	41	87	168	142	97
		1989	225	155	160	98	80	56	37	75	37	41	70	64	92
		1990	72	46	47	38	19	31	19	20	18	19	67	46	37
		1991	89	195	48	33	28	18	23	20	18				(52)
STETI	NW-4 km	1988	-	-	-	201	150	169	139	135	73	112	200	315	166
		1989	274	206	216	145	97	88	80	89	144	188	40	74	137
		1990	49	49	41	15	16	19	17	25	33	69	41	44	35
		1991	76	131	80	27	19	18	27	21	19				(46)
HORNI BERKOVIOE	SW-8 km	1988	-	-	-	165	102	78	54	75	62	121	294	375	147
		1989	231	161	142	80	80	30	24	28	84	88	99	113	97
		1990	74	54	51	42	20	40	23	26	20	44	39	57	41
		1991	36	116	55	28	32	17	11	17	19				(37)

Note: Average Concentration during 1 month

Table 5.2-1 Annual Average SO_2 Concentration Measured in the Observatory Stations around the Melnik Power Station (1988 - 1991) (2/2)

(Unit: $\mu g/m^3$)

Monitoring Point (Month)			1	2	3	4	5	6	7	8	9	10	11	12	Ave.
CHLOUMEK	SE- 7 km	1988	-	-	-	173	147	123	67	61	58	95	107	146	109
		1989	323	171	109	64	85	130	139	121	95	61	86	99	124
		1990	66	39	33	41	27	29	37	39	39	54	35	81	43
		1991	111	153	35	31	49	15	20	24	20	31			(54)
MLAZIOE	SSE- 4 km	1988	-	-	-	161	86	53	58	138	70	132	279	214	132
		1989	268	220	155	120	106	222	81	117	59	91	124	78	137
		1990	110	84	70	44	68	22	27	21	18	26	57	52	50
		1991	45	59	39	57	49	15	20	24	20	31			(40)
LUZEC	S- 10km	1988	-	-	-	119	87	51	30	40	67	95	132	131	84
		1989	151	303	351	188	98	91	109	48	57	34	28	49	126
		1990	48	49	43	48	40	29	27	25	46	43	71	70	45
		1991	90	139	61	36	21	18	15	17	25	28			(50)
JANDVA VES	E- 9 km	1988	-	-	-	113	73	73	56	49	69	99	135	197	96
		1989	181	145	97	57	56	57	39	79	103	151	131	58	94
		1990	54	55	37	25	15	24	21	28	28	33	35	40	33
		1991	60	83	50	22	20	31	21	24	19	32			(39)

Note: Average Concentration during 1 month

5.3 Selection of a Method of Prediction of Environmental Effects and a Prediction Model

The diffusion of emissions from stack is predicted numerically, this time, on the ground that the topography around the Melnik Power Station is flat and the smoke diffusion would be affected little by the topography.

In selecting a prediction model, it is necessary to select a most pertinent method taking such conditions as the weather of the area, current pollution level and smoke sources into consideration.

In Czechoslovakia, calculations have been made by using diffusion equations which are based on Paskil's diffusion parameters, and such diffusion equations are also used by modeling in this Report.

Diffusions will be calculated in this Report by using Paskil's and Sutton's diffusion equations. Various data are modeled by the procedures shown in Fig. 5.3-1 and environmental effects are evaluated by short-term predictions (ground level concentrations calculated from hourly emission) and long-term predictions (annual mean ground level concentrations calculated based on weather conditions such as wind direction and speed and hourly emissions) using diffusion equations corresponding to wind speed conditions.

(1) Short-term Predictions of Diffusion are Calculated by "Bosanquet-Satton's equations"

1) Calculation of effective stack height by Bosanquet's equation (I)

$$He = H_0 + \alpha (Hm + Ht)$$

$$Hm = \frac{4.77}{1+0.43\cdot\frac{U}{V}}\cdot\frac{\sqrt{Q\cdot V}}{U}$$

$$Ht = 6.37g\cdot\frac{Q(T-T1)}{U^3\cdot T1}(\log_e J^2+\frac{2}{J}-2)$$

$$J = \frac{U^2}{\sqrt{Q\cdot V}}(0.43\sqrt{\frac{T1}{g\cdot G}}-0.28\cdot\frac{V}{g}\cdot\frac{T1}{T-T1})+1$$

where,

He	:	Effective stack height (m)
H_0	:	Actual stack height (m)
Hm	:	Height of rise by momentum (m)
Ht	:	Height of rise by buoyancy (m)
α	:	Smoke rising coefficient
U	:	Wind speed (m/s)
Q	:	Gas discharging rate (m^3/s, 15°C equivalent)
T1	:	Temperature at which the density of discharged gas equals the atmospheric density (K)
T	:	Temperature of discharged gas (K)
G	:	Temperature gradient (°C/m)
g	:	Gravitational acceleration (= 9.8 m/s^2)
V	:	Speed of discharged gas (m/s)

2) Satton's diffusion formulas

$$C(x) = \frac{2q\eta}{\pi \cdot Cy \cdot Cz \cdot U \cdot X^{2-n}} \cdot \exp\left(-\frac{1}{X^{2-n}} \cdot \frac{He^2}{Cz^2}\right)$$

$$Cmax = 0.234 \cdot \frac{Cz}{Cy} \cdot \frac{q}{U \cdot He^2} \cdot \eta \cdot 10^6$$

$$Xmax = \left(\frac{He}{Cz}\right)^{\frac{2}{2-n}}$$

C(X)	:	Ground level concentration at a point X m leeward of the stack (mg/m^3)
X	:	Leeward distance from stack (m)
Cmax	:	Maximum ground level concentration (mg/m^3)
Xmax	:	Distance of the point of maximum ground level concentration (m)
q	:	Rate of pollutant emission (kg/s, 15°C equivalent)
Cy	:	Horizontal diffusion parameter
Cz	:	Vertical diffusion parameter
U	:	Wind speed (m/s)
n	:	Coefficient of atmospheric turbulence
He	:	Effective stack height (m)
η	:	Time correction coefficient

(2) As for long term predictions of diffusion, diffusions under wind and those under no wind are generally calculated by the "plume model" and the "puff model," respectively, and predictions are made combining the results of the two models. Here, the effective stack height is calculated using the Moses-Carson's formula (under wind) or the Briggs' formula (under no wind). Diffusion parameters are estimated by using the Paskil-Gifford's approximation and atmospheric stability.

1) Modeling of Weather Data

Wind conditions of upper atmosphere are required to calculate diffusions of flue gas discharged from a tall stack. The available weather data, however, provide only ground level wind data, and wind data in upper atmosphere are estimated from the basic weather data obtained in Section 5.2 by the following formula:

$$U = Us \cdot \left(\frac{Z}{Zs} \right)^{P}$$

where,

U = Estimated wind speed at Z (m) above ground (m/s)
Us = Wind speed measured at Zs (m) above ground (m/s)
P = Roughness, variable of the ground

Stability	A	B	C	D	E	F
P	0.10	0.15	0.20	0.25	0.25	0.30

2) Calculation of effective stack height

a. Moses-Carson's formula

$$He = H_0 + \Delta H$$
$$\Delta H = (C_1 \cdot V \cdot D + C_2 \cdot Q_H^{1/2})/U$$

b. Briggs' formula

$$He = H_0 + \Delta H$$
$$\Delta H = 1.4 \cdot Q_H^{1/4}(d\theta/dz)^{-3/8}$$

where,

He	=	Effective stack height (m)
H_0	=	Actual stack height (m)
ΔH	=	Height of rise of discharged smoke (m)
V	=	Speed of discharged gas (m/s)

C_1, C_2 = Coefficients of atmospheric stability

$d\theta/dz$	C_1	C_2	Atmospheric Stabilities
< 0 (Unstable)	3.47	0.33	B, C
= 0 (Neutral)	0.35	0.17	C-D, D
> 0 (Stable)	-1.04	0.145	E, F

$d\theta/dz$	=	Temperature gradient of atmosphere (A typical mean temperature gradient of 0.0033°C/m is used if no actually measured value is available.)
Q_H	=	Discharged heat (cal/sec)
	=	$P \cdot Q \cdot Cp \cdot (T - T1)$
P	=	Density of discharged gas at 0°C (= $1.293 \cdot 10^3$ g/m^3)
Q	=	Rate of gas discharge (m^{3}N/sec; 15°C equivalent)
Cp	=	Specific heat at constant pressure (= 0.24 cal/kg)
T_1	=	Temperature at which the density of discharged gas equals the atmospheric density (K)
T	=	Temperature of discharged gas (K)

3) Plume Model

In the plume model, the smoke discharged from stack is represented by a plume for calculation of diffusion. This model is suitable for estimating long-term mean concentrations under wind (of 0.5 m/s and faster), but it is difficult to take wind changes and turbulent winds due to topography and buildings into account. Different formulas are used for "point" and "area" sources, either of which is selected considering the size and site of the source of smoke in question. The formula for point source is used for the case of the Melnik Power Station.Wind direction and wind speed data are usually recorded as their means during the last 10 minutes of each hour. In addition, the wind direction is recorded as one of the 16 directions. Actual wind direction, however, rarely remains in a same direction. To take variations in wind direction into account a little, each direction is considered to have a width of 22.5° (360°/16), and simple formulas are used assuming that concentrations at points of same leeward distance within the range are the same.

$$C(X) = \frac{2Q}{\sqrt{2\pi}\cdot\frac{\pi}{8}\cdot X\cdot\sigma z\cdot U}\cdot\exp\left(-\frac{1}{2}\cdot\frac{He^2}{\sigma z^2}\right)\cdot 10^6$$

where,

C(X)	=	Ground level concentration at point X (mg/m^3)
X	=	Leeward distance in wind direction (m)
U	=	Wind speed (m/s)
Q	=	Rate of pollutant discharge (kg/s)
He	=	Effective stack height (m)
σz	=	Standard deviation of concentration in the Z direction (m)

4) Puff model

In the puff model, the smoke from stack is represented by puffs of smoke, and employed for estimating diffusion of smoke under no wind (wind speeds of not more than 0.4 m/s). The smoke continuously emitted from a source is sectioned into puffs according to short time intervals. The diffusion is calculated for each puff, and the ground level concentration at certain time interval is calculated by integrating diffusions of such puffs with respect to time. The source of smoke is assumed to be a point source also in this model for simplification. The simplified formula thus obtained is as follows:

$$C(R) = \frac{2Q}{(2\pi)^{3/2}\cdot\alpha^2\cdot\gamma}\cdot\frac{1}{\left(\frac{R^2}{\alpha^2}+\frac{He^2}{\gamma^2}\right)}\cdot 10^6$$

where,

C(R)	=	Ground level concentration at R (m) from source of smoke (mg/m^3)
α	=	Horizontal diffusion parameter (m/s)
γ	=	Vertical diffusion parameter (m/s)
He	=	Effective stack height (m)

5) Estimation of diffusion parameters

It is necessary to estimate diffusion parameters included in the plume and puff models from weather conditions before calculating diffusions. The "Paskil-Gifford's method", which uses Mead's stability classification, is employed in estimating the diffusion parameters.

Paskil, with Mead, classified the stability of atmosphere into 6 levels according to quantities of solar radiation and cloud and wind speed, and gave leeward vertical diffusion widths as Paskil-Gifford diagrams corresponding to the atmospheric stability.

Functions which approximate Paskil-Gifford diagrams shown in Tables 5.3-1 and 5.3-2 are used as diffusion parameters under wind, Paskil's stabilities shown in Table 5.3-3 are used as diffusion parameters under no wind.

As for upper atmospheric stabilities, it is estimated by ground level atmospheric stabilities determined from ground level weather data using the relation between upper and ground level atmospheric stabilities shown in Table 5.3-4.

Table 5.3-1 Dispersion Parameters at Windy Situations (Pasquill-Gifford Coefficients)

$$\sigma_z (x) = \gamma \cdot X^{\alpha}$$

σ_z : Vertical Dispersion Parameters

Air Stability	α	γ	Downwind Distance
B	0.964	0.1272	0 ~ 500
	1.094	0.0570	500 ~
C	0.918	0.1068	0 ~
C - D	0.872	0.1057	0 ~ 1,000
	0.775	0.2067	1,000 ~ 10,000
	0.737	0.2943	10,000 ~
D	0.826	0.1046	0 ~ 1,000
	0.632	0.400	1,000 ~ 10,000
	0.555	0.811	10,000 ~
E	0.788	0.0928	0 ~ 1,000
	0.565	0.433	1,000 ~ 10,000
	0.415	1.732	10,000 ~
F	0.784	0.0621	0 ~ 1,000
	0.526	0.370	1,000 ~ 10,000
	0.323	2.41	10,000 ~

Table 5.3-2 Dispersion Parameters at Windy Situations (Pasquill-Gifford Coefficients)

$$\sigma_y (x) = \gamma \cdot X^{\alpha}$$

σ_y : Y Axial Dispersion Parameters

Air Stability	α	γ	Downwind Distance
B	0.9144	0.2818	0 ~ 1,000
	0.8650	0.3964	1,000 ~
C	0.9243	0.1772	0 ~ 1,000
	0.8852	0.2321	1,000 ~
C - D	0.9268	0.1401	0 ~ 1,000
	0.8869	0.1845	1,000 ~
D	0.9294	0.1107	0 ~ 1,000
	0.8887	0.1467	1,000 ~
E	0.9208	0.0864	0 ~ 1,000
	0.8969	0.1019	1,000 ~
F	0.9294	0.0554	0 ~ 1,000
	0.8887	0.0733	1,000 ~

Table 5.3-3 Dispersion Parameters at Calm Wind

Air Stability	α	γ
B	0.781	0.474
C	0.635	0.208
C - D	0.542	0.153
D	0.470	0.113
E	0.439	0.067
F	0.439	0.048

Table 5.3-4 Relation between Air Stability on the Ground and at Higher Layer

Air Stability on the Ground	A	A - B	B	B - C	C	C - D	Dd	Dn	E	F	G
Air Stability at Higher Layer	B			C		C - D		D		E	F

Note: Dd shows D for day time and Dn shows D for night time.

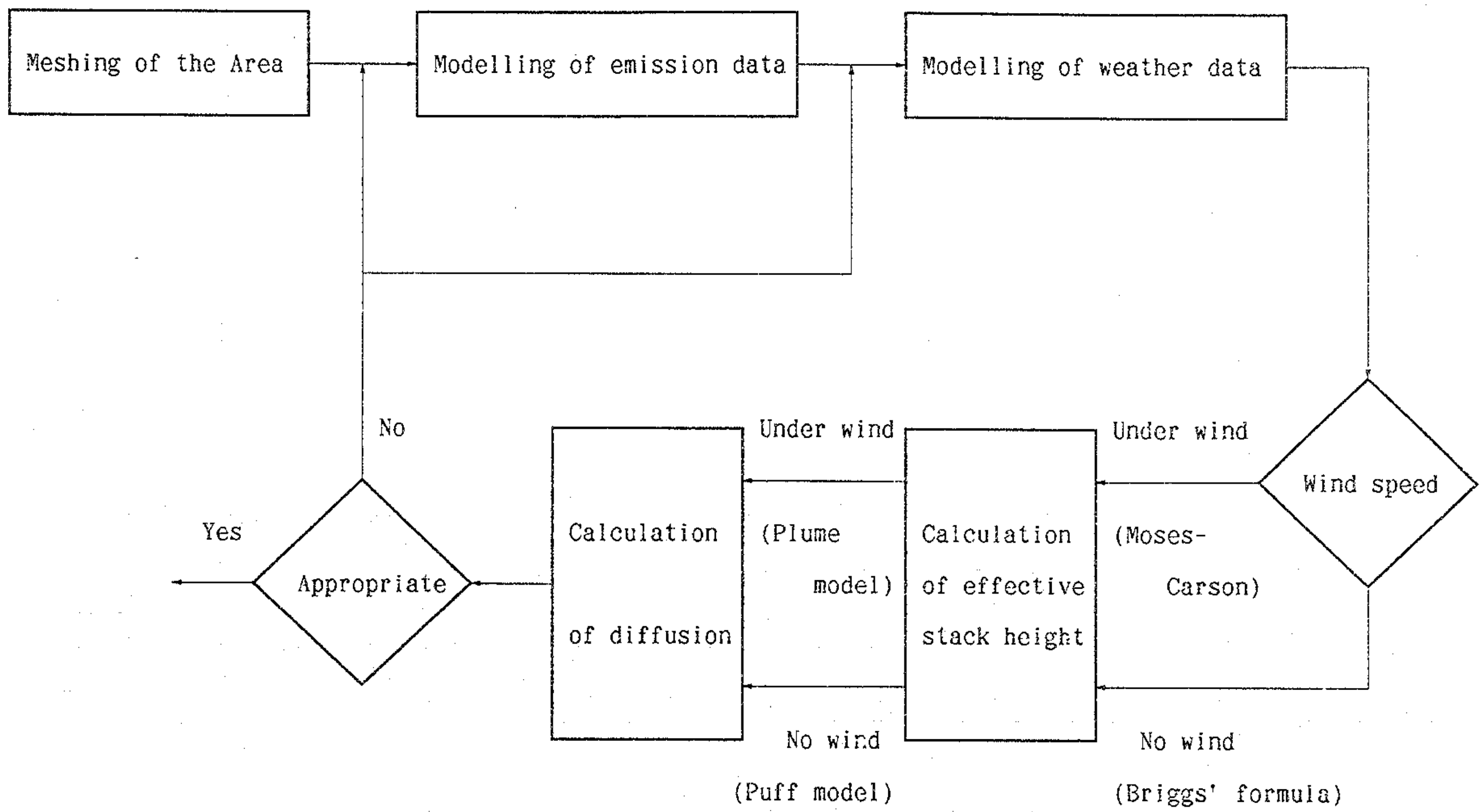


Fig. 5.3-1 ENVIRONMENTAL ASSESMENT METHOD

5.4 Prediction and Evaluation of Environmental Impact

(1) Data used in Predictions

1) Weather Data

Wind direction and wind speed distributions, diffusion parameters and atmospheric stabilities are estimated by analyzing weather data (at 7:00, 14:00 and 21:00 daily) of January to December collected at the Tisice observatory for the period of 1984 to 1990. The weather data used for calculations are shown in Table 5.4-1.

2) Smoke Source Data

Predictions are made using smoke source data which are derived from the emission level of each unit, studied in "Selection of Optimum FGD System" based on the emission standards of Czechoslovakia.

Smoke source data used in predictions are shown in Table 5.4-2.

(2) *Results of Diffusion Calculations*

Results of calculations made for short-term and long-term diffusions are shown in Table 5.4-3 to 5.4-4 and Figs. 5.4-1 to 5.4-5.

(3) Evaluations

Maximum ground level concentrations of SO_2 before and after installation of FGD units to Part II and Part III of the Melnik Power Station are estimated by diffusion calculations.

Ground concentrations predicted from 30-minute, 1-hour and 24-hour values of emission and mean annual ground concentrations predicted from 1-hour values of emission are as shown in Tables 5.4-3 and 5.4-4, respectively, and the results can be evaluated as follows:

In evaluating effects of the Melnik Power Station on the surrounding environment, the emission from Part I is overwhelming as shown in those tables, and the effects of the FGDs are reduced to half.

There is a plan to retrofit boilers of Part I to FBC boilers in future, and environmental predictions for the Melnik Power Station are made for the Power Station after such changes.

The SO_2 concentrations in surrounding areas meet the regulatory level of "500 $\mu g/m^3$" for 30-minute values specified in "Ministry of Health - 1981 (Revised in June 1991, November 1991 and May 1992) under current operating conditions, but daily mean SO_2 concentrations far exceed the regulatory level of "150 $\mu g/m^3$."

Ground concentrations after installation of FGDs and the retrofit of Part I are 93, 82 and 49 $\mu g/m^3$ for 30-minute, 1-hour and 24-hour values of emission, respectively, meeting all environmental standards.

The annual mean ground concentration is 48 $\mu g/m^3$ meeting the regulatory mean of 60 $\mu g/m^3$.

1) Short-term Predictions

The effective stack height was calculated using Bosanquet's formula, and diffusions were calculated using Sutton's formula.

a. Ground concentrations for 30-minute values

The level and point of maximum ground concentration are 0.280 mg/m^3-SO_2 and 12.6 km, respectively, before FGD installation (current) and 0.093 mg/m^3-SO_2 and 12.0 km after FGD installation.

b. Ground concentrations for 1-hour values

The level and point of maximum ground concentration are 0.247 mg/m^3-SO_2 and 12.6 km, respectively, before FGD installation (current) and 0.082 mg/m^3-SO_2 and 12.0 km after FGD installation.

c. Ground concentrations for 24-hour values

The level and point of maximum ground concentration are 0.148 mg/m^3-SO_2 and 12.6 km, respectively, before FGD installation (current) and 0.049 mg/m^3-SO_2 and 12.0 km after FGD installation.

2) Annual mean ground concentrations for 1-hour values (long-term predictions)

Weather analysis for diffusion calculation was made on wind direction frequencies for wind speed grade and wind speed data using weather data for 7 years collected at the Tisice observatory.

According to the weather analysis, the frequency of no wind (up to 0.4 m/s) accounted for 37.9% indicating that weather conditions were for smaller smoke diffusion. When windy, wind directions were mostly in the range of southwest, west and northwest corresponding to a frequency of about 35% of all winds, and winds of such directions represent predominant winds for all year.

According to the predictions, the mean ground level concentration is 0.166 mg/m^3-SO_2 before FGD installation and 0.097 mg/m^3-SO_2 after installation, indicating that the value after installation does not meet the mean value of 60 μg/m^3 specified as an environmental standard. The prediction made for the case after boiler retrofit at Part I is 0.048 mg/m^3 which well meets the environmental standard.

3) Reduction of Dust

The annual mean ground dust concentration somewhat reduces from 0.014 mg/m^3 before installation to 0.012 mg/m^3 after installation.

As in the case of SO_2 concentration, the dust emission from Part I is affecting the result much.

4) The annual mean ground concentration meets the mean concentration of the environmental standard when FGDs are installed at Part II and Part III and boilers are retrofited at Part I. In addition, considering the predominant wind direction for the year, which is from west around the Power Station, environmental effects of SO_2 from the Power Station on the cities of Melnik and Prague, which are on the east of the Power Station, will be reduced, and the installation of FGDs will contribute much to the improvement of natural and living environment of such cities.

Table 5.4-1 Weather Data

Item	Unit	Short Term	Long Term
Atmospheric temperature	°C	15	15
Velocity of the wind	m/s	6	-
Temperature gradient	°C/m	0.0033	0.0033
Coefficient of the gas lifting	-	0.65	0.65

Distribution of Wind Direction

(1) Windy

Velocity of the Wind	Representative	Air Stability	Frequency of Appearnace (%)							
			N	NNE	NE	ENE	E	ESE	SE	SSE
0.5-1.9	1.0	C	1.1	0.1	2.2	0.2	4.3	0.8	3.2	0.2
2.0-3.9	3.0	CD	0.7	0.1	1.1	0.2	2.8	0.3	1.5	0.0
4.0-5.9	5.0	D	0.4	0.0	0.3	0.0	0.6	0.0	0.3	0.0
6.0<	6.0	D	0.1	0.0	0.1	0.0	0.7	0.3	0.4	0.0
			S	SSW	SW	WSW	W	WNW	NW	NNW
0.5-1.9	1.0	C	1.2	0.3	3.5	0.3	3.6	0.5	6.0	0.4
2.0-3.9	3.0	CD	0.7	0.1	3.7	0.5	3.4	0.2	2.0	0.2
4.0-5.9	5.0	D	0.2	0.1	2.6	0.2	1.8	0.2	1.3	0.1
6.0<	6.0	D	0.2	0.1	2.1	0.2	2.4	0.2	1.2	0.1

(2) Windless

Air Stability	Frequency of Appearance (%)
C	37.9

Table 5.4-2 Data of Emission Sources (1/2)

1. Flue Gas Characteristics

Items		Unit	Part I	Part II	Part III
Fuel Consumtpion		Ton/h	330 Wet. 6U 231 Dry. 6U	440.0 Wet. 4U 307.2 Dry. 4U	493.0 Wet 344.1 Dry
Design Flue Gas Characteristics	O_2	%	9.0	8	7.5
	H_2O	%	11.5	12.8	13.4
	Flue Gas Amount (as Wet)	m^3N/h	2,106,000	2,084,000	2,217,000
	Flue Gas Amount (as Dry)	m^3N/h	1,848,000	1,844,000	1,954,000
Flue Gas Amount at Stack Outlet	Flue Gas Amount (as Wet)	m^3N/h	2,106,000	2,290,000	2,484,000
	Flue Gas Amount (as Dry)	m^3N/h	1,848,000	1,992,000	2,110,000
SO_2 Amount		kg/h	6,930	7,740	8,470
$SO_2(O_2=6\%$, Dry)		mg/m^3N	4,590	4,840	4,840
DeSOx Efficiency		%	(70<)	70<	85<

Note: There are 2 stacks in Part I.

Figure in ( ) is based on the assumption of deSOx efficiency after reconstruction to FBC Boiler.

Flue Gas Amount at Stack Outlet is included agitation air.

Table 5.4-2 Data of Emission Sources (2/2)

2. Input Data

(1) Current Levels

Item	Unit	Part I	Part II	Part III
Flue Gas Amount (as wet)	$10^3m^3N/h$	1,053.0	2,120.0	2,300.0
Flue Gas Temperature	°C	140.0	140.0	145.0
Stack Height	m	120.0	200.0	270.0
Stack Outlet Diameter	m	5.8	6.7	8.6
SO_2	kg/h	6,930.0	7,740.0	8,470.0
NO_x	kg/h	720.0	1,460.0	1,400.0
Dust	kg/h	1,110.0	230.0	200.0

Note: 1 stack is regarded as being in Part I to calculate.

(2) DeSOx Installation

Item	Unit	Part I	Part II	Part III
Flue Gas Amount (as wet)	$10^3m^3N/h$	1,053.0	2,290.0	2,484.0
Flue Gas Temperature	°C	140.0	100.0	100.0
Stack Height	m	120.0	200.0	270.0
Stack Outlet Diameter	m	5.8	6.7	8.6
SO_2	kg/h	2,070.0	2,500.0	1,360.0
NO_x	kg/h	720.0	1,460.0	1,400.0
Dust	kg/h	1,110.0	80.0	20.0

Note: Value of SO_2 in Part I is assumed after reconstruction to FBC Boiler.

Table 5.4-3 Result of Diffusion Calculation (1/3)
(Short-term Prediction of Diffusion)

1. 30 Minutes Value

(1) Current Levels

Wind	Stack	He (m)	CMAX (mg/m³)		XMAX (km)	
6 m/s	Part I	256.9	0.193	(Total) 0.280	11.9	(Total) 12.6
	Part II	419.0	0.081		20.7	
	Part III	515.9	0.059		26.3	

(2) DeSOx Installation (Before Reconstruction of Part I)

Wind	Stack	He (m)	CMAX (mg/m³)		XMAX (km)	
6 m/s	Part I	256.9	0.193	(Total) 0.233	11.9	(Total) 12.0
	Part II	375.1	0.033		18.3	
	Part III	456.1	0.012		22.8	

(3) DeSOx Installation (After Reconstruction of Part I)

Wind	Stack	He (m)	CMAX (mg/m³)		XMAX (km)	
6 m/s	Part I	256.9	0.058	(Total) 0.093	11.9	(Total) 12.0
	Part II	375.1	0.033		18.3	
	Part III	456.1	0.012		22.8	

Table 5.4-3 Result of Diffusion Calculation (2/3)
(Short-term Prediction of Diffusion)

2. 1 Hour Value

(1) Current Levels

Wind	Stack	He (m)	CMAX (mg/m^3)		XMAX (km)	
6 m/s	Part I	256.9	0.170	(Total) 0.247	11.9	(Total) 12.6
	Part II	419.0	0.072		20.7	
	Part III	515.9	0.057		26.3	

(2) DeSOx Installation (Before Reconstruction of Part I)

Wind	Stack	He (m)	CMAX (mg/m^3)		XMAX (km)	
6 m/s	Part I	256.9	0.170	(Total) 0.197	11.9	(Total) 12.0
	Part II	375.1	0.029		18.3	
	Part III	456.1	0.011		22.8	

(3) DeSOx Installation (After Reconstruction of Part I)

Wind	Stack	He (m)	CMAX (mg/m^3)		XMAX (km)	
6 m/s	Part I	256.9	0.051	(Total) 0.082	11.9	(Total) 12.0
	Part II	375.1	0.029		18.3	
	Part III	456.1	0.011		22.8	

Table 5.4-3 Result of Diffusion Calculation (3/3)
(Short-term Prediction of Diffusion)

3. 24 Hours Value

(1) Current Levels

Wind	Stack	He (m)	C_{MAX} (mg/m^3)		X_{MAX} (km)	
6 m/s	Part I	256.9	0.102	(Total) 0.148	11.9	(Total) 12.6
	Part II	419.0	0.043		20.7	
	Part III	515.9	0.031		26.3	

(2) DeSOx Installation (Before Reconstruction of Part I)

Wind	Stack	He (m)	C_{MAX} (mg/m^3)		X_{MAX} (km)	
6 m/s	Part I	256.9	0.102	(Total) 0.118	11.9	(Total) 12.0
	Part II	375.1	0.017		18.3	
	Part III	456.1	0.006		22.8	

(3) DeSOx Installation (After Reconstruction of Part I)

Wind	Stack	He (m)	C_{MAX} (mg/m^3)		X_{MAX} (km)	
6 m/s	Part I	256.9	0.030	(Total) 0.049	11.9	(Total) 12.0
	Part II	375.1	0.017		18.3	
	Part III	456.1	0.006		22.8	

Table 5.4-4 Result of Diffusion Calculation
(Long-term Prediction of Diffusion)

(1) Current Levels

Stack	C_{MAX} (mg/m³)	
Part I	0.071	(Total) 0.166
Part II	0.050	
Part III	0.046	

(2) DeSOx Installation (Before Reconstruction of Part I)

Stack	C_{MAX} (mg/m³)	
Part I	0.071	(Total) 0.097
Part II	0.018	
Part III	0.008	

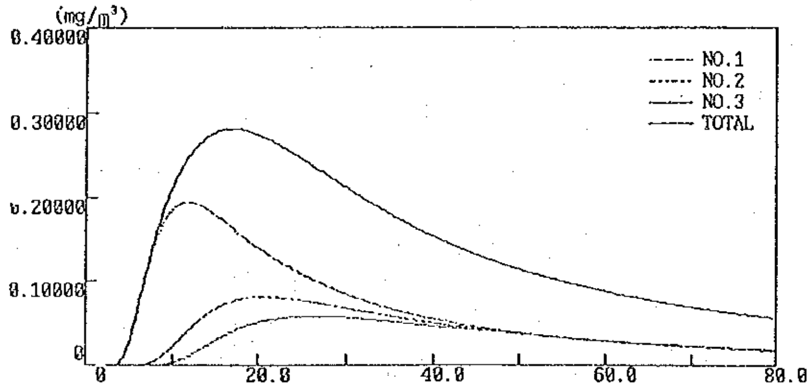
(3) DeSOx Installation (After Reconstruction of Part I)

Stack	C_{MAX} (mg/m³)	
Part I	0.021	(Total) 0.048
Part II	0.018	
Part III	0.008	

(1) Current Levels

Item	Sign	Unit	Part I	Part II	Part III	Total
Effective Stack Height	He	m	256.9	419.0	515.9	
Speed of Discharged Gas	V	m/s	16.7	25.3	16.8	
Maximum Ground Level Concentration (C_{max})	SO_2	mg/m^3	0.193	0.081	0.059	0.280
	NOx	mg/m^3	0.020	0.015	0.010	0.039
	Dust	mg/m^3	0.031	0.002	0.002	0.033
Distance of the C_{max} Point	X_{max}	km	11.9	20.7	26.3	12.6

Concentration Sectional Curve



(2) DeSOx Installation

Item	Sign	Unit	Part I	Part II	Part III	Total
Effective Stack Height	He	m	256.9	375.1	456.1	
Speed of Discharged Gas	V	m/s	16.7	24.7	16.2	
Maximum Ground Level Concentration (C_{max})	SO_2	mg/m^3	0.058	0.033	0.012	0.093
	NOx	mg/m^3	0.020	0.019	0.012	0.047
	Dust	mg/m^3	0.031	0.001	0.000	0.032
Distance of the C_{max} Point	X_{max}	km	11.9	18.3	22.8	12.0

Concentration Sectional Curve

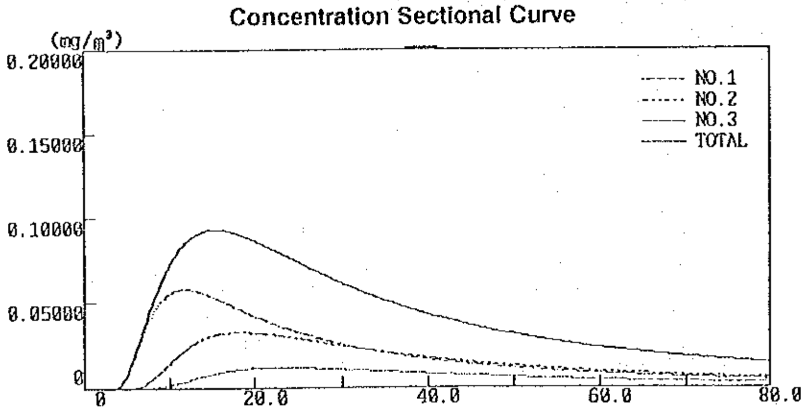
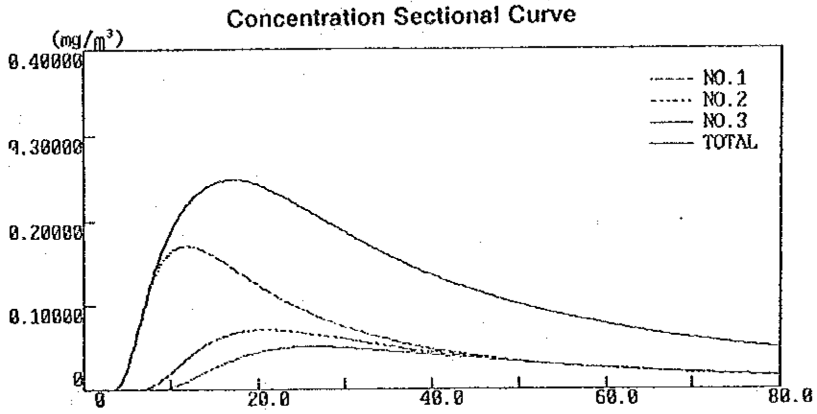


Fig. 5.4-1 RESULT OF DIFFUSION CALCULATION (30 Minutes Value)

(1) Current Levels

Item	Sign	Unit	Part I	Part II	Part III	Total
Effective Stack Height	He	m	256.9	419.0	515.9	
Speed of Discharged Gas	V	m/s	16.7	25.3	16.8	
Maximum Ground Level Concentration (C_{max})	SO_2	mg/m^3	0.171	0.072	0.052	0.247
	NOx	mg/m^3	0.018	0.014	0.009	0.034
	Dust	mg/m^3	0.027	0.002	0.001	0.029
Distance of the C_{max} Point	X_{max}	km	11.9	20.7	26.3	12.6



(2) DeSOx Installation

Item	Sign	Unit	Part I	Part II	Part III	Total
Effective Stack Height	He	m	256.9	375.1	456.1	
Speed of Discharged Gas	V	m/s	16.7	24.7	16.2	
Maximum Ground Level Concentration (C_{max})	SO_2	mg/m^3	0.051	0.029	0.011	0.082
	NOx	mg/m^3	0.018	0.017	0.011	0.041
	Dust	mg/m^3	0.027	0.001	0.000	0.028
Distance of the C_{max} Point	X_{max}	km	11.9	18.3	22.8	12.0

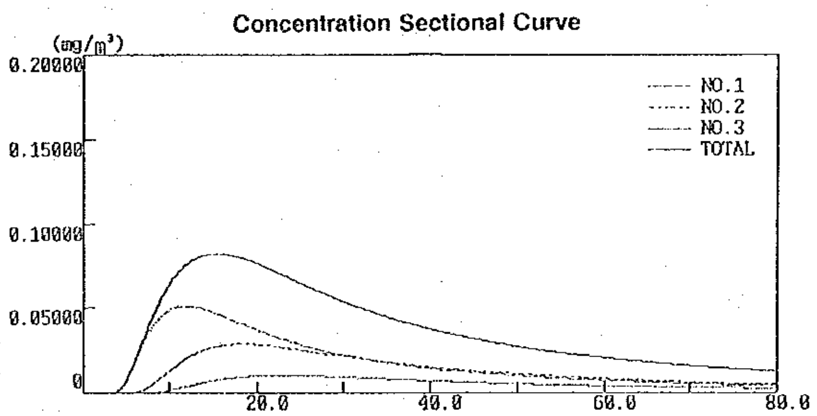
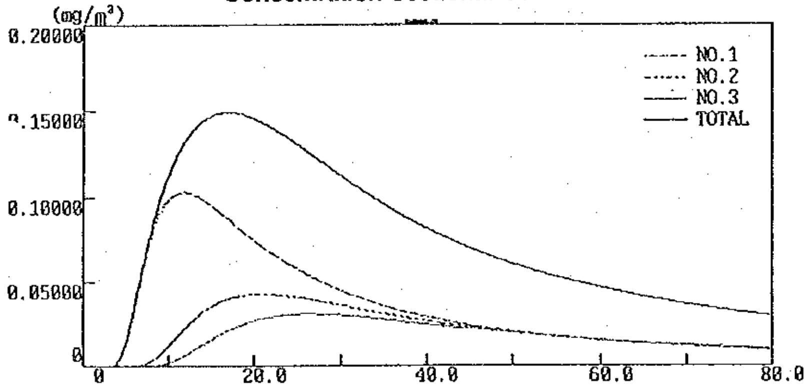


Fig. 5.4-2 RESULT OF DIFFUSION CALCULATION (1 Hour Value)

(1) Current Levels

Item	Sign	Unit	Part I	Part II	Part III	Total
Effective Stack Height	He	m	256.9	419.0	515.9	
Speed of Discharged Gas	V	m/s	16.7	25.3	16.8	
Maximum Ground Level Concentration (C_{max})	SO_2	mg/m^3	0.102	0.043	0.031	0.148
	NOx	mg/m^3	0.011	0.008	0.005	0.020
	Dust	mg/m^3	0.016	0.001	0.001	0.017
Distance of the C_{max} Point	X_{max}	km	11.9	20.7	26.3	12.6

Concentration Sectional Curve



(2) DeSOx Installation

Item	Sign	Unit	Part I	Part II	Part III	Total
Effective Stack Height	He	m	256.9	375.1	456.1	
Speed of Discharged Gas	V	m/s	16.7	24.7	16.2	
Maximum Ground Level Concentration (C_{max})	SO_2	mg/m^3	0.031	0.017	0.006	0.049
	NOx	mg/m^3	0.011	0.010	0.007	0.025
	Dust	mg/m^3	0.016	0.000	0.000	0.017
Distance of the C_{max} Point	X_{max}	km	11.9	18.3	22.8	12.0

Concentration Sectional Curve

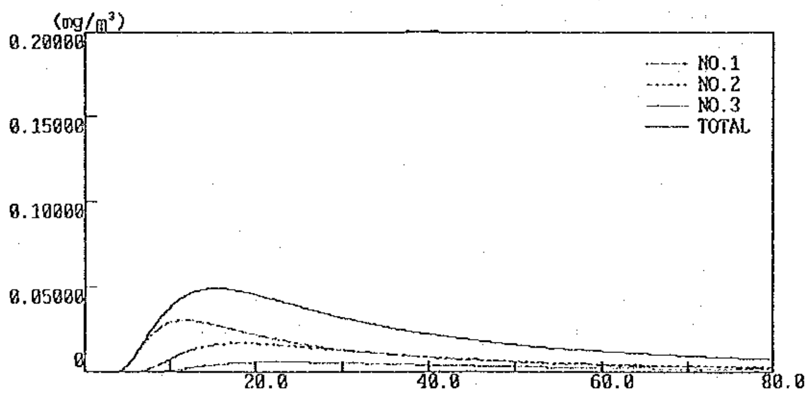
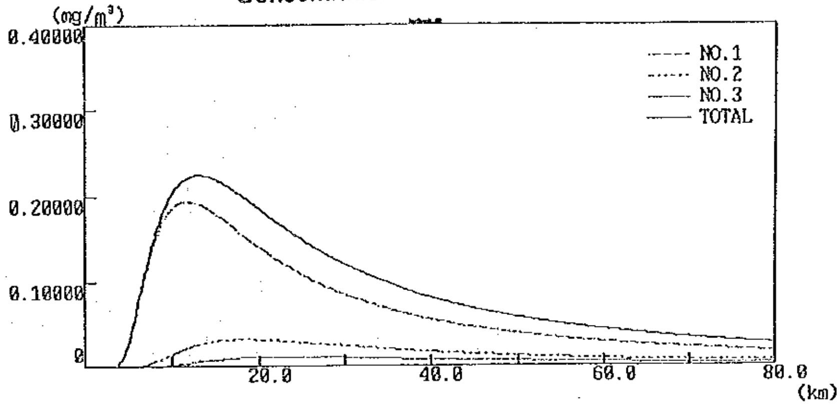


Fig. 5.4-3 RESULT OF DIFFUSION CALCULATION (24 Hours Value)

(1) 30 Minutes Value

Item	Sign	Unit	Part I	Part II	Part III	Total
Effective Stack Height	He	m	256.9	375.1	456.1	
Speed of Discharged Gas	V	m/s	16.7	24.7	16.2	
Maximum Ground Level Concentration (C_{max})	SO_2	mg/m^3	0.193	0.033	0.012	0.223
	NOx	mg/m^3	0.020	0.019	0.012	0.047
	Dust	mg/m^3	0.031	0.001	0.000	0.032
Distance of the C_{max} Point	X_{max}	km	11.9	18.3	22.8	12.0

Concentration Sectional Curve



(2) DeSOx Installation

Item	Sign	Unit	Part I	Part II	Part III	Total
Effective Stack Height	He	m	256.9	375.1	456.1	
Speed of Discharged Gas	V	m/s	16.7	24.7	16.2	
Maximum Ground Level Concentration (C_{max})	SO_2	mg/m^3	0.102	0.017	0.006	0.118
	NOx	mg/m^3	0.011	0.010	0.007	0.025
	Dust	mg/m^3	0.016	0.000	0.000	0.017
Distance of the C_{max} Point	X_{max}	km	11.9	18.3	22.8	12.0

Concentration Sectional Curve

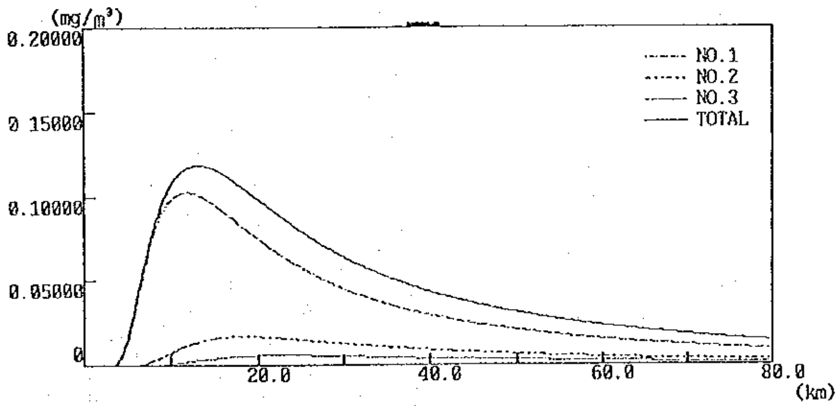
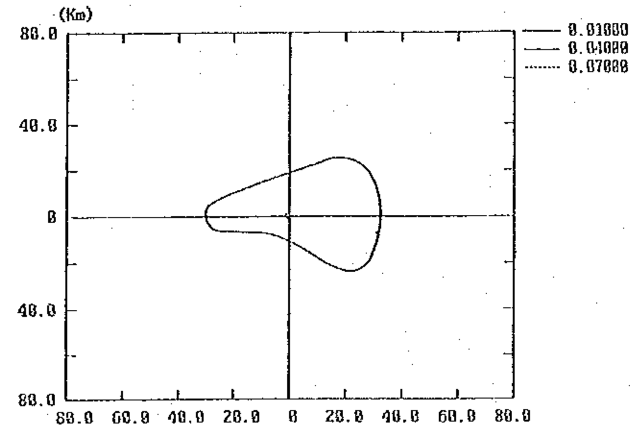


Fig. 5.4-4 RESULT OF DIFFUSION CALCULATION (DeSOx Installation and Reconstruction of Part I)

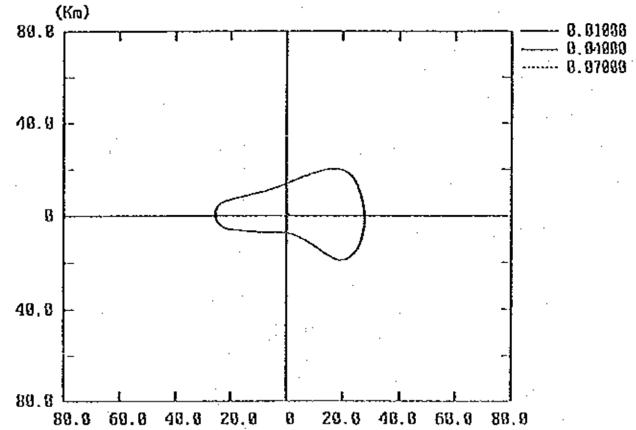
(1) Current Levels

Item	Sign	Unit	Part I	Part II	Part III	Total
Maximum Ground Level Concentration (C_{max})	SO_2	mg/m^3	0.071	0.050	0.046	0.166
	NOx	mg/m^3	0.007	0.009	0.008	0.024
	Dust	mg/m^3	0.011	0.001	0.001	0.014
Direction of the C_{max} Point	-	-	C	C	C	C
Distance of the C_{max} Point	X_{max}	km	0.0	0.0	0.0	0.0

(1) Part II only



(2) Part III only



(3) Total of Power Station

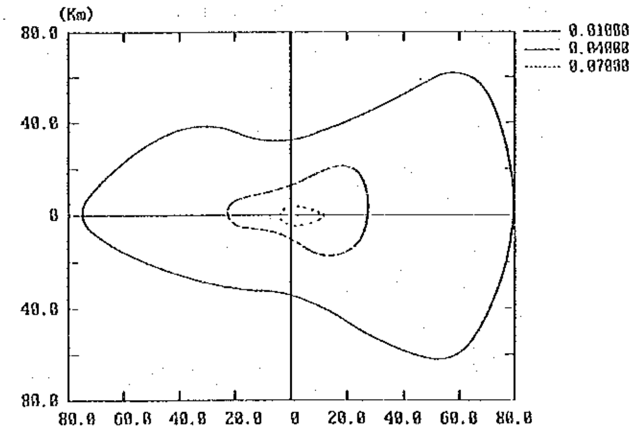
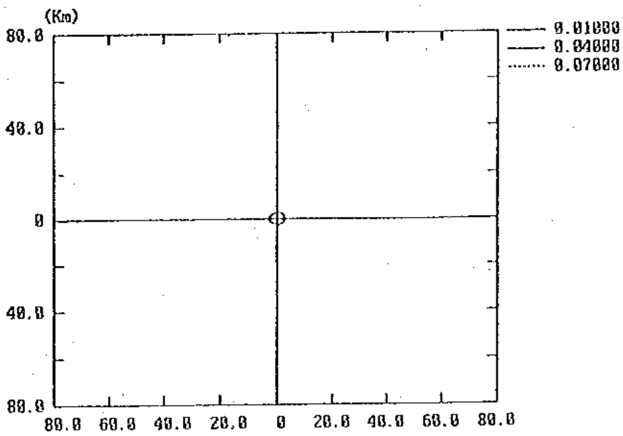


Fig. 5.4-5 CONCENTRATION DISTRIBUTION CURVE (1/2)
(Average Concentration during 1 Year)

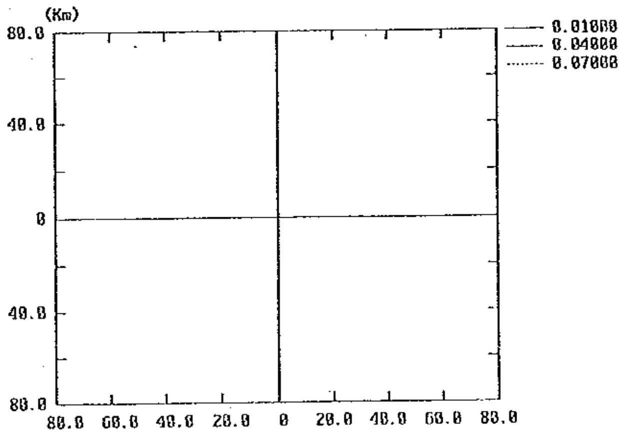
(2) DeSOx Installation

Item	Sign	Unit	Part I	Part II	Part III	Total
Maximum Ground Level Concentration (C_{max})	SO_2	mg/m^3	0.021	0.018	0.008	0.048
	NOx	mg/m^3	0.007	0.011	0.009	0.026
	Dust	mg/m^3	0.011	0.000	0.000	0.012
Direction of the C_{max} Point	-	-	C	C	C	C
Distance of the C_{max} Point	X_{max}	km	0.0	0.0	0.0	0.0

(1) Part II only



(2) Part III only



(3) Total of Power Station

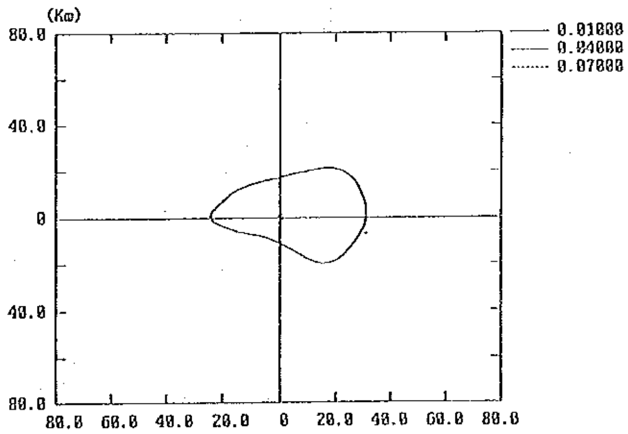


Fig. 5.4-5 CONCENTRATION DISTRIBUTION CURVE (2/2)
(Average Concentration during 1 Year)

Chapter 6 Conceptual Design of DeSOx System

CHAPTER 6 CONCEPTUAL DESIGN OF DeSOx SYSTEM

Contents

List of Tables

List of Figures

Chapter 6 Conceptual Design of DeSOx System

6.1 Basic Plan for DeSOx System

A basic plan is prepared for conceptual design of DeSOx system applied for Parts II and III of Melnik Power Station based on the results of the "Selection of the optimum DeSOx system" and the collected data and information during the Study of the 1st stage.

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

(1) Coal Properties

a.	Calorific value (LHV)	4,200 kcal/kg (dry base)
		3,680 kcal/kg (air dry base)
b.	Total moisture	30.2 % (as received)
c.	Moisture content	12.4 % (air dry base)
d.	Sulphur content	1.5 % (dry base)
e.	Ash	38.04 % (dry base)

(2) FGD System

[Part II]

a. Method : Wet-type limestone-gypsum method (Single-tower in-situ oxidation spraying tower method)

b. Capacity and number of units : 110-MW equivalent, 4 units

c. DeSOx efficiency : 70% (The intra-tower deSOx efficiency is set to be 91% for treatment capacity of 80% with the consideration of leakage at GGH.)

d. Power plants of FGD installation : 4 FGD units for Nos. 7, 8, 9 and 10 power plants (110 MW x 4)

[Part III]

a. Method : Wet-type limestone-gypsum method (Single-tower in-situ oxidation spraying tower method)

b. Capacity and number of units : 500-MW equivalent, 1 units

c. DeSOx efficiency : 85% (The intra-tower deSOx efficiency is set to be 90% for full volume treatment with the consideration of leakage at bypass damper and GGH.)

d. Power plant of FGD installation : 1 FGD unit for No. 11 power plant (500 MW)

(3) Design Conditions of FGD Units

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

[Part II: For each Unit]

a.	Inlet gas volume (Capacity)	:	417,000 m^3N/h wet (440,000 m^3N/h wet) (80% fluegas treatment of 521,000 m^3N/h at total.)
b.	Inlet gas temperature	:	170°C (Intermediate temperature of 160-180°C)
c.	Byproduct production	:	Gypsum of quantity corresponding to that generated when the flue gas is continuously treated at the deSOx efficiency of 70% while coal of characteristics shown in (1) is consumed continuously.

[Part III]

a.	Inlet gas volume (Capacity)	:	2,217,000 m^3N/h wet (2,300,000 m^3N/h wet)
b.	Inlet gas temperature	:	190°C (Intermediate temperature of 180-200°C)
c.	Byproduct production	:	Gypsum of quantity corresponding to that generated when the flue gas is continuously treated at the deSOx efficiency of 85% while coal of characteristics shown in (1) is consumed continuously.

(4) Planned Performance of FGD Units

Planned performance of the FGD Units are shown in Table 6.1-2.

(5) Absorbent (limestone) Characteristics

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

a.	Purity	$CaCO_3$	96% or more
b.	Grain size	ϕ 22.5 ~ 80 mm	

(6) Pretreatment of Absorbent

To use limestone as absorbent in the wet-type limestone-gypsum method, it is necessary to make limestone into powder of which more than 95% passes 325 mesh (particle sizes below 43 μm).

Therefore, a crusher and a wet mill should be installed as pretreatment equipment for this purpose.

(7) Water for the FGD

Water from the Labe River is used as water for the FGD by branching from the turbine condenser cooling system of Part II.

Table 6.1-3 shows planned water qualities for the FGD which have been set based on the results of analysis made on water from the Labe River obtained at the Power Station.

(8) Air

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

(9) Electric Facility

It is planned to supply electric power to FGDs by branching the secondary 110 kV bus bar of the main transformer of Part II and lowering the voltage to 6.0 kV by a transformer for FGD to be installed for the purpose. Switchgears will be installed in an electric room of a new two-storied building to be built between Part II and Part III for housing both electric and control rooms.

(10) Control Systems

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

(11) Byproduct Treatment

Of all gypsum generated at the Melnik Power Station, the quantity of gypsum corresponding to that produced at Part III is to be supplied to the gypsum board plant which is planned to be built adjacent to the Power Station. The rest (corresponding to the quantity produced at Part II) is to be transported on railroad and disposed to the ash disposal area to be built in the future.

Qualities of gypsum are the same for gypsum produced at Part II or Part III, and gypsum from either Part II or Pasrt III is not differentiated in its treatment.

(12) Byproduct Disposal Area

The byproduct disposal area will have impermeable construction using water-proofing sheet. the impermeable sheet will, however, be used for minimum number of byproduct disposal area which keep byproduct for a period necessary for stabilization of byproduct. In this study, it is planned for 12.5 years period.

(13) Waste Water Treatment

Waste water blowing is to be carried out periodically or continuously to control the chlorine concentration in the absorber to below a certain level, and it is planned to install waste water treatment equipment so that such discharged water would not adversely affect the water of the river.

Table 6.1-1 Design Condition of FGD Units

	Item	Unit	Design Condition	
			Part II for 1 Unit	Part III
1.	Capacity of Power Plant	MW	110	500
2.	FGD Process	-	Wet-Limestone-Gypsum	Wet-Limestone-Gypsum
3.	Total Gas Flow Rate	m^3N/h, wet	521,000 (530,000)*	2,127,000 (2,300,000)*
	FGD Inlet Flue Gas Rate	"	417,000 (440,000)*	2,127,000 (2,300,000)*
4.	Inlet Flue Gas Temperature	°C	190	170
5.	Inlet Flue Gas Composition			
	H_2O	vol%	13.0	13.4
	O_2	vol%	8.0	7.5
	SO_2 (as O_2=6% & Dry base)	mg/m^3N, dry	4,840	4,840
	HF (")	mg/m^3N, dry	94.6	94.7
	HCl (")	mg/m^3N, dry	19.1	19.1
	SO_3 (")	mg/m^3N, dry	48.4	48.8
6.	SO_2 Removal Efficiency	%	70 (91)**	85
7.	Dust Concentration			
	Outlet of the Existing EP	mg/m^3N, dry	<100	
8.	Absorbent	-	Limestone	
	Purity	%	96% or more	
	Grain Size	φ mm	22.5 - 80	
9.	Gypsum		To be discarded	To be used as the material of gypsum board
10.	Outlet Flue Gas Temperature at the Inlet of the Stack	°C	100	
11.	Cl Concentration in Make-up Water	mg/ℓ	27	

* Flue gas flow rate in ( ) is the normal value.
** Figure in ( ) shows the value with consideration of the duct by-passing and GGH leakage.

Table 6.1-2 Design Performance of FGD Units

	Item	Unit	Design Performance	
			Part II for 1 Unit	Part III
1.	Capacity of Power Plant	MW	110	500
2.	Gas Flow Rate	m^3N/h, wet	417,000	2,127,000
3.	Inlet Gas Condition			
	Temperature	°C	190	170
	SO_2 (as O_2=6% & Dry base)	mg/m^3N	4,840	4,840
	*SO_3 (")	mg/m^3N	48.4	48.4
	Dust Load	mg/m^3N	100	100
4.	Outlet Gas Condition			
	Temperature	°C	100	100
	SO_2 (as O_2=6% & Dry base)	mg/m^3N	1,452	726
	SO_3 (")	mg/m^3N	24	24
	Dust Load	mg/m^3N, dry	40	40
5.	SO_2, Removal Efficiency	%	70	85
6.	Ca/S (Injected Ca/Treated S)	-	1.06	1.06
7.	Draft Loss of FGD Plant	mmAq	230	230
8.	Gypsum Slurry	t/h	4.27	22.73

Remarks: The value with the * mark is the assumption with 1% of the SO_3 conversion rate in the boiler (furnace), and it is necessary to measure the actual SO_3 concentration in flue gas at the definite design stage in order to consider the prevention measures from corrosion condition of the flue gas line (ie: inner surface of flue gas duct and GGH elements.)

Table 6.1-3 Design River Water Analysis

Item	Unit	Anaysis
COD-Mn	mg/ℓ	8.0
COD-Cr	mg/ℓ	62
Total Hardness	$CaCO_3$ mg/ℓ	150
Na	mg/ℓ	290
K	mg/ℓ	20.0
Ca	mg/ℓ	43.0
Mg	mg/ℓ	16.0
SS	mg/ℓ	0.2
Cl	mg/ℓ	27.0
SO_4	mg/ℓ	91.0
SS	mg/ℓ	<1

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

6.2 Plan for Overall FGD Layout

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

The FGDs are arranged between the coal yard and power plants of Part II, and in the space on the west of power plant of Part III in consideration of the items described below for achieving an economical layout with minimum equipment remodeling.

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

a. Coal conveyer

b. Sludge crushing station existing between Part II and Part III

c. Oxygen cylinder room existing beside the flue gas duct of Part III

(2) Existing Facilities to be Removed and Relocated

a. Coal train defreezing tunnel and railway truck existing along the flue gas duct of Part II

b. Material warehouse for maintenance existing beside the coal train defreezing tunnel

c. Ash slurry transport piping, piping for supplying heat to the city of Melnik and their racks

d. Other smaller pipings and cables, etc.

(3) Existing Facilities to be Reconstructed

a. Existing common ducts for connection of FGD units

b. Stack lining

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

One way to cope with more stringent regulation on SOx emission in the future is to install an additional FGD unit for Part II power plants. For this reason, the layout of the FGD system to be installed this time must also plan for possible installation of an additional FGD.

(5) Indoor Equipment

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

a. Absorber recirculation pumps

To be installed adjacent to each absorber for both Part II and Part III.

b. Oxidation air blowers and air compressors

These are to be installed in one building as equipment each of all FGDs for Part II and Part III respectively.

c. Water acquisition pumps for desulfurization

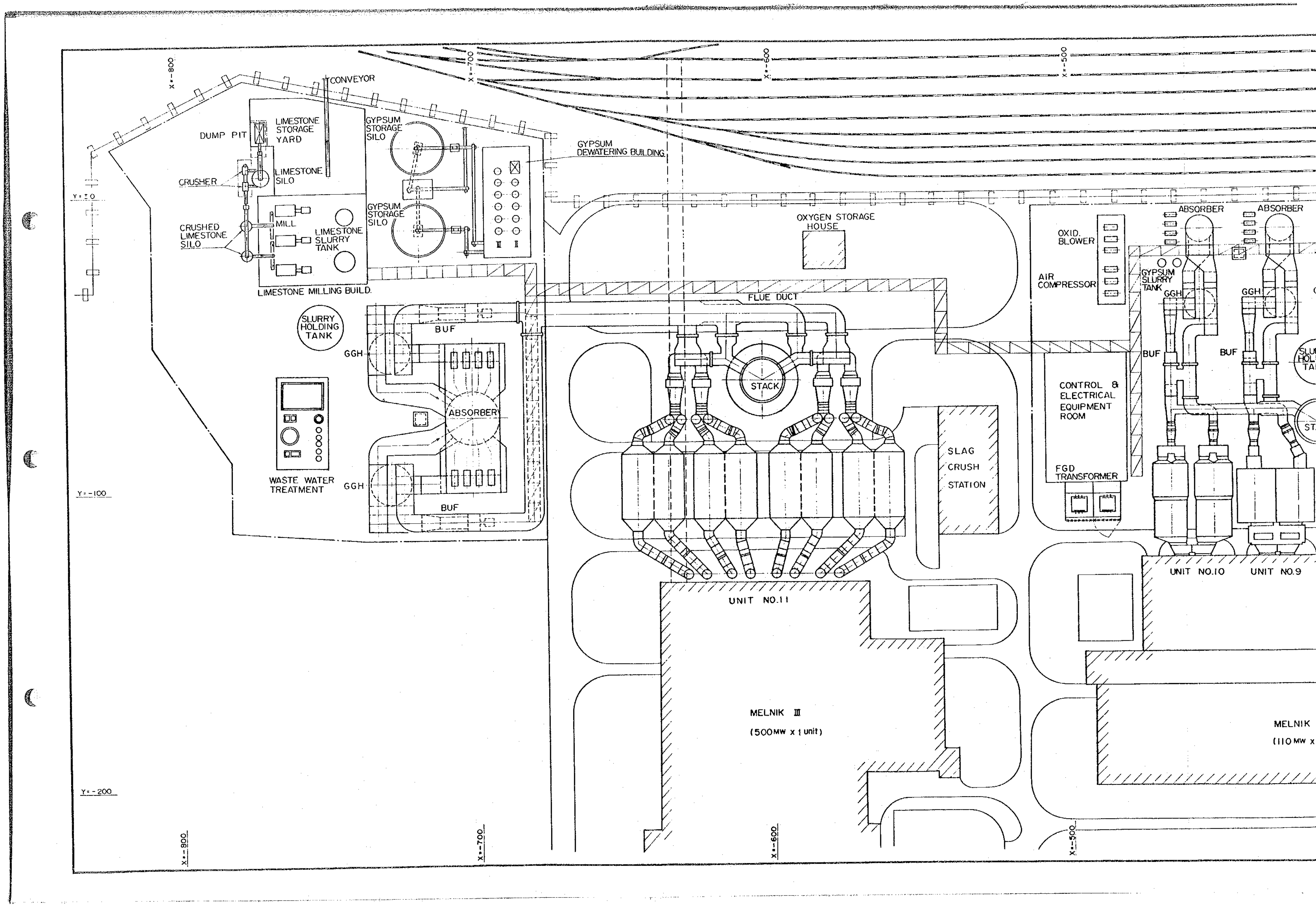
These are to be installed in one building as equipment common to all FGDs of Part II and Part III.

d. Limestone crushers, mills and limestone slurry tanks

These are to be installed in one building as equipment common to all FGDs of Part II and Part III.

e. Centrifuges for gypsum dewatering

These are to be installed in one building as equipment common to all FGDs of Part II and Part III.


X=-800
X=-700
X=-600
X=-500
CONVEYOR
DUMP PIT
LIMESTONE STORAGE YARD
LIMESTONE SILO
CRUSHER
CRUSHED LIMESTONE SILO
MILL
LIMESTONE SLURRY TANK
LIMESTONE MILLING BUILD.
GYPSUM STORAGE SILO
GYPSUM STORAGE SILO
GYPSUM DEWATERING BUILDING
Y=0
Y=-100
Y=-200
SLURRY HOLDING TANK
WASTE WATER TREATMENT
BUF
GGH
ABSORBER
GGH
BUF
OXYGEN STORAGE HOUSE
FLUE DUCT
STACK
UNIT NO.11
MELNIK III
(500MW x 1 unit)
SLAG CRUSH STATION
OXID. BLOWER
AIR COMPRESSOR
CONTROL & ELECTRICAL EQUIPMENT ROOM
FGD TRANSFORMER
GYPSUM SLURRY TANK
ABSORBER
ABSORBER
GGH
GGH
BUF
BUF
UNIT NO.10
UNIT NO.9
MELNIK
(110MW x

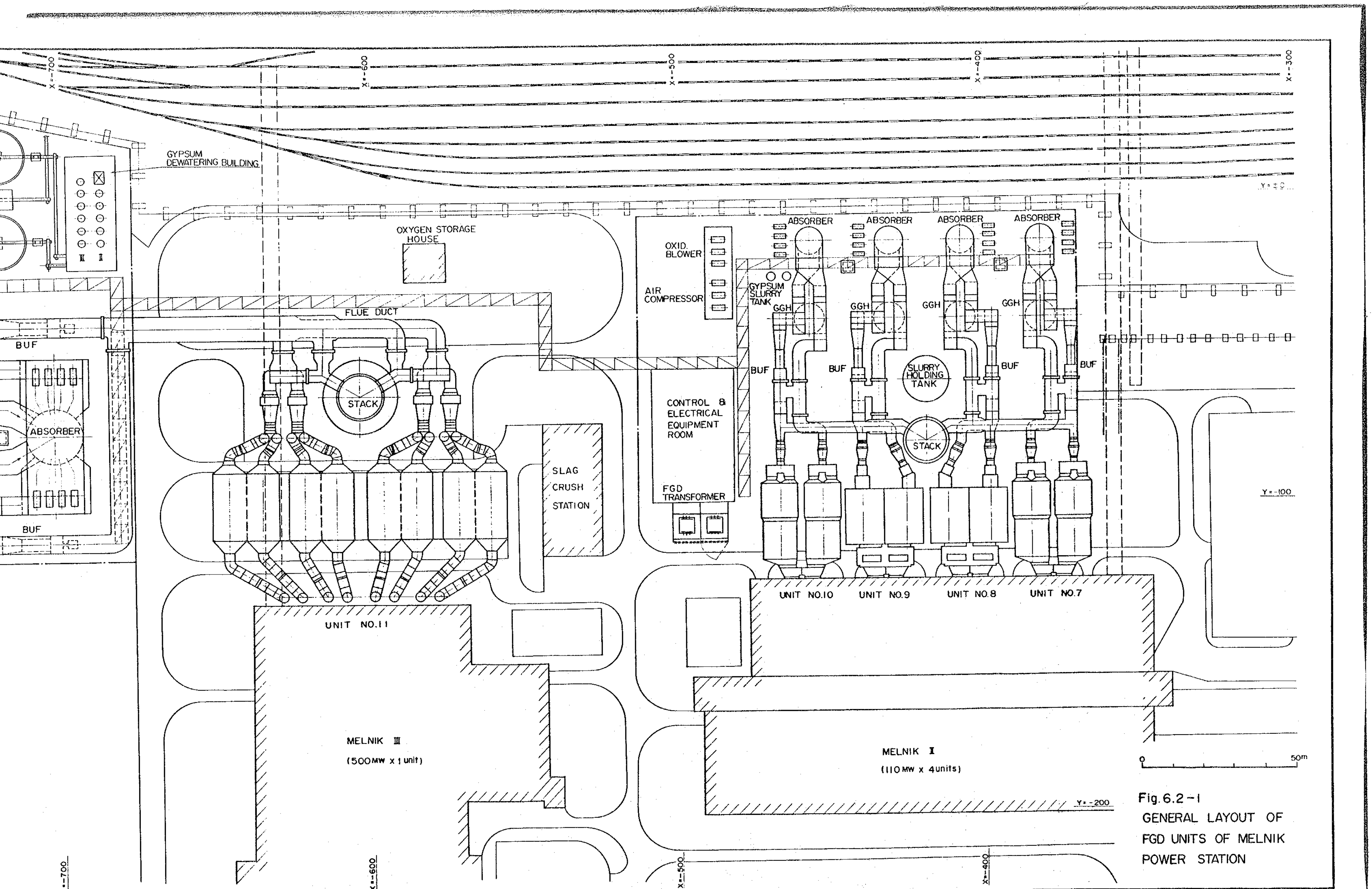


Fig.6.2-1
GENERAL LAYOUT OF FGD UNITS OF MELNIK POWER STATION

6.3 System Diagram of DeSOx System and Specifications of Major Equipment

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

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

Table 6.3-1 Specification of Major Equipment for FGD System of Melnik Power Station

(1/9)

Equipment	Specification
[Part II]	
II - 1 Absorbing System	
1) Absorber	
Number	1 x 4 Units
Type	Spray Tower
Dia. x Height	ϕ 8.0 m x H 22.5 m
Capacity	440,000 m^3N/h
2) Absorber Recirculation Pump	
Number	4 x 4 Units
Type	Centrifugal
Capacity	30 m^3/min
Head	20 m
Motor	145 kW
3) Absorber Bleed Pump	
Number	4 + 4 Stand-by
Type	Centrifugal
Capacity	0.55 m^3/min
Head	15 m
Motor	45 kW
4) Agitator for Absorber Recir. Tank	
Number	2 x 4 Units
Type	Horizontal Axial Propeller
Motor	30 kW
5) Oxidation Agitator on Absorber	
Number	3 x 4 Units
Type	Horizontal Axial Propeller
Motor	30 kW
6) Oxidation Air Blower (Common for 2 Units)	
Number	2 + 1 Stand-by
Type	Rotary Blower
Capacity	22 m^3/min
Head	0.6 kg/cm^3g
Motor	110 kW
7) Slurry Holding Tank (Common for 4 Units)	
Number	1
Type	Vertical Cylinder
Capacity	1,770 m^3
8) Slurry Holding Tank	
Transfer Pump (Common for 4 Units)	1 + 1 Stand-by
Number	Centrifugal
Capacity	13 m^3/min
Head	23 m
Motor	75 kW

Equipment	Specification
9) Absorber Area Drain Pit (Common for 2 Units)	
Number	1 x 2 Units
Type	Underground Concrete Pit
Capacity	22 m^3
10) Absorber Area Drain Pump (Common for 2 Units)	
Number	1 x 2 Units
Type	Centrifugal
Capacity	2.4 m^3/min
Head	20 m
Motor	15 kW
11) Emergency Head Tank	
Number	1 + 4 Units
Type	Vertical Cylinder
Capacity	5 m^3
II - 2 Gypsum Recovery System	
1) Centrifuge (Comon for 4 Units)	
Number	4 + 1 Stand-by
Capacity (as dry Gypsum)	1,200 kg/h/batch
Motor	160 kW
2) Centrifuge Filtrate Pit (Common for 4 Units)	
Number	1
Type	Vertical Cylinder
Capacity	88 m^3
3) Centrifuge Filtrate Pump (Common for 4 Units)	
Number	1 + 1 Stand-by
Type	Centrifugal
Capacity	2.7 m^3/min
Head	38 m
Motor	30 kW
4) Blow Down Tank (Common for 4 Units)	
Number	1
Type	Vertical Cylinder
Capacity	1.2 m^3
8) Blow Down Pump (Common for 4 Units)	
Number	1 + 1 Stand-by
Type	Centrifugal
Capacity	0.01 m^3/min
Head	20 m

Equipment	Specification
II-3 Draft System	
1) Boost Up Fan	
Number	1 x 4 Units
Type	Axial Flow
Capacity	13,700 m^3/min
Head	270 mmAq
Motor	700 kW
2) Flue Gas Reheating System	
Number	1 x 4 Units
Type	Rotary Regenerative type Gas to Gas Heat Exchanger
Capacity	5.0 x 10^6 Kcal/h
Motor	5 kW
3) Bypass Damper	
Number	1 x 4 Units
Type	Multi Louver
Material	Corten
4) Inlet Isolation Damper	
Number	1 x 4 Units
Type	Multi Louver
Material	Carbon Steel
5) Outlet Isolation Damper	
Number	1 x 4 Units
Type	Multi Louver
Material	Corten
II - 4 Auxiliary System	
1) Make-up Water Pump (Common for 4 Units)	
Number	1 + 1 Stand-by
Type	Centrifugal
Capacity	2.3 m^3/min
Head	20 m
Motor	15 kW
2) Air Compressor (Common for 2 Units)	
Number	2 + 1 Stand-by
Type	Reciprocating
Capacity	50 m^3N/H
Pressure	7 kg/cm^2g
Motor	90 kW

Equipment	Specification
[Part III]	
III - 1 Absorbing System	
1) Absorber	
Number	1
Type	Spray Tower
Dia. x Height	φ 18.1 m x H 24.8 m
Capacity	2,300,000m^3N/h
2) Absorber Recirculation Pump	
Number	8
Type	Centrifugal
Capacity	74 m^3/min
Head	21 m
Motor	390 kW
3) Absorber Bleed Pum	
Number	1 + 1 Stand-by
Type	Centrifugal
Capacity	2.9 m^3/min
Head	28 m
Motor	37 kW
4) Agitator for Absorber Recir. Tank	
Number	6
Type	Horizontal Axial Propeller
Motor	30 kW
5) Oxidation Agitator on Absorber	
Number	8
Type	Horizontal Axial Propeller
Motor	30 kW
6) Oxidation Air Blower	
Number	1 + 1 Stand-by
Type	Rotary Blower
Capacity	220 m^3/min
Head	0.6 kg/cm^3g
Motor	310 kW
7) Slurry Holding Tank	
Number	1
Type	Vertical Cylinder
Capacity	2,200 m^3
8) Slurry Holding Tank Transfer Pump	
Number	1
Type	Centrifugal
Capacity	4.3 m^3/min
Head	23 m
Motor	30 kW

Equipment	Specification
9) Absorber Area Drain Pit	
Number	1
Type	Underground Concrete Pit
Capacity	100 m^3
10) Absorber Area Drain Pit Pump	
Number	1
Type	Centrifugal
Capacity	5.5 m^3/min
Head	20 m
Motor	55 kW
11) Emergency Head Tank	
Number	1
Type	Vertical Cylinder
Capacity	22 m^3
III - 2 Gypsum Recovery System	
1) Centrifuge	
Number	5 + 1 Stand-by
Capacity (as dry Gypsum)	1,200 kg/h/batch
Motor	160 kW
2) Centrifuge Filtrate Pit	
Number	1
Type	Vertical Cylinder
Capacity	147 m^3
3) Centrifuge Filtrate Pump	
Number	1 + 1 Stand-by
Type	Centrifugal
Capacity	4.9 m^3/min
Head	38 m
Motor	55 kW
4) Blow Down Tank	
Number	1
Type	Vertical Cylinder
Capacity	1.2 m^3
8) Blow Down Pump	
Number	1 + 1 Stand-by
Type	Centrifugal
Capacity	0.1 m^3/min
Head	20 m

Equipment	Specification
III - 3 Draft System	
1) Boost Up Fan	
Number	2
Type	Axial Flow
Capacity	34,200 m^3N/h
Head	290 mmAq
Motor	1,570 kW
2) Flue gas Reheating System	
Number	2
Type	Rotary Regenerative type Gas to Gas Heat Exchanger
Capacity	17.3 x 10^6 kcal/h
Motor	22 kW
3) Bypass Damper	
Number	1
Type	Multi Louver
Material	Corten
4) Inlet Isolation Damper	
Number	2
Type	Multi Louver
Material	Carbon Steel
5) Outlet Isolation Damper	
Number	2
Type	Multi Louver
Material	Corten
III - 4 Auxiliary	
1) Make-up Water Pump	
Number	1 + 1 Stand-by
Type	Centrifugal
Capacity	2.3 m^3/min
Head	20 m
Motor	15 kW
2) Air Compressor	
Number	1 + 1 Stand-by
Type	Reciprocating
Capacity	150 m^3N/h
Pressure	7 kg/cm^3g
Motor	170 kW

Equipment	Specification
[Common for Parts II and III]	
C - 1 Limestone Preparation System	
1) Limestone Siro	
Number	1
Type	Vertical Cylinder
Capacity	200 m^3
2) Limestone Crusher	
Number	1 + 1 Stand-by
Type	Hammer Type
Capacity	24.0 t/h
Motor	130 kW
3) Crushed Limestone Siro	
Number	2
Type	Vertical Cylinder
Capacity (for Par II/Part III)	78 m^3/90 m^3
4) Limestone Mill	
Number	2 + 1 Stand-by
Type	Wet type Ball Mill
Capacity	13.7 t/h
Motor	550 kW
5) Limestone Slurry Tank	
Number	2
Type	Vertical Cylinder
Capacity (for Part II/Part III)	190 m^3/320 m^3
6) Limestone Feeder	
Number	2
Capacity (for Part II/Part III)	10.3 t/h / 13.7 t/h
7) Limestone Feeder	
Number	1
Type	Belt type
Capacity (for Part II/Part III)	10.3 t/h / 13.7 t/h
8) Limestone Slurry Pump	
Number	2
Type	Submerged
Capacity (for Part II/Part III)	0. 3m^3/min / 1.5 m^3/min
Head	26 m
9) Dump pit	
Number	1
Type	Underground Concrete Pit
Capacity	380 m^3
10) Limestone Storage Yard	
Number	1
Capacity	30 m x 25 m

Equipment	Specification
C - 2 Gypsum Recovery System	
1) Gypsum Storage Silo	
Number	2 Units
Type	Vertical Cylinder
Capacity	ϕ 17.0 m x H 25 m (3,000 tons)
2) Gypsum Conveyor (from Centrifuge to Gypsum Storage Silo)	
Number	4
Type	Belt type
Capacity	108 t/h
3) Reclimer (Inside the Silo)	
Number	2
Type	Screw type
Capacity	500 t/h
4) Gypsum Conveyor (for Discharge)	
Number	2
Type	Belt type
Capacity	450 t/h
C - 3 Auxiliary System	
1) Make-up Water Tank	
Number	1
Type	Vertical Cylinder
Capacity	280 m^3
C - 4 Waste Water Treatment System	
1) Waste Water Storage Pit	
Number	1
Type	Concrete Basin
Capacity	300 m^3
2) Adjustment Coagulation Pit	
Number	1
Type	Concrete Basin
Capacity	9 m^3
3) Sedimentation Pit	
Number	1
Type	Concrete Basin
Capacity	60 m^3
4) Neutralization Pit	
Number	1
Type	Concrete Basin
Capacity	10 m^3
5) Sludge Thickner	
Number	1
Capacity	0.4 m^3/h

Equipment	Specification
C - 5 Electrical System	
1) FGD Transformer (110 kV Incoming)	
Number	2 Units
Capacity of Windings	5 Tap
Rated Voltage	110 kV / 6 kV
Capacity	35 MVA
2) Disconnecting Switch	
Number	25 sets
Rated Voltage	110 kV
3) Switchgears	
Rated Voltage (M/C / P/C / MCC)	7.2 / 0.415 / 0.415 kV
4) Battery	
Number	5 sets
Rated Voltage	0.1 kV
Capacity	500 AH / 10 A
5) Charger	
Number	5 sets
Type	Thyristor Rectifier
Capacity	50 kVA
C - 6 Control & Instrumentation	
1) Control Desk	
Number	5
Type	Steel Plate Desk Type
CRT (Cathode Ray Tube)	1 CRT for each Desk
2) Controller	
Type	Self-standing Steel Plated Digital Controller
3) Relay Panels	
Type	Self-standing Steel Plated Hard-wired Type
4) CVCF (Constant Voltage Constant Frequency)	
Number	5
Type	Thyristor Inverter Type
Capacity	25 kVA

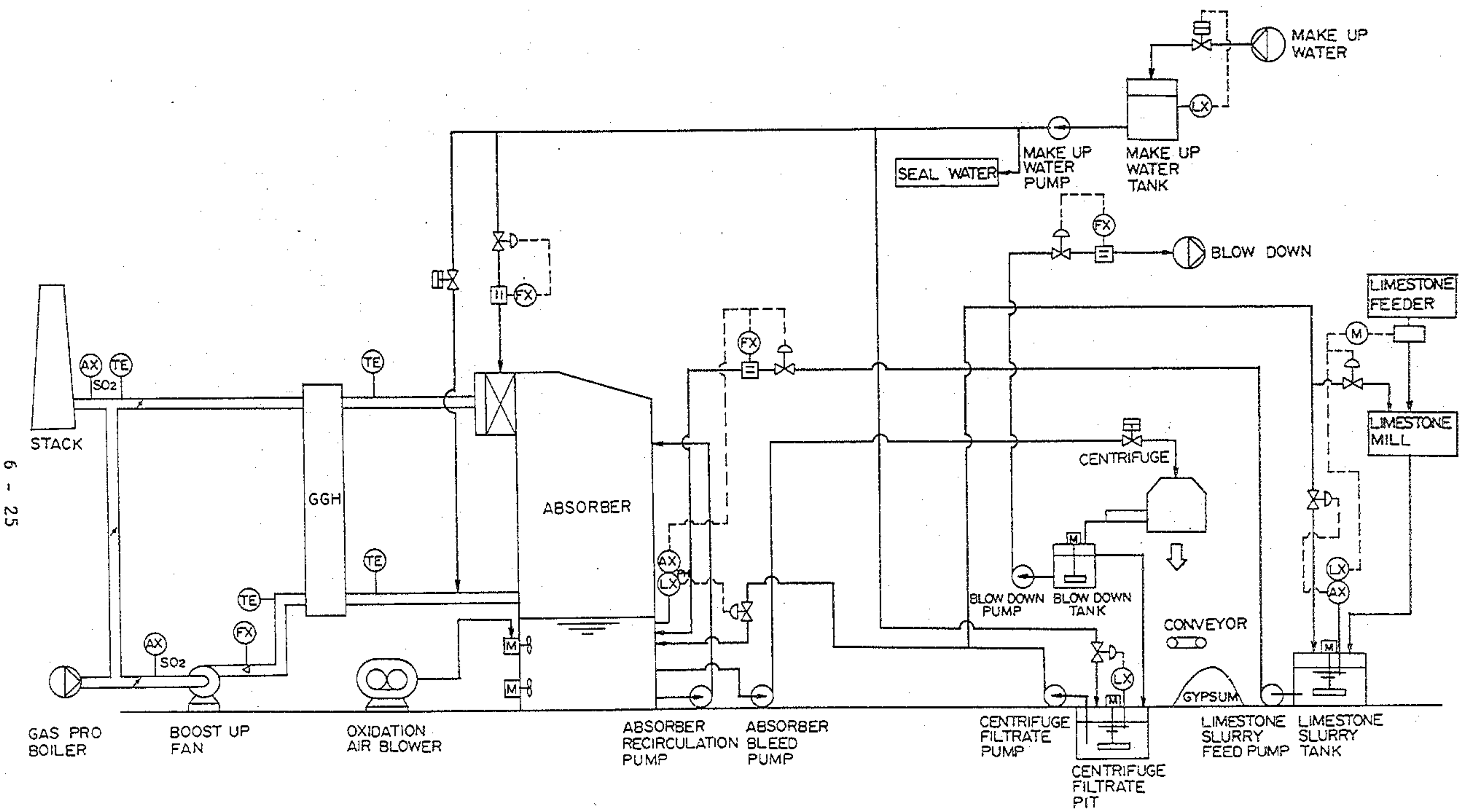


Fig.6.3-1 FLOW DIAGRAM OF FGD PLANT

6.4 DeSOx System Material Balance

Material balances of the FGDs installed at Part II and Part III are shown in Fig. 6.4-1 and Fig. 6.4-2, respectively.

These material balances are for the case where the chlorine concentration in coal is 116 mg/kg and the fluorine concentration is 587 mg/kg. Chlorine is assumed to be present in process water of the system in the form of $CaCl_2$ and fluorine is assumed to move fully into byproduct gypsum in the form of CaF_2. The purity of gypsum in this case is 94.1 to 94.2%.

The fluorine concentration in coal referred above was that measured by the combustion tube method. Measurements of fluorine concentration by the Bomb method were also carried out at analysis of coal samples collected at the Second Stage Survey, and the fluorine concentration obtained by this method was 185 mg/kg, as shown in parentheses in Table 4.3-6, which is relatively low. In addition, data obtained during operation of FGDs in Japan are indicating that the percentage of fluorine absorbed at the absorber is only as low as 60% with the low temperature ESPs (electrostatic precipitators) application.

When material balances are calculated with such assumptions, results of fluorine balance were as shown in parentheses in Figs. 6.4-1 and 6.4-2. the gypsum purity calculated using such results is 95.6%.

As for fluorine balance, a comprehensive examination must be carried out again, at the time of definite design stage, including such topics as prerequisites for effective utilization of gypsum and measurement of flue gas.

As for the required volume of waste water described in material balances, it was calculated as an hourly mean of the volume of blow water necessary to maintain the chlorine concentration in the absorber system of the FGD at 10,000 ppm, and it is judged, from past operational experiences, that operation of FGD at chlorine concentrations of this level is fully possible.

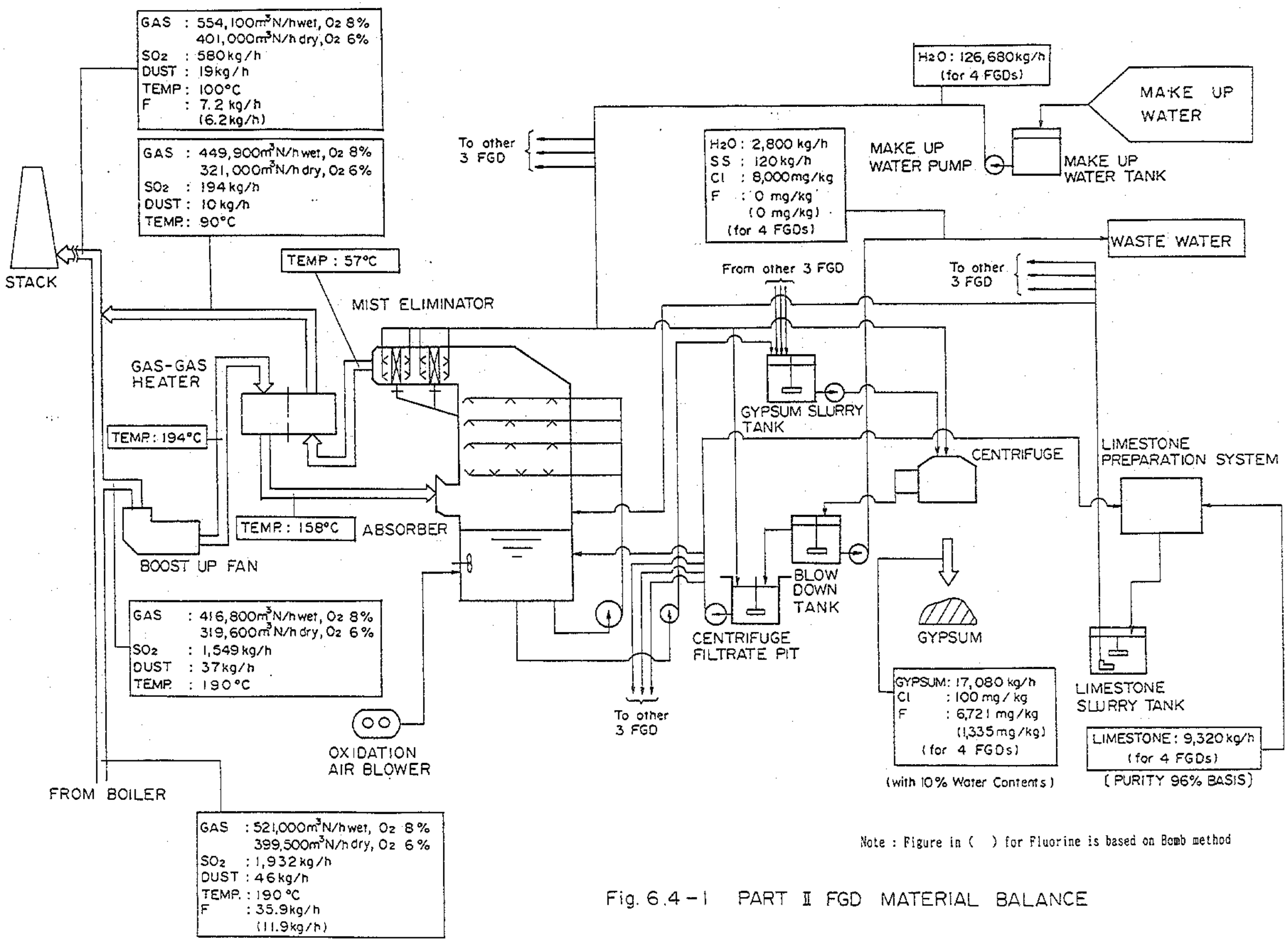
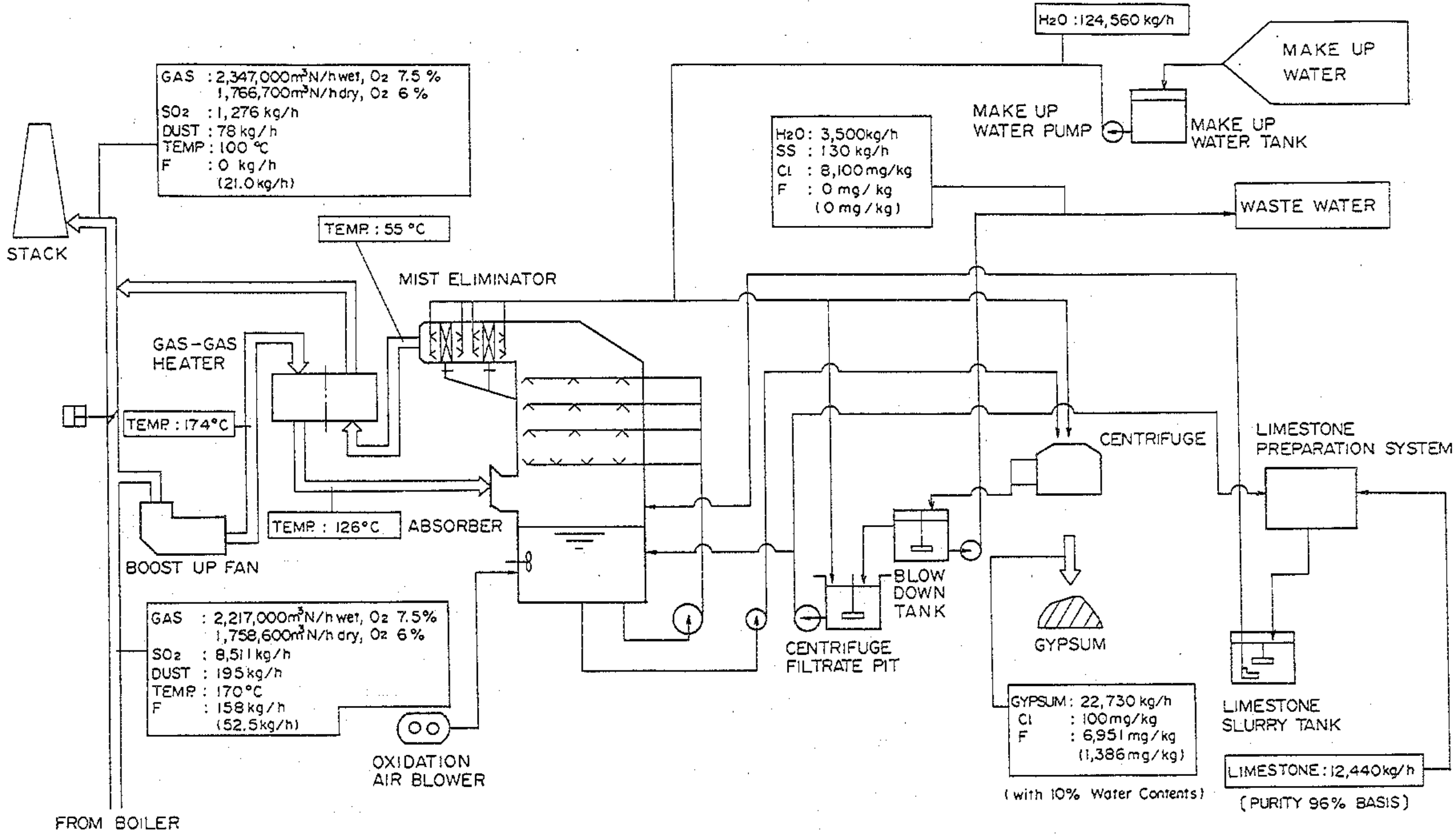


Fig. 6.4-1 PART II FGD MATERIAL BALANCE



Note : Figure in ( ) for Fluorine is based on Bomb method

Fig. 6.4-2 PART III FGD MATERIAL BALANCE