THE STUDY
ON
THE AIR QUALITY MANAGEMENT PLANNING
FOR
THE SAMUT PRAKARN INDUSTRIAL DISTRICT
IN THE KINGDOM OF THAILAND
FINAL REPORT

SUMMARY

JANUARY, 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

1. Introduction

1.1 Objectives of the Survey

This survey has two objectives: one, that the Japanese government provide the Thai government with the data and advice necessary for the latter to formulate an environmental control plan for air pollution (with respect to SO_2, NO_2, and suspended particulate matters) primarily accompanied by industrial activities in the Samut Prakarn district of the country; and two, that the survey team on behalf of the JICA accomplish technology transfer concerning the survey work to the ONEB (Office of the National Environment Board), the counterpart agency of Thailand, while this survey is under way.

1.2 Outline of the Survey

In order to furnish the necessary data useful for planning the environmental control of air pollution, the team firstly measured the atmospheric concentration levels of pollutants and meteorological variables as well as the amounts of air pollutants exhausted from the sources across the district. Secondly, the team investigated the correlation between the emission volumes and ambient pollutant concentrations by using air diffusion simulation models, thus clarifying the contributions of individual sources to the environment. In order to induce the necessary advice for planning environmental control measures, the team also compared the current ambient pollutant concentrations with the environmental standards; screened the target emission sources that required remedial actions based on the contribution rates of such sources; studied the methods of depleting the emission sources (including such measures as reduction of emissions, installation of higher stacks, and improvement of fuel quality); estimated the costs required for abatement of emission sources; assessed the possible impact of such source improvements on production cost and national economy; predicted the future ambient pollutant concentrations after such remedial measures are implemented to sources; and confirmed the compliance of the improvements with the environmental standards. The team furthermore reviewed the monitoring system of sources and ambient pollutant concentrations and collected various relevant data that lead to the improvement of legislative and administrative structures involved in environmental conservation, thus making comprehensive suggestions for formulation of the environmental control plan while considering the social and economic situations of Thailand.

Figure 1 illustrates the outline of the survey and the job relationships.

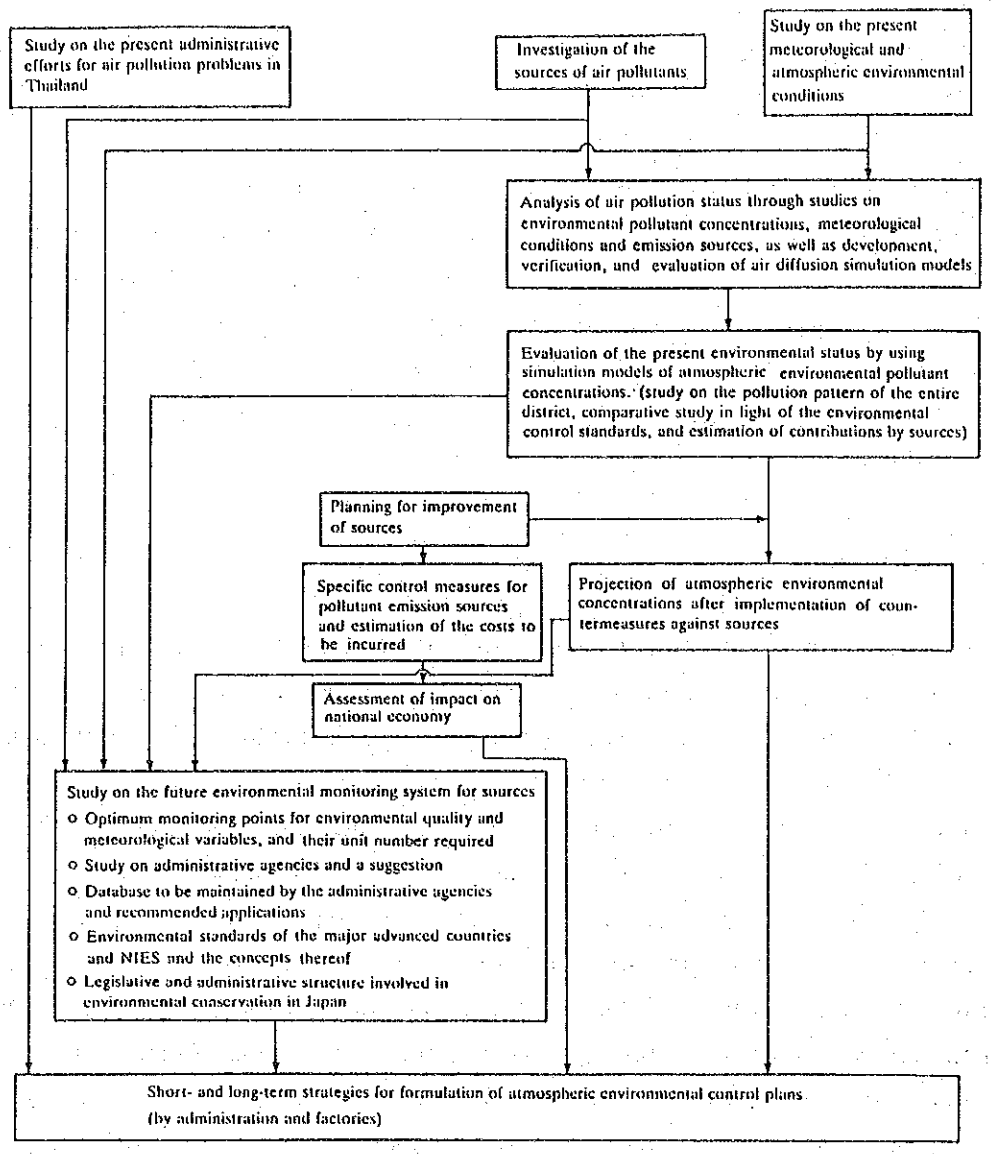

Figure 1 Flow Chart of the Entire Survey

1.3 Survey Area

Samut Prakarn Province is situated on the south side of the metropolitan region of Bangkok, comprising the counties of Phra Pradaeng, Muang, and Bang Plee. This survey covers, as shown in Figure 2, an area of about 60 km from east to west and about 30 km from south to north including these counties and part of Bangkok City.

1.4 General Statement of the Area

(1) Geographical features

Samut Prakarn Province is situated in latitudes 101° East and 14° North and on the south side of the metropolitan region of Bangkok, and is an industrial area having an area of about 890 km^2. The

south side of this province is facing the Gulf of Thailand as shown in Figure 2, with the Chao Phraya River flowing nearly in the center of Muang, and is nearly flat across its whole area, the maximum elevation of which is less than 20 m.

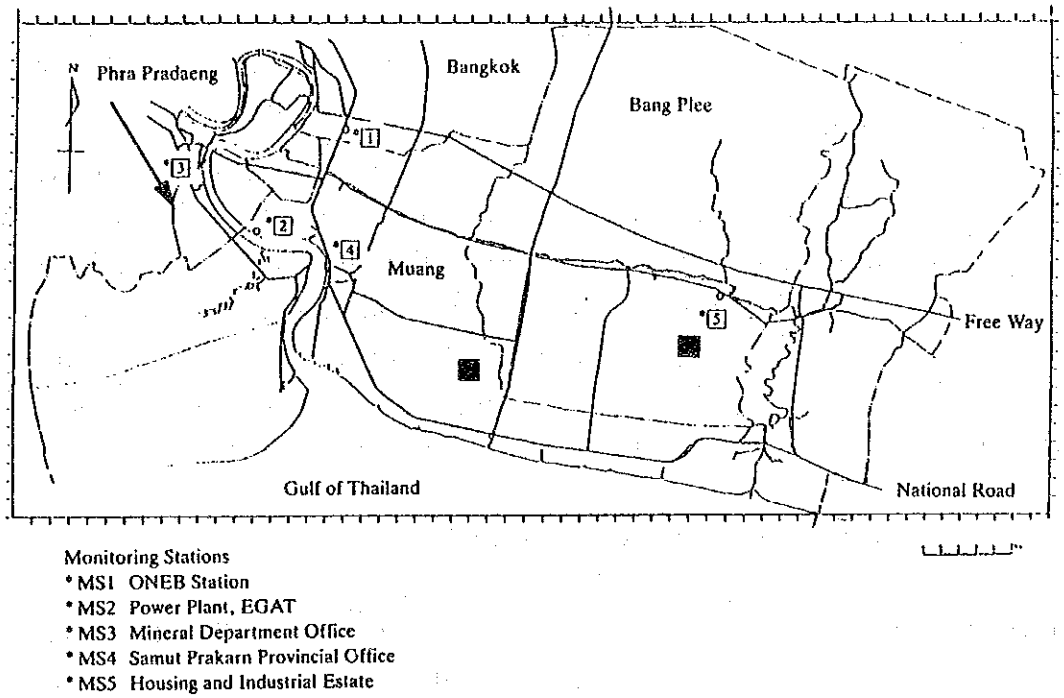

Figure 2 The Regional Map of Samut Prakarn Province

(2) Climate

There is little change in temperature throughout the year, and the annual average temperature is 28°C to 30°C. Humidity also stays at 75% to 80% the year round, characteristic of a typical tropical climate. The climate is divided into three seasons, the Hot season (March to June), the Rainy season (July to October), and the Cool season (November to February) by wind type and by rainfall frequency. The wind maintains a mostly S direction in February to August, and an N direction in November to December, but no consistent direction in the other months. The wind velocity is around 1 m/s to 3 m/s, often less than 1 m/s.

(3) Distribution of sources

There are about 2,500 small and large factories located in Samut Prakarn Province, most of which are concentrated in Phra Pradaeng, the central area of Muang, and the south banks of the Chao Phraya River. Outside of these counties, the factories are sporadically located in Bang Poo Industrial Park and Bang Plee Industrial Park, and along the expressway of Bang Plee.

The trunk roadways in these provinces are expressways, and state and provincial roads, the total length of which reaches over 200 km with a daily average traffic volume of about 500 to 75,000

cars (including motorbicycles) depending on the routes.

The other emission sources of air pollutants include ferryboats and ships. About 150 ships per day with tonnages of several hundreds to over 10,000 are sailing along the Chao Phraya River. In addition, the ferryboats are in service between both banks of the Chao Phraya River running through Phra Pradaeng, with their number at about 1,300 a day (which accounts for the frequency of services between three landing spots for the boats).

(4) Plan for development

Two industrial parks, Bang Poo Industrial Park and Bang Plee Industrial Park have been developed in the province to attract factories from within Thailand and from abroad. Bang Plee Industrial Park is inland based and has a short history since its development, and at present about 20% of the site is occupied by factories. Bang Poo Industrial Park, on the contrary, has been well developed, enjoying about 1/3 usage of the 600 ha industrial park area being used by a variety of factories in operation including foodstuffs, chemicals, metals, textiles, plastics, rubber, and clothes. In the future, the whole site of the park is likely to be occupied as more factories are moving in.

2. Present Status of the Ambient Pollutant Concentrations

In order to understand the status quo of the concentrations of air pollutants {such as SO_2, NO_2, suspended particulate matters (SPM), total suspended particulates (TSP)} and also to clarify the meteorological pattern of the district and to grasp the conditions of air diffusion, the study team placed monitoring stations at 5 spots in the target district, as agreed upon between both governments and thus monitored air pollutants and meteorological variables year-round. The team also identified all the sources (including factories, cars, ships, and ferryboats) which emit air pollutants, and quantified the ambient concentrations of SO_2 and NO_2 in the district as a whole by means of the air diffusion models. The result of the survey and the current ambient concentrations of pollutants in Samut Prakarn Province are described as follows.

2.1 Contents of the Survey

(1) Field survey of atmospheric pollutant concentrations and meteorological variables

With the monitoring stations installed at 5 spots in Samut Prakarn Province, the ambient pollutant concentrations and meteorological conditions shown in Table 1 were monitored for the period from January 17, 1988 through January 16, 1989. Furthermore, the team clarified the composition of the chemical components in the particulate matters, and then analyzed 39 chemical components in TSP by the neutron activation analysis and others for the purpose of estimating the percentage contributions of particulate matter by sources using the CMB (chemical mass balance) method. In addition, in order to determine the chemical compositions of sources of particulate matter, the team conducted chemical analysis on soil, roadway dust, and gasoline.

Table 1 Items to be Monitored at Monitoring Stations

Measurements	Station#	Period of monitoring	Instruments applied
SO_2	1, 2, 3, 4, 5	1 year	Ultraviolet-fluorescent-automatic-continuous measuring instrument (instantaneous and an hour average)
NO_x (NO, NO_2)	1, 2, 3, 4, 5	1 year	Chemiluminescence-automatic-continuous measuring instrument (instantaneous and an hour average)
SPM	1, 2, 3, 4, 5	1 year	β-ray absorption automatic continuous measuring instrument (an hour average)
TSP	1, 2, 3, 4, 5	1 year	Low volume samplers (a month average with two times filter replacement, 15 days/filter) Two samplers in use are one with a quartz filter and the other with a polyfluorocarbon filter.
TSP size distribution	1, 2, 3, 4, 5	3 seasons rainy, dry, mid-term	Andersen sampler 15 days average
Wind velocity direction	1 (3-dimensional) 2, 5 (2-dimensional)	1 year	2- and 3-dimensional ultrasonic automatic continuous anemometer 10 minutes moving average
Solar radiation Radiation balance	1	1 year	Automatic continuous measuring instrument (instantaneous and an hour average)
Air turbulency	1	1 year	3-dimensional ultrasonic anemometer (horizontal and vertical direction)

(2) Investigation of the sources of air pollutants

1) Factories

The amounts of SO_2 and NO_x exhausted from factories were estimated in principle based on the results of the questionnaire survey. As for those minor factories to which no questionnaire was sent and those from which no response to the questionnaires was received (572 factories), we set the base unit of fuel consumption per employee utilizing the data from the responding factories who reached to 208, and thus estimated the fuel consumption and emission volumes of SO_2 and NO_x of the former factories.

2) Cars

The team calculated the amounts of SO_2 and NO_x exhausted from cars running on the roads with the total length of 243 km based on the traffic volume by type of car and data on driving speeds as well as the emission factor of non-emission controled cars established by Japan's Ministry of Construction.

3) Ships and ferryboats

We estimated the amounts of SO_2 and NO_x exhausted from the ships navigating along the Chao Phraya River and the ferryboats in service between both banks of the Chao Phraya River running through Phra Pradaeng, based upon the survey of the number of ships, the emission factor of ships established by Japan's Ministry of International Trade and Industry and the results of the analysis which was separately conducted on the sulfur contents of fuels.

(3) Simulation of air pollutants

1) SO_2 and NO_2

In this survey, it was thought necessary to calculate under various meteorological conditions

the ambient pollutant concentrations across the whole area of Samut Prakarn Province, having a huge number of sources. Furthermore, since the topographic effect on the state of diffusion is considered negligible due to the flat configuration of the ground in the area, the study complied with the manual of the ambient SO_x and NO_x prediction method in comprehensive environmental assessment issued by Japan's Ministry of International Trade and Industry, thus calculating the long-term average concentrations (yearly average concentrations) of SO_2 and NO_2 by using a plume-puff model.

2) TSP

The simulation of the atmospheric concentrations of particulate matters involves various problems such as the diversity of sources, modeling of the production of secondary particles and modeling of the precipitation and deposition of particles, making it difficult to use an air diffusion model. Relying on the chemical mass balance method (CMB method) which has recently drawn worldwide attention, the team estimated the contribution rates of particulate matters by type of source (i.e., sea salt particles, soil and roadway dust, diesel cars, gasoline cars, the iron and steel industry, the glass industry, and oil combustion).

2.2 Outline of Survey Results

(1) Concentrations of air pollutants

1) Present status of ambient pollutant concentrations

When the concentrations of SO_2 and NO_2 (Table 2) measured in Samut Prakarn Province are compared with the national air quality standards of Thailand (Table 3), it can be seen that all of the monitoring stations have satisfied the standards. As compared with the environmental standards of other countries (Table 4), however, the value of SO_2 at MS 3 exceeds the standard values of England, France, Canada, Australia, and Japan. As for NO_2, the values at MS 1 and MS 4 exceed the standard level of West Germany, and further, the value at MS 4 exceeds the standards of Taiwan, Korea, Australia, and Japan.

With respect to SPM, no standard value has been established in Thailand. When compared with the standard values of the U.S. and Japan where the environmental standards have been stipulated, it is found that Thai values, except for the measurement at MS 5, are all found to exceed the U.S. and Japanese standards.

2) Daily variations of the concentrations of air pollutants

As for SO_2, although the concentrations at MS 2 and MS 3 are relatively higher than at the other monitoring stations, all the stations show high concentrations during the time frame from night until early morning, and low concentrations in the daytime.

Regarding NO_2 and NO_x ($NO + NO_2$), the concentrations at MS 1 and MS 4 along the trunk road are higher than those at the other stations, but all stations exhibit a double-peak type pattern having a peak at 7:00 to 8:00 and 19:00 to 21:00, respectively.

The values of SPM do not show very significant differences among stations, indicating the same double-peak pattern as in NO_2 and NO_x.

Table 2 Measured Values of Air Pollutants

Item Code (unit)	Station	Effective monitoring days (days)	Monitoring hours (hrs)	Yearly Average	Yearly Geometric Average	Maximum values of hourly data	Maximum values of daily average data	Values of 98% cumulative daily average
SO_2 (ppb)	MS 1	362	8684	7	4	109	23	19
	MS 2	354	8515	12	8	112	34	30
	MS 3	352	8502	24	16	199	71	60
	MS 4	360	8562	5	3	79	20	14
	MS 5	296	7225	3	2	48	21	8
NO_2 (ppb)	MS 1	354	8560	16	12	138	49	33
	MS 2	316	7763	9	6	69	32	20
	MS 3	276	6805	13	10	81	41	30
	MS 4	289	7097	15	10	150	69	46
	MS 5	315	7640	5	3	48	16	14
NOx (ppb)	MS 1	354	8558	38	23	497	176	112
	MS 2	316	7763	18	14	132	56	40
	MS 3	270	6674	24	18	251	75	62
	MS 4	289	7092	34	22	343	180	105
	MS 5	315	7639	9	6	127	36	25
SPM ($\mu g/m^3$)	MS 1	348	8399	60	46	477	156	130
	MS 2	344	8419	56	42	870	169	125
	MS 3	355	8579	63	50	702	157	132
	MS 4	350	8504	68	49	605	201	162
	MS 5	343	8322	43	32	661	119	103

Note) An effective monitoring day has 20 monitoring hours or over

Table 3 Thailand's Environmental Control Standards for Air Pollutants

Pollutant		Standard of air pollution	
		($\mu g/m^3$)	(ppm)
SO_2	Daily average	0.30	0.117
	Yearly geometric average	0.10	0.039
NO_2	Hourly data	0.32	0.173
TSP	Daily average	0.33	—
	Yearly geometric average	0.10	—

3) Seasonal variations of the concentrations of air pollutants

While the concentration of SO_2 somewhat varies from one monitoring station to another, it is generally high during the dry season (November to April) and low during the rainy season (May to October). As for NO_2 and NO_x, on the other hand, the stations except for MS 1 show high concentrations from the rainy season to the dry season (August to December), whereas the concentrations at MS 1 are high during the rainy season (May to October). Regarding SPM, the concentration is high from November to March, but all stations show low concentrations from May through August representing the rainy season.

Table 4 Environmental Air Quality Control Standards of Major Countries

Country	SO_2	NO_2	Particulate matter
England France	Permissible limits ($\mu g/m^3$) Yearly average (of daily average values) IF SMOKE<34 0.042 ppm IF SMOKE≧34 0.028 ppm Winter average (of daily average values from October to March) IF SMOKE<51 0.063 ppm IF SMOKE≧51 0.045 ppm Yearly peak (of daily average values) IF SMOKE<128 0.122 ppm IF SMOKE≧128 0.087 ppm Guideline value Yearly average (of daily average values) 0.014~0.021 ppm 24-hour value 0.035~0.052 ppm		SMOKE* environment standard Permissible limits Yearly average (of daily average values) 68 $\mu g/m^3$ Winter average (of daily average values from October to March) 111 $\mu g/m^3$ Yearly peak (98% value of daily average concentration) 213 $\mu g/m^3$ Guideline value Yearly average (of daily average values) 34~51 $\mu g/m^3$ 24-hour value 85~128 $\mu g/m^3$ *SMOKE: A portion in particle diameter of less than 15 μm of soot and dust exhausted by fossil fuel combustion.
West Germany	30-min value 0.350 ppm 24-hour average value 0.105 ppm	30-min value 0.098 ppm 24-hour average value 0.049 ppm	30-min value 300 $\mu g/m^3$ 24-hour average value 200 $\mu g/m^3$ Yearly average value 100 $\mu g/m^3$
Italy	Yearly average value of daily average concentrations 0.028 ppm 98% value of daily average concentration during a year 0.087 ppm	Arithmetic mean of one-hour average concentrations 0.070 ppm (The value should not be maintained longer than one hour per day.)	Yearly arithmetic mean of daily average concentrations 150 $\mu g/m^3$ 95% value of daily average concentration during a year 300 $\mu g/m^3$
Nether-lands	50% value of 24-hour average concentration 0.026 ppm 95% value of 24-hour average concentration 0.070 ppm 98% value of 24-hour average concentration 0.087 ppm 24-hour average value 0.175 ppm One hour average value 0.290 ppm	50% value of 24-hour average concentration 0.024 ppm 95% value of 24-hour average concentration 0.049 ppm 95% value of one-hour average concentration * 0.054 ppm 98% value of 24-hour average concentration 0.059 ppm 98% value of one-hour average concentration 0.066 ppm 24-hour average value 0.073 ppm One hour average value 0.146 ppm 4-hour average value* 0.016 ppm The mark * is for the protection of fauna and flora, and the other is for the protection of human health.	50% value of 24-hour average concentration 30 $\mu g/m^3$ 95% value of 24-hour average concentration 75 $\mu g/m^3$ 98% value of 24-hour average concentration 90 $\mu g/m^3$ 24-hour average value 150 $\mu g/m^3$
South Africa	0.02 ppm (Shall not exceed 0.04 ppm) Averaging time is unknown.		Dependention chemical and physical property of substance and threshold value Example Asbstos 0.02 fibers/cc (max. 0.04), Nuisance dust 0.1 mg·m^3 (max. 0.2)
Taiwan	(Non-industrial district) (Industrial district) Yearly average value of one-hour values: 0.05 ppm or less, 0.075 ppm or less Daily average value of one-hour values: 0.1 ppm or less, 0.15 ppm or less One-hour value: 0.3 ppm or less, 0.5 ppm or less	(Non-industrial district) (Industrial district) Daily average value of one-hour values: 0.05 ppm or less, 0.1 ppm or less Daily average value which exceeds this standard shall be less than 10% of yearly data.	(Non-industrial district) (Industrial district) Diameter of particle: 10 μm or less Monthly average value: 210 $\mu g/Nm^3$ or less, 240 $\mu g/Nm^3$ or less Yearly average value: 140 $\mu g \cdot Nm^3$ or less, 160 $\mu g/Nm^3$ or less Including a portion in with a particle diameter of 10 μm or more Monthly average value: 260 $\mu g \cdot Nm^3$ or less, 290 $\mu g/Nm^3$ or less Yearly average value: 170 μg Nm^3 or less, 190 $\mu g/Nm^3$ or less Monthly average value which exceeds this standard must be less than two times per year.
Korea	Yearly average value: 0.05 ppm or less Daily average value: 0.1 ppm or less (Shall not exceed three times per year.)	Yearly average value: 0.05 ppm or less One-hour average value: 0.15 ppm or less (Shall not exceed three times per year.)	Yearly average value: 150 $\mu g/m^3$ Daily average value: 300 $\mu g/m^3$ (Shall not exceed three times per year.)
Australia	(Victoria) Acceptable level Detrimental level One-hour value 0.17 ppm 0.34 ppm 24-hour value 0.06 ppm 0.11 ppm	(Victoria) Acceptable level Detrimental level One-hour value 0.15 ppm 0.25 ppm 24-hour value 0.06 ppm 0.15 ppm	
U.S.A.	(Primary) Yearly arithmetic average: 0.03 ppm 24-hour average 0.14 ppm (Secondary) 3-hour average 0.5 ppm	Yearly average 0.053 ppm	SPM environmenta standard Yearly average (arithmetic average): 50 $\mu g/m^3$ 24-hour average: 150 $\mu g/m^3$
Canada	(1) Desirable level a) Yearly arithmetic average value 0~0.010 ppm b) 24-hour average concentration 0~0.052 ppm c) One-hour average concentration 0~0.157 ppm (2) Acceptable level a) Yearly arithmetic average value 0.008~0.021 ppm b) 24-hour average concentration 0.052~0.105 ppm c) One-hour average concentration 0.157~0.315 ppm (3) Tolerable level Average concentration measured continuously for 24 hours or more 0.105 ~0.280 ppm	(1) Desirable level a) Yearly arithmetic average value 0~0.029 ppm (2) Acceptable level a) Yearly arithmetic average value 0~0.049 ppm b) Average concentration for 24 hours or more 0~0.098 ppm c) Average concentration for one hour or more 0~0.195 ppm (3) Tolerable level Average concentration measured continuously for one hour or more 0.195 ~0.488 ppm	(1) Desirable level a) Yearly geometrical average 0~60 $\mu g/m^3$ (2) Acceptable level a) Yearly geometrical average 60~70 $\mu g/m^3$ b) Average concentration for 24 hours or more 0~120 $\mu g/m^3$ (3) Tolerable level Average concentration for 24 hours or more 120~400 $\mu g/m^3$
Japan	Daily average value of one-hour value: 0.04 ppm or less One-hour value: 0.1 ppm or less (98% value)	Daily average value of one-hour value shall be within the zone of 0.04 ppm to 0.06 ppm or less.	Daily average of one-hour values shall be 100 $\mu g/m^3$ or less. One-hour value 200 $\mu g/m^3$ or less (98% value) Particulate matter with a diameter of 10 μm or less (SPM)

(2) Meteorological Structure

1) Wind direction and wind velocity

The wind pattern in Samut Prakarn Province is uniform despite the fact that this district covers a wide area of 60 km from east to west and 30 km from south to north, and does not exhibit any presence of a local wind pattern. The wind velocity is generally low, with the yearly average recorded as about 2 to 3 m/s, and it is rare to experience a wind velocity of 6 m/s or higher. As for the daily variations of wind velocity, it is high in the daytime, and low in the nighttime. In addition, there is little seasonal variation in the wind velocity. The wind direction, on the other hand, has a noticeable seasonal feature in that it is S system from February to August, N system in November and December, and not fixed in the months of January, September, and October, which represent the turning of the seasons.

2) Atmospheric turbulence and the conditions of diffusion

The degree of turbulence in the horizontal and vertical directions, which exerts effects on the advection and diffusion, becomes dominant when daytime radiation is strong with good conditions of diffusion, whereas it is depressed during the nighttime with no radiation, accompanied by poor conditions of diffusion. There is a general tendency, furthermore, that the turbulence size becomes larger as the wind velocity becomes greater.

(3) Emission Volume of Pollutants

The amount of SO_2 currently emitted from the whole area of Samut Prakarn Province is 21,134 tons/year; 18,330 tons/year (86.7%) of which is attributable to factories; followed by 1,330 tons/year (8.2%) to ships and ferryboats; and 1,474 tons/year (7.0%) to cars. The amount of NO_x exhausted from the whole area is 18,502 tons/year; which is broken down into 8,820 tons/year (47.7%) from factories; 7,812 tons/year (42.2%) from cars; and 1,870 tons/year (10.1%) from ships and ferryboats.

(4) Ambient Pollutant Concentrations in the District obtained by Air Diffusion Simulation

1) SO_2 and NO_2

Using the emission volumes of SO_2 and NO_2 and the meteorological conditions as input data, the team calculated the yearly average concentrations of SO_2 and NO_2 in the target district using air diffusion simulation models. The evaluation of the diffusion models (the compliance between measured and calculated values) made based on the criteria of Japan's Environment Agency is rated both in terms of SO_2 and NO_2 at A rank, supporting a finding that the air simulation models adopted in this survey had a satisfactory precision.

When the ambient concentrations of SO_2 and NO_2 in the district were compared with the environmental standards of Thailand, the team found no spot that showed a value in excess of the said environmental standards and that the whole district met the environmental standards in the year of 1988.

As for top eight points with higher yearly average concentrations, a high SO_2 appears near MS 3, and NO_2, near MS 1. The rate of contribution by sources is calculated as follows: in

the case of SO_2, 77.1 to 88.1% by factories; 3.8 to 5.6% by cars; 5.4 to 11.2% by ships; and 0.05 to 8.0% by ferryboats; and in the case of NO_2, 2.9 to 8.5% by factories; 28.7 to 74.5% by cars; 2.4 to 12.3% by ships; and 0.07 to 28.3% by ferryboats; thus showing a large contribution by factories in SO_2, and by cars in NO_2.

In regard to the rate of contribution by factory stack, small sources with a stack height of about 10 m are placed at higher ranks in both SO_2 and NO_2, whereas there is no single emission source which has a contribution as great as tens of percentage.

2) Particulate matters

As the sources of particulate matters, the team targeted sea salt particles, soil and roadway dust, diesel cars, gasoline cars, the iron and steel industry, oil combustion, and the glass industry, and calculated the rate of contribution by these sources using the CMB method. The rates of contribution of natural and artificial sources vary depending on the measured spots and seasons. Among the artificial sources, the highest contribution rate is found in diesel cars (with black smoke in exhaust gas), while those of oil combustion and the iron and steel industry are relatively small with several percent. These contribution rates are found in good agreement with those of similar areas which have been estimated in various countries of the world.

3. Countermeasures for Sources, Effects and Influences on Economy

3.1 Future Atmospheric SO_2 and NO_2 Concentration when No Source Countermeasure is Conducted

Since adverse impact on the environment was forecasted if the 6th economic/social development and the following economic development would be progressed, the atmospheric SO_2 and NO_2 concentrations in future (1992 and 1999) were estimated in the case of the economic development without the execution of any countermeasures for emission source of pollutants. As a result, it was found that the concentration of SO_2 would not exceed the environmental standards for the above years, but that NO_2 would exceed the standard in 1999.

3.2 Improvement of Emission Sources and Consideration of its Effect

As mentioned above, atmospheric SO_2 concentration will not exceed the environment standards. For furnishing Thai Government with useful information to conduct emission control in the future, however, we predicted the atmospheric SO_2 concentration when emission control for factories/plants would be implemented. The reasons why factories became to be target for emission control are as follows:

① Factories take a large contribution rate at high SO_2 concentration points in range of 80–90 percent.

② Problems related to unfair competition may result from an imbalance among factories related to SO_2 emission volume.

We predicted also the atmospheric NO_2 concentration when NO_x emission control for cars is introduced in Thailand in future as cars share most contribution rate of NO_2 at the points where it exceeds the environment standards.

(1) Countermeasures for factories (SO_2 emission controls)

As a result of the discussion with ONEB on which type of controls would be best if SO_2 emission controls were to be introduced for factories in Thailand, we reached the conclusion that the concept of Japan's K-value control should be introduced. From this conclusion, we estimated atmospheric SO_2 concentration if SO_2 emission controls were introduced in 1999. This K-value control is a landing concentration restriction, and can be executed by making stack higher or reducing SO_2 emission volume. From the points of view of economy and feasibility, however, we estimated atmospheric SO_2 concentration on the basis of adopting plans whereby stacks would be made higher. As a concrete K-value, the value of 13 was determined by referring to the K-value set for industrial areas in Japan which are similar to Samut Prakarn district in the SO_2 emission volume per unit area. As a result, if SO_2 emission controls were introduced in Samut Prakarn district, it was found that 49 stacks could not meet the K=13 standard, and that current stack heights of 10 to 15 meters would have to be increased to about 20 meters.

(2) Cars

Because the reason that NO_2 environmental standard will be exceeded in future is mostly occupied by cars (contribution rate: 80 through 90%), the NO_x volume emitted from cars should be reduced to achieve NO_x environmental standard. Thus the introduction of NO_x emission controlled cars was considered and it was made evident that in 1999, the NO_x emission control just like the 1978 controlled car in Japan should be introduced.

(3) Environment air concentration after implementation of countermeasures

Although atmospheric SO_2 concentration will not exceed the environmental standards even if countermeasure will not be taken in the future, we estimated the atmospheric SO_2 concentration based on the assumption that countermeasure (introduction of higher stacks at factories) will be introduced in 1999. As a result, it was clear that the atmospheric SO_2 concentration would be lower than if emission controls were not implemented. If NO_x emission controlled car was introduced in 1999, we found that the atmospheric NO_2 concentration in the Samut Prakarn district would not exceed the environmental standards, even if the current economic/social development plans are carried out.

3.3 Estimate of Cost for the Improvement of Emission Sources

We estimated the actual cost for the implementation of SO_2 emission control for factories. Although the proposed countermeasure to meet emission control value was the method of making stack higher, the costs for energy saving, desulfurization of fuel oil, fuel conversion to natural gas and desulfurization of flue gas were also estimated. Consequently, the cost for the making stack

higher of 49 stacks was estimated to be about 115 million bahts. The costs for energy saving at the 49 stacks, desulfurization of fuel oil (processing volume: 3,500 barrels/day for use by 49 stacks), fuel conversion at the 49 stacks and desulfurization of flue gas at the 49 stacks were estimated to be 160 million, 880 million, 83 million, and 540 million bahts respectively.

3.4 Influences of the Countermeasures on the Economy of Thailand

(1) Influence of making stack higher on the GDP of Thailand

Since the production amount of manufacturing sector in Samut Prakarn district occupies 12% of the overall production amount of manufacturing sector in Thailand, it was assumed that the cost for making stack higher in Thailand was borne at the same rate. Consequently, the slow down of the growth rate of GDP from 1992 to 1999 were estimated at, when calculated on the yearly basis, 0.07% (case A that the measure starts in 1993), 0.05% (case B that the measure starts in 1995) and 0.03% (case C that the meaure starts in 1997). Concerning the reduction of GDP amount in 1999, the case A, B and C indicate the reductions by 12.07 billion bahts (0.42%), 8.63 billion bahts (0.30%) and 5.18 billion bahts (0.18%) toward the case that no making stack higher measure is conducted. From this, it was evident that the measure would make little influence upon the economy of Thailand.

(2) Investment on energy saving in Samut Prakarn district and its effect

The investment on energy saving and its effect were estimated assuming that energy saving would progress at a constant growth rate of 2.81% per year from 1993 to 1999. As a result, the energy saving amount from 1993 to 1999 should be 65,549 kl (fuel oil), and judging by the unit price of fuel oil of 3,960 bahts/kl in 1999, about 260 million bahts could be saved—about 1.6 times the investment amount on energy saving (160 million bahts).

(3) Investment on energy saving in Thailand and its effect

The fuel oil consumption of the plants in Samut Prakarn district requiring countermeasures occupies 16% of the total in the district if SO_2 emission control is introduced. Thus the effect of energy saving when investment on energy saving is conducted by plants corresponding to 16% the fuel oil consumption of manufacturing sector in Thailand was considered. As a result, the energy saving amount of manufacturing sector in Thailand and investment on energy saving were estimated to be 314,000 kl and 546 million bahts respectively. In addition, those of the overall industries in Thailand were estimated to be 666,000 kl and 998 million bahts respectively. Considering the difference between the consumptions before and after the energy saving measure, the effect of energy saving of manufacturing sector in 1999 was estimated to be 1.2 billion bahts and that of the overall industries was estimated to be 2.6 billion bahts.

(4) Influence of energy saving on the GDP in Thailand

The influences of the investment on energy saving by executing energy saving meaure and

export of surplus energy on the GDP in Thailand was investigated. Consequently, it was estimated that, if only the manufacturing sector invested on energy saving, the GDP would increase by 1 billion bahts and in the case of the entire industries, it would increase by 2 billion bahts. Namely, it is considered that the GDP of Thailand increases by conducting energy saving measures and converting surplus energy to export.

4. Legal and Administrative Framework for Future Environment Control in Thailand

Although the atmospheric SO_2 concentration in the Samut Prakarn district does not currently (1988) exceed the environmental standards, and it will not exceed the standards in the future (1992 and 1999), there is some anxiety about the effects on the environment if economic and social development plans, including and after the sixth economic/social development plan, are implemented. Furthermore, Thailand does not currently have any SO_2 emission control for factories, and it is believed that the problem of fairness will be developed because of the imbalance in SO_2 emissions among factories. Because of these factors, it is felt that SO_2 emission control for factories will be necessary in the future. With regard to the atmospheric NO_2 concentration, the estimates show that it will exceed the environmental standards in the future (1999), so that countermeasures for emission sources are necessary. We, therefore, summarized the environment control and pollution regulation system desired from the administrative viewpoint to make the countermeasures to be executed by the Thai Government feasible.

First, we analyzed the current legal and administrative framework for the pollution control in Thailand so that we could propose the recommendations to improve some constrains existing in it. Second, we introduced the legal system related to the air pollution control in Japan and concepts of environmental standards and emission standards in foreign countries for the Thai Government to refer to executing environment control administration. Further, we proposed the desirable surveillance system and monitoring methdos from the technical viewpoint to observe environment air quality and emission sources. Our recommendation on the improvement of legal and administrative framework related to pollution control in Thailand are as follows.

(1) In Thailand the basic policy of the environmental preservation is determined by the National Environment Board (NEB) based on the Improvement and Conservation of National Environmental Quality Act (ICNEQA) and implemented by the Office of the National Environment Board (ONEB). In this respect, the unification of the environmental administration has been established and the implementation of the consistent policy has been possible, like that in other countries. We, however, recommend the following revisions must be made in ICNEQA to strengthen ONEB's power.

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. Namely, 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. Further, 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.

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. That is, it is necessary to clarify the environmental standard serving as the core of environmental quality control and stipulate the responsibilities of national and local governments of Thailand to always supervise the environmental quality.

(2) Although the basic laws for fulfilling the environmental administration in Thailand is established, the laws to execute air pollution control have not been arranged yet. Namely, concrete matters, who shall control according to what law and standards, have not been specified. Thus, to aim at effective air pollution prevention, it is considered necessary to establish an air pollution control law and arrange the following items legally.

① To clarify the scope of the substances and facilities (depending on scale of facility and substance emitted) to be regulated

② To clarify regulation method (by an emission facility and emission standard for each substance)

③ To clarify the responsibility of emission sources (responsibility of measuring pollutant, etc.)

(3) 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, however, 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.

5. Prospect of Short- and Long-Term Strategy for Environment Air Quality Management Planning

Although the atmospheric SO_2 and NO_2 concentration in the Samut Prakarn district of Thailand meet the environmental standards of Thailand at the present time (1988), it was found that the atmospheric NO_2 concentration would exceed the standards at 31 mesh points in 1999 if the economic and social development plans of the Thai Government are carried out. If, however, countermeasures are taken to reduce emissions from cars, such as the introduction of NO_x emission controlled car, we found that it would be possible to maintain the levels of NO_2 so that it meet the environmental standards even in the future.

Even though the atmospheric SO_2 concentration will not exceed the environmental standards in the future (1992 and 1999), the contribution rate of stationary emission sources is high at 80 to 90 percent and there is no existing SO_2 emission controls for factories at the present, so that on apprehension about the effects of SO_2 on the environment is predicted if economic and social development plans are continued from and after the sixth economic/social development plan. Therefore, it is believed that establishment of SO_2 emission control will be necessary in the future (1999 or after). We discussed the best control methods to be taken with ONEB if SO_2 emission controls for factories were implemented in the future. As a result, ONEB agreed that, if Thailand should adopt SO_2 emission controls in the future, the concept of K-value regulation used being adopted in Japan should be introduced in Thailand. As a concrete K-value, the value of 13 was determined by referring to the K-value set for industrial areas in Japan which are similar to Samut Prakarn district in the SO_2 emission volume per unit area. As a result, if SO_2 emission controls were introduced in Samut Prakarn district, it was found that 49 stacks could not meet the K=13 standard, and that current stack heights of 10 to 15 meters would have to be increased to about 20 meters. As a result of estimating the atmospheric SO_2 concentration in the Samut Prakarn district in 1999 on the basis of this improvement plan, it was found that the environment would be improved comparing with the case that no SO_2 emission control would be introduced.

Whether the concentration of total suspended particulate satisfies the environmental standard is not clear because the measuring method used in this study is different from the standard measuring method used for the evaluation of environment in Thailand. As a result of the calculation of the contribution rates of such sources as sea salt, soil, road dust, diesel vehicles, gasoline vehicles, iron works, oil burning and glass industry as the sources of pollutant by using the Chemical Mass Balance Method (CMB), however, it was demonstrated that the contribution rates of natural and artificial generation sources share about half each, and any countermeasure for artificial generation sources would not have enough effect.

As for the costs of the countermeasures for stationary emission sources to meet emission standard value, it was estimated that the application of making stack higher costs about 115 million bahts and desulfurization of fuel oil costs 880 million bahts, and if making stack higher are applied all over Thailand at the same scale of Samut Prakarn, the economy of Thailand is affected little so that the reduction of GDP is 0.42 through 0.18%. If SO_2 emission control was to be implemented, 49 stacks which can not meet the environment standards come into view. The investment volume was estimated to be 160 million bahts in case that such 49 stacks requiring countermeasures adopt an energy saving measure, it was made clear, however, that about 260 million bahts could be saved by

implementing energy saving at the investment rate of 2.81% from 1993 to 1999. Further, the effects of energy saving when such a scale energy saving are spread all over Thailand was estimated to total 2.6 billion bahts for all industries and by making the effective use of surplus energy saved by energy saving, the GDP of Thailand will increase by about 2 billion bahts.

To grasp the current legal and administrative framework related to the pollution control in Thailand, we collected the concerned laws and interviewed with the officials of the governmental agencies concerned. As a result of our study based on the collected information, we found out that the legal system for executing air pollution control was currently incomplete though the basic laws for fulfilling environmental administration were established.

From what are mentioned above, we propose the following short- and long-term strategies for the environment air quality management planning in Thailand.

5.1 Prospect of Short-Term Strategy (objective for 1992)

(1) Establishing Technical Methods for Surveillance System for Emission Sources

In 1992, atmospheric concentraiton levels of SO_2 or NO_2 will not exceed the environmental standards of Thailand at any point, however, it goes without saying that surveillance of emission sources is importrant for the development of an environmental air quality management plan. In this study, 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 422 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.

In Japan, the responsible party for the emission of soot and smoke is obliged to measure the exhaust gas volume or emission concentration. Furthermore, from 1978 on, questionnaires have been sent by the Environmenta 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 corresctive actions.

It is our belief, therefore, that surverllance of emission sources is important to: Smoothly execute management of the environment; estimate air pollutant emission volume increases with progress of economic geowth; estimate air pollutants volume when emission control is to be established in the future; and estimate air pollutant volume in areas other than the Samut Prakarn district. The

actual measurement of concentrations for surveillance for emission sources should not be performed by administrative organ such as ONEB but as described later, related legal framework should be arranged so that the responsibility for measurement is placed on factories, the actual measurement is performed by private parties (entrusted measuring companies with), and ONEB collects and manages measuring data.

As prospect of short-term strategy, first, ONEB should acquire the technical method (described in details in Part VIII, Chapter 3) to measure the concentration and volume of air pollutant exhausted from factories and next, raise private measuring companies to transfer its technical know-how. In addition, it is absolutely necessary to grasp the air pollutant emission volume of other areas than Samut Prakarn district in studies by questionnaries like performed this time. The questionnaire form and check method for the questionnaires have been already shown as reference. Because questionnaires are means to grasp air pollutant emission volume accurately, it is necessary to collect as many data as possible about the items mentioned below.

[Factory name]
[Address]
[Division/section and name of the person responsible for data]
[Telephone number]
[Content of operation]

A. Outline of factory

① Location of factory (marked on attached map)
② Factory illustration (indicating stack positions and Nos., height, and length and width of buildings higher than 5 m) (map scale larger than 1/5000)
③ Area (m^2)
④ Operation start time (expected)
⑤ Major product items and yearly production amount
   a. Present
   b. Future
⑥ Capacity and operating years of major production equipment
   a. Present
   b. Future
⑦ Type and yearly consumption of fuel
   a. Present
   b. Future

B. Related to soot and smoke

① Capacity of facility generating soot and smoke (rated, maximum)
② Consumption of raw fuel by facility (currently)
③ Details of each facility
   a. Type, capacity and scale of facility (for boilers, heat conducting area, etc.)
   b. Type, consumption, heat amount and sulfur contents of raw fuel

c. Daily generations of SO_2 and NO_x (rated, maximum/usual volume)
d. Soot and smoke treatment facility (type, name, treatment capacity)
e. Stack specification (No., height, shape, bore, etc.)
f. Emission volume of soot and smoke per hour (rated, maximum and usual volumes of emission gas, SO_2 and NO_x)
g. Emission gas temperature
h. Emisssion gas exhaust speed
i. Daily operation condition (operation start/shutdown times)
j. Yearly operating hours

(2) Monitoring System of Environmental Air Concentration

What is important for fulfilling the environment air quality management is to grasp atmospheric pollutant concentration levels as well as to obtain emission volume of pollutant at target areas accurately. Although we think that the investigation in Samut Prakarn district this time has satisfied this requirement, it is necessary to continue monitoring air quality in future, in order to grasp the change of air pollutants concentration with a passage of time. In addition, to proceed with the environment air quality management of Thailand, it is necessary to grasp the air pollutants concentration of other places than Samut Prakarn district. Upon determining the location of measuring stations, the following matters must be considered as mentioned in details in Part VIII, Chapter 3.

① The site where the pollutant concentration is highest.
② The most densely populated area, especially such one where the pollutant concentration is also high.
③ The area which borders the neighbouring county and makes it possible to quantify the pollutants coming into the area from the neighbouring province.
④ The site where the significant impact of future development is expected.
⑤ The site where the effectiveness of air pollution control measures can be evaluated with less difficulty.
⑥ The site where the obtained data represent the general status of air pollution in the area.

Because data collected by measuring stations are used for administrative measures, they are required to be highly accurate. Thus it is important to control and maintain measuring instruments completely. For this purpose, it is necessary to establish the maintenance/control system as mentioned below to secure the standardization of measurement. The items and contents of the maintenance and control are shown in Table 5.

1) Technical Staff

The maintenance of measuring instruments requires the assignment of appropriate personnel in compliance with the contents of maintenance work. In the present survey in the Samut Prakarn district, the highly qualified technical staff of ONEB carried out the daily inspection of measuring instruments, calibration, and parts replacement in a collective manner. In the future, however, it will be necessary to assign appropriate personnel depending

upon the contents of maintenance work and thus to perform the maintenance of measuring instruments. This will require that management ensure and foster capable personnel for monitoring of the environment. The standard number of the personnels for maintenance and control of measuring stations is a person per 20 stations.

2) Entrusted Maintenance and Supervision

As long as ONEB can ensure a sufficient number of technical experts, the permanent monitoring operations for air pollution are preferably under their independent management. If it is difficult to ensure and foster such technical specialists, there is a way of entrusting the operations to private organizations. In this case, it will become necessary to provide the private contractors with education and training related to the maintenance of measuring instruments and thus upgrade their technical capabilities.

The entrusted maintenance is an unavoidable measure to cope with the shortage of personnel, but it may sometimes involve a risk of causing a decline in the accuracy of measured values. Taking this into account, therefore, it is necessary to pay attention to the following three points: ① not to entrust the operations which have a decisive impact on the precision of measurement; ② to determine the technical level of each contractor and not to entrust the work in excess of the contractor's capacity of fulfilling the order; and ③ to create a system for staff's supervision and checking of the entrusted jobs in order to minimize the risk that could be caused by the entrusted maintenance.

Table 5 Types and Contents of Maintenance

Classification of maintenance	Purpose	Executing agency	Frequency of execution	Contents
Ordinary inspection (patrol maintenance)	To allow automatic measuring instruments to run normally and continuously (acquisition of data)	ONEB and private contractors as its subsidiary agencies	Once/week or more often	1. to confirm the operating status of each measuring instrument 2. to replace and replenish supplies 3. to perform simple calibration and checking 4. to clean and replace simple components
Periodic inspection	To maintain the performance of instruments and carry out preventive maintenance against troubles (to assure the precision within the standard range)	ONEB and manufacturers of measuring instruments	Once/year or more often	1. to test passage regions 2. to test detection regions 3. to test control and transmission systems 4. to test amplification and recording regions
Emergency inspection	To perform prompt and emergency inspection upon outbreak of an abnormality or accident (return to a normal state)	ONEB and private contractors as its subsidiary agencies	Upon outbreak of an abnormality	1. to discover troubles and make minor repairs 2. to clarify the causes completely and ensure repairs (by the manufacturer)
Initial examination	To preserve continuity in maintenance or data appraisal and to prevent troubles (to determine the properties of instruments)	ONEB	When instruments are purchased (including remodeling, replacement, and renewal), for one month	1. to test the performance of instruments (including the check of standard gas meters and equivalent solutions) 2. to test the stability of instruments (including flow changes, zero and span drifts) 3. to assess measured data (such as matching with old measuring instruments)
Dynamic verification	To determine the substance of a precision range	ONEB and verifying agencies	from time to time	1. to check by using a standard gas 2. to prepare analytical lines

5.2 Prospect of Long-Term Strategy (objective for 1999)

(1) Achievement of Environmental Standard

According to our estimation, atmospheric NO_2 concentration will exceed the environmental standards of Thailand at many points in 1999. To solve this problem, it is necessary to set the NO_x emission control corresponding to the 1978 controlled car in Japan. For this purpose, revision of the concerned laws as mentioned later will be required. As a method to achieve the environmental standard, the introduction of NO_x controlled car is a direct method. The methods mentioned below, however, need to be considered as administrative measures in future.

① Construction of railroad and subway
② Traffic control of individual owned cars depending on use purpose
③ Traffic control of one-person riding car
④ Smoothing of traffic flow by applying two-level crossings, widening road width and arranging roads.
⑤ Arrangement of bypass system
⑥ Preventing emission gas from being worse by appropriate car driving —— preventing an over load
⑦ Smoothing of traffic flow by improving and reviewing traffic control system (improvement and review of signal distance and signal control system)
⑧ Smoothing of traffic flow by setting one-way traffic area

(2) Necessity for revision of the Thai environmental standards

Our study reached to the conclusion that the atmospheric SO_2 and NO_2 concentration in the Samut Prakarn industrial district meet the Thai environmental stnadards at the present time (1988). It is evident, however, that the Thai environmental standards are lenient in comparison with those of other nations explained in section 1.2.5 of Part III; for example, current atmospheric SO_2 concentration exceeded Japan and the United States' environmental standards, and the NO_2 concentration exceeded Japan's standards. Since environmental standards are an administrative goal to preserve human health and natural environment, we consider Thai government has to make an effort to carry forward the revision work on its environmental standard level, taking account of social and economic development.

To carry forward revision of the Thai environmental standards, the atmospheric concentration throughout Thailand must be monitored continuously and an adverse influlence on human body, animals and plants, and property must be studied by using methods of toxicology, epidemiology, clinical study and other scientific means as well as administrative and economical feasibility is examined.

As per the above, revision work for environmental standards requires vital efforts and time. We expect, however, Thai government will commence the revision work in near future on the basis of the said aim since the National Policies and Measures on Environmental Development proposed by NEB in 1981 has already stated that the standing laws related to the environmental quality

preservation must be reviewed with social and economic development.

(3) Execution of SO_2 Emission Control for Factories

Although the environmental standard will probably be maintainable in the Samut Prakarn district in future (by 1999), there is a fear that the environment may be affected badly by air pollutant, with the progress of economic and social developments after the 6th economic and social development project. Currently in Thailand, no SO_2 emission control is executed for factories and, if no countermeasure is taken, a problem will occur in fairness due to unbalanced charges of expenses for installing pollution preventing equipment among factories related to SO_2 emission. For the reason, it will be necessary to restrict SO_2 emission for factories in future. As a concrete restriction method is described in Chapter 4 of PART VI, "Remedical Efforts against Emission Source Improvements and their Effects", the K-value regulation executed in Japan is estimated to be appropriate and, as a concrete K-value, the value of 13 is considered to be optimum from the viewpoint of feasibility. In a conclusion, 49 stacks have to be improved when the K-value (=13) regulation is applied.

Because the K-value regulation method is to restrict the concentration on the ground, and to satisfy a specified K-value, either making stack higher or reducing SO_2 emission volume can be selected, we proposed the way of making stack higher for the Samut Prakarn district this time, considering economic efficiency and feasibility. What must be noted here is that although heightening of stacks seems to widen pollution area, if emission gas volume is the same, the ground concentration of pollutant exhausted from a high stack is always lower than that of pollutant exhausted from a low stack under the same diffusion condition and the pollution distance under the lee is the same. Because the reduction of absolute SO_2 emission volume has been internationally demanded from the viewpoint of eliminating environmental pollutions in global points such as acid rain providing damage across countries, however, administrative measures for reducing SO_2 emission volume will be required, in future.

The concrete methods for reducing SO_2 emission volume are heavy oil desulfurization, conversion of fuel to natural gas, flue-gas desulfurization and energy saving. The costs for taking countermeasures against emission sources including making stack higher are estimated as follows: 115 million bahts for making stack higher (for 49 stacks), 880 million bahts for heavy oil desulfurization (3,500-barrel processing amount per day used for 49 stacks), 83 million bahts for conversion of fuel (for 49 stacks), 540 million bahts for flue-gas desulfurization (for 49 stacks) and 160 million bahts for energy saving (for 49 stacks). Although these investments are not inexpensive, the influence on Thailand's GDP is small. Therefore, it is necessary to execute countermeasures against emission sources from the long-term prospect.

(4) Intensification and Expansion of Legal and Administrative Framework Related to Environment

In Thailand the basic policy of the environmental preservation is determined by NEB (National Environment Boad) based on ICNEQA (Improvement and Conservation of National Environment

Quality Act) and implemented by ONEB (Office of the National Environment Boad). In this respect, the unification of the environmental administration has been established and the implementation of the consistent policy has been possible, like that in other countries. In the stage of the executing air pollution control, however, the main administrative organ related to the control for stationary sources is the Ministry of Industry which makes FAC (Factory Act) the basic law while the Department of Land Transport and the Department of Police are responsible for the motor vehicle exhaust gas control. In addition, FAC itself is not the law aiming at the prevention of industrial pollution but is the control law related to establishment of a factory.

From the observation of the present state of the legal system and the administrative organization in the measures for air pollution in Thailand, the following constraints can be pointed out:

1) The acts to enforce the air pollution control or the existent codes have not been adjusted. ICNEQA prescribes the establishment of NEB, policy planning by NEB, establishment of the environmental standards by the Prime Minister, recommendation of the establishment of the emission standards to the government agencies concerned, prior examination of development projects by ONEB, etc. so that ONEB can determine and implement the framework of the environment preservation administration. It, however, does not have the provisions as to enforcement of control: ① how, ② by whom, and ③ based on which standards an industrial emission source should be controlled.

   In FAC it is prescribed that the examination of the application for approval of establishment and the operation of a factory should be made based on the smoke blackness degree and ONEB environmental standards (guideline) as one factor of the examination condition, but its effectiveness seems slight because the air pollution control is not the main part of this Act.

   The Land Transport Act has the constraint that the regulation on car exhaust gas restriction is not specifiecd in the relation with ICNEQA.

2) Because the execution acts for the air pollution control have not been adjusted, the following points are not clear:

   ① Control objective substances as the scope of control

   The following are shown in the environmental standards as a guideline according to ONEB notification but this does not have the legal ground:

   CO, NO_2, SO_2, TSP, Photochemical oxidant, Pb

   ② Emission facilities as the scope of control

   To make the objects of the administrative control clear, it is necessary to define emission facilities based on the kind, emission volume and concentration.

   ③ Control objective persons—control objective emission sources

   The emission sources which emit the substances of 1) from their facilities in 2) are not defined. Consequently, the persons to be controlled became many and unspecific, and the data collection on emission sources has not been achieved, thus the effective admin-

istration has not been implemented. It is necessary to make clear the scope of the control objective persons also in the meaning to expect the emission sources to take an autonomous attitude toward the environmental quality preservation.

④ Control measures

It is an absolutely necessary condition as measures for controlling an industrial emission source to set up the obligation to the establishment of emission disposal facilities and the emission standards (concentration or volume) for every control objective substance and emission facilities. In addition, it is also necessary to designate a control objective area if consideration is made from the viewpoint of more effective administration.

⑤ Data collection system for emission sources

For implementing the air environmental control, it is necessary for the administration side to collect the detailed data of each emission source. They are, if shown concretely, as follows:

① Name and address of factory

② Kind and structure of emission facility (details of capacity such as burning capacity and heating area)

③ Way of use of emission facilities (details of operating condition, kind and volume of fuel used, etc.)

④ Smoke treatment method, etc.

These are required to be sufficiently useful for the judgement of the planning and execution of policies on the administrative side.

3) The control of the environmental quality can be performed in the linkage in which the administrative purpose (environmental standards as an objective or index) is set up, in which measures such as emission control are used to attain the purpose and in which these control measures are constantly checked if they are effectively carried out. In other words, the permanent monitoring of the environmental quality enables the mutual check between the administrative purpose and the administrative measures. However, there are no prescriptions in ICNEQA for the obligation to permanently monitor the environmental quality on the administrative side.

4) ICNEQA prescribes that the prime minister has the power to establish the environmental quality standards and the measuring methods in Section 17 and says in Section 25 that "whoever violates it shall be liable to imprisonment for a term of not exceeding one month or to a fine of not more than 1,000 baht or both". In other words, the environmental quality standards in this provision are judged not to be the concept of the objective or index for carrying out the administrative measures but to be the concept of the control standards. It is considered that application of a penalty is practically difficult because it is usually difficult to specify the violator for the environmental standards and that Section 17 (2) lacks appropriateness from the viewpoint of a legal theory because the setting up of the control stand-

ards are prescribed in Section 5 (6). Basically, it is a problem that the prescription of the environmental quality standards which are to be the core of the environmental quality control has not been adjusted.

5) As discussed in the Part VI, the contribution rate of motor vehicle exhaust gas reached 80% to 90% of NO_2 concentration at the point where the environmental standard of NO_2 is exceeded in Samut Prakarn industrial district. Thus, to reduce the concentration of NO_x, the restriction of motor vehicle exhaust gas is important, however, the current motor vehicle exhaust gas restriction in Thailand has the following constraint to be improved:
   ① The substances objective for restriction are only black smoke and CO, but NO_x is not regarded as the objective.
   ② The vehicle types under the control by Land Transport Department are limited to buses and trucks, but the ordinary passenger vehicles are excluded.

6) The repletion of the staff on the administrative side to implement the environmental control is not enough. ONEB is a system with a sufficient organization and staff to perform the promotion of the environmental administration in Thailand. Moreover, in the DIW (Department of Industrial Work) of the Ministry of Industry, the Industrial Environmental Division and the Air Pollution Control Section are also established.
   However, it cannot be expected for these staff of the central government agencies to execute the environmental control administration including the collection of the emission source data and the smooth promotion of the control measures covering 72 Changwats in the whole country of Thailand. Further, even in Samut Prakarn Province which is the greatest industrial province in Thailand, since there is no specialized environment division or department although the Provincial Industrial Office exists, it is impossible to execute the environmental administration in close contact with a region. In addition, the technical staff carrying out the permanent monitoring of the environmental quality is very deficient.

It is necessary to improve some points 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 environmen-

tal 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 those points indicated we 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 as a core of environment administration in Thailand.

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, which are a prior notification system of smoke and soot emitting facilities, a plan modification order and improvement order on structure of such facilities.

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.

i) 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. To put it in the concrete:

(i) For stationary emission sources—Conbusion facilities exceeding 10 ℓ/h of fuel consumption in heavy oil conversion, 160 Nm^3/h of emission gas volume and 0.1

Nm^3/h of SO_2 emission volume.

(ii) For mobile emission sources—Motor vehicles including tricycle cars but excluding two-wheeled vehicles.

ii) Clarify the regulation methods.

① Setting the emission standards: Separate the emission standards of a stationary 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

We suggest that K value control must be adopted to reduce SO_2 ambient concentration as stationary emission control, and that reasonable K value to be applied is K=13. As for motor vehicle, we also suggest that nitrogen oxides and hydrocarbon must be added to the list of the regulated substances, and consider that appropriate regulated-value of those are the 1978 value explained in Section 3.8 of Part VIII.

iii) 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

iv) 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

v) 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. The followings are the plans for improvement of

the administrative organization and for trainnings of technical staffs:

i) Improvement of the administrative organization ONEB has an administrative office and four (4) divisions which consist of five (5) to seven (7) sections respectively. The administrative function of each division is as follows:

Information and Environmental Quality Promotion Division

① Public relations related to the whole ONEB

② Implementation of education, enlightenment and training on environment

③ Cooperation with foreign governments and institutes, and various international organizations

Environmental Policy and Planning Division

① Determination of long and short term environment improvement plans and determination of various policy drafts and of their implementation methods

② Surveillance of activities of government agencies, government enterprises and private sector, related to environmental quality

Environmental Impact Evaluation Division

① Examination and evaluation of Environmental Impact Assessment (EIA) on development projects

② Investigation and study for determining plans for overall environmental preservation of specially designated areas (Chao Phraya river basin, etc.)

Environmental Quality Standard Division

① Monitoring of environmental quality and collection of data

② Study of environmental standards and other environmental-quality-related standards, and representation of opinion on them

③ Investigation and examination on pollution problems

After improving ICNEQA and establishing Air Pollution Control Law, we suggest that ONEB has to strengthen, expand and re-construct the divisions to manage air pollution control in conformity those laws.

We consider that Environmental Quality Standard Division has to have sections related to air quality control as shown in Fig. 3. We also hope that ONEB will try to transfer its administrative power to local-self governments with advances of improvement of their environment administrative structures.

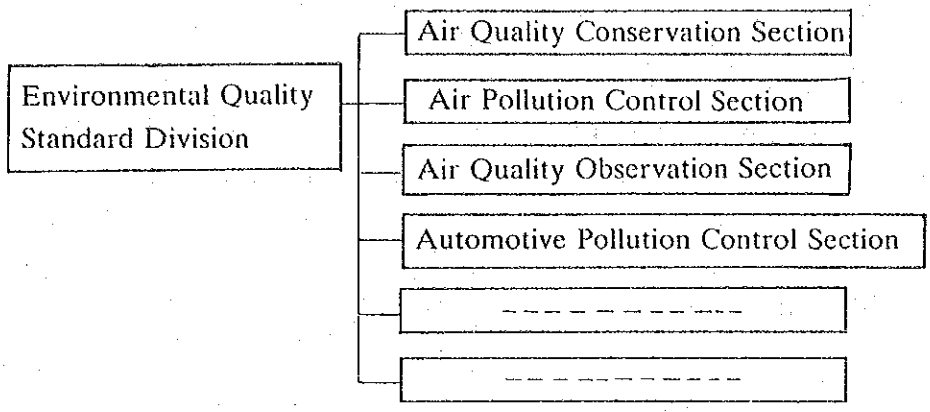

Figure 3 The Desirable Structure of Environmental Quality Standard Division, ONEB

The administrative function of each section is as follows. The figrues indicated in parentheses are desirable numbers of staffs to be arranged.

Air Quality Conservation Section (20): Establishment of conprehensive plans for air pollution control and management of relationship with local-self-government on air pollution

Air Pollution Control: Section (30): Drawing up air pollution control plan, examination of documents submitted from factories based on related regulation, instruction and ordinance against emission sources.

Air Quality Observation: Section (30): Executive of permanent observation on air quality, announcement of air quality to the public, management and collection of data/record related to emission sources.

Automotive Pollution: Control Section (20): Drawing up plans for automotive pollution (air and noise) and management on co-ordination with related government agencies.

ii) Improvement and Expansion of the Administrative Organization

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 Chululongkorn 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.

(5) Execution of Countermeasures for Energy Saving

Because energy saving not only saves and makes the effective use of energy but also provides effects on the environmental aspects (reduction of SO_2 and NO_x emission volume), it is necessary to stand on a long-term perspective upon the execution of this countermeasure. The energy saving plan in a concrete form is shown in Table 6.

Table 6 Outlines of Energy Usage Rationalization Criteria Used by Managers Involved with Factories

	(1) Rationalization of the combustion of fuel	(2) Rationalization of heating, cooling and thermal transfer	(3) Prevention of thermal loss through radiation, conduction, etc.	(4) Recovery and usage of waste heat.	(5) Rationalization of conversion of heat to power, etc.	(6) Prevention of loss of electricity through resistance, etc.	(7) Rationalization of conversion of electricity to power, heat, etc.
Establishment of standards for improvement of control standards.	Control standards for air ratios	Standards for the temperatures of heated and cooled items, standards for the temperatures, pressures, flow rates, etc. of thermal media, and standards for the temperature and humidity of air conditioning.	Standards for insulation construction.	Standards for the recovery and utilization of waste heat	Standards for the adjustment of loads between multiple boilers and turbines, and standards for the minimum tolerated pressure in exhaust and back pressure turbines.	Control standards for the voltages, currents, power factors, load factors and demand factors of substations and distribution equipment.	Standards for voltages, currents, power factors and demand factors related to electric power application, electrical heating, illumination equipment, etc.
Implementation of instrumentation, records, etc.	Instrumentation and records, etc. for fuel supply quantities, exhaust gas temperatures, residual oxygen quantities in exhaust gases, etc.	Instrumentation and records, etc. for gaining an understanding of thermal movement through temperatures, pressures, flow rates, etc., and instrumentation and records, etc. for the temperature and humidity of air conditioning.	Implementation of thermal account analyses.	Instrumentation and records, etc. for items related to understanding the status of waste heat, and investigation of effective methods for utilizing waste heat.	Instrumentation and records for the thermal efficiency of main boilers and turbines. Instrumentation and records for operation under minimum tolerated pressure.	Instrumentation and records for the values above.	Instrumentation and records for the values above. (Including the intensity of illumination.)
Implementation of maintenance and inspection.	Maintenance and inspection of combustion facilities.	Prevention of decreases in thermal conductivity performance, water quality control for boiler water, and maintenance and inspection of air conditioning facilities.	Prevention of leaking from damage in heat transfer media, maintenance of insulation sections, and maintenance and inspection of steam traps.	Removal of grime from the thermal transfer surfaces of waste heat recovery equipment, prevention of leaking of heat transfer media from equipment, etc.	Maintenance and inspection of boilers and turbines, maintenance and inspection of turbine blades, etc. during operation under minimum tolerance pressure.	Maintenance and inspection of substations and power distribution facilities.	Reduction of mechanical loss such as friction, prevention of fluid leaks in machines which handle fluids, and maintenance and inspection for other thermoelectric, electrolysis, and illumination facilities.
Improvement measures and equipment introduced for rationalization.	Adjustment of combustion loads, selection of appropriate burners, improvements in ventilation devices, installation of combustion control devices, and installation of heat accumulators.	Reviews of heat usage conditions and supply conditions, improvements in heat patterns, adjustment of loads, improvements in direct heating, multiple stage use of heat, introduction of equipment which have high thermal efficiency, introduction of continuous and combined processes, and the shortening and removal of processes.	Improvements in insulation, reducing the size of openings, installation of covering facilities for open type equipment, rationalization of piping routes, etc.	Preventing decreases in temperatures of waste heat during transfer processes, improvements in the heat transfer aspects of waste heat recovery devices, installation of recovery and utilization equipment to meet the uses of waste heat.	Modifications to turbines to reduce the minimum tolerance pressure. Utilization of usable surplus steam for power generation and sources of energy for work.	Improvements in power factors, such as the operation of transformers at appropriate loads, using transformers with the appropriate capacities, levelling of loads, and appropriate allocation of substation equipment, and improvements in three phase unbalance.	Preventing motors from running free, appropriate allocation of loads, and implementation of speed controls, etc. Installation of motors with the appropriate capacities, etc. Other improvements in equipment and the introduction of other equipment.