deterioration of boiler efficiency. In case this system is employed, daily cleaning of the flue is necessary.

5.4.3 Other Dry-Type Desulfurization Methods

(1) Activated Carbon Absorption Method

In the activated carbon adsorption method, dust is collected first by pre-filters or electric dust collectors, and then pre-cooled effluent is pressurized by fans and introduced into the tower filled with activated carbon where SO_2 is removed. Many kinds of auxiliary facilities such as dust collectors, activated carbon desulfurizing tower, rinsing and retrieval devices, etc. are required and a large amount of investment is necessary. Another disadvantage of this system is that the absorbing capacity of the activated carbon is generally about 15% of its weight. When it is used as absorbent for such fuels as Tacbilec lignite that contains a lot of tarry substances and emits high concentrations of NOx and HC, its life (cycle) is short, requiring complicated maintenance such as rinsing and retrieval, and enormous operating cost.

For the reasons stated above, this method is not suitable for heating purpose.

(2) Contact Catalytic Oxidation Method and Direct Reduction Method

The contact catalytic oxidation method and the direct reduction method were developed for large scale desulfurization plants. Both methods require a large space and enormous amount of investment. At the same time, operating cost is prohibitive. Presently in Japan, these method are rarely seen in actual use. As with the activated carbon adsorption method, these methods are not suitable for small boilers.

(3) Electron Beam Irradiation Method

Irradiation of electron beam is considered to be very effective for denitrification and desulfurization at large scale plants such as thermoelectric power plant.

When a bundle of high speed electron beam from the generator is irradiated into the reactor, collision of electrons with the molecules of N_2, O_2, and H_2O, that are the major components of the effluent, triggers the production of strong oxidizing species such as OH, O, and HO_2. This process features the production of active oxidizing agents in the irradiated space under an optimum condition.

$$N_2, O_2, H_2O + e^- \longrightarrow OH, H, HO_2$$

By the active oxidizing agents thus produced, SOx and NOx are oxidized to become mist of the molecules of sulfuric and nitric acid.

$$SOx \xrightarrow[HO_2]{OH,\ O} H_2SO_4$$

$$NOx \xrightarrow[HO_2]{OH,\ O} HNO_3$$

In the presence of ammonium, sulfuric acid and nitric acid are neutralized into fine particles of ammonium sulfate and ammonium nitrate. These fine particles are agglomerated into larger particles in a short time during transportation in a duct from the reactor to the dust collector. These agglomerated particles are retrieved by the dust collector.

Quite different from the conventional wet types, this dry type system eliminates the corrosion and scaling problems and considerably saves labor and other expenditures required for maintenance. Furthermore, highly efficient synchronized desulfurization and denitrification are carried out in the reactor and the dust collector. As no filler is used in each of devices, the loss of pressure in the system is small. Operation can be smoothly adjusted depending on the concentration of SOx and NOx in the effluent, various local emission standards, and various combustion conditions of boilers. And with this system, startup and shutdown can be made easily in a short time, and by-products can be used as fertilizer.

In case two units of lignite-thermoelectric power stations each having a capacity of 210 MW are to be installed to supply electricity to Ankara City, the initial investment is expected to total 32.5 - 34.5 billion TL. The operating cost of desulfurizing facilities at coal-thermoelectric power stations is generally 4.2 TL/kwh, occupying 12 -15% of the total operating cost. Since by-products can be used as fertilizer, the cost performance can be improved.

(4) Fluidized Bed Boiler

The system of desulfurization, denitrification, and dust collection in a power plant with fluidized bed boiler employs the same principles as stated in Sec. 5.4.2. SO_2 is converted to $CaSO_4$ in the combustion chamber. Different from ordinary boilers is that pressurized air is blown to produce turbulance on the fluidized bed where pulverized coal and lime are mixed and burned at low temperatures (about 800°C).

As a consequence, the size of the boiler can be made smaller and low grade fuels can be used with less pollutant emission. This system is said to be the boiler of the next generation.

The United States plans to build a demonstration plant of this type with a capacity of 150 - 200 MW.

In Japan, a pilot plant with a capacity of 50 MW is planned to be constructed for the test aiming to be on stream in 1987.

5.4.4 Wet-Type Desulfurization Method

(1) Absorbents

Typical absorbents used in the wet-type desulfurization are $CaCO_3$, $Ca(OH)_2$, NaOH, and NH_3. For small sized desulfurizing facilities, NaOH is considered to be most suitable as an absorbent in view of operation and maintenance.

Other absorbents have the following disadvantages.

a. When an absorbent such as $CaCO_3$ or $Ca(OH)_2$ is used, it becomes slurry, which causes clogging nozzles and pipes, thus making operation and maintenance difficult.

b. When NH_3 is used to operate at neutral pH, SO_3 and NH_3 in the effluent are reacted to form fumes of $(NH_4)_2SO_4$, which increases the amount of dust emission.

(2) Operational Cost

Calculation is made in the following case;

Volume of Gas Treated		1,000 m^3N/h
SOx Concentration		900 ppm
Unit Price	$CaCO_3$	30 TL/kg
	NaOH	126 TL/kg(solid)
	NH_3	160 TL/kg

The cost per hour of the operation will be as follows.

Kind of Absorbent	NaOH	$CaCO_3$	NH_3
Amount of Absorbent Used kg/hr	2.56	3.4	1.09
Running Cost TL/hr	322.6	102	174.4

Based on the on-site survey at the boiler room, the following estimation was made for the case of NaOH:

Operating Hours	11 hr/day x 160 days/year (1760 hr/year)
NaOH Cost	322.6 TL/hr
Operating Cost	322.6 TL x 1760 hr=567,776 TL/year

The effluent generated in the wet type process has an appearance of thick smoke and causes corrosion in the flue and smoke pipes. To avoid this, about one-fourth of untreated effluent has to be mixed with the treated gas for drying and re-heating. As a consequence, desulfurizing rate would be about 70%. In the case of the wet type desulfurization, treatment of water used in the process is of great importance. If it is discharged without treatment, it will cause pollution in rivers and other waterways.

Therefore, the treatment of the effluent water is necessary. The cost of the treatment plant is estimated below.

In case of a plant with desulfurizing capacity of 1,000 m^3N/h, the condition of the effluent water under the maximum loading would be as follows;

Amount of the Effluent	0.68 m^3/h
SS Concentration	24,900 ppm (estimated)
COD (by $KMnO_4$)	1,600 ppm (estimated)

If the effluent water from 100 plants each having 1,000 Nm^3/h desulfurizing capacity is to be collectively treated at one site, the following system should be employed.

Storage Pool ⟶ SS Removal Facility

⟶ Oxidization Facility ⟶ Discharge

Even excluding the cost of storage pool, 500 million TL will be necessary only for SS removal and oxidization facilities.

Assuming that each of 100 plants is equipped with this kind of desulfurizing unit and water treatment unit, the cost per one plant will be as followers;

(1) Desulfurizing Unit	25,000,000 TL
(2) Water Treatment Unit	5,000,000 TL
	30,000,000 TL

Taking depreciation (5 years), repairs (10%), and interest (8%) into account, the annual operating cost amounts to about 11,400,000 TL. Even without the cost of electricity and absorbents required for operation, this amount is more than 9 times that of 90 tons of lignite (1,260,000 TL/year) consumed in one building annually.

The wet type is more efficient than the dry type in dust collection and desulfurization when adapted to boilers for the building heaters. But if such equipment is to be attached to the conventional boilers, a large amount of investment is required as stated above.

Recently, a compact gas collecting-and-rinsing equipment for smaller boilers has been developed, in which pre-cooled flue gas is treated in a spray-and-rinse chamber revolving at a high speed. Though the initial investment cost tends to be lower, about 13,000,000 TL will be required including installation cost.

The operating cost for one heating season is:

Absorbent	568,000 TL
Electricity	518,800 TL
Total	1,086,800 TL

In addition, 90 l/min of water for circulation is necessary. Depreciation (5 years), repairs (10%), and interest (8%) add up to 4,940,000 TL/year. Even excluding the cost of water and water treatment, the total annual expenditure amounts to 6,926,000 TL, 4.78 times that of 90 tons of lignite.

5.4.5 Dust Removal

As a consequence of high content of ash in lignite, a large amount of particulate matter is emitted into ambient air, causing poor visibility at the time of low wind. It comes down as low as 20 meters in the central area of the City. Next to desulfurization, dust removal is of great importance.

(1) Performances of Various Types of Dust Collector

Performance of various types of dust collectors are shown in Table 5.4.7.

Table 5.4.7 Types of Dust Collector and Their Performance

Type	Main Features	Principle	Particle Diameter Separated (μm)	Dust Collection Rate (%)
Gravitational Collector	One-Chamber Type Multi-Strata Type	Gravitational Sodimentation	30	50-60
Inertial Dust Collector	Collision Type Reversal Type	Inertia	20	60-80
Multi-Cyclone Dust Collector	High Efficiency Type Multi Type	Centrifuged Power	5	80-98
	Large Type		15	60-80
Filtration Dust Collector	Bag Filter Type	Dispersion	0.5	99.8
	Filled Strata Type	Collision Buffering	1-5	98
Electric Precipitator	2 Step Type	Static Electicity	0.1	More than 90
	1 Step Type 1 Step Wet Type			90-99.9
Scrubber	Benchly Type	Dispersion	0.5	98
	Filled Tower Type	Collision	0.5	85
	Wet Wall Type	Condensation	1	95
	Water Film Type		5	96-98

(2) Principles and Structure of Dust Collector

i) Cyclone

a. Characteristics

This type has long been used, because of its simple structure. It is very effective when used for the right purposes. Advantages and disadvantages of this type are as follows:

Advantages

* Highly efficient for its simple structure.
* Can be installed in a small space compared to the volume of gas treated.
* Can be operated at relatively high temperatures.
* Highly effective when a amount of dust has to be collected.
* Not only as a dust collector it can be used as a separator at the bottom of the pneumatic transportation system.
* Low construction cost.
* Easy check and maintenance because no moving part is employed.

Disadvantages

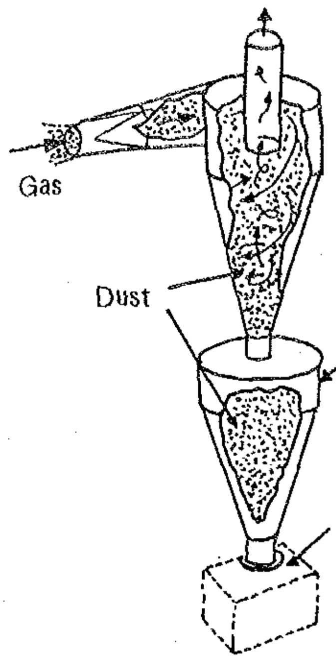
* Unsuitable for removal of micro dust particles which sometimes gives rise to pollution problems.
* For its simplicity, theoretical analysis of the function is difficult. The right design for the right purpose is hard to obtain.
* Pressure loss is great.
* In case of absorbing type, small air leakage leads to poor dust collection rate.

b. Principle and Structure of Cyclone

Dust-containing gas is revolved in a cylinder, dust being attached to the wall with centrifugal power and slid down along the wall. The centrifugal power which acts upon the dust particles is 500-2,000 times of their weight. Even particles as small as 5 μm which will not sink down in the air can be caught with this system.

* Multi Cyclone

With a small sized cyclone with a small diameter, the diameter of the dust prticles collected can be smaller and high efficiency is obtained. On the other hand, the amount of gas treated gets smaller in inverse proportion to the diameter. When a large amount of gas is to be treated, a number of small cyclones are installed in parallel.



Principle of Cyclone

Assuming that such cyclones are attached to the lignite boilers for heating in Ankara City, the initial investment is estimated in the following for the two typical types of boilers actually used in Ankara City.

500 Nm/h of gas volume

Cyclone (350ϕ x 2 mH)		¥175,000
Fan Q=20, SP=200		¥250,000
Motor 1.5kw 42p 400v		¥35,000
Connecting Duct (with secondary air inlet)		¥70,000
Paint		¥85,000
Packing		¥100,000
		¥715,000
Total	(about	1,500,000 TL)

1,000 Nm/h of gas volume

Cyclone (500ϕ x 2.5mH)	¥215,000
Fan Q=40 SP=200	¥270,000
Motor 3.7kw 4p 400v	¥48,000

Connecting Duct (with secondary air inlet)		110,000
Paint		¥130,000
Packing		¥140,000
Total		¥913,000
	(about	1,900,000 TL)

* Note 1) Material-- S - TEN - 1 (Acid-Proof)
2) Weight of Steel --- 2.3-3.2 tons

ii) Bag Filter

a. Characteristics

This system can be applied to a wide variety of uses and is effective where high dust collection rate is required.

Though it is suitable for treating the flue gas from fuel oil, in view of filter cloth's heat resistance, it is not suitable for treating gas from lignite.

Advantages

* Concentration of the effluent is not much influenced by the dust concentration of the gas.
* Comparatively lighly heated gas can be treated and applied to a wide variety to uses.
* Collection of micro particles is possible.
* Filter cloth can be chosen in accordance with the characteristics of the gas and dust to be treated.
* The amount of dust re-emitted is small.

Disadvantages

* The upper limit of the temprature of the gas to be treated is set by the heat resistnce properties of filter cloth.
* At temperatures below dew point, or with highly moisture absorbent dust, this system is not adoptable.
* Compared to cyclones, the equipment occupies larger dimension(s).
* Ranges of pressure less varies to a great extent.

b. Principle and Structure of Bag Filter

The gas is filtrated on the surface of the filter cloth and the dust is separated. In terms of mechanical energy, inertia collision, dispersion, buffering, and gravity are used.

As for filter cloth, polyester, polyamid, and felt are mainly used. but clothes made from natural fibers such as cotton or wool is also used. Heat resistant nylon or glass fiber is also employed according to the characteristics of gas and dust.

Filter cloth is made into cylindrical or flat-board-like shape, and several of them are put together to make the surface area necessary for filtration. They are set in one or several bag houses.

The dust layer itself which sticks to the filter cloth acts as a filter but it gets thicker with passing of time, deteriorating the efficiency. The dust thus collected is got rid of when the dust layer has reached a certain thickness.

iii) Electric Precipitator

a. Characteristics

Among various kinds of dust collectors, this type is as efficient as bag filters, and especially suitable for collection of micro particles below 1μm. This type has also long been used.

Advantages

* Suitable for collection of sub-micron particles.
* Operating and maintenance cost is inexpensive as pressure loss is small.
* Suitable for treatment of high temperature gas.
* Collection of oil mist is possible.
* Wet type dust collection is also possible.
* Can be used as a electrostatic condenser.

Disadvantages

* Large dimension is required for installation.
* Extreme mechanical accuracy is required, resulting in expensive construction cost.

* Dust collection rate depends on the electrical properties of the dust, which sets limits to applicable fields.
* Can not be applied to combustible gas and dust.

b. Principle and Structure

Corona discharge is triggered by charging high voltage electricity of 15,000-70,000V between electrodes. Positive ions and negative ions are generated then. While positive ions are immediately neutralized by electrodes, negative ions move to the dust collecting pole. When the dust containing gas passes by, collision of dust particles and ions takes place and charged particles are separated and caught by the dust collecting pole.

This method is classified into two types----one step type and two step type.

The former is widely employed for industrial use as this type is suitable for treating the gas with comparatively high dust concentration. The latter is mainly used for air-cleaning to remove micro dust particles of low concentration. With this type, positive corona is generated which produces less ozone. In the dry type equipment, efficiency is largely dependent on specific resistance value of the dust. The best efficiency is obtained with the dust having specific resistance value of 10^3-10^{11} Ω.cm.

In case of the dust below this value, it loses its electric charge as soon as it is attracted to the collecting pole and re-emitted. In case of the dust above this value, reversal ionization takes place due to the delayed neutralization of charged particles, resulting in low dust collection rate.

Structurally, air-flow resistance is rather small and because of this, pressure loss is about 30-60 mm H_2O, much lower than other methods. If the right materials are chosen, operation is possible at temperatures as high as 350°C.

iv) Mist Separator

a. Characteristics

Mist is often generated in the production process causing environmental and health problems. Because mist can be retrieved and recycled, this system is very effective from the view point of energy saving.

Advantages

* Retrieved oil can be re-used or burned as fuel.
* Environmental pollution characteristic with oil mist can be prevented.
* Because it is retrieved in liquid form, it can be easily processed.
* The mixture of mist and dust can be treated.
* Separation can be carried out with comparatively small pressure loss.

Disadvantages

* The diameter of mist particles varies largely depending on the production process. As a consequence, a single unit can not be applicable to a wide variety of uses.
* Mist produced in the vapor condensation contains particles with a submicron diameter. Such mist can not be easily separated.
* Unless the ducts which absorb mist are tightly joined, liquid oil will leak from the flanges, causing product and environmental pollution.

b. Principle and Structure

In case of the oil mist which is generated by mechanical factors such as rupture of oil film, the diameter of the mist particles is mostly more than 10μm, and much of it can be trapped by an eliminator in which corrugated boards are combined together. However, the diameter of mist particles which is formed in the process of vapor condensation is smaller than 1μm. Several layers of filters filled with fiber is necessary to trap these small particles. The mist trapped in this manner becomes oil film or drops, flows down, and seldom evaporate again. When the mixture of such mist and dust has to be trapped, an automatic filter washer is sometimes required. In many cases, filters have to be replaced as expendable supplies at an interval of 6-12 months. Pressure loss is largely dependent on the kinds of mist, but general value would be in the range between 50-100mmH_2O.

In case of sticky oil mist, an electric dust collector is sometimes employed. But its use is limited to the case in which there is no danger of fire triggered by electric sparking.

To trap mist from highly evaporative liquid, a cooler is used to improve efficiency. For more efficient trapping, sometimes vapor is further cooled to promote condensation. But in this case, high efficiency cannot be expected unless the correlation between vapor pressure characteristics and vapor concentration is taken into consideration.

v) Lavation Dust Collector

This system is sometimes called scrubber. Dust is separated and treated in water.

A complicated process is required for disposal of water. This equipment is not suitable for Ankara City where water supply is occasionally interrupted. Detailed description of the equipment is thus omitted here.

5.5 IMPROVEMENT OF THERMAL INSULATION OF BUILDINGS

5.5.1 Study Approach

In this section, the effect of using the heat insulation materials on the heating load reduction is studied.

Study procedures are:

(1) Assume typical construction specifications of the walls and partitions on an un-insulated building and calculate coefficients of heat transmission for these components of the building.

(2) Calculate coefficients of heat transmission for building components with the improved specifications on which information was given from the Urban Reconstruction Directorate of the Metropolitan Municipality of Ankara.

(3) Calculate coefficients of heat transmission of the building having a heat insulation capacity which is defined officially in the Building Code in Turkey.

(4) Calculate the heat loss for each case mentioned above to find out the heating load in the coldest period in Ankara.

(5) Evaluate the effect of improving building heat insulation capacity by making a comparison of the results of the heating loss computations.

5.5.2 Effect in Improvement of Insulation Capacity

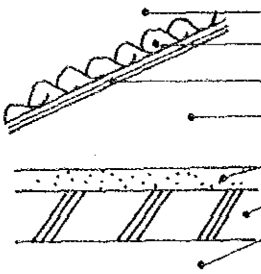
(1) Coefficients of Heat Transmission of Existing Buildings

Coefficients of heat transmission of various components of an un-insulated building are assumed as shown in Figure 5.5.1.

(2) Coefficients of Heat Transmission of Buildings with the Improved Specifications Which Have been Commonly Applied.

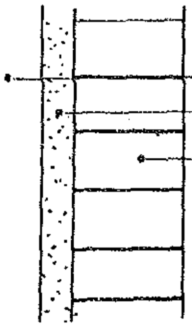
Coefficients of heat transmission of the components of the building are assumed as shown in Figure 5.5.2.

Roof



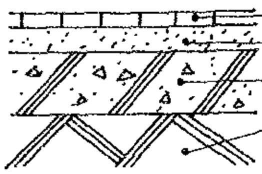
		λ (Kcal/m·h·°C)	R (m²·h·°C/Kcal)
Outer Surface			0.13
Roof Tile	22 mm	1.1	0.02
Batten	10	0.11	0.09
Air Space			0.19
Concrete	50	1.3	0.04
Concrete	150	1.3	0.11
Inner Surface			0.05
		ΣR =	0.63
		U =	1.59 (m²·h·°C/Kcal)

Wall



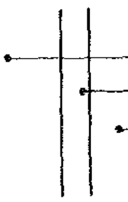
		λ	R
Outer Surface			0.13
Mortar	30 mm	1.2	0.03
Bricle	125	0.52	0.24
Inner Surface			0.05
		ΣR =	0.45
		U =	2.22

Floor



		λ	R
Inner Surface			0.05
Mosaic Tile	25 mm	1.55	0.02
Mortar	20	1.2	0.02
Concrete	120	1.3	0.09
Earth	1000	1.3	0.77
		ΣR =	0.95
		U =	1.05

Window

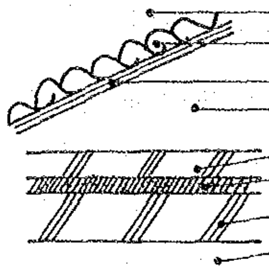


	λ	R
Outer Surface		0.13
Glass 6 mm	0.68	0.01
Inner Surface		0.05
	ΣR =	0.19
	U =	5.3

λ : Coefficient of Heat Conductivity
R : Heat Resistance
U : Coefficient of Heat Transmission

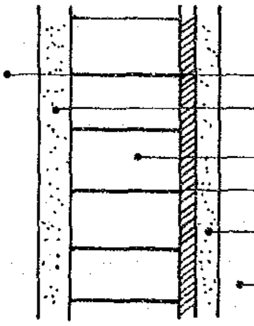
Figure 5.5.1 Heat Transmission Factors (Un-Insulated Building)

Roof



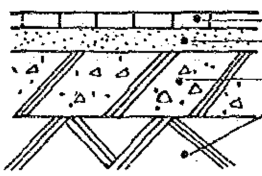
	Thickness	Kcal/m·h·°C λ	m²·h·°C/Kcal R
Outer Surface			0.13
Roof Tile	22 mm	1.1	0.02
Batten	10	0.11	0.09
Air Space			0.19
Concrete	50	1.3	0.04
Insulation	15	0.035	0.43
Concrete	150	1.3	0.11
Inner Surface			0.05
		ΣR =	1.06
		U =	0.94 (m²·h·°C/Kcal)

Wall



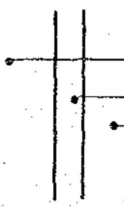
	Thickness	λ	R
Outer Surface			0.13
Mortar	30 mm	1.2	0.03
Bricle	125	0.52	0.24
Insulation	10	0.035	0.29
Mortar	15	1.2	0.01
Inner Surface			0.05
		ΣR =	0.95
		U =	1.33

Floor



	Thickness	λ	R
Inner Surface			0.05
Mosaic Tile	25 mm	1.55	0.02
Mortar	20	1.2	0.02
Concrete	120	1.3	0.09
Earth	1000	1.3	0.77
		ΣR =	0.95
		U =	1.05

Window



	λ	R
Outer Surface		0.13
Glass 6 mm	0.68	0.01
Inner Surface		0.05
	ΣR =	0.19
	U =	5.3

λ : Coefficient of Heat Conductivity
R : Heat Resistance
U : Coefficient of Heat Transmission

Figure 5.5.2 Heat Transmission Factors (Insulated Building)

(3) Regulated Thermal Insulation for Building

By Official Gazette No. 18580 dated November 19, 1984, minimum thermal resistances of building components have been specified as follows:

For Zone 3 (Ankara):

Roof: $Rr = 2.40\ m^2 \cdot h \cdot {}^oC/Kcal$

Floor: $Rf = 1.50\ m^2 \cdot h \cdot {}^oC/Kcal$

Wall: $Rw = 0.92\ m^2 \cdot h \cdot {}^oC/Kcal$

Blocked Window: $Rb = 0.92\ m^2 \cdot h \cdot {}^oC/Kcal$

(4) Assumption of Typical Layout of Building

In order to make heating load calculations, a building layout is assumed as shown in Figure 5.5.3.

Total Floor Area : 100 m^2

Number of People : 5 persons

Window Area : 16 m^2

Floor Area Heated : 62.5 m^2

Floor Hight : 3.5 m

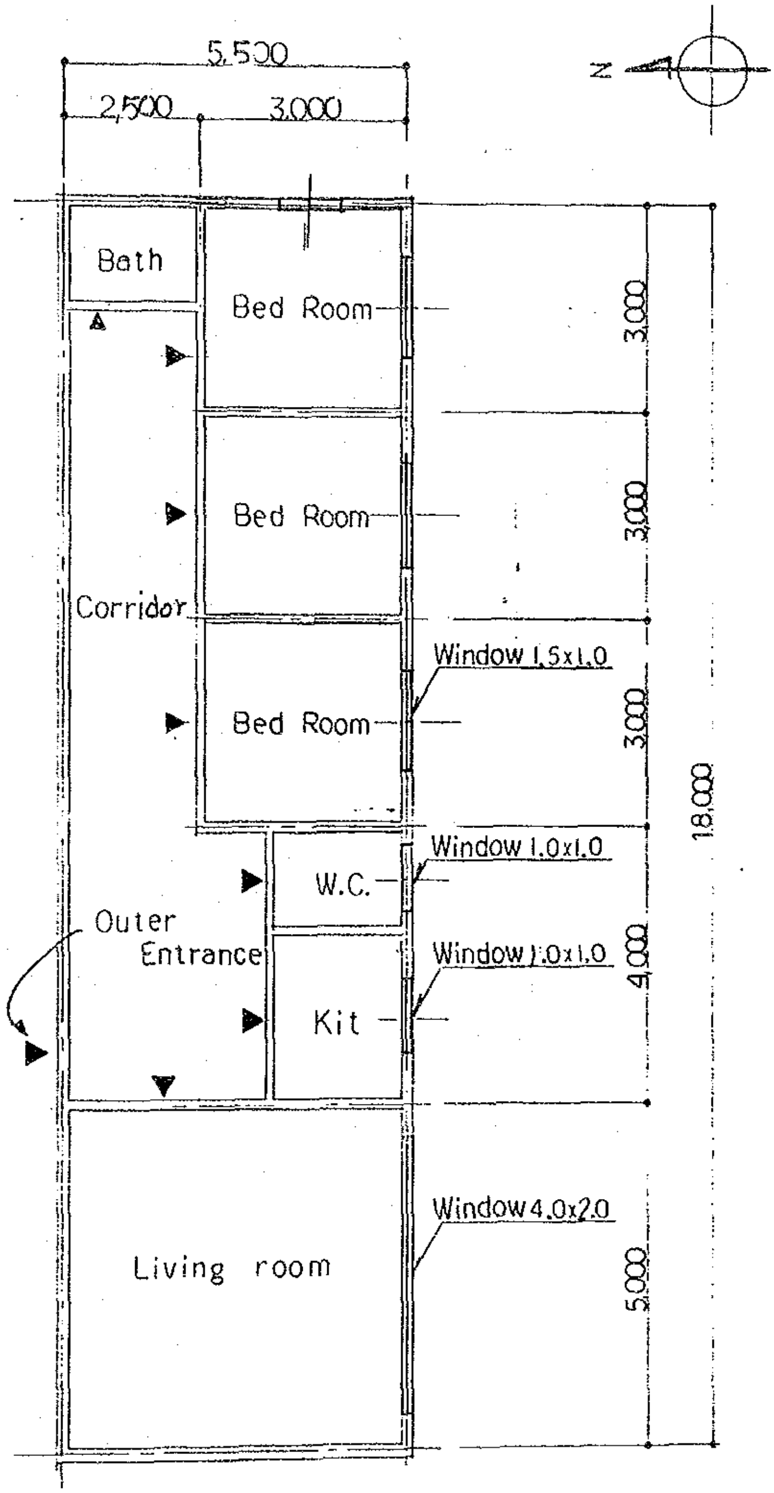
(5) Heating Loss Calculations

Following assumption is made for heating loss calculations :

i) Intermediate Temperature (Non-Heated Area)

The temperature of non-heated area is assume to be the average of the room temperature and the outside air temperature as follows:

$$\frac{-11.1 + 20.0}{2} = 4.5^oC$$



Floor Area : 100 m^2

Floor Height : 3.5 m

Figure 5.5.3 Layout of Building (Example)

ii) Ground Temperature

Ground temperature is assumed to be equivalent to the intermediate temperature as 4.5°C.

iii) Reduction of Window Area

The window area facing to the south is to be reduced to fifteen (15) percent of the floor area.

Heating loss (HL) is computed as follows:

$$HL = \Sigma (U \cdot \Delta t \cdot A \cdot \eta) \text{ Kcal/h}$$

U :	Coefficient of Heat Transmssion	$Kcal/m^2 \cdot h \cdot {}^oC$
Δt :	Temperature Difference	^oC
A :	Area	m^2
η :	Orientation Factor	(1.0 - 1.1)

(6) Results and Conclusion

Results of the heat loss calculation are shown in Table 5.5.1.

Compared with the un-insulated building, heat loss reduction of forty-six (46) percent is obtainable with the building having insulation capacity which is in accord with the Building Code, and that of twenty-seven (27) percent is attainable with the improved specifications as applied commonly in the City of Ankara.

Consequently, it may be said that approximately thirty (30) percent of the fuel consumption for the space heating can be reduced by improving building heat insulation capacity.

Table 5.5.1 Results of Heat Loss Calculation

	Un-insulated Building	Improved Specification Commonly Applied in Ankara City	Insulatted
Glass	2,544 Kcal/h	2,468 Kcal/h	2,339 Kcal/h
Walls	6,359	3,810	2,606
Roof	2,198	1,299	2,606
Floor	723	723	413
Partitions	1,202	1,202	1,202
Total	13,026 Kcal/h	9,502 Kcal/h	7,099 Kcal/h

5.6 INTRODUCTION OF DISTRICT HEATING SYSTEM

5.6.1 Study Approach

Utilizing the results of the computation of the geographical distribution of the fuel consumption, heating load density will be calculated zone by zone. And an assumption is made that the district heating systems are to be introduced to those zones which have a heating density greater than a certain level.

Based on the said assumption, capacity of the district heating plants will be determined and their construction and operational costs will be estimated. District heating systems are assumed to be built with desulfurization facility in the estimation of the quantity of SO_2 gas reduction to evaluate the effect of the application of the district heating systems.

The systems with three(3) types of the fuels, ungraded lignite, laved lignite, and fuel oil are to be studied with an assumption that each type of the fuels is exclusively used in the district heating plants.

The area of approximately two hundred (200) square-kilometer is considered in this study, as shown in Figure 5.6.1, and it is subdivided into the blocks of 500-meter by 500-meter (25 ha) each for the purpose of regional study.

Major factors which may contribute to the reduction of SO_2 gas emission by introducing the district heating systems are:

- Reduction in the fuel consumption is expected due to the improved combustion efficiency at centralized heating plants.

- Emission of SO_2 in the exhaust gas can be reduced with the desulfurization facility.

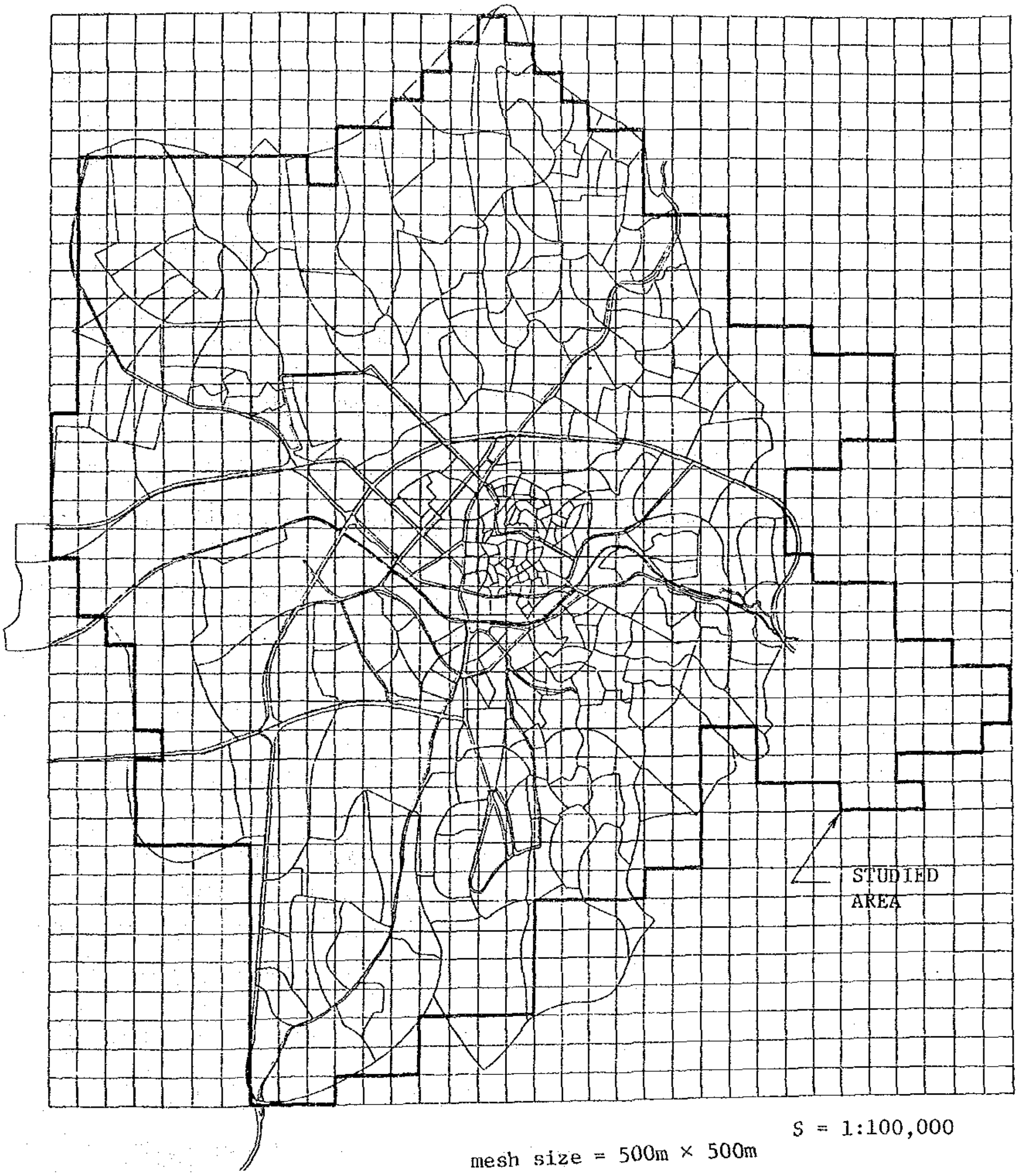


Figure 5.6.1 Study Area of District Heating Systems

5.6.2 Heating Load

(1) Notation

The following symbols will be used in the computation of heating load.

PHL	: Peak heating load	(Gcal/Hr·Mesh)
THL	: Total heating load	(Gcal/Winter·Mesh)
MHL	: Monthly heating load	(Gcal/Month·Mesh)
PMHL	: Peak month heating load	(Gcal/Month·Mesh)
PDHL	: Peak day heating load	(Gcal/Day·Mesh)
HM	: Heating months	(Months/Season)
HD	: Heating days per month	(Days/Month)
HH	: Heating hours per day	(Hours/Day)
MHLF	: Monthly heating load factor	
PMHLF	: Peak month heating load factor	
PDHLF	: Peak day heatig load factor	
PMAT	: Peak month average temperature	(^{o}C)
PDAT	: Peak day average temperature	(^{o}C)
DT	: Design temperature of Outside Air	(^{o}C)
RT	: Room temperature	(^{o}C)

(2) Total Heating Load (THL)

From consumption of coke, ungraded lignite, laved lignite, coke-briquette, and fuel oil for space heating in winter in each 500-meter mesh, total heating load(THL) from November to March is computed as follows:

THL = Amount of Fuel Consumption
x Calorific Value of Fuel
x Combustion Efficiency of Heating Apparatus

i) Calorific Values of Fuels

Calorific values of the fuels used in Ankara City for space heating are shown in Table 5.6.1.

Table 5.6.1 Calorific Values of Fuels

Type of Fuel	Calorific Value (kcal/kg)
Coke	5400
Coke-Briquette	5330
Ungraded Lignite	4750
Laved Lignite	4980
Fuel Oil	10500

Table 5.6.2 Combustion Efficiency of Heating Apparatus

Type of Combustion Apparatus	Efficiency(%)
Lignite Boiler	65
Oil Boiler	80
Lignite Stove	60
Coke Stove	70

ii) Combustion Efficiency of Heating Apparatus

Combustion efficiencies of heating apparatus are assumed as shown in Table 5.6.2.

iii) Heating Load by Types of Fuels

a. Stove Heating

Coke : 5400 x 0.7 x Coke Consumption

Briquette : 5300 x 0.6 x Briquette Consumption

Ungraded Lignite : 4750 x 0.6 x Lignite Consumption

Laved Lignite : 4980 x 0.6 x Laved Lignite Consumption

b. Boiler Heating

Ungraded Lignite : 4750 x 0.65 x Lignite Consumption

Laved Lignite : 4980 x 0.65 x Laved Lignite Consumption

Fuel Oil : 10500 x 0.8 x Fuel Oil Consumption

iv) Total Heating Load (THL)

Total heating load (THL) in winter is a total of the heating loads by stove heating and boiler heating.

(3) Peak Heating Load (PHL)

From the calculated results of THLs, the peak heating load (PHL) is obtained as follows:

$$PHL = \frac{THL}{HH \times PDHLF \times PMHLF \times HD \times MHLF} \quad \text{(Gcal/hr)}$$

i) Peak Day Heating Load Factor (PDHLF)

Within the peak day (coldest day), hourly heating load is equivalent to or less than that of the peak hour. Peak day heating load (PDHL) will be obtained as:

Peak Day Heating Load (PDHL)

= Peak Heating Load (PHL) x Heating Hours (HH)

x Peak Day Heating Load Factor (PDHLF)

PDHLF

$$= \frac{\text{Room Temperature (RT) - Peak Day Average Temperature (PDAT)}}{\text{Room Temperature (RT) - Design Temperature (DT)}}$$

Since PDHLF is generally considered as a universal factor to all cities, PDHLF calculated based on the data in Tokyo may be applicable to Ankara City:

RT : 18°C

DT : -2.9°C

PDAT : 0.76°C

$$PDHLF = \frac{18 - 0.76}{18 - (-2.9)} = 0.82$$

ii) Peak Month Heating Load Factor (PMHLF)

Within the peak month (coldest month), daily heating load is less than that of the peak day. Peak month heating load (PMHL) will be obtained as follows:

Peak Month Heating Load (PMHL)

= Peak Day Heating Load (PDHL)

x Heating Day (HD)

x Peak Month Heating Load Factor (PMHLF)

$$PMHLF = \frac{\text{Room Temp(RT) - Peak Month Average Temperature(PMAT)}}{\text{Room Temp(RT) - Peak Day Average Temperature(PDAT)}}$$

Utilizing the date in Tokyo, PMHLF is calculated as follow:

RT : 18°C

DT : 3.7°C

PDAT : 0.76°C

$$PDHLF = \frac{18 - 3.7}{18 - 0.76} = 0.82$$

iii) Monthly Heating Load Factor (MHLF)

Generally, the monthly heating load is considered to be inversely proportional to the monthly average temperature. Whereas, degree days are proportional to the outside air temperatures. Then, using degree days as a parameter, monthly heating load factor (MHLF) in each month will be determined, taking the degree days in the coldest month (January) as 1.0, referring to the Figure 5.6.2. MHLFs obtained are shown in Table 5.6.3.

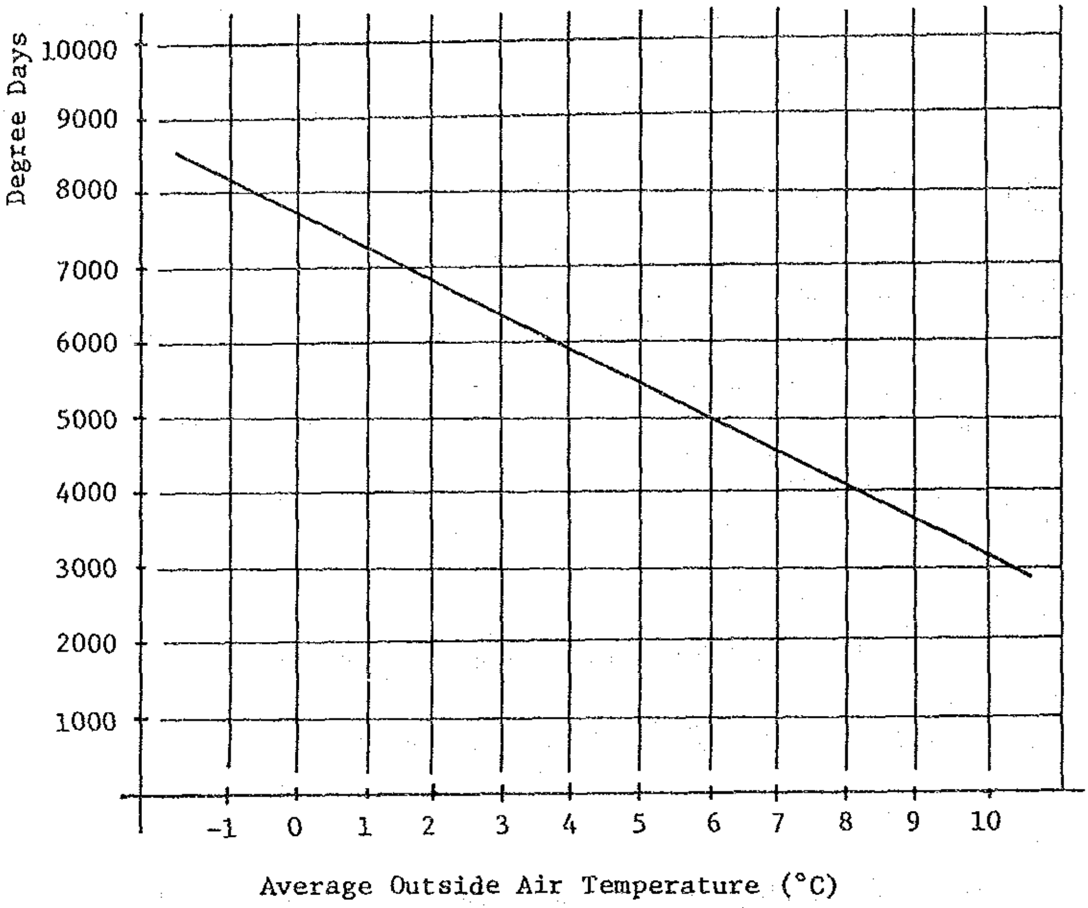


Figure 5.6.2 Average Outside Air Temperature vs Degree Days

Table 5.6.3 Monthly Heating Load Factors (MHLF)

Month	Average Outside Air Temperatures	Degree Days	MHLF
Nov	8.3°C	3800	0.48
Dec	2.2	6500	0.81
Jan	-0.3	8000	1.00
Feb	1.1	7300	0.91
Mar	5.0	5500	0.69
Total			3.89

iv) Calculation of PHL

HH : 16 hours/day

PDHLF : 0.82

PMHLF : 0.83

HD : 30 days/month

MHLF : 3.89

Consequently, the formula presented in 5.6.2(3) is rewritten as follows:

$$PHL = \frac{THL}{HH \times PDHLF \times PMHLF \times HD \times MHLF}$$

$$= \frac{THL}{16 \times 0.82 \times 0.83 \times 30 \times 3.89}$$

$$= \frac{THL}{1270.8} \quad \text{(Gcal/hr.mesh)}$$

(4) District Heating Plant Load

Peak heating load (PHL) is not necessarily the heating load for district heating plant. By centralizing the heat generation, a certain degree of reduction in heating load is expected. Therefore, a reduction factor η should be considered. Then, heating load for the plant is expressed as follow:

Plant heating load = η x PHL G cal/hr·mesh

The factor η is generally said to be 0.8.

$\eta = 0.8$

5.6.3 Selection of Applicable Area in Ankara

A district heating system is practically applicable only to those areas which have a heating load density above a certain level.

From the experiences in Japan, the minimum heating load density for the application of district heating system can be assumed to be 50 $kcal/m^2 \cdot hr$. It corresponds to the heating load of 12.5 Gcal/hr for one mesh (25 ha), covering both space heating and domestic hot water loads.

Generally, portion for the domestic hot water load is said to be 15 percent of the total load. Accordingly, the heating density which makes a district heating system practical for one mesh will be:

$$12.5 \times (1-0.15) = 10.0 \text{ Gcal/hr} \cdot \text{mesh}$$

Meshes that have a heat density greater than 10.0 Gcal/hr·mesh are selected to be covered by the district heating system.

Selected meshes are shown in Figure 5.6.3.

The total seasonal heating load in the selected 118 meshes is:

3,021,284 Gcal/season

Whereas, that in all the meshes is:

4,764,853 Gcal/season

Consequently, the percentage of the seasonal heating load to be covered by the district heating systems is:

$$\frac{3{,}021{,}284 \text{ Gcal/season}}{4{,}764{,}853 \text{ Gcal/season}} = 0.634\ (63.4\%)$$

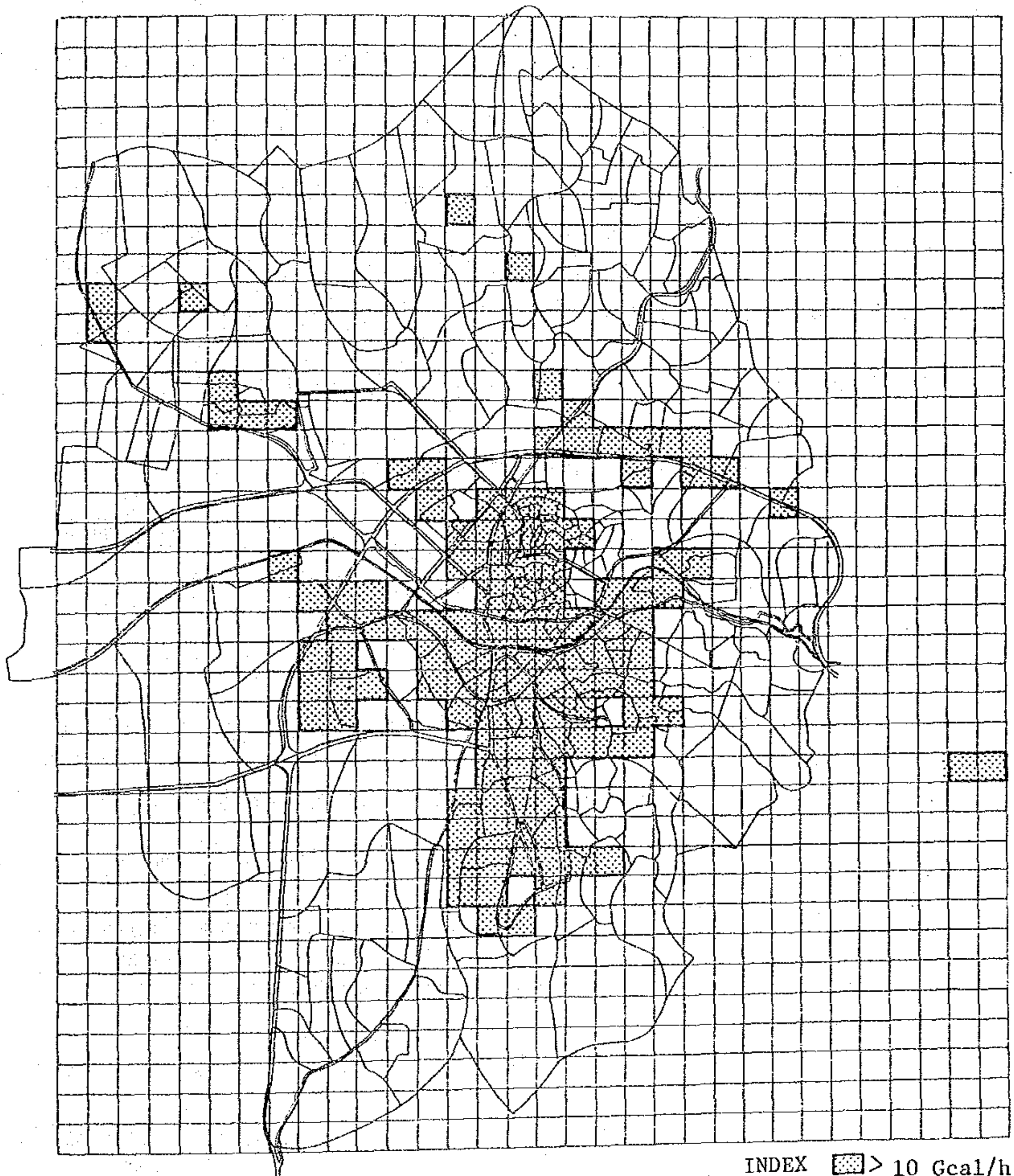


Figure 5.6.3 Selected Meshes for the Application of District Heating System

5.6.4 Effect and Cost

(1) Effect of the Application

i) Seasonal Fuel Consumption

a. Seasonal District Heating Plant Load (SDHPL)

The total heating loads (THL) calculated from the fuel consumption as above are those of individual (non-centralized) heating systems. If the district heating systems are introduced, seasonal district heating load will be smaller than the said total heating loads due to centralization.

District Heating Load = THL x η'

η' : Coefficient of Centralization

The value of η which was specified previously for the computation of PHL can be used as η':

$\eta' = 0.8$

In this study, three types of fuels, ungraded lignite, laved lignite, and fuel oil are considered for the district heating systems. Calorific values and sulfur contents of these fuels are shown in Table 5.6.4.

Table 5.6.4 Calorific Values and Sulfur Contents of Fuels

Type of Fuel	Calorific Value	Sulfur Content
Ungraded Lignite	4750 kcal/kg	2.7%
Laved Lignite	4980	1.4
Fuel Oil	10500	0.9

b. Seasonal Fuel Consumption (SFC)

Boiler efficiency is assumed to be 85%.

Accordingly, SFCs are determined, respectively, as follows:

$$\text{SFC by Ungraded Lignite} = \frac{\text{SDHPL}}{4750 \times 0.85 \times 10^3} \quad \text{(tons/season)}$$

$$\text{SFC by Laved Lignite} = \frac{\text{SDHPL}}{4950 \times 0.85 \times 10^3}$$

$$\text{SFC by Fuel Oil} = \frac{\text{SDHPL}}{10500 \times 0.85 \times 10^3}$$

Total SFCs are as follows:

Ungraded Lignite system	:	589,853 tons/season
Laved Lignite System	:	571,974
Fuel Oil System	:	269,607

(2) Cost Estimation

i) Construction Cost

It is generally said that the construction cost of the district heating systems is 50 million yen per heating capacity of one Gcal/Hr, including piping network, desulfurization facility, plant building, and so forth.

Total district heating plant capacity required is obtained by totalling all the plant loads of the selected meshes.

Plant Capacity = 1811.5 Gcal/hr

Accordingly, the total construction cost is:

50 million yen x 1811.5 = 90.6 billion yen
(190 billion TL)

ii) Operational Cost

According to an experimental study in Tokyo, components of the total operational cost of the district heating plant are as follows:

Table 5.6.5 Components of the Total Operational Cost

Items	Percentage
Operational Costs	
Fuel Cost	42.9
Utility Costs	1.7
Personnel Cost	15.3
Land Cost	2.5
Maintenance/Repair Cost	4.7
Tax	2.7
Subtotal	69.8
Fixed Costs	
Amortization/Interest	30.2
Total	100.0

From Table 5.6.5, the total operational cost of the district heating system can be expressed in terms of the fuel cost as follows:

Total Operational Cost = Fuel Cost x 2.33

The unit costs of the fuels are assumed to be as follows:

Ungraded Lignite	:	14,000 TL/ton
Laved Lignite	:	14,000
Fuel Oil	:	108,585

The total fuel consumptions in the selected meshes are previously obtained. Therefore, the operational costs of the district heating plants are obtained as follows.

Ungraded Lignite	:	19.24 billion TL/season
Laved Lignite	:	18.66
Fuel Oil	:	68.21

(3) Reduction of Sulfur Dioxide Emission

Sulfur contents in the fuels are 2.7% in ungraded lignite, 1.4% in laved lignite, and 0.9% in fuel oil. When combusted, the amount of SO_2 gas to be emitted is:

Ungraded Lignite	:	$SFC \times \frac{54}{1000}$ tons/season
Laved Lignite	:	$SFC \times \frac{28}{1000}$
Fuel Oil	:	$SFC \times \frac{18}{1000}$

By installation of desulfurization facility, a maximum of fifty (50) percent of SO_2 will be collected out of the exhaust gas.

Then, total seasonal SO_2 gas emission in the selected 118 meshes is:

Ungraded Lignite	:	15,926 tons/season
Laved Lignite	:	7,497
Fuel Oil	:	2,365

Present quantity of SO_2 gas emitted into the air in winter from the heating apparatus in the selected 118 meshes is 25,105 Tons.

By introduction of district heating systems, the following reduction of SO_2 emission is expected for each system in the selected 118 meshes:

Ungraded Lignite System	:	9,179 tons/season	(36.6%)
Laved Lignite System	:	17,608	(70.1%)
Fuel Oil System	:	22,740	(90.6%)

5.7 EVALUATION OF THE SOURCE CONTROL MEASURES

5.7.1 Characteristics of the Measures

The characteristics of the pollutant source control measures discussed in the previous Sections are summarized in terms of three aspects, i.e., technical, economic, and financial, and are shown in Table 5.7.1.

5.7.2 Evaluation by Matrix

Each measure of pollutant source control was evaluated based on the criteria shown in Table 5.7.2. Evaluation was made on the relative basis using 4 classes of symbols as follows:

A+ :	Excellent	(> 70% in case of sulfur reduction effect)
A :	Good	(50 - 70% in case of sulfur reduction effect)
B :	Fair	(30 - 50% in case of sulfur reduction effect)
C :	Not good	(< 30% in case of sulfur reduction effect)

Results of the evaluation are shown in Table 5.7.3 in a matrix form.

Table 5.7.2 Criteria for Evaluation of Source Control Measures

Aspect	Evaluation Item	Criteria
Technical	Sulfur reduction effect	Effect in sulfur reduction by the applied measure. Larger the better.
	Lead time	Time required until the improvement effect becomes explicit after start of adoption. Shorter the better.
	Applicable area	Size of applicable area. Larger the better, particularly if it is applicable in city center.
	Availability	Availability of necessary material within the country. Higher the better.
	Manegeability	Simplicity of the implementation. Better if specific technique or caution is not required.
Economic	Import reliance	Reliance on import. Lower the better.
	Rate of return	Internal rate of return of investment. Higher the better
Financial	User's expense	Cost to be paid by users. Smaller the better
	Subsidy	Subsidy by government. Smaller the better.

Table 5.7.1 Characteristics of Pollutant Source Control Measures

Source Control Measure			Technical Characteristics	Economic Characteristics	Financial Characteristics
Switchover from ungraded lignite to laved lignite			· 48% S reduction	· cost higher than ungraded lignite	· retail price same as ungraded lignite adjusted by government
Lignite quality improvement	Briquette		· S fixation by lime · shaping into Maschec type · cement binder · 77 - 81% S reduction	· plant cost 5,400M.TL for the capacity of 100,000 t/yr	· expense increase per household 24% with existing stove, 12% with improved stove
	Rentan		· S fixation by lime · cylindrical shape · cement binder · 86% S reduction	· plant cost 1,930 M.TL for the capacity of 84,000 t/yr	· new type stove required · expense decrease per household 18%
	Biocoal		· S fixation by lime · shaping into Maschec type · pulverized wood binder · 79 - 82 S reduction	· plant cost 4,940 M.TL for the capacity of 100,000 t/yr	· expense decrease per household 1% with existing stove, 12% with improved stove
Improvement of combustion and heating apparatus and combustion methods	Lignite stove	Improvement of devices	· combustion efficiency improvement by use of damper and steel made stove · 20 - 28% fuel saving	· price of stove is 10,000 - 15,000 TL higher than present type · fast capital return	· entrust supply to market · expense decrease by fuel saving
		Lime mixed combustion	· lime added to lignite in 3 separate layers for mixed combustion · S reduction up to 60%	· low cost	· government propaganda and education required for popularization
	Boiler combustion and maintenance	Training of boiler operator	· knowledge and technics on combustion facilities and combustion methods	· fuel saving effect	· cost borne by employer and beneficiary
		Cleaning of smoke tubes	· vaccum smoke tube cleaner · 23% fuel saving · large effect for lignite boiler	· price of vacuum cleaner 570,000 TL	· joint ownership by 3 - 5 apartments, or round service by commercial base
		Utilization of damper	· control of heat loss from stack · 10% fuel saving	· small effect for fuel saving	· no direct expense
		Cleaning of water pipes	· periodic cleaning of water pipes by the use of agents · 20 - 30% fuel saving	· fuel saving effect 250,000 TL/boiler	· medium expense · compensated by fuel saving
	Heating control system	Variable flow rate/ constant temperature	· installation of flow controller corresponding to room temperature in each room · 20 - 27% fuel saving	· investment cost 38,000 M.TL in total · fuel saving about 6,000 M.TL/yr	· initial expense per household 235,000 TL · compensated by fuel saving
		Constant flow rate/ variable temperature	· installation of water temperature controller · large effect for fuel oil system · 20-25% fuel saving	· investment cost 16,800 M.TL in total · fuel saving about 6,000 M.TL/yr	· initial expense per household 105,000 TL · net gain by fuel saving
Introduction of smoke and soot removal devices	Flue gas desulfurization	Dry type	· blowing lime into boiler S reduction up to 50%	· investment cost 2.1 M.TL for 90 t/yr boiler	· maintenance cost 1,350,000 TL/yr for average building
		Wet type	· absorption of sulfur by alkalisolution · large amount of water and its treatment required · 70% S reduction	· investment cost 500 M.TL for treating 1,000 Nm^3/hr flue gas	· maintenance cost at least 6,000,000 TL/yr for average building
	Dust removal	Cyclone	· gravity settling · simple mechanism	· investment cost 1.5 - 1.9 M.TL	· large expense · no sulfur removal effect
		Bag filter	· filtration by bag filter	· cost higher than cyclone	same as above
		Electric precipitator	· dusts are ionized and adsorbed on the electrode	· same as above	same as above
		Others	· mist separater · scrubber, etc.	· same as above	same as above
Improvement of thermal insulation of buildings			· about 30% fuel saving	· increase of construction cost · capital return possible	· market supply necessary
Introduction of district heating system	Ungraded lignite system		· applicable to the area of heating density greater than 40 Gcal/hr·km^2 · S reduction up to 37%	· plant cost 1,800 billion TL	· organization of large scale public corporation necessary
	Laved lignite system		· same as above · S reduction up to 70%	· same as above	same as above
	Fuel oil system		· same as above · S reduction up to 90%	· same as above	same as above

Table 5.7.3 Evaluation Matrix for Source Control Measures

Source Control Measure			Technical					Economic		Financial		Experience in Ankara
			Sulfur reduction effect	Lead time	Applicable area	Availability	Manage-ability	Import reliance	Rate of return	User's expense	Subsidy	
Switchover from ungraded lignite to laved lignite			B	B	A+	A+	A+	A+	A+	A+	A+	planned
Lignite quality improvement	Briquette		A+	B	A+	A+	A	C	C	B	B	
	Rentan		A+	B	B	A	B	B	B	A+	A	
	Biocoal		A+	B	A+	A+	A	C	C	A+	B	
Improvement of combustion and heating apparatus and combustion methods	Lignite stove	Improvement of devices	C	A	B	A	B	A+	B	B	B	being done partially
		Lime mixed combustion	A	A	B	A	B	A+	A+	A+	B	described in the text-book for boiler operation
	Boiler combustion and maintenance	Training of boiler opertor	C	B	A	C	B	A	A	A	C	institutionalized
		Cleaning of smoke tubes	C	A+	A	B	B	A	A	A	A	described in the text-book for boiler operation
		Utilization of damper	C	A+	A	A	A	A	A	A	A	installed in some boilers
		Cleaning of water pipes	C	A+	A	A	A+	A	A	A+	A	a few experience
	Heating system	Variable flow rate/ constant temperature	C	C	A	C	A+	C	C	C	B	manufacturers exist
		Constant flow rate/ variable temperature	C	B	A	C	A+	C	A	A	B	
Introduction of smoke and soot removal devices	Flue gas desulfurization	Dry type	B	B	A	B	B	A	B	A	B	
		Wet type	A	C	B	C	C	C	C	C	B	
	Dust removal	Cyclone	C	A	B	B	B	A	B	C	B	used at some factories
		Bag filter	C	B	B	A	B	C	C	C	B	
		Electric precipitator	C	B	A	C	C	C	C	C	B	
		Others	C	C	C	C	B	C	C	C	B	
Improvement of thermal insulation of buildings			C	C	A	A	A+	A	B	C	A	institutionalized
Introduction of district heating system	Ungraded lignite system		B	C	B	C	B	C	C	C	C	adopted in Batikent and other projects
	Laved lignite system		B	C	B	C	B	C	C	C	C	
	Fuel oil system		B	C	B	C	B	C	C	C	C	

CHAPTER 6 SELECTION OF POLLUTANT SOURCE CONTROL PLAN

CHAPTER 6 SELECTION OF POLLUTANT SOURCE CONTROL PLAN

6.1 METHOD OF SELECTION

Individual measures will be selected first, and then source control plans will be selected by combining those individual measures.

Individual measures are selected from those which received high points, A^+ or A, in the evaluation matrix in Section 5.7. The target of the control plan are determined referring to the pollution levels set as the basis for issueing an order of emergency measures specified by the Provincial Government of Ankara. These levels are given by 24-hour mean values for SO_2 and PM in four steps starting with the 1st level, 700 $\mu g/m^3$ for SO_2, and 400 $\mu g/m^3$ for PM, and specifying higher values for the consecutive three levels.

Emergency measures are also classified into 4 steps corresponding to these pollution levels. Restriction on heating hours is given from the 1st level, and gradually becomes harder in the consecutive levels. Thus, inconvenience in the public life and city functions is inevitable.

Although the primary purpose of air pollution control is the protection of public health, securing comfortable living environment is also an important goal. In this view, setting a target that "never to exceed the 1st level of the emergency" has a deep significance. This means that the occurrence of high levels of pollution exceeding the 1st level on the 155 days (total of 7 stations) observed by the Study Team during the winter of 1984/85 is to be eliminated completely. It will contribute to the protection of the public health by reducing radically the concentration of SO_2. Therefore, the target of pollution measure is set as follows;

> One-day mean concentration of SO_2 in Ankara is to be kept below 700 $\mu g/m^3$.

Individual measures already set up by the Turkish authorities are included here as one of the measures of the control plan. They are considered to be effective if implemented. Because of the fact that those measures were determined recently, some of the anticipated effects have not been seen to date.

6.2 SELECTED MEASURES

Number of A and A+ for the individual measures are shown in Table 6.2.1. The measures to which 4 or more of A or A+ are given are considerated to be desirable to be adapted.

Table 6.2.1 Number of A and A+ for Individual Measures

Source Control Measure			Number of A and A+			
			Technical	Economic	Financial	Total
Switchover from ungraded lignite to laved lignite or low-sulfur coal			3	2	2	7
Lignite Quality Improvement	Briquette		4	0	0	4
	Rentan		2	0	2	4
	Biocoal		4	0	1	5
Improvement of combustion and heating apparatus and combustion methods	Lignite stove	Improvement of devices	2	1	0	3
		Lime mixed combustion	3	2	1	6
	Boiler combustion and maintenance	Training of boiler operator	1	2	1	4
		Cleaning of smoke pipes	2	2	2	6
		Utilization of dumper	4	2	2	8
		Cleaning of water pipes	4	2	2	8
	Heating control system	Variable flow-rate/constant temperature	2	0	0	2
		Constant flow-rate/variable temperature	2	1	1	4
Introduction of smoke and soot removal devices	Flue gas desulfurization	Dry type	1	1	1	3
		Wet type	1	0	0	1
	Dust removal	Cyclone	1	1	0	2
		Bag filter	1	0	0	1
		Electric precipitator	1	0	0	1
		Others	1	0	0	1
Improvement of thermal insulation of buildings			3	1	1	5
Introduction of district heating system	Ungraded lignite system		0	0	0	0
	Laved lignite system		0	0	0	0
	Fuel oil system		0	0	0	0

Based on the evaluation results, following individual measures are selected to constitute the control plan.

i) Switchover from ungraded lignite to laved lignite or low-sulfur coal

ii) Lignite quality improvement

   a. Rentan
   b. Biocoal

iii) Improvement of combustion and heating apparatus and combustion methods

   a. Lime mixed combustion in lignite stove
   b. Training of boiler operator
   c. Cleaning of smoke pipes
   d. Utilization of damper
   e. Cleaning of water pipes
   f. Constant flowrate/variable temperature system

iv) Improvement of thermal insulation of buildings

Although receiving high mark in Table 6.2.1, an alternative to use briquette is not selected because it is inferior to the use of biocoal, in respect to cost saving. Thus, the measure to use biocoal was selected here.

6.3 SELECTED PLANS

6.3.1 Mid-term Plan and Temporary Plan

A mid-term plan to achieve the target, and a temporary plan to be implemented for a limited period are selected and are shown in Table 6.3.1 together with the cases for no plan and existing plan.

Table 6.3.1 Mid-term Plan and Temporary Plan

Case / Objective	Without plan	Existing plan	Temporary plan(*)	Mid-term plan	Remarks
Lignite stove	Ungraded lignite	Same as left	Switchover to laved lignite in 100%	Convert to rentan and biocoal*	*from ungraded lignite
Lignite boiler	Laved lignite : 50% Ungraded lignite: 50%	Switchover to laved lignite in 100%	Same as left	Convert to biocoal**, cleaning smoke pipes and water pipes, utilization of damper	**from laved lignite
Fuel oil boiler	New buildings use fuel oil	Same as left	Same as left	Use constant flowrate/ variable temperature. Cleaning smoke pipes and water pipes, utilization of damper	
Improvement of thermal insulation of buildings	New buildings save 30% of the fuel	Same as left	Same as left	Same as left	
Training of boiler operator	Gradual realization	Same as left	Same as left	Same as left	

(*) Although the switchover to the laved lignite in 100% is assumed here, other low-sulfur fuels such as bituminus coal can be used in place of the ungraded lignite or the laved lignite totally or partly depending on the quality of the fuel.

The approximate investment costs for the mid-term plan are shown in Table 6.3.2. Cost for the temporary plan is not estimated here, because it is basically the same as the existing plan.

Table 6.3.2 Investment Cost for the Mid-term Plan

Measure	Unit	Cost per unit (MTL)	Number of units	Investment cost (MTL)	Remarks
Rentan	84,000	1,930	4	7,720	
Biocoal	100,000^{t}	4,940	6	29,640	
Constant flow rate/variable temperature system	Oil boiler 1 unit	0.84	5,300	4,450	
Cleaning of smoke pipes	Cleaner 1 unit	Vacuum type cleaner 0.57	3,200 1/5 of total number of boilers	1,820	
Utilization of damper	-	-	-	-	Use existing dampers or small investment
Cleaning of water pipes	Boiler 1 unit	Cleaning agent 0.25/boiler	16,000	4,000	
Total				47,630	

Effects in fuel saving and reduction of SO_2 emission by the implementation of mid-term plan and the temporary plan are shown in Table 6.3.3 and Table 6.3.4, respectively. Reduction of SO_2 emission by the mid-term measures is 77% against the no measure case, and 37% by the temporary measures.

Table 6.3.3 Effect of Mid-term Measures (1995)

Source	Fuel	Fuel consumption ($1,000^t$/season)		SO_2 Emission ($1,000^t$/season)	
		No plan	Mid-term plan	No plan	Mid-term plan
Stove	Ungraded lignite	603	-	33	-
	Rentan	-	320	-	3
	Biocoal	-	120	-	2
	Coke, Coke-briquette	14	14	2	2
Boiler	Ungraded lignite	266	-	14	-
	Laved lignite	275	-	8	-
	Biocoal	-	398	-	4
	Fuel oil	220	153	4	3
Total		1,378	1,005	61	14
Ratio to no-plan case		100	73	100	23

Table 6.3.4 Effect of Temporary Measures (1986)

Source	Fuel	Fuel consumption ($1,000^t$/season)		SO_2 Emission ($1,000^t$/season)	
		No plan	Temporary plan	No plan	Temporary plan
Stove	Ungraded lignite	574	-	31	-
	Laved lignite	-	574	-	16
	Coke, Coke-briquette	14	14	2	2
Boiler	Ungraded lignite	266	-	14	-
	Laved lignite	275	541	8	15
	Fuel oil	220	220	4	4
Total		1,349	1,349	59	37
Ratio to no-plan case		100	100	100	63

6.3.2 Emergency Plan

The total effect of the aforementioned mid-term measures will appear after the completion of the step-by-step implementation of individual measures. In that process, such a high level of pollution might occur that requires emergency measures.

Besides the existing emergency measure, the Study Team recommends a simple desulferization by the lime mixed combustion in lignite stoves at emergency case. By this measure alone, total emission of SO_2 will be reduced by 25% as shown in Table 6.3.5.

Table 6.3.5 Reduction of SO_2 by Emergency Measure (1986)

Source	Fuel	Fuel Consumption (1,000 t/season)	SO_2 Emission (1,000 t/season)	
			No-measure	Emergency measure
Stove	Lignite	574	31	16
	Coke, Coke-briquette	14	2	2
Boiler	Lignite	541	22	22
	Fuel oil	220	4	4
Total		1,349	59	44
Ratio to no-measure case (%)			100	75

6.4 EFFECTS OF THE IMPLEMENTATION OF THE CONTROL PLANS ON THE CONCENTRATION OF SULFUR DIOXIDE

6.4.1 Cases and Conditions for Simulation

In order to estimate the effect of implementing each selected control plan in reducing ambient concentration of SO_2, computations were carried out using the simulation models developed and used in the analysis of the present state of air pollution.

Cases and conditions for the simulation are summarized in Table 6.4.1.

Table 6.4.1 Cases and Conditions for Simulation

Simulation Case		Object Year	Total emission reduction rate in the central part of the City (%)	Outline of control plan	Simulation Period and Meteorological Condition
General Plan	(1) Without Plan	1995	0	see Sec. 6.3.1	• Dec. 1984 -- Mar. 1985 • Observed conditions during the period
	(2) Existing Plan	1995	12% against (1)	see Sec. 6.3.1	
	(3) Mid-term Plan	1995	77% against (1)	see Sec. 6.3.1	
	(4) Temporary Plan	1986	37% against the present	see Sec. 6.3.1	
Emergency Plan	(5) Emergency Plan	1986	25% against the present	see Sec. 6.3.2	• Feb. 21, 1985 one day period • Observed conditions during the day
	(6) Existing Emergency Plan for the 1st Level	1986	40% against the present	•plan for the warning level •heating 4 hrs. each in the morning and afternoon	

The existing emergency plan shown in Table 6.4.1 is that proclaimed by the Provincial Government of Ankara for the 1st warning level (see Sec. 3.2.1). This case was included in the simulation cases for reference.

6.4.2 Simulation Results and Evaluation

(1) General Plans

Results of the computation of SO_2 concentration with the implementation of the general plans, i.e., without plan, existing plan, mid-term plan, and temporary plan, are shown in Figure 6.4.1 in the form of isoplethes for the winter average, high 24-hour mean, and high one-hour mean concentrations.

In the case of no plan, as a matter of course, SO_2 levels increased by a certain degree in comparison with those at present (see Sec. 2.7.1). The high 24-hour mean levels that exceed the 3rd warning level (about 580ppb) appeared in the area of about 100 ha in the vicinity of Kavaklidere. The area where the concentration exceeded the 1st warning level (about 270 ppb) occupied the greater part of the computation area (19,200 ha).

In the case of the existing plan, the area where the high 24-hour mean concentration exceeded the 1st warning level still occupied about a half of the object area, although the area exceeding the 3rd warning level virtually disapeared.

In the case of the mid-term plan, the area where the high 24-hour mean concentration exceeded the 1st warning level disappeared completely. The maximum concentration is about 170 ppb at the center of the City being 100 ppb lower than the 1st warning level.

In the case of the temporary plan, the area of high 24-hour mean levels exceeding the 1st warning level is about 400 ha (21% of the computation area) and that exceeding the second warning level (about 390 ppb) is about 800 ha (4% of the computation area), a significant improvement from the present (see Sec. 2.7.1).
The area exceeding the 3rd warning level seen in the present case over 100 ha does not appear with adoption of the temporary plan.

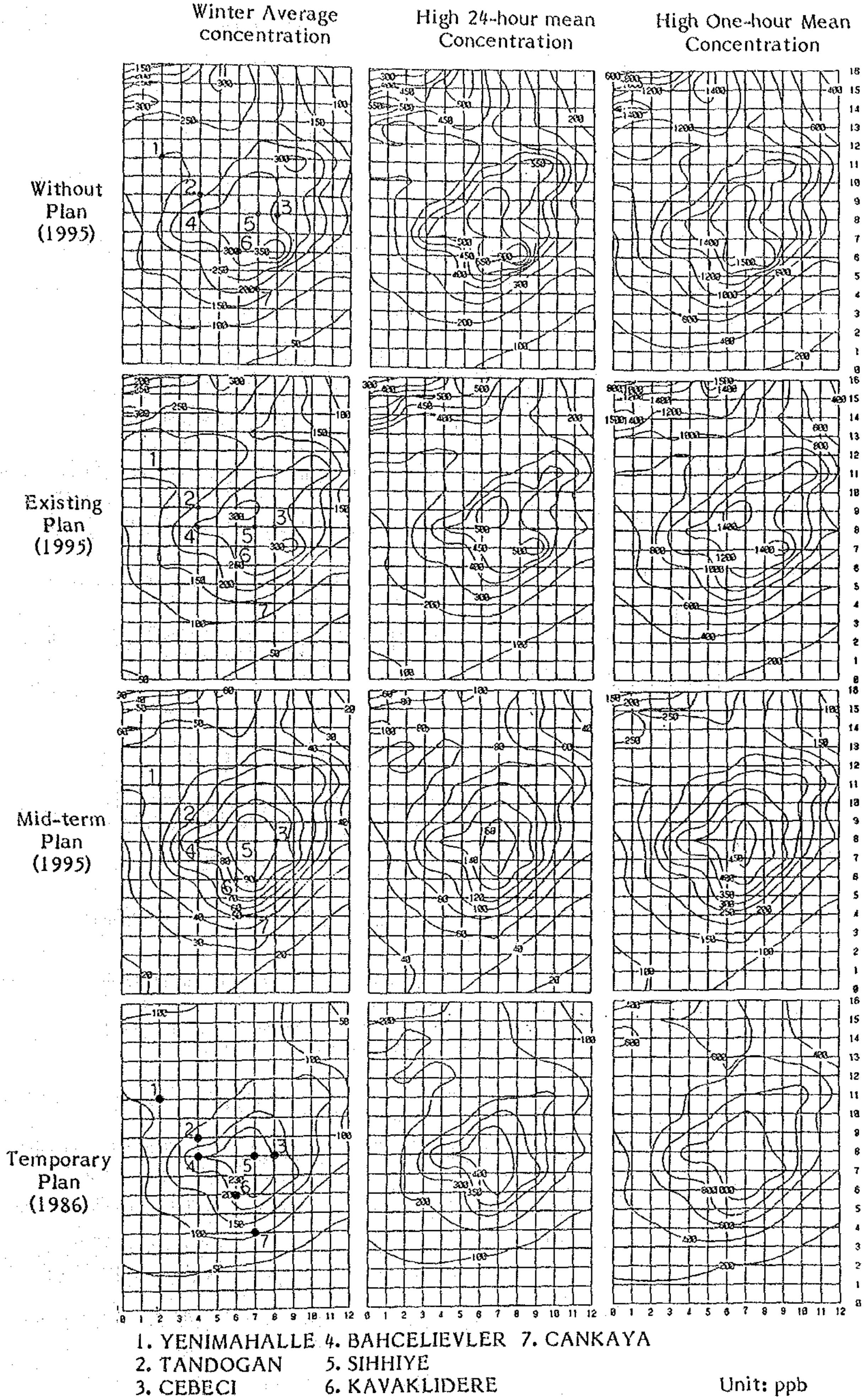


Figure 6.4.1 SO_2 Concentation with and without Implementation of General Plans

(2) Emergency Plans

i) Lime Mixed Stove Combustion

The reduction rates in SO_2 concentration due to the adoption of this plan are shown in Table 6.4.2 by each monitoring station.

Table 6.4.2 Rate of Reduction of SO_2 Concentration

Station	Morning peak hour (%)	Evening peak hour (%)	One day average (%)
Yenimahalle	17	17	17
Tandogan	13	20	18
Cebeci	18	19	19
Bahcelievler	7	19	11
Sihhiye	17	20	18
Kavaklidere	19	24	18
Cankaya	13	11	10

Notes 1) Reductions in concentration of SO_2 were obtained in reference to the concentrations under no action plan (see Sec. 2.7.3).

2) Reduction rates may be smaller than the above figures when the background concentration is added to the computed ones.

3) The period between 1 a.m. and 4 a.m. was excluded in the calculation of one-day average reduction rate because of the expected large relative errors due to the small values of concentration.

A considerable degree of reduction is expected by 10% - 20% as a whole. The rates of reduction at Bahcelievler and Cankaya are considerably lower than those at the other stations. Geographical distribution pattern of low-height emission sources, locational relationship between these sources and monitoring stations, and the prevailing meteorological conditions such as wind direction/speed and atmospheric stability are the influential factors to cause the local differences in the concentration reduction rates.

Time variation in the concentration of SO_2 (excluding background concentration) at each station is shown in Figure 6.4.2 in comparison with that at present. Reductions in the concentration at peak hours vary from 50 ppb to 300 ppb depending on the location.

ii) Existing Plan for the 1st Warning Level

Concentration reduction rates due to the adoption of this plan are shown in Table 6.4.3. Background concentration was again excluded in the computation. One-day mean reduction rates range from 33% to 44% among seven stations. The rate is the highest at Sihhiye and the lowest at Kavaklidere.

Table 6.4.3 Concentration Reduction Rate (One-day Average)

Station	Concentration Reduction Rate (%)
Yenimahalle	37.2
Tandogan	40.6
Cebeci	41.3
Bahcelievler	36.6
Sihhiye	43.6
Kavaklidere	32.6
Cankaya	40.9

Considering that the total reduction of SO_2 emission is about 40% by adopting this plan, higher rates are attained in the reduction of concentration at Sihhiye, Cebeci, Cankaya, and Tandogan. In the other stations concentration reductions are lower than 40%.

Time variation in the concentration of SO_2 (excluding background concentration) at each station is shown in Figure 6.4.3 in comparison with that at present. Reductions in the concentration at peak hours are between 0 and 100 ppb being smaller than those attained in the case of lime-mixed stove combustion.

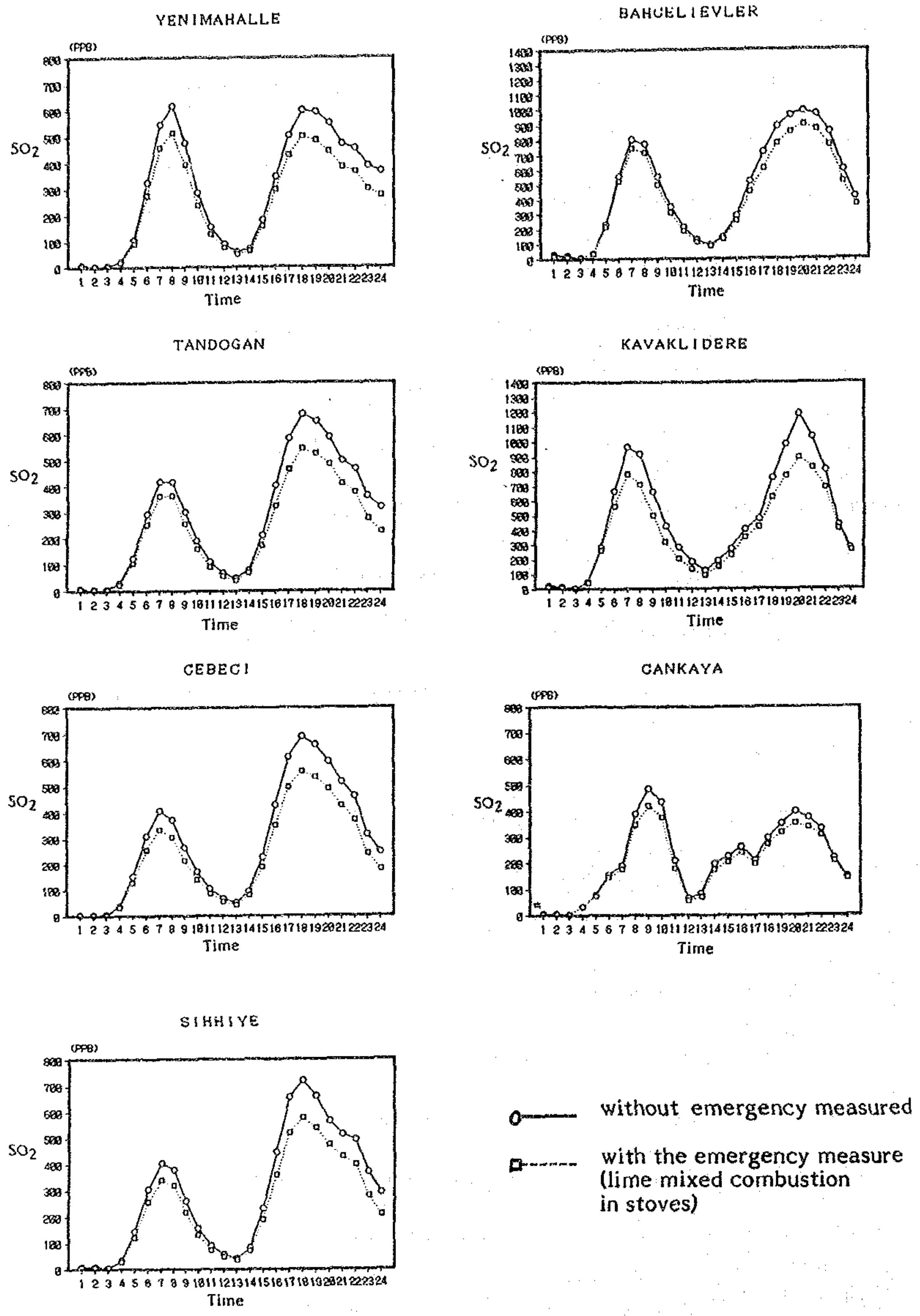


Figure 6.4.2 Time Variation of SO_2 Concentration With and Without Emergency Measure (Background conc. excluded)

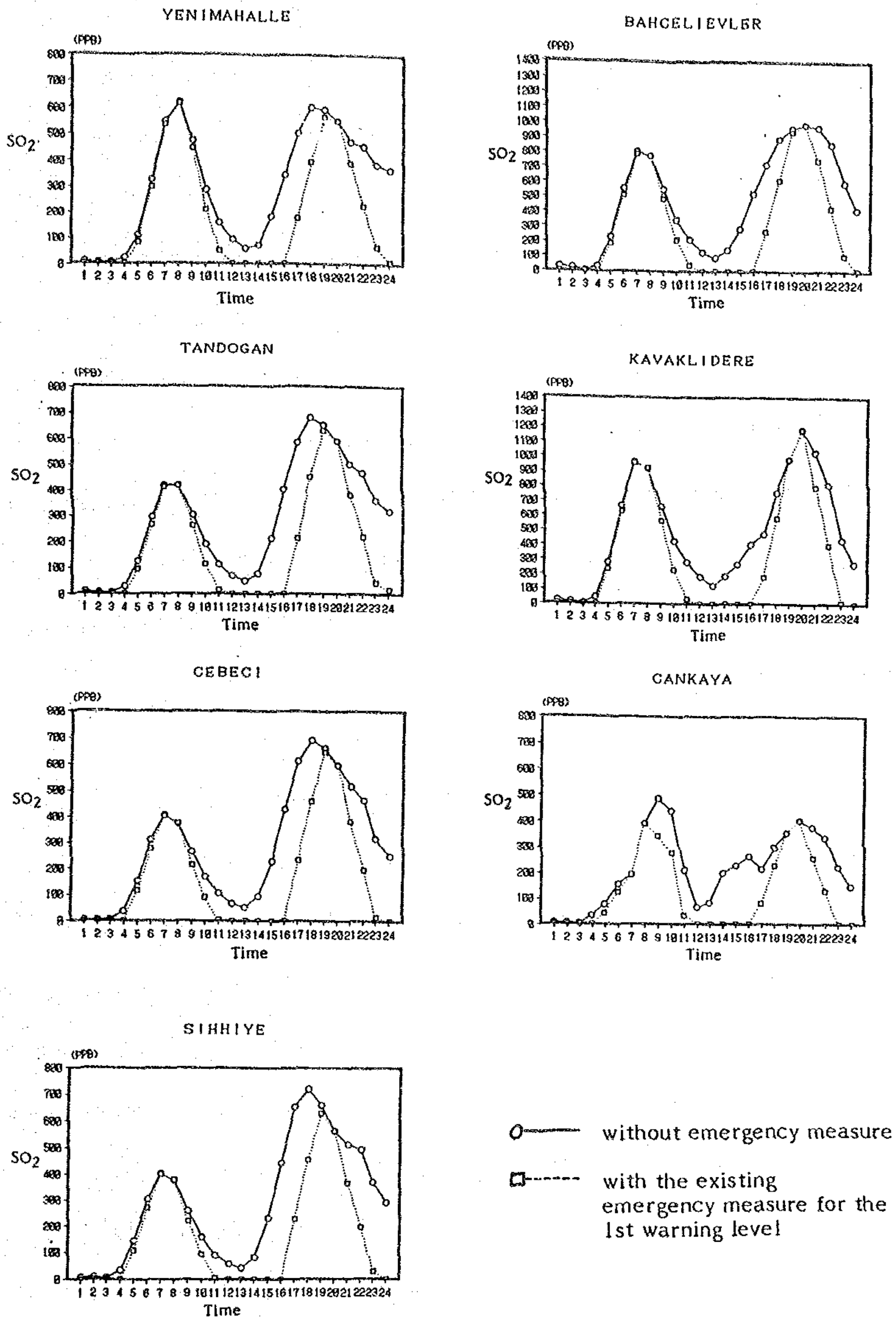


Figure 6.4.3 Time Variation of SO_2 Concentration With and Without Existing Emergency Measure(Background conc. excluded)

CHAPTER 7 PROPOSAL ON THE MONITORING SYSTEM AND ORGANIZATION

CHAPTER 7 PROPOSAL ON THE MONITORING SYSTEM AND ORGANIZATION

7.1 IMPORTANCE OF MONITORING SYSTEM AND ORGANIZATION

Establishment of monitoring system and organization is very important for promoting air pollution control. Air pollution in Ankara is, as described before, caused by the combination of emission gas generated by the domestic heating and topographic and meteorological conditions. As the main pollutant source is a large number of heating devices in houses and offices, participation of the citizen is essential for the effective implementation of the measures for reducing the pollutant emission. Announcing the present state of air pollution known through the monitoring will help the public to understand the situation and to form concensus on the necessity of drastic measures. Strong support of the public is needed for realization of the drastic measures because it requires a large amount of investment.

Control of air pollution can be made economically, though partially, by means of informing the public that 1) air pollution is caused by their heating apparatus, and 2) saving fuel will contribute to reduce air pollution. The effect in SO_2 reduction by this way may appear to be gradual. However, the effect of gradual measures as well as drastic measures will be certainly reflected in the concentration levels to be measured at the monitoring stations. Recognition of the effect of a measure by the citizen will promote further implementation of the measure.

As a part of the pollutant source control plans, an emergency plan was proposed in Chapter 6. In this relation, monitoring system is a means of obtaining data for forecasting the pollution level and deciding the announcement of forecast pollution level in order to ask the public for their cooperation in the emergency measures.

Publicizing an occurrence of high level pollution appeals to the public the seriousness of the need of the emergency measure, and it facilitates the execution of the control plans.

Position of the aforementioned monitoring system and organization in the implementation process of the pollution control program is shown in Figure 7.1.1.

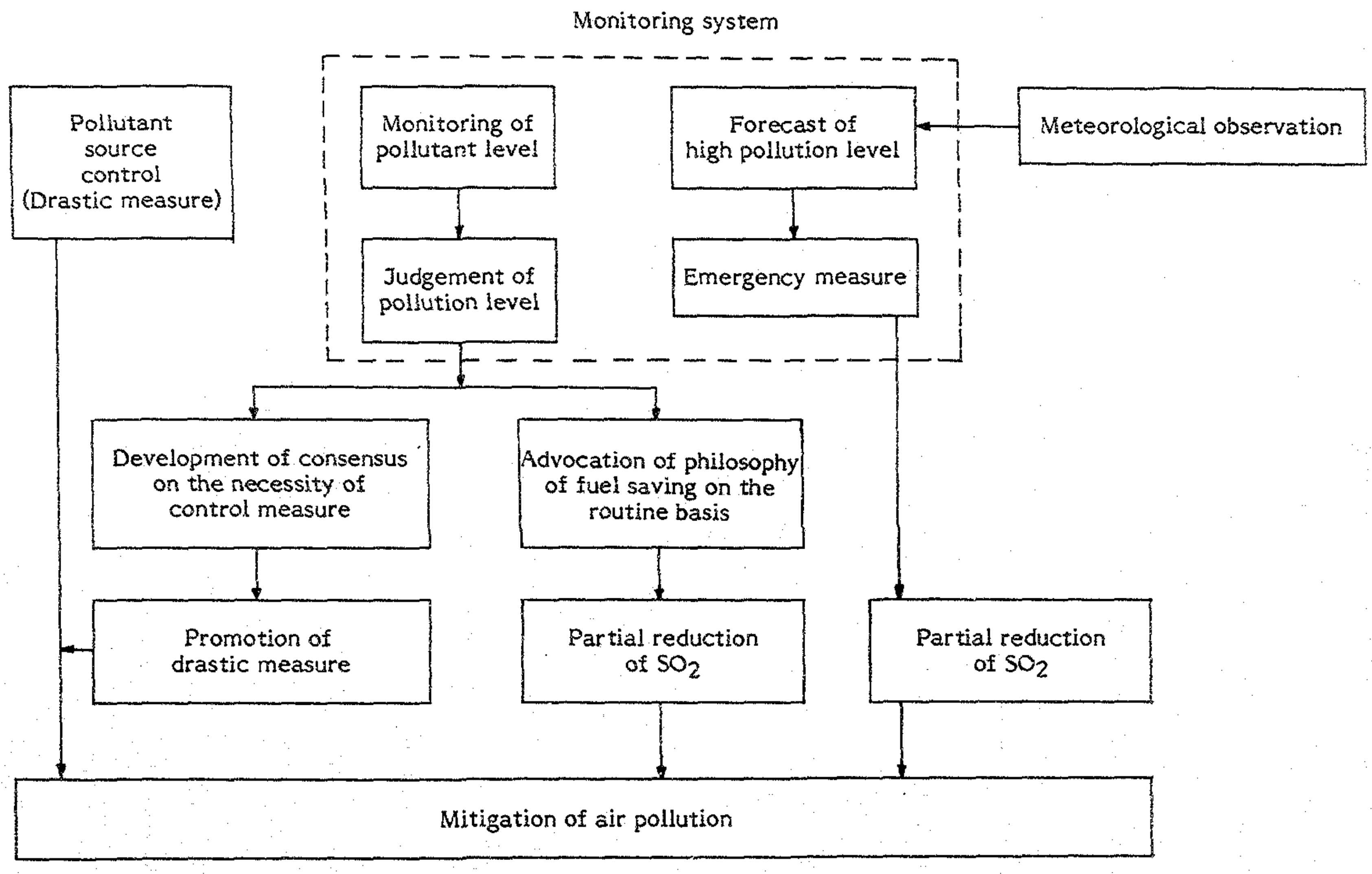


Figure 7.1.1 Monitoring System and Organization in the Process of Air Pollution Control

7.2 RECOMMENDATION OF MONITORING SYSTEM

At present in Ankara, sampling of PM (smoke) and SO_2 is made for 24 hours from 11 o'clock in the morning till the same time of the next day on the every day basis. Samples are sent to the Public Health Institute for analyses, and the results are reported to GDE on the same day, except on Saturday and Sunday, by telephone.

By this system, GDE can judge the pollution level by the 24-hour mean value of the previous day. Judgement of Friday data is made on Monday in the next week.

Present system may be useful only to know the daily condition of air pollution. For effective means for the source control at emergency case, however, it is preferable to inform the public more recent monitoring result because it is more persuasive for them to realize the situation. For this purpose, analyses and judgement of pollution level should be made also on weekends and holidays. It is also necessary to establish well defined regulations for efficient use of these results and for quick administrative action.

Establishment of a new organization may not be required for the announcement of the monitoring results. But, the way of the announcement needs careful consideration so that it enlighten the public to cooperate with administration not to react abusively against the administrative responsibility.

When proper method of announcement of the monitoring results is established and the public attitude toward the control activities is recognized to be cooperative, a more quick system of monitoring may be introduced enabling more effective promotion of the control measure.

Outline of a system of automatic monitoring and central control, called as telemetric system, is presented in the Appendix for reference.

7.3 PROPOSAL OF FORECAST SYSTEM

For implementing the emergency measures, an advance judgement on the pollution level is required, because certain time is needed until the announcement reaches widely to the users of heating devices. For this reason, forecast of the occurrence of high level pollution several hours ahead is required based on the information obtained by the time of the announcement.

Occurence of unusually high level of pollution should be forecasted in well coordination with weather forecast, because it is influenced by the meteorological conditions such as wind speed and temperature. Analyses of the meteorological conditions during the period of observation made by the Study Team revealed the relationship between meteorological condition and pollution characteristics (Table 7.3.1). Possibility if this relationship is always applicable, or if this can be used as a basis for the execution of the emergency measures must be studied and judged through the further accumulation of verification by the monitoring results.

Table 7.3.1 Relationship between Meteorological Condition and Pollution Level

	Pollution forecast	Pollution level (24-hour mean)	Meteorological condition (V: Average daily wind speed)
(A)	Not apt to become high level	Below emergency level	V: More than 2 m/s When cyclone or front is approaching or passing
(B)	Apt to become high level	1st level (700 μg/m^3) 2nd level (1,000 μg/m^3)	V: 1 - 2 m/s Average temperature: Daytime 0 - 5°C Night 0 - -10°C When wind speed in the upper layer weather chart is less than 20 m/s
(C)	Highly apt to become high level	3rd level (1,500 μg/m^3)	(i) V: Less than 1 m/s Average temperature Day and night: Over 0°C (ii) V: 1 - 2 m/s Average temperature Daytime: -3 - -10°C Night: below -10°C

Note: This table is made based on the monitoring results of SO_2 at Kavaklidereand Bahcelievler, and meteorological data of Ankara Meteorological Observatory during the period from Dec. 18, 1984 to Mar. 9, 1985.

If the crude forecast based on these classification becomes possible, the forecast of pollution level may become a next subject of study. This subject contains difficult technical problems. An example of the program concerning this subject is made based on the results of the field observation, and presented in the Appendix for reference. It contains also a forecast method to be made based on weather charts.

CHAPTER 8 IMPLEMENTATION PROGRAM OF AIR POLLUTION CONTROL PLAN

CHAPTER 8 IMPLEMENTATION PROGRAM OF AIR POLLUTION CONTROL PLAN

8.1 SOURCE CONTROL PLANS

Technical details and effects of the major source control measures were already given in the previous chapters. The control plans made up of several kinds of measures were also presented.

In this section, realistic programs for the implementation of the source control plans over the period of 10 years will be proposed.

8.1.1 Measures for Stoves

Control strategy for stove is focussed on those using ungraded lignite. The stoves using coke and coke-briquette are not included. The following measures are to be implemented in step by step, and enforced with emergency measure whenever necessary.

(1) Temporary Plan

Ungraded lignite is to be replaced by the laved lignite or low-sulfur coals immediately.

(2) Conversion to Rentan

In the year 1989, rentan using ungraded lignite as raw material is to be supplied by the amount of 80,000 tons to replace the laved or low-sulfur coals. The annual supply of the rentan is to be increased to 320,000 tons before or by the year 1992.

(3) Conversion to Biocoal

In the year 1989, biocoal made from ungraded lignite is to be supplied by the amount of 30,000 tons. The annual supply of the biocoal for stoves is to be increased to 120,000 tons before or by the year 1992.

8.1.2 Measures for Lignite Boilers

(1) Switchover to the Laved Lignite or Low-sulfur Coal

In 1986 the ungraded lignite (average sulfur content 2.7%) is to be totally switched over to the laved lignite (average sulfur content 1.4%) or to low-sulfur coal.

(2) Cleaning of Smoke Tubes and Water Pipes and Utilization of Damper

These measures are to be implemented from 1987.

(3) Switchover to Biocoal

In the year 1989, biocoal made from the laved lignite is to be supplied by the amount of 70,000 tons to replace the laved lignite or low-sulfur coal. The annual supply of the biocoal for lignite boilers is to be increased to 480,000 tons before or by the year 1994.

8.1.3 Measures for Fuel Oil Boilers

(1) Cleaning of Smoke Tubes

Smoke tube cleaning is to be started in 1987 at the same time for lignite boilers.

(2) Introduction of Automatic Temperature Control System

The automatic temperature control system by the constant flowrate-variable temperature mode is to be introduced from the year 1990, and wholly disseminated by the year of 1995.

8.1.4 Time Schedule for the Supply of Rentan and Biocoal

To begin the supply of the rentan and biocoal as soon as possible, necessary works for the construction of production plants must be started immediately. The works to be done and the time periods required for them are shown in Table 8.1.1.

Table 8.1.1 Processes and Lead Time for the Construction of Production Plants for Biocoal and Rentan

Work	Time required (month)
1. Master planning including the site selection considering the conditions in transportation, utilities, labor forces, etc.	6
2. Selection of engineering consultant by tender, basic design, and preparation of tender documents	8
3. Selection of contractor by tender, detailed design, and plant making	13
4. On-site construction of buildings and transportation of the plants	3
5. Plant installation and test operation	6
Total	36

As indicated in Table 8.1.1, it is considered reasonable to set the beginning year of supply of rentan and biocoal as 1989 because of the period of about three years required for the preparation. Beyond 1989, two cases of time schedule are considered for the expansion of supply capacity to reach the target level.

Case 1 Rentan is to be supplied from the year 1989 incremented annually by 80,000 tons for 4 years, reaching the supply capacity of 320,000 tons/yr in 1993.

Biocoal is to be supplied from the year 1989 incremented annually by 100,000 tons for 6 years, reaching the supply capacity of 600,000 tons/yr in 1994.

Case 2 The beginning year is the same as of Case 1. The target capacities are to be reached in the 2nd year, 1990.

In the Case 2, a special emphasis is placed on the environmental protection to anticipate the earlier improvement of air quality. However, the following technical and economic difficulties must be overcome for the implementation.

a. Rentan stoves must be supplied and the citizen must become familiar with the use of them in a short time.

b. Transporting means and stock yards for raw materials must be ensured.

c. Intensive capital investment is required.

d. A sufficient labor force must be secured for the operation of the plants.

e. Time for the step-by-step improvement of plant performances may be necessary.

In the Case 1, the difficulties mentioned above are minimized. However, the improvement of air quality will be delayed as compared with the Case 2.

8.1.5 SO_2 Emission Reduction by Implementatin of the Plans

Expected effect of implementation of the source control plans described above in reducing the emission of SO_2 is shown in Table 8.1.2 and Figure 8.1.1 for the Case 1 schedule, and in Table 8.1.3 and Figure 8.1.2 for the Case 2 schedule.

Table 8.1.2 SO_2 Reduction by Implementation of the Case 1 Plan

Unit: 1000 ton/season

Year	SO_2 emission without plan	With the plan	
		Quantity of SO_2 emission	Reduction (%)
1985	58.5	58.5	0.0
1986	58.7	36.5	38
1987	58.9	35.5	40
1988	59.1	35.6	40
1989	59.2	31.2	47
1990	59.4	26.8	55
1991	59.6	22.4	62
1992	59.7	18.0	70
1993	59.9	14.2	76
1994	60.1	14.2	76
1995	60.3	14.0	77

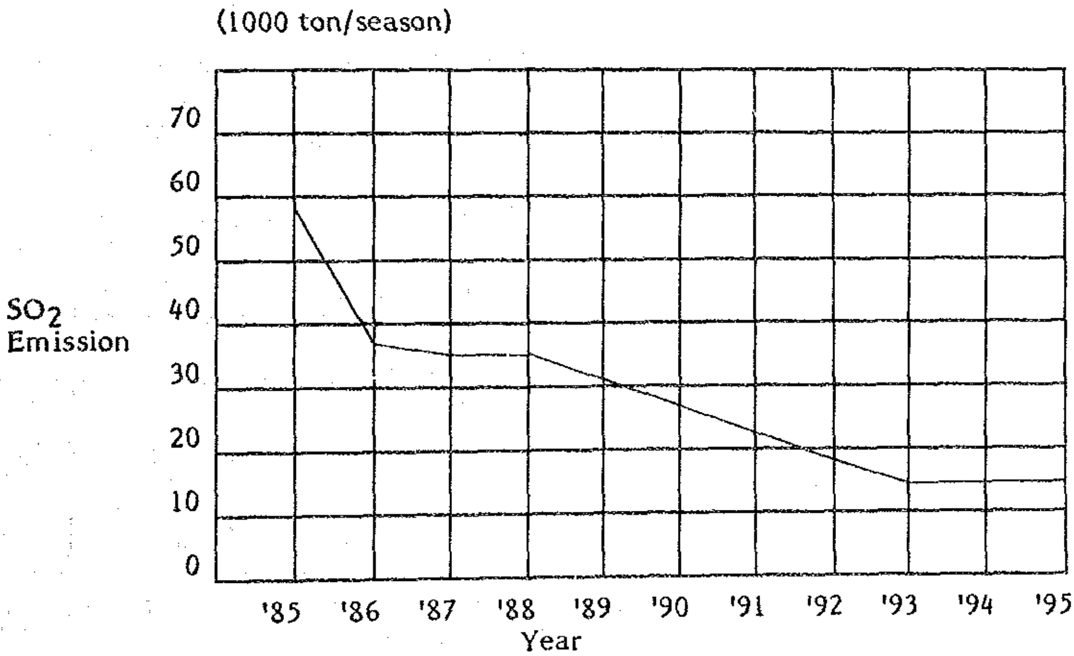


Figure 8.1.1 Annual Emission Quantity of SO_2 with Implementation of the Case 1 Plan

Table 8.1.3 SO_2 Reduction by Implementation of the Case 2 Plan

Unit: 1000 ton/season

Year	SO_2 emission without plan	With the plan	
		Quantity of SO_2 emission	Reduction (%)
1985	58.5	58.5	0.0
1986	58.7	36.5	38
1987	58.9	35.5	40
1988	59.1	35.6	40
1989	59.2	31.2	47
1990	59.4	14.1	76
1991	59.6	14.1	76
1992	59.7	14.2	76
1993	59.9	14.2	76
1994	60.1	14.2	76
1995	60.3	14.0	77

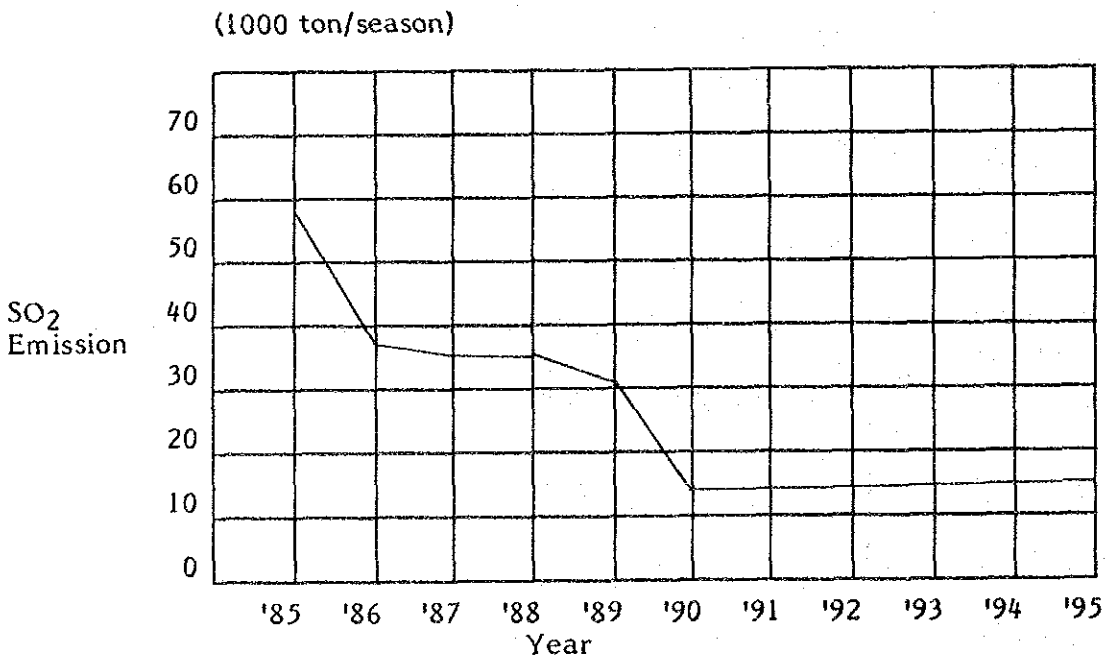


Figure 8.1.2 Annual Emission Quantity of SO_2 with Implementation of the Case 2 Plan

8.2 MONITORING SYSTEM AND ORGANIZATION

A proposal was made in Chapter 7 on the improvement of the present system of monitoring, organization for judging and publicizing pollution level, and development of the method of forecasting high pollution level.

A realistic schedule for the implementation of these programs over the period of 10 years is considered to be as follows.

The program that is considered to be necessary to start immediately is the establishment of monitoring system and organization of judging and publicizing pollution levels. These constitute the basis of air pollution control strategy, and require the definite position in policy and institutional and organizational support based on the recognition of the importance of protecting public health.

It is considered to be pertinent to start development of forecasting method for high pollution level in parallel to the aforementioned program. It is recommended to compile knowledge on the relationship between meteorological condition and measurement result of pollutant concentration, and to start adopting corroborated technique in the actual forecast.

8.3 PUBLIC ENLIGHTENMENT

Enlightenment of public on a routine basis to seek their cooperation is important for the smooth implementation of the whole air pollution control plan, as important as source control plan and monitoring plan are. It is recommended to let the public recognize the peculiar characteristics of the problem that major cause of air pollution in Ankara is the method of heating that is commonly practiced by the citizen. And it is also recommended to inform the public the control plan being adopted by the administration and the necessity of public cooperation.

It is considered to be highly effective in enlightening the public to explain by means of specific examples that the saving of heating energy reduces the air pollution and at the same time leads to the economic gain by the public.

8.4 IMPLEMENTATION PROGRAM

The implementation programs proposed in the previous sections are summarized in Figure 8.4.1.

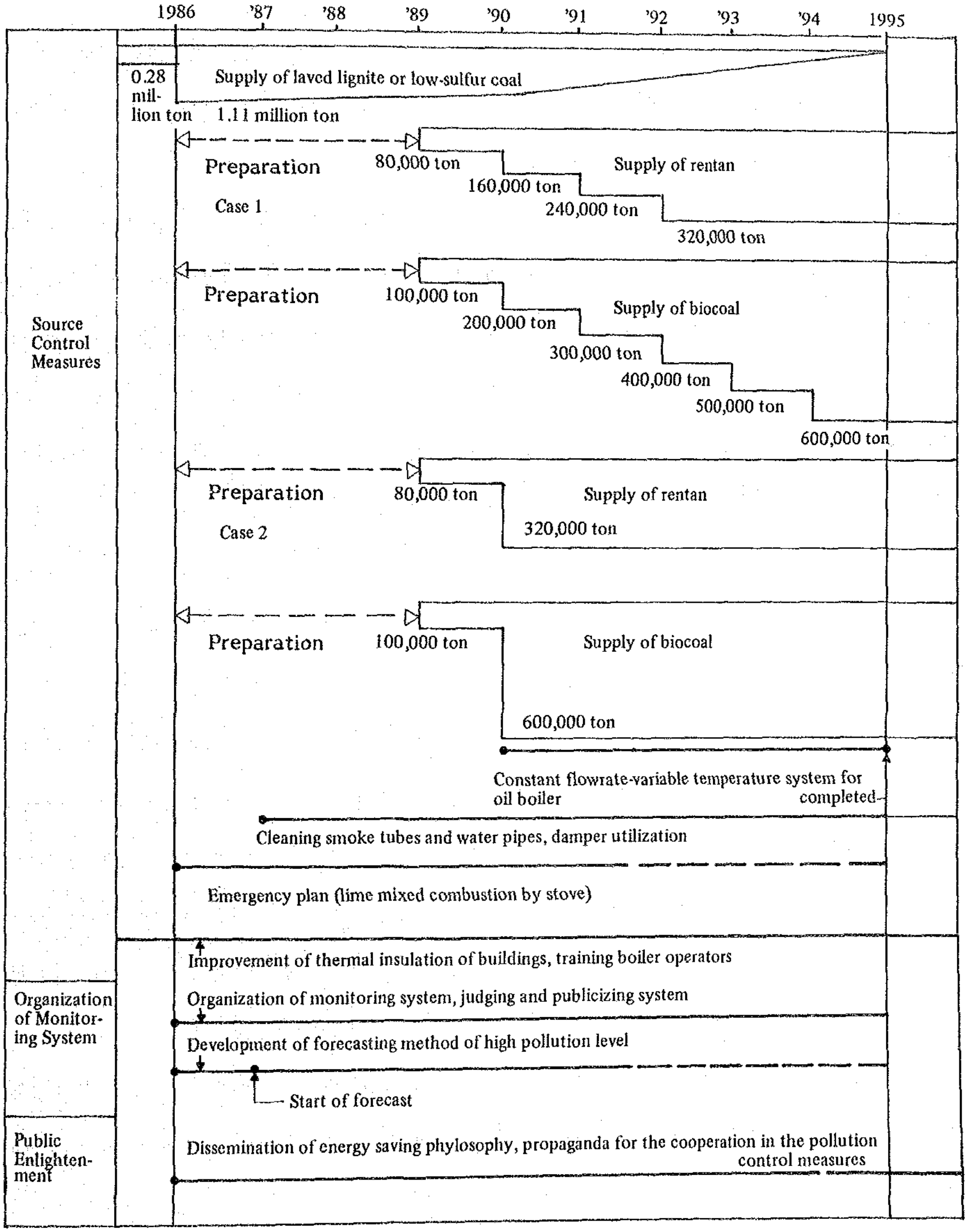


Figure 8.4.1 Time Schedule for the Implementation of the Control Plans