

substances, nitrogen oxide needs to undergo emission volume control like sulfur oxides. The total mass emission control standard, however, is applied to it as mentioned in the next paragraph 2).

The summary of the emission standards for soot and smoke is shown in Table 2-2.

Table 2-2 Concept of Emission Standard

	Substance	Example of substance	Emission style	Emission facility	Type standard	Basis of standard setting
Soot and smoke	Sulfur oxide	SO ₂ , SO ₃	Combustion of materials	Soot and smoke emitting facility	Emission standard (emission volume control, K-value control method, total mass emission control)	First concept
	Soot and dust	Soot, etc.	Same as above	Same as above	Same as above (concentration control depending on facility type and scale)	First concept
	Hazardous substances	NO _x , Cd, Pb, HF, Cl ₂ , HCl, etc.	Combustion of material, synthesis, resolution, pressurization	Same as above	Same as above (concentration control depending on substance type and facility type. For NO _x , total mass emission control standard is applied.)	Second concept
	Special hazardous substance	Unspecified	Combustion of material	Same as above	Same as above (emission volume control, (K-value control method))	First concept

② Special emission standard

For an area polluted more than a specified level, the special emission standard is applied to prevent the pollution from accelerating more. Based on the fact that new removal equipment can treat emission gas more effectively than the existing equipment, a more strict emission standard than the standard applied to existing facilities is applied to a new facility. The special emission standard is applicable in only an area in where emission facilities of sulfur oxides and soot and dust are concentrated.

③ More stringent prefectural standard

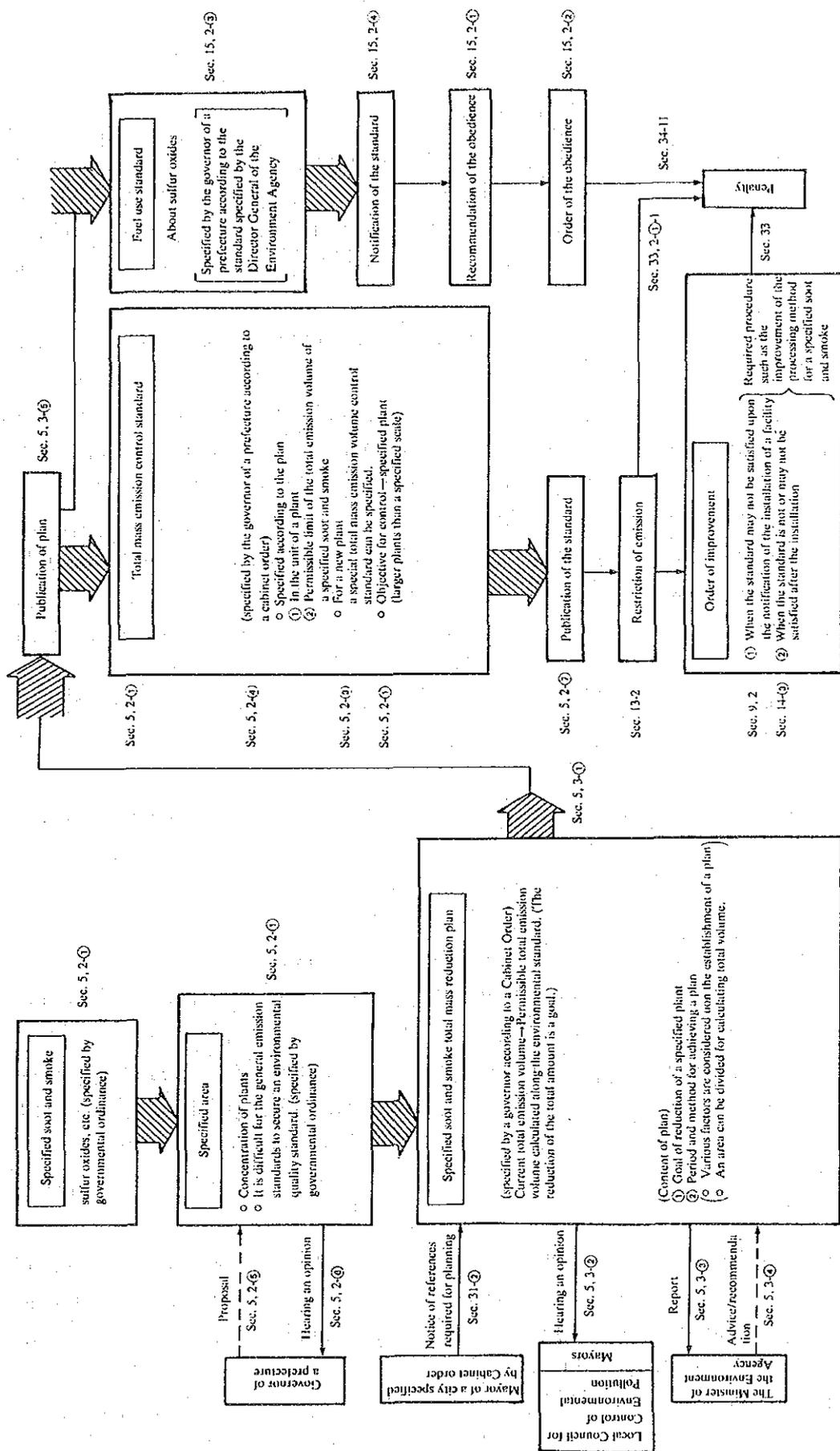
In case the general emission standard established by the national government produces only an insufficient effect for protecting human health and preserving the living environment judging from the natural and social conditions, the local government can set by ordinance a more strict criteria called the "More Stringent Prefectural Standard" than the national general standard. The substances the "More stringent Prefectural Standard" can cover are limited to soot and dust and hazardous substances, but sulfur oxide is excluded from the objective. The reasons for exception of sulfur oxides are that (i) the general emission standard of sulfur oxide is determined for each area depending on pollution level and (ii) reduction of sulfur contents in fuel, which is the basic countermeasure for the emission of sulfur oxides, should be conducted by the national government on the basis of the supply-and-demand relationship. In addition, the Director General of the Environment Agency can recommend that a prefecture determine or change its "More Stringent prefectural standard" when he recognizes the necessity to prevent air pollution.

2) Total mass emission control standard

Although, as mentioned in the Emission Standards of the previous section, the ground concentration control system by the K-value control is employed for sulfur oxide, this type of emission standard cannot suppress the total emission volume in an area where plants are concentrated. It is, therefore, quite difficult to satisfy the environmental quality standard in such an area. The total mass emission control method was created to deal with this condition. Since the procedure of the total mass emission control is relatively complicated as shown in Fig. 2-2, the basic system is described as follows:

- ① The national government specifies an area (specified area) to which total mass emission control is applied and type of soot and smoke (specified soot and smoke), and determines the standard concerning the scale of a plant emitting a specified soot and smoke.
- ② According to the national standard, the governor of a prefecture determines the scale standard of a plant emitting a specified soot and smoke in a specified area, makes a specified soot and smoke total mass reduction plan related to a plant exceeding the scale standard (specified plant) and determines a total mass emission control standard along the guideline set by the national Government.
- ③ The governor of the prefecture must decide following matters in a reduction plan.
 - (i) Total emission volume of specified soot and smoke emitted in a specified area
 - (ii) Total emission volume of a specified soot and smoke emitted from all specified plants in a specified area
 - (iii) Permissible total emission volume of a specified soot and smoke in a specified area, calculated according to a calculation method specified by the national government along the environmental quality standard
 - (iv) Goal of reduction of total emission volume mentioned in (ii) taking into account the ratio of (ii) occupying (i), scale of specified plants in a specified area and future prospect on raw material and fuel used by the specified plants
 - (v) Period of project achievement and method
- ④ Upon the establishment of the specified soot and smoke total mass reduction plan, the prefecture is obliged to listen to the opinions of concerned cities and villages and report an established plan to the Director General of the Environment Agency. As the prominent means of the method (v) executing the goal of reduction mentioned in (iv) of the paragraph ③, allocation of reduction volume to specified plants is employed in many plans.

Soot and smoke specified for total mass emission control are sulfur oxides and nitrogen oxides. As of 1989, 24 areas are specified for sulfur oxides and three areas for nitrogen oxide. The governor of a prefecture has the privilege to establish a special total mass emission control standard which is based on the same principle as the special emission standard in contrast with the general emission standard.



Remark: Section 33, 2-1, for example, in the diagram above indicates the article 33, 2, section 1, No. 1 of the Air Pollution Control Law.

Fig. 2-2 Systematic Chart of Total Mass Emission Control

3) Fuel use standard

The fuel use standard is classified into the following two types.

- ① Measures relating to the seasonal use of fuel
- ② Measures relating to the use of fuel in a specified area

In the measure of ①, to correspond to a pollution by sulfur oxides in the building section in the center of a city, a fuel use standard is specified for each area so that the use of excellent quality fuel and the reduction of fuel can be recommended or ordered to reduce its emission volume.

Although the emission standard for sulfur oxides is specified for each area, in the building section in the center of a city, the pollution sometimes becomes serious in the winter even if the pollution concentration throughout a year is not so high. This is due to the increase of fuel consumption by heating of buildings. This measure, therefore, is set to cope with such phenomenon. The areas were specified according to the notice dated in 1970 (regarding the prevention of air pollution due to the heating of buildings in the center of cities), and the conditions of such area are that (i) the air is or can be seriously polluted so that the monthly average of the pollution concentration by emitted sulfur oxides of the same month in these two years is over 0.05 ppm or there is a month when at least that value is exceeded and (ii) such soot and smoke emitting facility that consumes fuel of more than 10,000 kl per year is or is certain to be installed in a building in a given area. Currently, 14 areas are specified all over Japan.

The reason for setting the measure of ② is, upon the introduction of the total mass emission control related to sulfur oxides, to encourage small plants to improve their sulfur oxides emission because they are also contributing to air pollution by sulfur oxides.

4) Standard on particulate discharging facility

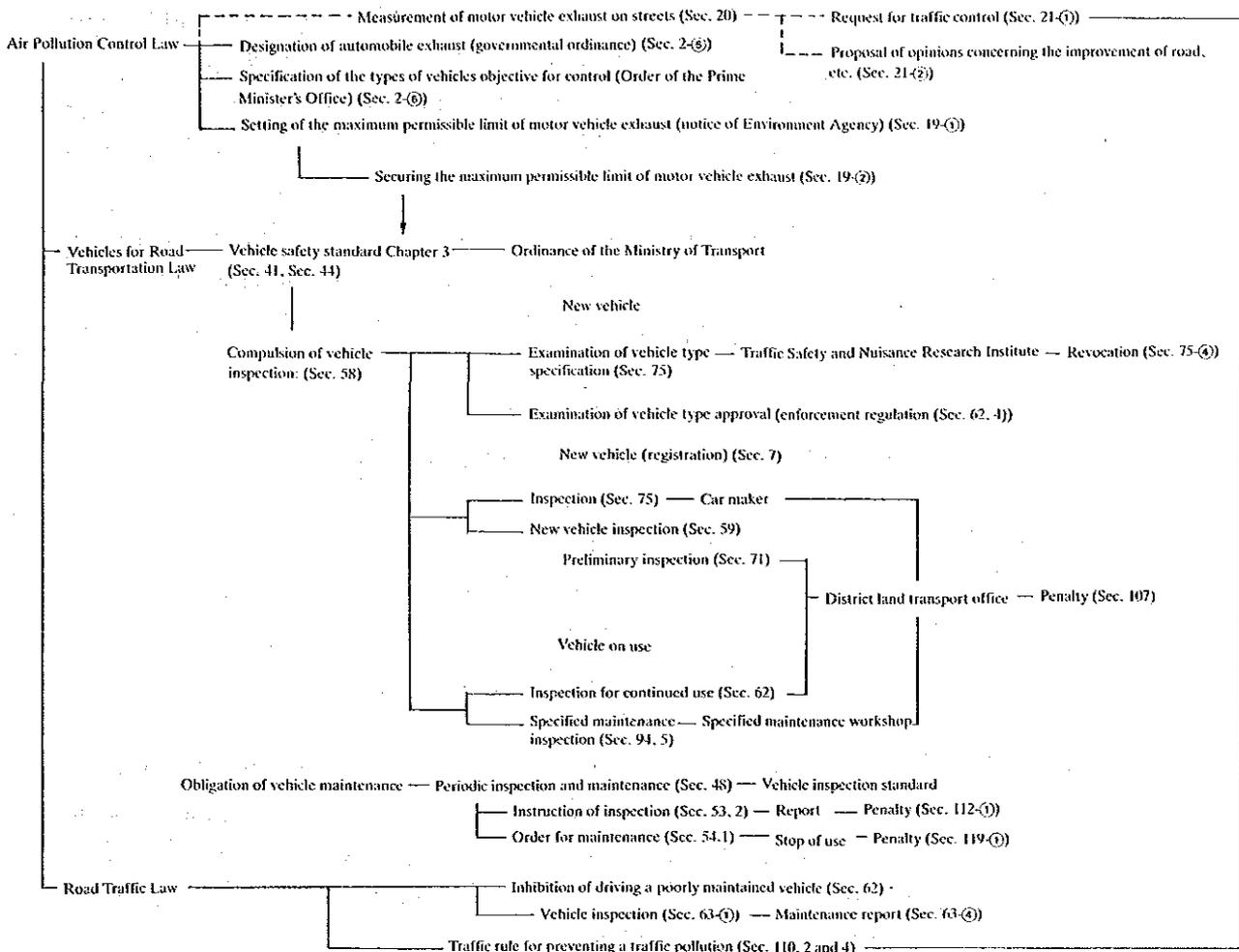
In contrast to soot and dust, particulates undergo no emission concentration control. The standard concerning the structure, operation and management of a particulate discharging facility is applied. The reasons why the discharge of particulates is not restricted quantitatively but by such standard are that; ① particulate is discharged in a different style from soot and dust, and not discharged from a stack; ② an influence of particulates on the health is thought to be lower than soot and dust because the size of particulate is relatively large; ③ particulate is scattered over a smaller area so that the damage is limited to near a plant.

5) Maximum permissible limits of motor vehicle exhaust

The law specifies that the Director General of the Environment Agency should determine the maximum permissible limit of the volume of exhaust (carbon monoxide, hydrocarbon, lead compound, nitrogen oxide and particulate matter) discharged in the air when a motor vehicle runs under a specified condition.

Because the volume of automobile exhausts is closely related to the structure and equipment of a motor vehicle, it is not restricted by the Air Pollution Control Law but in the

system of the Vehicles for Road Transportation Law. When determining a matter concerning the control of motor vehicle exhaust in accordance with the Law, the Ministry of Transport must take into account securing of the maximum permissible limit specified by the Director General of the Environment Agency. Fig. 2-3 shows the system for motor vehicle exhaust control.



Note: Section 21-1 means, for example, the article 21, section 1 of the Air Pollution Control Law.

Fig. 2-3 Systematic Chart of Motor Vehicle Exhaust Control

(5) Regulation concerning the observance of the control standard

As the procedure for adapting to the control standard, as for soot and smoke, ① the prior report system of an emitting facility, ② order of modification in a proposed plan such as the structure of a soot and smoke emitting facility, ③ order of improvement of a soot and smoke emitting facility and ④ penalty to a violation of the emission standard are specified. Concerning particulates, the order for adapting to its facility standard is specified. In addition, the penalties for a violation of such orders are specified. These orders and penalties are described below.

1) Order related to soot and smoke

① Prior report system

This system makes a person who intends to install a soot and smoke emitting facility in his plant notify in advance the governor of a prefecture to examine whether or not that facility is adaptable to the emission standard.

It is very difficult to take a preventive countermeasure from the technical and economic reasons after an emitting facility is constructed. Thus this system is based on the concept to take a sufficient measure at the construction stage to make the emission control really effective. This system enables the governor of a prefecture not only to check in advance but also to obtain the data of emitting facilities existing in his responsible area completely. (In the case of disuse of an emitting facility also, the obligation of notification is placed.)

The prior report must be submitted to the Governor 60 days before the installation of an emitting facility. The governor of a prefecture examines the case in these 60 days and as required, dispatches an order of modification in the proposed plan, which is mentioned in next section, to the factory.

The matters which should be notified are as follows.

- (i) Name, address and president name of a company
- (ii) Name and address of a factory
- (iii) Type of the soot and smoke emitting facility
- (iv) Structure of the soot and smoke emitting facility
- (v) Use method of the soot and smoke emitting facility
- (vi) Disposal method of soot and smoke

When a new soot and smoke emitting facility is specified, the factory equipped with that facility is under an obligation to notify the governor of a prefecture of it in the same manner as the prior report system. In this case, as it is impossible to dispatch an order of modification in the proposed plan concerning an existing facility, the order of improvement mentioned later is dispatched instead.

When changing the structure, use method and so on of a notified soot and smoke emitting facility also, the factory is under obligation to notify the governor of it. The governor examines it in the same manner as the prior reported cases and, as required, dispatches an order for modification in the proposed plan.

② Order for modification in proposed plan

The governor of a prefecture examines the prior report of a soot and smoke emitting facility from a factory, and if he recognizes that the emission standard (general emission standard, special emission standard and more stringent prefectural standard) is not satisfied, he can dispatch an order for modification to a factory.

Although, practically, the content of an order for modification in the proposed plan varies depending on the individual case, the basic concept is that (i) the dispatch of an

order for modification should be limited in an indispensable case because such orders impose a serious burden on a concerned person and (ii) an order of improvement of disposal method and so on should be substituted if possible.

③ Order of improvement

In case the governor of the prefecture recognizes that a soot and smoke emitting facility is likely to continuously emit soot and smoke whose volume or concentration fails to meet the emission standards at the outlet and that continued emission of such soot and smoke may cause damage to human health or the living environment, he may order the person in charge to improve, within a prescribed period, the structure, the method of operation, or the method of disposal of soot and smoke generated by the soot and smoke emitting facility, or to suspend the operation of the facility temporarily.

While the prior report system and order for modification in a proposed plan are preventive measures to prevent air pollution by checking in advance, an order of improvement is dispatched when the emission standard is or may be violated (this is not an only possibility but means that emission of soot and smoke not complying with the standard is estimated because an inappropriate dust collector is used without improvement). For the reason, this serves as a security for the obedience to the standard aiming to force the emission standard to be followed. It can be said, however, that a preventive concept is also contained in this measure because the case of "likely to continuously emit soot and smoke" is included in the objectives of dispatching this order.

④ Penalty for a violation of the emission standard (direct penalty)

A person in charge of an emitting soot and smoke facility such as a plant is inhibited from emitting soot and smoke not complying with the emission standard. If he violates this standard, he will be treated judicially as an administrative criminal immediately without such a procedure as an order of improvement and subjected to imprisonment with labor not more than six months or a fine of not more than ¥100,000.

While the order of improvement has a preventive characteristic to prevent a violation of the emission standard despite a security procedure for securing the standard, the direct penalty system aims at enforcing obedience to the standard by arresting the person who actually causes the violation. Anyway, this aims at strengthening the security for the standard by combining it with an order of improvement.

2) Order related to particulates

Concerning a particulate discharging facility also, a person in charge of discharging particulates is under an obligation to submit to the governor of a prefecture a prior report of an establishment/extension of the facility or modification of its structure for the same reason as a soot and smoke emitting facility. As mentioned in the section of restriction standards, however, particulate is different from soot and smoke in its generation style and particle size thereby affecting human health and the living environment less. In addition, the related restriction standard is not an emission standard but a standard related to the structure, operation and management of a facility. For these reasons, the security procedure for secur-

ing the standard related to particulates is more lenient than that for soot and smoke.

Although the prior report system is adopted, no order for modification in a proposed plan is specified as well as order of improvement and direct penalty are not specified. As a security procedure for the standard, only the order for conforming to the facility standard is specified. Although the content of the order for conforming to the facility standard differs depending on the individual case, the basic concept is that the governor of a prefecture, when he recognizes that a particulate discharging facility does not satisfy its standard, can order the person possessing that facility to conform to the standard and, as required, to temporarily suspend the operation of the facility.

(6) Obligation of monitoring and surveillance

A person in charge of emitting soot and smoke is under an obligation to monitor the volume and concentration of soot and smoke related to a soot and smoke emitting facility and record the result. This is based on the concept that a person in charge of emitting soot and smoke is expected to observe the emission standard by fulfilling this obligation and at the same time, the governor of a prefecture is expected to be able to take an appropriate air pollution preventive measure by gathering the data measured. The frequency and method of the measurement are specified in by the Environmental Agency and Table 2-3 shows the outline.

(7) Obligation of the governor of a prefecture on surveillance of air pollution

The governor of a prefecture is under an obligation to monitor and survey from time to time the level of air pollution and publicize the conditions of air pollution. It is necessary to manage the air environment to prevent an air pollution. Thus the reason why this obligation is placed on the governor of a prefecture is to confirm always how effectively the emission control is fulfilled and check the coordination between administrative purpose and means.

Concretely, the governor confirms how the environmental quality standards are satisfied on the basis of information obtained from this surveillance and, if worsening of air pollution is recognized, he can propose the necessity of the application of a special emission standard to the national government and take such a countermeasure as setting more stringent prefectural standard.

As a supervisory measure to individual emission sources, the governor is privileged with an authority to have his competent officials enter a factory for inspection. In addition, the governor is obliged to measure an air pollution concentration in the area near a road which is or can be seriously polluted by motor vehicle exhaust.

(8) Emergency countermeasure taken by the governor of a prefecture

Even if a person in charge of emitting soot and smoke observes the emission standard, air pollution can occur rapidly due to weather conditions and so on. The procedure which the governor should take at such an emergency and the requirement for its countermeasure are specified. Table 2-4 shows the requirements for emergency countermeasures.

Table 2-3 Measurement and Recording Methods

Substance	Type of soot and smoke emitting facility to be measured	Measuring period and frequency	Measuring method	Record storage
Emission volume of sulfur oxides	Facility at which emission volume of sulfur oxides exceeds 10 Nm ³ /h	Once or more in a work period of less than two months	Any one of the following methods must be taken. ① Measurement of concentration: the method specified on JIS K 0103. Measurement of emission volume: the method specified on JIS Z 8808 ② Measurement of sulfur content: the methods specified on JIS K 2301, K 2541 or M 8813. Measurement of fuel consumption: the methods specified on JIS Z 8762 and Z 8763 or other methods ③ Measurement by the method specified by the Director General of the Environment Agency	Record in a specified recording sheet (for regular measurement, record specified matters in an arbitrary paper) and store it for three years.
	Same as above (facility installed in a specified plant)	Always	Same as above	
Sulfur content in fuel	All facilities related to sulfur oxides		Measurement by the method specified on JIS K 2301, K 2541 or M 8813. If another method is available for measuring the content, its use is permitted.	
Concentration of soot and dust	Facility at which emission volume exceeds 40,000 m ³ /h	Once or more in a work period of less than two months	Measurement by the method specified on JIS Z 8808	
	Facility at which emission volume exceeds 40,000 m ³ /h	Twice or more per year		
Concentration of hazardous substances	Facility at which emission volume exceeds 40,000 m ³ /h	Once or more in a work period of less than two months	<Cadmium, lead> Collected by the method specified on JIS Z 8808 and measured by atomic absorption spectrometry, spectrophotometry or polarography	
	Same as above	Always	<Chlorine> Measured by ortho toline method or continuous analysis method specified on JIS K 0106	
	Facility at which emission volume exceeds 40,000 m ³ /h	Twice or more per year	<Hydrogen chloride> Measured by mercuric thiocyanate method specified on JIS K 0107 <Hydrogen fluoride> Measured by the spectrophotometry on JIS K0105 <Nitrogen oxides> Measured by the method specified on JIS K 0104. At the same time, it is necessary to measure the density of residual oxygen concentration in discharged gas by means of orsat apparatus. For regular measurement, a method specified by the Director General of the Environment Agency can be substituted.	

Table 2-4 Requirements for Emergency Countermeasures

Substance	General emergency	Serious emergency
Sulfur oxides	0.2 ppm or more for three hours 0.3 ppm or more for two hours 0.5 ppm or more Average for 48 hours: 0.15 ppm or more	0.5 ppm for three hours 0.7 ppm for two hours
Suspended particle matter	2 mg/Nm ³ for two hours	3 mg/Nm ³ for three hours
Carbon monoxide	30 ppm or more	50 ppm or more
Nitrogen dioxide	0.5 ppm or more	1 ppm or more
Oxidant	0.12 ppm or more	0.4 ppm or more

Note: All the values mentioned here are the hourly mean.

As shown in Table 2-4, the emergency countermeasures are classified into relatively slight general emergency and serious emergency and the countermeasure taken by the governor corresponds to this classification. The main measures for general emergency are ① to publicize that air pollution occurs and ② to recommend that persons in charge of emitting soot and smoke and motor vehicle drivers reduce the emission volume of soot and smoke and refrain from driving cars, respectively. The main measures for a serious emergency are to order ① the reduction of soot and smoke concentration and ② the restriction of the use of soot and smoke emitting facilities. Concerning the facility emitting sulfur oxides of more than 10 m³ per hour, the person responsible for that facility is ordered to make and submit an emission volume reduction plan both at a general and a serious emergency. The governor's recommendation or order related to emergency countermeasures will be formed according to his submitted plan.

Because judging whether an emergency condition is temporary or continual is closely related to weather conditions, it is necessary for the governor of a prefecture to communicate with the weather bureau, and cooperate with related cities and persons in charge of emitting soot and smoke to invoke an emergency countermeasure and exercise it smoothly. For this reason, the governor is expected to cooperate with the concerned organizations beforehand so as to determine an emergency countermeasure invoking procedure.

(9) Compensation for damages—Strict liability of enterprises

This law specifies that if human life or physical condition is menaced by a health damaging substance (soot and smoke, specified substances and particulates specified by the governmental ordinance as a substance which can damage only the living environment) emitted from the operation of a plant, the enterprise is responsible for compensation for the damage. This makes clear the strict liability of enterprises. An injury caused on operation is excluded from the application. This is based on the reasons that because a worker is doing business operation with enterprises under a work contract, a damage caused in business activity should not be treated in the same manner as the damage given to a third party and such a damage should be treated in the ranges of the Labor Standard Act and Labor Accident Compensation Security Law.

(10) Others

In addition to (1) through (9) mentioned above, the following regulation are added, so that the entire system consists of 37 articles. The details of the various standards are specified by the governmental and cabinet ordinances.

- ① Matters concerning the rights for requesting a person in charge of emitting soot and smoke to submit reference materials and on-the-spot inspection, given to related administrative organizations and local government to an extent necessary for the fulfillment of this law.
- ② Matters concerning the obligation of a person responsible for emitting soot and smoke to report to related administrative organizations and local government, corresponding to the ① above

- ③ Matters concerning the promotion of the research for air pollution prevention by the national government
- ④ Matters concerning the financial and technological assistances to persons responsible for emitting soot and smoke for air pollution prevention by the national government
- ⑤ Specification about exclusion of nuclear substances from the application of this law
- ⑥ Penalty for a violation of the responsibility or order imposed on a person responsible for emitting soot and smoke, specified on this law
- ⑦ Matters concerning the relation between this law and local government regulations

2.1.3 Law for the Establishment of the Organization for Pollution Control in Specified Factories

Although the pollution control in Japan was executed with the Air Pollution Control Law, Water Pollution Control Law and other regulations based on the Basic Law for Environmental Pollution Control, there was a great gap between the content of the restriction demanded by the laws and the pollution preventive system of a factory objective for control. Considering such circumstances, this law was enacted in 1971 to smoothen the responsibility of an enterprise to pollution control, by imposing an obligation of establishment of a pollution preventive organization in a factory on an enterprise.

The pollution preventive organization stipulated in this law is constituted of the pollution control manager, who possesses specialized knowledge and skills related to pollution prevention, the pollution control supervisor, who supervises the pollution control manager and, in a plant equipped with both soot and smoke emitting and waste water effluent facilities in the specified scale, the chief pollution control manager, who directs pollution control managers and assists pollution control supervisors. The requirement of this law is satisfied by registering this system to an appropriate governor of this system.

Due to the enforcement of this law, since 1971, the establishment of the pollution prevention system in individual factories were progressed year by year, so that the purpose of this law has been achieved. In addition, the prevailing of this system contributed to spreading of pollution preventive technology and strengthening of the cooperation between administrative side and enterprises.

This section describes the outline of this law from the viewpoint of air pollution control managers.

(1) Objective factory

Of factories equipped with a soot and smoke emitting facility specified by the Air Pollution Control Law, a factory belonging to any one of (1) manufacturer, (2) electric supplier, (3) gas supplier and (4) heat supplier is under an obligation to establish its pollution preventive organization.

(2) Structure of pollution preventive organization

As mentioned previously, the law specifies that this system is organized of a pollution control

supervisor, a chief pollution control manager (applicable only to factories larger than a specified scale) and pollution control managers. Each role and requirement of qualification are specified as follows:

1) Pollution control supervisor

Requirement of qualification: Person supervising the business operation of a factory

- Role:
- ① Administration of a soot and smoke emitting facility, disposal processing facility and attached facilities
 - ② Administration of measurement and recording of emission volume
 - ③ Administration of the work necessary for air pollution control

2) Pollution control manager

Requirement of qualification: Person who has passed the examination or mastered a qualification training course given by the national government

- Role:
- ① Inspection of fuel and raw material
 - ② Operation, inspection and repair of soot and emitting facility
 - ③ Measurement of the emission concentration and volume of soot and smoke
 - ④ Inspection and repair of measuring devices
 - ⑤ Emergency measure for an accident of a soot and smoke emitting facility
 - ⑥ Measures for reduction of the emission concentration and volume of soot and smoke at an emergency

3) Chief pollution control manager

Requirement of qualification: Person who has passed the examination given by the national government

Role: Assistance for a pollution control supervisor and direction of pollution control managers in respect to the role of a pollution control manager

Practically, often, the role of a pollution control supervisor is played by the general director of a factory, a pollution control manager by a manager who has passed the examination or mastered a qualification training course, and a chief pollution control manager by director who has passed the examination. Although a pollution control supervisor and a chief pollution control manager each are assigned in a factory, a pollution control manager must be assigned to each individual soot and smoke emitting facility. In addition, each factory is under obligation to assign qualified substitutes of a pollution control supervisor, a chief pollution control manager and a pollution control manager so as to cope with possible deaths, transfers, and business trips.

(3) State examination and qualification training course

The requirement for the qualification of a pollution control manager is to pass a state examination or master a qualification training course. The pollution control managers are classified into the following five categories depending on the scale and characteristic of a plant:

- ① First grade air pollution control manager

Factory emitting soot and smoke of more than 40,000 m³ per hour, containing any of the hazardous substances specified in the Air Pollution Control Law

② Second grade air pollution control manager

Factory emitting soot and smoke of less than 40,000 m³ per hour, containing any of the hazardous substances specified in the Air Pollution Control Law

③ Third grade air pollution control manager

Factory emitting soot and smoke of more than 40,000 m³ per hour

④ Fourth grade air pollution control manager

Factory emitting soot and smoke of less than 40,000 m³ per hour

⑤ Dust Pollution control manager

Factory having a dust discharging facility

A state examination is held once a year under the four classifications mentioned above. Until 1989 since this law was enforced, a total of 19 state examinations have been given and 52,156 persons in total from type 1 to type 4 received the qualification of air pollution control manager and 4,141 persons of dust pollution control manager.

The qualification training course is the system to give the same qualification as the state examination through participation in the training course. However, the objective qualifications are only the Second and Fourth grades, and the dust pollution. Factories requiring the assignment of a pollution control manager of those categories are relatively small in most cases. Thus this procedure is set considering that it is difficult for such small factories to correspond to the requirement of this law if no such special measure is provided, because they seldom have a sufficient capacity to give an in-house seminar for the state examination. This training course is held every year and the persons receiving both grades 2 and 4 totals 44,870, and 14,952 for the dust pollution.

2.2 Environmental Quality Standard in Foreign Countries and its Concept

2.2.1 Basic Concept of Setting an Environmental Quality Standard

An environmental quality standard is a criteria obtained by determining a concentration level of pollutants in an environment to attain administrative goals of conducting environmental evaluation on pollutant emission sources and establishing anti-pollution policy, in order to maintain health of a community and preserve environment. Since the word "environmental quality standard" is originally an administrative term, however, the meaning differs depending on the administrative purpose of each country. The concept of the environmental quality standard has the following four meanings:

- ① The standard which has legal restriction for administrative acts
- ② The guide or guideline for environmental administration in the community
- ③ The goal or desirous goal for the present to take administrative or technical measures for the environment in the community
- ④ The criteria to judge the environmental quality

Those four items have the same purpose to maintain the health of the community and to protect the environment, but the contents and the operation method differ. The standard has a legal and administrative power and is the strongest of all the four concepts. While no definite distinction exists between the guide/guideline and the goal, the criteria is the basis and an accumulation of scientific knowledge for setting the environmental quality standard. The environmental quality standard is also derived from the criteria considering the relation between cost and benefit, scientific and economic feasibility. To set the environmental quality standard, the action of the pollutant concentration upon the human body, and the effect on the animals, plants and materials should be examined scientifically. However, the effect on the health of human beings must be given top priority. For this reason, toxicology information, epidemiological research results, and clinical cases are demanded. From the reasons mentioned above, the international comparison of the environmental quality standard must be made on basis of the precise understanding on the unit of measurement (for example, a one hour value and 30 minute value), the measurement method, etc. as well as the characteristics and roles of the criteria. In 1963 a World Health Organization (WHO) expert committee on air pollution presented four categories regarding concentration, exposure time, and the corresponding effects as a guide to air pollution. These categories, which are very helpful in considering the environmental conditions which should be maintained to protect the health of the human beings and keep the living environment in good condition, are shown below.

- Level I: Combination of concentration and exposure time in which an effect (including a change of reflection, adaptation, or protective response) is not observed directly or indirectly with the present knowledge in the case of a certain value or less
- Level II: Combination of concentration and exposure time in which the stimulation of a sensitive organ, damage to plant life, decrease of visibility, or adverse influence on other environments may occur in the case of a certain value or more
- Level III: Combination of concentration and exposure time in which various changes which are likely to lead to the obstruction of important physiological functions, chronic diseases, or short life may occur in the case of a certain value or more
- Level IV: Combination of concentration and exposure time in which an acute disease or death may occur in a sensitive group among inhabitants in the case of a certain value or more

2.2.2 Japan

(1) Concept of environmental quality standard

The environmental quality standards in Japan are defined explicitly in the Basic Law for Environmental Pollution Control. Namely, they delineate the pollutant level at which the health and living environment of the general inhabitants may not be ruined by the contamination phenomena and are an administrative target value in pollution control. The goal of the standards is that the pollutant is "desirable to be maintained" below the target level. Therefore, an excess of the level does not necessarily ruin the health of the inhabitants immediately. If the excess continues, howev-

er, an effect on the sick and the aged or deaths are likely to increase. Keeping the pollutants less than the level will stop these matters and maintain the health of the inhabitants in a desirable condition. If the pollutants exceed these standards, an administrative office takes various measures to reduce the pollutant concentration, but unlike the case of the emission standard it does not carry out control directly against each emission source. However, it is expected that tightening of restrictions is required to maintain the environmental criteria. Therefore, it can be said that the environmental quality standards take on a characteristic of indirect restriction of the emission source.

For establishing the standards, protection of the health of the human beings should be given top priority and consideration should be given to maintenance of the living environment before economic development. Also, appropriate scientific judgment is always added to these standards and necessary revision is made. In Japan, the government establishes the standards as an administrative goal and takes required measures, such as stipulation of a pollution control plan or revision of emission standards, in order to attain this goal. Therefore, these standards are neither scholarly tolerance limits nor restrictive standards which immediately execute administrative power if the goal is not attained.

(2) Establishment of environmental quality standards

The environmental quality standards in Japan are established concerning air pollution, water pollution, noise and soil pollution based on the Basic Law for Environmental Pollution Control. As far as air pollution is concerned, the standard values have been set in the order of SO₂ (1969), CO (1970), and SPM (1972). In 1973 the environmental standard concerning SO₂ were revised and those concerning the photochemical oxidant and NO₂ were also set. Furthermore, the standard concerning NO₂ was revised in 1978.

The Central Council for Environmental Pollution Control submits a report on the environmental quality standards in reply to a question put by the Director-General of the Environment Agency, and the environmental quality standards are established based on this report as a notification of the Environment Agency. The Prime Minister appoints persons learning and experience on pollution control to the Central Council for Environmental Pollution Control, and not only scholars and researchers are selected but also people from every class of society such as representatives of inhabitants, workers and the industrial world. The environmental quality standards can be determined from two points of view, "protection of the health of the human beings" and "maintenance of the living environment." The environmental quality standards concerning air pollution were mainly determined from a viewpoint to protect the health of human beings and the living environment can be maintained in its limits. These standards correspond to level I of the WHO and are determined considering the effect of each substance upon human beings, and the actual situation of air pollution in Japan based on the home and foreign information in view of complete safety.

(3) SO₂

SO₂ is the substance for which the environmental quality standards were established for the first time in Japan. The outline of the standard established in 1969 is as follows:

- ① The number of hours when the concentration level is maintained at 0.2 ppm or less in an hour must be 99% or more against the total number of hours throughout the year.
- ② The number of days when a daily average of the concentration level in an hour is maintained at 0.05 ppm or less must be 70% or more against the total number of days throughout the year.
- ③ The number of hours when the concentration level is maintained at 0.01 ppm or less in an hour must be 88% or more against the total number of hours throughout the year.
- ④ The annual average of the concentration level in an hour must not exceed 0.05 ppm throughout the year.

The air pollution subcommittee of the Central Council for Environmental Pollution Control, however, reexamined the standard for the following reasons:

- ① There was a fair chance that the standard would be attained and maintained in all areas during 1973 by promoting various measures.
- ② Judging from fact that an adverse effect of air pollution was observed even in areas which satisfy the standard, the standard was not sufficient to protect the health of human beings.

It is widely known that SO₂ exerts influence on the respiratory system organs in the long and short terms and the influence of SO₂ is strengthened if it coexists with SPM and NO_x. It is testified that SO₂ itself causes a cerebro-physiological response, increase of respiratory tract resistance, pathological change of the superior respiratory tract, and a decrease of immunity of the respiratory organ against bacteria and viruses. Moreover, with respect to the influence of SO₂ upon human beings in the regional environment the following were considered the minimum conditions which are the criteria to prevent the obstacle to the health of human beings:

- ① The worsening of the patient's condition is not proved epidemiologically
- ② An increase of mortality rate is not proved
- ③ An increase of the chronic symptom of the obstructive respiratory organ is not proved
- ④ An undesirable response or trouble of the respiratory function of youths is not proved epidemiologically

In addition to the reasons mentioned above, considering the conditions on which SO₂ does not exert undesirable influence upon the health of human beings in the present knowledge, the new standard was established in 1973. Considering that the new standard was strict from the international point of view, and that a large quantity of good quality fossil fuel is hard to obtain, attainment and maintenance of the new standard were an extremely difficult task. Consequently, the following measures were taken comprehensively and powerfully:

- ① Promoting a low sulfurization program
- ② Strengthening restriction to an emission source
- ③ Stipulating and carrying out the pollution control plan
- ④ Carrying out the environmental assessment
- ⑤ Using the energy efficiently

- ⑥ Establishing the monitor and measurement system
- ⑦ Promoting investigation and research

As a result, SO₂ concentration in the air continues to decrease. As shown in Fig. 2-4, the annual average of SO₂ at the air monitoring stations was decreasing with 0.059 ppm in 1967 at its peak, and it fell to 0.01 ppm in 1987. In addition, the attainment rate of the new standard became 99.6% in 1987, which satisfies the standard value in almost all the points.

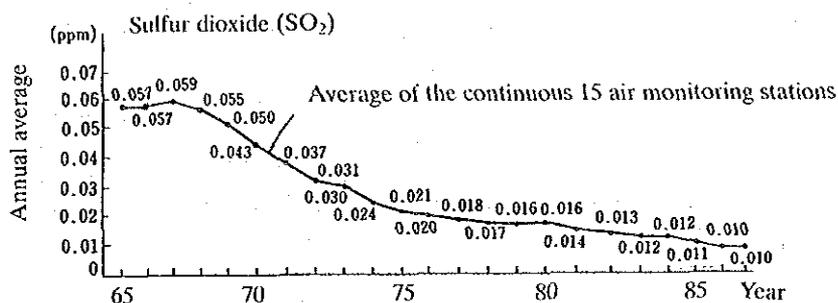


Fig. 2-4 Secular Change of Ambient Air Concentration of SO₂

(4) NO₂

NO₂ easily infiltrates the deepest part of the lung, exerts an adverse impact on the lung and other organs, and the toxicity of NO₂ itself is stronger than SO₂. In addition, if it coexists with SO₂ and SPM, its toxicity is strengthened. Moreover, NO₂ exerts a bad influence on the living environment such as damage to animals and plants, and reacts with hydrocarbon, particularly unsaturated hydrocarbon under ultraviolet radiation, leading to secondary production of a photochemical oxidant. Japan's environmental standard for NO₂ was established in 1973. With respect to the environmental conditions, the daily average was 0.02 ppm and the achievement period was 8 years in big cities and 5 years in general regions. The standard, which was extremely strict considering the complete safety, was established based on the information available at that time. Afterwards, as the scientific development on the influence of NO₂ on health had been progressed, the Central Council for Environmental Pollution Control reexamined the standard in 1977, and the standard was revised based on its report in 1978. The new information on the influence of NO₂ on health was as follows.

The WHO Environmental Health Criteria Expert Council on the nitrogenous compound considered that 0.5 ppm is the minimum level at which an undesirable effect is observed from the information obtained by experiments on animals in the case of a single exposure of NO₂ and determined that the exposure level required for the protection of public health is a one hour value of 0.10 to 0.17 ppm or less.

The Central Council for Environmental Pollution Control, to which a re-evaluation of criteria and guidelines on the influence of NO₂ upon human beings is referred, examined the single effect of NO₂ and the coexistence effect with other substances through laboratory experiments and evalu-

ated home and foreign epidemiological research, and then suggested that the guidelines for a one hour exposure be 0.1 to 0.2 ppm for a short-term exposure and that the annual average be 0.02 to 0.03 ppm for a long-term exposure. When establishing the environmental standard, the Council esteemed the guideline as much as possible, formed a political judgment on the reliability as an administrative goal, and set the standard value within the zone of 0.04 to 0.06 ppm using a daily average of the one hour value as before. This has a close relation with the annual 98% value of the daily average and the annual average, and the standard value 0.04 to 0.06 ppm set by the daily average is nearly comparable to the annual average 0.02 to 0.03 ppm of the Council's guideline. In addition, if this standard value is satisfied, the one hour value 0.1 to 0.2 ppm which was indicated as the short-term guideline can be secured with high probability judging from the observation data so far obtained. This environmental standard value of NO₂ is equivalent to the guidelines suggested by the expert committee of the Central Council as the environmental conditions. The criteria and guidelines were established asking for experts' judgment and the environmental standard itself was established on the government office's own judgment and responsibility. Establishment of the standard is characterized by the fact that science and administration, so to speak, shared the responsibility.

A new trial of setting the standard within a zone was made, which had not been found in the conventional standards, and the following matters must be done to achieve and maintain the standard.

- ① In an area where the daily average exceeds 0.06 ppm we should try to attain 0.06 ppm at all the monitoring stations of the corresponding area.
- ② In an area where the daily average is within a zone of 0.04 ppm to 0.06 ppm, as a general rule, we should maintain the present level if little change is found in the urbanization and industrialization within this zone, and if the urbanization and industrialization progress, the daily average should not exceed the above-mentioned value. This is usually called the "principle of nonaggravation." It is quite natural that this stipulation neither means that the concentration can be raised to 0.06 ppm without special reasons nor denies an improvement of the present level within the zone through practically possible and reasonable efforts.
- ③ As a general rule, in an area where the daily average is 0.04 ppm or less we should prevent it from exceeding 0.04 ppm to a considerable degree.

Most of the nitrogenous compounds in the air are produced with combustion. The emission sources of NO₂ can be divided into two types, stationary sources like factories and mobil sources like motor vehicles. The concentration of NO₂ in the air shows a slight improvement in and after 1979 as shown in Fig. 2-5. However, the situation was worse in 1987 than in 1986 both in the air monitoring stations which were established throughout the nation in order to know the general situation of the air pollution and in the motor vehicle emission gas monitoring stations (monitoring stations installed along streets in order to observe the air pollution near roads). 6.0% of the air monitoring stations and 37.4% of the motor vehicle emission gas monitoring stations exceeded the upper limit of the standard in 1987.

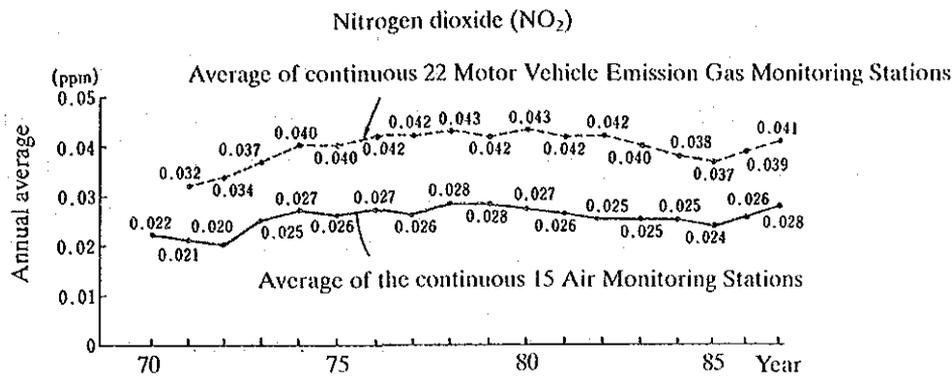


Fig. 2-5 Secular Change of Ambient Air Concentration of NO₂

(5) SPM

Preparations for establishment of the SPM environmental standard had been made before the Environment Agency started. At the beginning the expert committee of the Living Environment Council which responded to the request for advice of the Minister for Health and Welfare carried out an examination from the technical point of view for approximately one year and submitted "a report of the expert committee on the environmental standard for suspended particulate matters" in 1970. As the Environment Agency started, the Central Council for Environmental Pollution Control took over the deliberation of this matter and submitted the proposal of the SPM environmental standard to the Director-General of the Environment Agency in 1971. The Environment Agency established the environmental standard for suspended particulate matters as Notification No. 1 of the Environment Agency in 1972 based on this proposal. A part of the measurement method was added and revised in 1981. The grounds for establishment of the standard are as follows:

Particulate matters cause a visibility disorder and damage animals and plants, implements, buildings, clothes, etc. and also exert an adverse influence on the health of human beings. Among them, the suspended particulate matters with a particle diameter of 10 μm or less have a big influence on the health of human beings because of the following medical characteristics: ① The particles with a particle diameter of 10 μm or less are slow in precipitation and stay in the air for a relatively long time. ② Most of the particulate matters with a particle diameter of 10 μm or more are captured by the nostril, pharynx and larynx, but 90% of particulate matters with a particle diameter of 10 μm to 5 μm precipitate on the respiratory tracts and pulmonary alveoli causing an adverse influence on the respiratory organs. ③ The precipitation rate on the pulmonary alveoli of the particulate matters with a particle diameter of 4 μm to 2 μm or less is the highest.

Incidentally, the size of a particle which is an object of the environmental standard is determined by its measurement method. In the EPA high volume method adopted in the United States and Canada, it is said that particles with a particle diameter of 0.1 to 100 μm are captured, and these total suspended particulates are an object of the environmental standard. In the LIB high volume method adopted in West Germany and Sweden, it is said that particles with a particle diameter of 0.5 to 80 μm are captured. Since a low-volume pump is used in the BS standard

method or OECD smoke method, it is considered that the maximum particle diameter of the captured particles is approximately 20 to 30 μm . Only Japan covers the particles with a particle diameter of 10 μm or less as of May 1987, and most of the countries cover total suspended particulates with a particle diameter of 20 to 30 μm or less. A lot of research has been done recently on particle diameters when particulate matters are taken in by the human body and its mechanism. The relation between the medical effect of being taken in by the human body and particle diameters is as follows:

- >10 μm : most all the particles are captured by the nasal cavity and pharynx.
- 5 to 10 μm : 90% of the particles are precipitated on the respiratory tract and pulmonary alveoli. (The precipitation rate on the pulmonary alveoli is maximum when the particle diameter is 2 to 4 μm .)
- 0.5 to 5 μm : The precipitation rate gradually decreases and it is 25 to 30% when the particle diameter is 0.5 μm .
- <0.5 μm : The precipitation rate increases again.

It is considered that the particle diameter of the particulate matters which may have an influence on the respiratory organs is 10 μm or less, and the standard in Japan which took this point into consideration are worthy of special mention. The EPA reexamined comprehensively an influence of particulate matters on health, weather conditions, etc. and issued the final regulation of the air environmental standard for SPM on June 3, 1987 (40 CFR50).

Fig. 2-6 shows an annual average of the suspended particulate matters at the air monitoring stations in Japan. It has decreased gradually since 1974, but it remained at the same level during the past few years. The achievement rate of the environmental standard in the air monitoring stations was as low as 52.6% in 1987. The diesel black smoke with the increase of diesel cars recently and dusts caused by spike tires in cold districts are at issue.

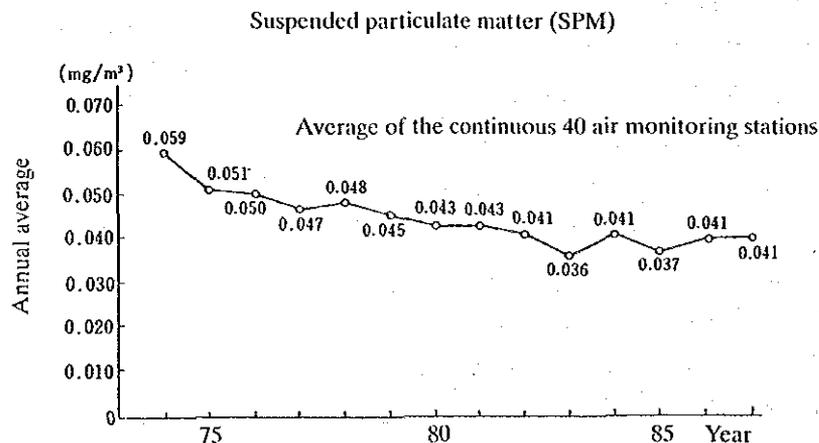


Fig. 2-6 Secular Change of Ambient Air Concentration of SPM

2.2.3 Korea

The environmental issues in Korea came into the open from the beginning of 1960 when Korea started to industrialize. There is no doubt that sporadic environmental disputes occurred before that time. However, generally they merely appeared as an infringement of personal properties or damage to health partly because the the concern about environment pollution was very low in the community. Under these circumstances the Pollution Control Law was established in 1963. As the industrial development was accelerated before long, river contamination and air pollution in cities became aggravated. Particularly, construction of highways in big cities increased air pollution. In the latter half of the 1960s a campaign against pollution became active so that the nation's awareness of the environment started to change. Since the national policy gives top priority to economic development, however, it cannot be denied that the environmental policies took a back seat. At the end of 1970s the environmental pollution had become a grave health threat to human beings. Finally in 1978 the Environmental Preservation Law was enacted and the National Environment Research Center was established and in 1980 the Environment Agency was inaugurated. In Korea an environmental right is stipulated in the Constitution. That is, "① The people shall have the right to live in a wholesome and comfortable environment and the nation and people shall have the obligation to cooperate in order to preserve the environment. ② The contents and functions of the environmental rights shall be determined by law." A harmony between economic development and environmental protection is positioned as a basic line of the environmental policies in the 5th Economic Development Plan (1982 to 1986).

The Environmental Preservation Law deals with the basic environmental policies, air and water pollution control, noise and vibration regulations, fund raising of the environmental policy project, and arbitration of environmental disputes. The laws such as the National Environmental Policy Law, Environmental Dispute Arbitration Law, Air Pollution Control Law, Water Pollution Control Law, Noise and Vibration Regulation Law were enacted to supplement the Environmental Preservation Law. The air environmental standards stipulated by the Air Pollution Control Law are shown in Table 2-5.

Table 2-5 Air Quality Standards in Korea

Item	Standard value
Sulfur dioxide (SO ₂)	Annual average: 0.05 ppm or less 24-hour average: 0.15 ppm or less (SO ₂ must not exceed this value three times or more a year.)
Carbon monoxide (CO)	Monthly average: 8 ppm or less 8-hour average: 20 ppm or less (CO must not exceed this value three times or more a year.)
Nitrogen oxides (NO ₂)	Annual average: 0.05 ppm or less One-hour average: 0.15 ppm or less (NO ₂ must not exceed this value three times or more a year.)
Total Suspended particulate (TSP)	Annual average: 150 µg/m ³ or less 24-hour average: 300 µg/m ³ or less (TSP must not exceed this value three times or more a year.)
Oxidant (as O ₃)	Annual average: 0.02 ppm or less One-hour average: 0.1 ppm or less (O ₃ must not exceed this value three times or more a year.)
Hydrocarbon (HC)	Annual average: 3 ppm or less One-hour average: 10 ppm or less (HC must not exceed this value three times or more a year.)

Source: Data of the Environment Agency in Korea

Among stationary sources in Korea, almost all the fuels used in factories are high sulfur content heavy oil and approximately 75% of home heating is charcoal briquette. As moving sources, almost all buses and freight trains use light oil, taxis use LPG, and private vehicles use gasoline. For this reason, SO₂ and suspended particulates are a main problem in the air pollution of Korea. As for the SO₂ concentration of the main Korean cities in 1986, the annual average in Seoul and Incheon exceeded the environmental standard, and particularly the SO₂ concentration in winter (December to February) reached 0.088 ppm. It is assumed that fuel containing a high percentage of sulfur such as heavy oil of 1.6% sulfur (heating in buildings), light oil of 0.4% sulfur (vehicle fuel), briquette of 0.3 to 0.9% sulfur (heating in houses) caused this situation. The suspended particulates show a similar seasonal change. It is considered that the suspended particulates are due to discard and transport of ash of briquette for heating, and scattering of coal and lignite stored in open air. The environmental concentrations of TSP in Seoul and that in Pusan in 1987 were 175 and 197 $\mu\text{g}/\text{m}^3$, respectively, which exceeded the standard value. As the mode of living is changing, however, the briquette is replaced with oil and town gas, and dust tends to decrease. Recently people have a growing interest in air pollution caused by cars.

2.2.4 Taiwan

The economy in Taiwan has been led by the development of the export-oriented industries since the 1960s and the economic growth rate as high as 9.1% in 1960 and 10% in the 1970s on average was attained. Furthermore, the national income per capita amounted to US\$4,987.00 in 1987 and it was estimated at US\$6,045.00 in 1988, which is an income level following Japan, Singapore, and Hong Kong in Asian countries. With respect to the energy supply-demand in Taiwan, coal, oil, and water power resources are scarce. Taiwan has ample natural gas resources which now rank first in the energy supply. The energy used for the industrial development, however, has depended on imported coal and oil. After the oil crisis, emphasis has been laid on coal and atomic energy. Since there are some constraint on atomic energy, the import of coal is increasing rapidly. Under these circumstances, although the environmental legislation in Taiwan started with the factory law, the legislation suitable for the promotion of industrialization and economic development was arranged in the 1970s. The Water Pollution Control Law, Air Pollution Control Law, and Waste Matter Disposal Law were established in 1974, 1975 and 1980, respectively, and in 1983 the Noise Control Law was also established. In 1987 the Executive Yuan Health Bureau Environmental Protection Agency was raised to the status of the Executive Yuan Environmental Protection Bureau. With this raising of its status, various laws related to environment protection have been established and revision work also has been actively carried out. Table 2-6 shows the environmental standards related to air pollution.

Table 2-6 Ambient Air Quality Standards in Taiwan

Environmental air quality standards

(a) Suspended particulate matters (SPM)

Item	Permissible value excluding the coarse particulates with a particle diameter of 10 μ or more	Permissible value including the coarse particulates with a particle diameter of 10 μ or more	(Unit: $\mu\text{g}/\text{Nm}^3$)
Monthly average	Non-industrial area: 210 Industrial area: 240	Non-industrial area: 260 Industrial area: 290	The Particulate Matter concentration must not exceed the permissible value twice or more throughout the year.
Annual average	Non-industrial area: 140 Industrial area: 160	Non-industrial area: 170 Industrial area: 190	

(b) Sulfur oxides

* Sulfur oxides concentration

By area	Non-industrial area	Industrial area
One hour value	0.3 ppm	0.5 ppm
Daily average of one hour value	0.1	0.15
Annual average of one hour value	0.05	0.075

* Accumulative volume of sulfur oxides (Accumulative volume calculated in terms of sulfur trioxide for 30 consecutive days with an exhaust area of 100 cm^2)

Non-industrial area	60	Unit: $\text{mg}(\text{SO}_2)/100\text{ cm}^2/30\text{ days}$
Industrial area	90	

(c) Nitrogen oxides

By area	Non-industrial area	Industrial area
Daily average	0.05 ppm	0.1 ppm

(d) Carbon monoxide

8 hour average	Daily average	The concentration of carbon monoxide must not exceed this value.
20 ppm	10 ppm	40 ppm

In addition to the above-mentioned, a long-term target is set as shown below.

Long-term air pollution control target

Item	Suspended particulate matters (SPM)		SO_2 ppm	CO ppm	NO_2 ppm	Non methane hydrocarbon ppm	Ozone ppm	Lead $\mu\text{g}/\text{m}^3$
	Including particulates with a diameter of 10 μm or more	Excluding particulates with a diameter of less 10 μm						
Target								
1991	170	140	0.05	10 (1)	0.05	1.0	0.12	1.5
1996	100	75	0.03	10 (2)	0.05	0.31	0.12	1.5
Remarks	Annual average	Annual average	Annual average	(1) Daily average (2) 8 hour average	Daily average	6 a.m. - 9 a.m. average	Hourly average	Three month average

The actual environment pollution in the main cities of Taiwan and the conformance rate of the environmental standards are made public, and the concentration of pollutant in Taipei and its industrial vicinity is high. The Environmental Protection Bureau published the situation of the air pollution as PSI (Pollution Standard Index) to try to arouse the citizen's attention. However, there

are still many areas where PSI is 100 or more. SO₂ seems to be improved considerably, but 34% of the monitoring stations have not attained the standard as of 1987. There were 7,700,000 motor vehicles at the end of 1987, and motorcycles accounted for 77.3%. Furthermore, cars are increasing at the rate of 5,000 per month, which is a main factor of the NO_x and CO pollution in the urban districts.

2.2.5 China

Coal is used in China for energy of power plants and factories, and heating and cooking in houses, and it accounts for approximately 70% of the primary energy in the country. For this reason, the air pollution caused by dust, SO₂, and NO_x is worsening. The Environmental Protection Law (trial) enacted in 1979 expresses the environment policy called the "Three Simultaneous Principles." That is; ① to design the production facilities and pollution control facilities simultaneously, ② to execute the construction of both facilities simultaneously and ③ to operate them simultaneously. Installation of wet type dust collectors (they account for approximately 60% of all the devices) in old power plants and electric dust collectors in modern large-size plants have been carried out as improvement measures against dust and particulates discharged from power plants. Although desulfurizers were not installed in the past for an economic reason, they have been installed in the areas such as Sichuan where acid rain does serious damage to agricultural products. However, denitration equipment has not been installed yet.

Laws and regulations related to the air environment in China are as follows. Table 2-7 shows the environment air quality standards stipulated in the Air Pollution Control Law.

Environmental Protection Law (trial) (1979)

Environmental Air Quality Standards (1982)

Air Pollutant Emission Standards (1983)

Boiler Dust Emission Standards (1983)

Pollutant Emission Standards for Low Speed Automobile (1983)

Smoke Emission Standards for Free Acceleration Diesel Car (1983)

Air Pollution Control Law (1987)

Table 2-7 Environmental Air Quality Standard in China

Item	Sampling time	Maximum concentration value (mg/Nm ³)		
		1st class standard	2nd class standard	3rd class standard
Total particulate matters (100 μm or less)	Daily average	0.15	0.30	0.50
	Once	0.30	1.00	1.50
Suspended particulate matters (10 μm or less)	Daily average	0.05	0.15	0.25
	Once	0.15	0.50	0.70
Sulfur dioxide	Annual daily average	0.02	0.06	0.10
	Daily average	0.05	0.15	0.25
	Once	0.15	0.50	0.70
Nitrogen oxides	Daily average	0.05	0.10	0.15
	Once	0.10	0.15	0.30
Carbon monoxide	Daily average	4.00	4.00	6.00
	Once	10.00	10.00	20.00
Oxidant	One hour average	0.12	0.16	0.20

(Note)

1. The daily average means a maximum value which any daily average concentration must not exceed.
2. Once means a maximum value which any one-time sample must not exceed.
3. Annual daily average means a maximum value which any annual daily average concentration must not exceed.
4. One hour average means a maximum value which a one hour value must not exceed once or more a month.
5. 1st class standard: Air quality which does not exert any adverse impact on a natural ecosystem and the health of human beings even through a longtime contact.
2nd class standard: Air quality which does not damage the health of human beings and animals and plants in cities and rural communities even through longtime contact.
3rd class standard: Air quality which does not cause any acute or chronic intoxication to human beings or prevent the animals and plants in cities (excluding the sensitive ones) grow normally
6. The environmental air quality standards are classified into the following three categories depending on the geographical features of each district, weather conditions, ecology, politics, economics, and degree of air pollution.
1st category: Protection zones of natural environment, beauty spots, places of historic interest, and areas of medical treatment prescribed by the government
2nd category: Residential areas, mixed areas of commerce, traffic, and residences, cultural area, beauty spots and places of historic interest and suburban rural communities, which are designed by city planning.
3rd category: Urban industrial areas where the air is seriously polluted and the center of the municipal transport, trunk lines, etc.

The environmental standards in China shows values as severe as in developed countries including Japan, but the percentage of achievement of standards seems to be rather low. The following concrete cases are reported.

- ① Air pollution in big cities including Peking, Shanghai, Wuhan, and Kuangchou
- ② Occurrence of smog and photochemical smog caused by SO_x , NO_x , and dust emitted from petroleum complexes located in inland basins such as Lanchou
- ③ Crop damage due to acid rain produced in areas, south of Yangtzechiang including Chung-ching, Kueiyang, Kungchou, and Nanchang

It is said in this connection that the coal used in China has a sulfuric content as high as 2 to 3% and 18,000,000 tons of SO_2 are emitted in a year.

2.2.6 U.S.A.

A movement towards federal lawmaking related to air pollution in the U.S. was triggered by the outbreak of an air pollution problem in California in 1950. In 1955, a law was enacted to mandate the Secretary of Health, Education, and welfare to take the initiative in education, training, and technical assistance concerning air pollution in the said state and other regions, followed by the establishment of the Air Pollution Control Act to expand the above law in 1959. Both the Senate and the House of Representatives organized their committees, actively discussing the legislation of air pollution. The committee of the House of Representatives targeted automobile exhaust gas, resulting in the institution of the Automobile Exhaust Gas Study Act in 1960, coupled with discussion about the roles of the federal government. In 1962, "Silent Spring" by R. Carson was published, and there occurred the event of fog in London, enhancing interest in legal restrictions on pollution. The 2nd National Convention of the Academic Society of Air Pollution held in Washington D.C. was attended by 1,500 people. In 1963, the Clean Air Law was passed by Congress, followed by the institution of the Automobile Air Pollution Control Law in 1983, thus initiating emission control for new cars. Since then, the Clean Air Act has received minor and major amendments over 10 times up to 1983. While this act has brought about considerable improvements

in air quality, there remain some regions which fail to fulfill the environmental standards.

The U.S. air quality standards have been established under the Clean Air Act: they are divided into the standards established with attention paid to human health (Primary Standards) and the other standards taking note of the living environment (Secondary Standards). Both stipulate the standard values of 6 items such as SO₂ and NO₂, respectively (see Part III, Table 1-18). In order to maintain these environmental standards, each state is to formulate its own implementation plan and obtain its approval by the Environmental Protection Agency. Following this plan, each state is carrying out the emission control for stationary sources. In addition, the Environmental Protection Agency itself has also established the national standard values of emission from mobile sources, main new sources, and sources of toxic substances. The evaluation of air quality is performed based on data available from the national air quality measurement data bank of the Environmental Protection Agency. These data are assembled from about 5,000 air pollution monitors all over the U.S.

Reviewing the status of conformity with the environmental standards for air pollutants in U.S., the standards for SO₂, TSP, NO₂, and Pb have been fulfilled in most regions. CO and O₃, however, are still at problematical levels, though a decreasing trend can be seen. The cause thereof is apparently automobiles, against which various restrictive measures have been taken. Especially for O₃, air pollution control plans have been formulated to enable the fulfillment of the standards till 1990, except in such cities as Los Angeles, Houston and New York. In Anchorage, though it is a local topic, a problem occurred with air pollution caused by CO emission from engines which were left idling to prevent cars from freezing while parked. The most critical problem for the power industry is falling acid matters, which are known in the form of acid rain. Some people believe that the current standards can sufficiently manage the inhibition of SO₂ and NO_x, which are the precursors of acid rain, whereas other people believe the standards to be insufficient and thus bring bills before the Congress, but in many cases they receive no backing and find it withdrawn. This is due to the uncertainties of data and their interpretation as well. The data pertinent to acid rain are assembled from monitoring stations spread over the whole country. At present, wet falling matters are being measured at 150 stations, and a plan is now being worked out to add 100 monitoring stations to measure dry falling matters.

2.2.7 West Germany

The Federal Immission Control Act established in 1974 is the basic law concerning air pollution control and noise reduction in West Germany. The term "Immission" is a German word which has no synonym in English, and it has been defined as "air pollutants, noise, vibration, light, heat, radiation, and related environmental factors, which affect humans, animals, plants, and other objects." In addition, "Emission" has been defined as "pollutants, noise, vibration, heat, radiation, and related phenomena, which stem from apparatuses." This act provided a new base for environmental preservation, and its principle is to prevent pollution at its sources. Under this law, moreover, the factory manager is obliged mandatorily to appoint a manager for environmental preservation. His duties include: ① to develop those processes and products that are harmless to the environment; ② to examine the environmental conformity of new processes and products; ③ to

check the requirements for environmental protection in the company and propose the improvement of deficiencies; and ④ to educate employees about the effect of this law. He is also requested to make suggestions on investment required for environmental preservation.

In West Germany under a federal system, the nation's functions are performed by the federal, state, and municipal governments. In the field of environmental protection, the federal government has a full legislative power concerning air pollution control, waste disposal, and noise prevention, while administrative measures are executed by each state. Recently, the national legislation has been increasingly supplemented by the legislative action of the EC. The federal Environmental Agency was organized in 1974, when the Environmental Preservation Law was enacted, and this Agency coordinates environmental studies in the federal government, utilizing the results of such studies. In addition, the Environmental Statistics Law was instituted in the same year, providing a legal base for acquisition of ecological, economic and financial data on specific environmental loads. West Germany's environmental standards are as shown in Table 1-18 of Part III.

Air quality is monitored through a broad monitoring network, which takes measurements at the following numbers of stations: SO₂ at 220 stations; CO at 150; particulate matter at 140; O₃ and NO₂ at 125 each; and H₂S at 9. This monitoring network is also utilized for a European air monitoring plan. With regard to the emission volumes of air pollutants, the volume of sooty particulates emitted from power plants, cement factories, steel mills, etc. was substantially reduced subject to a "Guide to Technical Instructions on Air Pollution Control" which stipulates general restrictions on emission, the restricted values of emission from specific plants and technical requirements. The emission volume of SO₂ has slightly decreased since the middle of 1970. The desulfurization of combustion gas was introduced around 1974, and has increased its prevalence in association with acid rain. Of the emission volume of NO_x, power plants are reportedly occupying 40%. In West Germany, the following matters are now the urgent themes on air pollution control:

- ① Global scale environmental problems such as the prohibition of the use of chlorofluorocarbon, and the reduction of the volume of CO₂ generated.
- ② Prohibition of the use of leaded gasoline, the reduction of particulate matters emitted from diesel cars, and the reduction of air pollutants from automobile emission.
- ③ Continuation of countermeasures for prevention of forest destruction.
- ④ Remodeling of plants for air pollution control

2.3 Emission Standards in Foreign Countries and its Concept

2.3.1 Japan

The followings are two basic concepts of setting the emission standards.

- ① The concept that emission standard should be established as a restrictive measure to attain environmental standards, which is applicable for SO₂, NO₂, and so on which are usually emitted on a broad scale area.
- ② The concept that a specified dilution rate between emission concentration and environmen-

tal concentration may be considered if facilities emitting pollutants such as Cd, HCl, etc. are limited and combined pollutants are considered negligible.

The first concept is based on the assumption that the total emission volume of pollutants and the environmental concentration of pollutants in a specified area are proportional to each other if facilities are concentrated in the area at more than the specified level. Consequently, the emission standard value differs depending on the degree of the concentration of facilities and the emission volume of the pollutant in an area. In other words, in association with economy growth which leads to more production of a pollutant, the more severe of an emission standard value should be legislated. Emission standards, however, are established by giving administrative consideration such as technical and economic feasibility.

The second concept is that it is enough to consider only the influence of one facility producing the pollutant upon the environment. In that case, it is necessary to assume the permissible environment concentration concerning the corresponding pollution component around a factory which is subject to the most influence. If the acceptable environment concentration is assumed, in order to correlate the permissible environmental concentration with the emission concentration called the emission standards, it is necessary to consider how much the substance is diluted when it is emitted in the air. Further, in case of final legislation of the emission standard value, the concept that the value can be varied depending on individual sources should be noted, because the pollutants volume and diffusion concentration are affected with factory size, emission volume, etc. In the case of TOXIC substances, however, even if the emission volume of TOXIC substances differs to the scale of factories, a uniform value applicable to all emission sources should be instituted based on administrative judgement of existing emission control techniques for toxic substances.

(1) Sulfur oxides

If residents made a complaint about an individual damage due to an air pollution phenomenon caused by soot and smoke accompanied with coal combustion, necessary measures were taken according to the prefectural or municipal ordinances of Tokyo, Osaka, and Kanagawa, etc. until around 1955. However, generally black smoke coming from a forest of stacks was accepted as a symbol of economic prosperity and the pollution was considered to be a geographical problem. After the government decided to install a petrochemical complex in Yotsukaichi in 1955 in order to measure the economic growth in Japan, regional developments were planned and promoted aiming at heavy chemical industrialization throughout the country. Yotsukaichi complexes have begun operation successively since 1960 and following this the production facilities were expanded at the same time throughout the country. Consequently, the output of the mining and manufacturing industries increased and energy consumption increased rapidly. The total energy supplied mainly by the domestic coal around 1955 was 560×10^{12} Kcal (44.8% of domestic coal, 4.4% of imported coal, 20.2% of oil, 9.4% of other energy sources), while in 1965 it amounted to $1,656 \times 10^{12}$ Kcal (19% of domestic coal, 8.2% of imported coal, 58.4% of oil, 11.3% of water power) owing to the energy conversion policy to cope with an increasing energy demand. Energy consumption was almost tripled in 10 years. Japan was able to cope with the increase in energy consumption because of

import of oil containing a high percentage of sulfur from the Middle and Near East. Afterwards in 1970 the energy demand doubled amounting to $3,105 \times 10^{12}$ Kcal (8.1% of domestic coal, 12.6% of imported coal, 70.8% of oil, 6.3% of water power).

Under these circumstances the phenomenon of air pollution became an issue over a wide area exceeding the limit of a local public entity. An influence on the health of people and the living environment became more and more serious and countermeasures were required on a nationwide scale. Namely, from 1954 to 1957 legislation concerning "the living environment pollution control" was examined, but it was not realized. The Soot and Smoke Regulation Law was enacted in 1962. This law stipulated the following:

- ① An area where remarkable air pollution occurs is designated as an area requiring the regulation.
- ② If a prescribed apparatus exhausting soot and smoke is installed in factories, etc. of the area, it is mandatory to give a prior notification.
- ③ If the concentration of soot and smoke emitted from an facility exceeds a given standard, orders are given to take measures such as a structural improvement of the facility exhausting soot and smoke. In addition, financing and other subsidies are provided if necessary to promote installation of smoke and soot removal facilities in the factories and enterprises, and technical studies to cope with the automobile exhaust gas and other problems are promoted.

This law regulated the emission of soot and smoke in main industrial cities such as Tokyo, Kawasaki, Yotsukaichi, Osaka, and Kyushuu. However, since even in the designated areas the emission of soot and smoke of small-scale facilities is not regulated, a partial revision of the law was made in 1963 so that the local self-governing bodies were able to stipulate necessary regulations, and the concentration of the sulfur oxides emitted from the facilities was limited to 2,200 ppm. These regulations contributed to the installation of dust collectors and at the same time the coal combustion rate was lowered owing to energy conversion so that the air pollution caused by the dust fall which was a big issue at that time was greatly improved.

The air pollution caused by the sulfur oxides, however, was aggravated with the sharp increase of oil fuel. On the other hand, effective measures were not taken in the method of regulating the emission concentration in each facility. The number of cars also has rapidly increased, and the air pollution caused by the automobile exhaust gas has been aggravated. Therefore, the development of desulfurization of heavy oil of which technical research has been done since 1966 and the promotion of guidance to install the desulfurizer of exhaust gas were resolved in the Diet, and the Special Committee for Anti Industrial Pollution made examinations in a wide area. In the examinations the Special Committee drastically reconsidered the past antipollution measures which did not produce the anticipated results because individual emergency measures lacked organic correlation among measures and consistency, and clarified the basic principle and idea of the antipollution measures. In 1967 the Basic Law for Environmental Pollution Control was enacted to prepare and promote the comprehensive and systematic antipollution measures.

As the Basic Law for Environmental Pollution Control was established, "the Soot and Smoke Regulation Law and other laws" were reviewed, and the Air Pollution Control Law were established together with the governmental and ministerial ordinances in 1968.

The outline of the emission regulation established by the Air Pollution Control Law is as follows:

- ① Designate an area where facilities that exhaust soot and smoke are installed densely and smoke emitted from these facilities pollute the air considerably and where installation of facilities exhausting soot and smoke is certain so that air pollution is forecast as a regulation target area in advance (designated area).
- ② Establish the emission standards to be observed by emission sources in each designated area. With respect to the emission standards for sulfur oxides, an allowable limit of the volume of sulfur oxides emitted from stacks is set according to the stack height. With respect to soot and other dust, an allowable volume limit for soot and other dust included in the matters emitted from stacks is set for each type of facility.
- ③ Require prior notification when a facility emitting soot and smoke is installed in the designated area and to observe the emission standards for emission sources. If they do not conform to the emission standards, they are ordered to change their plan (including abolition of their plan) and to make an improvement. Furthermore, in the case of an emergency where the air pollution is serious and the health of human beings may be damaged, these ordinances can ask emission sources for help to reduce the smoke discharge and advise installers of facilities exhausting a large amount of sulfur oxides that they should take measures to reduce its discharge. There are 20 designated areas in 17 metropolitan cities and districts. The sulfur oxide emission concentration is set to 1,800 to 2,800 ppm with a certain latitude allowed.

The regulations which were established twice aims at preventing the environmental pollution by controlling the sulfur oxides emitted from each chimney. Since the establishment of the environmental criteria was forced to be postponed until 1969, only aggravation of air pollution caused by sulfur oxides was prevented in opposition to an increasing energy consumption. Under these circumstances the ideal way of regulating the sulfur oxides changed to a more rational one in connection with the environmental concentration. Namely, before the Environmental Pollution Prevention Act was established, a conception of the environmental criteria did not exist. Therefore, people understood the necessity of reducing the environmental pollution caused by emission of air pollutants, but did not have a clear goal of how much it should be reduced. Even if the sulfur oxide emission concentration of the source is constant in the past emission regulation, the more the gas discharge is, the more the sulfur oxide discharge becomes so that the environmental concentration on earth becomes high.

Furthermore, even if the sulfur oxide discharge is the same, the environmental concentration on earth becomes high when stacks are lower. Consequently, the emission concentration regulation

system can neither improve the environmental concentration drastically nor set up a standard for the emission regulation value with which environmental improvements can be realized. When the Environmental Pollution Prevention Act was established, this point was taken into consideration, and in the Air Pollution Control Law established in June 1968 the quantity regulation system (K value regulation) in accordance with the effective stack height was adopted.

The less the K value is, the severer the emission regulation becomes in this K value regulation as shown in paragraph 4.1 of Chapter VI, and the K value can be satisfied by either reducing the SO₂ discharge or by making the stacks higher. Also, this K value regulation has a relation that 584 times of the concentration (ppm) on earth are the K value. Therefore, when the K value is given, the emission regulation value (emission tolerance) can be calculated from the effective stack height.

In making a summary of the history of the K value regulation so far, a regulation of K=20.4 to 29.2 was established in 27 areas in December 1968. The regulation was tightened 5 times by May 1973 when the environmental criteria were reviewed. During this period the regulation was extended throughout the country (June 1971), and the K value was made severer within the range of 6.42 to 22.2. Furthermore, when the second K value regulation tightening was carried out, a concept was introduced so that special emission standards more rigorous than the general ones are applied if new facilities are installed in an area which is polluted to a high degree by sulfur oxides. Also, in 1971 a fuel regulation system where fuel containing a low percentage of sulfur is used was introduced to cope with a seasonal phenomenon of environmental aggravation due to house heating in winter. Afterwards, the K value regulation tightening (3.0 to 17.5) was carried out twice in order to satisfy the environmental criteria which were revised and tightened in 1973. In addition, a total discharge regulation system where the total discharge of sulfur oxides are regulated by factory was introduced in 1974. These regulations contributed much to a gradual reduction of the environmental concentration of sulfur oxides and the conformance rate of the environmental criteria attained 99.6% in 1987. (The number of measurement stations was 1,603.)

(2) Nitrogen oxides

When the Air Pollution Control Law was established, with respect to the emission regulation of nitrogen oxides there was still no sign of development of the denitration technique, and the problem was not taken up for discussion. However, in the case of future emission regulation, it was decided that the emission standards would be set for each type of facility uniformly throughout the country. This is because the discharge of nitrogen oxides differs depending on the facility and fuel and the K value regulation cannot be established like in the case of sulfur oxides. Then, after the environmental criteria for nitrogen dioxide were established in 1973, the regulations were carried out three times successively: the first one for large-size facilities in the same year, and in 1975 the second one in which the environmental criteria were applied to more facilities, and in 1977 the third one in which the criteria for the existing large-size facilities were tightened, these criteria were applied to more facilities, and the criteria for newly established facilities were tightened. Among approximately 144,000 facilities emitting smoke, the emission standards were set for 13,000 facili-

ties (they accounted for approximately 9% of all the facilities emitting smoke and their NO_x discharge accounted for 73% of the total discharge) which were the main source of nitrogen oxides. Moreover, since there were some facilities where a contribution to the environmental concentration was not negligible among the remaining facilities to which the emission standards were not applied, the 4th revision was carried out in 1979 to extend the regulation. As a result, a regulation was carried out in 105,000 facilities (they accounted for more than 70% of all the facilities emitting smoke and their NO_x discharge accounted for 95% of the total discharge). Furthermore, from the technological point of view the criteria of a level which the low NO_x combustion technique was able to clear as before was established. Small-sized boilers with the minimum-scale heating surface area of 10 m² or less having a large combustion capacity which emit a large amount of NO_x have spread since September 1985. Since an aggravation of the air pollution might be caused, a condition that the burner combustion capacity was 50 l/h or more was newly established and added to a facility emitting soot and smoke in order to secure the validity of the law. In addition, it was expected that the gas turbines and diesel engines would spread to some extent particularly in big cities in the future so that the condition was added to a facility emitting soot and smoke since February 1987. The environmental criteria of nitrogen oxides were revised in July 1978, and the Tokyo Metropolis, Yokohama city, and Osaka city where it was considered that these criteria were attained urgently were designated as a total quantity regulation area in June 1981. The emission standards of nitrogen oxides were established by facilities (62 facilities), by size of facilities, and by installation date of facilities. For the details of these values refer to the section of data on the "Air Pollution Control Law."

(3) Dust

The dust emission regulation was carried out for the first time in 1962 by "the law concerning dust emission regulation, etc." Regardless of the size of facilities, the emission standards were established uniformly for individual facilities, for example, 1.2 g/Nm³ for a boiler, 1.0 g/Nm³ for a cement kiln, and 0.5 g/Nm³ for a blast furnace. Afterwards, as the Air Pollution Control Law was established, the emission standards were revised to a value as severe as 1/3 to 1/10 of the old emission standards, and the concentration regulation by type and size of facilities was also established. When a revision was made, the environmental criteria of suspended particulate matters had not been established yet. The emission concentration of dust was determined almost uniformly according to the performance of the dust collector to be installed. Since the conventional system produced results to some extent, the concentration regulation system was adopted. However, even if the emission concentration is the same, the bigger the facilities are, the larger the discharge becomes. Therefore, the severer concentration emission standards are applied to bigger facilities. An idea of quantity regulation is incorporated in the form of concentration regulation. Then, the third revision was made in 1982 after approximately 11 years had passed. As far as the third revision was concerned, the emission standards were tightened to about half the value, a standard oxygen concentration correction system of dust concentration was introduced in order to prevent unfair conformance of the emission standards by diluting emission gas and to establish and take fair

regulations and measures for a facility emitting soot and smoke, and new emission standards were established for 7 kinds of facilities emitting soot and smoke. As a result, approximately 5,000 facilities were newly regulated. Consequently, more than 99% of the facilities emitting soot and smoke in Japan were regulated. Furthermore, in 1987 gas turbines and diesel engines were designated as apparatus emitting soot and smoke and the emission standards were established. The dust emission standards are established by type (59 facilities) and size of facilities. For the detail of the values refer to the section of data "the Air Pollution Control Law."

(4) Toxic substances

The government ordinance designated cadmium and its compounds, chlorine, hydrogen chloride, fluorine, hydrogen fluoride, silicon fluoride, lead and its compounds, and nitrogen oxides as toxic substances. Among them the emission standards for nitrogen oxides are established separately. Therefore, usually matters other than the nitrogen oxides are designated as toxic substances. The emission standards (concentration) of lead and its compounds, for example, are determined in terms of the amount of lead because of the restriction of the measurement technique. Consequently, the emission standards are established for 5 elements of chlorine, hydrogen chloride, fluorine, lead, and cadmium.

When the emission standards for the toxic substances were established in Japan (1971), the emission source concentration and the concentration in the environment of SO_2 and CO of which the number of measurement cases was large were adopted for reference to know the degree of diffusion of toxic substances. Namely, the following dilution was observed on the whole. When the emission concentration of SO_2 was approximately 1,000 ppm, a long-time average concentration in the air was 0.05 ppm, which was approximately 20,000 times thinner. And a short-time average concentration in the air, which was denser, was 0.5 ppm, which was approximately 2,000 times thinner. In addition, since the CO content of the automobile exhaust gas was 5% (50,000 ppm) on average and the environmental concentration was 25 to 50 ppm at that time, it was considered that the dilution rate was 2,000 to 1,000 times.

The above-mentioned two cases indicate a dilution rate by two or more sources, and it is considered that the dilution rate by a single source which produces toxic substances is larger than that by two or more sources. However, when the emission standards of toxic substances were established, the dilution rate was considered to be 1,000 times that of the environmental acceptable concentration taking safety into consideration. The value of 1/30 to 1/100 of the industrial environmental concentration was adopted as the permissible environmental concentration of toxic substances referring to the concentration indicated in the Industrial Health Law, etc. in nations worldwide.

The emission standards for toxic substances are established by toxic substance and facilities. For the detail of the values refer to the section of data on the "Air Pollution Control Law."

2.3.2 U.S.A.

In the U.S.A. the National Ambient Air Quality Standard (NAAQS) of 6 types of main air

pollutants (SO₂, SPM, CO, NO₂, lead, and ozone) was established by the Clean Air Act (CAA), and it is stipulated that each state prepares a State Implementation Plan necessary to achieve the NAAQS according to the criteria instituted by the Environment Protection Agency (EPA) and obtains an approval from the EPA so that 247 Air Quality Control Regions throughout the U.S.A. can achieve the NAAQS. In the U.S.A., there are many regions which have an air quality cleaner than the NAAQS, and the Prevention of Significant Deterioration (PSD) is carried out for these regions so that pollution may not become worse than the present situation. Under these circumstances, the following 4 air pollutant emission standards are applied to newly installed fixed sources, and the emission standards based on the Reasonably Available Control Technology (RACT) is applied to the existing facilities.

- ① NSPS (New Source Performance Standard)
- ② NESHAP (National Emission Standards for Hazardous Air Pollutants)
- ③ BACT (Best Available Control Technology)
- ④ LAER (Lowest Achievable Emission Rate)

The NSPS is the emission standard of the special air pollutants (dust, SO₂, NO_x, CO, acid mist, H₂S, VOC (Volatile Organic Compound), TRC (Total Reduced Compound), etc.) for the stationary sources to be newly installed in the NAAQS achievement areas. The NESHAP are the emission standards for stationary sources emitting the toxic substances prescribed in Article 112 of the CAA. On the other hand, BACT and LAER are the emission standards applied to stationary sources to be newly installed in the PSD areas and the NAAQS nonachievement areas. The NSPS and NESHAP are the emission standards which were standardized at the federal government level, and the BACT and LAER are the allowable discharge determined by an EPA branch or state government according to the condition of air quality in each area, and the emission tolerance differs depending on the area where the newly installed and added factories are located even if the industry type is the same.

(1) Outline of NSPS

The EPA established the NSPS of the main facilities in December 1971 and made it public as an EPA rule (40CFR60). Article 111 of the Clean Air Act also stipulates that a review should be made every four years of the type of facilities to which the NSPS is applied and the emission concentration of air pollutants emitted from the corresponding facilities in view of the development of the air pollutant emission technology. With this stipulation, the EPA has continued to revise the NSPS after 1971 and established the NSPS for 56 facilities as of 1986. The emission standard value of this NSPS differs depending on the facilities, and the target pollutants for the emission regulation differ depending on the facilities. Table 2-8 shows an example thereof.

Table 2-8 Example of New Source Performance Standard in the U.S.A.

Target facilities	Emission standards	Remarks
Sewage disposal facilities (Sludge incinerator)	Dust, 0.65 g/kg (sludge)	
Incinerator (45 t/day or more)	Dust, 0.18 g/Nm ³	When CO ₂ is 12%
Portland cement (kiln, clinker crusher)	Dust Kiln 0.15 kg/ton Clinker 0.05 kg/ton	Proportionate to the amount of products
Nitric acid factory	NO _x , 1.5 kg/ton	
Sulfuric acid factory	SO ₂ , 2 kg/ton Sulfuric acid mist, 0.075 kg/ton	
Asphalt concrete	Dust, 90 mg/Nm ³	
Coal cleaning factory	Dust, 0.07 g/Nm ³	
Ferroalloy manufacture	Dust 0.23 to 0.45 kg/kWh	
Iron manufacture (Electric furnace)	Dust, 12 mg/Nm ³	
Thermal power plant boiler (Constructed after September 18, 1978) (73,000 kWh or more)	Dust, 46.8 mg/kWh NO _x Anthracite } 936 mg/kWh Bituminous coal } Sub-bituminous coal 756 mg/kWh Lignite (From the Dakotas, etc.) 1.22 g/kWh SO ₂ Solid fuel 1.87 g/kWh Liquid gas 1.22 g/kWh	
General boiler 73,000 kWh or more	Particulate matters 0.155 g/kWh SO ₂ (including mixed combustion with waste wood) Solid fuel 1.87 g/kWh Liquid 1.22 g/kWh NO _x (including mixed combustion with waste wood) Gas 0.31 g/kWh Liquid 0.46 g/kWh Solid 1.08 g/kWh	

(2) Outline of NESHAP

In Article 112 of the Clean Air Act the emission standards (NESHAP) for the toxic substances are stipulated. The EPA established the emission standards for the following 9 substances as the EPA rule (40CFR61) based on Article 112 of the CAA by January 1987 since the standing CAA was established in 1977.

- Radon-222 (Subpart-B, -W)
- Beryllium (Subpart-C, -D)
- Mercury (Subpart-E)
- Vinyl chloride (Subpart-F)
- Radioactive substances (Subpart-H, -I, -K)
- Benzene (Subpart-J)
- Asbestos (Subpart-M)
- Inorganic arsenic compounds (Subpart-N, -O, -P)
- Fugacious emission matters (Subpart-V)

The EPA is examining the necessity of establishing the NESHAP for the following 21 substances.

Acrylonitrile (50 FR 24319; June 10, 1985)
1,3-Butadiene (50 FR 41466; October 10, 1985)
[Added by 51 FR 11022, April 1, 1986]
Cadmium (50 FR 42000; October 16, 1985)
[Added by 51 FR 11022, April 1, 1986]
Carbon Tetrachloride (50 FR 32621; August 13, 1985)
Chlorinated Benzenes (50 FR 32628; August 13, 1985)
Chlorofluorocarbon — 113 (50 FR 24313; June 10, 1985)
Chloroform (50 FR 39626; September 27, 1985)
[Added by 51 FR 11022, April 1, 1986]
Chloroprene (50 FR 39632; September 27, 1985)
[Added by 51 FR 11022, April 1, 1986]
Chromium (50 FR 24317; June 10, 1985)
Epichlorohydrin (50 FR 24575; June 11, 1985)
Ethylene Dichloride (50 FR 41994; October 16, 1985)

[Added by 51 FR 11022, April 1, 1986]
Ethylene Oxide (50 FR 40286; October 2, 1985)
[Added by 51 FR 11022, April 1, 1986]
Hexachlorocyclopentadiene (50 FR 40154; October 1, 1985)
[Added by 51 FR 11022, April 1, 1986]
Manganese (50 FR 32627; August 13, 1985)
Methyl Chloroform (50 FR 24314; June 10, 1985)
Methylene Chloride (50 FR 42037; October 17, 1985)
[Added by 51 FR 11022, April 1, 1986]
Perchloroethylene (50 FR 52880, December 26, 1985)
[Added by 51 FR 7719, March 5, 1986]
Polycyclic Organic Matter (49 FR 31680; August 8, 1984)
Toluene (49 FR 22195; May 25, 1984)
Trichloroethylene (50 FR 52422; December 23, 1985)
[Added by 51 FR 7715, March 5, 1986]
Vinylidene Chloride (50 FR 32632; August 13, 1985)

(3) Outline of BACT and LAER

The BACT is the permissible limit of the specific air pollutants applied to stationary sources newly installed or established in the areas included in the SPD plan. On the other hand, the LAER is applied to stationary sources newly installed or established in the NAAQ nonachievement areas, which is tight emission standards to improve the environmental air quality disregarding the economic elements.

Since the emission standard value of BACT and LAER differs depending on the state in which the facilities are located even if the type of industry is the same, the EPA requests that PEI Associates Inc. collect information on the BACT and LAER which are carried out in various parts of the U.S.A. The PB report (PB 85-229664, BACT/LAER Clearinghouse; A Compilation of Control Technology Determinations) containing 2,000 pages published in June 1985 introduced 1,085 cases of the BACT and LAER which were approved for 113 types of industries and 2,181 manufacturing processes. This report contains detailed information such as the location of factories, the type of facilities to which the BACT/LAER is applied, the production process, and the type of air pollutants for which discharge is reduced and its emission tolerance. If you newly establish a factory in an area to which the BACT/LAER is applied, you can know what kind of emission standards are applied by checking this report.

(4) Emission standards based on RACT

The emission standards based on a feasible prevention technology are applied to the existing facilities. In the "RACT" the pollutants are reduced by using a feasible technology and the emission standards are determined in consideration of economic factors such as expense and other social factors. The EPA is now paying the most attention to the emission reduction system of the

air pollutants which approves a transaction of the pollutant emission volume called netting, banking, offset and bubble. The EPA released an implementation procedure called the "Emission Trading Policy Statement" in the Federal Register in April 7, 1982 (47FRI15076, April 17, 1982).

1) Bubble system

In the standing Clean Air Act the emission standards of the air pollutants are applied to each exhaust port. Practically, the discharge of air pollutants from some exhaust ports can be easily reduced, but other exhaust ports do not produce the anticipated result even at a great cost. Therefore, the whole factory with two or more exhaust ports is regarded as one area, and as long as the discharge of pollutants emitted from this area in the air satisfies the emission standards, the discharge of air pollutants in each exhaust port in the area is not regulated. This concept is called a bubble system. If this system is adopted, without reducing the discharge of the air pollutants from an exhaust port to which it is difficult to apply the prevention technology from an economic point of view, it is enough to reduce the discharge, which includes the required reduction from the above-mentioned exhaust port, from an exhaust port from which the discharge can be reduced to a large extent at a small cost. As a result, a factory can achieve the same effect at a smaller cost.

Approval, application, and planning of 197 bubbles were in progress by the end of 1982. A saving of expense including installation of air pollutant removers and the first year operational was estimated at approximately US\$600,000,000.

2) Banking and offset systems

The banking system is a system in which a factory reserves the difference between the present emission volume and the permissible emission volume as an Emission Reduction Credit (ERC), and the factory is allowed to keep it for the future new installation and establishment or sell it to another factory located in the same area in case the factory succeeds in reducing the emission volume more than the emission standards by installing an air pollutant remover or by improving a production process. This system means that the promotion of anti air pollution measures is related to economic profit of the company. Selling the ERC to another company in the same air pollution control area is called the offset system.

Generally, the banking system is carried out in the unit of the air quality control area, but the State of Oregon adopts this system on a state-wide scale. Also, Louisville, San Francisco, Seattle-Tacoma, and Allegheny County adopt the banking system in the unit of the area.

3) Netting system

This is similar to the offset system. In the netting system the targeted stationary source is required to be in the NAAQS achievement area.

2.3.3 China

China announced officially the emission standards of 13 types of air pollutants (Table 2-9) in 1973 and the dust emission standards concerning boilers (Table 2-10) in 1983 to regulate the emission of the air pollutants. A full-scale restriction, however, started around 1987 after the Air Pollution Control Law was promulgated, following the Environmental Protection Law and the Environmental Air Quality Standards in 1979 and 1982 respectively. The minimum stack height of boilers is regulated by the rated output, which is a distinctive feature of China's emission restriction (Table 2-11). The legal system in China differs from that of other countries in that there is a commendation and bounty system for a business unit and an individual who obtains excellent results or contribution to the environmental preservation as well as the system on tax reduction, tax exemption, preferential price and an exemption from payment of profit to the government which are given or allowed to the products made mainly from material such as exhaust gas and waste solution. On the contrary, a levy of pollution load is collected from the emitters of toxic substances, but 80% of the levy is refunded to the business units on condition that it should be allotted for environmental preservation works.

Table 2-9 13 Types of Toxic Substance Emission Standards in China (Partially Omitted, Promulgated in November 1973)

Number	Name of toxic substances	Enterprise emitting toxic substances* ²	Emission standards* ¹		
			Stack height (m)	Volume of emission* ³ (kg/h)	Emission concentration (mg/m ³)
1	SO ₂	Power plant	30~150 (7 categories)	82~2,400	
		Metallurgical industry	30~120 (6 categories)	52~ 670	
		Chemical industry	30~100 (5 categories)	34~ 280	
2	CS ₂	Light industries	20~120 (6 categories)	5.1~ 110	
3	H ₂ S	Chemical industry, light industry	20~120 (6 categories)	1.3~ 27	
4	Fluoride (as F)	Chemical industry	20~ 30 (2 categories)	1.8~ 4.1	
		Metallurgical industry	120	24	
5	NO _x (As NO ₂)	Chemical industry	20~100 (5 categories)	12~ 230	
6	Cl ₂	Chemical industry, metallurgical industry	20~ 50 (3 categories)	2.8~ 12	
		Metallurgical industry	80, 100 (2 categories)	27, 41	
7	HCl	Chemical industry, metallurgical industry	20~ 50 (3 categories)	1.4~ 5.9	
		Metallurgical industry	80, 100 (2 categories)	14, 20	
8	CO	Chemical industry, metallurgical industry	30~100 (3 categories)	160~1,700	
9	H ₂ SO ₄ (Mist)	Chemical industry	30~ 45 60~ 80		260 600
10	Pb	Metallurgical industry	100, 200 (2 categories)		34, 47
11	Hg	Light industry	20, 30 (2 categories)		0.01, 0.02
12	Beryllium compounds (As Be)		45~ 80		0.015
13	Dust and productive coarse particulates* ⁴	Power plant (Dust)	30~150 (7 categories)	82~2,400	

(Note) *¹ The actual table carries detailed values for each category, but here only the range of values and the number of categories are shown.

*² For enterprises not described here refer to the item of the similar enterprise.

*³ Values in continuous emission, intermittent emission, and emission many times a day. The values of 7 substances of SO₂, dust, productive coarse particulates, CS₂, Fluoride, Cl₂, HCl, and CO in the table can be tripled once a day or within one hour.

*⁴ The emission concentration is regulated for dust in places other than power plants, but it is omitted here.

Table 2-10 Boiler Dust Emission Standards and Application Area in China (Promulgated in September 1983)

Classification by area	Application area	Maximum permissible dust concentration mg/Nm ³	Maximum permissible Ringelmann blackness
1	Natural environment protection areas, beauty spots, medical treatment areas, scenic spots and places of historic interest, surroundings of important buildings	200	1
2	Municipal districts, suburban areas, industrial areas, urban districts more than prefectures	400	1
3	Others	600	2

(Note) 1. The people's government more than prefectures prescribes the range of application area.
 2. The standards are applied to boilers for production, heating, and daily life, and not applied to boilers for power generation.

Table 2-11 Boiler Stack Height in China (Promulgated in September 1983)

Rated output of boiler t/h or equivalent t/h	<1	1~<2	2~<6	6~<10	10~<20	20~<35
Minimum stack height m	20	25	30	35	40	45

(Note) 1. When there are buildings within 200 m around stacks, the stack must be usually higher by 3 m than the tallest building.
 2. The standards are applied to boilers for production, heating, and daily life, and not applied to boilers for power generation.

2.3.4 Korea

In Korea the Environmental Protection Law was established in 1977, and the environmental standards and emission standards were promulgated. The emission standards of 17 substances have been stipulated, which are SO₂ and NO₂ (Table 2-12) and coarse particulates (Table 2-13), fugacious dust (2 mg/Sm³), and dust (2 degrees or less in the Ringelmann smoke chart).

The distinctive feature in the Korean emission regulation is that after an order of improvement, shutdown of operations or transference is given when a factory has emitted pollutants exceeding the emission standards, if a factory is in operation further emitting pollutants exceeding the emission standards, the emission levy is collected. This levy is paid for an environmental pollution prevention fund established by an investment from the government. Furthermore, the environmental pollution prevention group uses and controls this fund to carry out environmental pollution prevention programs, give relief to sufferers of environmental pollution, and to accommodate entrepreneurs with a long-term low-interest loan for investment in environmental pollution prevention facilities.

Table 2-12 Gas Emission Permissible Level in Korea

Pollutant	Permissible level of exhaust port
Ammonia	250 ppm or less
Carbon monoxide	400 ppm or less
Hydrocarbon	25 ppm or less
Chlorine	10 ppm or less
Sulfur oxides (As SO ₂)	1,800 ppm or less (1,000 ppm or less for the emission facilities using T liquid fuel containing 1.6% or less of the sulfur such as fuel oil)
Nitrogen oxides (As NO ₂)	250 ppm or less (500 ppm or less for the exhaust port dedicated to coal)
Carbon disulfide	120 ppm or less
Formaldehyde	50 ppm or less
Hydrogen sulfide	30 ppm or less
Fluorine compounds (As F)	10 ppm or less
Cadmium compounds (As Cd)	1.0 mg/Sm ³ or less
Lead compounds (As Pb)	30 mg/Sm ³ or less
Cyanogen compounds (As CN)	10 ppm or less
Bromine compounds (As Br)	10 ppm or less
Benzene compounds (As C ₆ H ₆)	200 ppm or less
Chromium compounds (As Cr)	1.0 mg/Sm ³ or less
Copper compounds (As Cu)	30 mg/Sm ³ or less
Phenol compounds (C ₆ H ₅ OH)	10 ppm or less
Arsenic compounds (As As)	3 ppm or less

Table 2-13 Dust Emission Permissible Level in Korea

Classification by facilities	Permissible level of exhaust port
1. Heat supply facilities using liquid fuel which emits gas of 200,000 m ³ or more per hour	200 mg/Sm ³ or less
1. Heat supply facilities using liquid fuel which emits gas from 20,000 m ³ or more to less than 200,000 m ³ per hour 2. Facilities of melting, smelting, heat treatment, surface treatment of metal, and chemical product manufacture and refining facilities 3. Incinerating facilities	300 mg/Sm ³ or less
1. Heat supply facilities using solid fuel which emits gas of 200,000 m ³ or more per hour 2. Cement, lime, activated carbon, coal and coal products, ceramic products, glass manufacture facilities, and storage facilities of the above-mentioned material	400 mg/Sm ³ or less
Heat supply facilities using liquid and solid fuel which emits gas of 500 m ³ or less per hour	800 mg/Sm ³ or less
Emission facilities other than the above	500 mg/Sm ³ or less

2.3.5 Taiwan and the Philippines

Table 2-14 shows the emission standards of the air pollutants in Taiwan. The emission standards of nitrogen compounds are divided into two areas; the emission standards for the whole area of Taiwan Province and those for the special area including Taipei, which is densely populated, and Kaohsiung, where factories are concentrated.

Table 2-14 Air Pollutant Emission Standards in Taiwan

Facilities and size	SO ₂ (ppm)	NO _x (ppm)		Dust and coarse particulates
Combustion process				
Sulfur content: 2%	1100			
Domestic coal	1400			
Sulfur content: 1.5%	750			
Sulfur content: 1.0%	500			
Gaseous fuel		①	②	
Liquid fuel		300	150	
Solid fuel		400	250	
Other than the combustion process		500	350	
Waste disposal facilities				
Amount of disposal: 400 kg/h or more				100 mg/m ³
Amount of disposal: Less than 400 kg/h				250 mg/m ³

① Taiwan Province, ② Taipei and Kaohsiung Prefectures

The emission standards of the 24 air pollutants are established in the Philippines. Among them, with respect to the nitrogen oxides the emission standards of nitric acid and nitrogen oxides are determined at 2,000 mg/Nm³ in terms of NO₂. Also, with respect to the sulfur oxides, the emission standards for sulfuric acid, sulfur dioxides and sulfur trioxide are determined at 1,500 mg/Nm³ in terms of SO₂. The emission standards of particulate matters have not been established.

2.4 Desirable Legal and Administrative Improvements

It is necessary to improve some points pointed out in paragraph 1.2 in order to carry out the environmental quality control efficiently and smoothly in Thailand. These points have already been pointed out in the National Policies and Measures on Environmental Development proposed by the NEB in 1981. The National Policies and Measures on Environmental Development stated the following in the "Guidelines for Legal Procedures":

- ① The standing laws related to the environmental quality preservation must be reviewed with the social and economic development.
- ② The range of responsibility of the concerned ministries must be adjusted to carry out smooth administration.
- ③ A new law will be enacted to promote the environmental control of air, water, etc., if necessary.

Further, the policies stated that the following matters are required to carry out the environmental air quality control:

- ① The standing laws must be improved to carry out efficient administration.
- ② The power of the competent authorities must be strengthened.
- ③ The environmental standards and emission standards must be established.
- ④ An effective pollution control system for the emission source must be suggested.

Based on the points indicated in the paragraph 1.2, we will suggest some desirable improvements and expansion of the laws and administrative organization to promote the air pollution control plan effectively in Samut Prakan Province. Its basic concepts are as follows;

- ① The laws must be improved and expanded so that the ONEB can carry out policies related to the environmental air quality control planned and determined by the NEB and ONEB smoothly by virtue of the ONEB's administrative power.
- ② The administrative subject must be clarified in each stage of control and administration in the legal system, and the administration organization system must be improved and expanded based on the stipulation of the laws in order to realize the environmental air quality control administration effectively, and the responsibility of entrepreneurs must be stipulated so that the regulators and the regulated can participate in environmental control systematically.
- ③ In the knowledge that the vital point of the environmental air quality control administration is to set an administrative goal and to carry out mutual check of the validity of the goal and administrative measures and the progress, the establishment of the "mutual check" system

must be stipulated in the legal system and the implementation system must be improved and expanded.

The concrete suggestions based on the above-mentioned three points are as follows;

(1) Revision of ICNEQA

The following revisions must be made to strengthen the power of the ONEB's environmental air quality control administration.

- ① Concerning the establishment of the emission standards stipulated in the Provision 5 (6), the existing "suggestions to the government agencies having the legal force" must be changed to "the ONEB makes a determination based on the NEB's decision," and it must be stipulated that the emission standards can be established only from the viewpoint of environmental administration.
- ② The Provisions 17 (2) and 25 must be revised so that the environmental standards as the target reference value to carry out the environmental air quality control administration can be established and the establishment of the environmental standards can be the key to various environmental control plans.
Since the emission standards based on Provision 5 (6) are positioned as a means of regulation, the stipulation of the environmental standards must come before the emission standards as far as the order of the provisions is concerned. As described later, it is considered that the emission standards must be stipulated in the air pollution control law if it will be enacted.
- ③ The Provision 5 (1)–(4) and the Provision 12 must be revised and completed so that the ONEB can make and carry out the environmental quality control plan. That is, the environmental quality control plan must be made finally by right of ONEB if an approval is obtained from the NEB.
- ④ The responsibility (power and duty) of the environmental administration in the local government (provincial or municipal) must be clarified, and the obligations of the local government must be newly provided as a legal support.
- ⑤ To promote smooth and efficient environmental administration implemented by the national and local governments, the law must be amended to clarify the entrepreneur's duty and responsibility as a pollutor; (i) to cooperate with the government's activities, (ii) to make efforts for pollution prevention, and (iii) to share the expenses of pollution prevention work.

(2) Preparation and improvement of the air pollution regulation law

Adverse impact on the environmental quality is the same with air pollution, water pollution, noise pollution, etc. as with the destruction of nature caused by the construction of a dam, but the form of occurrence of these pollutions has its own characteristics and differs. Therefore, it is difficult to make a law for different types of pollution indiscriminately so that each law for air pollution, water pollution, etc. is necessary. If the ICNEQA is positioned as a basic law providing the general framework of environmental administration in Thailand, it is necessary to enact a law to

regulate air pollution, or the existing laws must be improved including a drastic revision of the FAC, etc. to promote the air pollution control plan in the Samut Prakan industrial area. Since it is unreasonable to incorporate the provisions related to the enforcement of the air pollution regulations into FAC in view of the legal purpose of FAC, it is desirable that an air pollution control law should be enacted. Whether it is an air pollution control law or the improvement of the existing law, it is necessary to improve the following items legally in order to prevent the air pollution effectively.

- 1) The following matters must be stipulated to clarify the scope of the substances and facilities to be regulated.
 - ① Substances to be regulated: Definition of dust, coarse particulates, automobile and ferryboat exhaust gas (mobile emission source of service along the Chao Phraya)
 - ② Facilities to be regulated: Scope of facilities to be regulated based on emission volume, type of pollutant and concentration, and scope of mobile emission sources.
- 2) Clarify the regulation methods.
 - ① Setting the emission standards: Separate the emission standards of a fixed emission source from those of a mobile emission source and establish them by substance to be regulated.
 - ② Adoption of a prior notification system of the facilities to be regulated
 - ③ Assignment of a duty to install smoke and soot removal facilities, etc. on the emission source
 - ④ Order to improve smoke and soot removal facilities, etc.
 - ⑤ Expansion of examination on the emission standards in term of motor vehicle type approval and motor vehicle inspection
- 3) Clarify matters to be carried out by the emission source.
 - ① Duty to measure the emission volume and concentration and to keep the records
 - ② Duty to submit data, etc. at the request of the government office
- 4) Clarify the matters to be carried out by the government offices
 - ① Duty to monitor the air and environmental quality
 - ② Duty to announce to the public the environmental air quality
 - ③ Collect and manage the data of the emission source
- 5) Clarify the scope of responsibility of the ONEB and other government agencies and the relationship between them. Also, clarify the scope of responsibility of the central agencies such as the ONEB and the local self-governing bodies and relationship between them.

(3) Improvement and expansion of the administrative organization

It is expected that the administrative organization to carry out the air and environmental quality control is improved and expanded of its own accord through the improvement and expansion of the ICNEQA and air pollution regulation laws. It is necessary to train public servants to be experts in environmental administration and technical staff and increase the staff in each stage of the administration to give satisfactory management results. Among others, it is of urgent necessity to establish environmental departments and sections in the local self-governing bodies. For this reason

the training of experts in administration and technical staff must be conducted urgently.

A broad scope of knowledge as specified below is required to execute administration for ambient air pollution control.

- ① Thorough knowledge of the present legal structure and administrative organs related to the control of air pollution
- ② Present situation of air pollution
- ③ Generating mechanism of air pollution
- ④ Adverse effects of air pollution
- ⑤ Control of combustion
- ⑥ Techniques for prevention of air pollution
- ⑦ Dispersion of pollutants in the air
- ⑧ Techniques for environmental assessment
- ⑨ Measuring techniques of air pollutants (environment and sources)

Although environmental administrative specialists may not have to be knowledgeable about the details of the above items ⑤ to ⑦, they will need to know them in general. For that purpose, first of all, it will be necessary to prepare a textbook entitled, for example, "The Fundamental Knowledge of Environmental Preservation Countermeasures," with which comprehensive education and training for execution of administration for ambient air pollution control will be provided not only to the administrative officials of central government, but also to those of the bureaus and departments fully in charge of environmental administration, which may be established on a local government basis in the future.

In addition, while technical staff are required to have high expertise concerning the above ③ to ⑨, not all of them need to have the whole knowledge. Namely, it is necessary to foster technical staff specializing in the individual items. In Thailand, presently, courses related to the above ③ to ⑨ have been started at Chulalongkorn University and various other universities. In order to increase the number of technical staff, however, it will be necessary to begin more courses as well as complete them. Especially for learning about the techniques for combustion control and prevention of air pollution, it will be a good idea to invite visiting professors from developed industrial countries or send students to such countries.

(4) Knowledge of Pollution Prevention

The postures taken by enterprises in tackling pollution prevention are greatly forced by such external impacts as legal restrictions and social responsibility, whereas the effect of these impacts is limited. Since the enterprises are in a position to be able to know best about the occurrence of industrial pollution, it is essential for them to establish their positive postures of dealing with the prevention of pollution by their own voluntary will. From this point of view, in order to make environmental preservation effective, the enterprises must become to think of the pollution prevention as an essential element of corporate management in terms of management philosophy. Furthermore, the enterprises must improve their constitution so as to be able to work out scientific and

rational countermeasures for pollution prevention and complete the corporate organization so as to be able to implement effectively the above countermeasures.

In line with the above described enterprises' efforts to prevent pollution, it is a matter of course that central and local governments need to educate and spread the knowledge of pollution prevention and take measures to provide subsidies required for execution of pollution control countermeasures. In order to specifically establish a setup to educate and spread the knowledge of pollution prevention, it will be first necessary that central and local governments give seminars on the knowledge of pollution prevention to enterprises' responsible personnel or the like and, moreover, that if employees in charge of pollution control are assigned in the enterprises in the future, the said governments should take a measure to hold technical seminars on more professional pollution prevention for the above employees. In addition, an environment center has presently been established in Thailand, and it will be beneficial to train private sector engineers who are in charge of pollution prevention at this center. For the future, in addition, it is expected that the pollution control organization system in the specified factories will be introduced into Thailand as explained in the paragraph 2.1.3 of the Part VIII.

3. Investigation of Pollutant Emission Sources and Monitoring of Ambient Pollutant Concentrations

This chapter deals with the technical aspect of the investigation of pollutant emission sources and monitoring of ambient pollutant concentrations which effectuates the legislative and administrative efforts in implementing national air pollution control plans.

3.1 Investigation of Emission Sources

The accurate monitoring investigation of emission sources is a critical item to substantiate any environmental control that administration undertakes. In other words, the measurement of the pollutant concentration from emission sources is prerequisite for administration to check the compliance of emission standards after any control is enacted addressing stationary emission sources. Such measurement also leads to the quantitative evaluation of the pollutant emission volume from the whole area. Questionnaires were sent to 577 factories as an effort to collect the information about emission volume in Samut Prakarn District and about 36 percent of the questionnaires were returned. It was also found later that there were 572 remaining factories to which the questionnaires were not sent although they have combustion facilities. To fill this deficiency, the unit fuel consumption per employee was calculated from retrieved data and then used for extrapolation to approximate the fuel consumption of these factories and the emission volume of SO_2 and NO_x . Even in the retrieved sheets there were quite a few missing data with respect to the emission volumes of SO_2 and NO_x and thus, the method applied is one in use in Japan for estimation of exhaust gas volume and NO_x emission volume that uses the exhaust gas factor and the NO_x emission factor. Therefore, the reporter would like to draw special attention to the fact that this investigation result on the air pollutant emission volume in the Samut Prakarn district is not based on the actual measurements but on said estimation efforts.

As already mentioned in the previous paragraph, the responsible party for the emission of soot and smoke is obliged to measure the exhaust gas volume or emission concentration and the chief of the local government (autonomas) has the right to enter a factory for inspection or measurement of the individual emission sources. Furthermore, from 1978 on, questionnaires have been sent by the Environment Agency and the Ministry of International Trade and Industry to all factories, as done in the Samut Prakarn prefecture this time, every three years for soot and dust and every year for SO_2 and NO_x to measure the quantity of air pollutants and the effort was found to be useful for succeeding corrective actions.

With aforementioned experience in Japan, the reporter thought that the careful monitoring of emission sources is extremely important for implementing any environmental control measure. Hereinafter described is the method for measurement of both concentration and volume of air pollutants emitted from factories. In Thailand, vehicles with emission gas controls are expected to increase in future and thus the method to analyze pollutants in the vehicle exhaust gas, namely, the testing method by a chassis dynamo meter is also described as well.

3.1.1 Stationary Emission Sources (Factories)

The combustion gas is generally led to a stack through a flue gas duct from combustion facilities. The sampling of pollutants in the flue gas is made by aspiration at a place selected to take a sample of gas in the flue duct or stack. It is also necessary to measure simultaneously the gas velocity, its flow rate, temperature, pressure, moisture and O₂ concentration in addition to the sampling of pollutants. Table 3-1 shows the measured variables and their objectives. In Japan it is stipulated that these measurements are to be practiced according to JIS (Chapter of materials) as shown in Table 3-2 which describes in detail the selection of a measuring position; type, materials and handling method of measuring instruments to be applied, measuring procedure; sampling method; treating method of analyzers, instruments, reagents and samples; preparation method of reagents; method of preparing calibration curves and method of calculating concentrations. The outline of these measuring methods is described as follows:

(1) Gas sampling

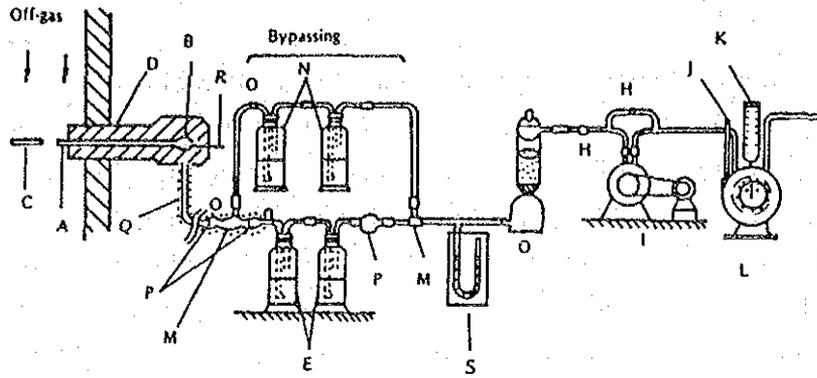
The gas sampler varies depending on the gas analysis method. An example is the chemical method to analyze the components of the poisonous gas collected by the appropriate absorption liquid by means of an absorption bottle through which a sample gas is passed. The analyzer consists of a sampling tube, connection tube, collection part, gas aspiration device and instrument for measuring the sucked gas volume. Another is a method with a continuous analyzer and this apparatus consists of a sampling tube, connection tube and continuous analyzer. The construction of these two types of gas sampling apparatus are shown in Fig. 3-1 and Fig. 3-2, respectively.

Table 3-1 Measuring Variables at Flue Duct and Their Objectives

Measuring variables	Measuring objectives
Flue gas temperature	① Calculation of flue gas (wet volume) ② Calculation of effective stack height
Moisture in flue gas	① Calculation of flue gas (dry volume)
Velocity of flue gas	① Calculation of flue gas volume ② Calculation of pollutant emission volume
Pressure	① Measurement of flue gas flow velocity
Concentration of O ₂ in flue gas	① Combustion control (appropriate air ratio) ② Monitoring of pollutant concentration decrease by increasing excess air ratio
Concentration of SO ₂ in flue gas	① Calculation of SO ₂ emission volume
Concentration of NO _x in flue gas	① Calculation of NO _x emission volume
Concentration of dust in flue gas	① Calculation of dust emission

Table 3-2 JIS No. of Measuring at Flue Duct

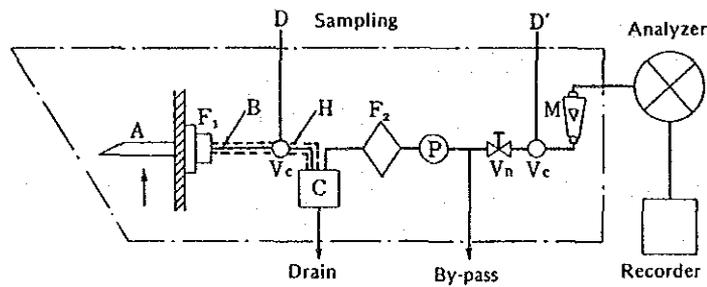
Measuring variables	JIS No.
Measuring point	JIS Z 8808 4. Measuring Position, Hole and Point
Flue gas temperature	JIS Z 8808 5. Measurement of Temperature of Flue Gas
Moisture in flue gas	JIS Z 8808 6. Measurement of Water Content in Flue Gas
Velocity of flue gas	JIS Z 8808 7. Measurement of Velocity and Flow Rate of Flue Gas
Sampling of flue gas	JIS K 0095 Method for Sampling of Stack Gas
Concentration of dust in flue gas	JIS Z 8808 8., 9., 10. Method of Measuring Dust Concentration Flue Gas
Concentration of SO _x in flue gas	JIS K 0103 Methods for Determination of Sulfur Oxides in Flue Gas
Concentration of SO ₂ in flue gas	JIS B 7981 Continuous Analyzer for Sulfur Dioxide in Flue Gas
Concentration of NO _x in flue gas	JIS K 0104 Methods for Determination of Oxides of Nitrogen in Flue Gas
Concentration of NO _x in flue gas	JIS B 7982 Continuous Analyzer for Oxides of Nitrogen in Flue Gas
Concentration of O ₂ in flue gas	JIS K 0301 Methods for Determination of Oxygen in Flue Gas



Where, A: Gas sampling tube (1,000 to 2,000 mm long, approx. 20 mm in dia.)

- B: Adapter
- C: Filter material
- D: Heat insulator
- E: Absorbing bottle (with an upside filter plate G_2 ; 150 to 250 ml in volume)
- F: Glass filter (G_3)
- G: Gas drying tower (silica gel particles)
- H: Flow control cock
- I: Enclosed suction pump (0.5~5 l/min)
- J: Thermometer
- K: Pressure gage
- L: Wet gas meter (1~5 l/one rotation)
- M: Three-way cock
- N: Bypassing wash bottle (same as E)
- O: Silicone rubber tube
- P: Spherical glass fitting
- Q: Heater
- R: Thermometer
- S: Mercury manometer

Fig. 3-1 Flue Gas Sampling Method Using Absorption Bottles



- A : Sampling tube
- B : Connecting tube
- C : Desiccator
- D, D' : Inlet for calibration gas
- F₁ : Coarse filter
- F₂ : Fine filter
- H : Heater
- V_c : Cut-off valve
- M : Flowmeter
- P : Suction pump
- V_n : Needle valve

Fig. 3-2 Flue Gas Sampling Method Using a Continuous Analyzer

1) Gas sampling tube and connecting tube

The gas sampling tube should be equipped with a filter material to remove soots and dust in flue gas as shown in Fig. 3-1. Materials ① that do not affect the results of the flue gas analysis, through chemical reactions or adsorptions ② which can withstand corrosion from components in flue gas, and those ③ which maintain sufficient mechanical strength at the high temperature of flue gas should be selected for the sampling tube, filter material, packing and connecting tube. Table 3-3 lists the materials suitable for the sampling tube or connecting tube for each gas to be analyzed. If the moisture in the flue gas condenses in the sampling tube or connecting tube, the gas to be analyzed dissolves into this condensate and causes troubles for the gas sampling.

Table 3-3 Materials of Gas Sampling Tube and Connecting Tube by Gas to be Analyzed

Gas to be analyzed	Sampling tube material	Packing material	Filter material
Carbon monoxide	① ② ③ ④ ⑤ ⑥ ⑦	⑥ ⑧ ⑨	Ⓐ Ⓑ Ⓒ
Ammonia	① ② ③ ④ ⑤ ⑧	⑥	Ⓐ Ⓑ Ⓒ
Total sulfur oxides & sulfur dioxide	① ② ④ ⑤ ⑥ ⑦	⑥	Ⓐ Ⓑ Ⓒ
Nitrogen oxides	① ② ④ ⑤ ⑥	⑥ ⑧ ⑨	Ⓐ Ⓑ Ⓒ
Fluorine compounds	④ ⑥	⑥	Ⓒ
Chlorine	⑤ ⑥ ⑦	⑥	Ⓐ Ⓑ Ⓒ
Hydrogen chloride	⑤ ⑥ ⑦	⑥	Ⓐ Ⓑ Ⓒ
Hydrogen sulfide	④ ⑤ ⑥ ⑦	⑥	Ⓐ Ⓑ Ⓒ
Hydrogen cyanide	④ ⑤ ⑥ ⑦	⑥	Ⓐ Ⓑ Ⓒ

Material of tube

- ① Hard glass
- ② Quartz
- ③ Ordinary steel
- ④ Stainless steel
- ⑤ Ceramic
- ⑥ Fluororesin or fluororubber
- ⑦ Polyvinyl chloride
- ⑧ Silicone rubber
- ⑨ Neoprene

Filter material

- Ⓐ Non-alkali glass-wool or silica-wool
- Ⓑ Sintered glass
- Ⓒ Carborundum

2) Sampling method using absorbing bottles

When the flue gas sampling volume is relatively large, absorbing bottles and by-pass wash bottles which are connected to a gas suction apparatus are used in the collecting part as shown in Fig. 3-1. The flue gas is passed through the absorbing bottles and the wash bottles, where the absorption liquid corresponding to the gas to be analyzed is placed to extract the toxic gas components. The shape and volume of the absorbing bottles are generally specified for each gas to be analyzed and accordingly the use of the specified one is recommendable.

The sampling of the flue gas is conducted first by passing the gas through the by-pass to replace the contents in the piping with the flue gas and then by sucking the flue gas into the absorbing bottles until a given quantity of the gas is sucked. The suction flow rate is about 2 ℓ/min at maximum. The quantity of the sampled flue gas is obtained as a dry gas usually set at 0°C and 1 atm.

3) Sampling method by means of a vacuum flask or injection cylinder

When the sampling volume of flue gas is small as in the case of NO_x, a flask or injection cylinder is used in the collecting section. An example of each sampling apparatus is shown in Fig. 3-3 and Fig. 3-4.

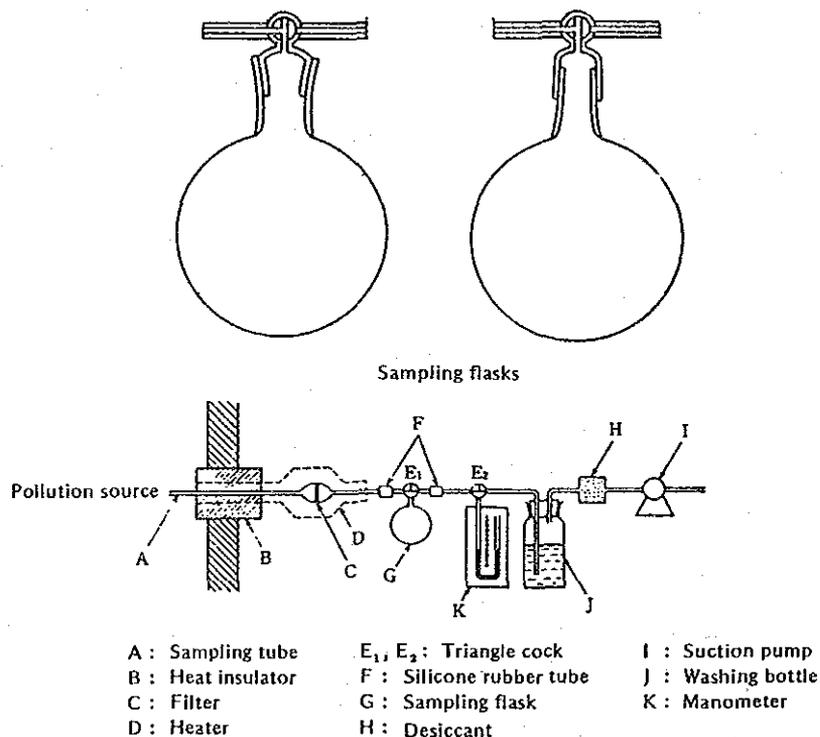


Fig. 3-3 Flue Gas Sampling Apparatus Using a Vacuum Flask

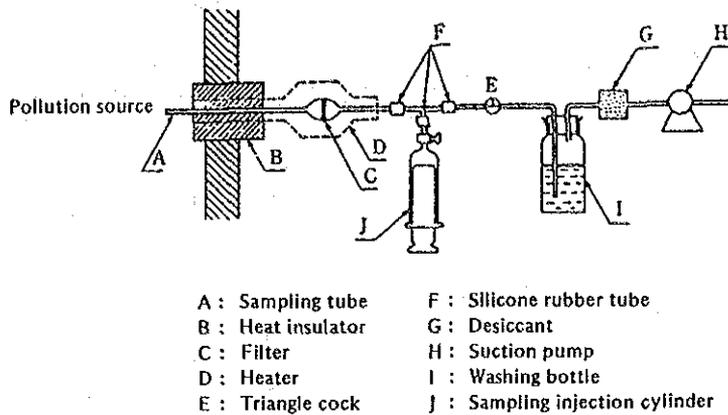


Fig. 3-4 Flue Gas Sampling Apparatus Using an Injection Cylinder

When a vacuum flask is used, absorbing fluid is poured into the flask with the internal volume of about 1 liter) and the interior is depressurized until the fluid boils. The internal pressure of the flask is measured just before the three-way cock is opened and the flue gas is sampled. After the sampling, the three-way cock is closed and the flask is removed from the sampling apparatus.

When an injection cylinder is used, it is moistened before it is mounted onto the sampling apparatus as shown in Fig. 3-4. After the interior of the piping is completely replaced with the flue gas, the cock of the injection cylinder is opened and a predetermined quantity of the flue gas is sampled by one-time suction. Immediately after that, the cock is closed and the injection cylinder is removed. After it is cooled, the volume of the sampled gas and the temperature are measured. Then, it is connected to another injection cylinder containing the absorbing fluid and the absorbing fluid is dropped into the sampling cylinder and is shaken. After it is kept for a certain period of time, the absorbing fluid is taken out.

4) Sampling method using a continuous analyzer

Generally, a continuous analyzer introduces gas at about room temperature and under atmospheric pressure into it for measurement and recording. If vapor is mixed in the flue gas, it often causes analytical problems. To avoid such troubles, the connecting tube is connected to a cooling desiccator and the gas is cooled and desiccated.

(2) Analysis of sulfur oxides

The method of measuring sulfur oxides in the flue gas is divided into two parts, the analysis of total sulfur oxides and that of sulfur dioxide. These analytical methods and the applicable analysis concentration ranges are shown in Table 3-4. (As for the details of the analytical methods, please refer to JIS K 0103 "Analytical method for sulfur oxides in flue gas" and JIS B 7981 "Automatic analyzer for sulfur dioxide in flue gas".)

Table 3-4 Analytical Method for Sulfur Oxides in Flue Gas

(a) Chemical Analysis Method

Methods	Items	Gases to be analyzed	Applicable concentration range (ppm)	Response time	Interfering Substance
① Neutrolization Titration Method		SO ₂ +SO ₃	more than 250		acid gas
② Precipitation Titration Method		SO ₂ +SO ₃	50~ 700		metal salt dust
③ Turbidimetric Method		SO ₂ +SO ₃	10~ 300	7~20 min.	

(b) Continuous analytical method (automatic measuring instrument)

④ Solution Conductivity Method		SO ₂	5~2,000	15 min.	HCl, HF
⑤ Infrared Absorption Method		SO ₂	10~2,000	4	CH ₄
⑥ Ultraviolet Absorption Method		SO ₂	10~2,000	4	
⑦ Flame Photometry Method		SO ₂	5~1,000	4	H ₂ S
⑧ Controlled Potential Electrolysis Method		SO ₂	5~2,000	4	HF, H ₂ S

(3) Analysis of nitrogen oxides

The method of measuring nitrogen oxides in the flue gas is grouped into the chemical analysis method and the continuous analysis method. These analytical methods and the applicable analysis concentration ranges are shown in Table 3-5. (As for the details of the analytical methods, please refer to JIS K 0104 "Analytical method for nitrogen oxides in flue gas" and JIS B 7982 "Automatic analyzer for nitrogen oxides in flue gas".)

Table 3-5 Analytical Methods for Nitrogen Oxides

(a) Chemical analysis method

Methods	Items	Gases to be analyzed	Applicable concentration range (ppm)	Required analysis hours	Effects of coexistent substances
Absorptiometric method	(1) Phenol disulfonic acid absorptiometry	NO+NO ₂	10~300	20 hours	Nitrate, nitrite and organic nitrogen compounds bring a positive error while halides a negative error.
	(2) Zinc reduction raphthylethylene diamine absorptiometry	NO+NO ₂	10~1000	20 minutes	2000 ppm or less SO ₂ brings no disturbance.
	(3) Salzman absorptiometry	NO ₂	5~500	20 minutes	

(b) Continuous analytical method (automatic measuring instrument)

(1) Chemiluminescence method		NO	0~25 to 0~1000	CO ₂ may give a negative error.
(2) Infrared absorption method		NO	0~100 to 0~1000	May be influenced by CO ₂ and H ₂ O. To remove these influences, gaseous, solid or special optical type filters are used.
(3) Ultraviolet absorption method I Ultraviolet absorption method II		NO NO ₂	Ditto	NO may be interfered with by SO ₂ and NO ₂ . Interference can be removed by the multicomponent operation method or correlative spectroscopic method. For NO ₂ , effect of coexistent gases is small.
(4) Controlled potential electrolysis method		NO+NO ₂	Ditto	May be interfered with by CO and aromatic hydrocarbons.

(4) Measurement of soot and dust volume

The measurement of soot and dust in flue gas is prescribed by JIS Z 8808 "Measuring method for the concentration of dust in flue gas". This method is to filtrate and collect dust by sucking the flue gas at the same flow rate as the flue gas (equal flow rate suction) through the suction nozzle of a dust sampling apparatus shown in Fig. 3-5 which is inserted into the duct from the measuring hole made on the flue duct wall. This measurement necessitates the determination of the flow rate of gas sucked at an equal flow rate at the measuring point beforehand. Therefore, it is necessary to measure the temperature, moisture, static pressure, mass per unit volume, flow rate, etc. of flue gas at the measuring point. Fig. 3-6 shows the outline of the dust measuring method.

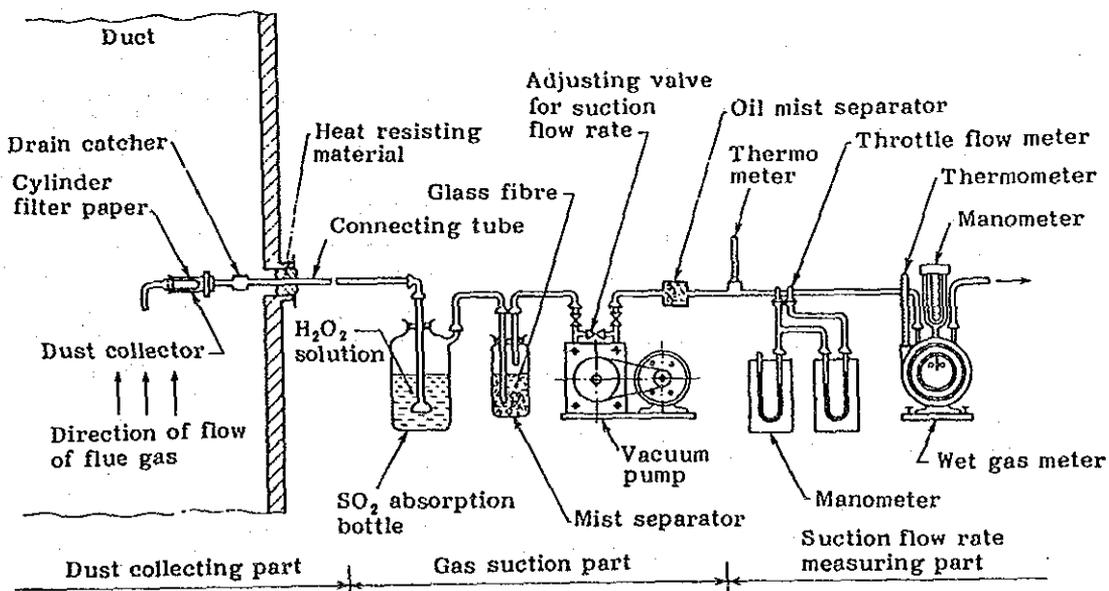
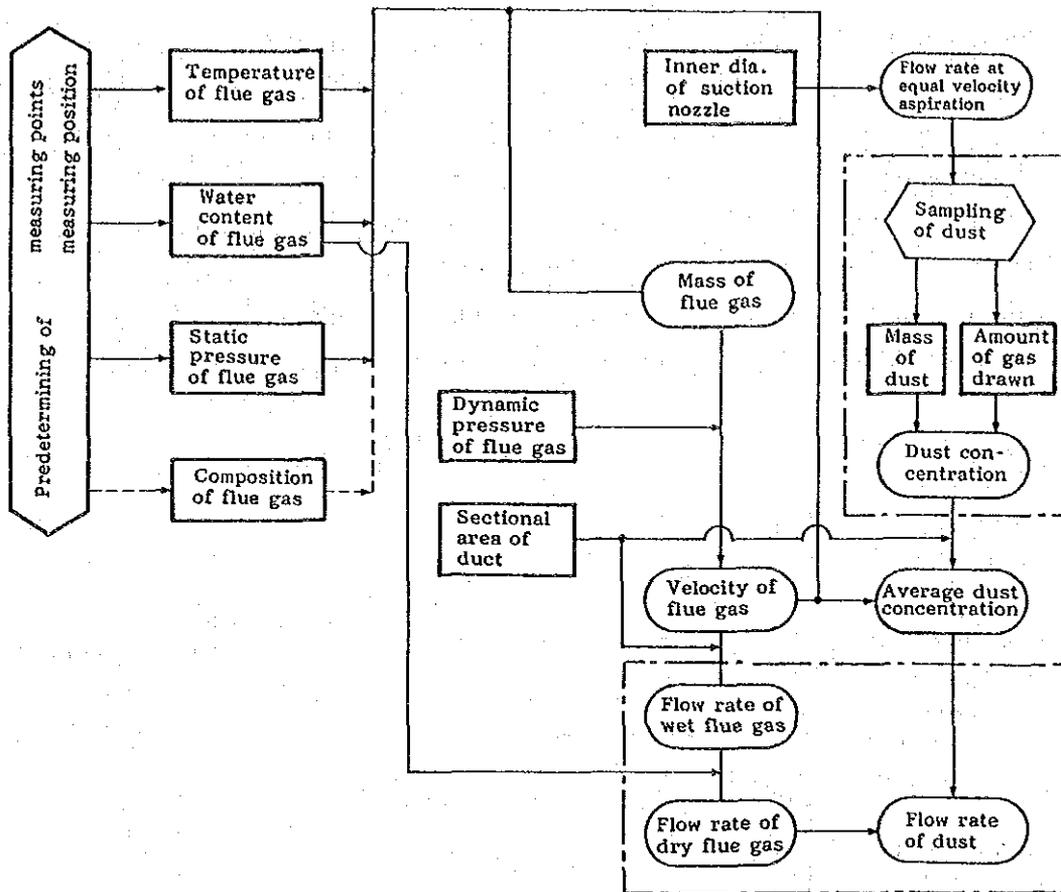


Fig. 3-5 Example of Construction of Dust Concentration Measuring Apparatus

The important point to be observed is to make the suction gas flow rate equal to the flue gas flow rate. In other words, if this equal flow rate suction is not appropriately maintained, for example, as shown in Fig. 3-7, if the suction rate is larger than the flow rate of the flue gas flowing through the duct, dust flowing in that condition by inertia does not enter the suction opening but passes through. Consequently, the result of the measurement is smaller than the true dust concentration. On the contrary, if the suction rate is smaller than the flow rate, the dust concentration measured becomes larger than the true value. This is the point which is basically different from the sampling of gaseous components in flue gas. (For details, please refer to JIS Z 8808).



- Remarks 1. The item within shows the measured value and that within the calculated one.
2. The processes indicated within the dashed lines are shown for the measurement by employing the balanced-type sampling apparatus.
3. The processes indicated within the frame of chain line are needed for the measurement of flow rate of flue gas or of dust.

Fig. 3-6 Outline of Dust Measuring Method (JIS Z 8808)

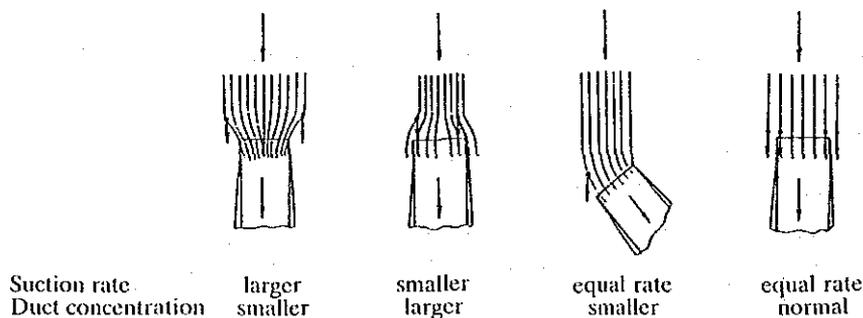


Fig. 3-7 Relation between Suction Rate and Dust Concentration

Recently, automatic continuous measuring instruments (phototransmission type, photoscattering type, contact electrification type, β -ray transmission type and Piezo balance type measuring instruments) relatively have come into wide use to continuously measure the dust concentration but these have not yet been prescribed in JIS methods, because the direct indication of the duct mass concentration in a dry flue gas is questionable.

3.1.2 Vehicles

The measurement of the exhaust gas from vehicles is generally made by using a chassis dynamometer. Because the flow rate of the exhaust of a vehicle engine varies widely, the exhaust gas sampling is made at a constant flow condition using CVS (Constant Volume Sampler) to measure its pollutant concentration.

The quantity of pollutants exhausted during the running of vehicles varies with depending on type of vehicle, running conditions (acceleration, running, deceleration, idling, etc.), manufacturing year and, strictly speaking, manufacturers and even from engine to engine. Furthermore, for a cargo truck, it varies also with its loading condition. Therefore, the measurement of pollutants by use of a chassis dynamometer is generally conducted in a given running mode.

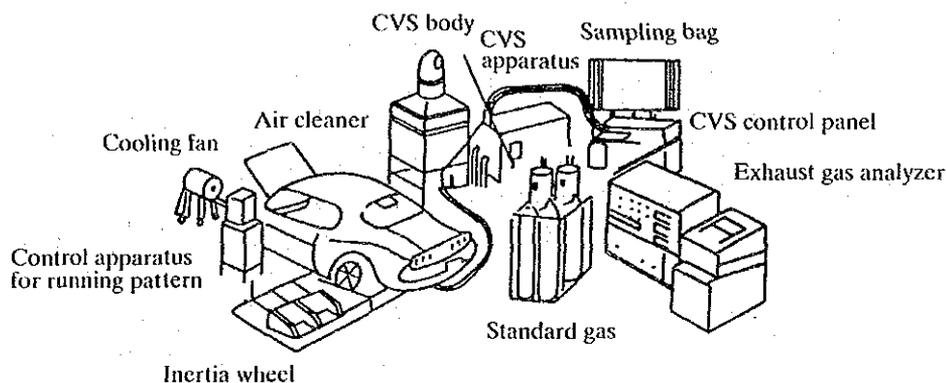


Fig. 3-8 Chassis Dynamometer Testing Apparatus

In Japan the exhausted quantity (quantity of exhausted pollutants per km of running) is measured in 10 modes for passenger vehicles and the pollutant concentration (ppm) is measured in six modes for cargo vehicles. The 10-mode measurement is the method to measure the quantity of pollutants exhausted from the exhaust pipe during the operation in a running mode shown in Fig. 3-9 after the engine of the vehicle to which a 110 kg dead weight was added becomes the warm-up condition. The running time in 10 modes is specified to be 135 seconds and the average speed 17.7 km/h.

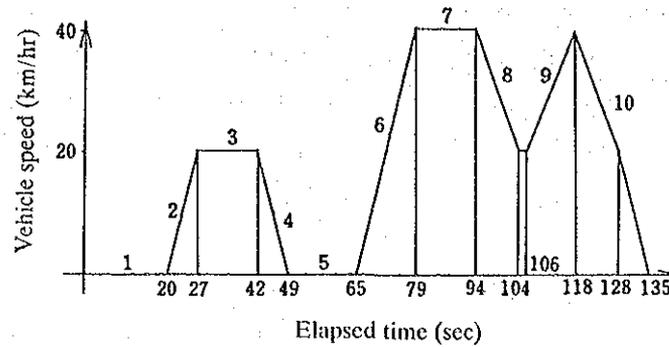


Fig. 3-9 10-Mode Measurement

The six-mode measurement, which corresponds to the running condition of a cargo vehicle, is the method to measure the concentration of the pollutants in the exhausted gas by adding the values obtained from the concentration, which is expressed as a volume ratio of the pollutants exhausted from the exhaust pipe during the running of the vehicle under the running conditions shown in Table 3-6, multiplied by the corresponding factor in the right column of the same table.

Table 3-6 6-mode Measurement (1)

Running condition	Factor
Condition in which the prime mover is run under no load.	0.125
Condition in which the prime mover is run at 2,000 revolutions (The inlet-manifold boost pressure shall be 125 mmHg in this case.)	0.114
Condition in which the prime mover is run at 3,000 revolutions (The inlet-manifold boost pressure shall be 125 mmHg in this case.)	0.277
Condition in which the prime mover is run at 3,000 revolutions (The inlet-manifold boost pressure shall be 200 mmHg in this case.)	0.254
Condition in which the prime mover is run at 2,000 revolutions (The inlet-manifold boost pressure shall be 420 mmHg in this case.)	0.139
Condition in which the prime mover is run at 2,000 revolutions (The inlet-manifold boost pressure shall be 420 mmHg in this case.) through condition of a decelerated running at 1,000 revolutions with the carburetor throttle valve totally closed (The time required to decelerate the prime mover from 2,000 to 1,000 revolutions shall be 10 seconds in this case.)	0.091

The six-mode measurement for diesel cargo vehicles is the method to measure the concentration of the pollutants in the exhausted gas by adding the values obtained from the concentration, which is expressed as a volume ratio of the pollutants exhausted from the exhaust pipe during the running of the vehicle under the running conditions shown in Table 3-7, multiplied by the corresponding factor in the right column of the same table.

When particulate matters are sampled, a dilution tunnel which dilutes them immediately after exhaustion from the muffler as quickly as possible and stabilizes the flow as a whole is used because it is necessary to keep the inlet condition of the sampling probe constant and to decrease the effect of moisture condensation on particles. When the measurement for hydrocarbons is made, an 11-mode system which consists of the 10-mode system and an additional condition of a cold start time because the 10-mode system is for a hot cycle.

Table 3-7 6-mode Measurement for Diesel Cargo Vehicles (2)

Running condition	Factor
Condition in which the prime mover is run under no load.	0.355
Condition in which the prime mover is run under the full load at revolutions 40% of those at its maximum power	0.071
Condition in which the prime mover is run under 25% of the full load at revolutions 40% of those at its maximum power	0.059
Condition in which the prime mover is run under the full load at revolutions 60% of those at its maximum power	0.107
Condition in which the prime mover is run under 25% of the full load at revolutions 60% of those at its maximum power	0.122
Conditions in which the prime mover is run under 75% of the full load at revolutions 80% of those at its maximum power	0.286

As is well-known, in Japan the emission control has been implemented since 1973 and consecutively reinforced against pollutants exhausted from vehicles. Such emission control standards are shown in Table 3-8 for reference.

Table 3-8(1) Transition of Vehicle Exhaust Gas Control Standards and its Application Time (Gasoline/LPG Vehicles)

Classification of controls		Controls in '73	Controls in '74	Controls in '75	Controls in '76	Controls in '77	
Kinds of vehicle/Pollutants							
Passenger car (capacity 10 persons or less)	CO		26.0 g/km (18.4 g/km) New, Apr. '73; Cont., Dec. '73		2.70 g/km (2.10 g/km) New, Apr. '75; Cont., Dec. '75		
	HC	2 cycle-light passenger car	22.5 g/km (16.6 g/km) New, Apr. '73; Cont., Dec. '73		0.39 g/km (0.25 g/km) New, Apr. '75; Cont., Dec. '75 Until Sept. 30 '77 5.6 g/km (4.5 g/km)		
		Others	3.80 g/km (2.94 g/km) New, Apr. '73; Cont., Dec. '73		0.39 g/km (0.25 g/km) New, Apr. '75; Cont., Dec. '75		
	NOx	Light passenger car	2 cycle	0.50 g/km (0.30 g/km) New, Apr. '73; Cont., Dec. '73			
			4 cycle			1.20 g/km (0.85 g/km) New, Apr. '76; Cont., Mar. '77	
		Ordinary or light type with equivalent inertia weight 1,000 kg or below		3.00 g/km (2.18 g/km) New, Apr. '73; Cont., Dec. '73		1.60 g/km (1.20 g/km) New, Apr. '75; Cont., Dec. '75	0.84 g/km (0.60 g/km) New, Apr. '76; Cont., Mar. '77
		Ordinary or light type with equivalent inertia weight above 1,000 kg					1.20 g/km (0.85 g/km) New, Apr. '76; Cont., Mar. '77
	Light and middle weight bus and truck	CO	Vehicle gross weight 1.7 t or below	26.0 g/km (18.4 g/km) New, Apr. '73; Cont., Dec. '73		17.0 g/km (13.0 g/km) New, Apr. '75; Cont., Dec. '75	
			Others				
		HC	2 cycle light truck	22.5 g/km (16.6 g/km) New, Apr. '73; Cont., Dec. '73		15.0 g/km (12.0 g/km) New, Apr. '75; Cont., Dec. '75	
Vehicle gross weight 1.7 t or below			3.80 g/km (2.94 g/km) New, Apr. '73; Cont., Dec. '73		2.70 g/km (2.10 g/km) New, Apr. '75; Cont., Dec. '75		
Others							
NOx		Light truck	2 cycle	0.50 g/km (0.30 g/km) New, Apr. '73; Cont., Dec. '73			
	4 cycle						
	Light weight	Vehicle gross weight 1.7 t or below	3.00 g/km (2.18 g/km) New, Apr. '73; Cont., Dec. '73		2.30 g/km (1.80 g/km) New, Apr. '75; Cont., Dec. '75		
	Middle weight	Vehicle gross weight above 1.7 t and not above 2.5 t					
Heavy weight bus and truck	CO		1.6% (1.2%)/LPG 1.1% (0.8%) New, Apr. '73; Cont., Dec. '73				
	HC		520 ppm (410 ppm)/LPG 440 ppm (350 ppm) New, Apr. '73; Cont., Dec. '73				
	NOx		2200 ppm (1830 ppm) New, Apr. '73; Cont., Dec. '73			1850 ppm (1550 ppm) New, Aug. '77; Cont., Apr. '78	

(Notes)

- Application time of exhaust gas control for calculation of exhaust gas volume was regarded equal to the period when the production of the said car continued.
- The upper row figures are allowable limits and figures in () are average values. The measuring methods are as follows:
 - For gasoline/LPG cars, passenger cars and light weight buses/trucks and for heavy weight buses/trucks a 10-mode test and a 6-mode test were used, respectively.
 - Diesel cars
To passenger cars of which capacity is 10 persons or less (controls in '86. and '87) and those of which gross vehicle weight is 1.7 t or below (controls in '88), a 10-mode test was applied and to other cars, a 6-mode test for diesel cars was applied.

Table 3-8(1) Transition of Vehicle Exhaust Gas Control Standards and its Application Time (Gasoline/LPG Vehicles)

Controls in '78	First target figures by Central Environmental Pollution Council	Second target figures by Controls Environmental Pollution Council				Controls in '86	Controls in '87	Report of Central Environmental Pollution Council (July 10, '86)		
	Controls in '79	Controls in '81	Controls in '82	Controls in '83	Controls in '88			Controls in '89	Controls in '90	
0.48 g/km (0.25 g/km) New, Apr. '78; Cont., Mar. '79										
									2.70 g/km (2.10 g/km) New, Dec. '88; Cont., Nov. '89	
									0.39 g/km (0.25 g/km) New, Dec. '88; Cont., Nov. '89	
	1.60 g/km (1.20 g/km) New, Jan. '79; Cont., Dec. '79		1.26 g/km (0.90 g/km) New, Jan. '82; Cont., Dec. '82							0.74 g/km (0.50 g/km) New, Oct. '90; Cont., Sept. '91
	1.40 g/km (1.00 g/km) New, Jan. '79; Cont., Dec. '79	0.84 g/km (0.60 g/km) New, Jan. '81; Cont., Dec. '81						0.48 g/km (0.25 g/km) New, Dec. '88; Cont., Nov. '89		
	1.60 g/km (1.20 g/km) New, Jan. '79; Cont., Dec. '79	1.26 g/km (0.90 g/km) New, Dec. '81; Cont., Nov. '82							0.98 g/km (0.70 g/km) New, Oct. '89; Cont., Sept. '90	
	1390 ppm (1100 ppm) New, Jan. '79; Cont., Dec. '79		990 ppm (750 ppm) New, Jan. '82; Cont., Dec. '82						850 ppm (650 ppm) New, Oct. '89; Cont., Sept. '90	

3. The lower row indicates the time when controls are applied to new type cars or continued-production cars.
4. The application time of controls in '82 (NO_x) for sub-chamber type diesel cars with a mark * is Jan. '82 for new type cars and Dec. '82 for continued-production cars for only passenger cars of which capacity is 10 persons or less.
5. Presently there are no vehicles corresponding to the direct injection type diesel cars with a mark ☆ of which gross vehicle weight is 1.7 t or below.
6. To the passenger cars and light/middle weight buses and trucks among gasoline/LPG cars, controls based on a 11-mode test is also applied in addition to the controls mentioned in this table.

Table 3-8(2) Transition of Vehicle Exhaust Gas Control and its Application Time (Diesel Vehicles)

Classification of controls			Controls in '73	Controls in '74	Controls in '75	Controls in '76	Controls in '77	Controls in '78	First target figures by Central Environmental Pollution Council	
Kinds of vehicle/Pollutants									Controls in '79	
Passenger car (capacity 10 persons or less)	CO	With manual shift								
		Others								
	HC	With manual shift								
		Others								
	NOx	With manual shift	Equivalent inertia weight 1,250 kg or below							
			Equivalent inertia weight above 1,250 kg							
Others		Equivalent inertia weight 1,250 kg or below								
		Equivalent inertia weight above 1,250 kg								
Same as bus and truck										
Bus and truck	CO	Vehicle gross weight 1.7 t or below		980 ppm (790 ppm) New, Sept. '74; Cont., Apr. '75						
		Vehicle gross weight above 1.7 t								
	HC	Vehicle gross weight 1.7 t or below		670 ppm (510 ppm) New, Sept. '74; Cont., Apr. '75						
		Vehicle gross weight above 1.7 t								
	Sub-chamber type	Vehicle gross weight 1.7 t or below		590 ppm (450 ppm) New, Sept. '74; Cont., Apr. '75			500 ppm (380 ppm) New, Aug. '77; Cont., Apr. '78		450 ppm (340 ppm) New, Apr. '79; Cont., Mar. '80	
		Vehicle gross weight above 1.7 t and not above 2.5 t								
		Vehicle gross weight above 2.5 t								
	NOx	Vehicle gross weight above 1.7 t and not above 2.5 t								
		☆Direct injection type	Vehicle gross weight below 3.5 t		1000 ppm (770 ppm) New, Sept. '74; Cont., Apr. '75			850 ppm (650 ppm) New, Aug. '77; Cont., Apr. '78		700 ppm (540 ppm) New, Apr. '79; Cont., Mar. '80
Vehicle gross weight above 3.5 t										
	Large truck and crane car									

(Notes)

- Application time of exhaust gas control for calculation of exhaust gas volume was regarded equal to the period when the production of the said car continued.
- The upper row figures are allowable limits and figures in () are average values. The measuring methods are as follows:
 - For gasoline/LPG cars, passenger cars and light weight buses/trucks and for heavy weight buses/trucks a 10-mode test and a 6-mode test were used, respectively.
 - Diesel cars
To passenger cars of which capacity is 10 persons or less (controls in '86, and '87) and those of which gross vehicle weight is 1.7 t or below (controls in '88), a 10-mode test was applied and to other cars, a 6-mode test for diesel cars was applied.

Table 3-8(2) Transition of Vehicle Exhaust Gas Control and its Application Time (Diesel Vehicles)

Second target figures by Controls Environmental Pollution Council			Controls in '86	Controls in '87	Report of Central Environmental Pollution Council (July 10, '86)		
Controls in '81	Controls in '82	Controls in '83			Controls in '88	Controls in '89	Controls in '90
			2.70 g/km (2.10 g/km) New, Oct. '86; Cont., Sept. '87				
				2.70 g/km (2.10 g/km) New, Oct. '87; Cont., Sept. '88			
			0.62 g/km (0.40 g/km) New, Oct. '86; Cont., Sept. '87				
				0.62 g/km (0.40 g/km) New, Oct. '87; Cont., Sept. '88			
			0.98 g/km (0.70 g/km) New, Oct. '86; Cont., Sept. '87				
			1.26 g/km (0.90 g/km) New, Oct. '86; Cont., Sept. '87				
				0.98 g/km (0.70 g/km) New, Oct. '87; Cont., Sept. '88			
				1.26 g/km (0.90 g/km) New, Oct. '87; Cont., Sept. '88			
					2.70 g/km (2.10 g/km) New, Dec. '88; Cont., Nov. '89		
					0.62 g/km (0.40 g/km) New, Dec. '88; Cont., Nov. '89		
					1.26 g/km (0.90 g/km) New, Dec. '88; Cont., Nov. '89		
	390 ppm (290 ppm) *New, Oct. '82; Cont., Sept. '83				350 ppm (260 ppm) New, Dec. '88; Cont., Nov. '89		
						350 ppm (260 ppm) New, Oct. '89; Cont., Sept. '90	
					500 ppm (380 ppm) New, Dec. '88; Cont., Nov. '89		
					520 ppm (400 ppm) New, Dec. '88; Cont., Nov. '89		
		610 ppm (470 ppm) New, Aug. '83; Cont., July '84				520 ppm (400 ppm) New, Oct. '89; Cont., Sept. '90	
							520 ppm (400 ppm) New, Oct. '90; Cont., Sept. '91

Application time of NOx:
New,
Jan. '82;
Cont.,
Dec. '82

3. The lower row indicates the time when controls are applied to new type cars or continued-production cars.
4. The application time of controls in '82 (NO_x) for sub-chamber type diesel cars with a mark * is Jan. '82 for new type cars and Dec. '82 for continued-production cars for only passenger cars of which capacity is 10 persons or less.
5. Presently there are no vehicles corresponding to the direct injection type diesel cars with a mark ☆ of which gross vehicle weight is 1.7 t or below.
6. To the passenger cars and light/middle weight buses and trucks among gasoline/LPG cars, controls based on a 11-mode test is also applied in addition to the controls mentioned in this table.

3.2. Optimal Monitoring Station

3.2.1 Basic Concept of Air Pollutant Monitoring

The purpose of measuring ambient pollutant concentrations is two-fold: one is to monitor the said concentrations on a continual basis so that comprehensive emergency countermeasures can be taken upon the outbreak of high pollutant concentrations; and the other is to help work out long-term air quality management plans such as pollution control planning and environmental impact assessment. The measurements of concentrations are also used to confirm their compliance with the environmental control standards and to provide a database for other administrative applications. Thus monitoring is practiced;

- ① to see if the measured values comply with the environment control standards for air pollution;
- ② to monitor high pollutant concentrations leading to implementation of emergency measures;
- ③ to obtain a database which will be used for planning air pollution controls to be put into force by central and local governments;
- ④ to obtain a database for environmental impact assessments related to newly established pollution sources; and
- ⑤ to evaluate the ambient concentration levels after the above ③ and ④ are put into practice.

Since the monitoring of air pollution plays the main role in administrative efforts for air quality conservation as described above, it is of critical importance to perfect the maintenance of measuring instruments and thus ensure highly accurate data collection.

The measurement of ambient pollutant concentrations is sometimes practiced at places such as along roadways and near intersections, to detect if the concentration of gas emission from cars is locally high or not, or may be prioritized for monitoring the average concentration across a broad region. It is therefore necessary to select the best places for monitoring stations depending on their application objectives. Since the number of monitoring stations is limited, it is also important to establish monitoring stations such that their measurements can be used as the pollution indicators that represent the entire target region. This requires the measured values at each individual station to represent a sufficiently wide area around the said station.

3.2.2 Allocation of Monitoring Stations

(1) Location of Monitoring Stations

A general monitoring station will be installed to measure the average concentrations over a sufficiently wide region around the station. The region that can be covered by each station varies depending on its local conditions and its position relative to pollutant sources, and thus extends from a range of several hundreds of meters to scores of kilometers. On the other hand, a station

like the automobile emission monitoring station, which is designed to measure the effects caused by specific sources, covers a very narrow area, which only extends over a diameter of several meters to several hundred meters at most.

Accordingly, when a monitoring station is installed or when measured values at that station are evaluated, the region that can be covered by the station (the representativeness of the station) must be always kept in mind.

Monitoring stations should be installed taking into account the purpose of monitoring and the representativeness of the station. It is, however, very difficult to quantify the representative region of a station. So at present, the allocation of a monitoring station is determined based on empirical judgement, coupled with such considerations as meteorological knowledge, the distribution of pollutant sources, and the current and future land utilization, as well as with thoughts to the items listed below:

- ① A zone with the highest pollutant concentrations in the region
- ② A densely populated zone in the region, especially one in the neighborhood of a district which is suffering from high pollutant concentrations
- ③ The vicinity of the regional borders where the station measures and evaluates ambient pollutants coming in from other regions
- ④ Places where the impacts of future development are expected
- ⑤ Places where countermeasures for prevention of air pollution can be easily evaluated
- ⑥ Places where the obtained data represent the said region.

(2) Number of Monitoring Stations

Though the number of monitoring stations obviously varies depending on the purpose of environmental monitoring, appropriate mathematical models and other rational methods have not been established yet. In the case that general ambient pollutant concentrations are measured, however, there are some countries that define the method of calculating the standard number of monitoring stations or the number of stations. According to the standards of the U.S. EPA¹⁾, the number of monitoring stations as shown in Table 3-9 is required for measurement of SO₂. Concerning NO₂, in the case of over one million population, the said standards require 2 stations in total, one regional-scale monitoring station and one urban-scale permanent monitoring station, respectively. In Japan, Article 22 of the Air Pollution Control Act stipulates the required number of monitoring stations as shown in Table 3-10.

Table 3-9 Number of Monitoring Stations for SO₂ Concentrations under the U.S. EPA Standards

Population	No. of monitoring stations-		
	High concentration region ^{a)}	Medium concentration region	Low concentration region ^{b)}
500,000 or more	6-8	4-6	0-2
100,000 to 500,000	4-6	2-4	0-2
100,000 or less	2-4	1-2	0

Note: a) Region in which the measured values exceed the primary environmental control standards [yearly average value 80 µg/m³ (0.028 ppm), 24-hour highest value 365 µg/m³ (0.128 ppm)]

b) Region in which the measured values are equal to, or lower than, 60% of the primary environmental control standards, or the secondary environmental control standards [3-hour highest value 1300 µg/m³ (0.455 ppm)]

Table 3-10 Method of Calculating the Number of Stations in a Basic Program for Optimal Distribution of Air Pollution Monitoring Stations²⁾

(1) In the case of development standards for air pollution permanent monitoring networks subject to Article 22 of the Air Pollution Control Act

The development of a monitoring network shall be targeted at an inhabitable area. For the required number of monitoring stations for such a network, the standard number shall be obtained as follows if population density against the inhabitable area (net area after deducting the areas of forests, intact fields, and lakes and marshes from the total area) is 2,600 persons (the national average value of population densities against inhabitable areas) or more:

$$(\text{Inhabitable area}) \div (25 \text{ km}^2) \times [\text{the percentage of the area's population density over 2,600 (the national average population density)}]$$

That is to say, the calculation formulae of the standard number of stations in the monitoring network are as follows:

If the area's population density against

1 km² of inhabitable area is 2,600 prs/km² or more:

$$\text{Inhabitable area} \div 25 \text{ km}^2 = \text{Standard number of stations}$$

If the said density is less than 2,600 prs/km²:

$$\text{Inhabitable area} \div 25 \text{ km}^2 \times \frac{\text{The area's population density}}{2,600 \text{ prs}} = \text{Standard number of stations}$$

(2) In the case of the development standards for automobile emission monitoring networks required to implement effectively and properly the measures subject to the provisions of Articles 20 to 23 of the Air Pollution Control Act

(i) Prefectures

The number of monitoring stations shall be one per prefecture, and, moreover, for each prefecture having those cities (including special wards) which are not government ordinance-designated ones and have a population of 150,000 or more, one station shall be added for each of such cities.

(ii) Government ordinance-designated cities

The number of monitoring stations shall be one per government ordinance-designated city, and for each government ordinance-designated city having an over 300,000 population, furthermore, there shall be added in principle the number of stations equivalent to those obtained as follows (omitting the figures below a decimal point):

$$(\text{population after deducting 300,000 from the population of the said government ordinance-designated city}) \div 500,000$$

(3) Positions of Air Sampling Outlets

A manual of ambient air permanent monitoring³⁾ issued by the Japanese Environment Agency sets forth that the following matters shall be kept in mind in selecting the positions of air sampling outlets:

- ① The positions of sampling outlets should be selected for such places which are not directly affected by the sources of pollutants including smoke stacks, and exhaust ducts.
- ② The height of a sampling outlet should be set at the level that enables the operators to determine precisely the status of pollution caused by the target pollutants to be measured.

Table 3-11 shows the heights of sampling outlets indicated in the Notice on the Environmental Control Standards.

Table 3-11 Standard Heights of Sampling Outlets (Japan)

Pollutants	Sulfur dioxide	Nitrogen dioxide	Photochemical oxidant	Suspended particulate matter
Height of sampling outlet	in principle, 1.5 m to 10 m above ground	in principle, 1.5 m to 10 m above ground	in principle, 1.5 m to 10 m above ground	in principle, 3 m to 10 m above ground

In addition, according to the U.S. Federal Regulations 40 CFR (amended by 46F 44163, September 3, 1981)¹⁾, the standard heights of air sampling outlets are prescribed as shown in Table 3-12.

Table 3-12 Standards for the Positions of Air Sampling Outlets (U.S.A.)

Pollutant	Target scale	Height above ground (m)	Distance from supporting structure		Other standards
			Vertical (m)	Horizontal (m)	
TSP (total suspended particulates)	all scales	2~15	—	2 or more	① Should be put away by 20 m or more from trees. ② The distance up to an obstacle such as a building should be two times or more of the height of that obstacle projecting above the sampler. ③ Wind in the direction of 180° around the sampler should not be blocked. ④ Should not be covered with smoke emitted from an incinerator or combustion furnace. ⑤ Should be kept away from the road in a greater distance than the standards.
SO ₂	All scales	3~15	1 or more	1 or more	①, ② and ④ are same as in the case of TSP. ③ Wind in the direction of 270° around the sampler should not be blocked. The direction should be 180° in case of the surface of a wall.
CO	Local scale	3±1/2	1 or more	1 or more	① Should be put away by 10 m or more from the intersection and be placed at the center of a single road section. ② The distance from the nearest traffic line should be within a range from 2 m to 10 m. ③ Wind in the direction of 180° around the sampler should not be blocked.
	Medium scale Neighboring scale	3~15	1 or more	1 or more	① Same as the paragraph ③ of TSP. ② Same as the paragraph ⑥ of TSP.
O ₃	All scales	3~15	1 or more	1 or more	① Same as the paragraph ① of TSP. ② Same as the paragraph ② of TSP. ③ Same as the paragraph ③ of SO ₂ . ④ Same as the paragraph ⑥ of TSP.
NO ₂	All scales	3~15	1 or more	1 or more	① to ④ are same as the paragraphs of O ₃ .

(4) Optimal Allocation of Monitoring Stations

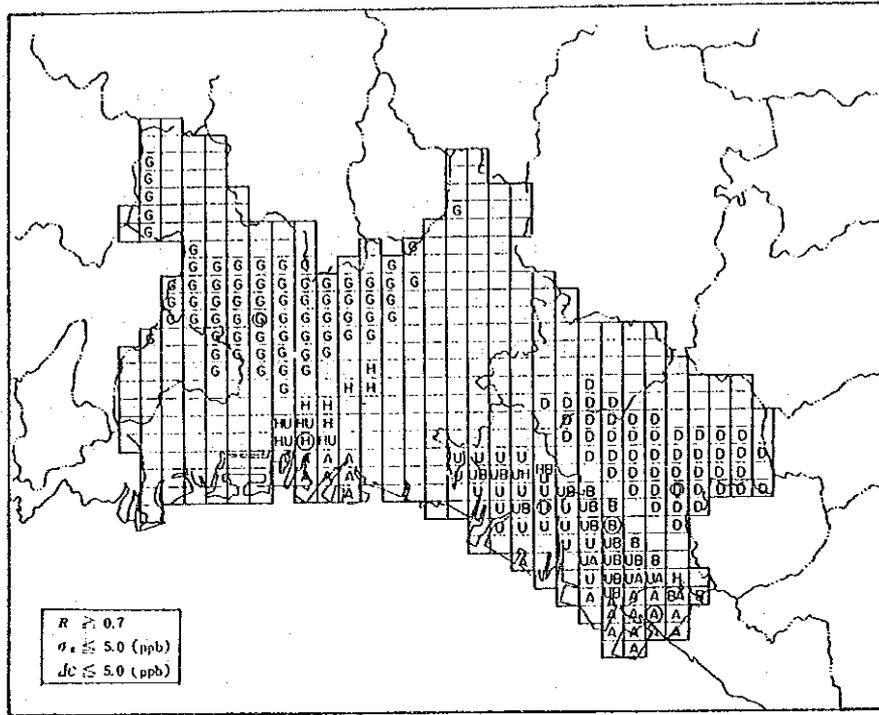
As described in (1), the allocation of a monitoring station is presently determined based on empirical judgement. The recent trend of studies on the optimal allocation monitoring stations will be presented below.

Monitoring stations are placed for various objectives that are often multiple including "finding high-concentration areas" and "measurement of average concentrations across a broad area". The allocation of a monitoring station which can meet such multiple needs is thought important. In optimal allocation of monitoring stations, consequently, the first consideration is to determine the distribution of pollutant concentrations in the whole target region as accurately as possible. The following are the ways to accomplish this objective:

- ① Placement of a number of simple measuring instruments across the whole region to obtain the distribution data of concentrations. One example is the measurement of SO₂ concentrations by Nashville's PbO₂ methods⁴⁾.
- ② Placement of temporary measuring instruments around the target monitoring station to monitor the concentrations for a certain period.
- ③ Estimation of the concentrations in the whole region from the data available at the existing stations by interpolation. The examples were reported by Van Egmond^{5),6)}, Otaki⁷⁾, Goldstein⁸⁾, Elson⁹⁾, etc.
- ④ Application of air diffusion simulation models to estimate the concentrations in the whole region or around the target monitoring station.

If the concentrations in the whole target region are known, the optimal allocation of monitoring stations can be easily selected. There are many studies on the practical methods of working out the optimal allocation pattern, including Nakamori et al.¹⁰⁾, Seinfeld¹¹⁾, Hougland et al.¹²⁾, Hougland et al.¹³⁾, Liu et al.¹⁴⁾ and Moore¹⁵⁾. While these proposed methods state the allocation of monitoring stations, however, they do not deal much with the size of a region that a station can represent. The following is a method studied by the Industrial Pollution Control Association of Japan.¹⁶⁾

According to this method, the annual daily average concentration at each grid point is first estimated by using a diffusion model, leading to the study of the representative region based on the statistical variables based on the said estimated values. That is to say, if R is the correlation coefficient between the concentrations, at a monitoring station and each grid point, σ_c the standard deviation of concentration differences, and ΔC the absolute value of the differences in the yearly average concentrations being within a certain limit, then this grid point is considered to be included in the representative region of the said station. Fig. 3-10 illustrates an example obtained as a result of analysis done by this method. In Figure 3-10, the alphabetic character marked in each mesh element represents the mesh that is included in the representative region of a monitoring station marked by that alphabetic character (Station A, B, D, G, H, or U).



The representative region of each monitoring station in the Standard Case 1 ($R \geq 0.7$, $\sigma_a \leq 5.0$ ppb, $\Delta C \leq 5.0$ ppb) of the representative region concerning NO_2 concentrations (for Stations A, B, D, G, H, and U)

Fig. 3-10 An Example Illustration the Representative Regions of Monitoring Stations

In order to determine the ambient pollutant concentrations by using a limited number of monitoring stations, the monitoring stations are ranked to screen and separate unnecessary stations from indispensable ones by prioritizing in light of the following five significance of monitoring stations:

- ① Concentrations at each monitoring station
- ② The highest concentration in the representative region of each monitoring station
- ③ The total of concentrations in the representative region of each monitoring station
- ④ The sum of products of population and concentration in the representative region of each monitoring station
- ⑤ The area in the representative region of each monitoring station

To be studied is how many monitoring stations can cover the target area by adding stations in compliance with the said priority order of the existing stations. Figure 3-11 shows an example exhibiting the results of this study, wherein the following three items have been established as the criteria for placement of stations.

- ① Cumulative area S of the representative region of each station

$$S = \int_0^s ds \dots\dots\dots (3-1)$$

- ② Cumulative concentration C of in the representative region of each station

$$C = \int_{D} cds \quad \dots\dots\dots (3-2)$$

- ③ Sum of products CP of population and concentration CP in the representative region of each station

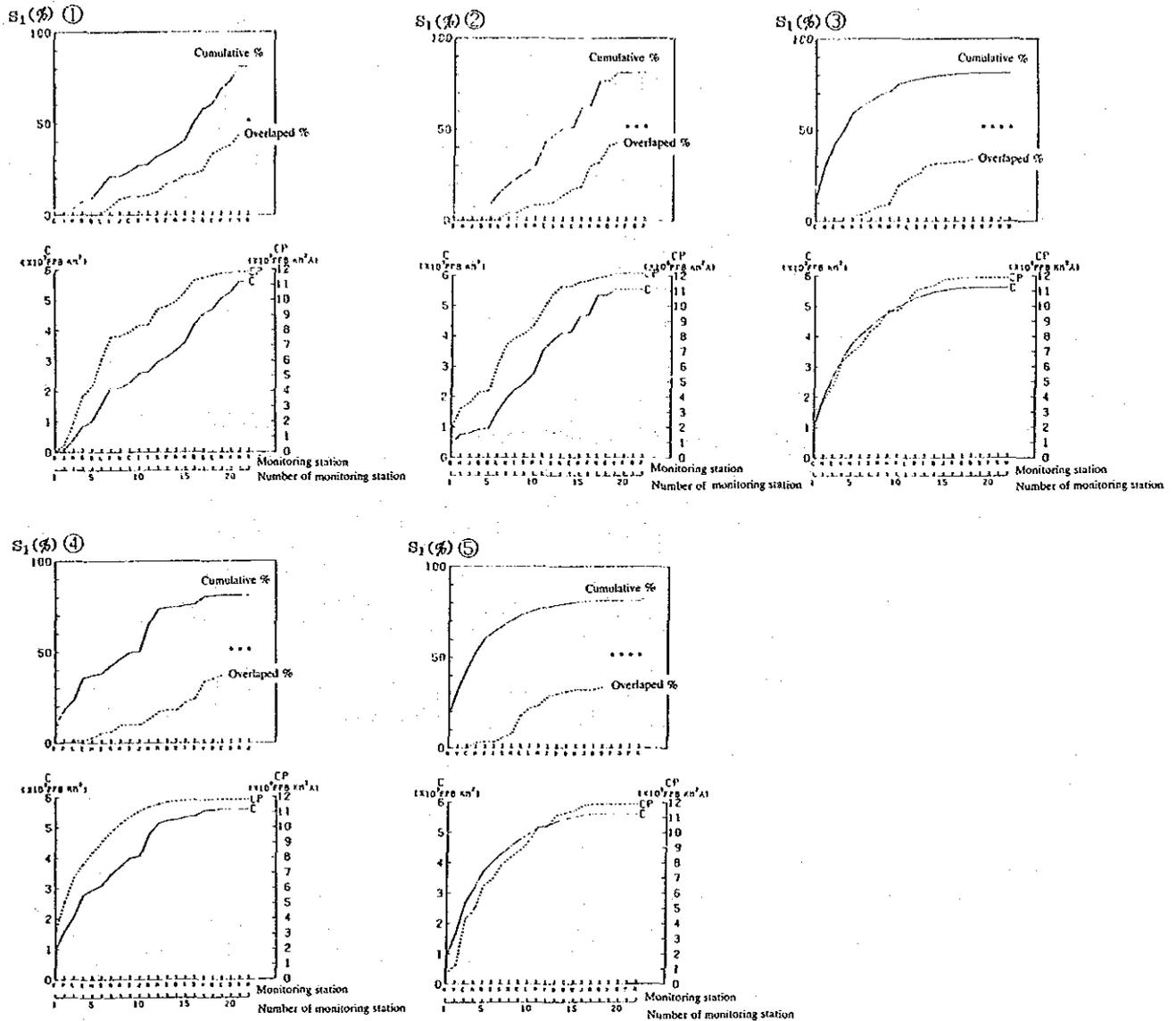
$$CP = \int_{D} cpsds \quad \dots\dots\dots (3-3)$$

wherein s, c, p, and D, respectively, represent area, concentration, population, and the representative region of each monitoring station.

The locations of monitoring stations to meet the following two objectives are under examination by using the method described above:

- ① To allocate the monitoring stations which can accurately high-concentration regions.
- ② To allocate the monitoring stations so that broader region can be covered by a smaller number of stations.

Moreover, the Industrial Pollution Control Association of Japan is studying the representative region of an automobile emission monitoring station based on the concept described above. An example of the study result is presented in Fig. 3-12.



Criteria for monitoring network:

- S_1 Ratio of the dimension of each representative region to the total area
- C Area dosage in each representative region
- CP Population dosage in each representative region

Prioritizing of monitoring stations:

- ① Concentrations at each station
- ② Maximum concentration in each representative region
- ③ Cumulative concentration in each representative region
- ④ Sum of products of population and concentration CP in each representative region
- ⑤ Area S of each representative region

Criteria for monitoring stations to meet the Standard Case 1 of the representative region of each monitoring station concerning the concentration of NO_2 (22 current status monitoring stations)

Fig. 3-11 An Example Illustrating the Criteria for Monitoring Networks