JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

FEDERAL MISTRY OF ECONOMY
CZECH AND SLOVAK FEDERAL REPUBLIC

FEASIBILITY STUDY ON FLUE GAS DESULPHURISATION FOR THE MELNIK POWER STATION

FINAL REPORT

SUMMARY

DECEMBER 1992

ELECTRC POWER DEVELOPMENT CO., LTD.

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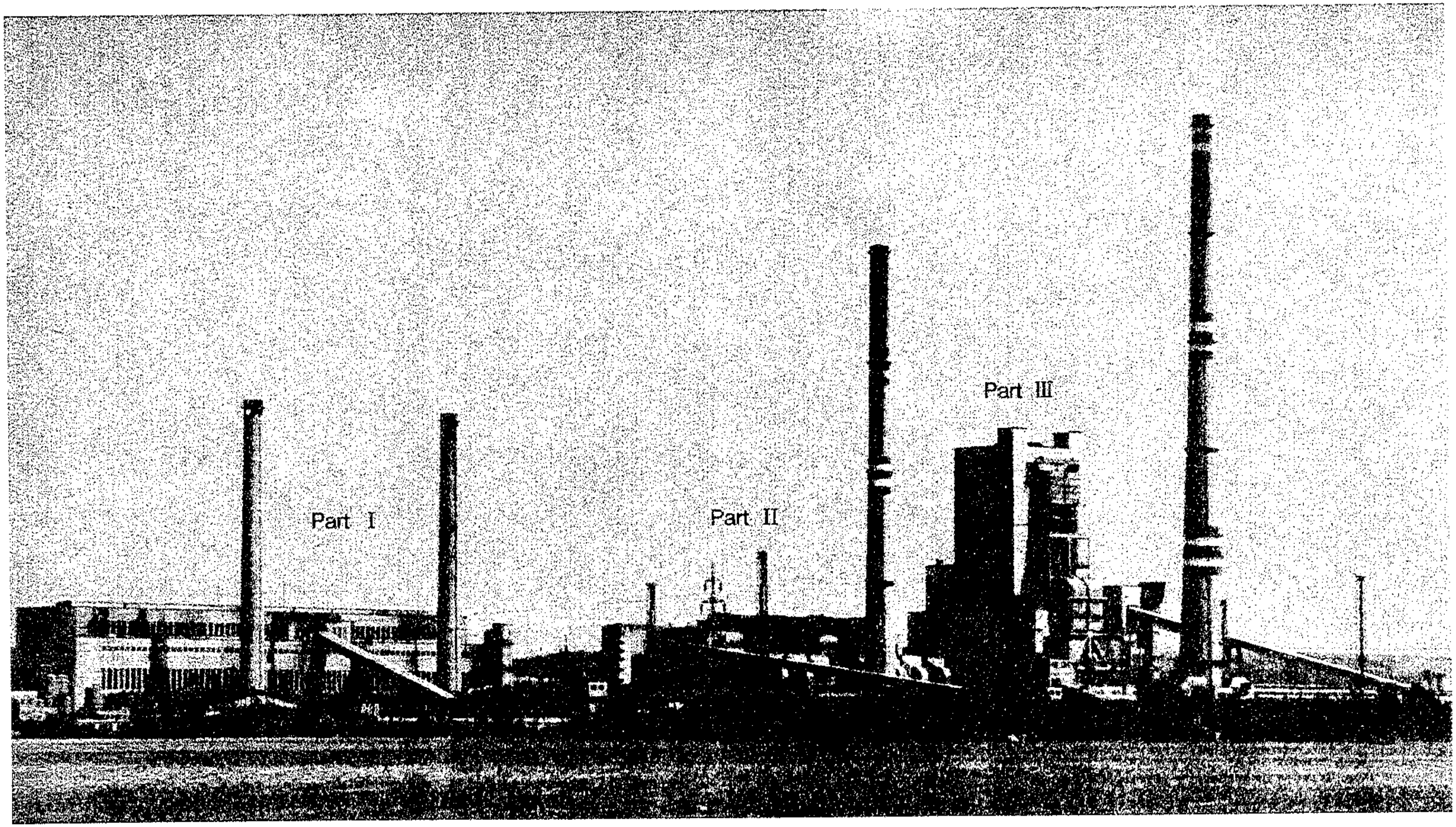
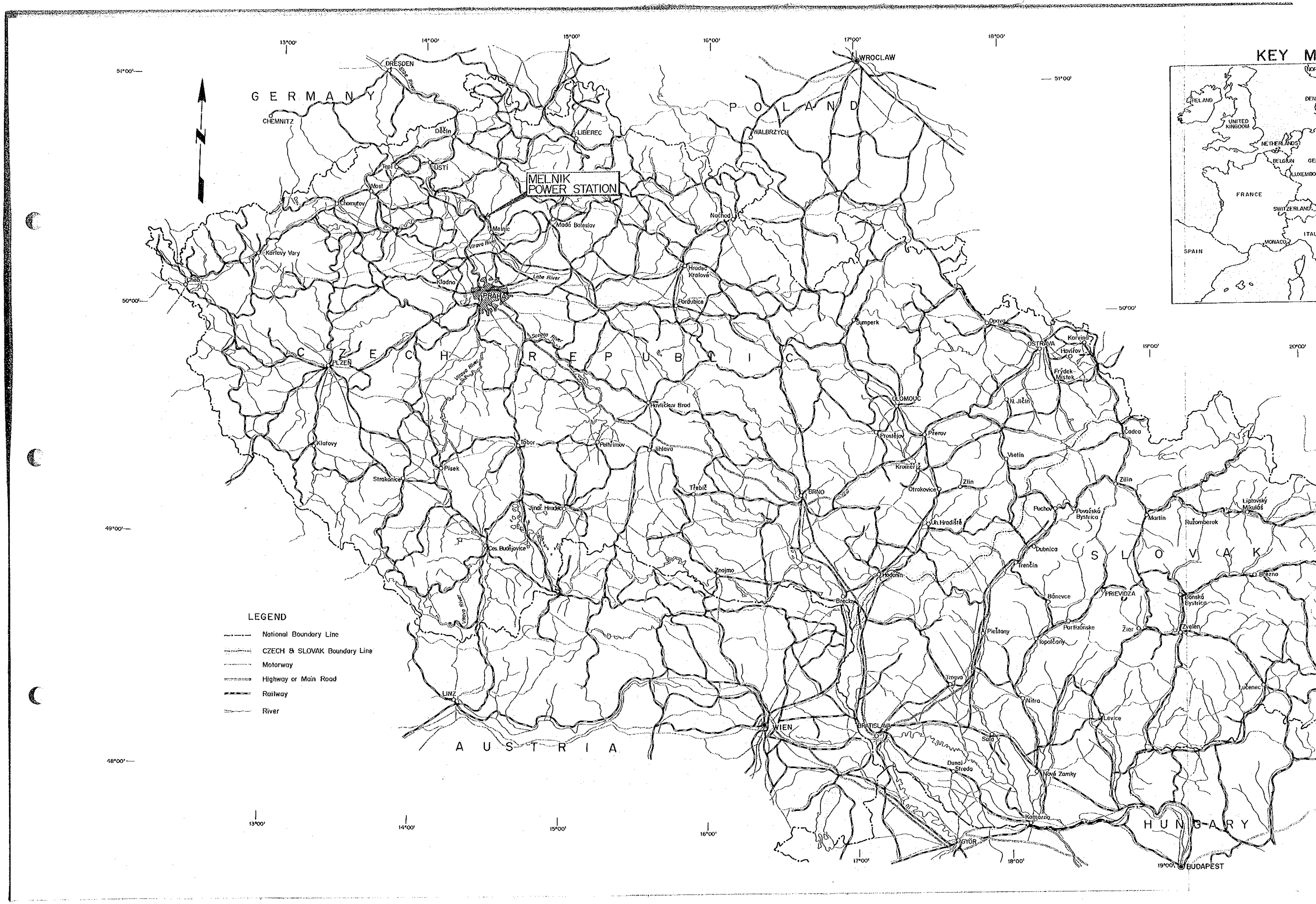
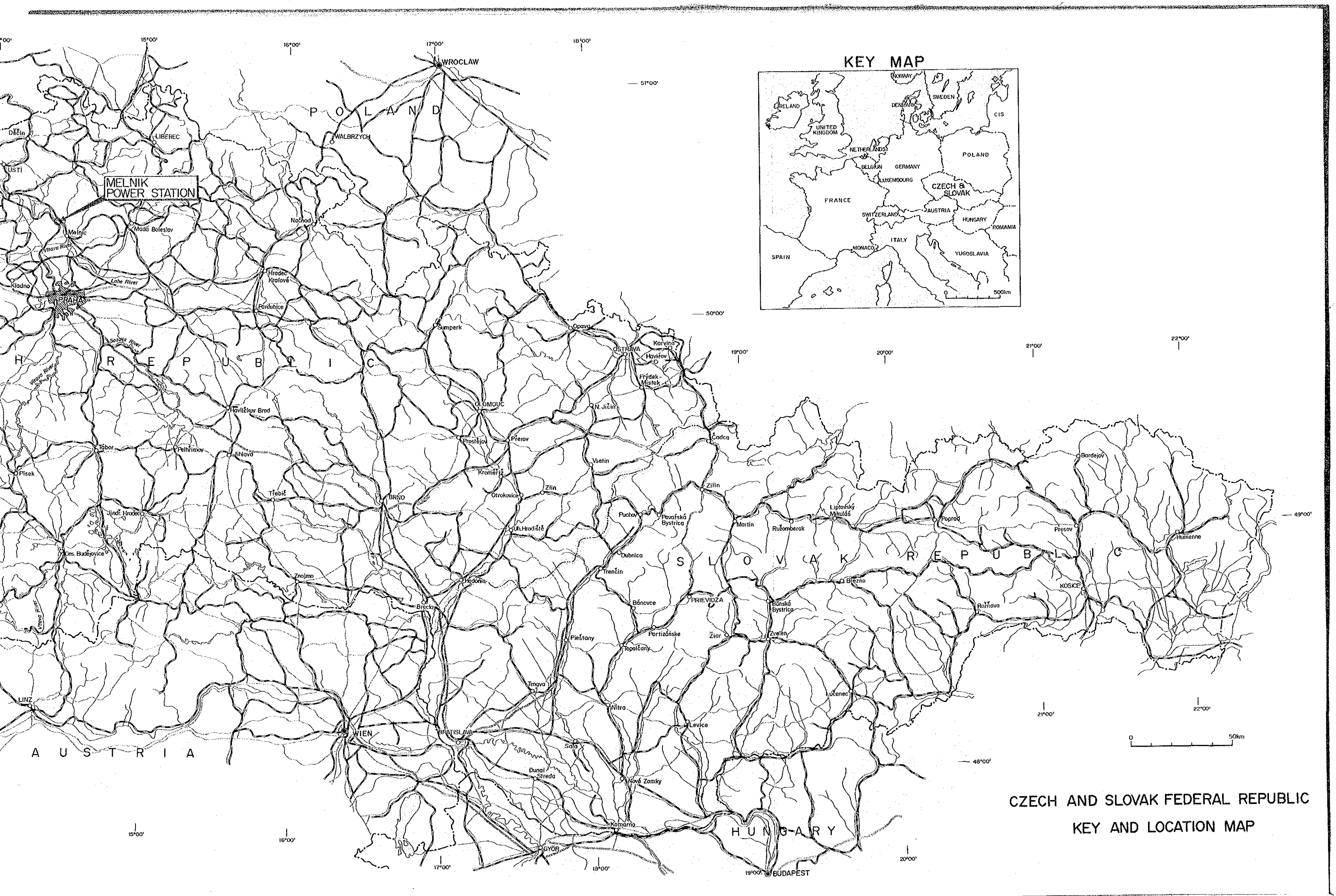


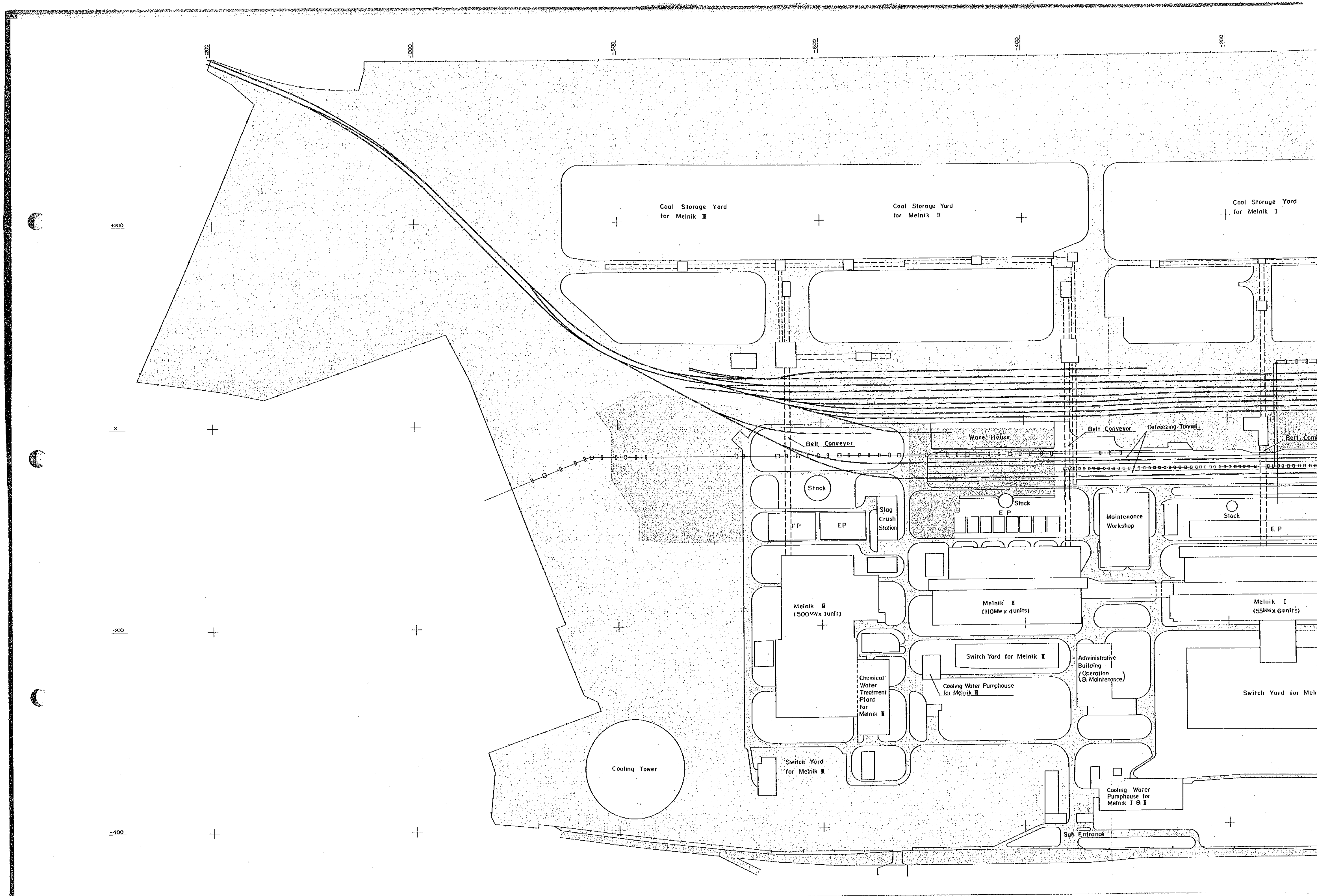
THE MELNIK POWER STATION


KEY M
IRELAND
UNITED KINGDOM
NETHERLANDS
BELGIUM
LUXEMBO
FRANCE
SWITZERLAND
MONACO
SPAIN
ITA
DEN
N
G E R M A N Y
P O L A N D
C Z E C H R E P U B L I C
S L O V A K
A U S T R I A
H U N G A R Y
MELNIK POWER STATION
DRESDEN
Elbe River
CHEMNITZ
Děčín
LIBEREC
WROCLAW
WALBRZYCH
Tepl
ÚSTÍ
Most
Chomutov
Mělník
Mladá Boleslav
Náchod
Karlovy Vary
Cheb
Vltava River
Labe River
Kladno
PRAHA
Hradec Králové
Pardubice
Šumperk
Opava
OSTRAVA
Karviná
Havířov
Frýdek-Místek
Sazava River
PLZEŇ
Havlíčkův Brod
OLOMOUC
N. Jičín
Čadca
Prostějov
Přerov
Klatovy
Tábor
Pelhřimov
Jihlava
Vsetín
Písek
Strakonice
Kroměříž
Třebíč
BRNO
Otrokovice
Zlín
Žilina
Jindř. Hradec
Púchov
Považská Bystrica
Martin
Ružomberok
Liptovský Mikuláš
Uh. Hradiště
Čes. Budějovice
Dubnica
Trenčín
Znojmo
Hodonín
Brezno
Břeclav
Bánovce
PRIEVIDZA
Banská Bystrica
Piešťany
Partizánske
Žiar
Zvolen
Topoľčany
Trnava
LINZ
Nitra
Lučenec
Levice
WIEN
BRATISLAVA
Šaľa
Dunaj. Streda
Nové Zámky
Komárno
GYŐR
BUDAPEST
LEGEND
National Boundary Line
CZECH & SLOVAK Boundary Line
Motorway
Highway or Main Road
Railway
River
13°00'
14°00'
15°00'
16°00'
17°00'
18°00'
19°00'
20°00'
51°00'
50°00'
49°00'
48°00'

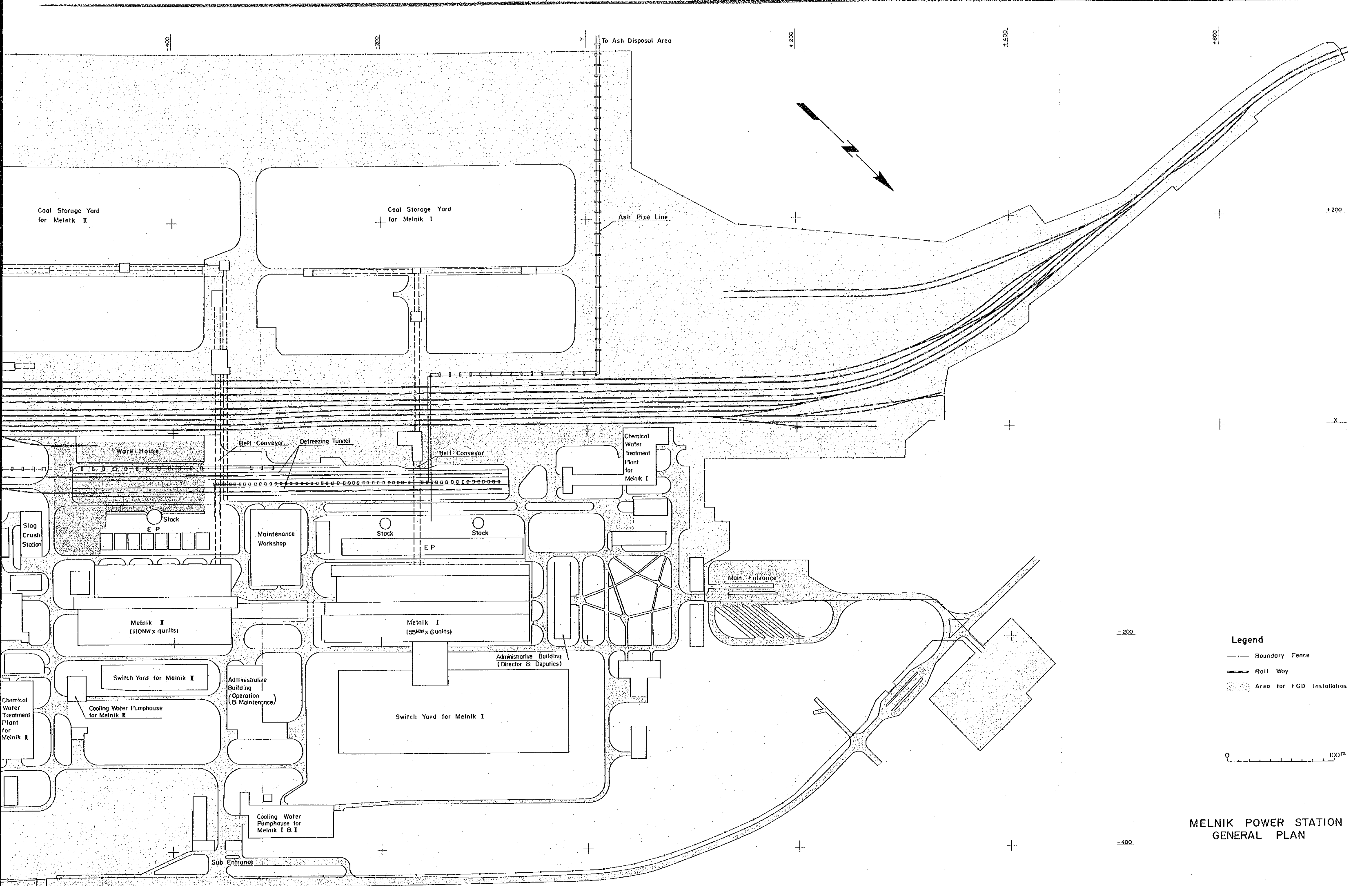


CZECH AND SLOVAK FEDERAL REPUBLIC

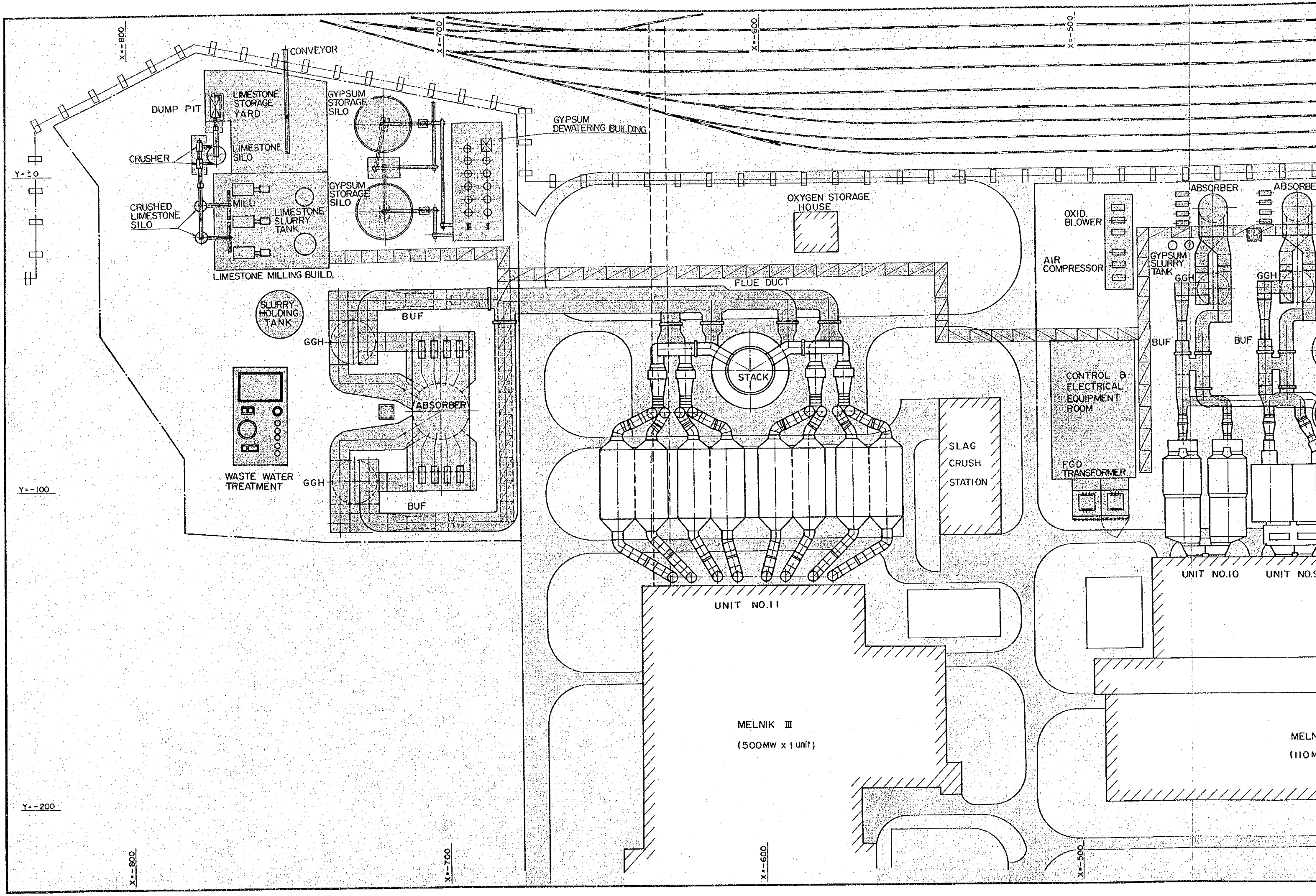
KEY AND LOCATION MAP



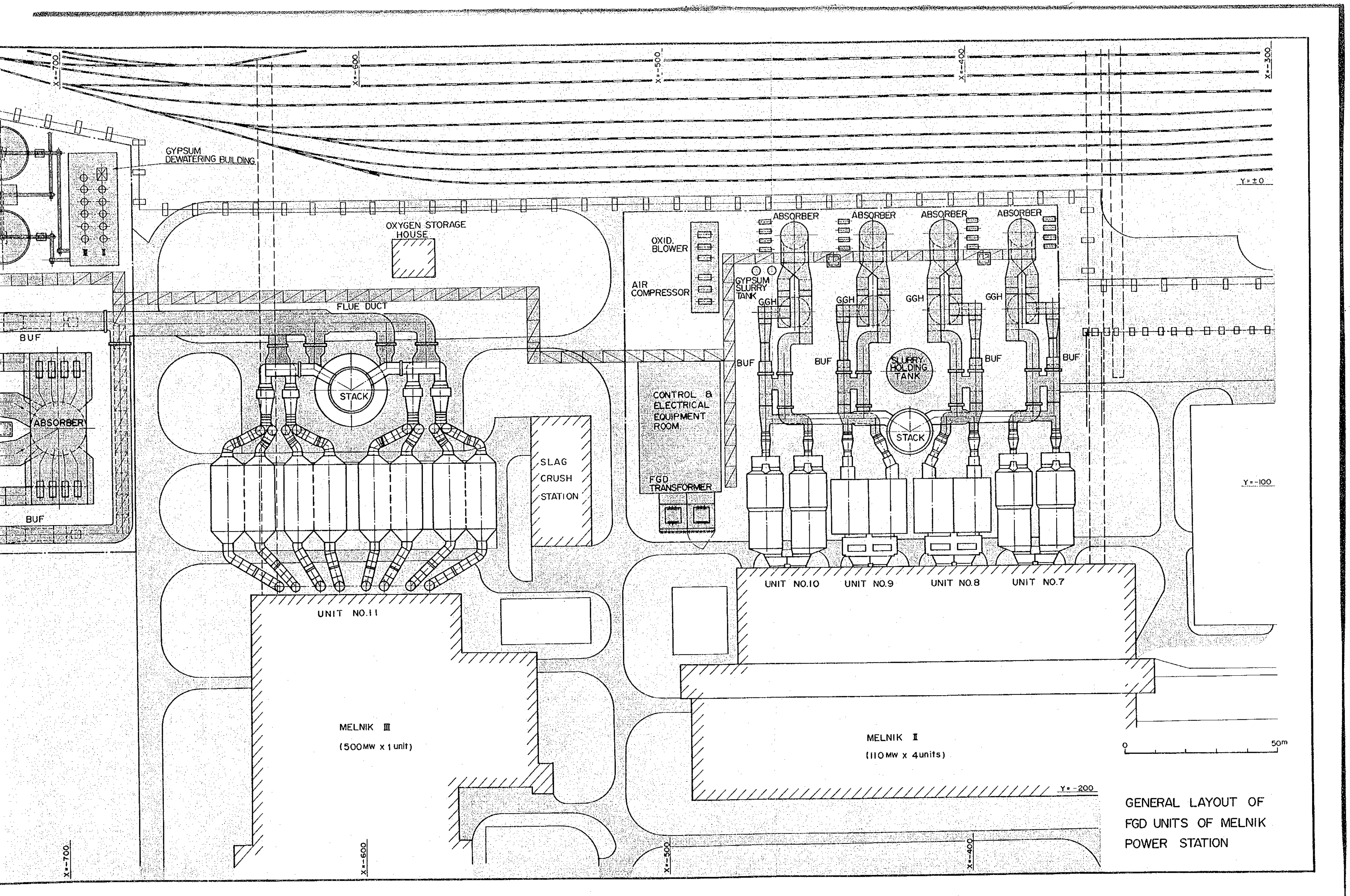
-1200
-1000
-800
-600
-400
-200
+200
x
-200
-400
Coal Storage Yard for Melnik III
Coal Storage Yard for Melnik II
Coal Storage Yard for Melnik I
Belt Conveyor
Ware House
Belt Conveyor
Defreezing Tunnel
Belt Conve
Stack
EP
EP
Slag Crush Station
Stack
E P
Maintenance Workshop
Stack
E P
Melnik III (500MW x 1unit)
Melnik II (110MW x 4units)
Melnik I (55MW x 6units)
Switch Yard for Melnik II
Administrative Building (Operation & Maintenance)
Chemical Water Treatment Plant for Melnik III
Cooling Water Pumphouse for Melnik III
Switch Yard for Melni
Switch Yard for Melnik III
Cooling Tower
Cooling Water Pumphouse for Melnik I & II
Sub Entrance



MELNIK POWER STATION
GENERAL PLAN



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



GENERAL LAYOUT OF FGD UNITS OF MELNIK POWER STATION

FEASIBILITY STUDY
ON
FLUE GAS DESULPHURISATIOHN
FOR
MELNIK POWER STATION
IN
CZECH AND SLOVAK FEDERAL REPUBLIC

SUMMARY

(CONTENTS)

OUTLINE OF THE STUDY

Study items of the Investigation of the Feasibility Study on Flue Gas Desulphurisation of Melnik Power Station in Czech and Slovak Federal Republic were as follows:

1st Stage

a. Collection and analysis of data related to the Feasibility Study

b. Determination of the level of SOx emission from the power plants, and environmental assessment based on the level of SOx emission of the power plants

c. Technical evaluations and economic comparison for selection of the optimum flue gas desulphurisation (FGD) method and equipment for the power plants

2nd Stage

a. Supplementary survey of the 1st stage field survey

b. Conceptual design of DeSOx system

c. Preparation of overall implementation plan

3rd Stage

a. Calculation of new tariff necessitated by introduction of DeSOx system

b. Assessment of benefits from introduction of DeSOx system

c. Assessment of socio-economic effects by introduction of DeSOx system

The Czech and Slovak Federal Republic ratified the Helsinki Agreement in 1985, the country is obliged to reduce the sulfur oxides emission (SOx) to about 70% of the 1980 level by 1993. The New Clean Air Act was enacted in October 1991 because of this background and regulatory limits of the sulfur SOx were defined for respective smoke sources. When such regulatory limits are applied to Part II (110 MW x 4 units) and Part III (500 MW x 1 unit) of Melnik Power Station, which are studied in this Study, the regulation are as follows:

By the 1st of October 1996

Part II : Installation of FGD with deSOx efficiency of over 70% for each of 110 MW power units

Part III : Installation of FGD with deSOx efficiency of over 85% for 500 MW unit

when emission standards are applied to Melnik Power Station, annual SOx emission reduces from about 77,300 ton to 17,500 ton.

Studies were made for the purpose of meeting such requirements and conclusions reached by the study were to install FGD of wet type limestone-gypsum process to both Part II and Part III.

Optimum combinations of power plants and FGDs are as follows:

Part II : To install one FGD unit, of 80% in flue gas treatment rate and 87.5% in deSOx efficiency and 70% in total deSOx efficiency, to each of the 110 MW power units

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

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

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

The study suggests that it is necessary to make an order of the FGD equipment by around the end of April in 1994 and to start the erection by around the end of May in 1995 in order to put into DeSOx system commercial operation from the 1st of October, 1996.

Estimations of the construction cost as of the 1st of July, 1992 were

Part II : 114,978,000 US$

Part III : 115,574,000 US$

If the figures are converted into unit cost per kW, they are

Part II : 261.3 US$/kW

Part III : 231.1 US$/kW

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

Tariff is calculated based on the annual cost including interest during construction. As a result of this calculation, 0.26 to 0.36 kčs/kWh at maximum additional burden in tariff is estimated.

For the economic evaluation, reconstruction of natural gas firing boilers was chosen.

According to this economic evaluation, this project is much superior to the reconstruction of natural gas firing boilers in terms of cost.

Following are analysis on introduction of DeSOx system in Czechoslovak power stations.

- Economic extension and increase in employment attributable to increase in investment.
- Absorbable effect on electricity tariff
- Increase in export

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

1. Socio-economic Background

The storms of democratization which occurred in Eastern Europe in the fall of 1989 also blew Czechoslovakia, and the communist rule of the country was demolished by the so-called "Velvet Revolution." The country is on the road to democratization since then.

In foreign relations, the country is starting to make more friends with western countries by changing its former posture with which it had tighter relations with former Soviet Union and other socialist countries. In September 1990, Czechoslovakia joined the IMF and the World Bank, and the country joined the EC as a quasi member in December 1991.

Economic reforms of the country is proceeding based on the "Scenarios of the Economic Reform" drafted in September 1990. Economy of the country, however, has been under negative growth in recent years mostly due to weaker relations with the former Soviet Union since 1989, confusion associated with economic reforms and deterioration in external economic environment.

Major policies being enforced for economic reforms include the following:

(1) Liberalization of pricing

(2) Liberalization of foreign trade

(3) Return of farmland to former owners

(4) Recovery of exchangeability to foreign currencies

(5) Privatization of nationally-owned enterprises

As for the availability of primary energies in Czechoslovakia, natural gas is present little, petroleum is almost nil and hydraulic energy for power generation is not abundant. Czechoslovakia is very cautious in handling uranium in consideration of effects to the environment. The electric power industry, which depends on the power source to electricity for brown and bituminous coals, now over 90%, is managed by two national corporations of the

CEZ (Ceske Energeticke Zavody) and the SEP (Slovenske Energeticke Podniky).

The CEZ changed to public limited company in May of 1992. 30% of all shares of CEZ is going to be sold to the public by the coupon system. (70% are going to be held by the republic.)

The total electric power generated in the country in 1991 was 83.4 TWh, and 51.6 TWh of the amount was generated by the CEZ. As for the energy mix of power generation, brown coal accounts for 75%, nuclear energy 23% and hydraulic power 2%. Low quality brown coal is being used much in the country not only for power generation but also for domestic heating. The total emission of SOx in the country is 2.56 million tons per year (current value) which is about 2.5 times as much as that in Japan. The emission rate is especially high in northern Bohemia and Prague region exceeding 100 t/year km^2. Forests have been severely damaged and adverse effects of such emission to humans are apprehended.

With such backgrounds, Czechoslovakia ratified the Helsinki Agreement in 1985, the country is now tackling in full force with air pollution to improve the environment with the help of the New Clean Air Act enforced in 1991.

In Table 1-1, Emission Standards in Czechoslovakia is shown.
The total generating capacity of 1,270 MW of the Melnik Power Station is about 6% of the total generating capacity of the country. The Melnik Power Station is the third largest power station in the country, and an important supplier to the capital of Prague.

It is judged, in comparison with other coal fired power plants of CEZ, that the production cost at the Melnik Power station is low (Part I: 535.22 kčs/MWh, II: 477.39 kčs/MWh, III: 435.59 kčs/MWh).

The structure of Melnik Power Station and the outline of Melnik Part II and III are shown in Table 1-2 and Table 1-3, respectively.

Table 1-1 **Emission Standards in Czechoslovakia**

Emission Standard				
Kind of Fuel	Emission Limits (mg/m^3N)	Installed Capacity (Thermal Output - MWt)		
		5 - 50	50 - 300	> 300
Solid (Coal)	SO_2	2,500	1,700*	500*
	ηDeSOx(%)		(70)	(85)
	NOx (as NO_2)	650	650	650
	Solid (Dust)	150	100	100
Liquied (Oil)	SO_2	1,700	1,700	500
	NOx (as NO_2)	450	450	450
	Solid (Dust)	100	50	50
Gas	SO_2	35	35	35
	NOx (as NO_2)	200	200	200
	Solid (Dust)	10	10	10
Remarks		• The value with *mark is the upper limit of SO_2 emission by regulation without DeSOx installation. If it is not possible to meet this regulation, the regulation of efficiency of over the value shown in brackets is applied. • Figure of concentration described here is all as of dry base and 6% O_2 equivalent. • Plant operation without DeSOx system, caused by FGD failure is allowed as long as 360 hours per year and 96 hours per once in maximum. • This standards are applied to all Emission Sources from October 1996.		

Table 1-2 **The Structure of Melnik Power Station**

Part	Unit Number	Output	Stack	Start of Construction	Date of Commissioning
I	1	55 MW	120 m high × 1	1957	Sep. 30, 1960
	2	55 MW			
	3	55 MW			∫
	4	55 MW	120 m high × 1		
	5	55 MW			
	6	55 MW			Sep. 27, 1961
II	7	110 MW	200 m high × 1	1967	Dec. 30, 1970
	8	110 MW			May 20, 1971
	9	110 MW			Sep. 28, 1971
	10	110 MW			Nov. 27, 1971
III	11	500 MW	270 m high × 1	1976	Nov. 5, 1981

Table 1-3 **Outline of Melnik Part II and III**

Items	Outline of Facilities	
	Part II	Part III
1. Major Equipment	Units Nos. 7 - 10	Unit No. 11
(1) Unit Output	110 MW	500 MW
(2) Boiler		
Type	Drum type, natural circulation type	Drum type, forced circulation type
Maximum Evaporation	350 T/H	1,670 T/H
Firing System	Pulverized coal-firing	Pulverized coal-firing
Fuel	Lignite	Lignite
Mill Type	Fan Type	Fan Type
(3) Turbine		
Type	Tandem reheat, condensers, 3-casing type	Tandem reheat, condensers, 3-casing type
Speed	3,000 rpm	3,000 rpm
Main Steam Pressure	129 kg/cm^2g	165 kg/cm^2g
Main Steam Temperature	540°C	540°C
Reheat Steam Temperature	540°C	540°C
(4) Environmental Facility	Electrostatic Precipitator (180 ~ 200°C)	Electrostatic Precipitator (160 ~ 180°C)
(5) Stack	1 stack for No. 7 - No. 10 Units 200 m Height	1 stack 270 m Height
2. Condenser Cooling Water	Taken from Labe River	Taken from the condenser outlet of Part II's cooling water.
3. Coal Yard	Outdoor storage system, 3 piles used by all Units, transported to coal yard by rail.	
4. Ash Disposal Site	Ash slurry transported by pipeline to a site about 1.5 km to the south-west of the plant.	

2. Conditions of the FGD Project Site

The Melnik Power Station is located on the left bank of the Labe (Elbe) River at about 35 km north of Prague. Roads and the railway from Prague to the Power Station are in good condition, and can be used effectively for transportation of FGD materials.

The climate of Czechoslovakia is just about middle of the oceanic climate of western Europe and the continental climate of Eastern Europe. In comparison with the climate in countries of similar latitudes in Western Europe, it is hotter in summer and colder in winter in Czechoslovakia. The annual precipitation is small at about 530 mm.

The topography around the Melnik Power Station is showing a moderate slope from a small hill (about 260 m in elevation on the southwest of the Power Station, where the ash disposal area is present) toward the Labe River. The elevation at the Power Station is 160 m.

As for the geology around the Melnik Power Station, the land surface is covered with sediments of the Labe River. About 2 m of soil at the top is loess, and layers of sand and gravel are existing down to 11 m deep (EL. 149 m) from the ground level (GL). Rock layers of sandy mudstone and muddy limestone are existing below EL. 149 m.

3. Selection of the Optimum DeSOx System

In Czechoslovakia, emission standards (shown in Table 1-1) were enacted in October 1991. Such emission standards will be enforced from October 1996, and emission sources are obliged to shut down if they do not meet applicable emission standards. Emission standards are applied to each emission source (i.e., each boiler), and emission standards to be applied to Part II and Part III of the Melnik Power Station are as follows:

- Part II of Melnik power station

  Single unit capacity: 110 MWe
  The regulation of "Installation of FGD with efficiency of over 70%" is applied.

- Part III of Melnik power station

  Unit capacity: 500 MWe
  The regulation of "Installation of FGD with efficiency of over 85%" is applied to Part III.

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

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

[Wet type]

a. Limestone-gypsum process -- Spray tower method

b. Limestone-gypsum process -- Jet bubbling method

[Semi-dry type]

c. Spray dryer method

d. Limestone injection into furnace method

e. Slaked lime injection into duct method

[Dry type]

f. Activated coke method (Regenerative type)

g. Electron beam method (Reference)

Reaction flow sheets and process flow sheets of these methods are shown in Fig. 3-2 to 3-15.

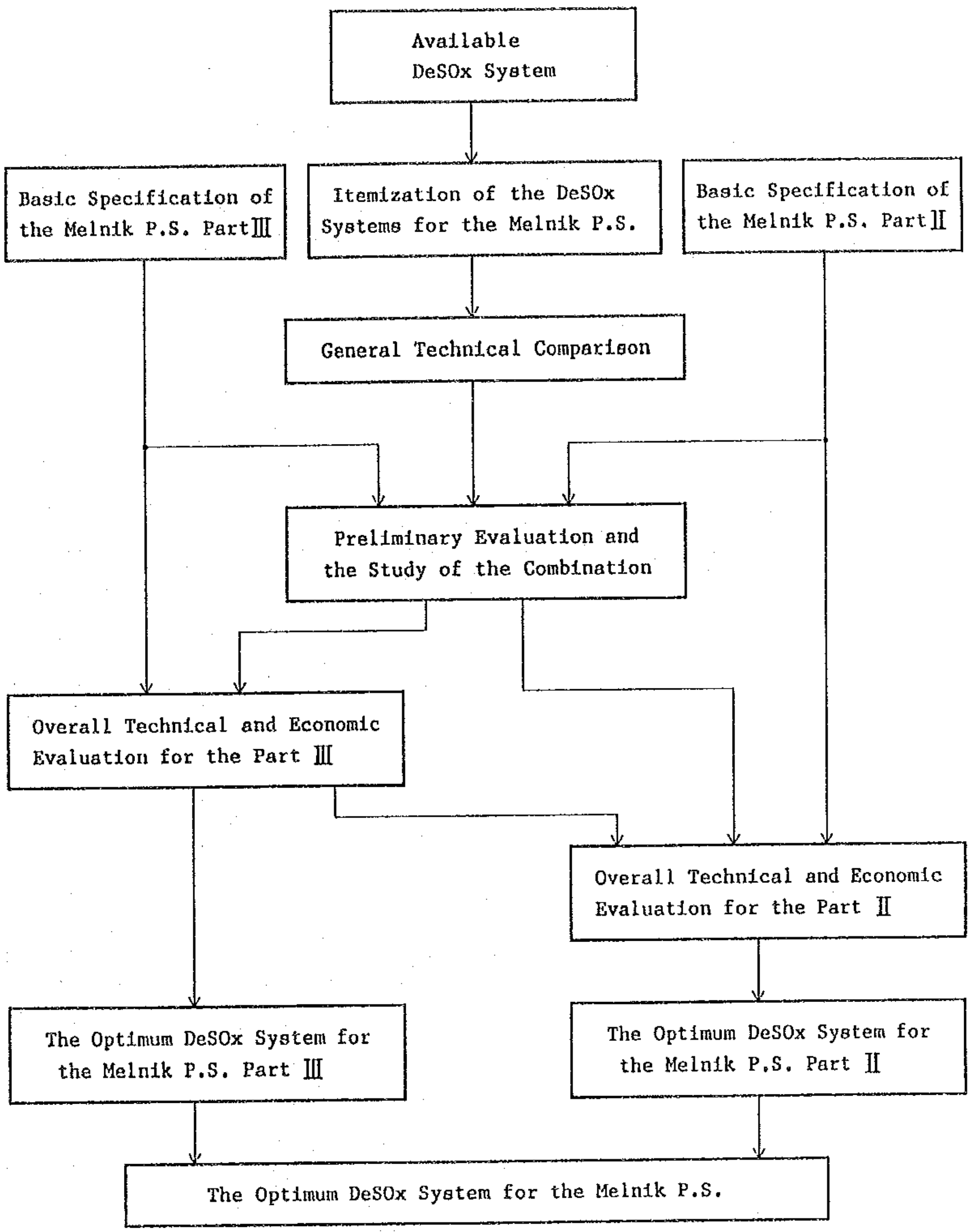


Fig. 3-1 SELECTION FLOW OF THE OPTIMUM DeSOx SYSTEM

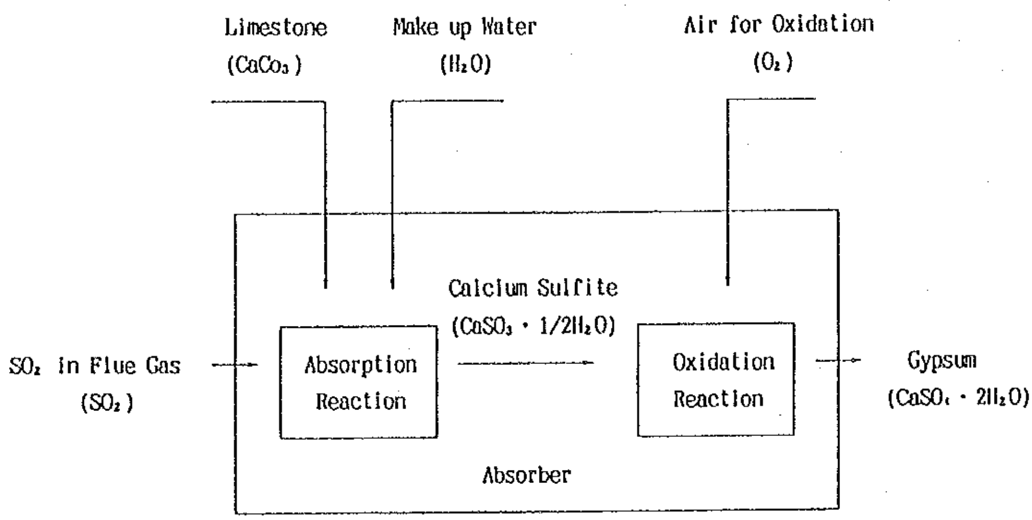


Fig. 3-2 REACTION FLOW OF WET LIMESTONE-GYPSUM PROCESS (SPRAY TOWER METHOD)

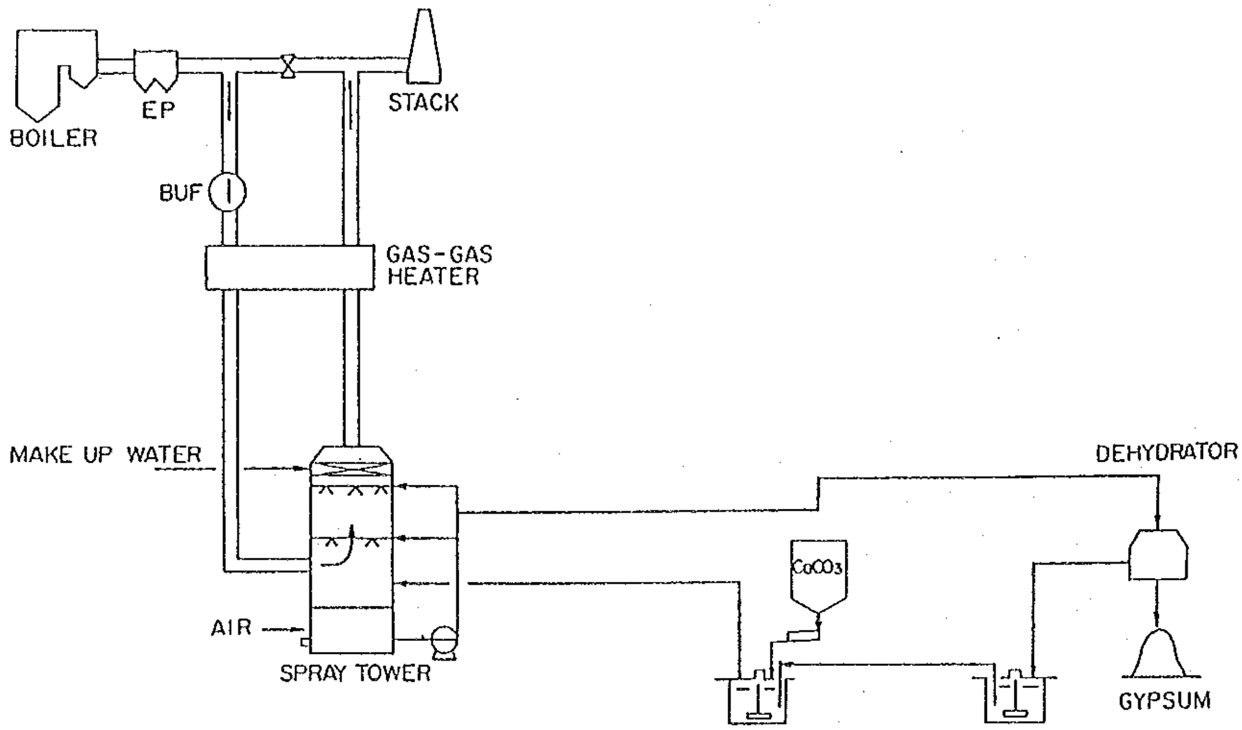


Fig. 3-3 PROCESS FLOW OF WET LIMESTONE-GYPSUM PROCESS (SPRAY TOWER METHOD)

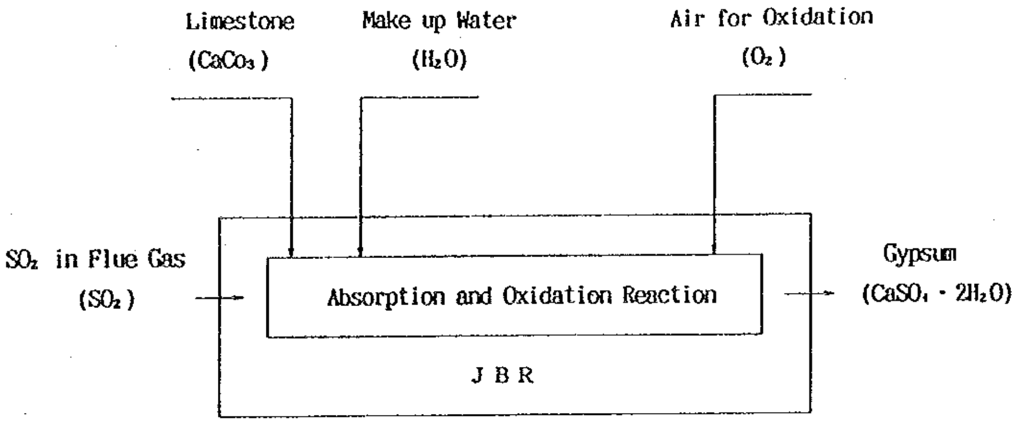


Fig. 3 - 4 REACTION FLOW OF WET LIMESTONE-GYPSUM PROCESS
(JET-BUBBLING METHOD)

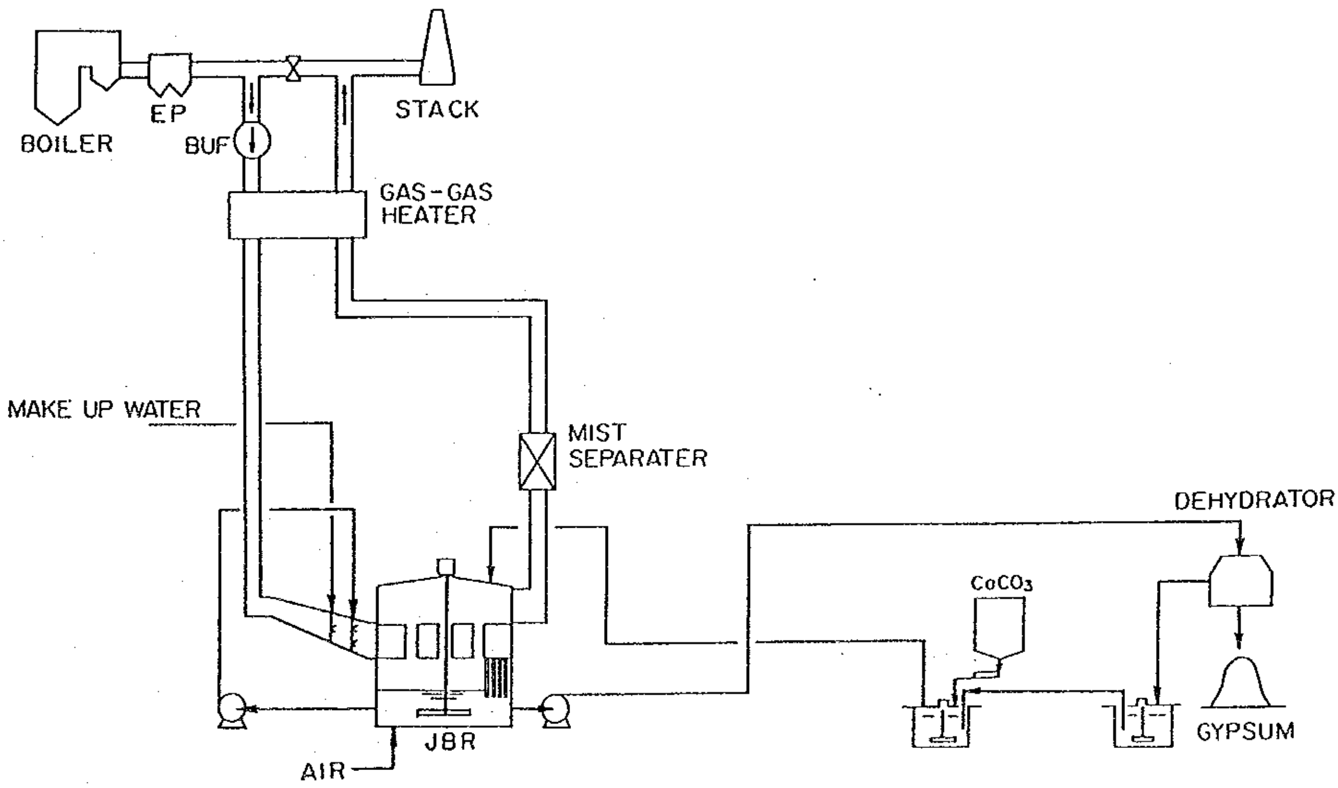


Fig. 3 - 5 PROCESS FLOW OF WET LIMESTONE-GYPSUM PROCESS
(JET-BUBBLING METHOD)

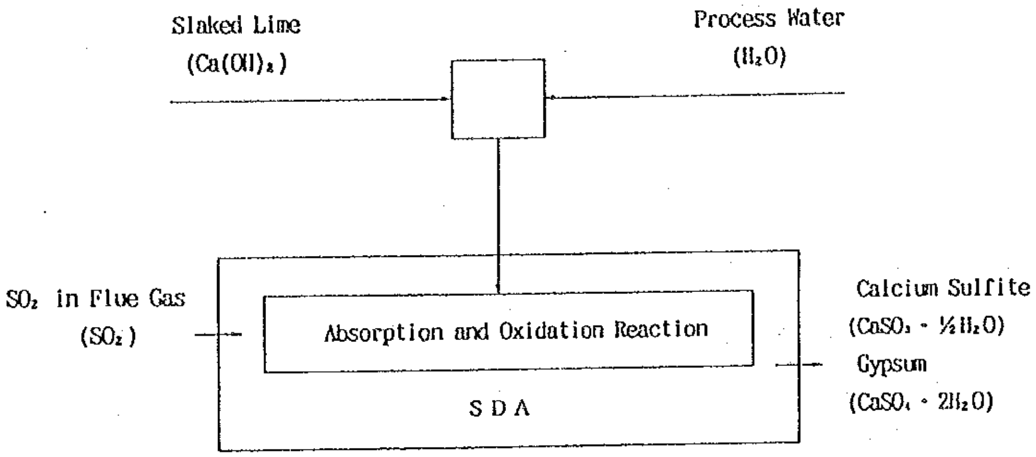


Fig. 3-6 REACTION FLOW OF SPRAY DRYER METHOD

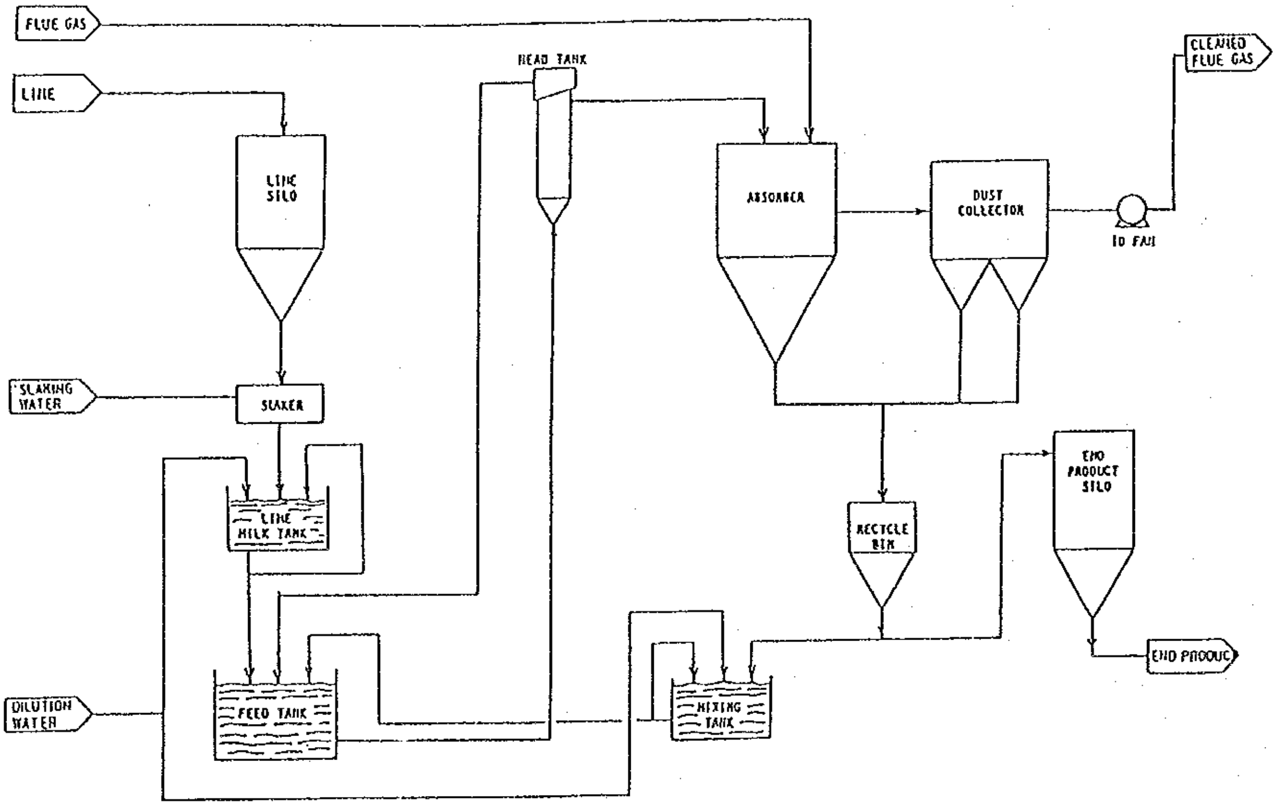


Fig. 3-7 PROCESS FLOW OF SPRAY DRYER METHOD

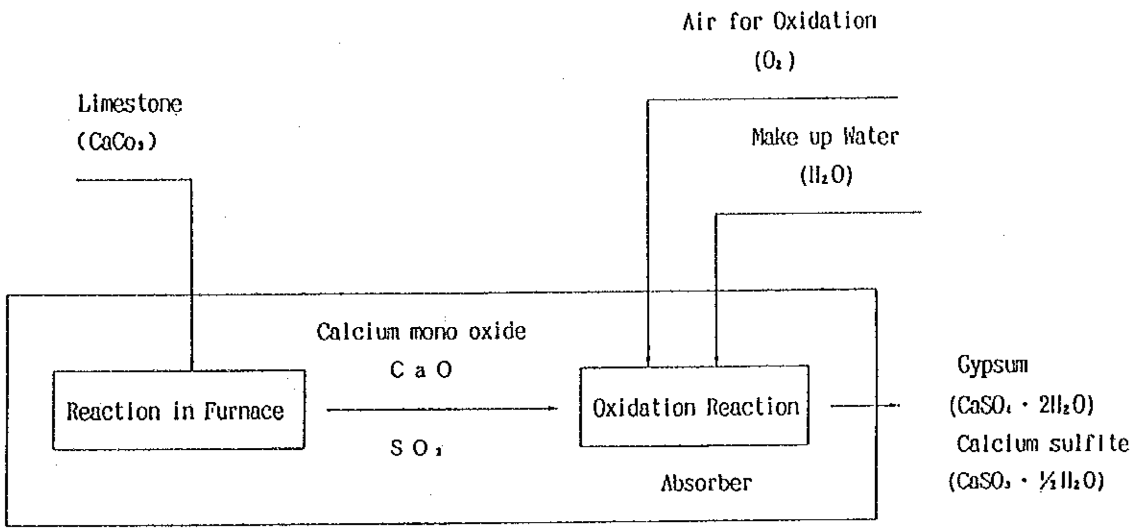


Fig. 3-8 REACTION FLOW OF DRY ABSORBENT FURNACE INJECTION SYSTEM

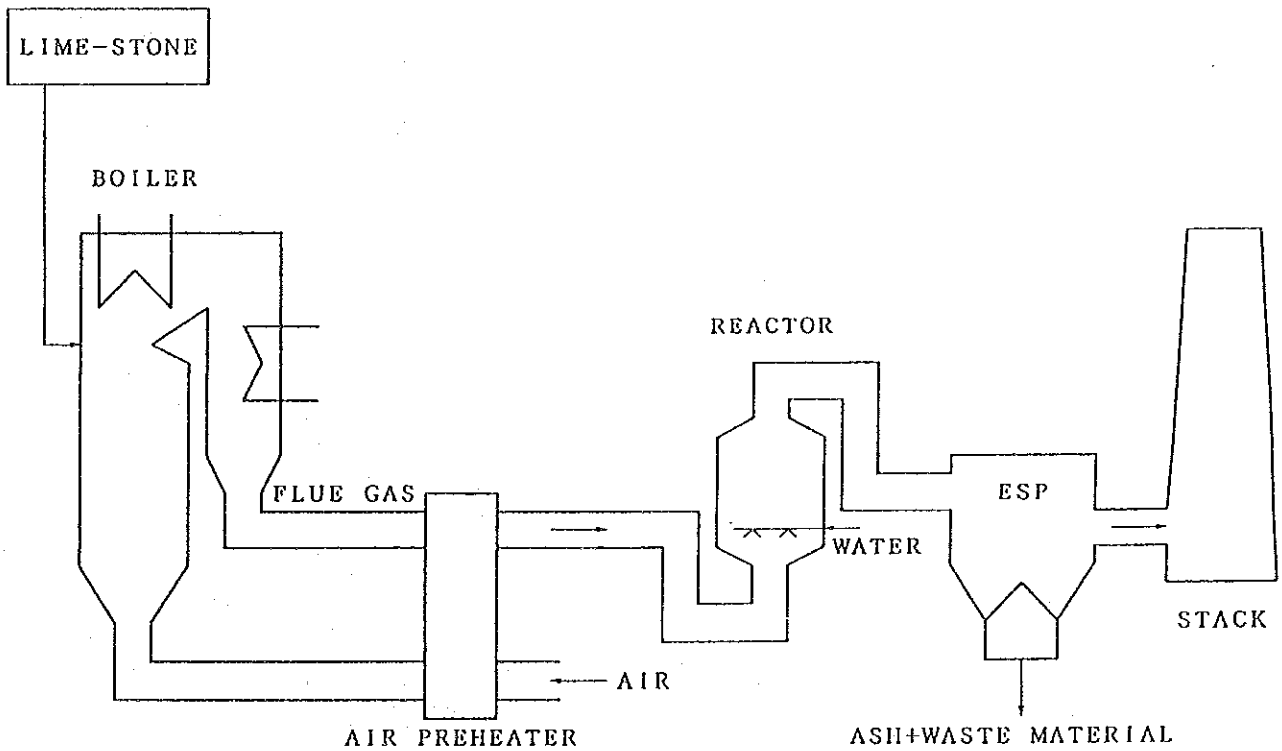


Fig. 3-9 PROCESS FLOW OF DRY ABSORBENT FURNACE INJECTION SYSTEM

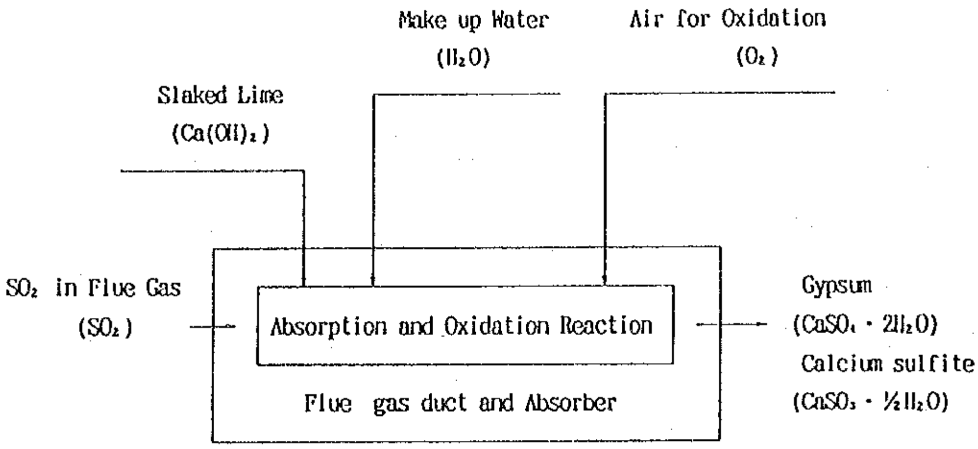


Fig. 3-10 REACTION FLOW OF DRY ABSORBENT DUCT INJECTION SYSTEM

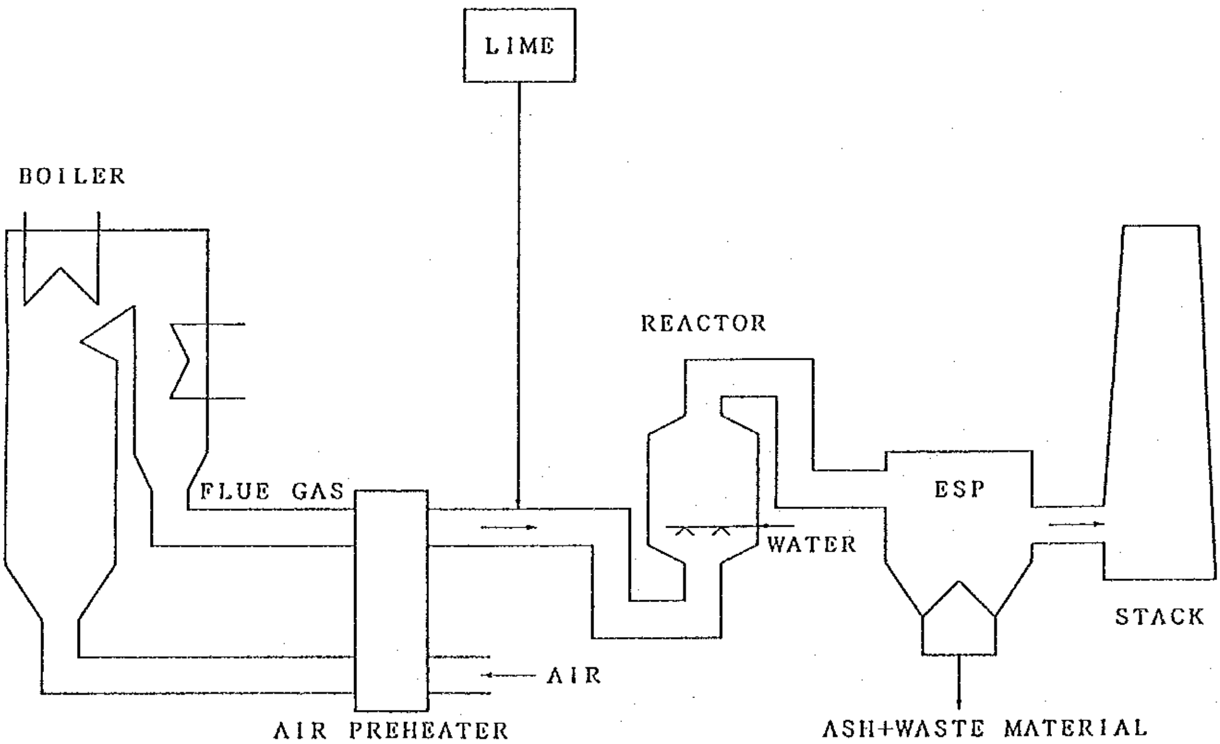


Fig. 3-11 PROCESS FLOW OF DRY ABSORBENT DUCT INJECTION SYSTEM

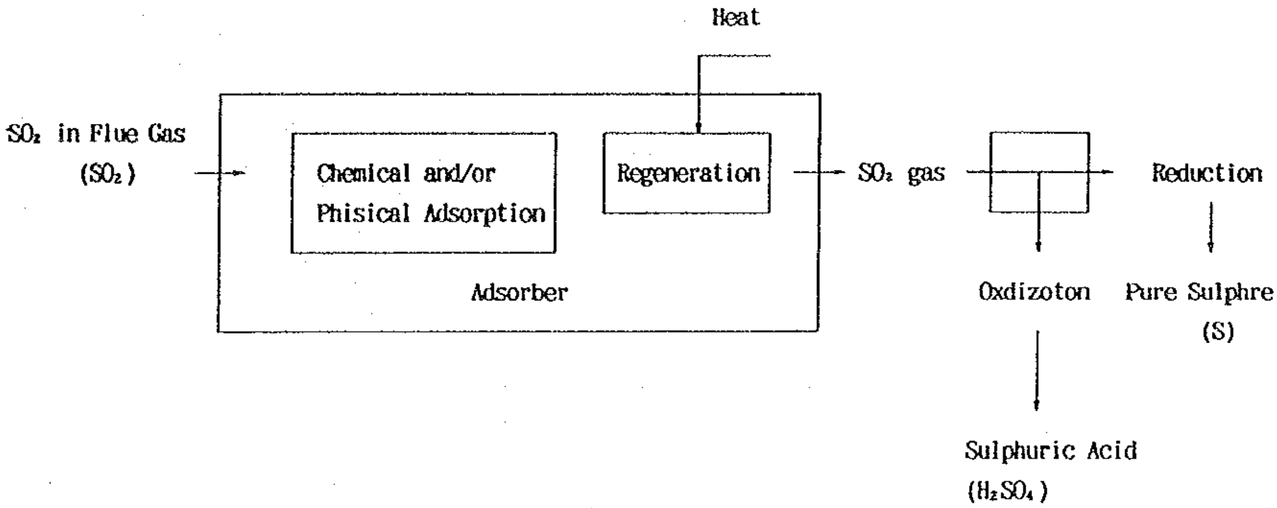


Fig. 3-12 ADSORPTION AND REGENERATION FLOW OF ACTIVATED COKE METHOD

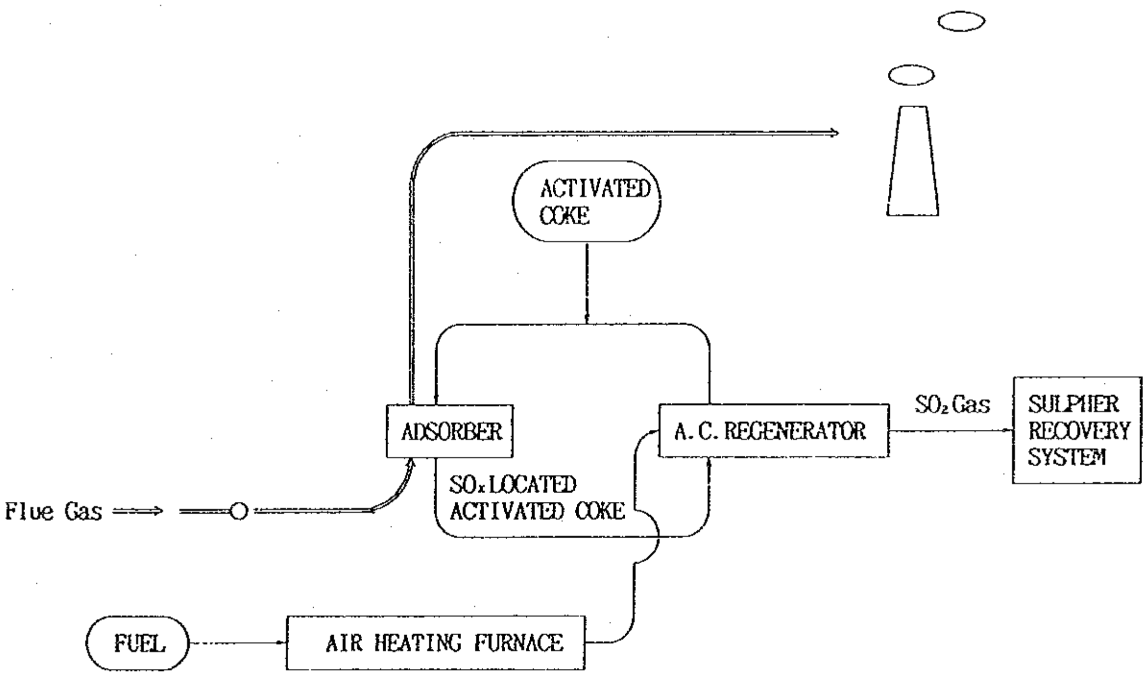


Fig. 3-13 PROCESS FLOW OF ACTIVATED COKE METHOD

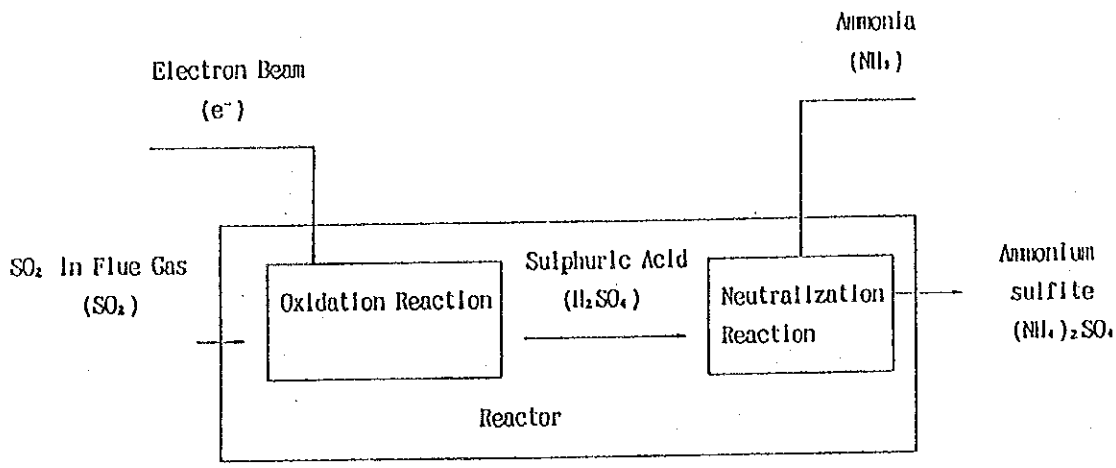


Fig. 3-14 REACTION FLOW OF ELECTRON BEAM SYSTEM WITH AMMONIA

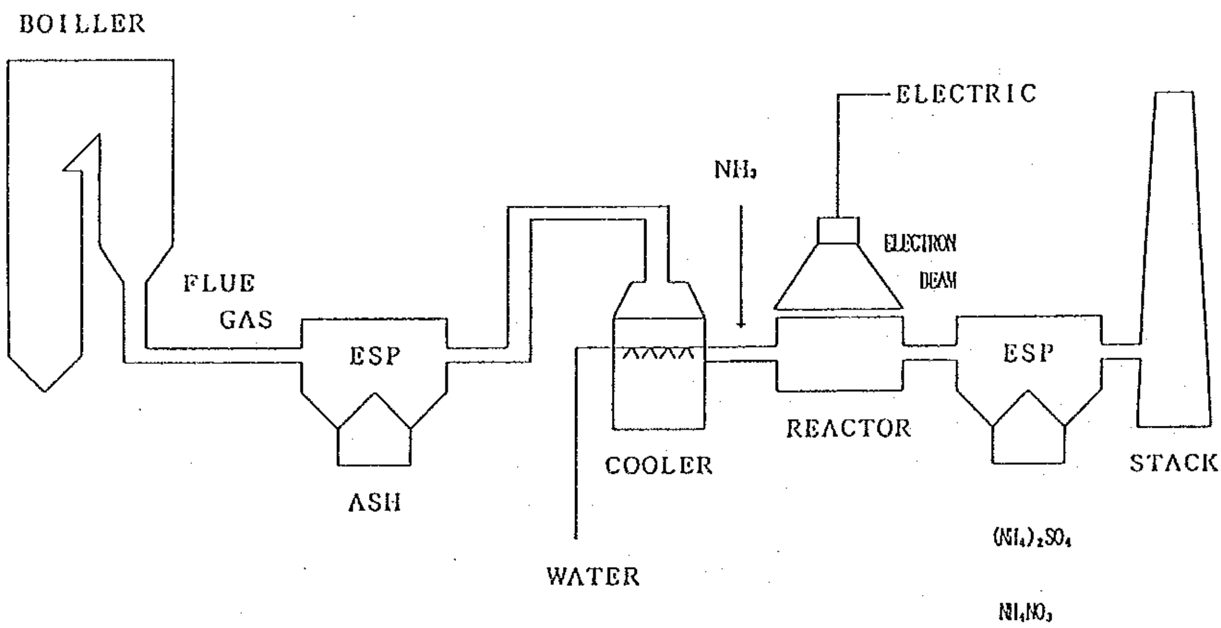


Fig. 3-15 PROCESS FLOW OF ELECTRON BEAM SYSTEM WITH AMMONIA

Conditions for the study on these methods are as follows.

(1) Capacity Factor

Part II: 58% (Corresponding to annual operation of 5,081 hours at the rated load)

Part III: 51% (corresponding to annual operation of 4,468 hours at the rated load)

(2) Plant Efficiency

Part II: 35.01% (at the rated load)
32.2% (average: from efficiency calculation of 1991, Melnik Power Station)

Part III: 36.09% (at the rated load)
33.6% (average, from efficiency calculation of 1991, Melnik Power Station)

(3) SO_2 Emission Amount and Regulation

a. Calculated concentration of SO_2 emission are as follows:

Part II: 4,840 mg/m^3N (as dry and O_2 = 6% base)

Part III: 4,840 mg/m^3N (as dry and O_2 = 6% base)

b. Regulatory limits on SO_2 emission after October 1996

Part II; DeSOx Efficiency more than 70%
(SO_2 concentration 1,450 mg/m^3N or less)

Part III: DeSOx Efficiency more than 85%
(SO_2 concentration 720 mg/m^3N or less)

(4) Operation Range of DeSOx System

Part II: 63.6-100% rated load (corresponding to 70-110 MW)
Part III: 60.0-100% rated load (corresponding to 300-500 MW)

(5) Water Source for DeSOx System

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

(6) Inlet and Outlet Conditions of FGD

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

(7) Coal Properties

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

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

(8) Dust at Electrostatic Precipitator (ESP) Inlet and Outlet

a. Dust concentrations at ESP inlet

110 MW unit: Max. 54.0 g/m^3_N, Dry
500 MW unit: Max. 85.0 g/m^3_N, Dry

b. Dust concentration at ESP outlet for the design of FGD.

100 mg/m^3_N

(9) Space of FGD Installation

Fig. 3-16 shows a general plan for the space available for FGD installation.

(10) Unit Prices of Utilities

Unit prices of utilities as of July 1992, the time of economic comparison of various FGD methods, are shown in Table 3-4.

Exchange rates of Czechoslovak crown (kčs) with other currencies as of July 1992 were as follows:

1 kčs = 4.634 yen
1 kčs = 0.036 US$
1 kčs = 0.053 DM

(11) Unit Price of By-product

a. Gypsum : -5 DM (German mark)/ton

b. Sulfuric acid : 0 kčs/ton

(12) Number of Years for Depreciation and Discount Rate

a. Depreciation term : 12.5 years (with residual value of zero)

b. Discount rate : 10%

Table 3-1 DeSOx Design Value (1/2)

(1) Inlet Condition

Item	Unit	Value
(1) Melnik II (1 Unit)		
Flue Gas Amount (as Wet base)	m^3N/h	530,000
SO_2 Concentration (as O_2 = 6% and Dry base)	mg/m^3N	4,840
O_2 Concentration (ESP Outlet, as Dry base))	%	8.0
H_2O Concentration (ESP Outlet)	%	13.0
HCI Concentration (as O_2 = 6% and Dry base)	mg/m^3N	19.1
HF Concentration (as O_2 = 6% and Dry base)	mg/m^3N	94.6
(2) Melnik III		
Flue Gas Amount (as Wet base)	m^3N/h	2,300,000
SO_2 Concentration (as O_2 = 6% and Dry base)	mg/m^3N	4,840
O_2 Concentration (ESP Outlet, as Dry base)	%	7.5
H_2O Concentration (ESP Outlet)	%	13.4
HCI Concentration (as O_2 = 6% and Dry base)	mg/m^3N	19.1
HF Concentration (as O_2 = 6% and Dry base)	mg/m^3N	94.7

DeSOx Design Value (2/2)

(2) Outlet Condition

Item	Unit	Value
(1) Melnik II (1 Unit)		
Stack Outlet Temperature	°C	100 or more
DeSOx Efficiency (at Stack)	%	70<
(Reference Value) SO_2 Concentration (as O_2 = 6% & dry base)	mg/m^3_N	1,450
(2) Melnik III		
Stack Outlet Temperature	°C	100 or more
DeSOx Efficiency (at Stack)	%	85<
(Reference Value) SO_2 Concentration (as O_2 = 6% & dry base)	mg/m^3_N	720

(3) For SO_3 Dew Point Consideration

Item	Unit	Value
SO_3 Conversion Ratio	%	Max 1
(1) Melnik II (1 Unit)		
SO_3 Concentration (as O_2 = 6% and Dry base)	mg/m^3_N	48.4
H_2O Concentration (ESP Outlet)	%	13.0
(2) Melnik III		
SO_3 Concentration (as O_2 = 6% and Dry base)	mg/m^3_N	48.4
H_2O Concentration (ESP Outlet)	%	13.4

Table 3-2 Coal Properties

Item	Unit	Value
Calorific Value		
Air Dry Base	Kcal/kg	3,680
Dry Base	Kcal/kg	4,200
Dry Base	MJ/kg	17.84
Wet Base (as received)	Kcal/kg	2,930
Wet Base (as received)	MJ/kg	12.27
Total Moisture	%	30.2
Proximate Analysis (Air Dry base)		
Inherent Moisture	%	12.4
Volatile Component	%	30.1
Ash	%	33.4
Fixed Carbon	%	24.1
Ultimate Analysis		
Carbon	%	44.22
Hydrogen	%	3.42
Oxygen	%	12.01
Nitrogen	%	0.81
Sulfur	%	1.5
Ash	%	38.04
Chlorine	mg/kg	116
Fluorine (Tube Furnace Method) (Bomb Method)	mg/kg	587 (185)
Boron	mg/kg	43
Grindability	HGI	75

Table 3-3 Coal Analysis by EPDC

Sampling Date: May & July, 1992

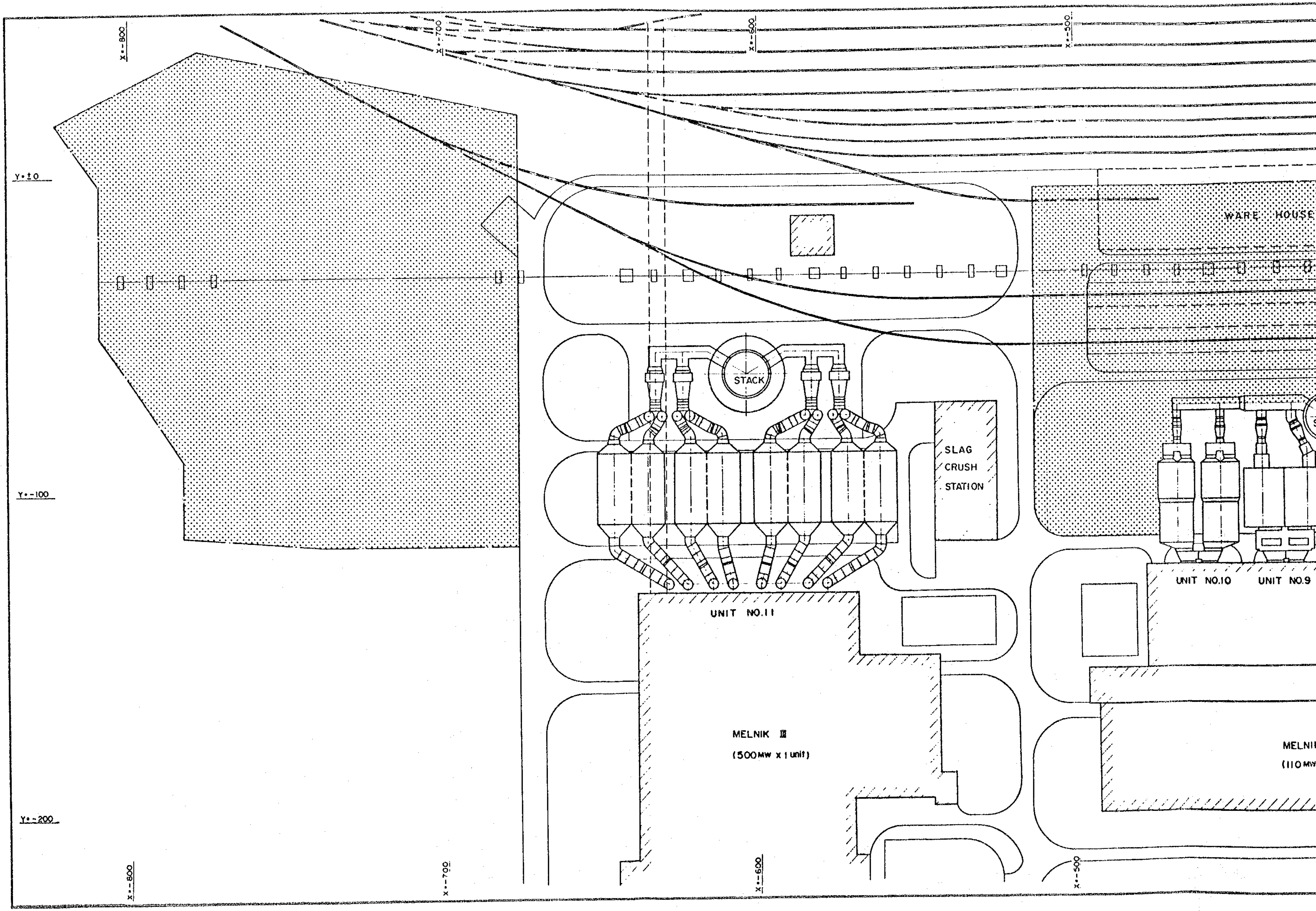
Item	Unit	Mine							
		VZOREK #-2	VZOREK #-3	MERKVR	LEDVICE	HERKVES	KOMORANY	Total Average	Mix Coal
Lower Heating Value (AD)	kcal/kg	3,870	3,930	3,330	4,650	2,980	3,330	3,680	4,390
Proximate Analysis (AD)									
Inherent Moisture	%	9.3	8.8	15.5	16.8	11.5	12.7	12.4	9.6
Ash	%	33.9	33.6	34.0	18.0	43.3	37.7	33.4	28.0
Volotile Matter	%	31.2	32.2	29.5	33.1	26.1	28.7	30.1	35.0
Fixed Carbon	%	25.6	25.4	21.0	32.1	19.1	20.9	24.0	27.4
Fuel Ratio (F.C/V.M)	-	0.82	0.79	0.71	0.97	0.73	0.73	0.79	0.72
Ultimate Analysis (Dry)									
Carbon	%	44.76	44.75	41.85	58.36	35.49	40.12	44.22	50.21
Hydrogen	%	3.41	3.56	3.10	4.19	2.98	3.25	3.42	3.86
Sulphur	%	2.38	1.23	2.20	0.82	1.44	2.20	1.71	1.58
Nitrogen	%	0.95	0.72	0.88	0.91	0.66	0.72	0.81	0.93
Ash	%	37.38	36.84	40.24	21.68	48.93	43.18	38.04	30.97
Oxygen	%	11.12	12.90	11.73	14.04	10.50	10.45	11.79	12.45
Fluorine (Tube Furnace Method) (Bomb Method)	mg/kg	500	760	600 (180)	530 (150)	610 (140)	520 (260)	587 (185)	690
Chlorine	mg/kg	154	123	102	100	117	102	116	87
Boron	mg/kg	42	37	44	27	52	57	43	32

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

Table 3-4 Unit Price of Utilities

Item	Unit	Value	Remarks
(1) Limestone ($CaCO_3$)	kčs/ton	130 (= 68 + 62) 212 (= 150 + 62)	• Particle size (22.5 ~ 80 mm) 95% purity • Crashed 95% purity
(2) Lime (CaO)	kčs/ton	812 (= 750 + 62) 1012 (= 950 + 62)	• Pieces • Dust
(3) Slaked Lime ($Ca(OH)_2$)	kčs/ton	912 (= 850 + 62) 1012 (= 950 + 62)	• Pieces • Dust
(4) Activated Carbon	kčs/ton	377,000	2,000 DM, 1 kčs = 0.053 DM
(5) Caustic Soda (NaOH)	kčs/kg	3.89	based on 45% concentration
(6) Sulfuric Acid (H_2SO_4)	kčs/kg	1.90 ~ 2.00	
(7) Auxiliary Steam	kčs/ton	Part II 125 Part III 125	
(8) Auxiliary Power	kčs/kwh	Part II 0.477 Part III 0.436	
(9) Law Water	kčs/m^3	0.54	river water

* As of end of July, 1992.


X=-800
X=-700
X=-600
X=-500
Y=±0
Y=-100
Y=-200
WARE HOUSE
STACK
SLAG
CRUSH
STATION
UNIT NO.11
UNIT NO.10
UNIT NO.9
MELNIK III
(500MW x 1 unit)
MELNI
(110MW

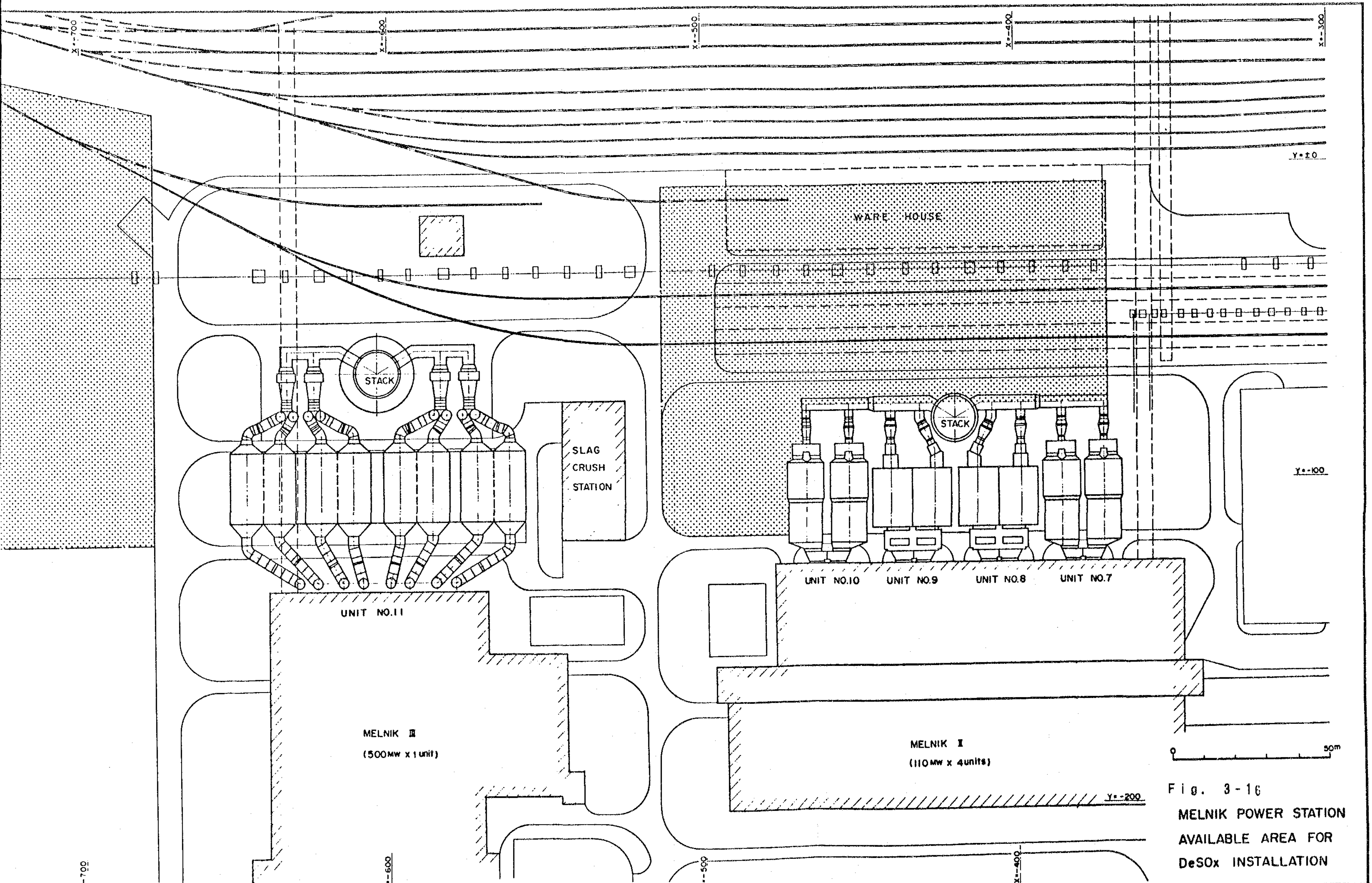


Fig. 3-16

MELNIK POWER STATION
AVAILABLE AREA FOR
DeSOx INSTALLATION

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

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

The absorbent injection methods (limestone injection into furnace and/or slaked lime injection into duct) show a deSOx efficiency on the order of 30 to 40% only by injection of absorbent into furnace or duct. For meeting the regulations at Part II of the Melnik Power Station, however, the deSOx efficiency of 70% or more is required when FGDs are installed with the "unit-to-unit" method for each power plant unit. To raise the deSOx efficiency to above 70%, it is necessary to add a water-spraying reaction tower to each unit in addition to the absorbent injection method. There is no space available for installation between the existing boiler house and the duct collector at Part II, and it would therefore be necessary to install the tower downstream of the existing ESP. If the tower is installed downstream of the ESP, an ESP must further be added in downstream of the tower, and the merit of the absorbent injection method requiring a smaller remodeling would be lost.

Since required deSOx efficiency for Part III is over 85%, the absorbent injection methods are not applicable for Part III.

The absorbent injection methods should be thus excluded from methods to be examined and compared.

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

Table 3-5 Combination of DeSOx Plants Installation

		Unit	Part II				Part III	Remarks
			Unit No. 7	Unit No. 8	Unit No. 9	Unit No. 10	Unit No. 11	
Case I-A	Flue gas through Reactor	%	400 (382)				100 (95)	100% Flue gas rate in Part II is difined as the 100% load operation of 1 Unit Boiler. Figure in ( ) shows the value calculated with consideration of GGH leakage.
	DeSOx Eff. in the Reactor	%	>70 (73.5)				>85 (90)	
	Total DeSOx Eff.	%	>70				>85	
	SO_2 Emission	mg/m^3N	≤1,450				≤720	
Case I-B	Flue gas through Reactor	%	330 (320)					
	DeSOx Eff. in the Reactor	%	>85 (87.5)					
	Total DeSOx Eff.	%	>70					
	SOx Emission	mg/m^3N	≤1,450					
Case II-A	Flue gas through Reactor	%	200 (191)		200 (191)			
	DeSOx Eff. in the Reactor	%	>70 (73.5)		>70 (73.5)			
	Total DeSOx Eff.	%	>70		>70			
	SO_2 Emission	mg/m^3N	≤1,450		≤1,450			
Case II-B	Flue gas through Reactor	%	165 (160)		165 (160)			
	DeSOx Eff. in the Reactor	%	>85 (87.5)		>85 (87.5)			
	Total DeSOx Eff.	%	>70		>70			
	SO_2 Emission	mg/m^3N	≤1,450		≤1,450			
Case III-A	Flue gas through Reactor	%	100 (95.5)	100 (95.5)	100 (95.5)	100 (95.5)		
	DeSOx Eff. in the Reactor	%	>70 (73.5)	>70 (73.5)	>70 (73.5)	>70 (73.5)		
	Total DeSOx Eff.	%	>70	>70	>70	>70		
	SO_2 Emission	mg/m^3N	≤1,450	≤1,450	≤1,450	≤1,450		
Case III-B	Flue gas through Reactor	%	82.5(80)	82.5(80)	82.5(80)	82.5(80)		
	DeSOx Eff. in the Reactor	%	>85(>87.5)	>85(>87.5)	>85(>87.5)	>85(>87.5)		
	Total DeSOx Eff.	%	>70	>70	>70	>70		
	SO_2 Emission	mg/m^3N	≤1,450	≤1,450	≤1,450	≤1,450		

Technical comparison of various FGD system and cost comparison of those for Part II and Part III are shown in Table 3-6 and Table 3-7, respectively.

It can be said that the wet type limestone-gypsum method or the spray dryer method is applicable to both Part II and Part III of the Melnik Power Station from the viewpoints of both technical and economic comparisons.

To determine the best FGD method from those of two methods, it is necessary to make a comprehensive decision not only from comparisons on current aspects but also from future expectations, and examinations are made on the points depicted below.

(1) Additional Examination on the Aspect of Economic Comparison

a. The prevailing prices in Czechoslovakia at present are distorted in comparison with standard prices (International market prices) in former West European countries. As the country moves into market economy in line with the "Scenarios for Economic Reform," however, the prevailing prices will get close to the international market prices, and it is certain that utility costs will increase from their costs as of July 1992. Actual differences in running costs between wet limestone gypsum method and spray-dryer method therefore tend to get larger. When standard prices in former West European countries are used in place of the prevailing prices for a try, the wet type limestone-gypsum method gets more advantageous than the spray dryer method as shown in parentheses in Table 3-7.

b. The annual cost is the sum of the depreciation cost and the running cost for the period of equipment depreciation (12.5 years). The usual life period of equipment is on the order of 30 years, and the annual cost consists only of the running cost for the remaining 17.5 years, and this makes the wet type limestone-gypsum method more advantageous.

It should be noted that both Part II and Part III are likely to be operating for the next 20 to 30 years in consideration of Part III which started operation in 1981 and are the largest and latest power plant in Czechoslovakia, and Part II for which 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.

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. 3-17 shows the summarization of evaluation flow till this selection result on the examinations.

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

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

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

Table 3-6 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 3-6 (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 20.5 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 3-6 (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.2 t/h Part III ca.3 t/h	Same as the left. Same as the left	None	ca.8 t/h

Table 3-6 (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 3 - 7 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 (A) = Investment x Levelizing Factor	
	Annual Payment for Investment	100% (Base)	102%	87%	118%		
3.	Running Cost					Annual Running Cost (B) = Running Cost - By-products Sale	Figure in ( ) is based on the assumption of absorbent price corrected by the inter-national market price.
	Annual Running Cost	100% (Base) (176)	104% (180)	193% (399)	734% (727)		
	Total Annual Cost	100% (Base) (100)	102% (102)	96% (107)	171% (160)	Total Annual Cost = A + B	

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 Dryer Method	Activated Carbon Method		
		Spray Tower Method	Jet-Bubbling 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 x 1	500MW x 1	500MW x 1	500MW x 1		
2.	Capital Cost					Annual Payment for Investment (A) = Investment x Levelizing Factor	
	Annual Payment for Investment	100% (Base)	101%	89%	119%		
3.	Running Cost					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.
	Annual Running Cost	100% (Base) (241)	108% (248)	332% (711)	1,325% (1,327)		
	Total Annual Cost	100% (Base) (100)	101% (101)	102% (114)	186% (172)	Total Annual Cost = A + B	

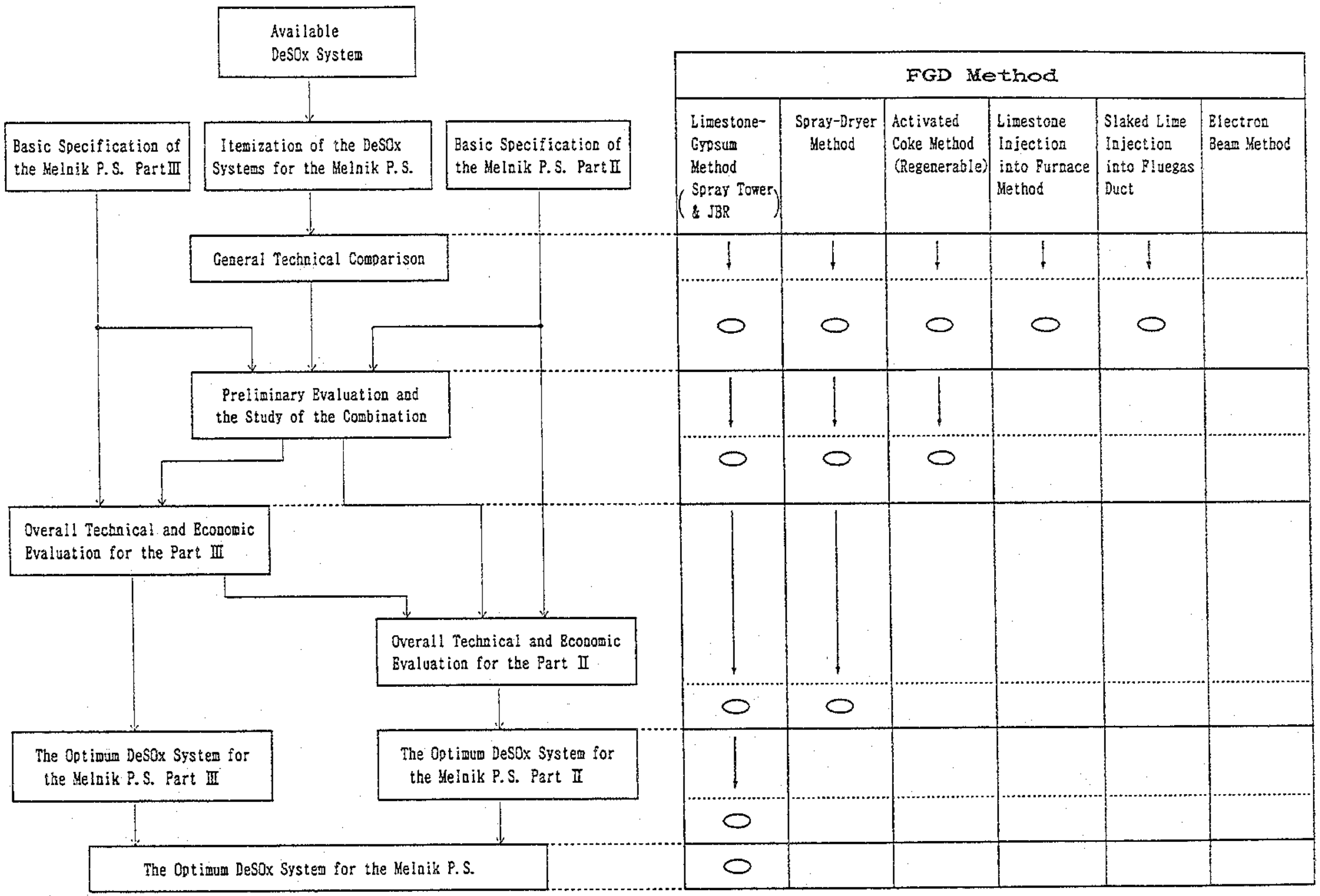


Fig. 3-17 Summarization of Evaluation Flow

4. Evaluation of Impacts on Environment

Obtain maximum ground level concentrations of SO_2 before and after installation of the FGD units were calculated using diffusion formulas.

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

When current values (before installation) and values after installation are compared:

- Short-term Predictions

  The level of maximum ground concentration reduces from 0.28 $mg/m^3.SO_2$ to 0.093 $mg/m^3.SO_2$ for 30 minute value, from 0.247 $mg/m^3.SO_2$ to 0.082 $mg/m^3.SO_2$ for 1 hour value and from 0.148 $mg/m^3.SO_2$ to 0.049 $mg/m^3.SO_2$ for 24 hour value.

- Long-term Predictions (Annual mean ground concentrations for 1-hour values)

  The mean ground level concentration reduces from 0.166 mg/m^3-SO_2 to 0.048 mg/m^3-SO_2. The environmental effects of SO_2 from the power station on the cities of Melnik and Prague will be reduced, and the installation of FGDs will contribute much to the improvement of natural and living environment of such cities with a view that measures will be taken at other smoke sources in the region.