[SO_2] :

after January 1, 1996	max.	380,000 t/year
after January 1, 2000	max.	280,000 t/year
after January 1, 2004	max.	150,000 t/year

[NO_X] :

after January 1, 1996	max.	40,000 t/year
after January 1, 2000	max.	35,000 t/year
after January 1, 2004	max.	30,000 t/year

[Solid materials (Dust)] :

after January 1, 1996	max.	25,000 t/year
after January 1, 2000	max.	20,000 t/year
after January 1, 2004	max.	10,000 t/year

4) Technological Emission Standards of Medium-capacity Firing Equipment with a Thermal Capacity of 120 kW - 15 MW

The technological limit values by fuel types shown in Table 7.1.17 are to be imposed.

5) Technological Emission Standards of Small-capacity Firing Equipment with a Thermal Capacity of 4 kW - 120 kW

The technological limit values by fuel types shown in Table 7.1.18 are to be imposed from January 1, 1996.

(11) The Draft Environmental Fee/Air Pollution Fee System for Air Polluting Sources

In the draft governmental decree (Ref.B-25) and the draft regulation on fees relating to air pollution (Ref.B-25), new concept of "environmental fee (fee for using environment)" has been adopted instead of the present basic fine system.

Fee for using environment will be paid by the procedure and degree ordained by KTM for the total mass of air pollutant emissions of stationary air polluting sources. Amount of payment for the environmental fee is calculated as follows:

Basic fee (BF)

$BF = 1.0 \bullet M$ Forint/kg pollutant

where, M: multiplying number
- $M=1$ for pollutants belonging to the hazardous level "3"
- $M=2$ for pollutants belonging to the hazardous level "2"
- $M=3$ for pollutants belonging to the hazardous level "1"

Table 7.1.17 Proposed Future Technological Emission Limit Values concerning Medium-capacity Firing Equipment

Air Pollutant	Fuel Type	Emission Limit Value (mg/m^3)	
		Application Period	
		till December 31, 1998	from January 1, 1999
Solid Material	Gas and liquid fuels		
	Fuel oils	250	200
	Liquid fuels	250	150
	Gases	150	50
	Solid	250	200
Soot	Fuel oils and evaporating burners	3 (Bacharach-scale)	2 (Bacharach-scale)
	Liquid fuels	3 (Bacharach-scale)	1 (Bacharach-scale)
	Gases	1 (Bacharach-scale)	0 (Bacharach-scale)
	Solid	2 (Ringelmann-scale)	2 (Ringelmann-scale)
CO	Fuel oils and liquid fuels	650	170
	Gases	650	100
	Solid	800	250
SO_2	Fuel oils	2000	1700
	Liquid fuels	1000	1000
	Gases	300	150
	Brown coals	3000	3000
	other solid fuels	1500	1000
NO_X	Fuel oils	1000	800
	Liquid fuels	600	450
	Gases	400	250
	Solid	600	450

Source: Ref.B-32

Note: Concentrations given in mg/m^3 of oils and gases are referred to 3 vol.% O_2 content and those of other fuels to 6 vol.% at a normal state (273°K, 101.3kPa).

Table 7.1.18 Proposed Future Technological Emission Limit Values concerning Small-capacity Firing Equipment

1)

Air Pollutant	Fuel Type	Emission Limit Value Application Period till December 31, 1998	 from January 1, 1999
Soot	Fuel oils and evaporating burners	3 (Bacharach-scale)	2 (Bacharach-scale)
	Liquid fuels	2 (Bacharach-scale)	1 (Bacharach-scale)
CO	Fuel oils and liquid fuels	650 mg/m^3	170 mg/m^3
	Gases	650 mg/m^3	100 mg/m^3

2)

Thermal Load Data (kW)	Smoke-gas Loss (%) Application Period till Dec. 31, 1996	 till Dec. 31, 1998	 from Jan. 1, 1999
4 ~ 25	18	16	12
25.1 ~ 50	17	15	11
50.1 ~ 120	16	14	10

Source: Ref.B-32

Note: Concentrations given in mg/m^3 refer to dry smoke-gas with 3 vol.% O_2 content at a normal state (273°K, 101.3kPa).

Fee for using environment (FUE)

$$FUEq = C \bullet A \bullet T \bullet BF \bullet 10^{-6}$$

where, FUEq: fee for using environment to be paid in every quarter of a year [Forint/quarter]

C: concentration of the pollutant at the emitting place [mg/m^3]

A: airflow of the chimney/stack [$m^3/hour$]

T: operation hours in a quarter of a year [hour]

Air pollution fee is imposed for emission exceeding limit values. Amount of air pollution fee is maximum 10 million Forints in each case, and it is charged by the environmental authority taking into consideration the amount of pollutants, conditions of emission and the hazardous level. If the existing stationary air polluting source, not belonging to domestic activity, exceeds emission limit values during the moratorium period, the operator/owner of the existing polluting source is obliged to pay a multiple environmental fee (air pollution fee). Air pollution fee is five times or ten times more than the environmental fee.

Fee for using environment and air pollution fee will be paid like tax by the polluter voluntarily and will be paid in every quarter of a year. Besides these fees, fine will be inflicted in case of violating regulations concerning air quality protection. These fees and fines will be paid into the Central Environmental Fund. Upon formal request, an air polluter can claim a refund of up to 50% of the air pollution fee if it is used for the reduction of the emission from the polluting source.

(12) The Draft Emission Standards of Mobile Sources proposed for the Future

According to the draft governmental decree , emission limit values concerning mobile air polluting sources will be imposed on public vehicles, railway vehicles, aircraft, ships and vessels, agricultural machines, tractors, motorized power vehicles and slow vehicles. The draft governmental decree touches on the obligations concerning user, manufacturer, trader and seller of mobile air polluting source and its fuel.

1) Standards on the environmental protection inspection and control of motor cars

Draft regulation of KHVM on the environmental protection inspection and control of motor cars (Ref.B-22) has been proposed to amend the present regulation of KHVM No.18/1991 (XII.18). This draft regulation is expected to come into force on January 1, 1996. Main items of amendment are as follows:

Period of the environmental protection inspection

Except for the first period and the period of the mileage prescribed by the manufacturer, the periodicity of the environmental protection inspection are determined depending on the design characteristics of the engine. The periodicity of the environmental protection inspection for motor vehicles are shown in the following:

[Motor vehicle equipped with a positive ignition (Otto) engine]

- traditional 2- and 4-stroke engine	12 months
- equipped with an uncontrolled, 3-way catalyzer	24/24/12 months
- equipped with a controlled, 3-way catalyzer	36/36/24 months

[Motor vehicle equipped with a compression ignition (Diesel) engine]

- traditional 2- and 4-stroke engine	24 months
- equipped with an oxidizing catalyzer	36/24/12 months
- equipped with a carbon deposit filter	36/36/36 months

[Motor vehicle used for the specific mileage and operational area]

Above-mentioned periods are altered with the multiplier "0.5" for the vehicles fulfilling public road service and with 30,000 km/year, and for buses.

Content and technology of the environmental protection inspection

Specific parameters to which should be referred at least for the inspection are described.

Permissible level of the exhaust gas pollutant emissions

[Motor vehicle equipped with a positive ignition (Otto) engine]

- the value defined in the existing regulation of KHVM No.18/1991 (XII.18)

[Motor vehicle equipped with an compression ignition (Diesel) engine]

- 1.2 times the free acceleration peak value measured with consent for a given type in accordance with European regulations
- the lowest values measured in accordance with Hungarian Standard and announced in the present regulation of KHVM No.18/1991 (XII.18)
- in case of vehicles equipped with a controlled or uncontrolled catalyzer , the maximum smoky exhaust cannot be higher than (K_1, K_2 =) 0.5 m^{-1}

- in case of the buses used for city public transport, 0.6 times the limit values imposed in the present regulation of KHVM No.18/1991 (XII.18), after January 1, 1997.

2) Standards on permitting motor cars into traffic and maintaining the operation of them

New emission standards on permitting mobile air polluting sources into traffic are proposed in the draft joint regulation of KTM and KHVM (Ref.B-23). The parts of the standards are shown as follows:

Motor cars not exceeding the total mass of 3500 kg and with a planning speed above 50 km/h

The parts of permissible limit values of pollutant emissions of are shown in the following.

[Average pollutant content of the exhaust gas]

Permissible limit values are shown in Table 7.1.19.

[Carbon monoxide content at basic speed]

- Basic adjustment $C_{CO} \leq 3.5$ V/V%
- Determined adjustment $C_{CO} \leq 4.5$ V/V%

[Gas emission of crank case]

Gases cannot be emitted from the crank case under any operational conditions.

[Evaporating emission]

HC ≤ 2 g/test (expressing the breathing loss of the fuel tank)

[Duration of structures increasing pollutant emission]

Average pollutant content of the exhaust gas shall be defined at every 10,000 km, and the measured values shall be multiplied with the Deterioration Factor (DF) which is determined as a component. A manufacturer of motor vehicle can choose either the measured DF values or the following values.

Category of Motor Car	Deterioration Factor (DF)		
	CO	$HC + NO_X$	Particle
Positive ignition (Otto) engine	1.2	1.2	-
Compression ignition (Diesel) engine	1.1	1.0	1.2

Trucks, buses and tractors equipped with compression ignition (Diesel) engine, with a total mass above 3500 kg and with a planning speed above 25 km/h

The permissible limit values of pollutant emissions are shown in the Table 7.1.20.

Motor cars provided with a Type-certificate before January 1, 1994 with a total mass not exceeding 3500 kg and with a plannung speed above 50 km/h

The permissible limit values of pollutant emissions are shown in the Table 7.1.21.

Besides the emission limit values, the regulation also touches on that a motor car equipped with a positive ignition (Otto) engine with permissible total mass above 3500 kg cannot be permitted into traffic, and that a motor car operated only with leaded fuel cannot be permitted into traffic after December 31, 1994.

Table 7.1.19 Proposed Future Permissible Limit Values of Average Pollutant Content of the Exhaust Gas of Motor Car with a Total Mass not exceeding 3500 kg and with a Planning Speed above 50 km/h

Category of Motor Car	Field of Application	Limit Value (g/km)		
		CO	HC + NO_X	Particle (Note 4)
1	Type approval	2.72	0.97	0.14
	Quality control of serial production	3.16	1.13	0.18
2 - group I	Type approval	2.72	0.97	0.14
- group II	from	5.17	1.40	0.19
- group III	January 1, 1995	6.90	1.70	0.25
2 - group I	Serial production	3.16	1.13	0.18
- group II	from	6.00	1.60	0.22
- group III	January 1, 1995	8.00	2.00	0.29

Source: Ref.B-32

Notes:

1. Category 1 is motor car of category M1 with at least 6 seats including the driver's seat and with the total mass not exceeding 2500 kg.
2. Category 2 is motor car of categories N1 and M1 with more than 6 seats or with the total mass above 2500 kg.
3. Categories M1 and N1 are in accordance with UNO ECE TRANS/SC1/WP29/78/Amend.3 (June 12, 1991).
4. Particle is to be investigated only in case of compression ignition (diesel) engine.
5. Motor car groups are defined as follows:
    - group I : reference mass ≤1250kg
    - group II : 1250<reference mass ≤1700kg
    - group III : 1700kg<reference mass

Table 7.1.20 Proposed Future Permissible Limit Values of Trucks, Buses, and Tractors equipped with Compression Ignition (Diesel) Engine, with a Total Mass above 3500 kg and with a Planning Speed above 25 km/h

Designated Emission Standard	Field of Application	Emission Limit Value (g/km)			
		CO	HC	NO_X	Particle
EURO I	Type Approval	4.5	1.1	8.0	0.36
valid Jan. 1, 1994	Serial Production	4.9	1.23	9.0	0.40
EURO II	Type Approval	4.0	1.1	7.0	0.15
valid Dec. 31, 1994	Serial Production	4.0	1.1	7.0	0.15

Source: Ref.B-32

Table 7.1.21 Proposed Future Permissible Limit Values of Motor Cars provided with a Type-certificate before January 1, 1994 with a total mass not exceeding 3500 kg and with a Planning Speed above 50 km/h

Type of Motor Car	Field of Application	Displacement of Engine	Limit Value (g/test)			
			CO	HC + NO_X	NO_X	Particle
Positive Ignition (Otto) Engine	Type Approval	$V_h>2000$	25	6.5	3.5	-
		$1400 \leq V_h \leq 2000$	30	8.0	-	-
		$V_h<1400$	45	15	6.0	-
	Serial Production	$V_h>2000$	30	8.1	4.4	-
		$1400 \leq V_h \leq 2000$	36	10.0	-	-
		$V_h<1400$	54	19	7.5	-
Compression Ignition (Diesel) Engine	Type Approval	$V_h \geq 1400$	30	8	-	0.8
		$V_h<1400$	45	15	6.0	1.1
	Serial Production	$V_h \geq 1400$	36	10	-	1.0
		$V_h<1400$	54	19	7.5	1.4

Source: Ref.B-32

Notes: The limit values for NO_X and particle included in the table are multiplied by 1.4 in case of a diesel engine with direct injection.

7.1.2 Air Pollution Control Organization

(1) Ministry for Environment and Regional Policy (KTM)

Main tasks of KTM are professional management and governmental coordination concerning air pollution abatement. Environmental Protection Bureau is a main executing body for several kinds of pollution control as shown in the conceptual structure of Figure 7.1.1. In the scope of its role and jurisdiction, KTM mainly executes the following matters:

- Suggestions to the government on the national strategy and policy concerning air pollution abatement;
- Imposing the rules and regulations concerning air pollution abatement;
- Establishment of comprehensive air pollution control plan
- Emission and immission (ambient air quality) monitoring; and
- Management and application of Central Environmental Protection Fund

(2) Ministry for Transport, Communication and Water Management (KHVM)

KHVM is an authority who takes charge of an air pollution control caused by mobile air polluting sources. Its conceptual organizational structure is shown in Figure 7.1.2. KTM mainly executes the following matters:

- Suggestions to the government on the national strategy and policy concerning control of mobile air polluting sources;
- Imposing the rules and regulations concerning control of mobile polluting sources;
- Administration and control of production, marketing and utilization of mobiles air polluting sources and fuels for them;
- Administration and control of traffic on public roads from the viewpoint of air pollution control; and
- Planning an optimum transportation networks from the viewpoint of air pollution abatement.

(3) Ministry of Welfare (NM)

NM is an authority who takes charge of air pollution abatement from the viewpoint of a public health.

(4) Ministry of Industry and Trade (IKM)

Main tasks concerning to air pollution abatement are taking the lead of industry and making a suggestion on control measures to be adopted.

(5) North Hungarian Environmental Protection Inspectorate (EKF)

There are 12 environmental protection inspectorates under the control of KTM, and EKF is one of them who acts as the first level body to execute environmental protection issues defined in various legal regulations. The area of jurisdiction is BAZ county and a most part of Heves county excluding the valley of Zagyva. Total number of the personnel of EKF is 137, and 16 staffs are exclusively working for the tasks concerning air pollution control.

Main tasks concerning to air pollution abatement are execution of on-the-spot inspection of stationary polluting sources, collection of the fines, and management of database of polluting sources declared. EKF also executes operation and maintenance of background level monitoring of ambient air quality. EKF saves, updates and uses the data of air pollutants measured by EKF or declared by the polluters. If the emission is above the limit values, EKF imposes a limitation to avoid the harmful state. Using the database, various reports are prepared for higher bodies and if requested, for mayor offices of some communities. Emission data measured by EKF are regularly transferred to ANTSZ.

The organizational structure is shown in Figure 7.1.3. Air Cleanness Protection division consists of 16 staffs including 10 engineers, and executes emission and immision monitoring/measurement. Environmental Assessment and Information department executes comprehensive environmental analyses, inspects/studies the impact on environment and coordinate the work of the remaining departments in joint tasks. Information division processes the data of pollutants declared by the polluters, and maintain the computer hardware and software systems in EKF. Laboratory produces absorbent liquids for air pollution protection measurements and executes an necessary analysis after the measurements.

As for collaboration with other administrative bodies, EKF and ANTSZ regularly inform each other of the air pollution data from the air quality monitoring stations. In case of high air quality values, the city mayor imposes smog alarm according to the suggestion of ANTSZ and EKF, and EKF proposes the shutdown of large air polluting sources. In case of extraordinary environmental pollution, EKF proposes preventive measures against the damage to County Civil Defense Command.

(6) BAZ County Transport Management Office (BAZKF)

Within the unified transport authority administration formed since 1991, county and capital city transport management offices executes the official tasks under the control of KHVM. The organizational structure of BAZKF is shown in Figure 7.1.4.

BAZKF executes both sides of air pollution control; namely the emission control of exhaust gas and the traffic control. BAZKF permits an assembly and a transformation of road vehicles, and conducts technical and environmental inspection of roads vehicles before their entrance into traffic. BAZKF also conducts periodically environmental protection inspection (included in an ordinary car inspection system) and surprise road-side environmental inspection of road vehicles.

(7) National Public Health and Medical Officer's Service (ANTSZ)

ANTSZ is an execution body for public health and medical affairs under control of NM. Main tasks concerning air pollution abatement are operation and maintenance of regional monitoring network of ambient air quality, research and studies on the relation between air pollution and public health.

(8) National Meteorological Service (OMSZ)

OMSZ is one of the extra-departmental organizations connected with KTM. Main tasks concerning air pollution abatement are operation and maintenance of national monitoring network of ambient air quality, meteorological observation, research and studies on the relation between air pollution and meteorology, and research and development on air quality simulation model.

(9) City Mayor Office

Main task of city mayor office concerning air pollution control is a announcement of smog-alarm. In case of pollution exceeds the smog alarm limit values, the city mayor office shall be on duty during the period beyond working hours. The city duty officer provides an information on the development and changes of the smog situation cooperating with OMSZ and is responsible for arranging the information and warning the inhabitants. City mayor orders the imposition of the specifications for smog alarm categories depending on the air pollution level.

The provision for limitation on the stationary polluting sources and on the mobile sources are made public according to the suggestion by the city duty officer. The city operation and city supply department take action to ensure the non-interruption of traffic, to arrange for mass transportation and to incorporate the city police office in imposition of limitation on vehicle use.

The head of the city operation and city supply department is responsible for updating the smog alarm plan.

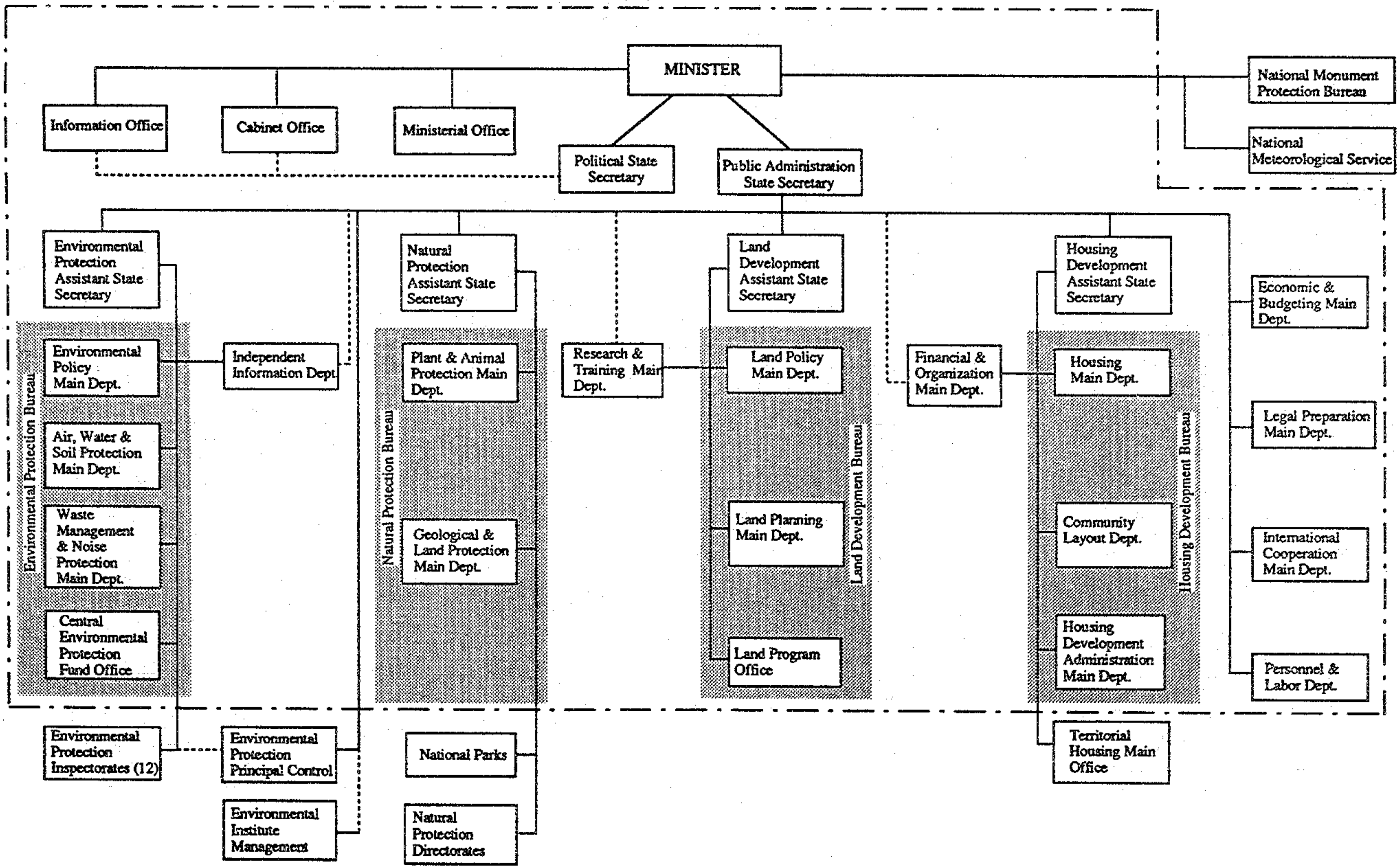


Figure 7.1.1 ORGANIZATIONAL STRUCTURE OF THE MINISTRY FOR ENVIRONMENT AND REGIONAL POLICY AND BODIES UNDER ITS CONTROL

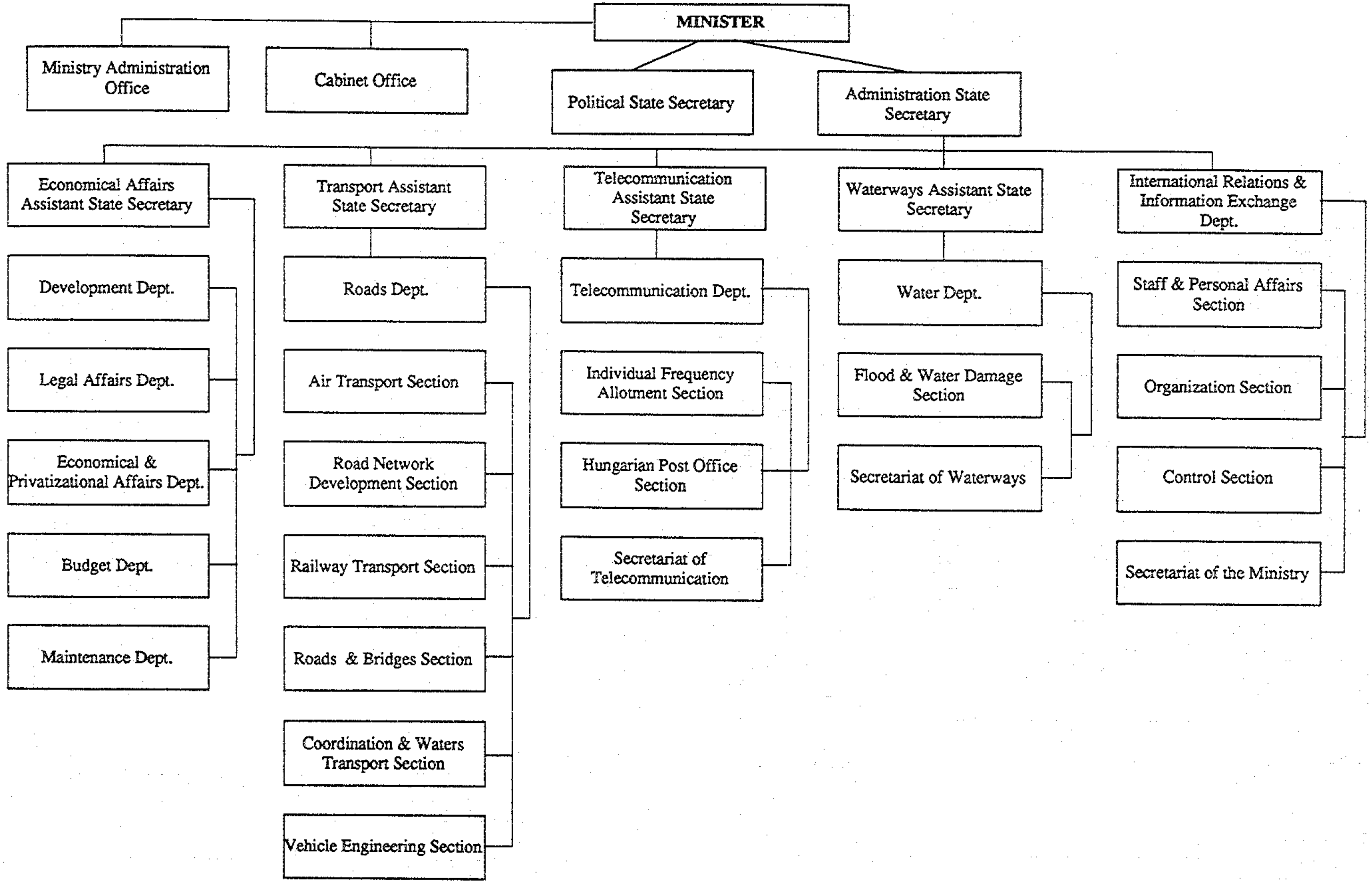


Figure 7.1.2 ORGANIZATIONAL STRUCTURE OF THE MINISTRY FOR TRANSPORT, COMMUNICATION AND WATER MANAGEMENT (KHVM)

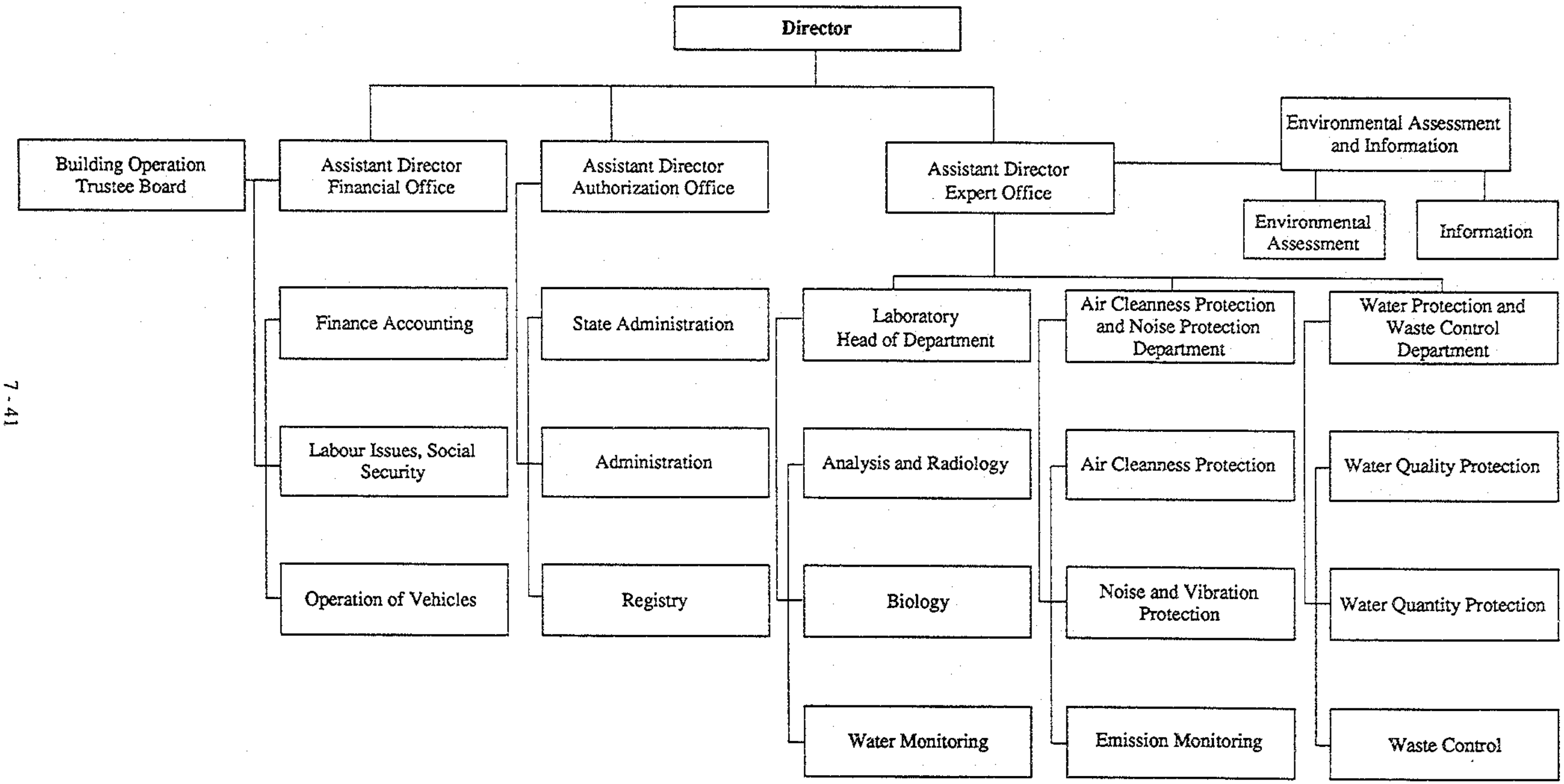


Figure 7.1.3 ORGANIZATIONAL STRUCTURE OF NORTH-HUNGARIAN ENVIRONMENTAL PROTECTION INSPECTORATE (EKF)

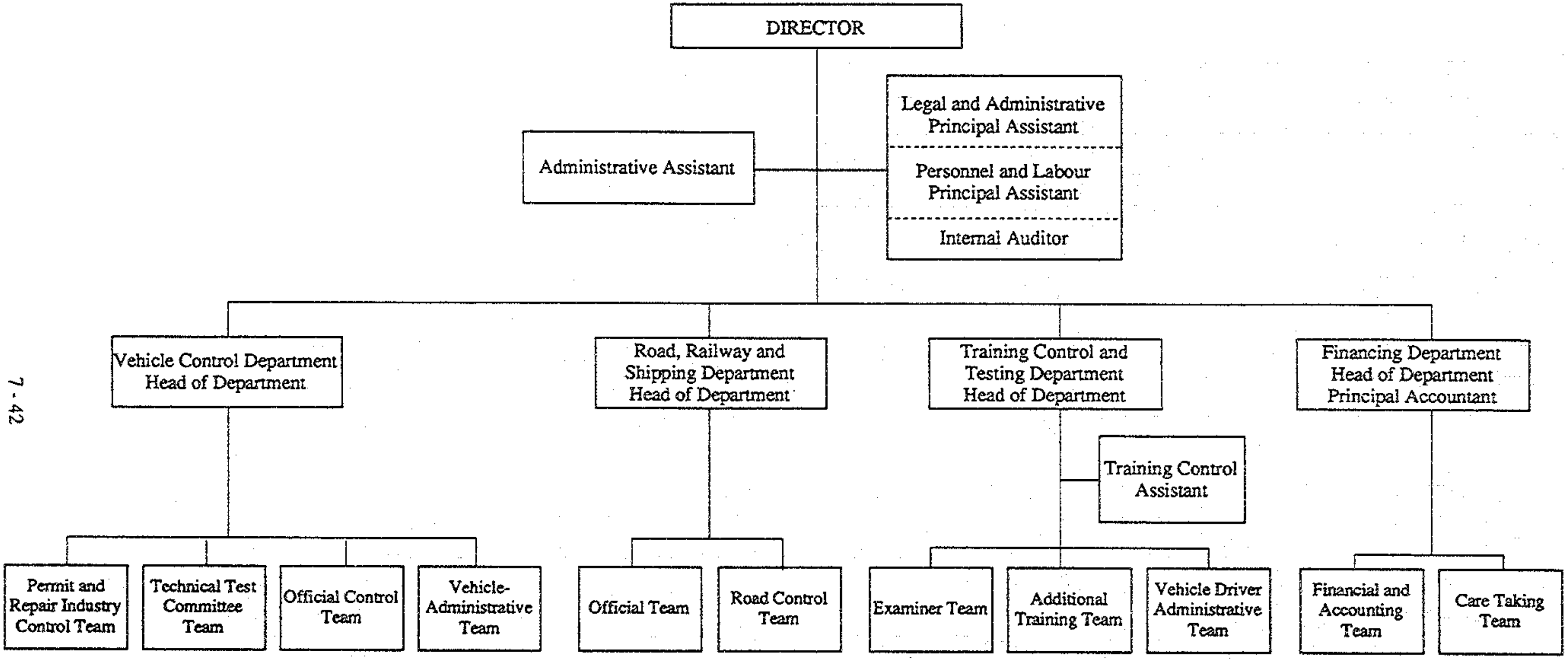


Figure 7.1.4 ORGANIZATIONAL STRUCTURE OF B.A.Z. COUNTY TRANSPORT MANAGEMENT OFFICE (BAZKF)

7.2 State of Air Pollution Control at Stationary Sources

7.2.1 Quality of Fuels

(1) Solid Fuel

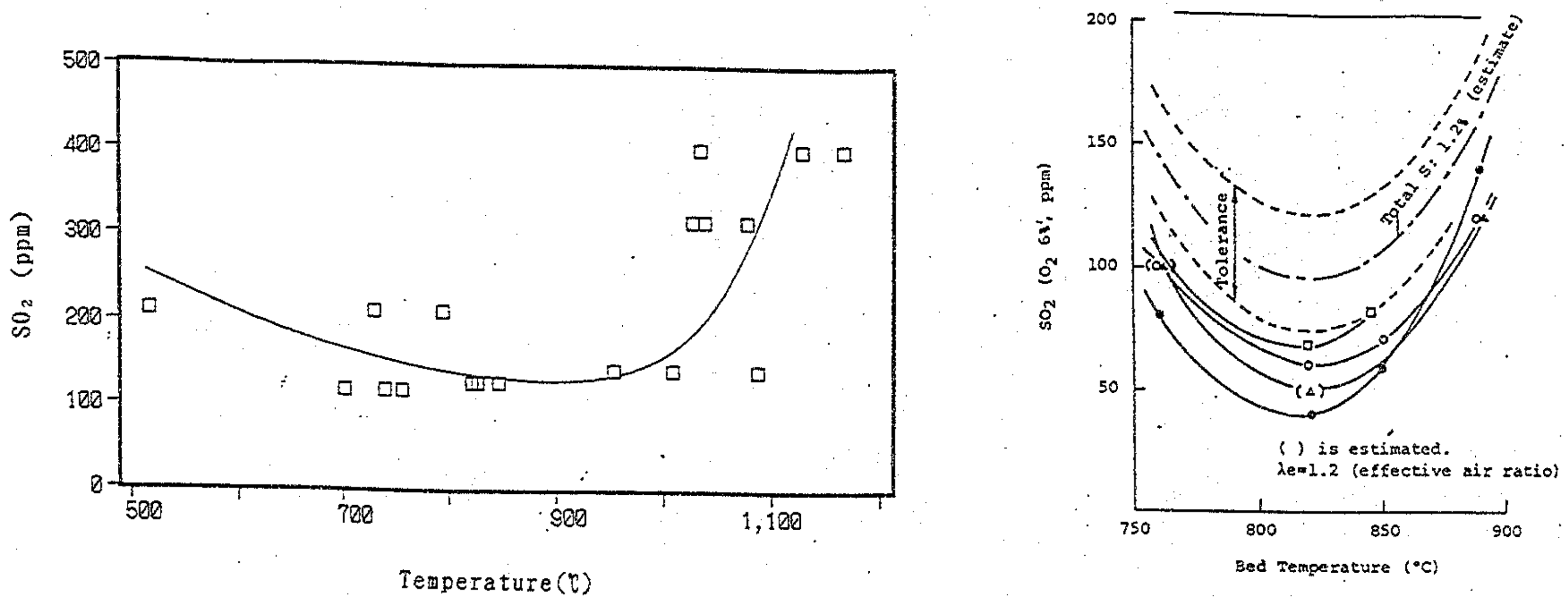
Analyzed value of 85 samples are described in detail in Section 4.1.4 Sixty-six (66) of the 85 samples are brown coal and lignite produced in Hungary. With regard to the calorific value, lignite of Bukkabrany Coalfield near the study area has the lowest at 6,600 KJ/kg (1,580 kcal/kg), while brown coal of Tatabanya Coalfield has the highest at 20,500 KJ/kg (4,900 kcal/kg). Coal of Visonta coalfield has the lowest content of sulfur 1.5 - 1.6% at total sulfur, while that of Balinka has the highest at 5.18%. The total sulfur content of lignite and brown coal averages 2 - 3% and that of Edeleny shows higher values of 3.6 - 3.8%.

The feature of the coal produced in the study area is its low ash softening point (1,000°C-1,100°C) and most of it melts when it is burnt at 1,200°C-1,300°C. This is also proven by the fact that large amount of clinker is seen in the ash dumping ground of the Borsod Power Plant. One of the reasons why imported coal is used in the stoker firing furnace instead of coal produced in the Borsod coalfield is that the ash softening point is low as well as the content of sulfur.

The coal which has the least sulfur is imported coal from Russia and most of it except for one example has less than 1% at total sulfur (import permission is not given to coal with a sulfur content of more than 1%). Because the majority has some CaO in ash , SO2 turns into CaSO4 and is fixed in the ash at a combustion temperature of 800 - 850°C (about 0.5 - 0.8 %).

However, this applies only in cases where the coal is burnt at the above low temperature. When it is burnt at more than 1,000°C and a large quantity of oxidizable gases such as O2 and CO are contained in the exhaust gas, although sulfur is combined into CaSO4, much of it is oxidized or decomposed to SO2 and is often emitted into the air. Figure 7.2.1 shows a correlation between the combustion temperature and SO2 concentration at stove and fluidized bed combustion.

This proves that SO2 concentration is lowest at a temperature range of 800 - 850°C and that it becomes nearly four times at a temperature of about 1,100°C in the stove combustion.



STOVE COMBUSTION

Fluidized bed Boiler

Figure 7.2.1 Correlation Between Combustion Temperature and SOx Concentration

According to the experience of the Study Team in combustion tests using coals such as black coal, brown coal, lignite etc., the exhaust gas SO2 concentration was found to be calculated as,

(total sulfur) x 0.9 x 2

rather than calculating from combustible sulfur except for the fluidized bed boiler where the furnace temperature can be maintained at 800 - 850°C. (It has been specified in analytical methods that combustible sulfur content in coal be obtained from the quantity of SO2 emitted at a combustion temperature of 815°C .)

Total sulfur content of powdered brown coal burnt at Borsod Power Plant is 2.05-2.10%. Coal burnt at Tisza I Power Plant is brown coal produced at many coalfields such as nearby coalfields and in West Hungary and its sulfur content greatly depends on the type of coal. It can vary in the same boiler inspected on the same day. For example, for brown coal burnt between 10:00-13:00 on June 22 when the inspection was made, total sulfur was 3.10% and combustible sulfur was 1.99%. For the of brown coal burnt between 14:00-15:30, total sulfur was 2.57% and combustible sulfur was 1.77%. For the brown coal burnt between 10:30 and 14:30 on June 29, total sulfur was 2.04% and the combustible sulfur was 1.62%, while at 10:00 on July 1, total sulfur was 1.74% and combustible sulfur was 1.53%. Since the percentage varies greatly, it is difficult to estimate typical values.

However, generally speaking, it is desirable to burn brown coal from Borsod at a combustion temperature of 800 - 850°C by adding the proper amount of CaO in the fluidized bed in consideration of the property of the coal.

(2) Liquid Fuels

Quality of fuel oil greatly varies with production sites from where National Oil Refinery, Mol. RT imports. The sulfur content of the residue oil sampled in August (burnt at Tisza II Power Plant) was 2.91%. However, according to data reported in 1992, the sulfur content of fuel oil was as follows:

January	3.43%	Average: 3.90%
February	4.14%	
March	4.14%	
August	4.39%	Average: 4.30%
September	4.21%	
October	2.77%	Average: 2.74%
November	2.77%	
December	2.68%	

Moreover, at present, the plant imports fuel oil with a sulfur content of 1.5% from Russia because of the international price reduction of crude oil with a low sulfur content. Therefore, the sulfur content of residue oil is around 2%.

In the analyzed result, normal fuel oil has 2.95% sulfur and 0.2% nitrogen while intermediate heavy oil with a slightly lower specific gravity (0.9514) than that of fuel oil has 2.51% sulfur and 0.2% nitrogen. Heavy oils for industrial use have properties close to the international standards : it has 0.17% sulfur and 0.1% nitrogen. And heavy gas oil and kerosene have 0.16-0.22% sulfur.

As for gasoline, both Petrol No. 92 and 98 have a specific gravity of 0.75, 0.04% sulfur, and 0.15% Pb.

(3) Gas Fuels

The supply ratio of natural gas is approximately 50% import and 50% domestic production. In the study area, domestic natural gas produced at Hajdúszoboszlo gas field is mainly supplied (calorific value: 34,000 KJ/Nm^3 (8,120 kcal/Nm^3), CH4: 97,65%, total sulfur: 2.8mg/m^3). Imported natural gas is supplied from Russia's gas pipeline "Testveriseg" (calorific value: 35,860 KJ/Nm^3 (8,560 kcal/Nm^3), CH4: 98.35%, total sulfur: 3.9mg/m^3).

Because inert gas which is used in Tisza II Power Plant has almost equal percentages of CO2 and CH4 (44%), its calorific value is as low as 16,160 KJ/Nm^3 (3,860 kcal/Nm^3) and its total sulfur is 2.2mg/m^3.

7.2.2 State of Air Pollution Control at Major Stationary Sources

(1) Outline of Stationary Pollution Sources in the Study Area

Among the large and medium size factories in the Sajo Valley area having potentiality of emitting air pollutants, 54 factories are operating. They include those factories that have gone bankruptcy but are still partially operating and 19 large-to-small size heating centers operating in the heating season. There are some factories that completely stopped operation after bankruptcy.

Examination of factories' answers to questionnaire submitted to EKF revealed that there are a total of 527 stacks emitting air pollutants in those 54 operating factories. Of these, 271 are emitting pollutants due to fuel combustion. Number of stacks emitting SO2 due to combustion of coals and oils is 56 including 8 stacks of 3 power stations. One of these 8 stacks discharges exhaust gas collected from 4 flues (4 boilers).

Those operating stacks mentioned above can be categorized by pollution source characteristics as shown in Table 7.2.1.

Facilities that burn sulfur containing fuels such as coal and heavy oil are mostly boilers in power stations, chemical factories, a petroleum refinery, etc.

Table 7.2.1 Categorization of Major Stationary Pollution Sources

Pollution Source Category	Kind of Pollutants Emitted	Number of Stacks
1) Sources emitting air pollutants due to fuel combustion	a) SO_2, NOx, CO, dust	56
	b) NOx, CO, HnCn, dust (natural gas used as main fuel)	215
2) Sources emitting air pollutants from production processes of chemical and petroleum products	Cl_2, HCl, $COCl_2$, HnCn, NOx, NH_4NO_3, dust	141
3) Sources of dust only (mostly metal factories)	dust	115

(2) General Situation of Air Pollution Control

Air pollution control measures must be studied for each type and scale of facilities. Pollution control situations in the major categories of stationary pollution sources in the Study Area are as follows.

There is no flue gas desulfurization facility in the factories in the Study Area. Some combustion facilities emit SO_2 with its amount exceeding the emission standards.

As for NOx, there are some facilities that seem to need combustion control with an appropriate air ratio. A certain facility seems to need low-NOx burners. But no specific measures are taken for these facilities.

For control of dust emission, electrostatic precipitators (EP) are installed in large-scale facilities such as a blast furnace in DNM and boilers in power stations. Sintering furnaces for iron ore in BEM are equipped with multi-cyclones with efficiency of 80-85 %. The blast furnace in DNM has no hood, therefore, iron ore dust escapes into atmosphere by about 4% of the total quantity. This amount is said to account for 75% of the total dust emission in Miskolc City. According to the decision of the Hungarian Government, the blast furnace is to be phased out by the year of 1996.

(3) Air Pollution Control at Power Plants

There are three thermoelectric power plans in the Study Area belonged to Borsodi Energetikai Kft and Tisza Eromu Rt, the power generation companies, as follows:

Borsodi Energetikai Kft :	
Borsod Power Plant	coal fired
Tisza Eromu Rt :	
Tiszapalkonya (Tisza I) Power Plant	coal fired
Tisza II Power Plant	gas and/or heavy oil fired

Flow charts of combustion and power generation at these thermal power stations are shown in Figures D7.2.1 through D7.2.4 in Data Book. For air pollution control, only EPs are installed at the two coal-fired power stations to collect dust, but they are very old, and inefficient. All the facilities in these two power plants are old, and lack both combustion efficiency and electric energy efficiency.

The current state of air pollutant emissions from each station in 1992 is described below.

1) Borsod Power Plant

Borsod Power Station is located near Kazincbarcika. It was built in 1955-57. It has ten conventional pulverized coal-fired boilers (100 t/h x 10), and six 30 MW turbine generator units. The installed capacity is 200 MWe.
The power station supplies electricity to the national electricity grid and heat energy to Kazincbarcika for district heating and to a nearby chemical company.
Production data of 1992 are as follows:

Electricity	599.33 GWh
Heat energy	3,167,737 GJ
Plant heat rate	14,208 KJ/KWh
Fuel input	
Brown coal	1,174,307 ton
Natural gas	31,857,000 Nm3
Oil	118 ton

The brown coal comes from Borsod mines. It is low-grade with high contents of ash and sulfur. Each boiler is equipped with an electrostatic precipitator (EP). The flue gas is discharged through 3 stacks. The stacks are 101 m high.

Borsod Power Plant's atmospheric emissions in 1992 are estimated to be as follows:

	Emissions (kg/h)			
	Dust	SO2	NOx	CO
Limit rate	160	600	240	12,000
No.1 stack	92.0	1,774	121.0	13.5
	89.5	1,376	117.3	13.0
	61.0	887	80.3	9.0
	81.5	1,670	107.2	12.0
No.2 stack	81.5	1,310	108.6	12.6
	55.7	962	73.9	8.5
	43.0	850	57.5	6.7
	49.8	958	66.5	7.7
No.3 stack	133.6	2,782	178.1	20.6
	79.2	1,456	105.1	12.0
	39.6	806	53.0	6.2
	52.0	1,056	69.4	8.1

2) Tisza I Power Plant

Tisza I Power Plant is located near Tiszaújváros. This power plant was commissioned in 1957-58. The installed capacity is 230 MWe. It has eight pulverized coal-fired boilers (125 t/h x 8).

The power plant supplies electricity to the national electricity grid and heat energy (hot water and steam) for district heating of Tiszaújváros, for a chemical company (TVK), and an oil refinery (TIFO). The boilers are fitted with EPs which were installed in 1977-80. Production data of 1992 are as follows:

Electricity	932.46 GWh
Heat energy	2,422,451 GJ
Plant heat rate	13,412 KJ/KWh
Fuel input	
Brown coal	1,328,871 ton
Natural gas	39,307,400 Nm3
Oil	476 ton

The brown coal comes from the Borsod and west Hungarian mines. The coal has high contents of sulfur and ash. The flue gas is discharged through 4 stacks of 120 m high.

Tisza I Power Plant's atmospheric emissions in 1992 are estimated to be as follows:

	Emissions (kg/h)			
	Dust	SO2	NOx	CO
Limit rate	90	375	150	7,500
No.1 stack	Nos. 1 and 2 boilers were under reconstruction.			
No.2 stack	150.3	1,497.7	137.6	157.9
	117.9	1,312.4	106.0	124.4
	100.4	1,325.9	88.8	100.4
	128.5	1,361.7	115.3	129.7
No.3 stack	38.7	1,233.4	115.2	131.8
	44.2	1,503.6	129.7	152.2
	34.3	1,417.0	99.0	111.6
	43.4	1,476.2	128.5	144.8
No.4 stack	115.0	1,316.0	123.5	141.3
	93.4	1,186.3	98.7	115.7
	82.0	1,283.9	85.6	96.8
	106.3	1,351.0	114.6	129.9

3) Tisza II Power Plant

Tisza II Power Station is located near Tiszapalkonya Power Station at about three kilometers from Tiszaújváros. Tisza II Power Station was commissioned in 1977-1978. It has four blocks each having a boiler for mixed combustion of oil and gas. The total boiler capacity is 670 t/h.

The installed power generation capacity is 860 MWe. It supplies electricity for the national grid.

Production data of 1992 are as follows:

Production	2,615.66 GWh
Plant heat rate	9,883 KJ/KWh
Fuel input	
	Natural gas 282,938,000 Nm3
	Inert gas 491,794,000 Nm3
	Oil 181,230 ton

The gas from 4 flues is discharged through a single stack of 250 m high.
Tisza II Power Plant's atmospheric emissions in 1992 are estimated to be as follows:

	Emissions (kg/h)		
	SO2	NOx	CO
Limit rate	1,875	750	37,500
No.1 block flue gas	319.0	158.7	9.4
	0.0	138.0	9.1
	2,075.0	170.0	9.1
	146.4	143.0	9.2
No.2 block flue gas	476.0	164.0	8.8
	587.0	126.0	8.6
	2,089.0	168.0	9.3
	190.5	137.0	8.6
No.3 block flue gas	457.7	164.0	9.3
	645.3	113.0	8.0
	572.0	142.0	8.1
	130.5	138.0	8.5
No.4 block flue gas	357.0	169.0	9.0
	838.0	160.0	9.2
	1,909.0	185.0	9.3
	139.9	161.0	8.8

4) Necessity of Emission Control

Concerning SO2, all of three power plants exceeded the Hungarian emission standard level. But NOx and CO emissions are below the standard level. Dust emissions from Borsod Power Plant are below the standard level. Dust emissions from No. 2 and No. 4 stacks in Tiszapa I Power Plant exceeded the standard level. As other stacks in the same station showed the emission values considerably below the standard level, the high emission values of No.2 and No. 4 stacks may be attributed to the faulty electrostatic precipitator. Since all of 3 plants show the SO2 emission far above the standard level, measures to reduce the SO2 emission are necessary.

(4) Air Pollution Control at Chemical Factories

Harmful gases, such as HCl, Cl_2, $COCl_2$, HNO_3, etc., emitted at high concentrations during processing of chemical and petroleum products are washed in absorbers with NaOH and H2O and released into the atmosphere. However, in most cases, only water spray scrubbers are used. Moreover, the ratio of liquid to gas is very low and the mixing is poor. (One pass is applied in most cases with no repetition.) These factors reduce efficiency. The desirable ratio of liquid to gas is 1:150 at minimum and 1:120 for optimum.

Flow charts of production processes in major 4 chemical factories are shown in Figures D7.2.5 through D7.2.19 in Data Book. The emission sources which should be monitored regularly are indicated by the black circular mark in the flow charts. Of these, the closest attention should be paid in future to the emission of SO2 from the sulfur collector at MOL desulfurization plant. This is because its collection percentage is 90% or less due to the 'one pass' of the Claus method, and also because the emission quantity of SO2 depends greatly on the sulfur content of the crude oil.

(5) Air Pollution Control at Metal Factories

Dust collectors such as bag filters and multicyclones are installed under the blast furnace of DNM company but the suction is insufficient. Moreover, problems concerning the collection and removal of the separated dust have not yet been solved. Because of the structural problem of the blast furnace (BF), more than 4% of the BF gas is emitted into the air each time the upper partition opens when raw materials are supplied, and this has become a serious cause of air pollution. It seems that great efforts have been made toward rebuilding this blast furnace. However, the Hungarian Government made a decision to phase out the blast furnace in DNM and the iron ore preparation plant in BEM (Ref. B-34). Outlines of these facilities are shown in Figures D7.2.20 and D7.2.21 in Data Book, respectively.

Manufacturing and technological data of DNM's blast furnace (1992) are as follows :

Manufacturing/operation hour per year:	257,010.5 t liquid crude iron/4,779 hour
Total iron-containing feeding:	184,109 t
Total coke feeding:	121,648.246 t
Total carbon feeding*:	122,039.176 t
Specific coke using*:	542.3 kg/t crude iron (calculated on the dry base)
Average temperature of blow-air:	1,031 °C
BF gas arising*:	3,560 m3/t coke
Total BF gas arising*:	496,196,000 m3
Utilized BF gas*:	476,579,000 m3
BF gas loss*:	19,619,000 m3 (3.954 %)
BF gas composition :	CO : 25.28 % = 1296.78 kg/hour NOx: 0.00002 % = 1.6856 kg/hour CO2: 15.1 %

dust*: 23-30 g/m3 = 98.53 kg/hour

BF gas wastages:	
cyclone + dust-sack dust :	7,336.2 t
dross of electrostatic separator:	about 18,000 t
Average dust content of cleaned BF gas:	8 mg/m3

Note: *: calculated data

(6) Heating Centers and Others

The heating centers in the study area are shown in Table 7.2.2. None of these enterprises exceed the Hungarian emission standards for SO2, NOx, CO and dust. These heating centers are closely connected to the regional society and are positively dealing with air pollution control.

Table 7.2.2 Present State of Central Heating in the Sajó Valley Area

Name of area	No. of households covered by central heating	No. of households (1990)	No. of public facilities covered by central heating	Volume of public heating (m^3)	Fuels used
Miskolc	31,722	73,500	569	635,979	Natural gas and coal
Kazincbarcika*	8,010	12,776	267	130,299	Coal (power station)
Sajoszentpeter	348	4,629	13	2,300	Natural gas
Ozd	5,516	16,135	162	177,625	Natural gas and coal
Tiszaújváros	5,473	6,250	119	155,026	Coal (power station)
Emod	42	1,857	8	3,257	Oil
Putnok**	452	2,535	3	6,641	Oil** and wood

Note *: Of 8,010 households registered in a heating network, 6188 households receive hot water heating. The total number of households of the city is 12,776 as of October, 1993.

**: Use of natural gas began on October 15, 1993.

1) Miskolc Heating Center

This company has ten boiler houses in Miskolc City. One of the houses (Korosi CS. S) is firing brown coal at present, but is scheduled to switch to natural gas in 1994-1995. The nine other houses use natural gas and their impacts on air pollution are small.

2) Miskolci FUTOMU Kft.

This company has two of PTVM100 (100Gcal/h) and two of PTVM50 (50Gcal/h) hot-water boilers. All of the four boilers fire natural gas and heavy oil. Heavy oil (S content: 2 to 4% maximum) is burnt in only two PTVM boilers which are rarely used. Because of the high S content in heavy oil, continued use of natural gas in lieu of heavy oil is recommended.

3) Miskolci EGYETEM EROMU (Miskolc University)

Since 1984, 65% of th total heating demand has been purchased from the heating centers in the city. Three coal fired boilers (one 3.5t/h boiler, two 7.5t/h boilers) remain and one of them is sometimes used temporarily. There are two oil fired boilers with rated steam generation capacities of 10t/h and 7t/h, respectively. At present, the heat demand is met by the 7t/h boiler alone. The fuel used is of the oil standard 60/130.

While, the total capacity of the facilities is 35.5t/h, only the 7t/h capacity or 20% of the total is operating.

The present status can be maintained. Unless use of coal is increased, no control measures are necessary.

4) Sajoszentpeteri Hoszolgato Vallalat (Heating Center)

This is a small-scale heating center with four boilers supplying heat and hot water to 348 houses. The boilers are installed on the roofs of the housing complex buildings. Natural gas is used as the fuel. Impacts on air pollution are small and no control measures are necessary.

5) EMOD NAGYKOZSEG GONDNOKSAGA (EMOD Heating Center)

This is a very small-scale heating center heating 42 houses and two public buildings. Diesel oil is used as the fuel. During the heating season, two boilers operate 24 hours per day. Three boilers are operated on especially cold days. The fuel consumption per boiler is 25 liters/h. The consumption is about 800 liters per day when two boilers operate 24 hours per day. Impacts on air pollution are small and no control measures are necessary.

6) PUTNOK VAROSI HOSZOLGALTATO UZEM (PUTNOK Heating Center)

On October 15, 1993, the center switched its fuel from heavy oil to natural gas. The site is adjacent to the service area and the center is making efforts to prevent air pollution.

7) OZDI TAVHO TERMELO HOSZOLGALTATO VALLALT (OZD Heating Center)

This is a new heating center established on August 1, 1992 in accordance with the Borsod County district heating system. It backs up the hot-water and heat supply service to 5600 households in Ozd City provided by OZDI KOHASZATI UZEMEK TORZSGYAR (OZD Metallurgy Industry). The facilities are new and natural gas is used as the fuel. No particular control measures are necessary.

8) KAZINCBARCIKA and TISZAUJVAROS

The heating centers for these two areas receive heat from nearby thermal power plants and distribute it as intermediaries. The centers do not have pollutant emitting facilities.

7.2.3 Existing Pollution Control Plans at Major Stationary Sources

(1) Borsod Power Plant

Since the facilities in this power plant are quite old, the company is planning to modernize the facilities in order to reduce pollutant emissions and improve power generation efficiency. According to the information given to the Study Team, six out of ten 100t/h existing boilers are to be phased out, and the following 2 projects are being planned.

1) New Installation of Circulating Fluidized Bed Construction System (CFBC)

Technical characteristics of CFBC system is discussed in Section 7.3.1. An outline of this project (called 150 MW circofluid extension) is as follows.

i) Main Equipment

Boiler:	Steam capacity (max.)	460 t/h	
	Continuous steam generation(max.)	454 t/h	
	Steam pressure	165 bar	
	Steam temperature	540 °C	
reheated parameter		424 t/h,	45 bar
	temperature of out flow	540 °C	

temperature of in flow	360 °C
Steam mass flow (max.)	19.4 kg/s (70 t/h)
Temperature at out flow	420 °C
Feed water temperature	243.0 °C
Planed pressure	188.0 bar
pressure loss (overheater)	8.0 bar
reheater	3.0 bar
economizer	1.0 bar
Combustion air flow	135.0 m^3/s (nominal)
Exhaust gas flow	157.0 m^3/s
Exhaust gas temperature	150 °C
Boiler efficiency:	
in case of brown coal (Borsod coal)	90 %
in case of black coal	92 %

Turbine generator:	150 MW, 3000 l/min.
Fresh steam	160 bar / 535 °C
Steam mass flow	126 kg/s (45 t/h)
Reheated steam parameter	43 bar / 535 °C
steam mass flow	118 kg/s (424 t/h)

Condenser:

Nominal steam flow	83 kg/s (299 t/h)
Condenser pressure	0.09 bar (15 °C)
Temperature of cooling water incoming	32 °C
Temperature of cooling water outgoing	40 °C
Cooling water mass flow	20,000 m^3//h

ii) Flue Gas

Flue gas quantity and amounts of pollutant emissions are expected to be as follows :

Flue gas :

Flue gas flow	518,400 Nm^3/h
Outlet flue gas temperature	150 °C

Emission of pollutants :

Solid particles	50 mg/Nm^3	(26 Kg/h)
SO2	400 mg/Nm^3	(207 Kg/h)
NOx	200 mg/Nm^3	(104 Kg/h)

The limit values of emission as a function of height of the chimney :

The height of the stach (m)	80	100	120
E [f,i]	2.0	4.0	6.0
Number of stacks in the given height range (pc)	1	2	1
E [f] = E [f,i]/n	2.0	2.0	6.0

Emission limit of the area, (kg/h) :

solid particles	80	80	240
SO2	180	180	540
NOx	180	180	540
CO	6,000	6,000	18,000

The planned emissions and the limit values of the area show that the emission quantities of solid particles, NOx and CO are below the limiting value at all stack sizes, but the SO$_2$ emission conforms to the regulation only over 120 m stack height. Concentration limit values are not regulated in Hungary. Comparison with the German standard limits for the capacity over 100 MW are as follows :

	German standards		Planned
Solid particles	80 mg/m^3	>	50 mg/m^3
SO2	650 mg/m^3	>	400 mg/m^3
NOx	600 mg/m^3	>	200 mg/m^3

The above data show that the planned values are below the limits of the German standard.

Further details of above plan are described in the report of "A Preliminary Environmental Study for the Reconstruction of the Borsod Thermal Power Station (Ref. D-8)" which was prepared by the company. An implementation schedule is shown in Figure D7.2.22 in Data Book.

2) Conversion of 100t/h Boilers Into Hybrid Fluidized Bed Combustion System (HFBC)

A study concerning conversion of four 100 t/h boilers into hybrid fluidized bed combustion (HFBC) boilers was conducted on the basis of assignment No. 11.92-226 of MVM RT.

HFBC system is a combination of fluidized firing and coal-dust firing, and is a patent of the Hungarian Institute of Electric Power Research (VEIKI). Technical characteristics of the HFBC and its applicability to this power station are discussed in detail in Section 7.3.1.

Its main advantages are as follows:

- The SO_2 and NOx emissions decrease.
- The contamination of furnace surfaces decreases.
- It provides stable firing at partial load even without supplementary firing.
- It can be established at a relatively low cost.

Some essential aspects of the planned system are shown in Figures D7.2.23 through D7.2.28 in Data Book.

3) Discussion

The CFBC system, planned to be employed in the Borsod Power Plant as described above, is drawing attention in the combustion-related industries as a latest technology. When this type of boiler is operated with a combustion temperature at about 950°C, its combustion efficiency is quite high; remaining ash is almost white with very low content of unburned carbon. Therefore, the operation at this temperature would save fuel consumption by about 10 % in comparison with conventional boilers. However, the optimal range of combustion temperature to attain maximum desulfurization efficiency within the boiler (85 % or more) is between 800°C and 850°C. The desulfurization efficiency decreases to 20-30 % or less when operated at 950°C; SO2 reduction including fuel saving effect is only 30-40 % or less at this temperature. Thus, the operating conditions for high combustion efficiency and high desulfurization efficiency contradict each others.

According to the Study Team's investigation of existing CFBC boilers in several countries, most of them are operated at about 950 °C to pursue economic effect.

Since the combustion temperature can be easily controlled, one alternative is to find optimum operating temperature of the boiler, with both the combustion efficiency and the desulfurization efficiency taken into consideration.

(2) Tiszapalkonya (Tisza I) Power Plant

For this power plant, MVM RT. plans to decrease gradually the productions of electricity and heat energy towards the future. Firstly, 3 boilers out of existing 8 boiler are to be abolished by 1995. For remaining boilers, retrofitting works for 2 boilers are to be completed in 1994, and the works for another 2 boilers are to be completed in 1995. Planned production output in 2005 is 1,700 TJ of heat energy and 35 GWh of electricity as compared with about 2,200 TJ of heat and 800 GWh of electricity in 1993.

No emission reduction facilities for SO_2 and NOx are planned to be installed.

(3) Tisza II Power Plant

This power plant is a very important electricity producer in the Hungarian electric system. The production of electricity has been 2,615 GWh in 1992 and 3,008 GWh in 1993. According to MVM Rt., the production level will be incresed until the year 2000 (3,805 GWh) and will be decreased to 1,581 GWh in 2005. The shortage of electricity is to be supplied from Donamenty thermal power plant which will be newly installed in 1999.

The company plans to install a continuous emission monitoring system at a cost of about USD 750,000. But no emission reduction facilities for SO_2 and NOx are planned to be installed.

(4) DNM metal Factory and BEM Ore Preparation Plant

The Hungarian government has made a decision on the policy for the reorganization of the Borsod steel industry (Ref. B-34). The blast furnace in DNM and related facilities such as LD converter (DNM) and iron ore preparation plant (BEM) are to be phased out by the year of 1996, although the companies had planned to improve their facilities including these facilities. Improvement plans for remaining facilities presented by the companies are as follows.

1) Combined Steel Work

- Implementation of independent primary and secondary suction in case of ASEA kettle-metallurgy, umbrella type suction by drawing off, utilization of separated dusts
- Settlement of independent suction and separation system at continuous steel caster, and closed treatment of utilized dust
- In case of capacity-increasing of UHP arc furnace, solving additional suction and separation in accordance with needs
- In case of kettle-repairing technologies: umbrella type suction, closed waste treatment for reuse
- Increased maintenance of environmental protecting equipment, automatic signalling of emission transgression, total utilization of separated dusts and drosses
- Study of utilization of converter-torch-gas (for heating or other technologies)
- Increasing of manufacturing capacity of continuous steel casting, decreasing by this the energy-need and environmental pollution of rolling-mill furnaces
- The closed system treatment of all collected dusts and drosses for all equipment, and their suctions

2) Rolling Mills

- Re-examine the necessity of numerous heating-furnaces, the possibility of decreasing. For moderation of energy loss of the remained furnaces, the not needed gaps of furnace chambers have to be closed. The furnaces, heat-utilizing boilers, if it is possible, have to be heated by BF gas or mixed gas (BF gas will not be used).
- Natural gas burners with capacity of more than 1,000 m3/h have to be changed to low NOx burners.
- Rust-waste arising from rolling has to be collected, stored in a closed system, and totally reused.
- For energy-saving and environmental protection, problems of missing automation and measuring instruments of the heating equipment have to be solved.
- The number of the ingot-polisher machines has to be reexamined, and the ingot-polishers survived have to provided with more efficient suction, and jet-filter type dust-separators. In case of building up secondary suction, individual separable places have to be solved. Separated dusts have to be totally reused.
- In rolling mills, the collecting-pipes have to be provided with oil-indicator (to indicate oil pollution in cooling-water in case of breakdown), which can control chemical-dosing, and oil-separation of water-cleaning work-shop as well.

3) Energy Supply

- The composition of smoke gasses of furnaces has to be continuously controlled in view of energy saving and environmental protection.
- The high capacity natural gas burners have to be changed to low NOx type.

4) Waste Processing Storage

- Wastes have to be transported on depot by closed transportation facilities. Roads in the factory have to be cleaned of dust.
- Dross processing and separating works in waste depot have to be made in closed, roofed area. To eliminate air pollution, waste depot has to be stabilized by recultivation or chemical treatment.
- The waste water (getting into the ground) of the depot, and water of the brook have to be totally utilized for the waste processing technologies.
- The open air storage of iron-containing muds and dusts has to be stopped, they should be worked up immediately, and re-utilized in metallurgy.

5) Technologies of Other Work Shops

- The number and importance of furnaces in HAMOR RT. and DAV Ltd. have to be re-examined. The lasted furnaces have to be urgently modernized and provided with energetical measuring and controlling system.
- The out of date technology of sand-preparatory work-shop has to be stopped, new one must be provided, or sand has to be obtained from outside source.
- The air pollution of casting houses can be reduced by umbrella-suction and closed technology (cleaning of casts, steel casting, sand-mould making and drying).
- Remove oil pollution of the ground and water, automatic control of oil getting into the cooling-water system of HAMOR RT. and CH RT.
- The sulfuric-acid steeper must be stopped, planting a new one instead or installation of mechanical grinding technology is necessary.

6) Recommendation by UNIDO

In the study of UNIDO in 1991, the following measures were recommended (Ref. D-9)

- Dust collecting measures for blast furnace (to be phased out, see Figure D7.2.29 in Data Book)
- Dust collecting measures for electric arc furnace (see Figure D7.2.30 in Data Book)
- Dust collecting measures for grinding machine (see Figure D7.2.31 in Data Book)

(5) DIOSGYORI Steel Mill and Casting Factory (DAV)

The following facility plan was provided by the company for suction devices and dust collectors used to trap solid waste (dust) generated by the electric furnace of electric steel mill I (see Figures D7.2.32 through D7.2.34 in Data Book).

1) Preface

A facility plan (installation of vacuum/dust collectors, parameters and cost) is being created for three electric furnaces (two 17.5t, one 2.5t) at the electric steel mill to protect the environment.

In the fourth quarter of 1989, the quantity of dust emitted by DAV exceeded the limit of the standard (0.00974 kg/h) and reached 54,852 kg. Out of this amount, 45,713.5 kg came from electric steel mill I. In 1992, the quantity of dust emitted by mill I reached 40.0 kg/h, an annual total of 59,560 kg (hours of operation: 1,489 hours). The residential areas near the mill, such as the top of Komlos, Varga hill, Avasi residential area, the college town, and the Miskolc villa area are believed to be affected by the dust.

When the plan is completed, 80% of the emitted dust will comply with the standard. This will contribute to securing clean air in Miskolc.

2) Emission Sources

i) 17.5t Electric arc furnace

First, to supply scrap for the 17.5t arc furnace using a crane, the furnace is drawn forward. The scrap is put in and the furnace returned to its original position. Next, an electrode is put in the furnace to melt the scrap. Inspection is made at the insertion opening and certain substances may be added. Because it is a rocking arc furnace, it can be turned over with the electrode in it. The hot water is drained, then chemicals are added to repair the fireproof wall inside the furnace. Waste is created at each stage.

When the electrode is lowered at the time of fusion, a large quantity of waste is created first with the excess pressure in the furnace.

When the furnace door is opened, a large quantity of waste escapes because of the excess pressure inside. However, this will not occur when the materials are provided with the furnace.

ii) 2.5t electric arc furnace

Materials are provided with a scoop. Then the electrode is lowered to melt the materials. Inspection is made at the furnace door and some substances may be added. The rocking arc is turned over to drain the hot water.

When the electrode is lowered and the furnace door is opened at the time of fusion, the pressure is excessive because of the heat, and a large quantity of waste escapes.

3) Bell-shaped Suction Device

The bell-shaped suction device is installed according to the length of the electrode and the movement of the furnace. The bell-shaped suction device is installed on the steel frame structure. When the electrode is replaced, the bell-shaped suction device and the steel frame structure are moved on caterpillar tracks. The rotating arm is moved through 180 degrees.

i) Air parameter

- Size of bell-shaped suction device of 17.5 t arc electric furnace
  Diameter: 2,500 mm
  Area: 4.9 m^2

- In the area of the bell-shaped suction device,
  Air flow velocity: 1.4 m/s
  Flow rate of air and smoke: 6.95 m^3/s (25,000 m^3/h)

- Size of bell-shaped suction device of 2.5 t arc electric furnace
  Diameter: 1,750 mm
  Area: 2.4 m^2

- In the area of the bell-shaped suction device
  Air flow rate: 1.4 m/s
  Flow rate of air and smoke: 3.33 $m^3/s/12{,}000m^3/h$

ii) Dust parameters

- Dust flow rate in the air and smoke:
  2.5 t furnace: 3.00 kg/h minimum, 12.00 kg maximum
  17.5 t furnace: 6.25 kg/h minimum, 25.00 kg/h maximum
  The maximum concentration lasts for only 15 minutes after fusion begins.

- Average dust flow rate:
  2.5t furnace : 5.2 kg/h in average
  17.5t furnace : 11.00 kg/h in average

4) Dust Collector

Filter of the suction system
Type: 2 pieces VFP-40/4-C
Rated capacity: 25,000 m^3/h
Filter area: 240 m^2
Type: 1 piece VFP-40/2-C
Rated capacity: 12,000 m^3/h filter
Area: 120 m^2
Through the filter of the dust collector, dust concentration will be 5mg/m^3.

5) Fans

Two NVHK-160-VF/1120-E24
    Air rated flow: 25,000 m^3/h
    Increase of total pressure: 5,750 Pa
One piece NVHK-100VF/1800-E20
    Rated air flow: 12,000 m^3/h
    Increase of total pressure: 5,750 Pa

6) Dust Processing

Dust should be transferred from the dust tank with a caterpillar movement and put in the container.

Amount of dust in one quarter
    Hours of operation: 1000 hours/quarter
    17.5t furnace : 19.8t/quarter
    2.5t furnace : 5.25t/quarter
Total amount of the dust in each quarter
    Q*=19.8+19.8+5.25=44.85 t/quarter
The amount in each quarter is equivalent to about 6 of 3.5 m^3 containers.

7) Implementation Procedure

The following procedure can be taken to save costs :

- The equipment is installed on the 17.5 t furnace first. It is connected to the front of the dust collector temporarily. After attaching the clack valve, VFP 40/4 C type dust collector is installed.
- Finally the duct is installed.

When following the above procedure, one furnace can be operated at a time. Simultaneous operation of the three furnaces will be a problem requiring a temporary or final solution.

That is, when operating the three furnaces at the same time, the height of the stack should be $35 < H < 50$m.

Therefore, before making the actual design, the problem of simultaneous operation should be resolved. When the height of the stack is 35m or higher, it should be secured more firmly and the foundation of the steel structure should be enlarged.

7.2.4 Problems in Air Pollution Control of Stationary Sources

(1) Coal Supply

The current production cost of coal in Hungary is about Ft. 220 - 230/GJ, and pricing competitive with imported oil should be at most Ft. 140 - 180/GJ or less.

Despite the high production costs, not all of the Hungarian coal mines are closing down. One of the reasons is that existing Hungarian coal-fired power plants can operate only by coals of a low caloric value (international coals have 25,000 - 30,000 kJ/kg, while Hungarian coals have only 12,000 kJ/kg). Another reason is that imported coal is not necessarily cheaper than Hungarian coals. The rivals of Hungarian coals are not necessarily imported coals, but natural gas and oil. Instead of the current coal-based power plants, however, the government plans to establish power plants with gas turbines and atomic energy sometime in the future. In 1993, Hungarian power-plants are to receive about 100,000 PJ domestic coal. Hungarian coal policy is obviously related to employment problems.

Formerly there were 35 deep mines in Hungary, now there are about 20, and by 2000 their number is likely to be reduced to 3 - 5. In 1990, there were some 50,000 workers in Hungarian coal mining, and by the end of 1992, the number reduced to about 30,000.

1) Structure of Coal Mining

The structure of coal production in Hungary (in peta joule) is as follows :

	1992	1995	2000
Surface-produced lignite	39	45	45
Black coal	18	16	8
Brown coal	101	79	52
Total	158	140	105

Coal mines to be closed down or remained by 2000 are as follows :

Coal mines as of 1992		Planned last year of production
Mecseki coal mines	Vasas	1994
	Komlo	1997 - 2000
	Szaszvar	1992
	Surface	-
Dorogi	Alagut	1992
	Lencsehegy	1996 - 2000
Tatabanyai	Many I/a	1999
	Zsigmond	1993
	Surface	1992
Oroszlanyi	Markushegy	-
	Surface	1994
Veszpremi	Ajka	1999
	Dudar	1993
	Varpalota	1993
Borsodi	Edeleny	1999
	Lyuko (*)	-
	Putnok	1995
	Feketevolgy	1998
	Rudolf	1992
	Surface	1994
Nogradi	Menkes	1992
	Nyirmend	1992
	Szekvolgy (Kereg)	-
	Surface	1992
Matraalji	Thorez	-
	Bukkabrany	-

Source : Ref. A-25

Note : (*) Dubicsány coal mine will be opened in the future in place of Lyuko mine.

2) Coal for Borsod Power Plant

On November 12, 1992, the Cabinet ruled about the establishment of "Coal- mine / Power-plant Complexes." Accordingly, three such complexes were organized on January 1, 1993 :

1. Matravideki Energetics Share-holding Company
2. Mecseki Energetics Share-holding Company
3. Ajkai Energetics Share-holding Company

According to current plans, the Tisza Power Plant Company in the Sajo Valley area will be merged with the Lyuko Coal Mine Company in BAZ County to form a new establishment called "the Coal Mine/Power Plant Complex" on January 1, 1994.

As far as domestically-produced brown coal is concerned, the Borsod power plant will have no alternative source of fuels but to use brown coal supplied mainly from the Lyuko coal mine, and then from the Dubicsány coal mine after the expected closure of the Lyuko mine. Quality of coals from these two mines are said to be similar. Meanwhile, the Borsod power plant is planning to employ the HFBC system developed based on the coal of the Ajka mine. However, as will be described in Section 7.3.1, when the Lyuko coal is used, the desulfurization rate of the HFBC system is not as high as that achieved by the use of the Ajka coal. This problem has to be solved in employing the HFBC system in the Borsod power plant.

(2) Energy Consumption

Until 1989 when Hungary was liberated from Soviet dominance and began shifting towards market economy, energy intensity of the country remained very high as shown in Figure 7.2.2. In contrast to low prices of produced goods, energy consumption was high. Energy consumption per US$1,000 of goods was four to five times higher than Japan's rate, and three times higher than the average of all industrialized nations. This is partly because the country, under the control of the former Soviet block, had not given careful consideration to competitiveness in the international market, and partly because the government's policy had attached no importance to energy saving efforts and energy efficiency. Soviet-style operations dominated both the manufacturing and farming industries.

During the 1973 oil shock, no special measures were taken by the government. Seven to eight years later in the early 1980s, the government began to formulate its energy policy, which was not intended to save energy, but was aimed at shifting the country's source of energy from oil to natural gas following instructions from the Soviet Union. Since the government had adopted and formed a Soviet-dependent economy, Hungary came under the pressure of the Soviet Union, and the country was unable to utilize sufficiently the oil pipeline from the Adriatic Sea.

Although Hungary imported electricity from other countries, a large amount was supplied by the East block nations. Before the economy was liberalized, the price of electricity was set at a lower rate than in other countries. In the 1990s, electricity prices have been raised to international market prices. In 1990 and 1991, natural gas was

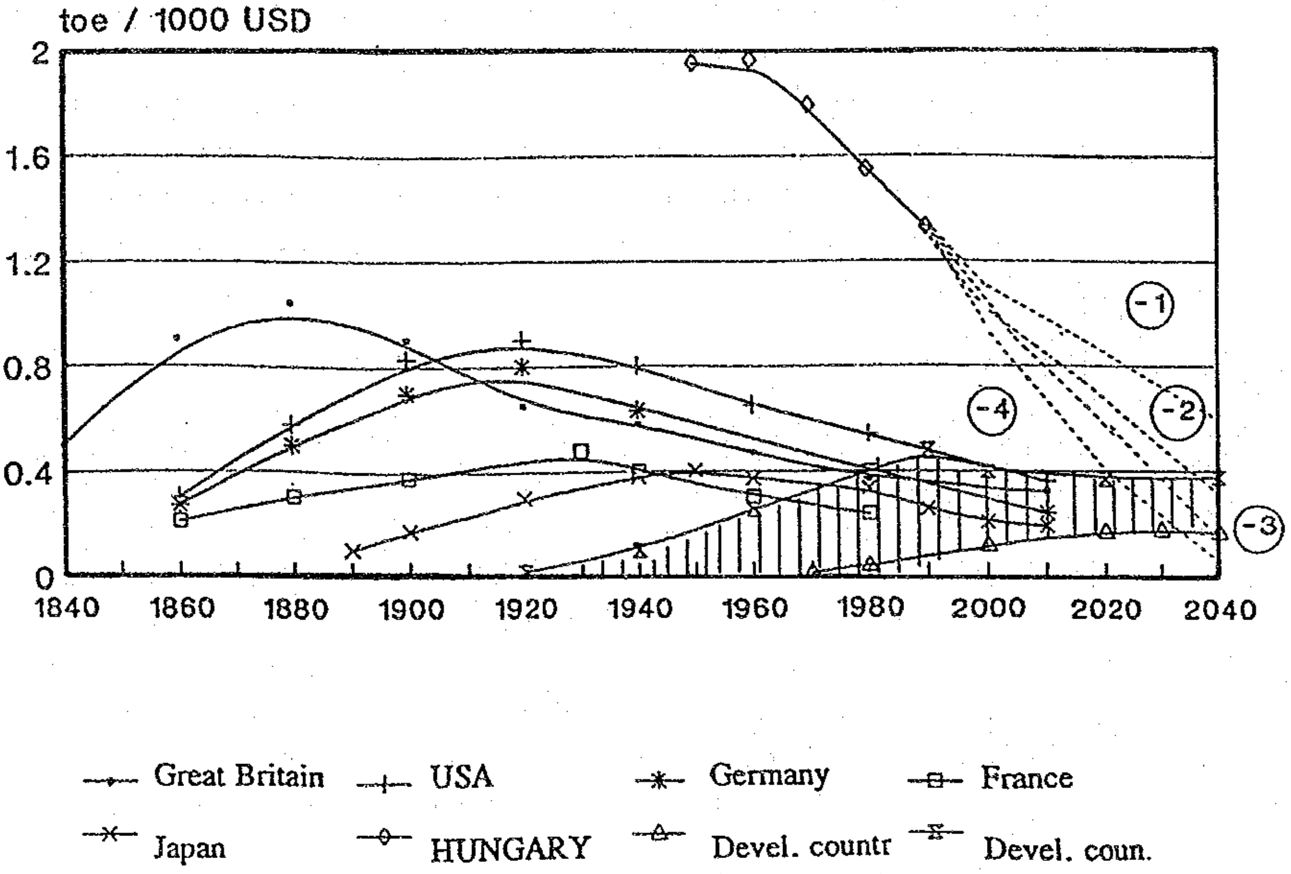


Figure 7.2.2 Movements of Energy Intensity - An International Comparison

purchased at market prices higher than those in Germany and France in the European Community.

Examples of waste of energy by companies are described below.

1) DNM KFT.

Blast Furnace (See Figure D7.2.35 in Data Book)

Manufacturing/operation hours per year : 257,010 t liquid crude iron/4,779 hour
Total iron-containing feeding : 184,109 t
Total coke-feeding : 121,648.246 t
Total carbon-feeding* : 122,039.176 t
Specific coke-using* : 542.3 kg/t crude iron
(Calculated on the dray base)
Average temperature of blow-air : 1,031°C
BF gas arising* : 3,560 m3/t coke
Total BF gas arising* : 496,196,000 m3
Utilized BF gas* : 476,579,000 m3
BF gas loss* : 19,619,000 m3
BF gas composition : CO : 25.28 % = 1296.78 kg/hour
NOx : 0.00002 % = 1.6856 kg/hour
CO2 : 15.1 %
dust* : 23-30 g/m^3 = 98.53 kg/hour
BF gas wastage : Cyclone + dust-sack dust : 7336.2 t
Dross of electrostatic separator : about 18,000 t
Average dust content of cleaned BF gas : 8 mg/m^3

Note : * : calculated data

The double sluice-chamber is provided on the top of the BF, and internal pressure of BF gas is high. Therefore, when the upper sluice is opened for feeding ores, coke and limestones, this gas runs away into the atmosphere. In this way the loss-gas takes a sum of about 4 - 6 % of the produced BF gas. The quantity of the loss-gas, owing to the height, temperature, pressure and poisoning-danger, is not directly measurable. On the basis of calculations and gas-analysis, the total loss-gas in 1992 was 19,619,700 m^3. BF gas has heating value of 800 - 900 $kcal/m^3$. If the average is taken as 850 kcal, the loss of energy amounts to about 4 tera joule.

LD Converter

The converter is a 80 ton normal capacity with top oxygen-blowing. Its average portion time is about 50 minutes, which includes 12-15 minutes of blowing. A sucker-cover fits to the mouth of the converter, but the closing of this cover is not complete. The arising converter gases become cool by a heat-utilizing boiler, then dust content is separated by a double, Venturi type (Baumco manufactured) water-system gas cleaner. The efficiency of cleaning is suitable : the dust emission from the 70 m stack is 1.4 - 2.4 kg/hour. The content burns away from converter-gas on top of this stack ; an automatic natural gas burner is installed. Disadvantages of this system are that no heat is utilized and CO burns only when the concentration is above 12.5 %. Therefore, it not burns during first 2 minutes and the last 2 - 3 minutes of the blowing, thereby releasing CO into the air.

Some examples of energy saving in ironworks in Japan are as follows.

Table 7.2.3 shows pricipal measures for energy saving in iron factories. Figure D7.2.36 in Data Book shows combustion equipment that burns low calorie gases, e.g. BF gas. Figure D7.2.37 in Data Book shows principal energy saving measures in iron factories.

Table 7.2.4 shows specific energy consumption (energy consumption per unit product) in DNM from 1988 to 1992. The specific energy consumption remained in the same level during this period.

2) HAMOR RT., DAV KFT., etc.

According to the survey of flue gas by the Study Team, the concentration of oxygen in exhaust gas, which is an indication of heat loss caused by exhaust gas, was 10% or more in almost all cases : only one sample showed 9.7% (DNM), and the maximum concentration was 17.6% (HAMOR). The temperature of exhaust gas was at higher levels with a maximum temperature of 415 °C (DAV). These findings indicate that large amounts of heat are being lost through exhaust gases.

When natural gas is used as fuel, normal oxygen concentrations in exhaust gas are 3 to 5% for small size furnaces of conventional type, or 1 to 2% for medium-to-large size furnaces, depending on the shape and type of the combustion facility.

Table 7.2.3 Principal Measures for Energy Saving in Iron Factories

Process	Measure	Function
Pig iron process	coke dry quenching (CDQ)	recovering wasteheat of red heat coke after dry distillation of coal
	recovery of wasteheat of sintered steel	recovering energy which are exhausted at sintered plant
	power generation at top of blast furnace	power generation by turbine with high pressure gas at top of blast furnace
	recovery of wasteheat in hotwind furnace	recovering and utilizing low heat exhaust gas from hot wind furnace
	coke oven gas (COG)	recovering and utilizing by-product gas of coke oven
Steel mill process	recovery of slag heat	recovering and utilizing heat of slag at blast furnace and converter
	converter gas (LDG)	recovering and utilizing by-product gas from converter
Rolling process	direct rolling	not through heating furnace but by direct rolling of slag
	insertion of heat slag	inserting heat slag into heating furnace before cooling down
	preheating by jet flow of heating furnace	spraying exhaust gas of heating furnace to pillet for preheating
	slag cooling boiler	recovering heat of slag to produce steam
	controlling number of revolutions of blower	controlling revolutions of blower for E.P. of blast furnace, according to volume of electric power

Table 7.2.4 Specific Energy Consumption in DNM

		1988	1989	1990	1991	1992
Blast Furnance						
Coke	kg/t	598.2	573.7	553.5	543.1	554.4
natural gas	m3/t	27.5	32.0	-	-	-
Electricity	kwh/t	16.29	16.3	16.1	15.11	17.4
Oxygen	m3/t	-	-	16.18	16.22	7.3
B.F. gas	m3/t	918.6	857.0	863.5	904.99	817.08
LD Converter						
Natural gas	m3/t	18.6	18.8	21.5	24.9	19.96
Electricity	kwh/t	54.2	47.51	44.75	32.21	26.75
Oxygen	m3/t	65.1	64.16	62.75	62.25	58.0
Erectric Furnace (UHP)						
Natural gas	m3/t	13.2	13.1	19.2	33.5	21.67
Electricity	kwh/t	549.61	523.07	510.73	522.5	497.85

3) SAGROCHEM KFT.

The survey, as mentioned above, indicated that the concentration of oxygen in exhaust gas was as high as 8.5 % and 7.6 % for P001 (20t/h) boiler that use heavy oil as fuel. Although a super heater had been installed, the temperature of the exhaust gas was measured to be 223°C and 194°C, indicating that heat recovery was insufficient.

The survey member recommended to the plant personnel that the oxygen concentration of the exhaust gas be reduced to less than 5% by slightly lowering the air ratio. However, the plant personnel insisted that the oxygen concentrations were in compliance with instructions of the maintenance service company for the burner, and they would not change their method of operation unless being instructed by the service company, although the current operations might lead to energy losses.

The burner in question was manufactured by SAACKE in Germany, and was an SAV-80 model (max. 800 kg/h and min. 100 kg/h) of the rotary type.

4) Power Plant Company

Figure 7.2.3 shows electric energy loss in Hungarian power stations, and Table 7.2.5 shows efficiency of heat supply as steam and hot water in Hungarian power stations and amount of the heat sold.

Table 7.2.5 Heat Supply from Power Stations in Hungary

Power Station	Heat supply efficiency (%)	Sold heat (TJ)
Dunament No.1	83.33	7967.4
Dunament No.2	-	-
Matra	66.67	151.5
Tisza II	-	-
Tiszapalkonya	72.84	2414.8
Oroszlany	67.91	363.5
Banhida	69.02	63.5
Pecs	65.69	3380.6
Borsod	67.83	3129.7
Ajka	71.27	3351.3
Inota	57.80	657.6
Matravidek	58.13	17.2
Base load power stations	73.11	2149.0

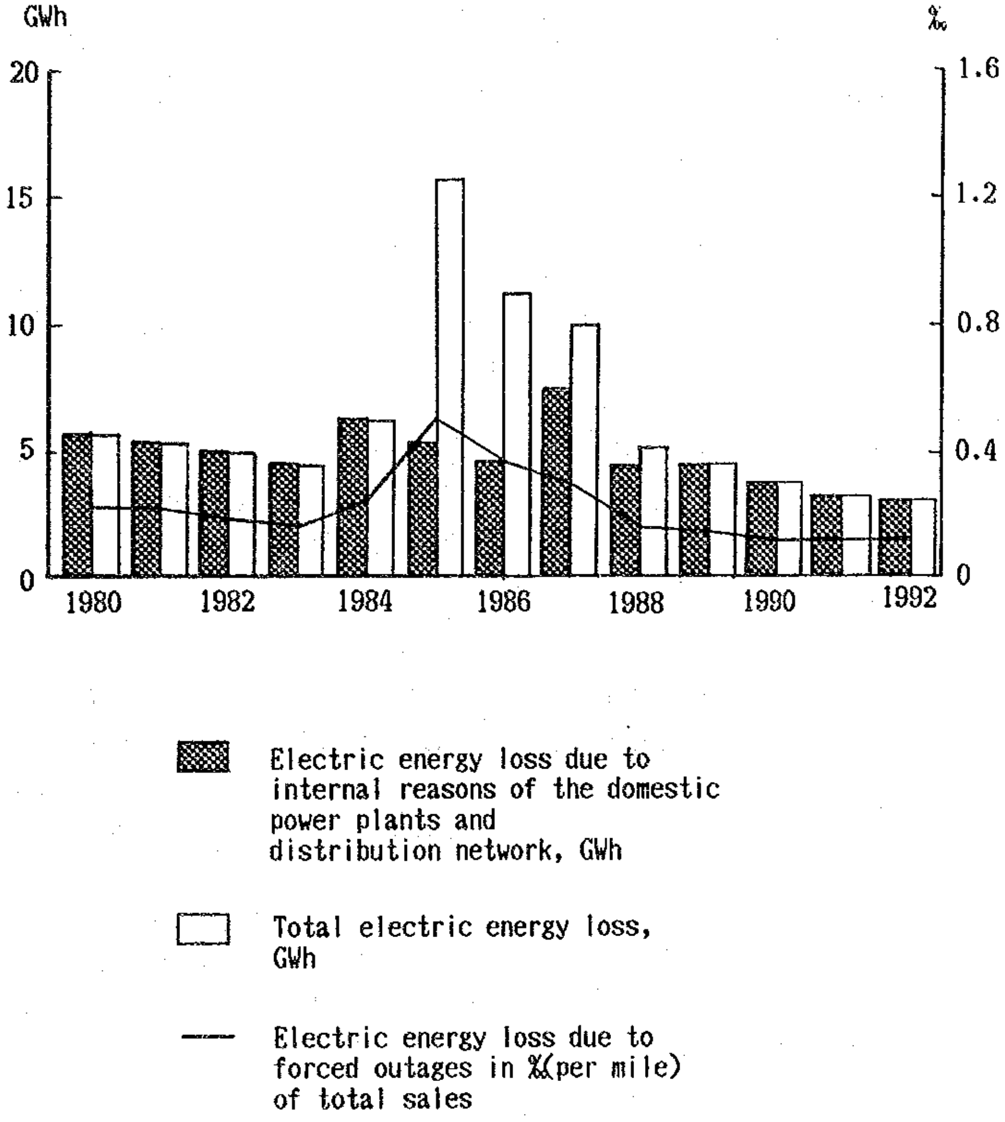


Figure 7.2.3 Electric Energy Loss in Hungarian Power Stations and on the Network

The financial statements of the Tisza Power Plant Company for the period from January 1, 1993 to August 31, 1993 showed the electric energy efficiency and heat supply efficiency achieved by the Borsod, Tisza Palkonya, and Tisza II power plants are as follows:

Power Plants	Electric Energy Efficiency	Heat Supply Efficiency
Borsod	26%	67%
Tisza Palkonya	26%	73.4%
Tisza II	36%	-

The rates of electric energy efficiency achieved by the coal-fired plants (Borsod and Tisza Palkonya) are much lower than the average rate of 38 - 40% achieved by all coal-fired power plants in Japan, and even lower than the lowest level found in China (27%).

The lower rates of heat supply efficiency are attributable to the causes described below:

In the case of the Borsod power plant, steam of 75 bars and 495°C produced in the boilers is converted to steam of 29 bars, 15 bars, and 6 bars, or to hot water through steam cooling equipment before supply. Moreover, no hot water is fed back from the steam cooler directly to the boiler, and the heat loss from the generator is not utilized effectively. (see Figure D7.2.38 in Data Book).

The case of the Tisza Palkonya (Tisza I) power plant is similar. Generated steam of 98 bars and 520 °C is converted to steam of 17 bars, and to hot water through the steam cooler before supply (see Figure D7.2.39 in Data Book). The boiler efficiency is less than 80%, which is much lower than the average for power plants.

In the case of the Tisza II power plant, the electric energy efficiency is 36% which is the average for power plants built in 1977, although much lower than that in Japan. More energy saving efforts should be made to improve energy efficiency .

Regarding steam and water supplied from by the Tisza Palkonya power plant, there had been no flow meters in consumers' houses in the town until the summer of 1992. In the winter of the same year, flow meters were installed in some residential areas in the town. The installation reportedly brought about a drastic decrease in the amount of heat supply. In the past, the lack of a flow meter monitoring system allowed consumers to continue to use heating resources wastefully. But now, consumers are making efforts to use less heating resources for saving utility bills, resulting in the drastic decrease of heat supply from the plant.

5) Abolition of State Subsidies

In Hungary, coal production has received no state subsidies since January 1992. On the other hand, gas and communal heating oil productions still receive state subsidies which are equal to 40 and 60 percent of their production costs, respectively. This is considered to be one of the main causes of the country's wasteful energy consumption habits.

After recommendations from the World Bank, the Government scheduled to abolish the subsidies of gas and oil in 1995. It is highly recommended to adopt a market pricing system in the country's energy sector.

7.3 Study on Pollution Control Technology for Stationary Sources

7.3.1 SO_2 Emission Control Technology

(1) Outline of SO_2 Emission Control Technology

Control measures for SO_2 pollution caused by burning coal are generally classified as shown in Figure 7.3.1. These are briefly explained below.

1) Preliminary Desulfurization Techniques

Physical removal:	30 - 90% of inorganic sulfur can be removed by the differences in specific gravity, degree of wetness by water and oil, and magnetization. However, little organic sulfur can be removed.
Chemical removal:	Organic sulfur can be removed by oxidation and substitution, however, the cost is higher than that of physical removal.
Biological removal:	Sulfur in coal can be removed using microorganisms. This takes longer time than other methods.

2) Simultaneous Desulfurization Techniques

In combustion of pulverized coal, desulfurization methods include a method of feeding limestone and coal sumultaneously into the furnace (blowing-into-furnace method) and a method of desulfurization using limestone as a fluidizing medium in fluidized bed combustion. Fluidized bed combustion does not achieve sufficient sulfur removal efficiency unless the Ca/S ratio is 2 - 3 or more since the grain size of limestone is comparatively large. Moreover, there is a problem of limestone wear. Pulverized coal firing has the problem of low desulfurization efficiency (about 40%). With some combustors as in a power plant, the grains stick to the wall of boiler, thereby possibly decreasing thermal efficiency.

3) Stack Gas Desulfurization Techniques

These techniques can be roughly divided into two kinds: dry process and wet process. In Japan, the wet process is mainly used. Recently, a method called semi-dry process has been studied.

i) Wet process

$SO2$ is removed by absorption solution. This has a high efficiency of 90 - 99%. It also removes dust passing through the scrubber. However, it requires a large volume of blow

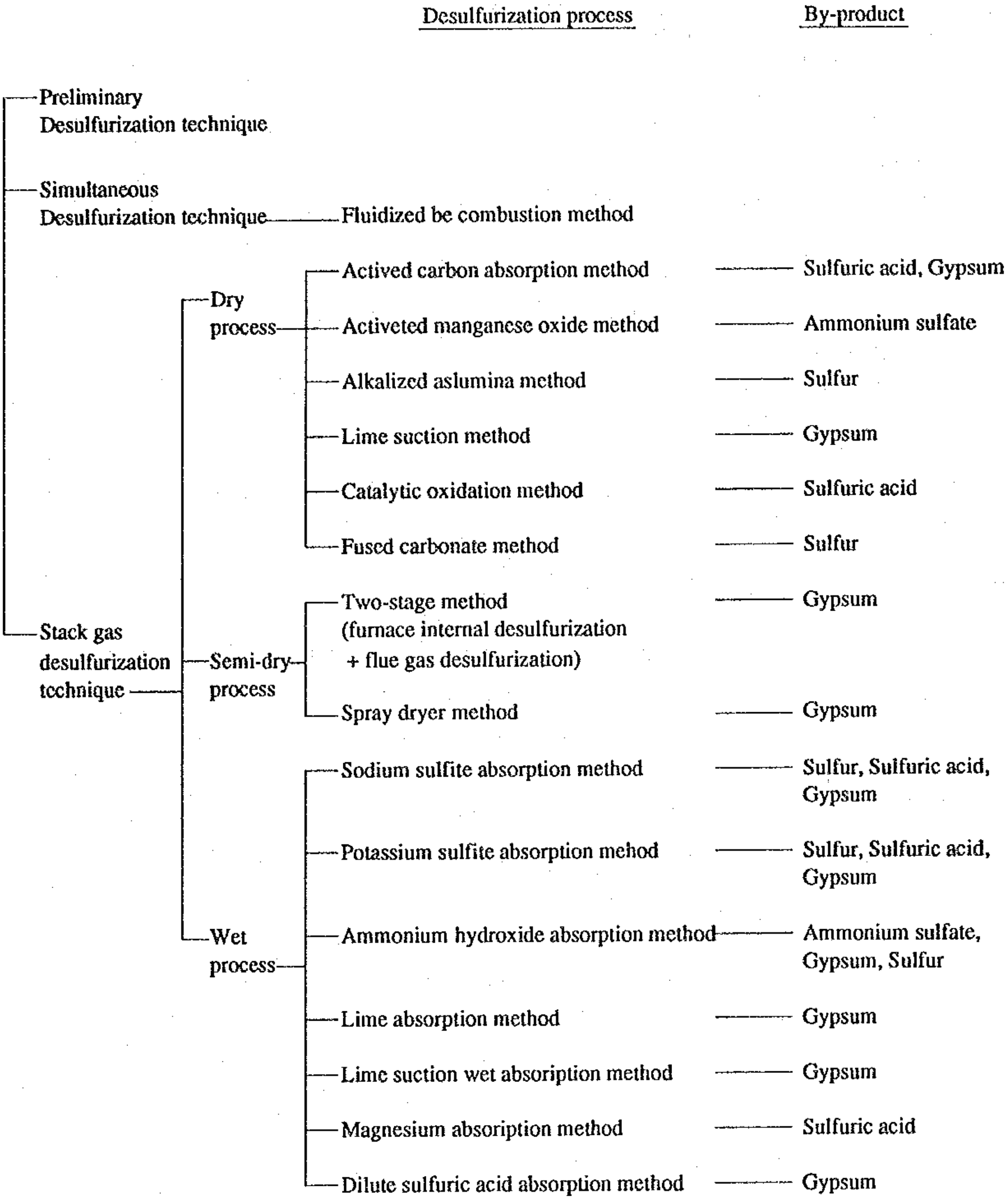


Figure 7.3.1 Various Desulfurization Method

water to be treated in wastewater treatment facilities, and the gas temperature drops to 50 - 60°C, which is near the dew point, causing heat loss. Running costs are high.

ii) Dry process

There are two desulfurization methods: absorption of exhaust gas SO2 using solid absorbent and absorption using activated carbon. These are suitable for mass treatment of exhaust gases. Since the exhaust gas temperature does not fall, dispersion of the stack exhaust gas is not hindered. Another advantage is that it uses little water. However, since the desulfurization percentage depends on the specific surface area of absorbent, a large amount of absorbent is required and the cost is high. Although, lime is cheap, it has a disadvantage of low reaction speed.

iii) Semi-dry process

This process increases the desulfurization efficiency of dry method by spraying water in the flue.

(2) Wet Type Limestone-Gypsum Process

This process uses fine limestone powder in a form of a slurry solution to absorb SO2 and to recover gypsum as a by-product (see Figure D7.3.1 in Data Book). This process is called the conventional type having a high desulfurization ratio (90 - 95%) generally applied to large plants. This process has been widely disseminated in Japan. The absorption reaction of this process is similar to the simple wet type limestone gypsum process described later.

(3) Semi-dry Type Two-stage Process

This process (furnace internal desulfurization + flue gas desulfurization) is divided into two phases : 1) primary desulfurization in which desulfurization is made within the combustion furnace using limestone (CaCO3) as a desulfurizing agent, and 2) secondary desulfurization in which the sulfur dioxide in the flue gas is desulfurized.

This process has the following features:

- The process is extremely simple because only blowing of the desulfurizing agent into the furnace and water spray into the flue gas are necessary.

- The water sprayed into the flue gas is totally evaporated into this gas and not drained from the process.

- High economical feasibility with low construction cost, inexpensive limestone (desulfurizing agent), and less power consumption

- Full automatic operation and easy to operate and maintain with less control points and without need to handle slurry.

This process is outlined below.

1) Primary Desulfurization

This so-called furnace internal desulfurization process with limestone blown into the combustion furnace has been tested and studied in many cases. This is simple as a desulfurizing system and can use limestone whose raw material is available at low cost. The furnace internal desulfurization by blowing lime-stone is described below. When blown into the high temperature zone in a furnace, quick lime (CaO) of the limestone (crushed into fine powder) is immediately decomposed by the high temperature gas and reacts with the sulfur dioxide (produced when sulfur (S) in the coal is burnt) and oxygen, producing calcium sulfate ($CaSO_4$).

$$CaCO_3 \xrightarrow{900^\circ C \text{ or more}} CaO + CO_2 \qquad (1)$$

$$CaO + SO_2 + 1/2\, O_2 \xrightarrow{1200^\circ C \text{ or less}} CaSO_4 \qquad (2)$$

This furnace internal desulfurization exerts the following effects on the desulfurization performance:

i) Desulfurizing agent blow rate

The desulfurization performance is enhanced when the Ca/S mole fraction, that is, the ratio between the blown limestone and the S content of coal is higher.

ii) Blowing furnace temperature

When the limestone is blown into the high temperature zone of 1200°C or more, the reaction equation of above (2) becomes difficult to shift to the right. As a result, the desulfurization performance is deteriorated. Namely, at around 1200°C, the calcium sulfate begins to be decomposed and at the same time the partial pressure of the sulfur dioxide and oxygen rises.

iii) Reaction time

The desulfurization reaction of the equation of (2) is made approximately within a temperature range of 800 - 1200°C. This reaction at high temperature is completed in about one second.

iv) Grain size of desulfurizing agent

The desulfurization performance rises with decreasing grain size. But its effect is not so critical as the difference in the specific surface area before blow. In view of these factors, this process has been applied to the furnace internal desulfurization as one the most simple desulfurization processes. However, this process suffers in a respect of low desulfurization ratio.

2) Secondary Desulfurization

The flue gas after the primary desulfurization contains surplus CaO not acted in the desulfurization reaction during furnace internal desulfurization. The secondary desulfurization involves water spray into the flue gas from the gas air heater to perform desulfurization by reusing non-reacted CaO (see Figure D7.3.2 in Data Book). In this secondary desulfurization, water is sprayed into the flue gas whose heat recovery has been completed in the gas air heater, thereby achieving desulfurization without cooling the flue gas to the steam saturation temperature.

Desulfurization reaction equation

$$H2O + SO2 \rightarrow H2SO3 \quad (3)$$
$$H2SO3 + CaO \rightarrow CaSO3\ 1/2H2O + 1/2H2O \quad (4)$$
$$CaO + H2O \rightarrow Ca(OH)2 \quad (5)$$
$$Ca(OH)2 + SO2 \rightarrow CaSO3\ 1/2H2O + 1/2H2O \quad (6)$$

The flue gas from the gas air heater contains coal ash and CaO as well as sulfur dioxide. These are alkaline components, and the sulfur dioxide is removed as expressed by equations (3) to (5) during cooling while increasing humidity with water sprayed in the spray cooler. In other words, the reactions of equations (3) and (5) are accelerated by spray water during increase in humidity and cooling causes drop of equilibrium partial pressure of the sulfur dioxide to accelerate the reactions of equations (3) and (6). The desulfurization performance in the spray cooler is enhanced with decreasing gas temperature after cooling, because the gas temperature approaches the saturation temperature (see Figure D7.3.3 in Data Book).

3) Overall Desulfurization Performance

The overall desulfurization ratio by the primary and secondary desulfurization is shown in Figure D7.3.4 in Data Book.

(4) Semi-dry Type Spray Dryer Process

This process in shown in Figure D7.3.5 in Data Book. In the conventional semi-dry process, quick lime or hydrated lime is used as an absorbent and sprayed, in a form of hydrated lime slurry, into the flue gas. Sulfur dioxide in the gas is caused to react with hydrated lime while the gas temperature is lowered by evaporation of water content, and collected in a form of dry solid by a dust collector. Therefore, the desulfurization performance is greatly dependent on the absorbent spray rate (Ca/S mole fraction) and the approach temperature (outlet temperature less steam saturation temperature of gas). A reaction equation between the atomized hydrated lime slurry solution drops and SO2 is shown below:

$$SO2 + H2O \rightarrow H2SO3$$

$$H2SO3 + Ca(OH)2 \rightarrow CaSO4 + 2H2O$$

In the case of this reaction, dissolution of hydrated lime into water determines the rate and the desulfurization performance rises as the quantity of hydrated lime grows and the approach temperature is low. On the other hand, there arises also difficulties, such as increase in the running cost (absorbent and raw material costs), corrosion of the dust collector due to wetting of solids, and discharge of solids.

1) Highly Activated Absorbent

When raw materials of absorbent (quick or hydrated lime) and coal ash and desulfurization products are mixed and protected in the hot water at 95°C, the microscopic structure of absorbent shows remarkable difference as the time passes. The absorbent produces the amorphous gel calcium silicate and becomes porous, thereby enhancing the desulfurization performance.

2) Adjusting Equipment for Desulfurizing Agent (High-performance rotary atomizer and spray dryer)

If the semi-dry type desulfurization system is to have high desulfurization performance, there is a process to intensify the activity of the above absorbent itself. It is also essential to enhance the performance of an absorbent atomizer or a heart of the system. It is necessary for treatment of large quantity of gas to obtain the stable operation in which large quantity of slurry is totally evaporated with the approach temperature kept lowered as much as possible while preventing adhesion and accumulation of solids in the tower.

3) Desulfurization Performance

Figure D7.3.6 in Data Book shows the relationship between the desulfurization ratio and Ca/S mole fraction and the approach temperature. When the hydrated lime absorbent is used, the desulfurization ratio as high as 70 - 85% can be achieved with the approach temperature of around 15C and the Ca/S mole fraction of 1.3 - 2.2. This performance is far above that of the desulfurization system in which quick or hydrated lime is sprayed into the atomized flue gas by water spray. When the high activated absorbent protected in hot water is used, the desulfurization ratio of 90% can be achieved with the approach temperature of 15 C and the Ca/S mole fraction of 2.2. This fact demonstrates that even the simple desulfurization system can achieve the high desulfurization performance.

(5) Wet Type Simple Limestone-Gypsum Process

This is a simplified version of the conventional wet limestone-gypsum process (see Figure D7.3.7 in Data Book). This simple type has achieved low construction cost and simplification of the maintenance by increasing the space velocity of flue gas to make the desulfurization absorption tower compact.

	Conventional	Simple
Desulfurization ratio	95 %	80 %
Flue gas space velocity	3 m/s	6 - 9 m/s The space velocity two to three times that of the conventional process employed to make a desulfurization absorption tower compact
Capacity of auxiliary equipment	Ratio consumed within a power station	Ratio consumed within a power station
Electricity consumption	1.0 - 1.2 %	0.7 - 1.0 % Equipment power cut down due to compact absorption tower
Desulfurizing agent	Limestone (325 mesh, 95%) (Max. grain size (40 u))	Limestone (100 mesh, 95%) (Max. grain size (150 u)) Desulfurization cost reduced substantially due to decrease in the cost of crushing the desulfurization agent
Technical level	Applied most widely in the world	Application of conventional technology
Treatment cost per ton of SO2	43,511 HUF	44,281 HUF

Fine lime is used in a form of slurry solution to absorb SO_2 and to recover gypsum as a by-product. The reaction of absorbing SO_2 into absorbent is as expressed below:

$$CaCO_3 + SO_2 + H_2O \rightarrow CaSO_3 + 1/2H_2O + CO_2 + 1/2H_2O$$

Calcium sulfite produced from this reaction is turned into the gypsum slurry partially by oxygen in the flue gas in an absorption tower and by air oxidation in another facility.

$$CaSO_3 + 1/2H_2O + 1/2O_2 + 3/2H_2O \rightarrow CaSO_4 + 2H_2O$$

The gypsum slurry is condensed by a thickener, then the by-product gypsum is separated by a separator.

(6) Wet Ammonia Process

The aqueous ammonia solution is used as an absorbent and ammonium sulfate is recovered to be used as a fertilizer (by-product). The absorption reaction is as shown below:

$$2NH_4OH + SO_2 \rightarrow (NH_4)_2SO_3 + H_2O$$
$$(NH_4)_2SO_3 + 1/2O_2 \rightarrow (NH_4)_2SO_4$$

(7) Outline of Fluidized Bed Combustion Method

1) Basic Characteristics

Regarding the desulfurization process of SO_2 in large-sized stationary sources, wet-type desulfurization process incorporating the wet-type limestone-gypsum method has been mainly used up to now in countries such as Japan, and it is well established technically. However with this method, although the desulfurization rate is very high, there are certain requirements such as large amount of water supply, wastewater treatment facilities and supplementary gas and gas heater facilities.

On the other hand, there is the fluidized bed combustion method for coal combustion. Its wide range applicability for various coals, in-furnace desulfurization and low pollution due to low temperature combustion (about 900°C) are advantages. The hot-dry desulfurization method is used for this fluidized bed combustion. A direct desulfurization agent (limestone, usually) is blown into the furnace, and as combustion continues, it removes SOx by absorbing it at the same time. There is almost no need for supplementary facilities, and there is no temperature decrease as occurs in the wet process, so it is thought to be a reasonable desulfurization process from the viewpoint of energy efficiency. Thus, including in-furnace desulfurization which accompanies fluidized bed combustion, hot-dry desulfurization is one process that can solve the above mentioned problem. However, the utilization rate of desulfurizing agent is low in fluidized bed in-furnace desulfurization. Because, this method is based on the reaction and absorption process which accompanies the increase of the specific molecular volume of desulfurizing solid particulate agent. Therefore, the major problem is that the Ca to S molar ratio of 2 - 4 is required in order to obtain a desulfurization rate greater than 80%.

The following are the basic characteristics of fluidized bed combustion:

- It can be applied to various kinds of coals.
- Low NOx combustion is possible due to combustion at low temperature.
- There are few problems with ash
- In-furnace desulfurization is possible.
- Heat transfer of the heat transfer pipe inside the bed is good and the heating area is smaller.

2) Types of Fluidized Bed Coal Combustion

By fluidized state of solid particulates, fluidized bed coal combustion is classified into the air bubbling fluidized bed combustion (BFBC) and the circulating fluidized bed combustion (CFBC). It is possible to further classify them into normal pressure type and the pressurized type. At first, studies and development of the fluidized bed were done using the normal pressure air bubbling fluidized bed type. However, with the aim of improving operation and combustion efficiency, research on various modifications is now under way. Moreover, in recent years, with the aim of increasing efficiency of electricity generation and making equipment more compact by incorporating the combined cycle with a gas turbine and steam turbine, studies and development of pressurized fluidized bed combustion (PFBC) have also been active. The Hungarian Institute of Electric Power Research (VEIKI) developed hybrid fluidized bed combustion (HFBC) for low calorie brown coal by modifying existing boilers.

(8) Circulating Fluidized Bed Combustion Process

The CFBC process uses the heat storage of the circulation material (bed ash) in the combustion chamber, and the heat from the fuel is transported from the suspended material (the flue gas generated and ash transported) to the heat absorption surface of the fluidized bed combustion chamber via convection and radiation. In this case, the low temperature of the combustion chamber can suppress NOx production to the lower level than the case of combustion of grained coal. Accordingly, desulfurization is achieved in the course of circulation fluidized bed combustion by means of the CaCO3 additive. It is said that there is no particular need to add the equipment of desulfurization and denitrification.

Fine limestone grains for desulfurization is mixed into the combustion chamber from the furnace side, with desulfurization executed directly in the combustion chamber.

Combustion of sulfur in fuel: $S + O_2 \rightarrow SO_2$
Burning of limestone: $CaCO_3 \rightarrow CaO + CO_2$
Reaction: $CaO + SO_2 + 1/2O_2 \rightarrow CaSO_4$ (gypsum)

CFBC has the following features:

- Easy to prepare the fuel
- High combustion efficiency
- Low NOx generation rate due to low combustion temperature of about 850°C
- Substantial reduction of the SO2 content in the flue gas through injection of limestone within an appropriate temperature
- Superior in correct load fluctuation and partial load change in operating conditions
- Higher operation reliability and applicability when compared with conventional equipment

Requirements to maintain these fundamental features are as follows:

- Combustion process (heat release) matched to appropriate combustion over the entire height of the combustion chamber
- Adequate grain size distribution for fuels, limestone and bed ash
- Well-matched relationship with internal and external circulation bed ash amount appropriate respectively to the fuel
- Effective introduction of required combustion air and additional flue gas circulation in the combustion chamber
- Step air supply
- Fly ash return in particular case
- Effective particle movement of individual grain pieces
- Sufficient reaction route and temperature
- Sufficient contact opportunity for each reactor

High-level technology to meet the above requirements will help achieve the high combustion quality and low pollutant generation.

(9) Hybrid Fluidized Bed Combustion Method

1) Development of Hybrid Fluidized Bed Combustion System

The Hungarian Institute of Electric Power Research (VEIKI) began research of BFBC in the middle of 1980s. They reconstructed the 47 t/h boiler at the Tatabanga thermal power plant and carried out experiments. In 1990, they reconstructed the old pulverized coal firing boiler for low calorie brown coal and developed hybrid fluidized bed combustion (HFBC) system. It is a combination of the conventional boiler for pulverized low-calorie brown coal and fluidized bed combustion.

Four of the 100 t/h boilers (12 through 9) at the Ajka thermal power plant were used for the reconstruction experiment, which was completed with the assistance of the PHARE Program of EC. This system is planned to be employed in the Borsod Power Plant as described in Section 7.2.3.

This system is relatively inexpensive and can be readily coupled with any existing boiler. Because of fluidized bed combustion, an air distributor is installed below a furnace. The fluidized bed is formed through utilization of the difference in the air flow rate jet out from this air distributor. (Three air boxes of the air distributor ensure forming of a main middle layer and layers on both ends circulating about two times.) The air distributor includes a membrane wall connected to a circulation system of the boiler. The air for fluidized bed is preheated (310°C) and supplied to air boxes through separate ventilators. Primary air and secondary air for grained coal injector are supplied by a forced draft fan.

Direct desulfurization directly in the combustion chamber proceeds as shown below :

Combustion of sulfur in fuel: $S + O_2 \rightarrow SO_2$
Burning of limestone: $CaCO_3 \rightarrow CaO + CO_2$
Reaction: $CaO + SO_2 + 1/2O_2 \rightarrow CaSO_4$ (gypsum)

The hybrid fluidized bed combustion has the following features:

- Applicable to combustion of coals with high ash content or coals differing in grade without help of oil
- Low-load stable combustion (40% of normal combustion)
- Decrease in SO_2 generation and decrease in NO_x generation by low-temperature combustion
- Satisfactory combustion efficiency

2) Combustion Test of HFBC Conducted by VEIKI

A combustion test of HFBC system was conducted by VEIKI at the Ajka Power Plant using 100 ton/h boilers. A part of the result is shown in Figures D7.3.8 and D7.3.9 in Data Book. The results indicate the following problems:

i) The desulfurization rate is considerably high at 70 - 80 % under the combustion load with the evaporation rate at 60 - 70 t/h, but it decreases to 50 - 60% under the evaporation rate at 100 t/h. The reason is considered to be as follows. The combustion proceeds within the fluidized bed up to the evaporation rate of 60 - 70 t/h. However, since heat transfer tubes are not installed within the fluidized bed, additional pulverized coal burners installed above the fluidized bed are used, thereby ignoring desulfurization effect, in order to increase the evaporation rate to 100 t/h. (When heat transfer tubes are installed within the fluidized bed, solid particles are highly fluidized and the heat transfer efficiency is increased enabling reduction of heat transfer surface area, therefore reduction of the boiler size. However, troubles due to abrasion of heat transfer tubes are unavoidable.)

ii) Under the combustion load with the evaporation rate at 100 t/h, the denitration rate tends to decrease, besides the reduction of desulfurization rate, with the increased concentration of NOx in the flue gas to 300 - 350 ppm. This is due to the appearance of a peak of the combustion chamber temperature around the flame of the pulverized coal combustion above the fluidized bed.

3) Combustion Test of HFBC Conducted by the JICA Study Team

When HFBC boilers are introduced to the Borsod Power Station, the following problems arise because the brown coal used in the Borsod plant differs from that of the Ajka plant.

i) The desulfurizing agent has to be added

ii) The desulfurization ratio drops because pulverized coal burning must be made during high load operation to compensate for deficient heat value obtained solely from fluidized bed combustion and thus the study must be made concerning substitution of the deficient heat value with a high quality fuel with less sulfur content.

iii) Improvement of the combustion method must be made to use the low-grade coal.

In view of the situation, the Lyuko coal and limestone used in the Borsod power station was transported to the Ajka station for the demonstration test of HFBC.

The test result shows the following (for details, see Data Book):

i) The desulfurization ratio was 42 - 45% (desulfurization ratio with added desulfurizing agent was 23 - 34%). The NOx concentration was lower by 40 - 80 ppm than that of the existing grained coal boilers.

ii) Though substituting the deficient heat value with the fuel with less sulfur content is technically possible, CaSO4 (gypsum) that has been subjected to desulfurization reaction in the fluidized layer combustion zone passes through the high-temperature combustion zone together with the flue gas, resulting in partial reduction and causing degradation of the desulfurization ratio.

iii) The desulfurization rate at 60% may be attainable if following measures are taken:

a) Increase the capacity of the coal feeder and dryer.

b) Ensure even temperature within the fluidized layer.

c) Study the grain size of desulfurizing agent (limestone) and loading method.

d) Install coal mill to finely purverize the Borsod coal.

e) Well mix coal and limestone.

f) Spray lime slurry into flue gas.

7.3.2 NOx Emission Control Technology

A Hungarian burner maker has developed a world high-ranking low-NOx burner, that has incorporated the advanced rocket combustion technology of the USA and former USSR, and is now marketing this product at a price far lower than the international level. In Sajó Valley area, however, the low-NOx combustion technology is not well disseminated. Twelve of 52 facilities surveyed appear to require introduction of a certain NOx reduction facility or denitrification equipment. They are two waste incinerators, one cement rotary kiln, two glass melting furnaces, one sintering furnace, two thermoelectric power stations, one soaking pit, one forging furnace, one heavy oil boiler for heating and one nitric acid plant.

An outline of NOx emission control technology and some of available methods that may be applied to above facilities are described below.

(1) Outline of NOx Emision Control Technology

The following description is mostly based on Reference D-7.

1) Principles of NOx Generation

When a material is burnt, nitrogen (N_2) in the air and organic nitrogen in the material (fuel N) are bound with oxygen (O_2) to produce nitrogen oxides (NOx). NOx produced by binding between nitrogen in the air and oxygen is called thermal NOx and the other is called fuel NOx.

i) Thermal NOx

The factors in the generation of thermal NOx include: (1) O_2 concentration in the combustion zone, (2) combustion temperature (flame temperature), and (3) combustion gas detention time at high temperature.

NOx generation increases as the detention time at high temperature increases and the O_2 concentration increases.

ii) Fuel NOx

Fuel N in heavy oil or coal is incorporated into the complex aromatic nucleus in the forms of pyridine, quinoline, pyrol, indol, and carbazol. It is also contained in sludge or dust in the form of ammonium or protein.

Fuel N is considered to be more easily oxidized than N_2 in the air. But the oxidation process and natures of decomposed intermedite products are not well known.

Assuming that N contained in a fuel by 0.1% is totally converted into NO, its concentration under the condition of 0% O_2 becomes as follows:

heavy oil	approx. 155 ppm
coal	approx. 200 ppm
sludge (13,810 kJ/kg DS)	approx. 440 ppm
municipal wastes (7,120 kJ/kg)	approx. 755 ppm

The concentration becomes higher as the calorific value per unit weight of the fuel is smaller.

The fuel NOx actually generated occupies a certain percentage of the above values. This ratio is called the fuel NOx conversion ratio.

The generation of fuel NOx exhibits the following tendencies:

a) Under combustion conditions with air deficiency or low excess air ratio, the generation of fuel NOx is suppressed.

b) The fuel NOx conversion ratio decreases with increasing N content in fuel. But the amount of NO generated increases with the increasing N content.

c) The generation of fuel NOx is faster than that of thermal NOx. Moreover, the effect of temperature on the rate of fuel NOx generation is small, i.e. fuel NOx is generated even at relatively low temperature.

d) The amount of NOx generation varies with the state of air-fuel mixing. NOx generation increases with higher degree of mixing.

2) Methods for Reduction of NOx Emission

There are three basic methods for reducing NOx emission from a combustion facility:

- Control of NOx generation itself
- Reduction of exhaust gas volume by fuel saving (reduction of NOx amount)
- Removal of generated NOx (denitration)

i) Control of NOx Generation

Considering the principles of NOx generation, the generation can be suppressed by taking the following measures:

a) Keep the O_2 concentration low in the combustion reaction zone
(Low air-ratio combustion, two-stage combustion, off-stoichiometric combustion, emulsion combustion, etc.)

b) Keep the flame temperature as low as possible
(Exhaust gas recirculation, steam/water injection, emulsion combustion, etc.)

c) Reduce the detention time at high temperature
(Rapid mixed combustion, combustion with extremely fine atomization of oil-in-water type emulsion, high-speed heat transmission type low-NOx burner)

d) Reduce the N content in fuel
(Change to quality fuel)

Various NOx generation control technology may be classified in relation to above principles as shown in Table 7.3.1.

ii) Reduction of NOx Emission by Energy Saving

The gross NOx emission amount is reduced by reducing fuel consumption thereby decreasing the amount of exhaust gas without increasing the NOx concentration through stabilization of furnace or boiler operation.

a) Energy Saving by Control of Furnace Operation

Energy consumption can be reduced by controlling the temperature of the material being heated (prevention of overheating, etc.) and by preventing air intrusion into the furnace.

b) Installation of Energy Saving Equipment

The waste heat can be recovered by installing an economizer (in case of a boiler) and an air preheater. In the case of ordinary burners, the NOx concentration will increase when air is preheated. Therefore, a low-NOx burner which does not cause increase of NOx concentration by air preheating needs to be used.

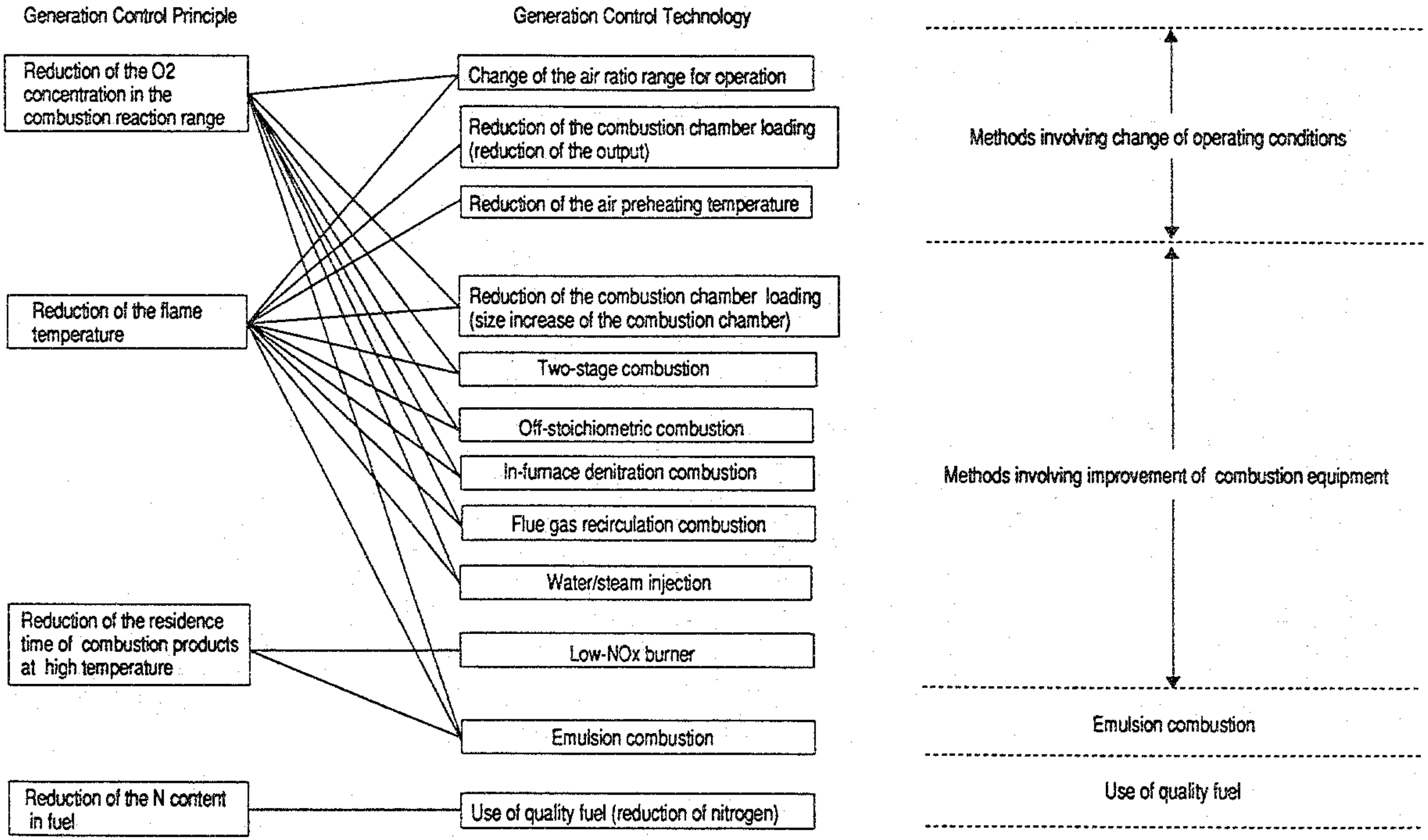
c) Low Air Ratio Combustion

The low air ratio combustion enables reduction in fuel consumption and resultant reduction of exhaust gas amount, leading to reduction of the NOx concentration itself.

iii) Denitration

Denitration is employed when control of NOx generation by changing combustion method is difficult or there are certain constraints to control NOx generation during combustion. For example, strengthening of NOx generation control may decrease NOx, but it may also hinder heat transmission to the material inside the furnace, thereby adversely affecting the quality of products or causing secondary pollution through generation of particulate matter (PM) or CO. In the case of solid waste incinerator, NOx generation control may cause incomplete combustion and unburnt materials may remain in the ash. This method should be considered in such cases, or when a high degree of reduction of NOx emission is required.

Table 7.3.1 NOx Generation Control Principles and Technology



a) Non-catalytic Denitration

In this method, NH_3 or urea is blown into flue gas of around 900°C containing NOx in order to reduce NOx to N_2. The NOx reduction rate by this method is normally around 40 - 70%.

b) Simplified Denitration Method

The non-catalytic denitration method requires that a considerable amount of NH_3 be blown in order to increase the denitration rate. This is often associated with an increase in non-reacted NH_3. The simplified denitration method employs a simple catalytic layer in the flue so as to utilize such non-reacted NH_3 to enhance the denitration rate while preventing release of NH_3.

c) Flue Gas Denitration Method

Wet and dry methods are available, and the dry method is currently used in most cases. In the wet method, NO is oxidized to more reactive NO2 by ozone or other oxidizing agents, and then washed and absorbed by water or alkalis. In the dry method, reduction of NOx by NH_3 is enhanced by the use of a catalyst. The flue gas temperature is 200 - 300°C and the denitration rate is 90% or more.

In some cases, however, problems such as damaging of the catalyst by SOx or clogging of the catalystic layer with smoke and soot may occur.

(2) Two-stage Combustion Burner

Combustion by the two-stage combustion burner consists of the first and the second stages. In the first-stage of combustion, the air ratio is set far below (around 0.5 - 0.7 though varying depending on the fuel) the level of the conventional combustion method and the fuel is decomposed to generate a combustion gas consisting mainly of CO and H_2. This gas is completely burnt with secondary air in the second stage.

For gas combustion, there is a reversed two-stage combustion method in which primary combustion is effected with a high air ratio and the combustion is completed with a low air ratio by blowing fuel again in the secondary combustion zone.

For waste liquid incineration, there is a type of burner with two-stage combustion (see Figure D7.3.10 in Data Book).

Primary air is divided into primary air "a" to be introduced near the burner nozzle and primary air "b" to be introduced into the flow at a right angle halfway within a primary combustion chamber. The gross flow is set at a standard value of 0.7 of the theoretical air flow. The residual air flow necessary for combustion is introduced, as secondary air, into a secondary combustion chamber. Waste liquid "c" is sprayed into the secondary combustion chamber via two atomizers provided in the middle portion of the secondary air nozzle. When the air ratio is appropriately adjusted, the NOx concentration may be reduced to 150 ppm or less.

(3) Oxygen Burner and Oxygen Production Method

The glass melting furnace requiring a temperature as high as 1500°C or more to melt the raw materials generates the thermal NOx (500 - 1500 ppm) in large quantity because of high-temperature combustion even when natural gas is burnt.

For natural gas combustion without Fuel N, a method to reduce NOx substantially by an oxygen burner has been developed. By using only the O2 gas without N content, instead of the combustion air, generation of the high-concentration thermal NOx can be suppressed. Moreover, the fuel can be saved by 5% due to the high-temperature combustion effect with O2.

However, when O2 is to be supplied in a cylinder from a gas maker, the running cost for the combustion becomes higher. Recently, a new process of oxygen production has been developed.

This process, called Lindox process, separates the oxygen in air by means of a pressure swing adsorption system (see Figure D7.3.11 in Data Book). The process is simple without particular equipment for heating and dehumidification. Though three or four adsorption towers are used mostly, there is no difference in the principle between them. The raw air is passed through the filter by a forced draft fan (FDF) to remove mist and drain, then supplied to one of adsorption towers. In the tower, the moisture, CO2, HC and N2 are adsorbed and O2 is separated.

After a certain period of time, air feed is switched to another adsorption tower automatically and the pressure of the previous tower is reduced slightly by a vacuum pump to fall off the adsorbed materials and to release and regenerate the absorption tower. The unit is compact and easy to start/stop with only one pushbutton. The purity of the product oxygen can be adjusted in the design conditions but is limited to maximum 95% (normally 93%) because argon existing in 0.93% in the air is mixed. The gas composition is as follows:

O2 :	95 vol%
Ar :	4.5 vol%

N2 : 0.5 vol%

The N2 content at this level produces only a few ppm of NOx.

Conventionally, O2 has been produced in a large scale by a super-low temperature air separator. This unit separates the air through liquefaction and distillation at super-low temperature. The product has been transported in a form of liquefied oxygen for applications of a small scale. The above Lindox process, however, is more compact than the super-low temperature air separator and enables easy and safe oxygen production on site at normal temperature and low pressure. The process is best suited for applications with the oxygen consumption of about 1 - 30 t/day for which there has been no appropriate oxygen supply method in the past. When O2 is used instead of an air for various applications which have relied conventionally on an air as an O2 source, substantial energy saving effects can be expected. They include increase in the reaction rate, improved yield, compact unit size, decrease in the heat loss, and substantial reduction of the flue gas amount.

Apart from the above, the Lindox process may be applied in the wide field, such as kiln, sintering furnace, metal smelting, chemical industry, fermentation industry, paper making industry, and wastewater treatment, which could only rely on the air.

(4) Internal Denitration Process of Vertical Water-tube Boiler Burning Pulverized Coal

The process utilizes the NOx reducing function of hydrocarbon fuels, in which a part of main fuel is bypassed to be used as a denitration fuel. The denitration reaction is completed wholly within a furnace. There are some variations in internal denitration technology. These processes are said to be able to reduce the NOx generation substantially in the purverized coal burning boilers.

Figure D7.3.12 in Data Book shows the combustion process when the furnace internal denitration method is applied to a coal burning vertical water-tube boiler. Firstly, primary combustion of the fuel is made with primary air at the normal air ratio, producing the fuel NOx and thermal NOx in considerable amount. Then, only the secondary fuel is supplied into the wake of the primary combustion in quantity far exceeding the residual oxygen from the primary combustion, so as to cause reducing combustion (secondary combustion). NOx produced from the primary combustion is reduced to nitrogen gas. In addition, the secondary air is supplied to the wake of the secondary combustion to complete combustion of unburnt matters remaining in the secondary combustion zone (tertiary combustion).

Recently, improved methods have come to be employed, which supply the proper quantity of air into the high-temperature area just downstream of the combustion zone, instead of blowing the secondary fuel. Subsequently, the air mainly for the secondary combustion is supplied from a position ensuring the sufficient retaining time from the burner. This type of process includes expanded reducing combustion, advanced MACT, IMPACT and DTS processes. Figure D7.3.13 in Data Book shows a conceptual view of application of this process to a boiler. Figure D7.3.14 in Data Book shows the difference between normal two-stage combustion process, furnace internal denitration process with secondary fuel blow, and improved furnace internal denitration process in which only the air instead of the secondary fuel is blown. With this improved furnace internal denitration process, a certain maker has achieved the NOx concentration of 100 ppm (140 ppm with high fuel-ratio coal) or less and the unburnt components in ash of 5% or less.

(5) Denitration Process in Ammonia Oxidation Furnace

This process (Pura Siv N process) is to eliminate and recover NOx contained in the flue gas from a nitric acid plant. A molecular sieve is provided with a catalytic capacity of NO + 1/2O2 => NO2 and NO in NOx reacts with the oxygen remaining normally in about 3% in the flue gas and turns into NO2, then adsorbed. The concentration of NOx left un-adsorbed is 10 ppm or less. This process is therefore extremely superior to various NOx eliminating processes that have been made available to data.

Regeneration is made at about 300°C and the nitric acid undertakes recovery to plant. The nitric acid yield can be enhanced by about 2.5%. When this process is compared with the NOx contact reducing process for flue gas treatment of a 300 t/day nitric acid plant, the equipment cost is higher by about 28%, but the total treatment cost is lower by 20%. Due to this cost merit and the superior treatment result of 10 ppm of NOx, this process is reported to be favorable for application. The life of molecular sieve is calculated to be two years in this case.

7.3.3 Energy Saving Measures and Organization

To propel energy saving, the enterprises will be required to establish such organization. Also, energy diagnosis procedures and decision criteria for rationalizing energy consumption should be established.

These measures are outlined below (based on Reference A-26).

(1) Organization to Implement Energy Saving Measures

Each plant should be organized to implement energy saving as described below.

i) Has a director for the implementation energy saving been appointed? Which section is responsible for energy calculations? How the effects of efforts and improvements and their results are reported to the president ?

ii) Are methods of improvement planning and evaluation appropriate? The following items require attention as a basis for selecting check items:

a) Are control criteria for each process prepared? Are manuals prepared for maintenance of measuring instruments and measuring procedures? Are forms for recorded data established?

b) Are items of maintenance and checking of facilities and machines in each process written as manuals? Are forms to show the results established?

c) Are the above forms translated into data forms allowing analysis?

These and other items must be confirmed in advance.

iii) Energy saving goals and check points requiring special attention

a) Decision on energy saving goals

b) Elimination of wastefulness of entire plant

To decide an energy saving campaign on goals to be tackled everyday, such as unit energy consumption requirement, prevention of idled operation by employee, and turning lights off when not necessary.

c) Energy saving by process rationalization

To analyze work movements for each process and to decide energy saving goals.

d) Energy saving by heat insulation and heat recovery

To study types and effect (economical efficiency) of heat-insulation materials, as well as heat recovery means and methods, and to decide energy saving goals, using a heat balance sheet as a reference.

e) Energy saving by installing energy saving equipment

To decide energy saving goals by installing new equipment, for example, high-efficiency burners, electric arc furnaces, high-efficiency ganged crucibles, high-performance slow cooling furnaces and heating furnaces.

Views will be coordinated with line operators and necessary training will be provided to accomplish the foregoing energy saving goals.

(2) Procedure for Energy Diagnosis

Procedure for energy diagnosis is shown in Figure 7.3.2.

(3) Decision Criteria for Rationalizing Energy Consumption

An outline of decision criteria for rationalizing energy consumption is shown in Table 7.3.2.

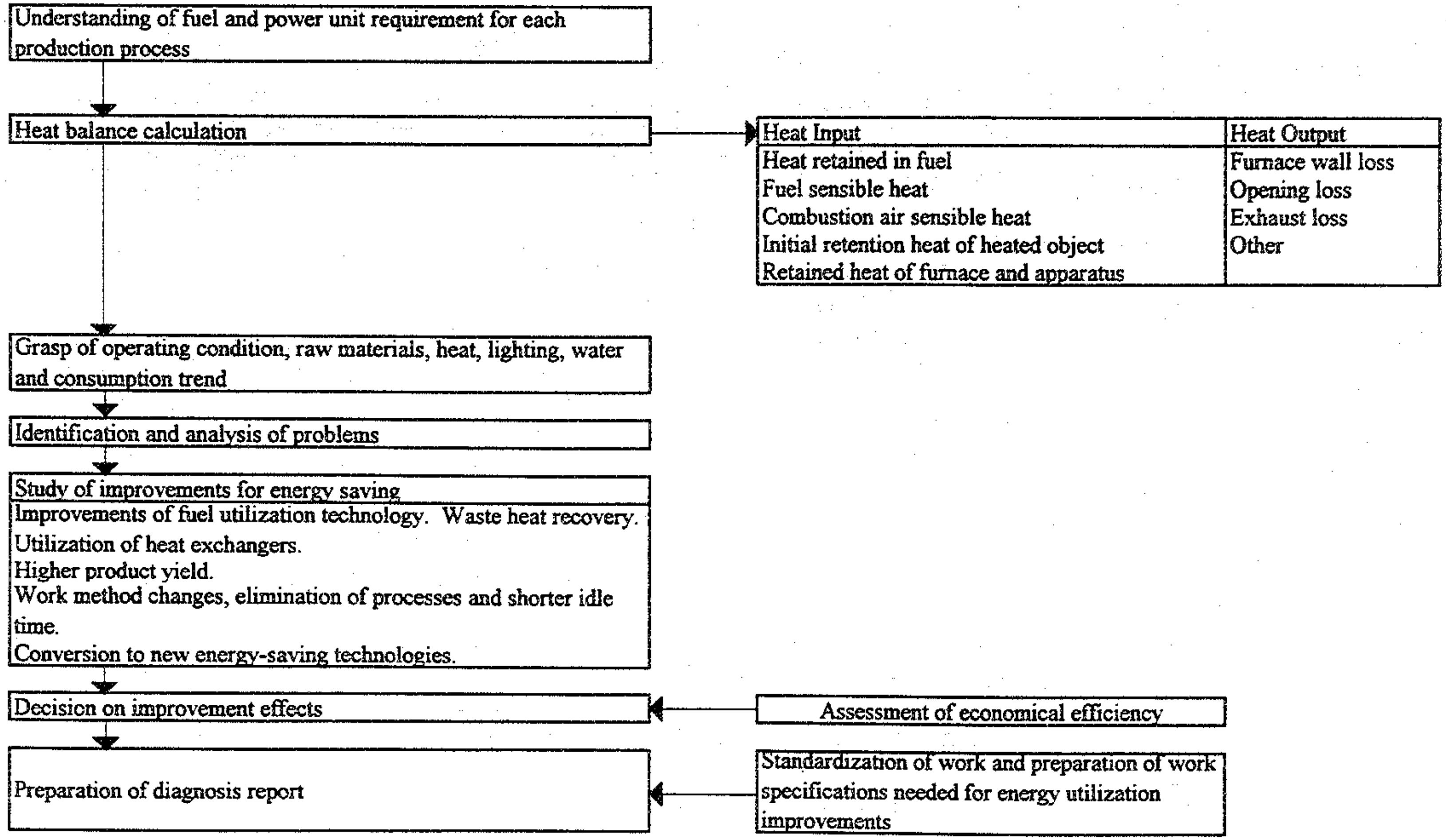


Figure 7.3.2 Procedure for Energy Diagnosis

Table 7.3.2 Outline of Decision Criteria for Energy Consumption Rationalization by Plant

(Based on article 4 of Japanese Law Concerning Rationalization of Energy Consumption)

	Fuel Combustion Rationalization	Heating, Cooling and Heat Transfer Rationalization	Prevention of Heat Loss by Radiation and Thermal Conduction	Waste Heat Recovery and Utilization	Rationalization by Converting Heat into Motive Power, etc.	Prevention of Power Loss by Resistance, etc.	Rationalization of Conversion of Power to Motive Power, Heat, etc.
Setting Standard for Improving Control Standards	Control standard for excess air ratio	Standards for temperatures of articles to be heated and cooled, of heat transfer medium, for pressure, flow and other parameters, and for air conditioning temperature and humidity.	Standard for heat-insulation works.	Standard for waste heat recovery utilization	Standard for load adjustment among boilers and turbines. Standard for minimum allowable pressure for exhaust and back pressure turbines.	Control standard for voltage, current, power factor, load factor and demand factor of incoming, transforming and distribution equipment.	Standards, etc. for voltage, current, power factor and demand factor on electric-motor applied, electric heating and lighting equipment.
Measurement and Recording	Measurement and recording of fuel supply quantities, emission gas temperature, amount of residual oxygen in emission gases and other parameters.	Measurement and recording to understand heat transfer conditions such as temperature, pressure and flow. Measurement and recording of air conditioning temperature and humidity.	Heat balance analysis.	Measurement and recording of items to understand waste heat condition. Study of effective waste heat utilization method.	Measurement and recording of heat efficiency of main boilers and turbines. Operation at minimum allowable pressure.	Measurement and recording of values listed above.	Measurement and recording of values listed above. (Coefficient of utilization also measured for lighting)
Maintenance and Checks	Maintenance and checks of combustion facilities.	Prevention of deterioration of heat transfer performance, control of boiler water quality, and maintenance and checks of air conditioning facilities.	Prevention of heat transfer medium leaks due to damaged or missing parts, maintenance of heat-insulation parts, maintenance and checks of steam traps.	Clean dirty heat transfer surfaces of waste heat recovery facilities. Prevention of heat transfer medium leaks from facilities.	Maintenance and checks of boilers and turbines. Maintenance and checks of turbine blades and other components in operation at minimum allowable pressure.	Maintenance and checks of incoming, transforming and distributing facilities.	Reduction of machine damage such as friction. Prevention of fluid leaks in fluid machines. Maintenance and checks of other electric heat, electrolytic and lighting
Improvements and Facility Installation for Rationalization	Adjustment of combustion load, selection of appropriate burners, improvements in ventilators and installation of combustion controllers and heat storage systems.	Review of heat consumption and supply conditions. Improvements in heat patterns, adjustment of loads and other improvements in direct heating. Installation of high-thermal efficiency facilities such as multi-stage use of heat. Continuation, integration, shortening and omission of processes.	More effective heat insulation, reduction in size of openings, installing covers on open-type facilities and rationalization of supply pipes.	Prevention of temperature loss during waste heat transport process. Improvements in heat transfer surfaces of waste heat recovery facilities, installation of recovery and utilization facilities suiting waste heat use.	Remodeling of turbines to lower minimum allowable pressure. Utilization of surplus steam, which has value for use, to power generation and work motive power.	Operation of transformers at appropriate load, optimization of transformer capacity, load leveling, optimal incoming and transforming equipment layout, improvements in power factor and imbalance among three phases.	Prevention of motor idling, appropriate distribution of loads, review of pump heads, speed control, installation of motors with appropriate capacities and other facility improvements and installation.

7.4 Air Pollution Control of Mobile Source

The major mobile source of air pollution in Sajó Valley Area is motor vehicles.

In general, control measures for mobile sources are roughly divided into two groups. One is to reduce the number of motor vehicles and the other is to improve motor vehicles technologically. However, since the reduction of motor vehicles as a control measure against air pollution is difficult, the improvement of motor vehicles has been applied generally.

7.4.1 Present State

Prior to the study of control measures for motor vehicles, it is useful to take a look at the current situation which will help to determine appropriate actions. In Hungary, the Ministry of Transport, Communication and Water Management (KHVM) has taken action to regulate air pollution from motor vehicles.

1) Number and Age of Registered Motor Vehicles

In 1990 , 2.2 million vehicles in Hungary, 0.13 million vehicles in BAZ county and 45,000 vehicles in Miskok were registered, respectively, as shown in Table 7.3.1. With regard to the ratio of vehicle types, passenger cars account for County 80 - 87%, buses account for 1.2 - 3.1%, and trucks account for 12 - 16% of the total number. The ratios of buses and trucks in Miskolc are somewhat higher than those in the country and BAZ County.

Table 7.4.1 Number of Registered Motor Vehicles by Type (in 1990)

	Ps. Cars	Buses	Trucks	Sum
Hungary	1,944,553	26,121	262,445	2,233,119
%	87.1	1.2	11.8	100.0
BAZ. country	109,674	2,180	17,093	128,947
%	85.1	1.7	13.3	100.0
Miskolc	35,928	1,401	7,226	44,555
%	80.6	3.1	16.2	100.0

The distribution of passenger cars in Hungary by manufacturers is illustrated in Figure 7.4.1. Only three manufacturers in Eeastern European countries i.e., Lada, Travant and Wartburg account for more than 60% of the total number of passenger cars in Hungary. Figure 7.4.2 indicates that 30 - 40% of all categories of motor vehicles in Hungary are 10 years or more of the age. This raito is highest for passenger cars.

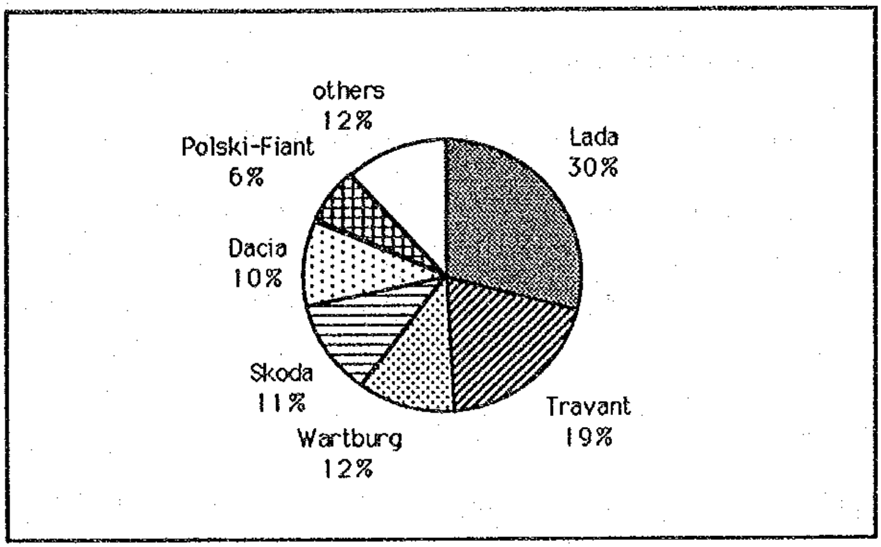


Figure 7.4.1 Shares of Passenger Cars by Manufactures

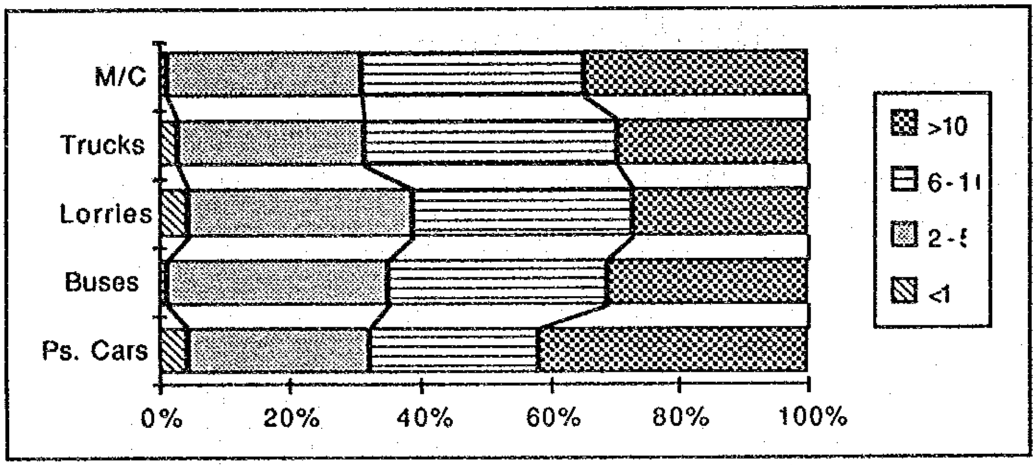


Figure 7.4.2 Age of Registered Motor Vehicles in Hungary (1990)

2) Engine Type of Motor Vehicles

It is considered that most passenger cars in the study area are equipped with gasoline engine. Concerning engine types, the existence of large number of two-stroke engine vehicles such as Trabant in the study area should be noted, because they emit much more pollutants than four-stroke engine vehicles.

From January 1, 1992, the use of two-stroke engine motor vehicles for public and commercial transport is banned if they are not equipped with catalytic converters.

3) Fuel Type of Motor Vehicles

Since many passenger cars in the study area were produced in the Eastern European countries or are highly aged, leaded gasoline is mostly used in the study area. Leaded gasoline should be gradually replaced by unleaded gasoline to facilitate use of motor vehicles equipped with catalytic converters.

7.4.2 Existing Motor Vehicle Pollution Control Plan

Hungarian government has established a five year plan for the air pollution control. The plan is named as "Government Resolution No. 1079/1993 (dated: December 23.); The improvement of the air quality in highly endangered geographical regions for period 1994-1998", and its content consists of 22 items as summarized in Table 7.4.2. The circled figures in the table are related to measures against mobile sources. The reduction volume of pollution load by this plan is expected to be about 13% for SO_2, 10% for Nox and 12% for CO.

Moreover, the government has been preparing "Governmental Decree on Air Pollution Abatement". According to a draft version of the new decree, the government mainly plans to replace the present vehicles to the new vehicles equipped catalytic converter gradually to control the air pollution caused by motor vehicles. The anti-pollution vehicles are conformable to EC's future exhaust emission regulations. The decree contains technological or institutional regulations in order to conduct that countermeasure.

Table 7.4.2 Summary Table of Hungarian Action Plan for the Period 1994 - 1998

○ : for the mobile sources

No.	Task Short identification	In charge first identified	Deadline
1.	Development of a technical and economic action plan for the seriously polluted regions with the inclusion of the local self-governments and ensuring their support	Minister for the Environment and Regional Policy	30th June 1994
2.	Provision of professional support to the local self-government	Minister for the Environment and Regional Policy	continuous
③	Provision of methodology for introducing traffic organisation and traffic restricting measures in the polluted settlements	Minister of Transport, Telecommunication and Water Management	30th June 1994
④	Preparation of a city public transport development program	Minister for the Environment and Regional Policy	30th September 1994
5.	Reduction in emission of carbo-hydrogens at fuel filling stations	Minister for the Environment and Regional Policy, Minister of Industry and Trade	31st May 1994
⑥	Increase in spot-checks of vehicles on the road	Minister of Transport, Telecommunication and Water Management	continuous
7.	Incentives to promote environmental protective heating methods	Minister for the Environment and Regional Policy	continuous
8.	Laying down the quality requirements of residential heating fuels	Minister for the Environment and Regional Policy	31st May 1994
9.	Identification of polluted areas, continuous monitoring	Minister of Welfare	31st March 1994
10.	Preparation of the implementation of air quality monitoring network concepts in and out of settlements	Minister for the Environment and Regional Policy	30th June 1994
11.	Securing the finances for the support of execution of clean air tasks	Minister for the Environment and Regional Policy	continuous
12.	Securing priority of Central Environmental Protection Funds to the implementation of the program	Minister for the Environment and Regional Policy	continuous (at the time of judging the applications)
13.	Development of the regulating system for Environment Loading Charge	Minister for the Environment and Regional Policy	31st August 1994
14.	Harmonising the reduction in emission with regional demand and international obligations	Minister for the Environment and Regional Policy	continuous (according to the execution of international obligations)
15.	Moderation of cross border air pollution through bi-lateral agreements	Minister for the Environment and Regional Policy	continuous (dependent on the execution of bi-lateral agreements)
⑯	Preparation of a support program to help the establishment of a more up to date vehicle fleet	Minister of Transport, Telecommunication and Water Management Minister of International Trading Relations	31st March 1994 30th April 1994
⑰	Introduction of domestic application of EC regulations	Minister of Transport, Telecommunication and Water Management	30th June 1994 31st January 1995
⑱	Securing the finances for the implementation of the catalyst program	Minister for the Environment and Regional Policy	30th June 1994
⑲	Further restriction of two-stroke cars in non-personal use	Minister for the Environment and Regional Policy	30th June 1994
⑳	Incentives, execution of equipping two-stroke engines with catalysts	Minister for the Environment and Regional Policy	31st October 1994 1st January 1995
21	Preparation of environmental requirements, supervision system of low power domestic heating appliances	Minister for the Environment and Regional Policy	31st October 1994 1st January 1995
22.	Preparation of mid-project and concluding reports on the execution of the program's tasks	Minister for the Environment and Regional Policy	31st December 1995 30th June 1999

CHAPTER 8

Chapter 8 PREDICTION OF FUTURE AIR QUALITY

8.1 Target Year

Generally, a target year for a regional air pollution control plan should be determined considering various factors including the following :

1) Target years of upper-ranked plans such as urban development plan and regional development plan.

2) Urgency of the plan, i.e. time allowed for a substantial improvement of air quality.

3) Future years for which projected figures for basic social and economic parameters are available.

4) Size of the planning area and scale of pollution sources in the area.

Considering above factors, the target year for the present study has been determined to be the year 2005.

8.2 Basic Future Conditions of Pollutant Sources

8.2.1 Power Stations

As described in Section 2.3.7, the electricity demand in the national level is projected by MVM Rt. According to this projection, annual average increase of the demand between 1995 - 2005 is 2.4 % in the case of lower demand increase and 3.5% in the case of higher demand increase.

However, in the Sajó Valley, MVM Rt. has specific plans for the existing 3 thermal power stations for electricity and heat energy production. Their plans are shown in Tables 8.2.1 through 8.2.3.

Table 8.2.1 Energy Production and Fuel Consumption Planned for Borsod Power Station

Year		1992	1993	1995	2000	2005
Production of Electiricy (GWh)		599.3	424.6	380	780 HFBC : 120 CFBC : 660	970 HFBC : 70 CFBC : 900
Production of Heat Energy of (TJ)		3,168	3,056	3,200	2,870 HFBC : 870 CFBC : 2,000	2,870 HFBC : 870 CFBC : 2,000
Fuel Consumption (TJ)	Coal	10,785	8,226	8,120	9,500	11,230
	N. Gas	1,080	1,199	900	185	160
	Oil	5	3	-	-	-
	Total	11,870	9,428	9,020	9,685	11,390

Source : Meeting with MVM Rt. in August 1994

Table 8.2.2 Energy Production and Fuel Consumption Planned for Tisza I Power Station

Year		1992	1993	1995	2000	2005
Production of Electiricy (GWh)		932.4	794.8	450	120	35
Production of Heat Energy of (TJ)		2,422	2,232	1,800	1,700	1,700
Fuel Consumption (TJ)	Coal	12,756	10,987	6,650	2,620	2,300
	N. Gas	1,333	1,364	750	300	250
	Oil	20	19	-	-	-
	Total	14,109	12,370	7,400	2,920	2,550

Source : Meeting with MVM Rt. in August 1994

Table 8.2.3 Electricity Production and Fuel Consumption Planned for Tisza II Power Station

Year		1992	1993	1995	2000	2005
Production of Electiricy (GWh)		2,615.6	3,008	3,300	3,805	1,581
Fuel Consumption (TJ)	N. Gas	17,564	19,711	31,710	36,600	15,210
	Oil	7,293	8,925			
	Total	24,857	28,636	31,710	36,600	15,210

Source : Meeting with MVM Rt. in August 1994

8.2.2 Major Factories

(1) Growth Rate of Energy Consumption

For the industrial sector, IKM projected that the energy consumption in 2000 would increase from the 1992 level by 5 - 7 % (annual rate at 0.610-0.849%) which accounts for reduction of energy intensity toward future as a result of energy saving.

The Study team adopted the upper limit of above growth rate band, i.e. annual 0.849%, as the industry-average growth rate of fuel consumption because it is safer to use higher rate for air pollution control planning. The team also assumed that this growth rate would continue up to 2005, i.e. increase of energy consumption by 11.6% from the 1992 level as the industry average.

However, since the growth rate will be different depending on the types of industry, major factories in the study area were divided into the four groups based on the industrial trends in Hungary as follows:

1) Types of industry whose growth rates are expected to be above the average

   - manufacture of agricultural machine, equipment and materials
   - manufacture of construction materials
   - engineering and manufacturing of household appliances
   - pharmaceutical industry
   - printing
   - construction
   - petrochemical industry
   - oil refining

2) Types of industry whose growth rates are expected to be about the average

   - textile and clothing
   - steel rolling
   - chemical industry
   - wire industry

3) Types of industry in which no growth is expected

   - iron manufacturing
   - mining

4) Types of industry to be phased out

   - blast furnace
   - ore preparing

The following growth rates for energy consumption are assumed for above groups of industry 1) through 3):

Group 1)	annual 1.02 - 1.53 %
Group 2)	annual 0.849 %
Group 3)	annual 0 %

(2) Operation Rate

The production level in the future can be estimated as follows:

$$Pf = Pp \times (Of/Op)$$

Where,

Pf = future production level
Pp = present production level
Of = future operation rate of the plant (%)
Op = present production rate of the plant (%)

and, $Of = Op \times (Ff/Fp) \times (Eip/Eif)$

Fp = fuel consumption at the present (1992 = 100)
Ff = fuel consumption in the future (2005 = 111.6 for the average group)
Eip = energy intensity at the present (1992 =100)
Eif = energy intensity in the future (2005 = 90 in normal)

As indicated above, energy saving by 10% in 2005 from the 1992 level is assumed expect for certain types of industry.

When the future operation rate of a factory calculated in above manner exceeds 100%, i.e. more than the rated capacity of the factory, the estimated fuel consumption is adjusted by assuming 100 % operation rate.

8.2.3 Communal Facilities

(1) Heating Centers

Generally, district heating is made to provide the heat to a well-urbanized area, particularly a densely built-up housing complex. In the housing areas in the study area not covered by the district heating, it is said that heating of individual houses is more economical than constructing new district heating system.

In view of expected population decrease in the future, expansion of district heating is not expected in the future, i.e. the fuel consumption in heating centers will not grow.

Present district heating areas are shown in Figures D8.2.1 through D8.2.6 in Data Book.

(2) Household Fuel

1) Natural Gas

According to the gas distribution company, the number of households using natural gas in the study area is 100,711 as of the end of December 1993, or about 57% of the total number of households based on the 1990 figure (178,180). The number of locations where public and industrial gas pipelines have been laid is 2,633 and 60, respectively. Figure 8.2.1 shows the towns and villages in the Study Area, where the natural gas is available.

Dissemination of the use of natural gas will proceed further in the future in the Study Area. Figure 8.2.2 shows the towns and villages in the Study Area, where the natural gas will be available in 2005 based on the plan of the gas distribution company.

According to ÉKF, out of the households in the Sajó Valley area not having natural gas supply at present, 75% desire the gas supply even though they have to bear the cost for individual pipe connection. However, since the price of natural gas is scheduled to be doubled by the end of the year 1996, ÉKF expects that this percentage will be decreased to 50 - 60% in the future.

According to the gas company, the annual consumption per household is 2000 - 3000 m^3 (34 MJ/m^3), and it is considered to be in the similar range in the future.

2) Coal and Firewood

Judging from the result of questionnaire (4.1.3) concerning household heating, the houses using coal are found around the coal mines while those using firewood are in the mountainous area. Dissemination of the natural gas will cause decrease in the use of coal and firewood in these areas.

3) Light Oil

Houses using light oil are very few (from the questionnaire concerning household heating), and light oil consumption can be neglected.

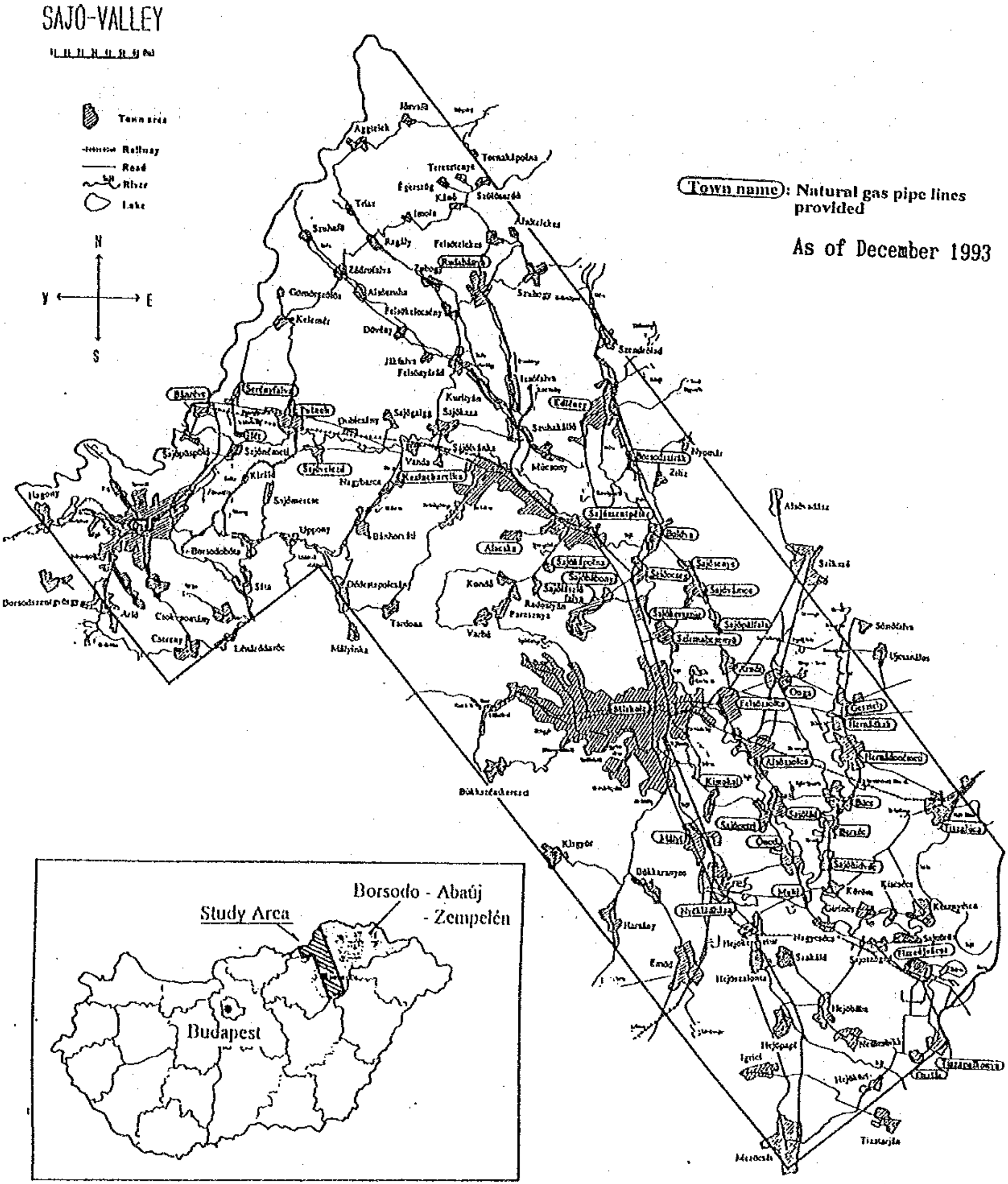


Figure 8.2.1 Towns and Villages Where Natural Gas Pipe Lines Have Been Laid

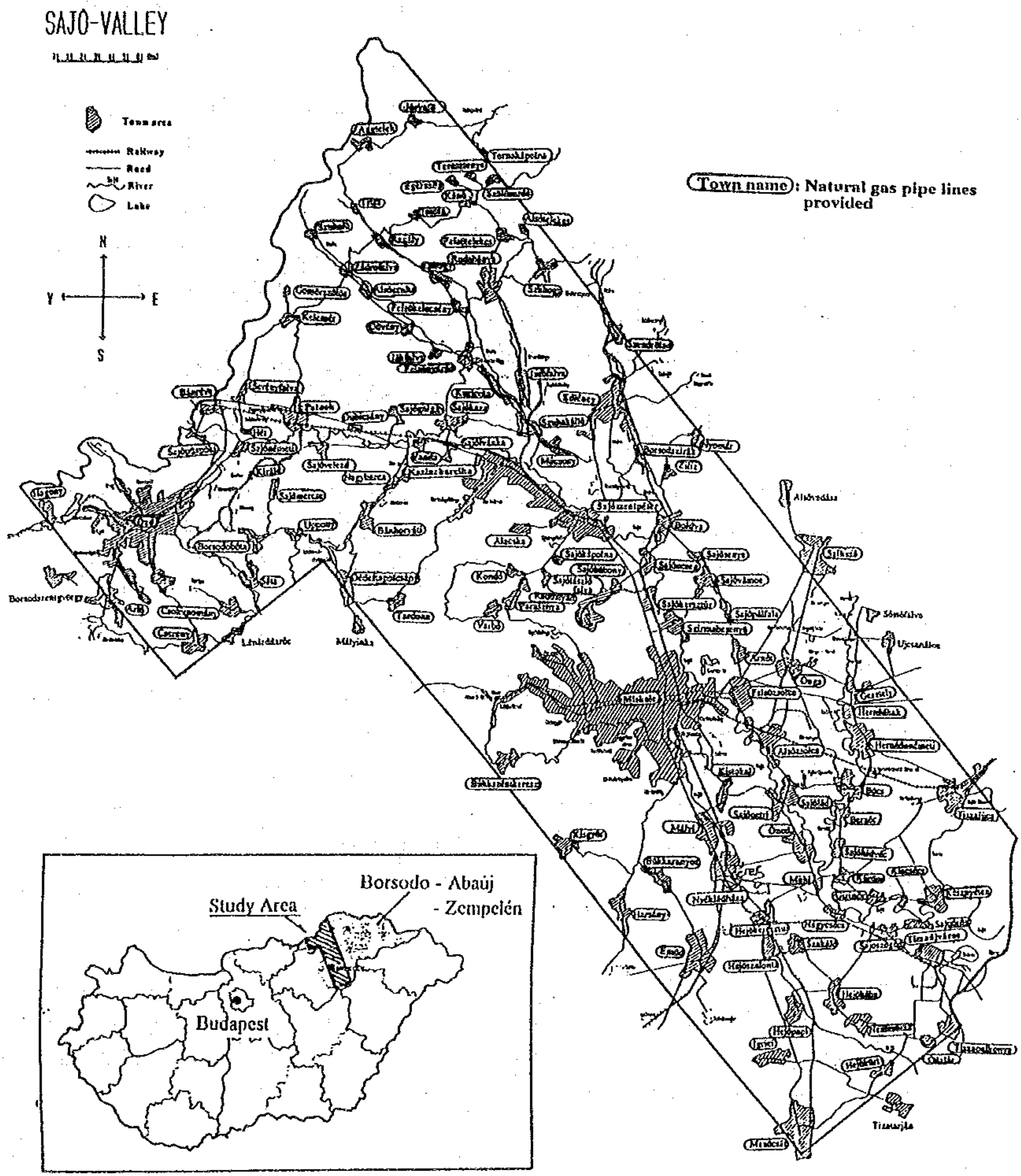


Figure 8.2.2 Towns and Villages Where Natural Gas Pipe Lines Will Have Been Laid by the Year 2005

8.2.4 Motor Vehicles

(1) Future Traffic Volume

A growth rate of traffic volume is one of the principal elements to estimate the future pollutant load from motor vehicles in the study area. Since the increase of traffic volume seems to be determined by many socio-economic factors affecting each others with complicated relations, it is difficult to predict the future traffic volume rationally. In this study, it is assumed that the traffic volume is proportional to the number of registered motor vehicles.

Figure 8.2.3 shows the regression curve for the number of registered motor vehicles in Hungary. The regression was made by the polynomial expression using the statistic data from 1976 to 1990 and the predicted data for 1991, 1995 and 2000 given in "The Long-term Development Program of the National Public Road Network, Oct. 1991" (Ref. C-13). The number of motor vehicle to be registered in Hungary in the target year 2005 is estimated to be 2,850,000 by this regression equation. The growth rate of registered motor vehicles in the country will be also applied to the study area.

The traffic volume thus estimated may be somewhat greater than the actual one. However, it is considered to be permissible for the purpose of this study since the estimate will be on the safety side for planning air pollution control.

(2) Emission Factor of Motor Vehicles

According to the information from BAZKF, the number of motor vehicles registered in BAZ County including the study area was 106,344 in 1993. Among them, approximately 2,400 vehicles or 2.3% are equipped with a catalytic converter. Ages of these motor vehicles are considered to be less than 5 years. The ratio of such relatively new cars to all the registered cars in BAZ County is assumed to be the same as that of the country in 1990 shown in Table 8.2.4, i.e. 33%. Then, the number of vehicles not older than 5 years is: 106,344 x 33% = 35,094 (Vehicles).

The number of motor vehicles in BAZ County equipped with catalytic converter (2,400) is 6.8% of 35,094. It is assumed that all vehicles older than 5 years are replaced by new vehicles by 2005, and in the no pollution control case, 6.8% of the total vehicles are equipped with a catalytic converter.