8.4 Air Quality Target Value

The dispersion model predicts annual mean values of pollutant concentrations in the Study. To evaluate the simulation results, certain criteria of annual values have to be defined. Besides, it is reasonable to evaluate ambient air quality and control air pollution sources based on long-term values. However, most of the Malaysian air quality guidelines are set for hourly values, eight-hour values and daily values (ten-minutes value, hourly value, and daily value for SO_2, hourly value for NO_2, and hourly and eight-hour value for CO, etc.). The annual mean targets of ambient air quality have to correspond to each of the Malaysian guidelines. These targets are called Air Quality Target Values. The Air Quality Target Values may be a guarantee for the observance of the guideline values.

In the Study, basically, the Air Quality Target Values were determined according to the empirical rule used by the United States Environmental Protection Agency (EPA) and Japan Environment Agency (JEA), that sets annual mean value at half the daily mean. Since the monitoring was conducted at only five stations for a year and insufficient to establish the Air Quality Target Values. Accumulation of the monitoring data for several years at more stations is required for the purpose. Then, the analysis of the monitored data in Kelang Valley Region was carried out to support the justification for adopting this rule.

A certain amount of error is inevitable in measurement of ambient air quality. Therefore some statistical values are adopted for the long-term evaluation. In this examination, 98 percentile values are adopted for the long-term evaluation.

8.4.1 Method for Estimating Air Quality Target Value

(1) SO_2, NO_2, and CO

Hourly values in the guidelines are inadequate for estimating the Air Quality Target Value. Because the measured hourly values that are used for evaluation may include unusual pollution sources and malfunctions of measurement equipment. The Malaysian guideline for SO_2 daily mean is 40 ppb and the Malaysian guideline for eight-hour mean of CO is 9 ppm. They were used for the estimation of the Air Quality Target Values. The case of the Japanese standard for CO daily mean value (10 ppm), was also examined for comparison. Since the Malaysian guideline of NO_2 is only defined for hourly value. Hence, the WHO guideline value for NO_2 daily mean (73 ppb) was used for the estimation.

The following three methods were examined to estimate the air quality target values. Schematic diagram of three methods is illustrated in Fig. 8.4.1.

1. Larsen Model and Linear Regression
   The air quality target values for each station are first obtained by the Larsen Model. At the same time, occurrence frequencies of the guideline values at each station are also obtained. Then the occurrence frequencies of the guideline values and the annual mean values at each station are plotted on lognormal coordinates to obtain the linear regression line. Finally, the air quality target value for the target area is determined from the corresponding annual mean at 98 percentile value on the regression line.

2. Larsen Model and Geometric Mean
   The procedure to obtain the air quality target values for each station are the same as in method 1. Then the air quality target value for the target area is determined as the geometric mean of the air quality target values of each station.

3. Linear Regression between Annual Mean Value and 98 Percentile Values
   A linear regression line is constructed between the annual mean values and 98 percentile values for each station. Then the air quality target value for the target area is determined.

(Larsen Model, Linear Regression, and Geometric Mean)

Generally, cumulative frequencies of pollutant concentrations are found to have a lognormal distribution. The Larsen Model is based on this characteristic and the relationships among the statistical values of the distribution. The process of method 1 for SO_2 daily value is illustrated in Fig. 8.4.2 and the similar figures for NO_2 and CO are shown in Section 5.1 of the Supporting Report. Some papers on the Larsen Model are listed in the Supporting Report (#3036, #3037, #3038).

In the case of the lognormal distribution, geometric standard deviation (Sg) is computed from the following equation. The index Sg can express the variability of each distribution.

$$Sg = \exp\{ln\ (Ca/Cb)/(Za-Zb)\} \qquad (1)$$

Ca, Cb: Concentrations at point (a) and point (b)

Za, Zb: Standard deviation numbers of concentrations at point (a) and point (b)

In this calculation, a standard deviation number of 50 percentile is taken as Za and a standard deviation number of 93.3 percentile is taken as Zb.

The geometric standard deviations are obtained for each station from equation (1). The linear regression line expressed by a solid line in Fig. 8.4.2 (1) is determined from the points (a) and (b) at each station. The cumulative distributions of the pollutants can be approximated by the straight line for at least from the 50 percent point to 93.3 percent point.

The relationship between the geometric mean (mg) and the guideline value as 98 percentile value (C98) is expressed by the equation (2).

For example, the guideline value for SO_2 daily mean is 40 ppb and 98 percentile value of monitoring daily mean should be below this guideline. Geometric mean (mg) to maintain this condition is determined by equation (2). In other words, the original regression line (solid line) should be shifted to the new line, which can satisfy the guideline (chain line), and geometric mean (mg) is obtained on this new line.

$$mg = C98/Sg^{Z98} \qquad (2)$$

C98: The guideline value as 98 percentile value

Z98: The standard deviation number of the 98 percentile

Moreover, the arithmetic mean (m), geometric mean (mg) and geometric standard deviation (Sg) satisfy the equation (3).

Arithmetic mean (m) to maintain the guideline is obtained with the geometric deviation (Sg) in equation (1) and the geometric mean (mg) in (2). This arithmetic mean (m) is used as the air quality target value at each station (Table 8.4.1).

$$m = mg \exp\{0.5\ ln^2 Sg\} \qquad (3)$$

To obtain the air quality target value for the target area by method 1, actual standard deviation numbers (Z) of the guideline value (C98) and annual means measured at each station are plotted on lognormal coordinates, and a linear regression line is obtained (Fig. 8.4.2(2)).

The regression line express the relationship between the annual mean values and the occurrence frequencies of the guideline value in the target area. Dashed line intercepts 98 % value with the air quality target value (27.5 ppb for SO_2).

By method 2, the air quality target values for the target area are obtained as geometric means of the air quality target values at each station (Table 8.4.1).

(Linear Regression between Annual Mean Value and 98 Percentile Value)

Linear regression lines are obtained between the annual mean values and the 98 percentile values at each station. Then the air quality target value for the target area is determined as the corresponding annual mean to the guideline value on the regression line (Fig. 8.4.3). Dashed lines intercept the guidelines with the air quality target values.

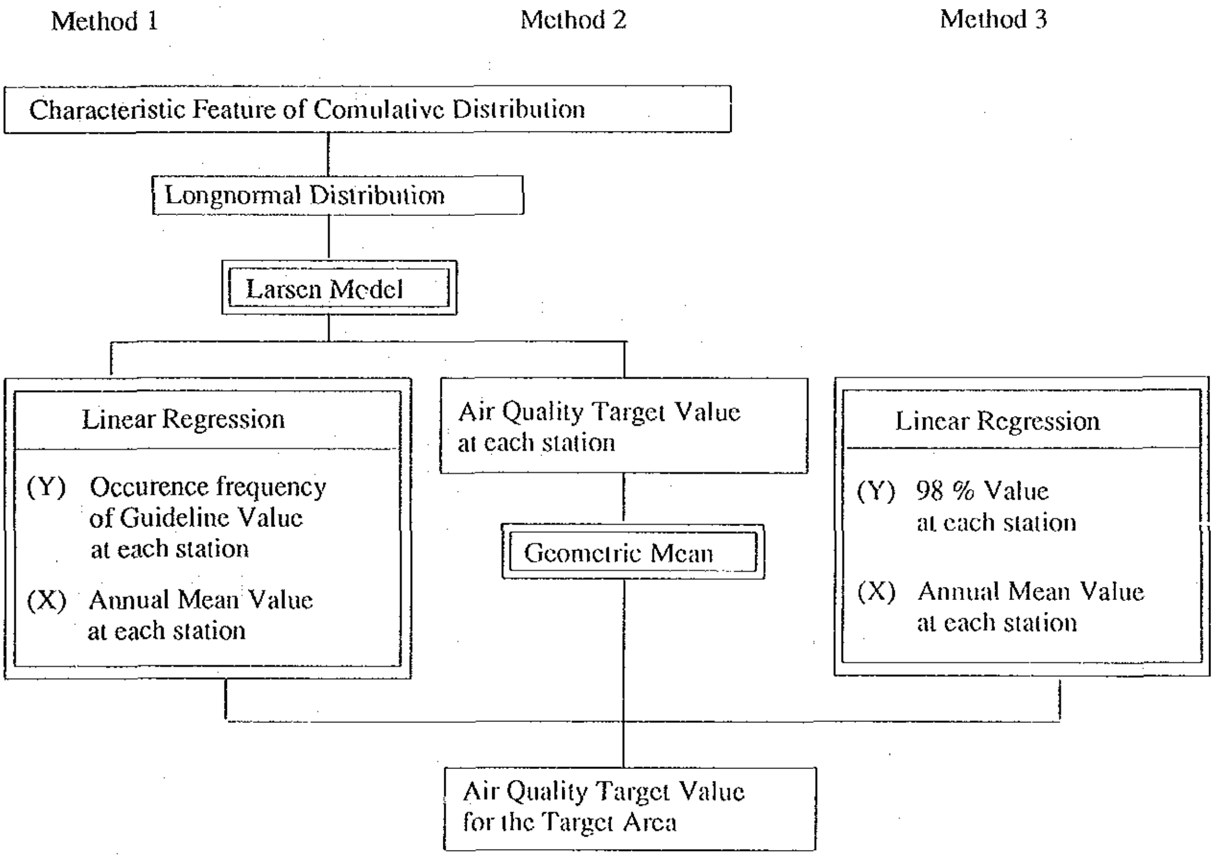
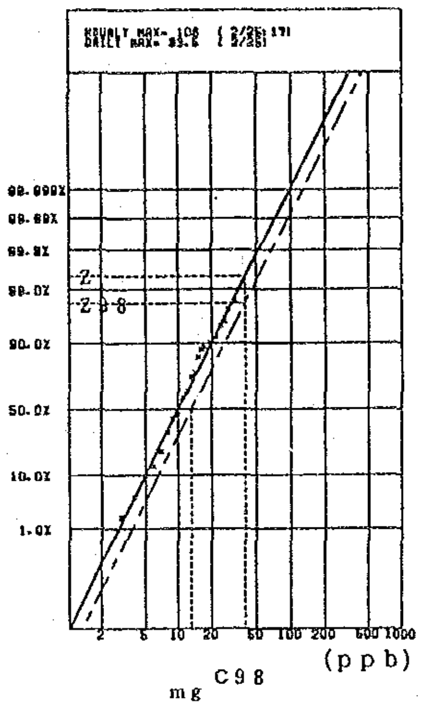


Fig. 8.4.1 Schematic Diagram of Three Methods to Estimate Air Quality Target Value

Fig. 8.4.2(1) Air Quality Target Value by Larsen Model (SO_2 daily value for each station, Mar. 1992 ~ Feb. 1993)

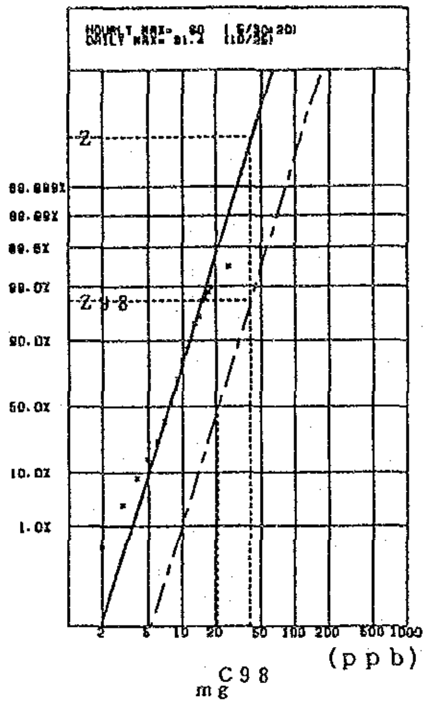
SO2

City Hall



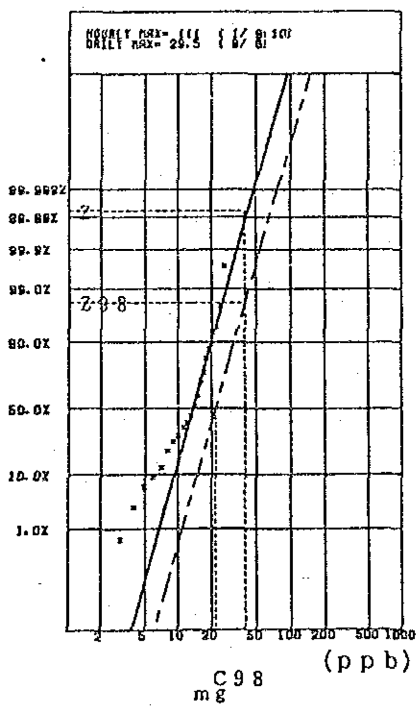
SO2

UPM



SO2

Petaling Jaya



SO2

Shah Alam

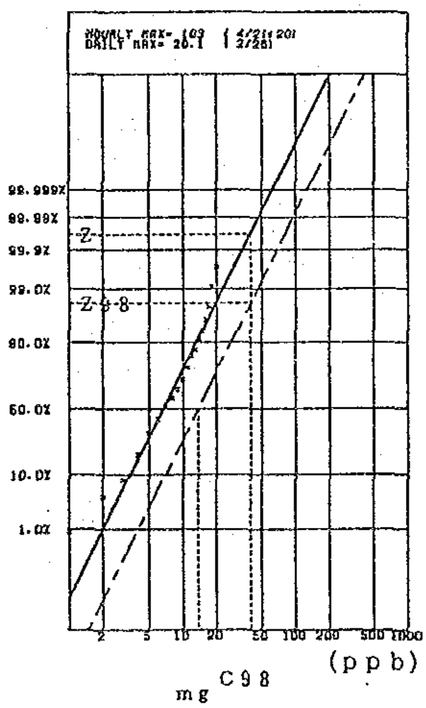
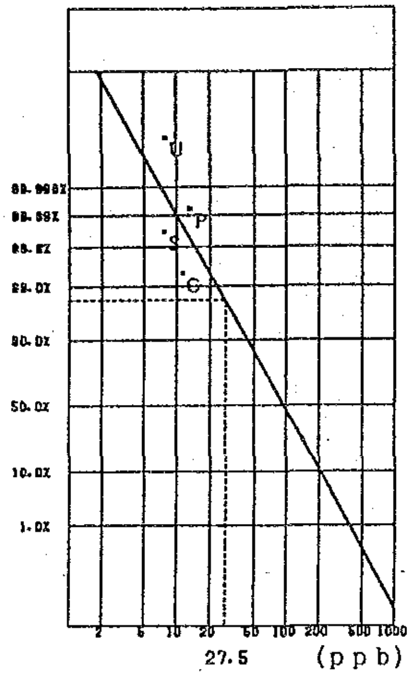


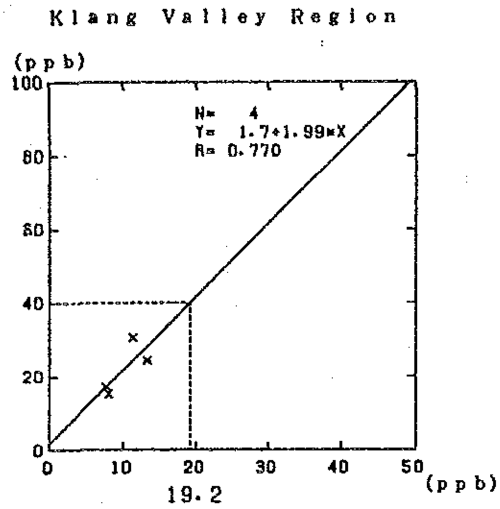
Fig. 8.4.2(2) Air Quality Target Value by Larsen Model and Linear Regression
(SO2 daily value for Kelang Valley Region, Mar. 1992 ~ Feb. 1993)

SO2



C: City Hall
U: UPM
P: Petaling Jaya
S: Shah Alam

Fig. 8.4.3 Air Quality Target Value by Linear Regression (SO_2 daily value for Kelang Valley Region, Mar. 1992 ~ Feb. 1993)



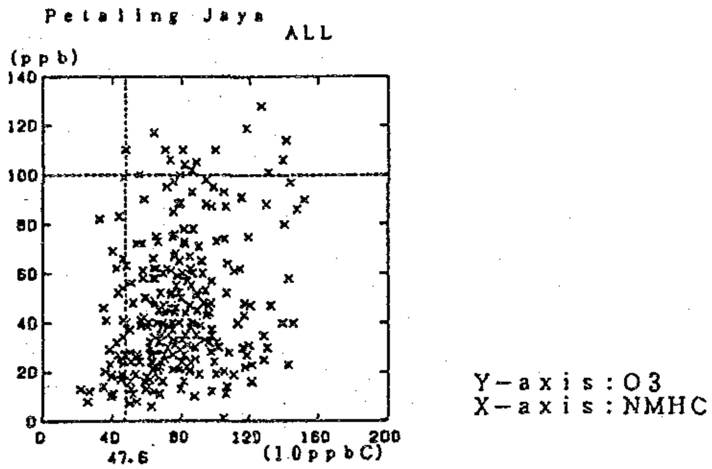
(2) NMHC and O_3

The Malaysian guideline value for hourly O_3 is 100 ppb, but O_3 cannot be reduced directly because O_3 is produced by complicated photochemical reactions. It is said that NMHC is one of the primary pollutant for O_3 production. Investigations on annual mean value of NMHC to maintain O_3 concentrations below the guideline follow.

The relationship between O_3 maximum values and NMHC daily mean values at Petaling Jaya is shown in Fig. 8.4.4. From the figure, the permissible value of NMHC daily mean to maintain O_3 maximum value below 100 ppb is determined as 47.6 pphmC. The unit pphmC refers to 10 ppbC.

The methods described above are used to estimate the annual mean values of NMHC. The annual mean values are determined in Table 8.4.2.

Fig. 8.4.4 Relationship between O_3 Maximum Value and NMHC Daily Mean



8.4.2 Setting of Air Quality Target Value

The estimated values by the three methods and the recommended Air Quality Target Values are summarized in Table 8.4.1. The estimated values for SO_2, NO_2 and CO from the monitoring data are close to half values of the guideline or standard values. The fact supports the justification for adopting the empirical rule that the Air Quality Target Value can be set at half of the guidelines or standards for daily value. The value for CO is set taking into consideration the Malaysian guideline.

Finally, the Air Quality Target Values for SO_2, NO_2, and CO are 20 ppb, 37 ppb, and 4 ppm respectively. The Malaysian guidelines have annual mean values for TSP and PM10, and they are chosen as the Air Quality Target Values. The annual mean value for NMHC (20 pphmC) is a tentative value and needs further examination.

The Air Quality Target Values should be reexamined and discussed at a certain stage in the future after accumulation of the sufficient monitoring data. Some backgrounds as air quality monitoring, air pollution countermeasures, and socio-economic conditions will also change.

Notice that the guidelines or the standards for hourly values, daily values and so on should be satisfied respectively. The air quality target values are used to evaluate the long-term air quality over a wide area. However, short-term and local area evaluations of the air quality are also important, and they were not fully covered in this project. Examination of air quality over a short-term and in local areas should be carried out in the future.

Table 8.4.1 Air Quality Target Value

		SO2 Daily	NO2 Daily	CO 8-Hrs	CO Daily	TSP Yearly	PM10 Yearly
(Unit)		ppb	ppb	0.1 ppm		ug/m^3	ug/m^3
Guidelines /Standards		40 (*)	73 (+)	90 (*)	100 (#)	90 (*)	50 (*)
Method 1, 2	City Hall	15.1	44.7	41.9	54.4		
	UPM	22.0	43.5	----	----		
	Petaling Jaya	22.6	43.7	40.7	51.5		
	Shah Alam	15.6	39.5	32.3	52.0		
Method 1	Whole Area	27.5	44.1	59.2	55.1		
Method 2	Whole Area	18.5	42.8	38.0	52.6		
Method 3	Whole Area	19.2	43.5	42.8	53.3		
Recommended (Yearly)	Whole Area	20	37	40		90	50
Maximum Mean	Fixed Stations	13.3 (PJ)	21.7 (CH)	28.4 (PJ)		81.8 (SA)	56.8 (SA)

*: Malaysian Guidelines, #: Japanese Standards,
+: WHO Guidelines
PJ: Petaling Jaya, CH: City Hall, SA: Shah Alam

Table 8.4.2 Annual Mean Value for NMHC

		NMHC(Daily)
(Unit)		pphmC
Permissible Value		47.6
Method 1,2	Petaling Jaya	26.1
	Shah Alam	14.9
Method 1	Whole Area	17.3
Method 2	Whole Area	19.7
Method 3	Whole Area	(1.5)
Recommended (Yearly)	Whole Area	20
Observed Mean Value	Petaling Jaya	79.1
	Shah Alam	22.5

8.5 Necessity of Emission Reduction

The simulation results for SO_2, NOx, NO_2, and CO in 1992 and in 2005 when no measures are taken are shown in Sections 6.3 and 8.3 respectively. The air quality target values for SO_2, NO_2, and CO were determined in Section 8.4. Then the simulation results can be evaluated by comparing with the air quality target values.

In 1992, maximum SO_2 concentration in the region is 59.7 ppb, far exceeding the air quality target value of 20 ppb. Maximum NO_2 concentration is 41.1 ppb, exceeding the air quality target value of 37 ppb. Maximum CO concentration is 4.92 ppm and exceeds the air quality target value of 4 ppm.

Factories and motor vehicles are the major contributors to SO_2 concentrations. Contribution from factories are high especially at the points with high SO_2 concentrations such as in Petaling Jaya and Shah Alam. The contributions by each type of pollution sources for NO_2 cannot be estimated because the simulation of NO_2 was carried out with the statistical model. NO_2 is converted from NOx and most of NOx is accounted for by motor vehicles. Almost all CO is produced by motor vehicles.

In 2005, SO_2 concentration at the maximum point in the region will be 65.8 ppb. This concentration is much greater than the air quality target value (20 ppb) and greater than the simulated concentration at the maximum point in 1992. SO_2 concentrations at City Hall and Petaling Jaya are at around the air quality target level. NO_2 concentration at the maximum point will be 63.1 ppb, which is much greater than the air quality target (37 ppb). NO_2 concentration at City Hall also exceeds the air quality target value. CO concentrations at the maximum point and City Hall will be 10.5 and 6.9 ppm respectively. Both of them exceed the air quality target value.

The manner and degree in which each type of pollutant source contributes are virtually identical to the year 1992.

As a result, ambient air quality of SO_2, NO_2, and CO concentrations are reaching problematic levels in some areas and are predicted to become worse in 2005. Factories are the most problematic contributors to high SO_2 concentrations while motor vehicles are the main contributors responsible for NO_2 and CO concentrations. Control measures to reduce the pollutant emission amounts from factories and motor vehicles should be carried out.

CHAPTER 9 CONTROL OVER AIR POLLUTION SOURCES

CHAPTER 9 CONTROL OVER AIR POLLUTION SOURCES

9.1 Factories and Establishments

9.1.1 Necessity for Control

Of a total of 248 facilities investigated as air pollution sources, 78% or 193 units were boilers. They ranged from small to medium sized ones with the exception of boilers at power stations. 75% of the 248 facilities were concentrated in three districts; Petaling Jaya, Shah Alam and Klang.

In 1992, sulphur rich fuel oil was the main source of SOx emission. Consumption was about 450,000 kl in Kelang Valley Region. Power stations contributed to 64% of SOx and 81% of NOx emissions in the Region. The main polluter was the PS-A Power Plant which emitted 20,000 tons of SOx in 1992 from two 300 MW coal (0.6% sulfur) burning boilers and one fuel oil firing boiler. General industries other than power stations emitted SOx by burning 190,000 kl of fuel oil, and palm wastes and wood wastes which contained around 0.2% of sulphur. SOx emission was not detected in the gas from the cement factory, although it was using 1.0% sulphur coal. However the cement plant emitted plenty of dust whenever power failures occurred, about 40 times in a year.

Although anti-pollution measures have been introduced to gradually convert to lower sulphur content or better fuel, these steps seem inadequate.

Installation and expansion of power stations have been planned to meet the rapid economic growth in Malaysia, as shown in Tables 9.1.1 and 9.1.2. Emission amounts in the year 2005 for the whole KVR can be estimated from the above tables with emission factors. They would exceed the air quality target values as simulated in Chapter 8.

Table 9.1.1 The Power Development

	Fuel type	1992	1993	1995	1996	2000	Total
PS-A	H.F.O	300	〃	〃	〃	〃	300
	N.Gas	300	〃	〃	〃	+500	800
	Coal	600	〃	+500	+500	1600	1600
	Sub total	1200	1200	1700	2200	2700	2700
PS-B	N.Gas	212	272	〃	〃	〃	272
	N.Gas	520	〃	〃	〃	〃	520
	Sub total	732	792	〃	〃	〃	792
PS-C	N.Gas	–	500	〃	〃	〃	500
	Sub total	-	500	〃	〃	〃	500
	total	1932	2492	2992	3492	3992	3992

unit:MWh

Table 9.1.2 Future Energy Demand in KVR

(1) Power Station

Year		1992	1997	2005
PS-A	PG-12	258750	258750	258750
	PG-28	275112	275112	715290
	PG-20	806400	1937376	1937376
PS-B	PG-28	1585998	1724656	1724656
PS-C	PG-28	0	347040	347040

unit:PG-12=kl/Y
PG-28=10^3 m^3
PG-20=t/Y

(2) Factory

Year	1992	1997	2005
Fuel oil	190	190	190
Ind.D. Oil	265	265	265
L P G	85	135	267
Wood Waste	307	307	307
Palm Waste	187	217	267
Coal (Cement)	89	133	198

Unit: million liter, except solid fuel (1000 tons)

The Dust emissions come largely from palm and wood wastes (Table 5.1.11) which are burnt in poorly controlled furnaces and with inadequate removal facilities. Combustion control is generally aimed to achieve complete combustion under optimum conditions which can be achieved after knowing flow rates of fuel and air, and from the analysis of flue gas. There seems no such control concept in KVR at present.

9.1.2 Present State of Pollution Control

Environmental Quality Act (EQA) published in 1974 was the beginning of concrete pollution control in Malaysia. EQA stipulates licenses, prohibition and control of pollution, appeal, penalty and others. It sets out requirement and approval of plans, and restrictions on pollution of atmosphere, the soil and inland water, on noise pollution, and etc. It also authorizes the Minister to issue acceptable conditions or guidelines for pollutant emissions. Moreover, it empowers the government to specify conditions of discharge, to enter and inspect, to require occupier to install, operate, repair control equipment, and to attach conditions to licenses such as to conduct a monitoring program designed to provide the Director General of DOE with information concerning the characteristics, quality or effects of the emission.

Environmental Quality (Clean Air) Regulations, 1978, governs the air pollutant emissions from factories. It stipulates emission standards for nine gaseous substances including SO_3, NOx etc. from any trade (except SO_2 from other than sulphuric acid plants and NOx from combustion sources), Dust or solid particles from asphalt concrete plants and portland cement plants, asbestos and free silica from any trade, and metals and their compounds as gaseous impurities.

The third edition of the 1956 British Clean Air Act Memorandum (#4020) has been applied to determine the height of new stacks. This memorandum is applicable to fuel burning plants with gross heat input of between 0.15 and 150 MW. Almost all chimneys in the Region are of 15 to 40 m high.

The Malaysian Department of Environment is limited by a shortage of budget and manpower resources. As local and municipal governments are not entrusted with many administrative powers, and since there are no person to take charge of environmental affairs in those government agencies, identification of pollution sources, monitoring of environmental conditions, guidance to the polluters and so on are not performed effectively at present.

9.1.3 Basic Techniques of Stationary Source Emission Control

(1) Mechanism of Air Pollutant Generation

1) Particles

a) Gaseous Soot: simply called soot, formed by incomplete combustion of fuel, and have fibrous shape of 0.02 to 0.03 microns.

b) Carbon Residue Soot: caused by residue carbon in fuel, have particle size of 10 to 300 microns, are slow burning and seldom burn completely in the furnace, composed of carbon, hydrogen and ash.

c) Fly Ash: generated by burning solid fuel. Almost all fly ash from pulverized coal combustion is emitted to the atmosphere with the exception of some adhesion to the furnace walls.

2) SOx

Combustible sulphur in fuel produces SOx by burning. Lower temperature tends to fix SOx into the coal ash of fixed bed combustion.

Some SO_2 is oxidized to SO_3 in the flame. SO_3 becomes sulphuric acid in the colder zone, which corrodes metallic parts, and it is emitted to the atmosphere as acid smut with particles.

3) NOx

NOx is mainly a mixture of NO (about 90%) and NO_2. NO_2 is generated by high temperature oxidation of NO in the furnace. There are thermal and fuel NOx.

a) Thermal NOx: formed from nitrogen in the air depending on fuel physical properties, combustion conditions and so on. More NOx is produced by higher temperatures, higher air ratios, and longer resident time at high temperature.

b) Fuel NOx: formed from nitrogen in fuel. If 100% of nitrogen in the fuel is converted to NOx, the NOx concentration in the dry flue gas may approximately be 1550 ppm by fuel oil combustion and 2000 ppm by coal combustion. The conversion yield differs according to air ratio, temperature and so on. The yield is illustrated in Fig. 9.1.1 in relation to air ratio.

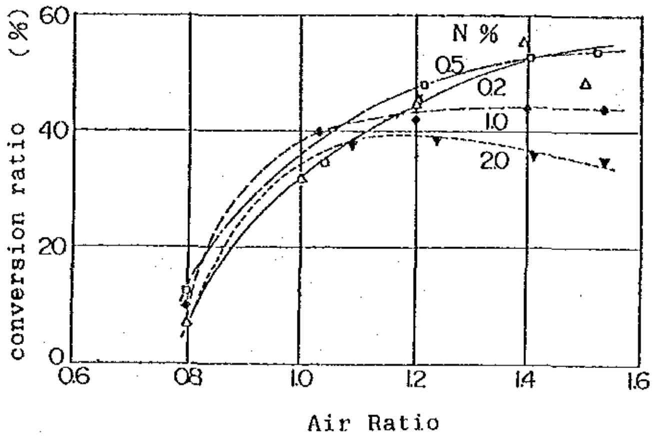


Fig. 9.1.1 Conversion of Nitrogen in Fuel vs Air Ratio

Fuel NOx from solid fuel is divided into volatile NOx which is generated from nitrogen in volatile matter and char NOx from nitrogen in char. The formation mechanism of the volatile NOx is similar to that of liquid or gaseous fuel combustion.

(2) Suppression of Pollutant Emission

1) Fuel Conversion

Since fuel composed of less sulphur, nitrogen, and residual carbon generates less SOx, NOx and particles, fuel conversion to such fuel is effective in reducing emissions. Also since a higher fuel ratio (fixed carbon/volatile matter) of coal means it is more difficult to burn and produces more unburnt soot, a lower fuel ratio is desirable to lower emissions.

2) Finer Liquid Fuel Droplets

Finer atomization of liquid fuel makes fuel mix better with air and possibly burn completely, and as a result reduces particle emission. However, because it increases thermal NOx and reduces fuel NOx, appropriate mixing conditions have to be created to produce a minimum amount of total NOx.

3) Air Ratio

Table 9.1.3 shows commonly used air ratios of fuels in various combustion methods.

Table 9.1.3 Typical Air Ratio & CO_2

Fuel	Combustion	Air Ratio	CO_2%.
Coal	Handfired horizontal grate	1.5 - 2.0	8 - 10
Coal	Spreader stoker	1.4 - 1.7	11 - 13
Coal	Moving grate(forced draft)	1.3 - 1.5	11 - 13
Coal	Underfeed stoker	1.4 - 1.7	12 - 15
Coal	Pulverized burner	1.2 - 1.4	11 - 15
Fuel Oil	Burner	1.1 - 1.3	11 - 14
Gas	Burner	1.1 - 1.2	8 - 20

Burning fuel with smaller or larger air ratios than optimum translates into incomplete combustion which produces more particles and reduces NOx. Normally, less excess air than that at the peak thermal NOx formation is applied to reduce NOx emission. Low excess air combustion reduces thermal loss with flue gas and hence saves energy. Fig. 9.1.2 indicates the relationship of air ratio and thermal loss.

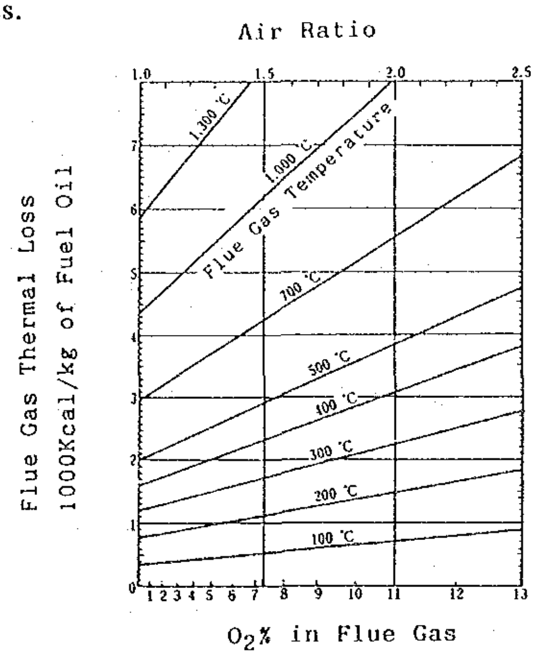


Fig. 9.1.2 Air Ratio vs. Flue Gas Thermal Loss

4) Air Preheat Temperature

Lowering air preheat temperature lowers combustion temperature and reduces NOx formation and increases particle emission. As the lowering of air preheat temperature can not reduce the amount of fuel NOx, it is not effective in burning heavier residual oil which contains a great amount of nitrogen.

5) Low NOx Burner

Low NOx burners can be categorized as follows by their principles.

a Separated flames
b. Self flue gas re-circulation
c. Off-stoichiometric combustion (mixture of burners with excess air and less air ratio)
d. Multi-stage combustion
e. Mixing enhanced combustion
f. Water injection
g. In-flame NOx removal (de-NOx)

Of the types which basically try to reduce flame temperature or O2 partial pressure, items c. d. and g. have been increasingly put to practical use.

SGR (separate gas recirculation, one example of item c. above), multi-stage combustion, and in-flame de-NOx are the main types of low NOx burners for pulverized coal combustion and employ the following NOx reduction principles.

* Reduction of primary air rate
* Fuel/secondary air mixing after volatile matter combustion
* Dilution of secondary air with flue gas

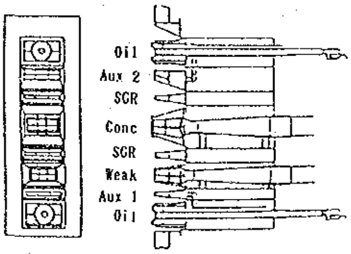
These burners can reduce formation of thermal NOx and volatile NOx. Below are configurations of these burners and a conceptual drawing of NOx reduction system (Fig. 9.1.3).

SGR burners reduce NOx formation by producing concentrated parts of powdered coal at the middle and diluted parts at both sides to burn coal in off-stoichiometric manner, and by delaying mixture of both layers by introducing flue gas in between.

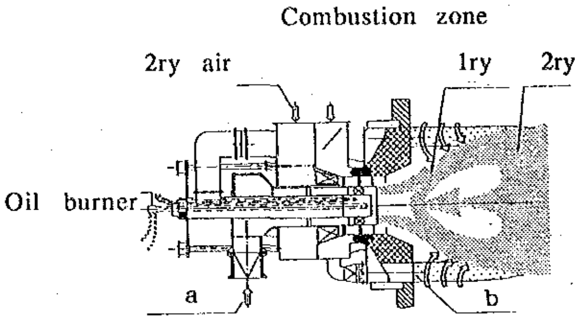
Multi-stage burners burn volatile matter of coal rapidly at the first stage, and there the generated heat decomposes and gasifies char. The produced char gas is combusted completely at the second and the third stage burners.

In-flame de-NOx burners rapidly ignite powdered coal and maintain a fuel rich flame, which results in reduced oxygen concentration by consuming oxygen from volatile NOx to burn radicals such as CH or C_2 and reduce to N_2. This type of burner can suppress conversion of nitrogen in char to NOx.

SGR Burner

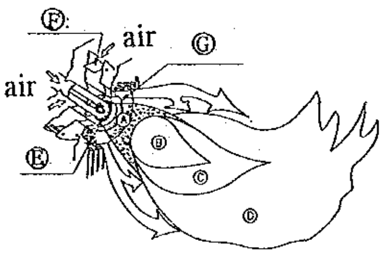


Multi-stage Burner



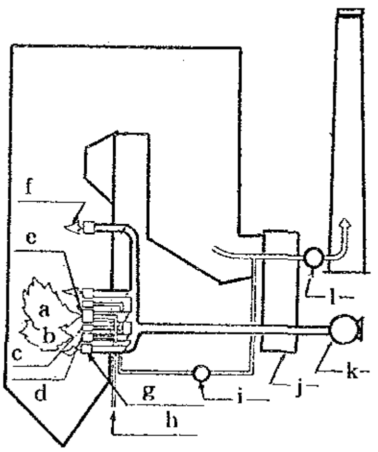
a: Pulverized coal/air
b: Air port

In-flame de-NOx Burner



A: Volatile matter burn zone
B: Reducing agent generation
C: De-NOx zone
D: *Oxidation zone*
E: Flame protection ring
F: Swirl
G: Guide sleeve

Fig. 9.1.3 (1) Low NOx Burners



a: Concentrated flame
b: Weak flame
c: SGR port
d: Fuel/air(weak compartment)
e: Fuel/air(conc. compartment)
f: Additional air
g: Auxiliary air(air compart
h: Pulverized coal/air mix
i: Recirculation fan
j: Air preheater
k: Forced draft fan
l: Induced fan

Fig. 9.1.3 (2) Concept of NOx Reduction

The in-flame LNB which can decompose NOx by excess hydrocarbons remaining in the high temperature flame is recommended. Unburnt fuel can also be reduced since the excess fuel region is at a high temperature. The other LNB models suppress NOx formation by retarded combustion. The performance differences can be seen in Fig. 9.1.4.

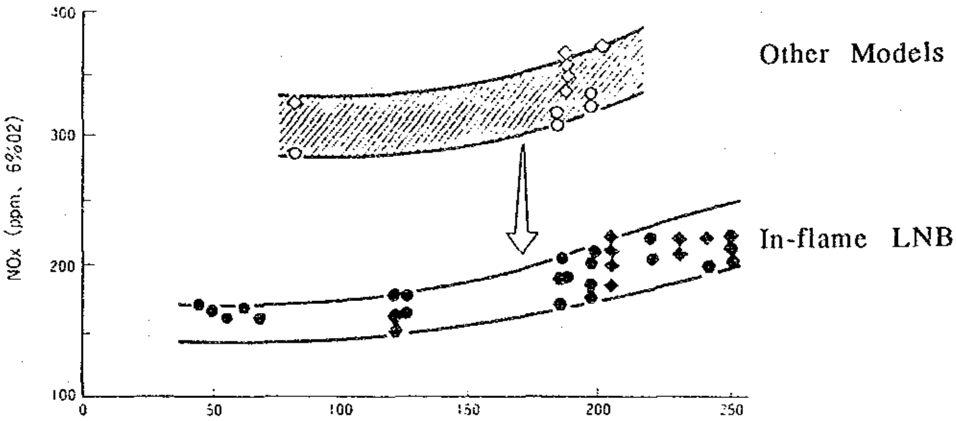


Fig. 9.1.4 Performance of Low NOx Burners

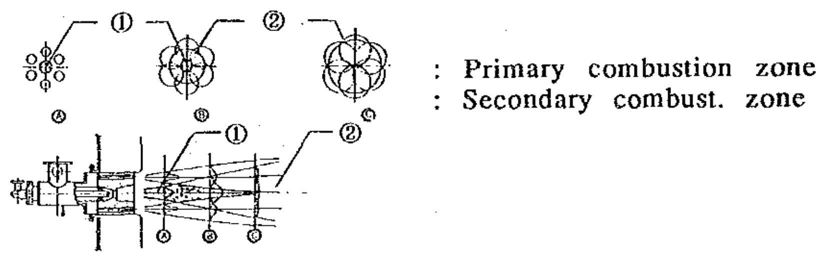


Fig. 9.1.5 Liquid/Gas Low NOx Burner

Fig. 9.1.5 depicts low NOx burners for liquid and gas fuels. This burner, a two stage combustion process, reduces NOx formed during the primary combustion to N_2. In the secondary combustion zone, oxygen in the secondary air is diluted with flue gas, thereby minimizing thermal NOx formation by restraining violent combustion reaction. This burner can reduce NOx emission to 50 ppm depending on fuel types and combustion conditions.

6) Two Stage Combustion

This method uses a NOx reduction capability of fuels. A part of the main fuel is utilized as an reduction agent and the whole reaction is completed in the furnace. This method may eliminate flue gas de-NOx units attached on pulverized coal boilers, because of its fairly low NOx emission. There are two types; one with a single fuel supply (Fig. 9.1.3 (2)) and the other with two fuel supply stages (Fig. 9.1.6). Air is supplied separately at two stages in either types.

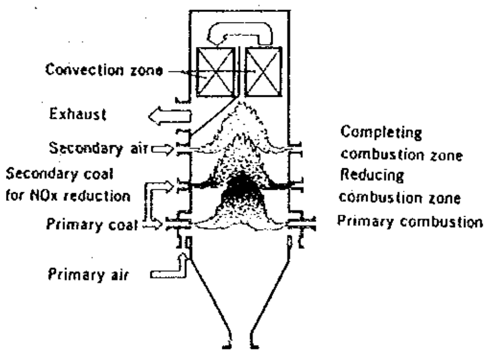
Table 9.1.4 explains the first type using an example. The example boiler had been remodeled at four stages successively. Originally (the first stage), the boiler emitted 570 ppm of NOx with the conventional design. At the second stage, 15% of the combustion air was separated and fed at the upper part of the burners. All burners were changed to LNB at the third stage and NOx emission was reduced to 300 ppm, 33% reduction from the second stage. Finally the secondary air was increased to 30% and NOx emission became to 150 ppm which was 50% reduction from the third stage or 74% from the first stage.

Table 9.1.4 Effects of Tow Stage Combustion
- NOx Reduction at Coal Boiler -

Stages	Techniques	NOx Emission (ppm, O_2: 6%)	% of NOx Reduction
1st		570	-
2nd	Two stage combustion, 15%	450	21
3rd	LNBs, all 24 burners	300	33
4th	Two stage combustion, 30%	150	50
Overall		150	74

In the two fuel supply type (Fig. 9.1.6), the primary combustion is operated at the normal air ratio and the secondary fuel is supplied in less equivalent to the remaining oxygen to produce reducing atmosphere which can reduce NOx to nitrogen. Later, enough amount of the secondary air is introduced to complete the combustion. Instead of supplying the secondary fuel, the system is recently changed in a manner to introduce an appropriate amount of air to the high temperature zone just after the combustion zone in order to keep reducing atmosphere. The secondary air is introduced afterward to complete the combustion. With this method, NOx emission is around 100 ppm.

Fig. 9.1.6 Two Fuel Supply Stage De-NOx Combustion



7) Combustion Control for TSP Reduction

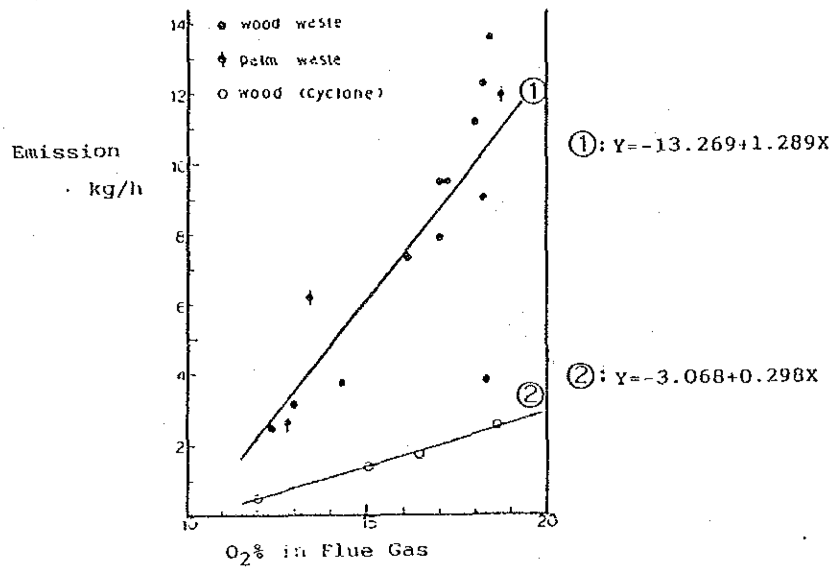
Dust is generated in combustion furnaces in the following reasons.

i) configuration unsuitable to fuel or combustion conditions
ii) wide load fluctuation
iii) load unmatched to furnace design
iv) unsatisfactory air introduction
v) premature operation techniques

Practically, the generation is due to lack of air supply and mixing with fuel, low temperature in combustion chamber, small combustion space or else. On the other hand, excess air may generate more dust as in Fig. 9.1.7 which is the measurement results of this study.

Main component of dust from combustion is carbon. Incomplete combustion emit unburnt carbon. Incomplete combustion emit unburnt carbon. Once it is generated, it is difficult to burn in the chamber. The principal control measures not to generate it are to keep combustion chamber temperature high enough and to mix fuel well with air. Following are the general methods to avoid its generation.

Fig. 9.1.7 Dust Emission vs. O_2 in Flue Gas



i) to supply, not too much but, optimum air

ii) to supply secondary air, when necessary, from front or back of furnace

iii) to charge small amount of fuel at regular intervals (manual feeder)

iv) to convert to mechanical feeder if possible, suitable to the specific furnace

v) to keep furnace temperature high and its volume spacious

vi) to plan good mixing of air and fuel

vii) not to burn excess fuel against furnace volume

It is effective to instruct factories so that they prepare operation manual of each furnace specifying air ratio, fuel rate, flue gas temperature, furnace wall temperature, control and maintenance, etc. Also instruction of installation of instruments for measurement of flow rates, oxygen concentration, temperature and so on will ensure the operation.

8) Pressurized Fluidized Bed Combustion (PFBC)

This combustion method coupled with steam turbines and exhaust gas turbines is applied to power generation because of the following features.

i) High efficiency: up to 41%

ii) Equipment is compact

iii) Possible SOx removal in furnace:

Efficiency of 85% at molar ratio of calcium/sulphur = 1.6

NOx emission is low because of lower temperature in the fluidized combustion bed and of its possible reduction by char to nitrogen. Generally the emission is around 100 ppm.

9) NOx Control of Gas Turbine

NOx emissions from gas turbines are around 110 ppm (as 6% O_2) at its capacity less than 2MW and 150 ppm at more than 2MW. The following control methods are usually applied.

- Low NOx Combustion
  - Water or Steam Injection
  - Diluted Mixed Combustion
  - Two-stage Combustion
  - Catalytic Comb.(under development)
- Flue Gas Treatment
  - Medium Temperature De-NOx
  - High Temperature De-NOx

Commonly used methods are water or steam injection, diluted mixed combustion, and medium temperature de-NOx. It is possible to remove 50 to 60% of NOx at the water or steam injection rate in the range of 0.5 to 1.0 of water to fuel by weight.

(3) Removal of Pollutants from Gas

1) Flue Gas Desulfurization (FGD)

There are various kinds of SOx removal technologies. Among the wet, semi-dry and dry methods, the wet method is widely applied throughout the world. It is able to remove 95 to 99% of SOx in flue gases, easy to operate, and suitable to flue gas containing high amounts of SOx. One drawback of the method is the lower temperature of the cleaned gases due to aqueous scrubbing solution.

Again, there are many varieties of the wet FGD method. Among them, widely used is a limestone scrubbing process. Between 5 and 15% of powdered limestone slurry scrubs SOx out of flue gas making calcium sulphite, which is then discarded or oxidized to calcium sulphate as a by-product for recovery. The natural form of calcium sulphate is gypsum. Artificial or natural, gypsum is used to make wallboards or portland cement. The limestone-gypsum process is generally recognized as the technically most reliable FGD currently.

Other FGD methods, semi-dry and dry methods, have been developed to reduce plant investment costs. However, they have drawbacks, such as low SOx removal and high reagent consumption.

The semi-dry method uses limestone or lime as a reagent. Limestone powder should be injected into a high temperature zone of a boiler furnace and later water should be injected into the gas to achieve reasonably high SOx removal efficiency of 70 to 85%. Higher molar ratio of limestone/SOx can remove much SOx, although a ratios of 2 to 3 is the limitation from the standpoint of economic and waste handling problems. Lime slurry may be sprayed into a duct work or equipment at a lower temperature. The water in the slurry must evaporate by heat of the flue gas to avoid sticking and plugging of the slurry and the absorbed product on the inside of equipment. Accurate operational control to cope with fluctuations of gas temperature and flow rate is mandatory to avoid this kind of problem.

The dry method uses an addition of limestone at the high temperature zone of the furnace without a subsequent spray of water. Although SOx removal is low, the sticking problem is avoided because of no water is sprayed. Of the three methods, this method requires the least amount of extra equipment for SOx removal.

Dolomite or coal ash if alkaline components in the ash are enough to remove required amount of SOx may be used as a reagent instead of limestone. Coal ash utilization has not been well demonstrated yet and the process encompasses difficulties in regard to ash handling and low SOx removal.

2) NOx Removal from Flue Gas

Two dry processes are commercially proved to remove NOx from flue gases and decompose it to nitrogen and water (#Power, June 1991).

Thermal or selective non-catalytic reduction (SNR) process relies on injecting ammonia, urea, or other nitrogen-containing compounds into the flue gas in a temperature regime of 850 to 1,300 °C to reduce NOx. SNR has found widespread application on municipal incinerators and others. While simple in concept, the SNR has some drawbacks. NOx removal is intimately dependent on flue-gas temperature. And it suffers from byproduct salt formation, especially when SO_3 content is high. Also, the effects of ash content and changing fuel properties and boiler turndown have to be fully addressed.

Selective catalytic reduction (SCR) process is similar to SNR instead of having catalyst beds to promote the reduction reaction at lower than for the SNR process -300 to 400°C. A key advantage of SCR is that it applies to all boiler designs and does not involve furnace modifications, minimizing outage time, and higher removal efficiency, possibly 90%. But it is an expensive technology.

3) Particle Control

In addition to combustion control, particle reduction is possible by several types of removal equipment as seen in Table 9.1.5.

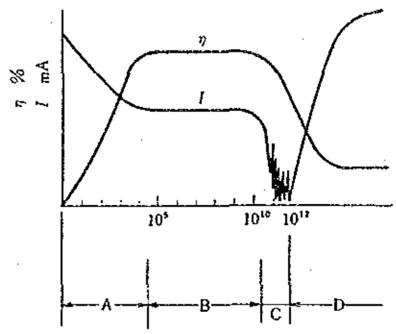
Table 9.1.5 Various Particulate Removal Equipment

Type	Particle size handled: μ	Pressure drop: mmAq	Removal %	Cost
Settling Chamber	1000 - 20	10 - 15	40 - 60	small
Louver Impinger	100 - 20	30 - 80	50 - 70	small
Cyclone Separator	100 - 5	100 - 200	70 - 95	medium
Venturi Scrubber	100 - 0.1	400 - 850	80 - 95	medium
Bag Filter	20 - 0.1	100 - 200	90 - 99	medium
ESP	20 - 0.05	10 - 20	80 - 99.9	large

Bag filter is suitable for gases contained finer particulates. Cyclone separator is commonly used in industrial boilers. Single cyclone has a lower removal efficiency and multi-cyclone shows better removal.

ESP (Electrostatic Precipitator) is applied to large scaled facilities such as those in power plants and cement factories.

Electric resistivity of particles is the most influential factor in particle removal in a ESP, as shown in Fig. 9.1.8.



η: Removal %

I : Discharged current mA

A: Abnormal, re-entrain.

B: Normal

C: Frequent spark

D: Reverse ionization

Apparent Electric Resistivity

Fig. 9.1.8 Apparent Electric Resistivity vs. Removal %

The ideal electric resistivity (ohms cm) for removal is in the range of 10^4 to 10^{10}. Particles having the resistivity lower than 10^4 are in the re-entrainment zone, while those having higher than $5x10^{10}$ are in the frequent spark zone. The electric resistivity of pulverized coal fired dusts is usually in the range of 10^{10} to 10^{13} and close to the frequent spark zone. Some measures have to be applied to enable normal operation and maintenance of good precipitator efficiency. Followings are some examples of the measures.

a) Conditioning of Flue Gas

The electric resistivity of particles can be adjusted by injection of water or SO_3. High sulphur coal or heavy oil is fired with the main pulverized coal for this purpose.

b) High temperature electrostatic precipitator

Higher temperature may be effective in removal as the electric resistivity of particles becomes around 100°C or lower. Pulverized coal boilers can use the precipitator before the air preheater where it is around 360°C.

c) Pulse Charge

Intermittent charges suppress spark and save energy. It is effective for particles having resistivity greater than $5x10^{10}$ ohms cm.

(4) Dispersion of Pollutants - Increment of Stack Height

Higher stacks are effective to reduce ground level concentration of dispersed pollutants, such as SOx, NOx, and particles. The effect varies with its height, emission velocity from the stack, gas temperature, pollutant concentration, etc. and also with meteorological and topographical condition. Among these factors, stack height and emission velocity are the most influential. Traditionally, increment of stack height is the elemental measure against the pollution control. Emission velocity can be accelerated by restricting a stack top opening and, if necessary, by installing a booster fan of higher discharge pressure. The modification of a stack may be hard from land availability, complicated construction work, selection of materials and so on. However, it is advantageous of less investment and operation costs than those of a flue gas treatment unit.

9.1.4 Proposed Individual Control Measures

As in Chapter 8, the investigation showed that several places in P. Jaya, S. Alam and Klang would exceed the air quality targets in 2005, if no further measure is applied.

(1) Power Station

If the expansion of power plants in the Region is to proceed as planned (see Table 9.1.1), future pollutant emission will be as shown in Table 9.1.6.

In this Section, proposed control measures on individual facility are described.

Table 9.1.6 Emissions from Power Stations (without control measures)

(unit: ton/year)

Year		1992	1997	2005
PS-A	Dust	1,844	2,190	2,260
	NOx	10,651	20,688	23,241
	SOx	19,522	30,040	30,040
PS-B	Dust	125	136	136
	NOx	2,141	2,328	2,328
	SOx	0	0	0
PS-C	Dust	0	27	27
	NOx	0	469	469
	SOx	0	0	0
Total	Dust	1,969	2,353	2,423
	NOx	12,792	23,485	26,038
	SOx	19,522	30,040	30,040

PS-A contributes most to the emissions in 2005, with 93% of dust, 89% of NOx and 100% of SOx, because it burns much heavy oil and coal, whereas the other two stations use natural gas only. PS-A does not have a dust collector for its heavy oil burning boiler.

1) PS-A Power Station

PS-A is burning HFO in No.1 Unit, natural gas in No.2 Unit and pulverized coal in No.3 and 4 Units. One boiler of pulverized coal each in 1995 and 1996, and one boiler of natural gas in 2000 will be added respectively. This power station emits 55% of SOx in the whole region currently and will emit 73% in 2005 if counter-measures are not taken. Around 17,000 tons or 60% of predicted increment of SOx emission in the Kelang Valley Region should be removed here in 2005.

<u>No. 1 Boiler</u>

Fuel conversion from heavy fuel oil to natural gas (SOx 12,000 tons reduction)

<u>Nos. 3 & 4 Boilers</u>

To burn coal of 0.6% sulphur until 2005;

To reduce particle emission to 0.1 g/Nm^3 by increasing EP efficiency with appropriate control or else;

<u>Nos. 5 & 6 Boilers</u>

No. 5 : To burn coal with 0.6% sulphur or less

No. 6 : to burn natural gas

No.1 Unit can be easily fired by natural gas as it was originally designed so, if the gas supply is ample. No.3 & 4 Units have Low NOx burners (LNBs) and two stage combustion. However, as the secondary combustion rate is 15%, the NOx suppression may be only 20%. According to the analyses conducted in this study, NOx concentration in the gas was 590 ppm at 2.5% of oxygen.

2) PS-B Power Station

This station discarded the outdated facilities and installed six gas turbines firing natural gas in 1992. Two of the six have power generating systems combined with steam turbines. There is no NOx analysis data of the flue gas. Since the combustion temperature is around 1,200°C in front of the turbines, 150 to 200 ppm of NOx can be assumed to be in the flue gas escaping to the stacks of 40 and 100 meter height. The assessment (#4018) conducted by TENAGA

NASIONAL BERHAD (TNB, National Electric Board) indicated that the environmental impact in the vicinity of the station would be small and air quality would not exceed the values in the guideline. As there is no feasible NOx suppression method for the turbine system, the control measures at this station were not investigated.

3) PS-C Power Station

This Station is located 30km south of KL and will start operating in 1993 with six gas combustion turbines. As the NOx emission from this station is assumed to be about 2,000 tons/year in 2005 (170 ppm of NOx) or around 7% of the total contribution from all power plants.

(2) Cement Factory

This factory commissioned in 1958 with a production capacity of 300,000 tons/year has currently 1,690,000 tons/year capacity. The equipment is rather new and dust emission is well under the limit of the emission standard. It is now planning to further reduce dust emission to $0.04 g/Nm^3$ by 1995. However, frequent power failures and insufficient operation control measures have caused frequent emissions of heavy dust from the stack.

Generally, NOx concentration is high as the clinker calcination temperature is high. The analyses done by this study team indicated NOx to be about 490ppm and dust to be about $0.17 g/Nm^3$ at O_2 2.5%, which is within the limits of $0.2 g/Nm^3$ (Standard C). NOx seems to have no special adverse effect on the neighbors.

Dust emission due to power failures has to be countered by preparing and enforcing an emergency operation manual. If the capacity of the stand-by emergency generator has to be upgraded if it is not enough.

(3) Factories (excluding Power Stations)

1) Boilers

Factories in Kelang Valley Region consumed 190,000 kl of sulphur rich heavy fuel oil in 1992, around 27% of the regional liquid fuel consumption (710,000 kl). Light fuel oil consumption was at around 37%. Lighter oils are predominantly consumed in the Region. However, more lighter oils have to be consumed, since SOx emissions will increase 1.35 times in the year of 2005 in the Region. Table 9.1.7 shows the amount of emissions in each district in 1992.

Table 9.1.7 Pollutant Emissions by Area (general factories, 1992)

(unit: ton/year)

Area	Dust	NOx	SOx
1. H. LANGAT	1,924	575	1,184
2. GOMBAK	199	720	556
3. K. LUMPUR	346	102	641
4. S. ALAM	1,113	612	3,264
5. P. JAYA	585	153	2,294
6. KLANG	2,867	818	3,108
TOTAL	7,034	2,979	11,047

As boilers in the factories (excluding power stations) are generally small in size, fuel conversion is the easiest way to reduce SOx emission without major alteration to the facilities and with some sacrifice for higher fuel cost. However, an abrupt or rapid conversion may cause imbalanced supply and demand in the oil market.

Boilers with larger amounts of pollutants are proposed to convert fuels; natural gas to boilers (fuel rate more than 150 kg/hr) in S. Alam and P. Jaya and light fuel oil to boilers (fuel rate more than 200 kg/hr) in other districts. The amount of reduced SOx emission from the factories will be around 52%.

2) Nitric Acid Plant

NOx in the exhaust gas of the nitric acid plant is currently catalytically reduced to nitrogen. However, yellow smoke is frequently observed from the chimney because of low removal efficiency and insufficient operation control and maintenance.

NOx reduction may be accomplished by changing the space velocity of the reduction reactor, early replacement of catalysts, or lowering the throughput of the plant and thus decreasing the load on the reduction reactor. These measures are feasible since the plant production is steady without peak or full rate operation, and the cost incurred in introducing this measures is not too high.

(4) Wood and Palm Waste Combustors (Boilers & Incinerators)

Data analyzed in this study indicates many palm and wood combustors generate large amount of Dust exceeding than the emission limits(standard C: $0.4 g/Nm^3$). Combustors burning more than 15,000 t/y of wood or palm are proposed to consider ways of reducing the dust emission to 0.1g/Nm^3, by the introduction of strict combustion control, and the installation of precipitators. The combustion management for TSP reduction (cf. 9.1.3) is to achieve complete combustion with continuous fuel feed, better feed methods, better air distribution, lower air ratio and so on.

As wood waste has a great amount of volatile matter, it has lower ignition temperature and higher burning velocity, and is relatively easier to burn completely.

However, as it consists of various water contents and shapes, it causes uneven combustion and has demerits of high particle emission, and difficulties of maintaining constant steam pressure and following to load changes. It is possible to burn evenly by sizing wood waste into uniform chips and using a spreader boiler.

It is relatively difficult to control NOx emission at this waste boiler.

Fig. 9.1.9 shows the drawing of the wood chip spreader stoker boiler. The boiler in this drawing is composed of the air preheater to improve boiler efficiency and the multi-cyclone to remove dust.

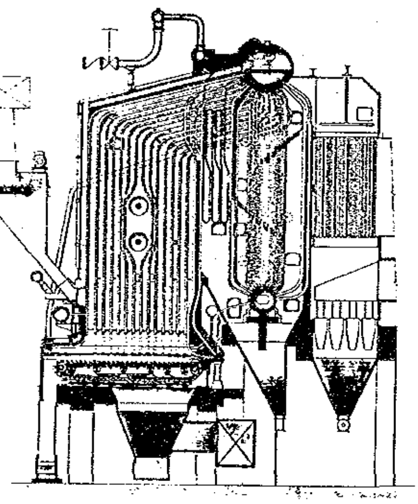


Fig. 9.1.9 Wood Chip Spreader Stoker Boiler

Precipitators may be selected using Fig. 9.1.10 as a guide and taking into consideration dust concentration and size distributions, gas temperature, etc.

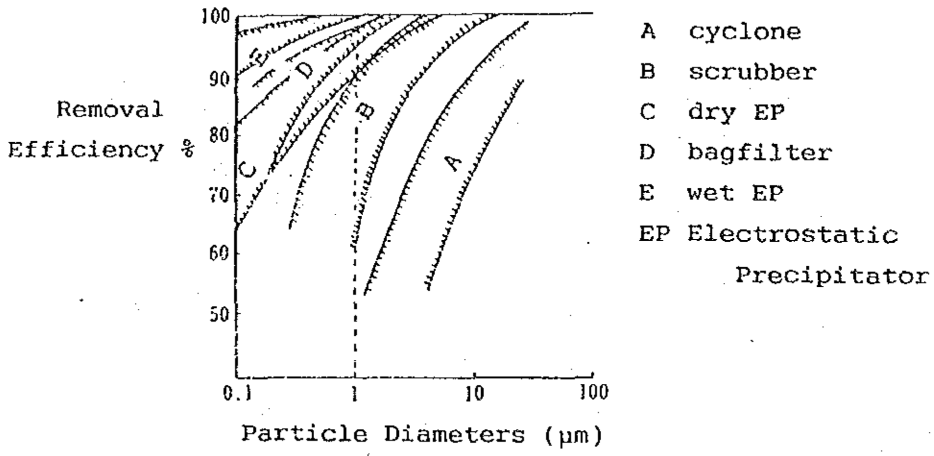


Fig. 9.1.10 Removal Efficiency of Various Precipitators

As palm and wood waste combustors emit particles larger than 10 microns in diameter, multicyclones can reduce dust emission with 80% removal efficiency. Three multicyclones shall be installed by 1997 and additional three by 2005 removing respectively 750 and 350 t/y (total 1100 t/y) of dust from wood burning. Meanwhile, ordinary bagfilters can remove 95% of particles larger than 1 micron diameter if the gas temperature is below 250°C.

It is recommended that outdated wood or palm waste combustors are replaced.

(5) Relocation of Factories

Those factories located in residential areas should be considered for relocation. Since timber and wood processing factories have allegedly received many complains, these may be considered for relocation. It is also necessary to give favorable credit and tax compensation to them for relocating.

(6) Pollution Control Agreement

1) Purpose

Pollution control agreement is a contract between the local government and a heavy polluter or a factory located in heavily polluted area, existed or planning to open newly, for the individual pollution control. The agreement may impose additional limitation to the published emission standard. However, it is to keep living environment of surrounding people in healthy condition. It may benefit of the factory in its citizen oriented position. The agreement is customarily concluded in Japan and is quite effective to control local pollution and to calm local dispute.

2) Contents

Contents of the agreement should be selected from the following in consideration of (i) crowdedness of pollution source and current pollution conditions in the surrounding area, (ii) contribution of the said factory to the pollution and (iii) distribution of households in the area.

A) Pollutant Emission Control

a) SOx
- to limit total emission amount from the factory
- to use better fuel and limit sulphur content in the fuel
- to install exhaust gas control unit

b) NOx
- to limit total emission amount from the factory
- to use better fuel
- to limit exhaust concentration
- to install exhaust gas control unit
- to apply combustion technics for emission reduction

c) Dust
- to use better fuel
- to limit exhaust concentration
- to install exhaust gas control unit
- to apply combustion management

B) Source Monitoring

Kinds of pollutants, Kinds of facilities, Methods and frequencies of measurement, Installation of equipment for continuous monitoring and/or centralized monitoring.

C) Provision of Pollution Control Organization and Management System

D) On-the spot Inspection

Purpose, Items to be inspected, Qualification of inspectors

E) Others Agreed by Both Parties

(7) Dust Control of Certain Non-point Sources

It is common to regulate dust emission (without referring to its concentration) by guidelines for the structure, use and management of dusty facilities, such as storage, transportation systems, crushers, screens, etc. of ores and stones. The guidelines are proposed here as follows.

1) Storage of ore, stone and waste soil

One of the following four items should be applied to material storage space exceeding $1000m^2$ of land area.

a) water from sprinkler system

b) screens covering the surface

c) anti-dispersion agent

d) presses to keep the surface hard

2) Belt and Bucket Conveyors

Conveyors with 40 cm wide belt or $0.02m^3$ of a bucket volume should be equipped with spray systems or other dust masking devices on charging ports, connections etc.

3) Crushers and Screens

Crushers, Screens and so on for ore, stone, cement, etc. have to be installed in enclosures, must be sprayed with water, or must be equipped with precipitators to prevent the dust from dispersing.

4) Follow-up treatment of Mines, Pits, Excavation Sites etc.

Remaining sites have to be reclaimed after excavation to prevent disasters and vegetation must be planted to preserve the environment.

a) *Final Wall: multi-layer walls with safety slope of a suitable height* and width for green vegetation

b) Vegetation: by seeds, transplants, cuttings or spraying; with rapidly growing cover plants found in nearby land

c) Maintenance: appropriate maintenance to promote growth and to avoid drying of filler soil

(8) Effects of Control Measures

The calculation results of emissions after implementing the control measures over power stations and other factories are tabulated in Table 9.1.8.

Table 9.1.8 Change of Pollutant Emission from Factories

1) Uncontrolled

(unit: ton/year)

Year		1992	1997	2005
SOx	P. Stations	19,522	30,040	30,040
	General Factories	11,047	11,137	11,283
	Total	30,569	41,177	41,323
NOx	P. Stations	12,792	23,485	26,038
	General Factories	2,979	3,509	4,415
	Total	15,771	26,994	30,453
Dust	P. Stations	1,969	2,353	2,423
	General Factories	7,034	7,461	8,163
	Total	9,003	9,814	10,586

2) Controlled

(unit: ton/year)

Year			1992	1997	2005
SOx		P. Stations	19,522	12,759	12,759
		General Factories	11,047	5,199	5,345
		Total	30,569	17,958	18,104
NOx		P. Stations	12,792	14,109	22,758
		General Factories	2,979	3,454	4,364
		Total	15,771	17,563	27,122
Dust	(without precipt.)	P. Stations	1,969	740	828
		General Factories	7,034	5,849	6,552
		Total	9,003	6,589	7,380
	(with precipt.)	P. Stations	1,969	-	828
		General Factories	7,034	-	5,451
		Total	9,003	-	6,279

[Summary of Expected Effects]

a. Dust: Without control measures, dust emission in the year 2005 would be 1.2 times of that in 1992. The measures, especially if applied to the power stations, will contribute towards almost 70% reduction of the current emission level.

b. NOx : Without control measures, NOx emission in the 2005 would be double of that in 1992. 76% of NOx come from the power stations (mainly from PS-A). Conversion to natural gas from MFO and intensification of the two stage coal combustion would help to reduce only about 3,330 t/y and thus the emission would be about 1.7 times of the amount in 1992. Selective reduction of NOx is available for further reduction.

c. SOx : Without control measures, SOx emission in the year 2005 would be 1.35 times of that in 1992. 70% of SOx come from MFO and coal burning power stations. It is not practical to reduce the sulphur content in the coal to less than 0.6%. The only possible way to reduce 17,000 t/y of SOx, is through fuel conversion (MFO to natural gas) or flue gas desulfurization at PS-A #1 boiler. General factories other than power plants should convert to natural gas in S. Alam and P. Jaya, where the SOx concentration greatly exceed the target value, and to light fuel oil in other districts. These measures should be implemented by 1997. Hence about 23,200 t/y of SOx emission will be reduced in KVR by 1997. The increment of 1.35 in 2005 would be reduced to 0.59 times.

d. Others: Combustion management engineers should be trained and assigned to all boilers burning more than 200 kg/h of fuel. This effect has been reflected in the above Table as a 5% energy savings.

9.1.5 Training of Engineers

Engineers should be trained through lectures and actual practice at a training center after establishing a new combustion management system.

(1) Requirement of Combustion Management System

72% of dust emission (around 12,600 tons in 1992) and about 30% of NOx emission (total around 54,500 tons in 1992) in the Klang Valley Region were generated from factories. These emissions will increase 1.2 times and 1.5 times respectively in 2005.

These emissions can substantially be reduced by appropriate combustion techniques. However, factories in the region lack such basic capabilities as fuel/air ratio control, fuel management (its quality, quantity, & safety precaution), burner maintenance and so on. Also they seem to have little notion of the effective use of energy. Even if low NOx burners are installed, it will be difficult to meet their expected performance without determination and motivation of concerned businesses.

To overcome this situation, it is necessary to mobilize engineers who are highly trained in non-pollution combustion techniques and energy saving operations. Also it is necessary to establish an integrated combustion management system to support these front-line engineers.

(2) Outline of Combustion Management System

The combustion management system is to undertake fuel management, management of energy generation and uses, non-pollution combustion, maintenance of instrument and else in an individual factory. The system enables the factory to take social responsibility by producing non-hazardous wastes or exhausts.

Factories emitting flue gases should be divided into two classes; designated factories which consume fuel more than the amount specified by the government and other factories which consume less than that amount of fuel.

The designated factories must have a first class licensed combustion engineer and the other factories a second class licensed engineer. These engineers should be selected from those trained by the government and those passed the government examination. Their assignments are as follows:

1) Maintenance and management of combustion facilities
2) Surveillance and modification of energy use
3) Planning, implementation of pollution control measures and measurement of their effects
4) Report of combustion management operations to the government

(3) Training Method

A combustion management technical training center (combustion training center) should be established and people in charge of combustion in factories should study and learn combustion techniques and management there. Graduates who pass the government examination should be licensed by the government to be designated class combustion engineers.

Outline of the center

1) Curriculum
   a. Lecture: basic knowledge of fuel and combustion, furnace, combustion management techniques, pollution control techniques, analytical technology.
   b. Practice: combustion, heat balance, energy saving method analytical technology

2) Term

a. First Class: three months

b. Second Class: one month

3) Capacity 20 people per course

4) Staff

7 technical specialists and 3 clerks

5) Facility and Equipment

(a) Test boiler A: one unit for both of liquid and gas fuel Smoke tube type with flue gas recirculation
Two burners: standard and low NOx types
Steam evaporation rate to be 1.2 t/hr

(b) Test boiler B: one unit for saw dust and wood chip fuel
Spreader stoker type, 1.2 t/hr steam

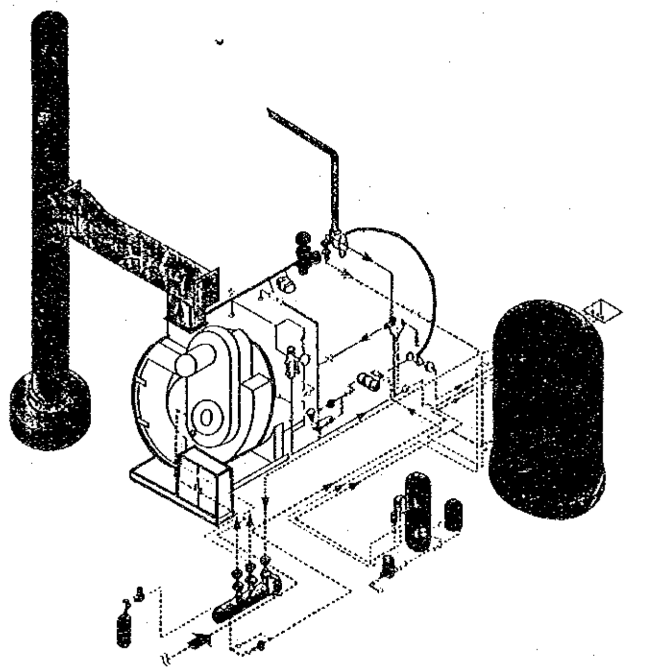


Fig. 9.1.11 Test Facility and Equipment

(c) Instrument:

* Hot wire anemometers (air, flue gas)
* Orsat gas analyzer (CO_2, O_2, CO)
* Displacement flow meters (oil, steam, water)
* Gas analyzer (O_2, SOx, NOx)
* Gas analyzer (CO_2, CO)
* Dust sampler
* Ringelmann charts

* Thermometers (t-couples, 6 point recorder)
* Hygrometer
* Water hardness analyzer
* Barometer
* Radiation pyrometers (flame temperature measure.)
* Data processor

6) Examination

Students shall be examined on the knowledge and techniques acquired at the center. A committee assigned by the government shall evaluate the students and determine successful candidates. The Minister in charge shall issue the licenses and register them.

9.1.6 Energy Saving

(1) General

Rationalization of energy usage and energy conservation should be promoted not only for fuel conservation and economic reasons but also to reduce air pollution.

Industry entrepreneurs, owners of buildings and houses, manufacturers of energy consuming machines and others who are involved in energy consumption should make in-house efforts to save energy. The government can assist them basically in establishing guidelines, offering directions, recommending modifications, etc. Also it can provide monetary and economic support and facilitate educational promotion or public awareness.

Methods to save energy

a) to keep facilities in good and smooth operating condition
b) to renovate facilities for more efficient operation (i.e. addition of heat exchanger, change of heater temperature, recovery of waste heat)
c) to modernize processes and systems

(2) Low Oxygen Combustion

Low oxygen combustion is an important technique for energy savings in boilers, generally adopted by power plants and other industries. It has the following notable effects.

1) Improvement of Thermal Efficiency

Air is charged into the boiler always in excess by controlling the air/fuel ratio manually or automatically. Minimizing this excess air reduces sensible heat loss with flue gas and improves boiler thermal efficiency. However, it is in ambivalent with loss of unburnt fuel. As suggested in Fig. 9.1.12, it is necessary to operate boilers at the optimum air/fuel ratio to achieve the highest efficiency.

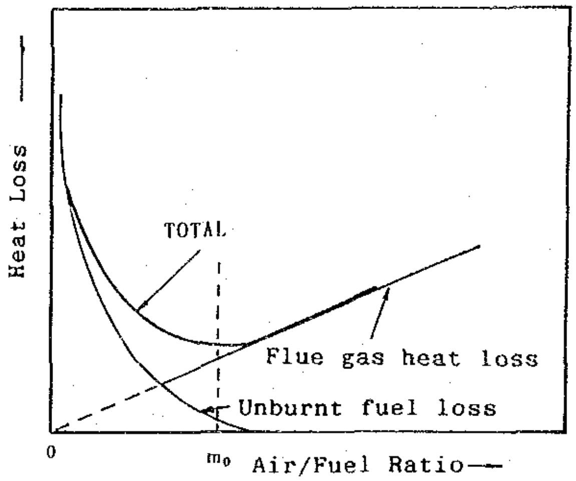


Fig. 9.1.12 Heat Loss vs. Air/Fuel Ratio

2) Suppression of NOx Formation

Rate of NOx formation in a boiler varies with oxygen content as indicated in Fig. 9.1.13. Reduction of air/fuel ratio lowers NOx formation. The ratio can not be reduced almost to one, since it will produce large amounts of soot.

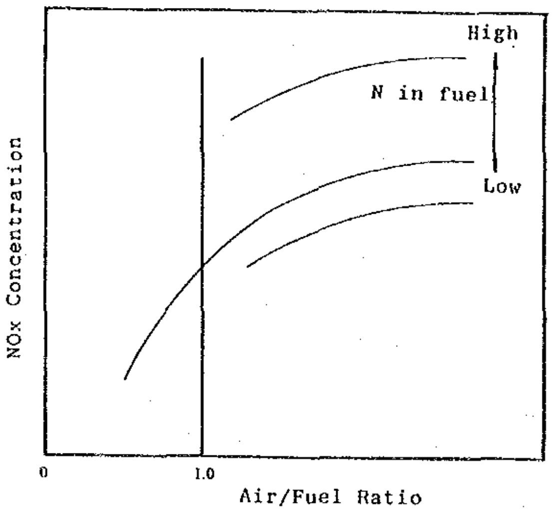


Fig. 9.1.13 NOx Concentration vs. Air/Fuel Ratio

3) Energy Saving by Low Excess Air Combustion

Fig. 9.1.14 shows the linear relationship between the boiler thermal efficiency and the air/fuel ratio. Generally the ratio is in the range of 1.2 to 1.4 for small and medium sized boilers. Those efficiencies are about 80 - 85% with around 20% of heat loss. To improve combustion operation, to clean the heat transfer surface, to recover steam drain and so on, are needed in order to reduce the heat loss.

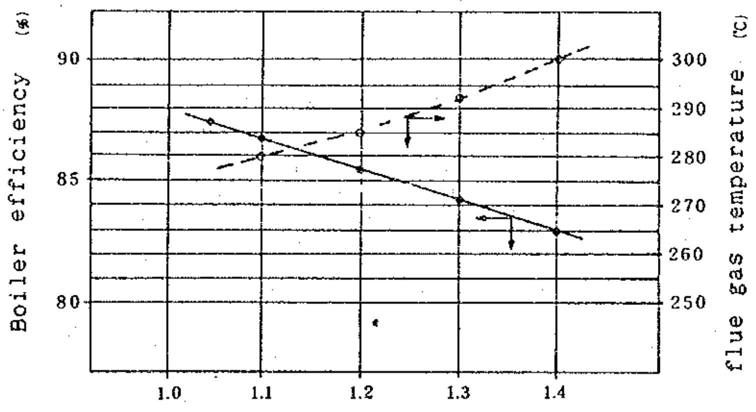


Fig. 9.1.14 Effects of Air/Fuel Ratio

(3) Energy Saving by Process Modification

Some examples of energy saving through process modification are explained in Table 9.1.9.

Table 9.1.9 Process and System Modernization

Items	Example
Simplification	Slab Cooling Manual Handling Heating (↓ Fuel) Rolling Steel Slab —— Heating (↑ Fuel) —— Rolling Steel
Continuous Operation	Chemical Ind.; batch continuous distillation Non-ferrous Mill; Continuous milling
Capacity Increasement	Refinery; bottle-neck removal Shipping; super-tanker
Utilization of Cascade Operation	Combined Cycle Power Generation; Gas Turbine Steam Turbine
Change of Process	Fuel Steel Mill; Open-hearth Revolving Furnace Cement Ind.; Suspension Preheat or New SP addition

(4) Energy Saving by Waste Heat Recovery

1) Common Ideas

Table 9.1.10 gives common ideas of waste heat recovery, a major factor in energy saving.

Table 9.1.10 Examples of Waste Heat Recovery

Utilization Items	Examples
By-product Gas	Blast furnace gas Petroleum Cracked Off-gas
Exhaust Pressure	Power generation by blast furnace gas Compressor driven by exhaust gas press.
Sensible Heat of Solid	Cokes dry quenching to recover as steam or electricity Slab cooling boiler
Steam Drain	Return to boiler
Cooling Water	Low temp. power generation Supply to fish pond, gardening
Exhaust Gas	Waste heat boiler, Absorptive chiller Low temp. power generation

2) Recovery of Steam Drain

Recovery of steam drain is the most effective energy saving method for boilers. Around 10% of fuel can be saved in small and medium boilers by this method. Steam drain is not as effective as flame or electricity as a heating agent. However, its recovery has the following merits.

i) fuel saving by recovering enthalpy of drain
ii) saving of boiler feed water
iii) reduction of air pollution by saving of fuel firing rate

There are direct and indirect methods to recover and use drain.

The direct method is to recover heat and water at the same time. It is necessary to confirm analytically beforehand the quality of water to ensure suitability for repeated use. The indirect method is to recover only the heat from the drain which has been or will be contaminated through its use, likely to be adopted in chemical factories or dye works. Fig. 9.1.15 to 9.1.17 are some of examples of the recovery.

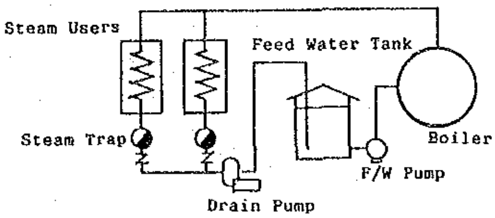


Fig. 9.1.15 Direct Recovery to Feed Water Tank

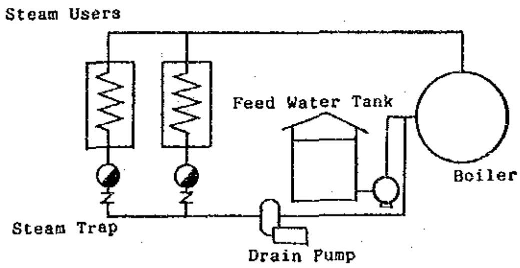


Fig. 9.1.16 Direct Recovery to Boiler

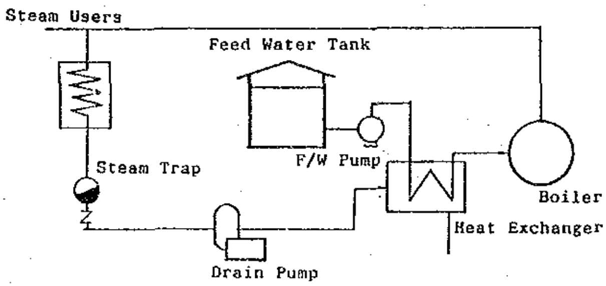


Fig. 9.1.17 Indirect Recovery through Heat Exchanger

3) Waste Heat Recovery Through Air Heater

Another example of heat recovery is to preheat charge air by an air heater with flue gas. This method is relatively easy to do and can be expected to be a great energy save. Fig. 9.1.18 shows the effect of air preheating.

If flue gas temperature falls 20 deg.C by using an air heater at an air ratio of 1.2, charge air temperature will rise around 23 deg.C and fuel saving will be around 1%. If the charge air temperature can be heated to about 115 deg.C, the fuel save will be around 2.5% and the flue gas temperature down to 100 deg.C. Note that the deg.C is the difference of the temperatures and not °C, the caloric temperature.

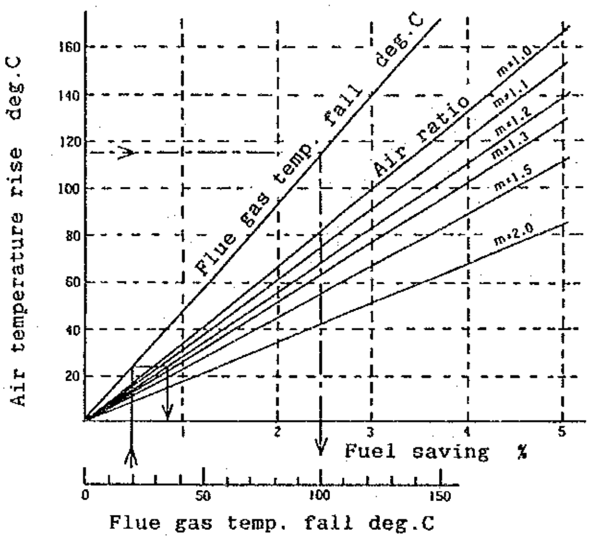


Fig. 9.1.18 Relationship of Air Heater and Fuel Saving

As higher charge air temperature accelerates combustion velocity, it will reduce requirement of excess air and production of unburnt matter. However, a drawback is that NOx formation will also be increased. It is desirable for the charge air temperature to be in the range of 100 to 120°C. Fig. 9.1.19 illustrates the heat recovery method by air heater.

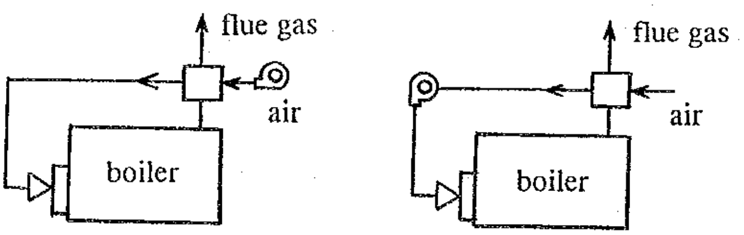


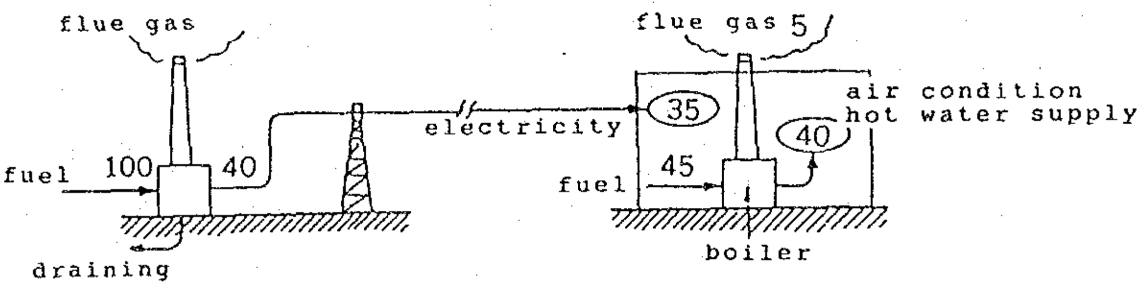
Fig 9.1.19 Heat Recovery by Air Heater

(5) Energy Saving in Natural Gas Combustion by Co-generation

Low pressure steam is usually used to air condition buildings, supply hot water, process materials in factories, etc. This system has about 50% energy utilization rate. Co-generation systems have become very popular to improve this efficiency. The system produces low pressure steam from waste heat from an electricity generating turbine. This system can be combined with an absorption refrigeration to air-condition factories, buildings, hotels etc.

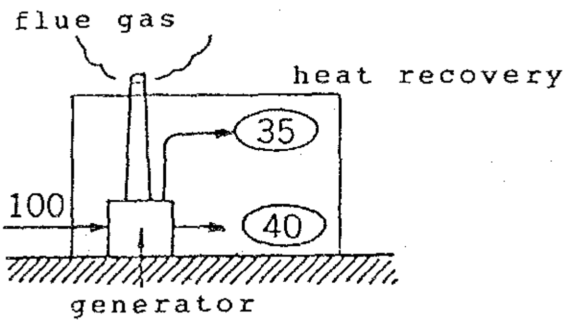
(a) Traditional System

Power Station　　　　Building



(b) Co-generation System

Building or Else　　　　Comparison of (a) & (b)



	a	b
supply energy	145	100
used energy	75	75
efficincy [%]	52	75

Source: KAGAKU KOGAKU (J) Vol. 51, No.3 (1987)

Fig. 9.1.20 Co-generation vs. Traditional System

The main pieces of equipment in the co-generating system are the gas turbine, the gas engine, or the diesel engine. As each one can be divided into small units and located separately, the system is easily expandable and should be strongly promoted. The major differences between this system and the traditional one are depicted in Fig. 9.1.20. Energy efficiency shown in the figure is based on the constant requirements of electric power and heat. They may actually be slightly lower because of demand fluctuation during the course of operation.

(6) Energy Saving in Factories

a) Recognition of Equipment Operating Conditions

It is quite important to recognize the current operating conditions of each piece of equipment related to energy supply and consumption in order to establish feasible, economical and concrete energy saving plans.

b) Control Committee

An energy saving control committee should be organized in each company or factory to discuss plans developed by each section, review overall energy saving policy and gather the necessary information.

c) Promotion of Energy Conservation Consciousness

It is advisable to publicize energy saving concepts, saving plans, manual, etc. and to schedule various events such as the rewarding of original saving idea, presentation of plans etc. in the company or factory to promote energy saving consciousness.

(7) Energy Saving of Buildings

The following considerations taken into account on the design and construction would prevent heat loss through walls, windows, etc. of offices, buildings, houses and so on.

a) to airtight fixtures on walls
b) to design shades to absorb direct sun rays
c) to control individual room temperature separately
d) to reinforce insulation

9.1.7 Technical Supporting System

The Association of Environmental Consultants and Contract of Malaysia (AECCOM) can provide technical support to industries who have pollution related problems. And, principally the support should come from independent and non-profit organizations. In the future, AECCOM is expected to support the training at the combustion training enter (Refer to Section 9.1.5).

Specialists may be additionally needed to oversee consultation at the combustion training operation and training on facilities and analytical equipment and apparatuses. These specialists may be recruited from university faculties, combustion researchers and engineers.

9.1.8 Financial Support System

A low interest rate fund loan system should be established within the government (national or local) or in some other appropriate organization to support industrial activities related to pollution control and facility modification. Laws or regulations governing this system may have to be established first.

It may also be necessary to ease taxes in order to encourage the installation, operation and maintenance of pollution control facilities.

9.1.9 Rough Cost Estimation

Below are rough estimates of investment costs for the anti-pollution measures at the power plant and the factories which have been proposed in the article 9.1.4.

Factories converting fuel oil to natural gas or to industrial diesel oil require more or less remodeling and additional investment. They have to install combustion managing instruments if they do not have these instruments. Similar instruments should be installed in those factories already burning cleaner fuel and having a capacity equivalent to the former group. Smaller factories may not need to install these instruments, although the combustion management will be enforced.

Investments for installing dust collectors in wood waste combustors are planned here as separate installation in 1997 and 2005. Also cost for modernization of an existing aged collector is included in the estimate. However, total requirement is unknown and not estimated here.

Only the equipment costs of Combustion Management Technical Training Center are included in the estimate, assuming that the existing facility is available.

All the costs given here are based upon costs in Japan (1992 price, M$1 = ¥50).

(1) Factories

1) Combustion Managing Instruments

Automatic O_2 analyzer to be installed at boilers larger than 400kg/h of fuel burning and manual gas analyzer (Orsat) to be installed at smaller boilers are required as managing instruments.

a) Automatic O_2 Analyzer

Specification: Magnetic or zirconia type, Range = 0 to 21%

Numbers installed: 23 units by 1997, 3 units by 2005

Investment Costs: M$11,000/each,

subtotal M$286,000

b) Orsat Analyzer

Numbers installed: 32 units

Investment Costs: M$1,000/each,

subtotal M$32,000

c) Sum of Combustion Management Instrument M$318,000

2) Fuel Conversion

a) Natural Gas Burner

Investment Costs:

Burner - M$126/(kg/h oil) (for sake of calculation)

Oil Pipings and others	- 0.67 times of burner cost	
Air Pipings and others	- 0.39 ditto	
Elect. and Instrument	- 0.56 ditto	
S. Alam 12 units		M$ 990,000
P. Jaya 16 units		1,880.000
Burner Total		M$ 2,870,000

3) Dust Collector

Three units by 1997 and additional three units by 2005 are assumed to be installed in the region at larger combustors. Multi-cyclons with blowers are selected for cost estimation.

Investment Costs: Cyclone M$0.82/Nm^3/h flue gas

Installation	- 0.47 times of cyclone cost	
Pipings	- 0.66 ditto	
Instrument	- 0.18 ditto	
Others	- 0.50 ditto	
	1997	M$2,890,000
	2005	1,100,000
Dust Collector Total		M$3,990,000

4) Wood Waste Boiler

a) Specification: water tube type, evaporation 3.5 tons/h spread stoker with multi-cyclone and chimney

b) Investment Cost:	Boiler	M$3,000,000
	Installation	80,000
	Subtotal	M$3,080,000
Total Cost		M$10,258,000

(2) Combustion Management Technical Training Center

1) Boiler

a) Oil & Gas Boiler

Specification:	Evaporation rate 1 ton/h with LNB, Air Heater, Chimney, Condenser		
Investment Cost:	Equipment		M$2,028,000
		Installation	80,000
		Subtotal	M$2,108,000

b) Wood Waste Boiler:

Specification:	Evaporation rate 3.5 tons/h with Multi-cyclone, chimney, wood mill (hammer 500kg)		
Investment Cost:	Boiler Equipment		M$3,000,000
		Installation	80,000
	Mill Equipment		132,000
		Installation	80,000
		Subtotal	M$3,292,000

2) Instruments

CO_2/CO Analyzer	M$17,000
Orsat Gas Analyzer	1,000
Gas Analyzer (NO_x, SO_x, O_2)	71,600
Three Thermometers (two kinds)	25,200
Hygrometer	11,200
Barometer	3,400
Two Anemometers	32,000
Flowmeters (water, oil, steam)	10,800
Flue Gas Sampler	18,600
Water Electroconductivity Meter	2,400
pH-meter	2,000
Water Hardness Analyzer	4,000
Dust Sampler	68,000
Subtotal	M$267,200

3)	Data Processor	M$13,200
	Total Equipment Cost	M$5,680,400

(3) Stack Modification

24 → 35 m high M$200,000/piece

9.2 Motor Vehicles

Motor vehicles are one of the major sources of air pollution in the Kelang Valley Region. Countermeasures for mobile sources are aimed at reducing the air pollutant emissions caused by motor vehicles.

9.2.1 Present State

Prior to an examination of countermeasures against air pollution, it is useful to take a look at the current situation which will determine appropriate actions. In Malaysia, the Department of Environment (DOE) has taken action to regulate air pollution from motor vehicles.

The Environmental Quality Act (EQA) 1974 outlines all activities relating to preventing or controlling pollution and protecting and enhancing the quality of the environment. Several regulations concerning motor vehicles have been enacted at present based on this Act. But as described earlier in Chapter 5, a huge volume of vehicles crowd the streets in KVR, emitting pollutants. In this Section, an outline of our research will be given on the following subjects :

(a) Countermeasures against pollution caused by motor vehicles
(b) Maintenance systems

(1) Countermeasures Against Pollution

The motor vehicle regulation was enforced in 1977 as "Motor Vehicle (Control of Smoke and Gas Emission) Rules" to control air pollution (black smoke) caused by motor vehicles using diesel fuel. In 1988, DOE undertook about 440 enforcement campaigns throughout the country, based on the law. A roving squad was also formed in KVR to check and prevent any inconveniences to the general public. Overall compliance in these campaigns was reported to be 84 percent.

Petrol vehicles are regulated by the, "Environmental Quality (Control of Lead Concentration in Motor Gasoline) Regulations 1985". The lead content in the fuel are being gradually reduced. Petrol is also regularly tested to monitor the content of lead level. In 1988, the results from the analyses of 87 samples, of which 50 were taken from oil refineries and the remaining 37 samples were from kiosks, showed that all met the stipulated standard of 0.4g/litre. And after 1991 lead level was strictly regulated to less than 0.15g/litre.

(2) Inspection and Maintenance of Vehicles

All vehicles registered in Malaysia are subject to annual inspection at the place where they are registered. These inspections mainly concentrate on safety, and inspection on amount of contaminants in the exhaust gas is rarely conducted. However, after the enforcement of the Motor Vehicle Rules 1977, as one preventive approach, DOE has carried out smoke checks on new vehicle models at the local assembly plant.

The Department has also responded to public complaints, traced the smoky vehicles and directed the vehicle owners to have the vehicles checked for compliance. Also officers visit respective workshops to test the smoke from stage buses. Under this system, stage buses of 9 companies operating in Kuala Lumpur and Petaling Jaya are regularly tested at their own workshop. The survey team discovered that some vehicles had their blow-by gas feedback hose disconnected. This proves that appropriate maintenance and checks before driving are not habituated.

(3) Types of Engine

More than 5,200,000 vehicles (Table 9.2.1) were registered in peninsular Malaysia in 1991, of which 366,990 (7.0%) use diesel engine. The diesel vehicles are vans, lorries, buses, and others. The majority of petrol fueled vehicles are motor cars, but motorcycles account for the greatest number.

Table 9.2.1 Peninsular Malaysia : Number of Motor Vehicles ,1991

Vehicle type	Number of Vehicles			Percent-age(%)
	Petrol	Diesel	Total	
Motorcycles	3,036,863	-	3,036,863	58.3
Taxis	9,576	16,932	26,508	0.5
Motor cars	1,633,352	44,719	1,678,071	32.2
Vans & Lorries	151,774	175,451	327,225	6.3
Buses	1,420	21,339	22,579	0.4
Others	11,947	108,549	120,496	2.3
Total	4,844,932	366,990	5,211,922	100.0
Total in 1988	3,974,845	274,913	4,249,758	—
Total in 1987	4,211,566	353,500	4,565,074	—

(4) Fuels Used

Table 9.2.2 shows change in petrol quality over time in Malaysia. With the exception of lead content, fuel standards in Malaysia are similar to those of Japan. Table 9.2.3 shows the amount of petrol supplied by Petronas to K.L. city and its surrounding areas.

Table 9.2.2 Change of Petrol Quality with Time

Year	Grade	Colour	lead (g/l)	Sulfur (%)	R V P	F B P
1973	97	Red	0.84	0.2	66	220
	85	Orange	0.75	0.2	66	220
1985	97	Red	0.4	0.2	66	210
	85	Orange	0.4	0.2	66	210
1991	97	Red	0.15	0.15	70	215
	85	Orange	0.15	0.15	70	215

Note) RVP : Reid vapor pressure(kg/cm^2)
FBP : Final boiling point(℃)

Table 9.2.3 Amount of Fuel Consumption for Motor Vehicles in 1990

(unit: million ton)

Fuel Categories		Klang Valley	(%)	Malaysia (%)
Premium gasoline	leaded	535	25.7	2078(100)
	unleaded	356	25.7	1385(100)
Regular gasoline		6	2.5	238(100)
Diesel oil		352	10.5	3342(100)

9.2.2 Necessity for Control of Exhaust Emission

(1) Air Quality in the Future

Our air quality study in KVR revealed that concentrations of CO and PM10 around the trunk roads exceeded the air quality guidelines. NOx pollution may become serious in the future as traffic becomes heavier. The future concentration maps are shown in Chapter 8.

(2) Exhaust Emission Generation Mechanism

Motor vehicles such as motor cars, buses and trucks run on a principle using combustion energy from petroleum fuel. Therefore, pollutants are emitted to the atmosphere as unburnt fuel components and generated substances during or after the combustion as explained in Table 9.2.4.

Table 9.2.4 Exhaust Emission Generation Mechanism

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="2">Generation mechanism</th><th rowspan="2">Characteristics</th></tr>
<tr><th>Gasoline engine</th><th>Diesel engine</th></tr>
<tr><td rowspan="3">Exhaust gases</td><td>C O</td><td colspan="2">Incomplete fuel combustion due to O_2 shortage</td><td>Determined mostly by air-fuel ratio</td></tr>
<tr><td>H C</td><td colspan="2">Emission of unburnt fuel
• Incomplete fuel combustion due to O_2 shortage or excess
• Quenching by combustion chamber wall
• Wrong fuel mixing
• Fuel blow through the chamber</td><td>• Uneven mixing ratio and temperature distribution
• Affected by many combustion impeding factors
• Large amount of HC emitted during deceleration in gasoline carburetor vehicles without catalyzing system
• Increased even under a light load (diesel vehicle)</td></tr>
<tr><td>NO x</td><td colspan="2">Reaction in flame and high-temperature burnt gases (oxidation of nitrogen)</td><td>Depending largely on max. combustion temperature and air-fuel ratio</td></tr>
<tr><td rowspan="2">Particulates</td><td>Smoke</td><td>——</td><td>Incomplete fuel combustion due to O_2 shortage</td><td>• Affected largely by air-fuel ratio
• Caused by uneven air-fuel ratio distribution</td></tr>
<tr><td>SOF and others</td><td>——</td><td>Emission of unburnt fuel
• Incomplete fuel combustion due to O_2 shortage
• Quenching by combustion chamber wall
• Wrong fuel mixing
Emission from lubricating oil due to incomplete combustion
Sulfur oxide emitted from sulfur in fuel</td><td>Affected by below
• Uneven mixing ratio and temperature distribution
• Affected by many combustion impeding factors
• Increased even under a light load condition
Affected by the amount of lube oil consumption
Affected by the amount of sulfur in fuel</td></tr>
</table>

(3) Outline of Control Measures for Motor Vehicles

Exhaust emission control measures for motor vehicles are examined in the categories described below (Fig. 9.2.1).

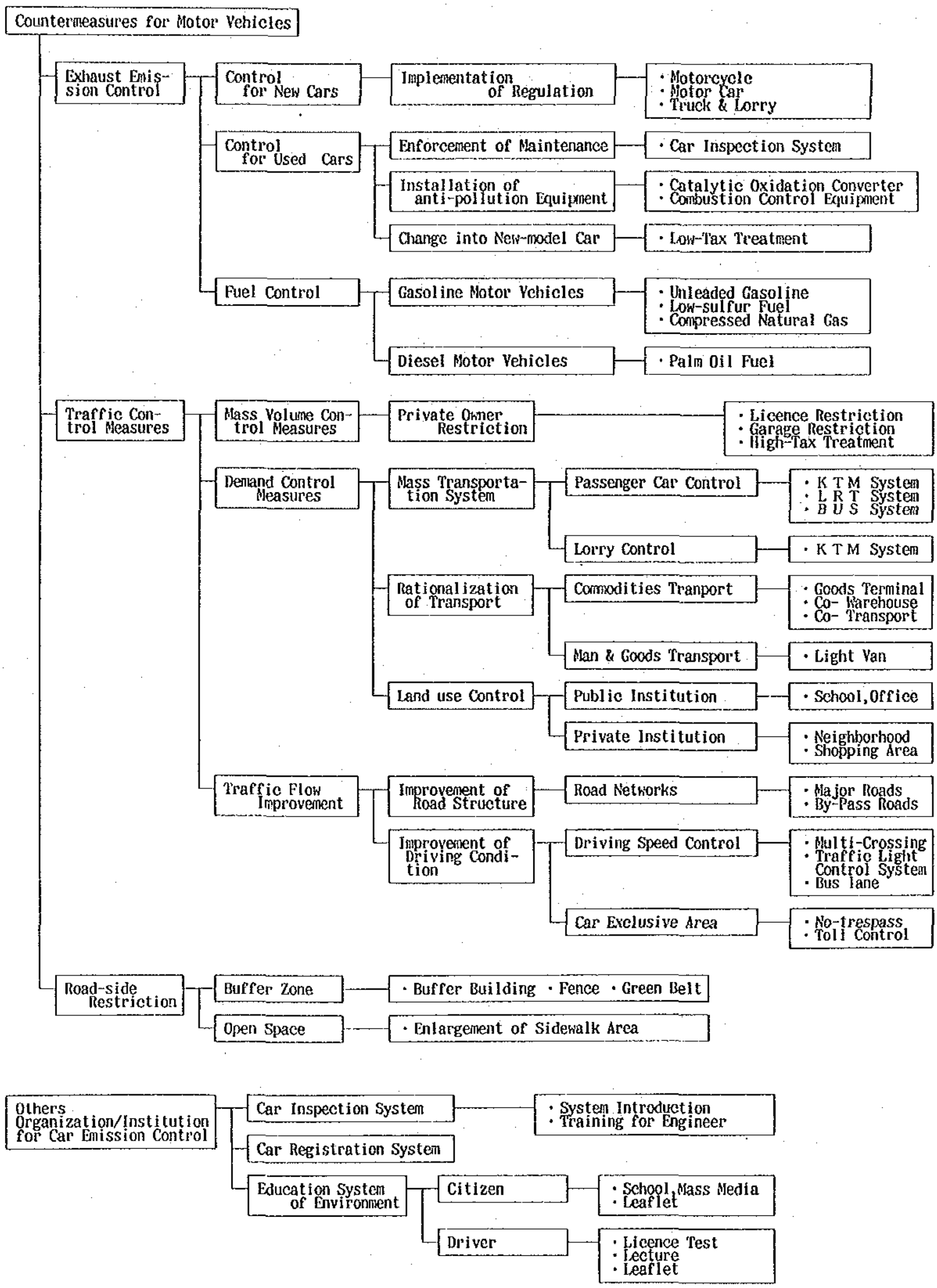


Fig. 9.2.1 Outline of Control Measures

9.2.3 Exhaust Emission Control

(1) Control Technologies

1) Petrol Motor Vehicles

(a) Countermeasures against CO and HC

Both CO and HC are emitted into the exhaust gas in large quantities when the air and petrol mixing are incomplete for combustion or during deceleration. Common measures are described in Table 9.2.5 and Fig. 9.2.2. Refer to Table 9.2.7 for abbreviated symbols in parentheses.

Table 9.2.5 Countermeasures against CO, and HC for Petrol Motor Vehicles

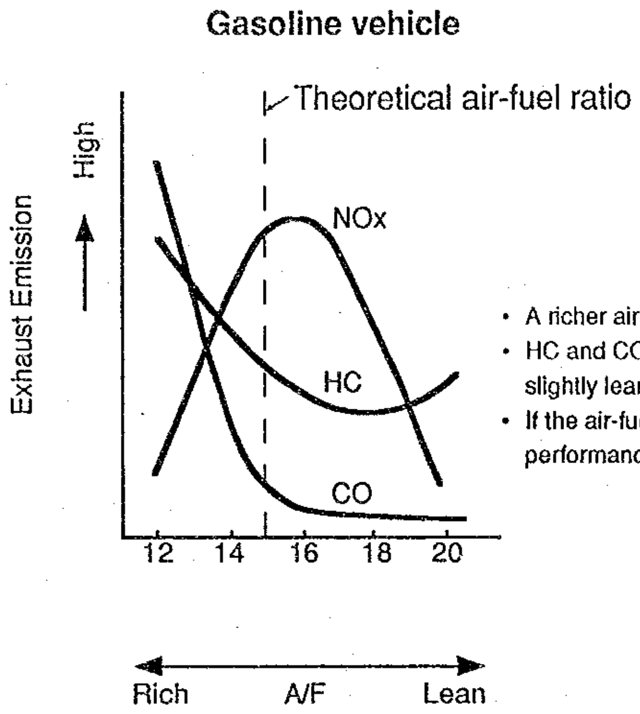
a)Improvement of carburetor performance (Enhancement of part accuracy, use of electronic control)
b)Employment of electronic fuel injector (EFI) in place of carburetor
c)Air preheating
d)Improvement of configuration of air intake manifold to improve gas distribution to each cylinder
e)Prevention of sudden closing of throttle valve during deceleration (TP,DP)
f)Introduction of air into air intake manifold during deceleration
g)Stop of gasoline supply during deceleration
h)Optimizing of valve timing to avoid leakage of non-combusted gas due to overlap
i)Increase in ignition energy
j)Reinforcement of re-combustion for unburnt gas by raising the temperature(SC)
k)Aiding re-combustion for unburnt gas by introducing secondary air into the exhaust manifold(AI,AS)
l)Installation of catalyst in the exhaust system (OC,TWC)
m)Positive crankcase ventilation system (PCV)
n)Fuel evaporation emission control system(EVAP)

(b) Countermeasures against NOx

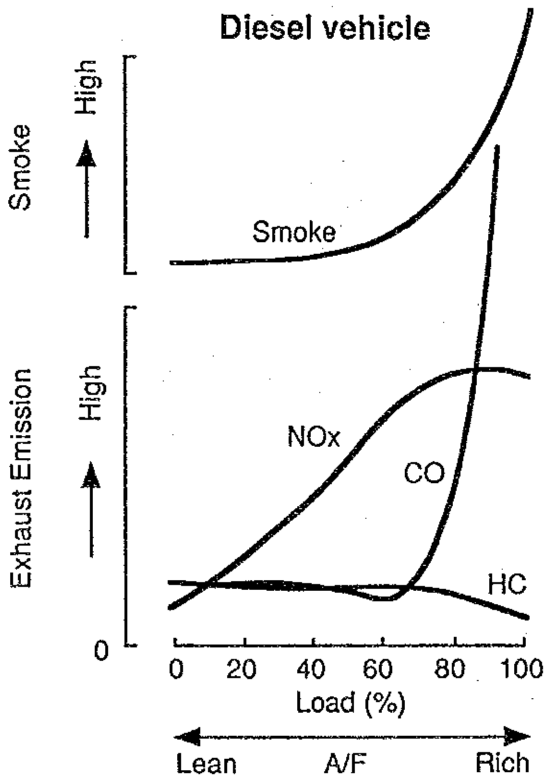
NOx emissions can be reduced by maintaining the theoretical air-fuel ratio (A/F) and lowering the combustion temperature. Table 9.2.6 and Fig. 9.2.2 explain common measures to control NOx emissions.

Table 9.2.6 Countermeasures against NOx from Petrol Vehicles

a)Maintaining the air-fuel mixture gas in a condition of the fuel-rich or the air-rich than the theoretical ratio(EFI)
b)Employment of an exhaust gas re-circulation method to keep the combustion temperature (EGR) low.
c)Optimization of the valve control timing to lower the combustion temperature
d)Installation of decomposition catalyst (TWC) in the exhaust system to eliminate nitrogen oxides



- A richer air-fuel ratio reduces NOx but increases HC and CO.
- HC and CO are low but NOx is high in the range near and slightly leaner than the theoretical air-fuel ratio.
- If the air-fuel ratio is made even leaner, the stable combustion performance is hampered.



- Smoke and CO surge sharply under a heavy load (rich air-fuel ratio condition).
- NOx rises as the air-fuel ratio changes from lean to rich, and levels off under a heavy load (rich air-fuel ratio).

Fig. 9.2.2 Relationship between Air-fuel Ratio and Exhaust Emission

(c) Practical Application of New Regulations

Emission gas regulations were put into practical application to counter-measure air pollution in California, USA, in 1962. Later similar regulations have been put into practice in various countries. The principal technologies employed to comply with these regulations are shown in Table 9.2.7.

Table 9.2.7 Exhaust Emission Control Devices Adopted by Some Countries

Country		HC	CO	NOX
ECE15	PCV	O		
	TP or DP	O	O	
	SC	O		O
	Lean-Set Car		O	
SWEDEN	PCV	O		
	TP or DP	O	O	
	SC	O		O
	EGR			O
	AI or AS	O	O	
CANADA	PCV	O		
	EVAP	O		
	TP or DP	O	O	
	SC	O		O
	EGR			O
	AI or AS	O	O	
	OC	O	O	
US'83	PCV	O		
	EVAP	O		
	DP	O	O	
	EGR			O
	TWC	O	O	O
	EFI	(Back up TWC)		
JAPAN S53	PCV	O		
	EVAP	O		
	DP	O	O	
	EGR			O
	TWC	O	O	O
	EFI	(Back up TWC)		

Note:

PCV:Positive Crankcase Ventilation System
TP :Throttle Positioner System
DP :Dash Pot System
SC :Ignition Timing Control System
EGR:Exhaust Gas Recirculation System
AI :Secondary Air Injection System
AS :Secondary Air Suction System
EVAP:Fuel Evaporation Control System
OC :Oxidation Catalyst System
TWC:Three-Way Catalyst System
EFI:Electronic Fuel Injection System

Table 9.2.8 shows a history of regulation and counter action in Japan.

Table 9.2.8 History of Regulation and Counteraction in Japan (Petrol)

Year	Japanese Regulations	Example of counteraction by Japanese Car Maker
1970	CO:4.5% during idling (Required to install a blow-by gas reducing unit)	Adjustment of the air-fuel ratio and installation of a CO meter at all service stations in the country
1972		Installation of activated carbon canister Change of engine design
1973	CO :26.0g/km HC : 3.8g/km NOX: 3.9g/km	
1975	CO : 2.7g/km HC : 0.4g/km NOX: 1.6g/km	Installation of oxidation catalyst
1976	NOX: GVW $<$ 1 ton:0.84g/km GVW $\geq$ 1 ton:1.20g/km	Employment of a diluted combustion method
1977		Installation of a three-way catalyst
1978	CO : 2.1 g/km HC : 0.25g/km NOX: 0.25g/km	

2) Diesel Motor Vehicles

Materials concerning pollution control for diesel vehicles are mainly aimed to counter black smoke and NOx, plus sulphur contents in diesel oil (Table 9.2.9). Control measures against black smoke, include improvement of air intake systems to secure a sufficient amount of air, optimization of air swirl flow in cylinders to improve mixture with fuel, and improvement of the injection timing and fuel atomization to ensure satisfactory combustion. But these measures have not been very effective, and a black smoke trap and catalyst unit are under study.

Various measures are employed to reduce NOx, such as the exhaust gas recirculation or the retard method to delay the injection timing. But these methods create some such problems as increased black smoke or engine wear, for which research is being currently carried out.

Table 9.2.9 Methods of Reducing Exhaust Emission from Diesel Vehicles

Exhaust emission	Engine improvements	Diesel fuel improvements
HC, CO	EM	Cetane numbe (high) 50% distillation temperature (low)
NOx	EM EGR Reduction catalyst	Cetane number (high) Viscosity (optimal) Sulfur (low)
Particulate	EM Oxidation catalyst DPF	Sulfur (low) Distillation temperature (low) Aromatic content (low)
Smoke (hot engine)	EM DPF	Cetane number (optimal) Aromatic content (low)

Note) EM : Engine Modification (fuel and injection systems)
DPF : Diesel Particulate Filter

3) Technologies to Meet Regulations

The regulations enforced in various countries, major control systems installed under the regulations, and corresponding price increases are given in the following Tables 9.2.10 and 11.

(a) Motor Cars (Petrol)

Table 9.2.10 Effect on Fuel Economy and Vehicle Price (Petrol)

Regula-tions	Country	Major exhaust emission control system	Effect on Fuel economy(%)	Increase in vehicle price(M$)
ECE15-04	Europe	①Engine modification Leaner air-fuel ratio Deceleration control Ignition timing control	0 ~- 5	~ 300
US 1973 US 1975	U.S.A	①EGR ②Secondary air/EGR	-10 ~-20	900 ~1,200
US'75/77 Japan'75	U.S.A Japan	①Secondary air/EGR ②Oxidation catalyst	- 5 ~-10	1,200 ~1,800
US 1981 Japan'78	U.S.A Japan	①Three-way catalyst ②Three-way catalyst/EGR	0 ~+ 5	3,000 ~4,000

Note : Exchange rate 1M$=¥50

(b) Motor Cars (Diesel)

Table 9.2.11 Effect on Fuel Economy and Vehicle Price (Diesel)

Regulations	Country	Major exhaust emission control system	Effect on Fuel economy(%)	Increase in vehicle price(M$)
ECE15-04 EEC /88/76	Europe	①Engine modification	0	0 ~ 80
Japan'86 Japan'87	Japan	①Engine modification ②Injection rate control ③Injection timing control (②, ③mechanical type) ④EGR	0	200 ~ 800
US'88LDT US'87LDV EEC /91/441 (CED I)	Europe	①Engine modification ②Injection rate control ③Injection timing control (②, ③mechanical type) ④EGR	0 ~- 2	800 ~1,000
Japan'90 Japan'92	Japan	①Engine modification ②Injection rate control (improve mechanical type) ③Injection timing control (electrical type) ④Increased EGR	-1 ~- 3	1,000 ~1,400

(2) Control over Motor Vehicles in Circulation

1) Background

According to our study of exhaust gas measurements at idling state, some of the motor cars, vans and small trucks tested showed high CO concentrations of over 10%. The most fundamental measure is to thoroughly maintain and inspect them. Besides implementation of countermeasures for them, shift to new and low emission vehicles is effective.

2) Car Inspection and Maintenance System

Examples in Japan explain how these vehicle exhaust emissions have been controlled. The inspection and maintenance system will be discussed in Section 9.2.6.

Table 9.2.12 shows the relevant Japanese regulations. Emission checks are conducted for CO, HC and diesel smoke, except for NOx which is under study currently. Service shops approved by the Japanese Ministry of Transport analyze the exhaust gas in accordance with the regulation and repair or change parts which do not meet the standards.

Table 9.2.12 Regulation of Exhaust Emission for In-use Vehicles in Japan

Pollutant	Vehicle type	Analysis Condition	Limit
C O	Gasoline or LPG fueled	Idling	4.5%
H C	Gasoline or LPG fueled (excluding 2 stroke)	Idling	1200ppm
	Gasoline or LPG fueled (2 stroke)	Idling	7800ppm
	Gasoline or LPG fueled Excluding the above	Idling	3300ppm
Smoke	Diesel fueled	Unload & acceleration	50 %

The effects of inspection and maintenance for motor cars are shown in Table 9.2.13 and Fig. 9.2.3.

Table 9.2.13 Benefits of Inspection and Maintenance
(Exhaust emission reduction - example of motor car)

Exhaust emission reduction system		Vehicle condition	Average of 10-mode test results g/km		
			C O	H C	N O x
Three-way catalyst	Electronic Fuel Injection 52 units	Before maintenance	1.42	0.12	0.24
		After maintenance	1.19	0.10	0.19
		Benefit of maintenance	16.2 (%)	16.7 (%)	20.8 (%)
	Carburetor 28 units	Before maintenance	4.45	0.22	0.23
		After maintenance	2.16	0.11	0.22
		Benefit of maintenance	51.5 (%)	50.0 (%)	4.3 (%)
Maximum Standards (mean value standards)			2.70 (2.10) (g/km)	0.39 (0.25) (g/km)	0.48 (0.25) (g/km)

Source: Japan Ministry of Transport March 1991

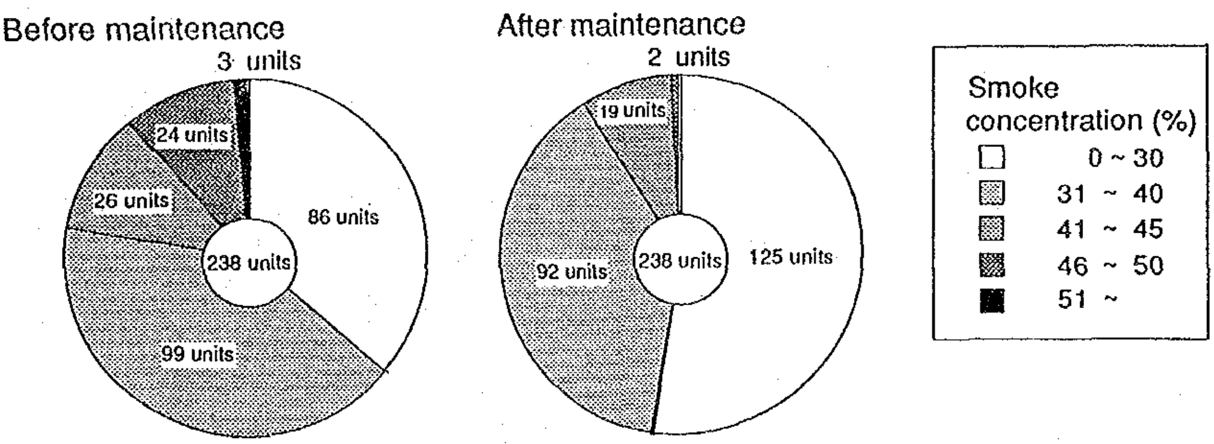


Fig. 9.2.3 Effect of Smoke Reduction by Inspection and Maintenance (Japan)

3) Example of Measures for In-use Vehicles and Their Problems

Table 9.2.14 outlines the measures for in-use vehicles (petrol vehicles). Although some measures are available to reduce emissions from vehicles, each has some problems.

Table 9.2.14 Measures for In-use Vehicles and Problems

	Measure # 1	Measure # 2	
Procedure	Retard ignition timing	Retro-fitted catalytic converter	
		Oxidation catalyst	Three way catalyst
Effects	HC,NOx reduced	HC,CO reduced	HC,CO,NOx reduced
Required Condition	――――	Use unleaded petrol	
		Install secondary air system	Install feedback control system of air/fuel ratio
Problems	Drivability and fuel economy worsened	①May cause damage to inlet/exhaust valve seals with use of unleaded petrol ②Excessive heat and reduced performance of unburnt CO and HC during deceleration ③May cause fire due to excessive heat of catalyst as exhaust gas temperature rises at high load	
Comments	Not difficult to carry out the procedure. This is recommended if above problems are acceptable	Not recommended procedure because above problems cannot be solved without complicated modification to the system	

(3) Introduction of Alternative Energy

1) Background

Introduction of alternative energy is important for diversification into various kinds of energy and for securing energy supply, and also for the purpose of air pollution control via effective energy usage and utilization of low polluting energy sources.

Motor vehicles move freely over a complicated and dense network of roads in big cities, and the number of motor vehicles keeps increasing with rapid urbanization. It is difficult to control exhaust emission as planned. With diesel vehicles, NOx and SPM are difficult to regulate using the present technology. This is because modification of combustion and development of filters create limitation in contrast to improved engine performance.

Recent introduction of vehicles fueled by alternative energy is becoming attractive as a countermeasure to the above issue. There are vehicles that are undergoing road test for methanol, CNG(compressed natural gas), electric powered, and also hybrid system which are equipped with both electric motor and conventional engine. These vehicles are expected to be low polluting with less emissions of PM, NOx and SOx, and without much technical problems.

2) Types and Characteristics of Alternative Energy Vehicles

Topics on impact on air quality and technology development of alternative energy vehicles are described below.

a) Pollutant Emissions

Electric vehicles are non-polluting as they produce no gas emission during running.

Methanol and CNG vehicles emit lower amounts of pollutants than diesels. The percentage of NOx reduction by converting to methanol and CNG is 50% and 14% respectively, and almost no particulate are emitted by either of these fuels. HC emission is zero from methanol vehicles, assuming installation of oxidation catalyst and is also almost zero as NMHC from CNG vehicles. Table 9.2.15 shows some emission amounts from these vehicles for comparison. Also the benefits of the alternative vehicles are indicated in the Table using marks (◎, O Δ and X from the highest to the lowest).

b) Natural Gas

Since all the fuel used in CNG vehicles is natural gas which is a natural resource of Malaysia, a large scale conversion from the petrol to CNG will occur. Also, methanol is largely produced from natural gas. Energy to power motor vehicles will be widely diversified by these two types of fuel.

Table 9.2.15 Comparison of Emission Level for Alternative Energies

Vehicle Type	Exhaust emission					Fuel safe-ty	Cruis-ing dist. index	Ease of use	Technological challenges
	CO PPM	HC PPM	SOx %	NOx PPM	PM %				
Petrol Vehicle	○ 592	△ 237	○ 0.00	× 424	○	○	100	◎	
Diesel Vehicle	○ 390	△ 295	△ 0.20	× 380	× 37	○	120	◎	Low-NOx Low-PM
Hybrid Vehicle	○	△	△	△	△	○	130	○	Optimization Battery life
Natural Gas Vehicle	◎ 32	○ 114	◎ 0	◎ 54	◎ 0	△	15~25	△	Running dis-tance Safety
Methanol Vehicle	◎ 8	◎ 6	◎ 0	◎ 196	◎ 0	△	50	△	Ignition plug Cataly system
Electric Vehicle	◎ 0	◎ 0	◎ 0	◎ 0	◎ 0	○	10~15	△	Running dist. Battery life

3) Fuel Economy of Alternative Energies

Motor vehicles are tools for mass transportation of people and goods using petroleum fuels which is basically stored energy in highly concentrated form. The economy of alternative fuels can be compared in fuel economy and loading capacity as in Table 9.2.16. The evaluation of the alternative fuels should take into account necessary infrastructure of these fuels required as well.

Table 9.2.16 Comparison of Economy of Alternative Fuels

Vehicle type / Item	Petrol truck	Diesel vehicle	Methanol vehicle	Electric vehicle	C N G vehicle
Mileage in urban area	600(100) ×1.2	600(100)	450(75) ×1.5	50(8)	175(30)
Load capacity	2t(100)	2t(100)	2t(100)	1t(100)	2t(100)
Price of vehicle	(90)	(100)	(110)	(200)	(110)
Cost of fuel (per Km)	(222)	(100)	(140) Plug change	(500) Battery change	(120)
Cost of infra-structure	Adjusted M$400,000	Adjusted M$400,000	Need adjustment M$400,000	Need adjustment M$1 milion	Need adjustment M$1 milion

9.2.4 Traffic Volume Control

An outline of traffic control will be described in this section.

(1) Traffic Management

A summary of the control measures for traffic volume, their expected effects and related problems are described below.

1) Traffic control

Table 9.2.17 Traffic Control

Measures	Terms		Method		Effect		Results & Problems	
	L	S	D	ID	E.F.	T V	Technical	Social & Economic
Car limits in Downtown		○	○			○	• More difficult to prohibit by usages	• Inconvenience to business activities
	Prohibit cars using designated area (by car type, purpose of use, and time)							
Bus lane		○		○		○	• Emission control • Congestion to other vehicles • Enforcement	• Inconvenience to business • Improvement of bus service
	Improve mobility of buses and encourage more people to use buses							
Traffic Signal Modernization		○	○		○		• Possiblity of uninterrupted flow • Speed control	• Investment required
	Smooth flow by sensing traffic in wider area							
Multi-level crossing		○	○		○		• Possiblity of un-interrupted flow	• Investment required

① L − Long term, S − Short term
② D − Direct, I D − Indirect
③ E.F. − Emission factor, T V − Traffic volume

2) Parking Lot

Table 9.2.18 Parking Lot Control

Measures	Terms L	Terms S	Method D	Method ID	Effect E.F.	Effect T V	Results & Problems: Technical	Results & Problems: Social & Economic
Prohibition of On-road Parking		O		O		O	· Stricter enforcement · Alternate transport system	· Inconvenience to business activities
	Prohibit parking on designated roads (by area, time zone)							
Regulation of Parking Lot Installation		O		O		O	· Stricter enforcement · Alternate transport system	· Inconvenience to business & social activities
	Close or restrict lots in designated area							

3) Methods for Traffic Light Control

Table 9.2.19 Types of Traffic Light Control

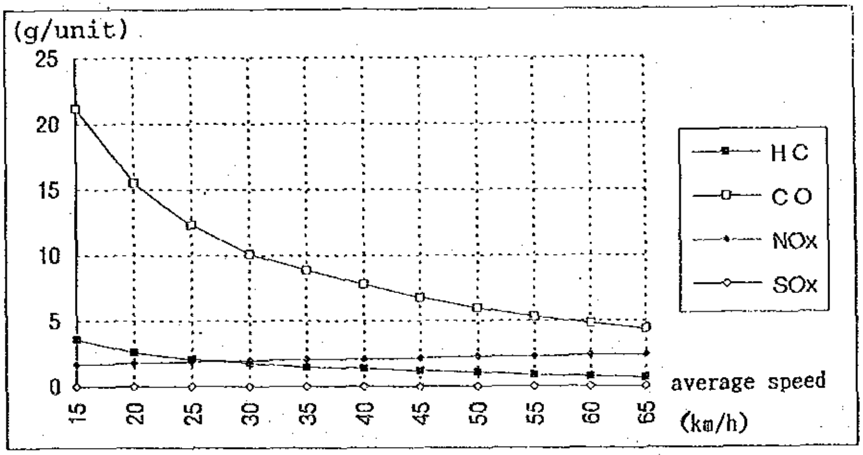
①Point sensor	Automatically control traffic signals by sensing variation of traffic volume at a intersection where the variation is supposed to be large (M$400,000)
② Night Semi-sensor	During night and early morning, to keep the main road uninterrupted at a small intersection except when traffic approaches there from the side road (M$ 20,000)
③ Night Push Button	During night and early morning, manual push buttons to cross an intersection (M$ 5,000)
④ Multi-programmed Control	Control traffic according to the programmed schedule not only hourly but daily on weekdays and holidays or any other specific day of a year(M$ 20,000)
⑤ Multi-expression Signal	Use a combination of signals simultaneously to improve traffic control at intersections where many roads intersect or where much traffic turn right and left (M$ 60,000)

Note) The cost of newly installed for traffic light (basic cost) is approximately M$ 40,000.

4) Velocity Control and Adjustment of Signal

Traffic flow will become smooth by controlling signal timing. This will help to control the flow velocity and thus reduce NOx and other emissions. Emission factors are plotted against velocity (Fig. 9.2.4) for motor cars which are identified to have great contribution to air pollution in KVR.

Fig. 9.2.4 Exhaust Emission Factor of Motor Car vs. Average Speed (in Malaysia)



(2) Discouraging Private Ownership of Vehicles

Table 9.2.20 Discouragement of Private Ownership of Vehicles

Measures	Terms L	Terms S	Method D	Method ID	Effect E.F.	Effect T V	Results & Problems: Technical	Results & Problems: Social & Economic
Hikes of Related Taxes & Tariffs		○		○		○	• Detailed survey to understand the effects	• Opposition from owners • Opposition from related sectors
	• Making hard to own cars • Allocate funds for environmental controls							
Tax Hike on Uncontrolled Cars		○		○	○	○	• Stricter enforcement • Opening of service shop	• Opposition from owners
	Impose emission control							
Restriction of Licence Grant		○		○		○	• Review of current licencing system	
	Implement stringent grant conditions of licences (by age, etc.)							
Restriction of Parking Space		○		○		○	• Issue of certification card • Stricter enforcement of unlawful parking	
	Issue car ownership who posses park space's certification							

(3) Management of Vehicle Demand on Roads

1) Implementation or Extension of Mass-transit System

Some examples of mass-transit system implementation and its extension are listed in Table 9.2.21 to illustrate their effects and problems.

Table 9.2.21 Management of Vehicle Demand on Roads

Measures	Terms		Method		Effect		Results & Problems	
	L	S	D	ID	E.F.	T V	Technical	Social & Economic
Trunk Public Transport System (K T M)	○			○		○	· Modernaiz-ation of existing rail system · New station	· Requireme-nt of huge investment · Great impact to economy
	Promote use of mass transport systems							
New Urban Transport System (L R T)	○			○		○	· Construct-ion of LRT network · New station	· Requireme-nt of huge investment · Great impact to economy
	Promote use of mass transport systems							
Improvement of Bus Services		○		○	○		· Emission controled bus · High class bus	· Investment required
	Promote use of public business for convenience and commuting to work							

2) Pollution Control by Proper Urban Planning

Table 9.2.22 Adjustments in Urban Planning

Measures	Terms		Method		Effect		Results & Problems	
	L	S	D	ID	E.F.	T V	Technical	Social & Economic
Urban Develo pement close to business zone	O			O		O	• Renovation of downtown • New traffic system	• Requirement of huge investment
	To reduce car traffic for commuting to work							
Organization of Inter-depended Facilities in One Place	O			O		O	• Construction of business towns, shopping malls etc.	• Huge investment required
	To reduce numbers & distances of business trips by organizing related facilities in close location							
Relocation of Industrial Facilities	O			O		O	• Centralization of related facilities • Modernization of facilitys	• Compensation to employees • Investment required
	To reduce business traffic by relocating into suburbs							
Restriction of Industrial Facilities in Town	O			O		O	• Centralization of related facilities • Modernization of facility	• Compensation to employees • Investment required
	To reduce business traffic by relocating into suburbs							
Construction of Transport Center		O		O		O	• Appropriate location • Arrangement of road networks	• Investment required
	To rationalize truck usage by creating transport centers							
Rationalization of Good Transport System		O		O		O	• High efficient trucking methods • Selection of business types • Requirement of agreement among business groups	
	Transport goods effectively and logistically by coordinating collection and distribution on a cooperative basis							

9.2.5 Type Approval System

(1) Certification System in Japan, U.S.A and Europe

The vehicle certification system for new models have already been implemented in many countries. The system consists of three major parts, namely

(a) Certification before mass-production
(b) Emission check during manufacture
(c) Inspection after manufacture

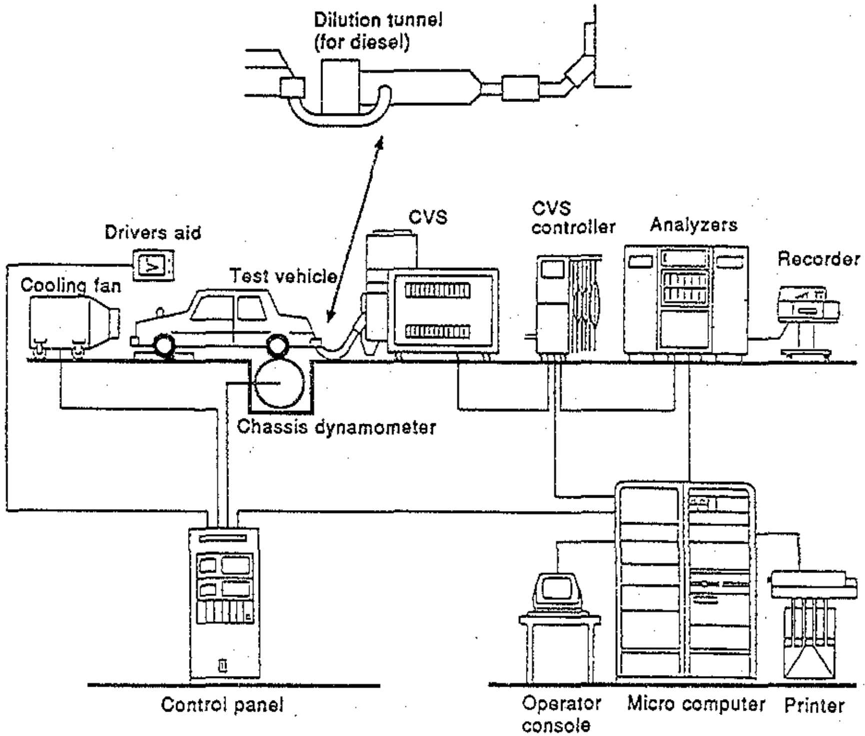
Detailed implementation is different in each country, as shown in Table 9.2.23.

Table 9.2.23 Certification System in Various Countries

Country	Pre-production		Assembly-line	In use
	Testing	Certificate		
Japan	Official laboratory	Issued by government	Sampling emission test by manufacturer	Periodic inspection and maintenance by government or authorized service shop
U.S.A	Official laboratory and/or manufacturer	Issued by government	Selective audit testing under the order of government	Emission testing of privately owned vehicle by government
EEC/ ECE	Official laboratory	Issued by government		
Australia	Manufacturer	Issued by government	Test Facility Inspection(TFI) Conformity of Production(COP)	Emission testing of new vehicle by some state government
EFTA	Official laboratory and/or manufacturer	Issued by government		Emission testing of stabilized vehicle by government
Canada	Manufacturer	Self certificate		Emission testing of stabilized vehicle by government

Hardwares required for the type approval are illustrated in Fig. 9.2.5. A flowchart of the Japanese type approval process is given in Fig. 9.2.6 as an example.

Fig. 9.2.5 Type Approval System



Approx. cost

	Automobile		Motorcycle
	Gasoline	Diesel	
Chassis dynamometer (Incl. drivers aid)	¥100,000,000 ($810,000)	←	←
CVS system	¥30,000,000 ($240,000)	←	←
Gas analyzers	¥50,000,000 ($410,000)	←	←
Dilution tunnel		¥30,000,000 ($240,000)	
Total	¥180,000,000 ($1,460,000)	¥210,000,000 ($1,700,000)	¥180,000,000 ($1,460,000)

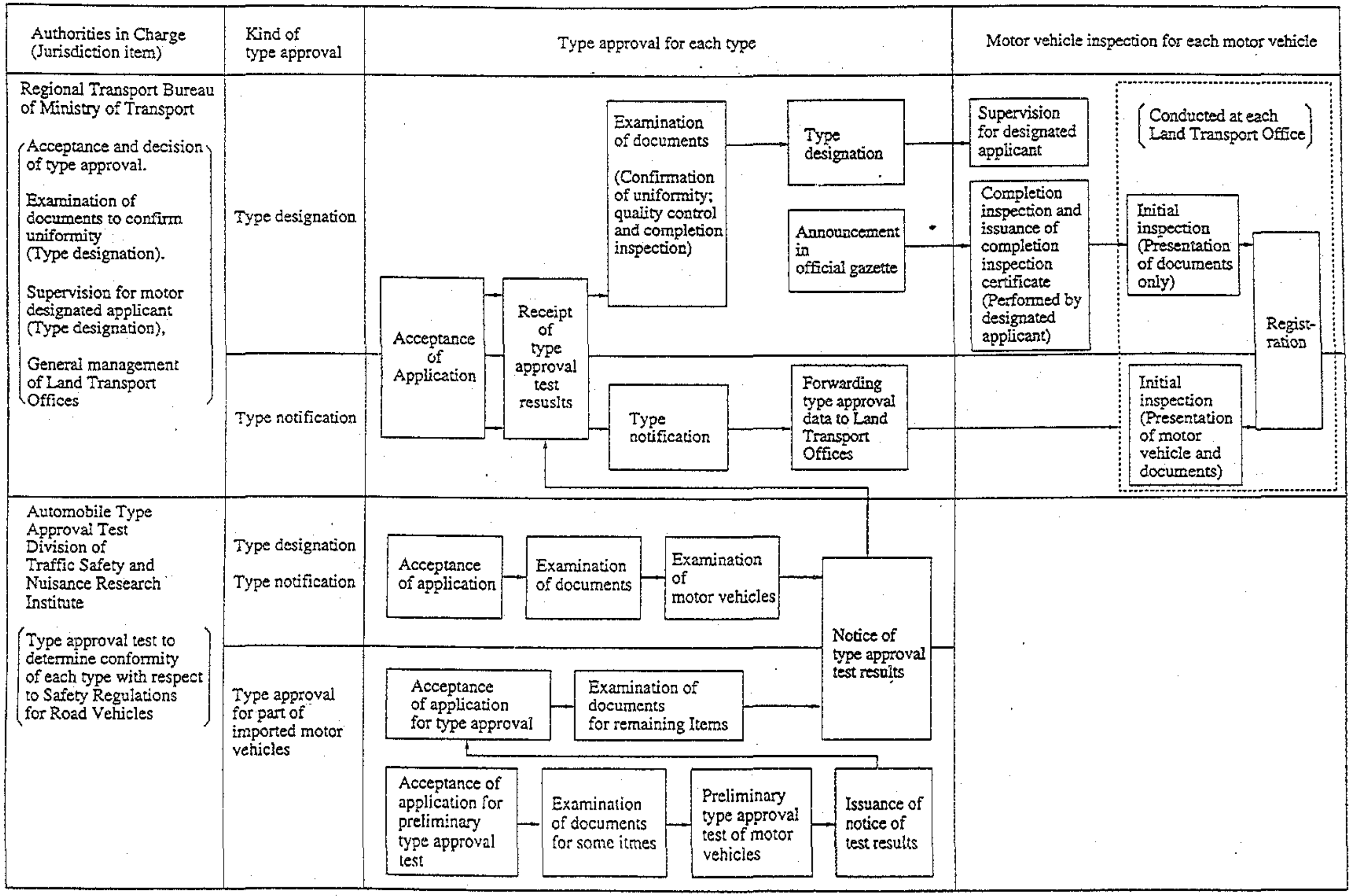
Required manpower

2

Driver

Operator for test equipment

Fig. 9.2.6 Flow Chart of Type Approval System in Japan



(2) Lead Time for Enforcement after Issuance

Tables 9.2.24 to 9.2.26 are examples of required period (lead time) before actual enforcement is carried out after the first publication or notification of each regulation.

1) Petrol Vehicles

Table 9.2.24 Lead Times for Enforcement for Petrol Vehicles

Country and Regulation	Lead time (months)							Enforced
		-36	-30	-24	-18	-12	-6	
Japan								
'75				△		○		●
'78				△	○			●
U.S.A								
'68					□			●
'75					□			●
'80			□					●
Australia								
ADR27					□			●
ADR37	47 □							●
Europe								
ECE15/04	46 □					○		●

Note : ○ New models , △ Exisiting models , □ All models

2) Diesel Vehicles

Table 9.2.25 Lead Times for Enforcement for Diesel Vehicles

Country and Regulation	Lead time (months)							Enforced
		-36	-30	-24	-18	-12	-6	
Japan								
'77					△	○		●
'79				△		○		●
U.S.A								
'74				28 □				●
'88	48 □							●

Note : ○ New models , △ Exisiting models , □ All models

3) Motorcycles

Table 9.2.26 Lead Times for Enforcement for Motorcycles

Country and Regulation	Lead time (months)							
		-36	-30	-24	-18	-12	-6	Enforced
U.S.A '78	49	▲				□		●
'80	▲	□						●
ECE NO.40	60 ▲					○		●

Note : ○ New models
□ All models
▲ Proposal

(3) Desirable Certification System in Malaysia

Enforcement of a certification system in Malaysia should be considered as an important issue, to control air pollution in anticipation of the increase of vehicles in the future.

The following steps are recommended for Malaysia, similar to those taken in Japan.

(a) Required emission allowance of each vehicle
(b) Safety regulations
(c) Certification system
(d) Regular inspection and maintenance system

9.2.6 Inspection and Maintenance System

(1) Necessity of Vehicle Check-up System

It is proposed that all motor vehicles (petrol and diesel) should be inspected and maintained at service centres certified by the government and those record be presented during road tax renewal. During use, vehicle may develop problems such as clogging of air cleaner, change in the air-fuel ratio due to contamination of carburetor, deviation in the ignition timing, decline in the engine performance due to carbonization of ignition plug, or deviation in the idling speed, resulting in increased emission of pollutants.

Also, there are vehicles which are releasing hydrocarbon gas from hoses disconnected from the blow-by gas returning unit. To prevent these problems, all exhaust, blow-by gas, and fuel evaporation gas system must be inspected and maintained periodically.

(2) Inspection System in Japan

1) Quality Assurance

Fig. 9.2.7 represents the distributions of exhaust emission test results for vehicles produced in Japan.

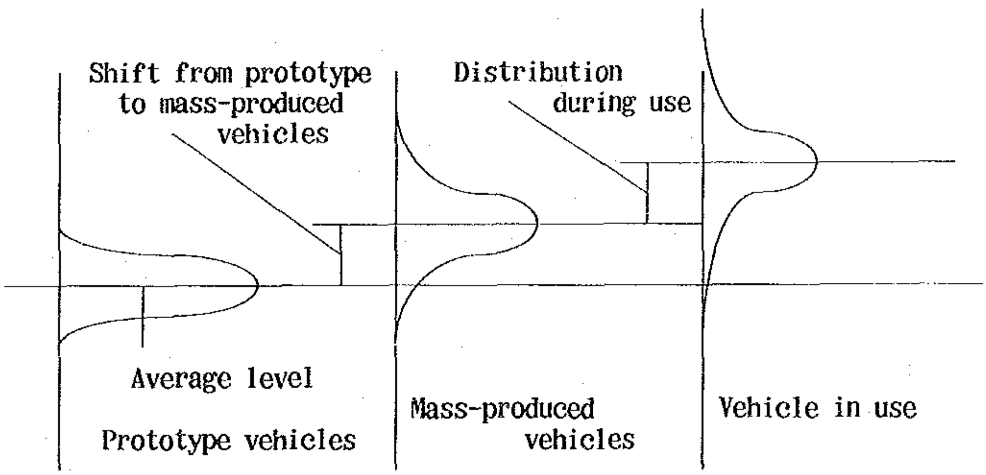


Fig. 9.2.7 Distribution of Exhaust Emission Rate

The representative distribution of exhaust emission increases in both the average value and the deviation, when the vehicles change from prototype to mass produced ones, due to differences in production procedures. Even among fully quality-controlled mass produced vehicles, the average value and deviation further increase once the vehicle is in use.

This is due to the deterioration of the engine and emission control systems as well as different driving conditions of motorists. Accordingly, it is necessary to incorporate sufficient quality control during development and mass production processes.

2) Type of Inspection

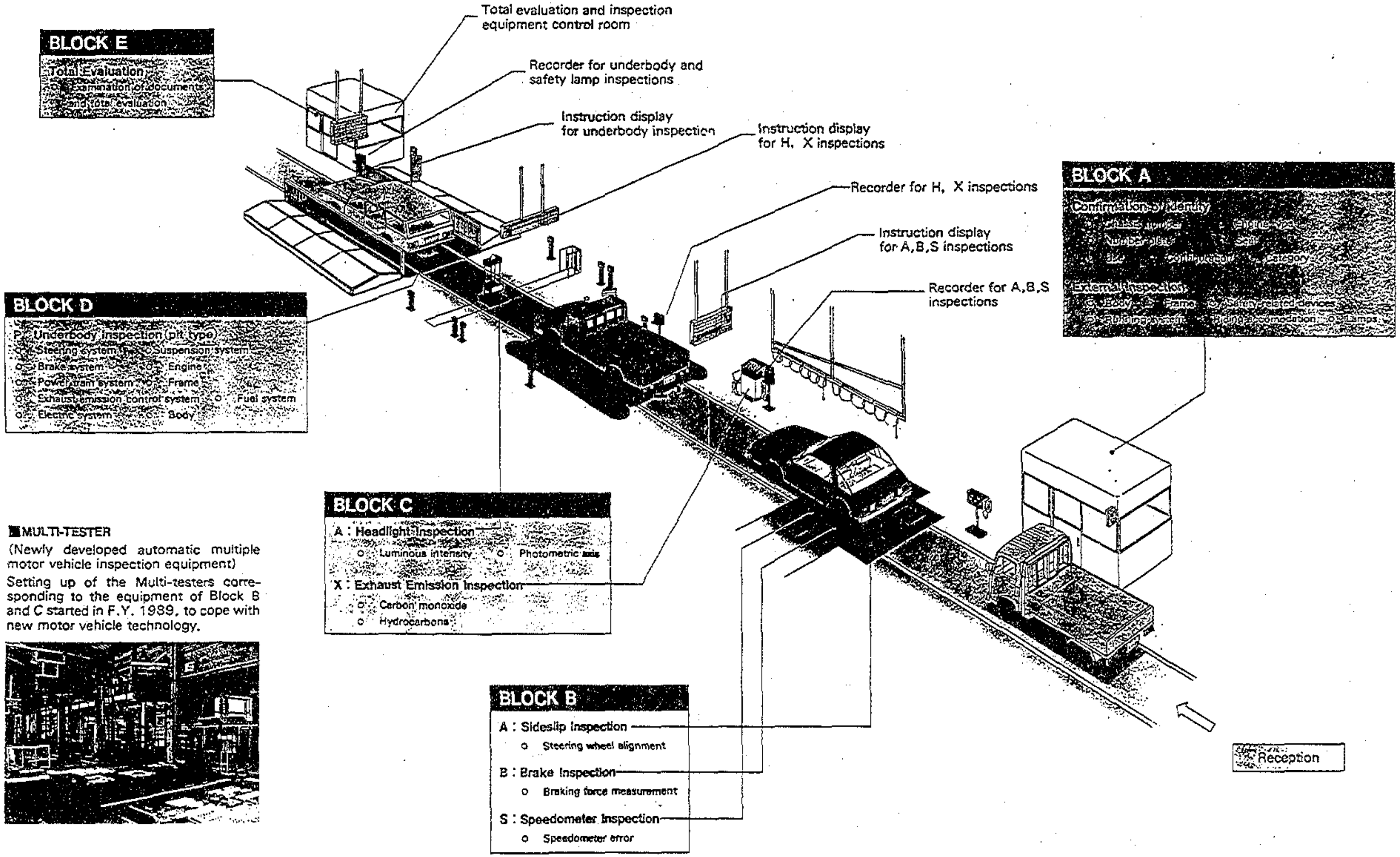
It is important that vehicles in use be checked and maintained regularly. Table 9.2.27 shows the legal inspections carried out under the Road Transport Vehicles Act of Japan. Fig. 9.2.8 illustrates the required hardware system for the inspection.

Table 9.2.27 Type of Inspection in Japan

Kind of inspection	Description	Inspection sector
Initial Inspection	Required inspection of a new motor vehicle when it's newly operated. (As for those type-designated motor vehicles, the presentation of the motor vehicle is omitted when a completion inspection certificate issued by the relevant manu-facturer,etc,is sumitted.)	Local Land Transport office which supervises the principal abode of use.
Renewal Inspection	Inspection of a motor vehicle must receive when it's to be operated continually after the term of validity of the motor vehicle inspection certificate has expired. (As regards those motor vehicles which have been serviced and inspected at a designated maintenance and repair business operator,the presentaion of the motor vehicle is omitted when a safety regulations comformity certificate is submitted.)	Nearby Local Land Transport office
Modification Inspection	Inspection of a motor vehicle when it has undergone such modifiations which have caused changes in the length,height ,width, the maximum pay-load and so forth of the motor vehicle.	Local Land Transport office which supervises the principal abode of use.

Others : Disassembling repairs
Preliminary inspection
Extraordinary inspection

Fig. 9.2.8 The Lines of Inspection System



3) Inspection Intervals

Example cases of inspection intervals are shown in Table 9.2.28.

Table 9.2.28 Inspection Intervals in Japan

Inspection intervals	Category of motor vehicles	
One year	①Motor vehicles for business use ②Motor vehicles for transporting goods ③Motor vehicles for private use which have been specified by the Ministry of Transport Ordinance a)Motor vehicles for private use with a passenger capacity of 11 persons or more b)Motor vehicles exclusively for carrying infants c)Motor vehicles aged more than ten years (11 years in case of passenger motor vehicles for private use)	Taxies,buses Trucks and lorries Buses for private use
Two years	①Passenger motor vehicles for private use, except new motor vehicles, which have been used for less than 10 years ②Two-wheels motor vehicles ③Large-sized special motor vehicles	
Three years	①New passenger motor vehicles for private use	

4) Reinforcement of the Inspection System

For extremely old commercial motor vehicles or ones with high mileage, once-a-year inspection is not enough. The Road Transport Vehicles Act of Japan sets forth that periodical inspection and maintenance, every six months for passenger carrier motor vehicles and every month for public vehicles (buses, taxis), and the presentation of the record at the time of official inspection.

(3) Implementation of Vehicle Check-up System

The Malaysian authorities should establish a schedule appropriate to the national situation, taking into consideration of the handling capacity of service centres and inspection organization, while referring to the system in Japan.

1) Evaluation of Inspection and Maintenance System

Inspection and maintenance are highly effective in reducing emissions. Table 9.2.29 shows examples of increase in exhaust emission due to tampering.

Table 9.2.29 Change in Exhaust Emission due to Tampering

Purpose of Tamper-ing	Contents of tampering		Change in exhaust emission
	Aim	Specific method	
Improve-ment of driving perform-ance	Advance ignition timing	Change of distributor's installat-ion position (Petrol vehicle)	Increase in NOx
	Increase in fuel supply	Readjustment of carburetor's idle mixture screw, and/or expansion of jet radius (Petrol vehicle)	Increase in HC & CO
		Readjustment of fuel injection volume setting screw (Diesel vehicle)	Increase in smoke
	Advance in fuel inject-ion timing	Readjustment of fuel injection timing	Increase in NOx
	Back pres-sure reduction	Removal of catalytic converter (Petrol vehicle)	Increase in HC, CO & NOx
	EGR gas reduction	Deletion of EGR system (Petrol, diesel vehicles)	Increase in NOx

The results of a follow-up survey carried out in Japan in 1968 is shown in Fig. 9.2.9.

The U.S. EPA also reported that motor vehicles going through periodical inspection and maintenance can achieve a reduction of CO and HC by 25% and NOx by 10%.

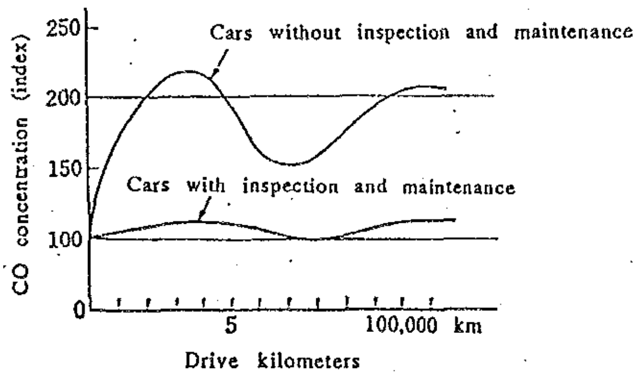


Fig. 9.2.9 Effects of Inspection and Maintenance in Japan

9.2.7 Education for Drivers and the Public

Operator training is given under the driving license system. It is recommended to include air quality deterioration problem in the training curriculum. As motor vehicles are the main means of transport for people in KVR, individuals should take responsibility for pollution caused by them.

Education should teach people how to maintain their vehicles regularly, to use proper fuel and create an awareness and interest in the activities related to air pollution control.

(1) User Education

1) Encourage vehicle owners to get periodical check
  (a) Compulsory checking (before vehicle inspection)
  (b) Checking recommended by manufacturer

2) Prevent tampering
  (a) Prohibition and control by regulation
  (b) Prevention by periodical checking
  (c) Prevention by sealing and other technical means

3) Encourage use of proper fuel and lubricating oil
  (a) Setting of fuel & lubricating oil property standards
  (b) Distinguish of fuels by use of different colours
  (c) Use of manufacturer-recommended fuel & lube oil
  (d) Use of labels encouraging use of unleaded petrol
  (e) Special design of oil guns and vehicle oil receptacles

4) Control unlawful driving
  (a) Prohibition of cargo over-loading by law
  (b) Campaigns encouraging drivers to avoid racing the engine, fast starts and over-acceleration driving.

9.2.8 Proposed Control Measures and Their Evaluation

(1) Selected Motor Vehicle Control Measures

The most feasible of previously described measures that are emission gas control, traffic volume control, inspection and maintenance system, public education and others, have been selected and evaluated for their effectiveness and in terms of required costs of implementation in Malaysia. Proposed control measures (Table 9.2.30) are divided into two groups, i.e., short/medium term and long term. The short/medium term group consists of measures to be implemented by 2005 and whose effects will be perceptible by 2005. The second group contains measures to be commenced preferably around 2005.

Utilization of "clean energy" may be one of the most desirable future measures and is recommended as research interests.

Table 9.2.30 Proposed Countermeasures for Motor Vehicles

Item	Short/Medium term	Long term
Exhaust emission control		
a. Enforcement of exhaust gas control	(a)Combustion improvement of motorcycle engine ・2-stroke⇒4-stroke ・Smokeless lube oil (b)Strengthen emission regulations ・91/441/EEC	
		(c)Installation of 3-way catalytic converter
b. Control of use of very old vehicles	(a)Promotion of low-pollution vehicles for commercial use ECE R15.04,R24,R49 , 91/441/EEC (b)Switch diesel-taxis to petrol (c)Prohibition of registration of new diesel motor car	
c. Fuel control	(a)Unleaded gasoline (b)Low-sulphur diesel fuel (c)Supply of oxygenated gasoline	

Table 9.2.30 Proposed Countermeasures for Motor Vehicles(continued)

Item	Short/Medium term	Long term
Organization/Institution	(a)Vehicles certification system (b)Inspection and maintenance system (c)Installation and operation of chassis dynamometers	
Alternative energy		(a)CNG Taxi (b)Methanol Trucks (c)Palm oil Trucks
Traffic volume conrol		
a.Klang valley transportation plan (Switching to mass-transit system from motor vehicles)	(a)KTM system (b)LRT system (c)Bus system (d)Road network plan · Expressway · Primary distributor · District distributor	
b.Restriction of motor car in congested areas	(a)Restriction of motor cars in city center (b)Introduction of flextime system (c)Traffic reduction in congested areas	
c.Rationalization of commodity transport system		
d.Traffic survey		

(2) Exhaust Emission Controls

1) Summary of Exhaust Gas Controls for Motor Vehicles

(a) Pollutants from Motor Vehicles

Motor vehicles such as motor cars, buses, and trucks run on a principle using combustion energy from petroleum fuel. As the result, unburnt fuel components and substances are generated in the emission of pollutants during or after combustion. The following table shows the control mechanisms of the pollutants in exhaust gas.

(b) Overview of Emission Reduction Systems

a) Petrol Vehicle

There are systems developed in Japan, USA, and Europe, to reduce exhaust gas emissions from motor vehicles. Representative systems are explained in Table 9.2.31.

Table 9.2.31 Exhaust Emission Reduction Systems for Petrol Vehicles

Exhaust Emission Control System		Effects	Problems
Engine Modification	Ignition timing control	HC, NOx	Power reduced and fuel economy worsened
	Throttle positioner dashpot	HC, NOx	Engine brake and fuel economy slightly worsened
EGR (Exhaust gas recirculation)		NOx	HC slightly increased, drivability worsened, so accurate control is necessary
Secondary Air		HC	
Oxidation Catalyst (+Secondary Air)		HC, CO	Fuel economy worsened
Three-way Catalyst (+EFI+Oxygen Sensor)		HC, CO, NOx	Accurate control of air-fuel (A/F) ratio is necessary

Note) EFI: Electronic Fuel Injector

b) Diesel Vehicles

Following reduction technologies (Table 9.2.32) are intended to control diesel vehicle emissions, many of which are still at the development stage.

Table 9.2.32 Exhaust Emission Reduction Systems for Diesel Vehicles

Exhaust Emission Control System		Effects	Problems
Engine Modification	Retard fuel injection timing	NOx	HC and PM increased, smoke worsened power reduced, fuel economy worsened and heat load increased
	Optimum control of fuel injection timing & rate	Smoke	May increase NOx
	Supercharger with Intercooler	CO, PM NOx, Smoke	
EGR (Exhuast gas recirculation)		NOx	HC and PM increased, smoke worsened drivability worsened and engine durability worsened

While waiting the above technologies for practical use, diesel oil can be improved for less emission. Sulphur content should be gradually reduced from the current value (0.4wt%) to 0.2wt% and further to 0.05wt%. The amendment of Clean Air Act in U.S.A. required it to be 0.05wt% from October, 1993. Also this reduction is needed for the application of oxidation catalyst which oxidizes SO_2 to SO_3 and hence increases particulate emissions. The oxidation catalyst can decompose soluble organic fractions (SOF) of hydrocarbons in the diesel exhaust gas.

(c) Evaluation of Exhaust Emission Regulation

Pollutants are to be removed or reduced by one of the countermeasures, during combustion in the engine or while exhausting. The emission control regulation is to prevent anticipated environmental deterioration by enforcing stricter emission limits on HC, CO, NOx, etc. Japan enacted the Air Pollution Control Law in 1967 and it has been amended gradually to include stricter and stricter emission standards for these pollutants.

In Malaysia, spearheaded by the Motor Vehicle (Control of Smoke and Gas Emission) Rules in 1977 to stipulate emissions from diesel vehicles, several rules were enforced to control lead content in petrol, and particulate emission.

The Malaysian government applied ECE.R15.04 on petrol vehicles and ECE.R49 and ECE.R24 (PM concentration) on diesel vehicles in June, 1992. In 1994, 91/441/EEC will be issued to petrol vehicles. These regulations will be taken into consideration in estimating emission factors in 2005. The following shows estimates of possible emission reduction through the enforcement of various regulations.

2) Enforcement of Exhaust Gas Control

(a) Combustion Improvement of Motorcycle Engines

a) Background

Motorcycles account for about 21% of traffic vehicles in KVR, next to motor cars and play an important role in the social life of the common people. Unfortunately, motorcycles are considered as one of the major sources of air pollution, since they account for 70% and 29% of HC and CO emissions from all vehicles in the Region. Most of the motorcycles in the Region are equipped with two-stroke engines which burn petrol and spent lube oil together which result in large amounts of unburnt emissions. This may be the reason for their high emission of pollutants (Table 9.2.33). Two types of measures are needed to counter this type of engine.

① Replacement of two-stroke engine with four-stroke engine
② Use of smokeless lube oil

b) Evaluation

① Four-stroke engine

Although a four-stroke engine emits more NOx than a two-stroke engine, the former emits substantially less CO, HC and PM because of combustion improvement. Therefore, motorcycles with four-stroke engine should be promoted for pollution control.

During the transition to four-stroke engines, smokeless lube oil should be supplied to cope with smoke emission from two-stroke engines in circulation.

Table 9.2.33 Emission Factor for Motorcycles

Vehicle type		Emission factor (g/unit)			Note
Vehicle type	Pollutant	Two-stroke engine	Four-stroke engine	Rate	Reference: Compilation of Air Pollutant Emission Factors (EPA, 1977)
Motorcycle	H C	9.9	1.8	0.18	
	C O	24.0	10.0	0.42	
	NOx	0.075	0.15	2.00	
	SOx	0.024	0.014	0.58	
	P M	0.21	0.029	0.14	

② Smokeless lube oil

Smokeless oil is a type of lube oil which contains polybutene or PIB (polyisobutylene) and the oil itself is capable of lubrication, and aids in the combustion of unburnt oil, consequently reducing CO and smoke emissions.

There are no technical drawbacks to use of lube oil containing polybutene, which is widely used in Japan, Taiwan and elsewhere. Thailand standardized it as an industrial product in 1991, which should help encourage its use in pollution reduction among Malaysia's neighbors. Effectiveness of polybutene on visible smoke concentration is shown in Fig. 9.2.10.

Apparently visible smoke (carbon particles and adsorbed hydrocarbons) is generally reduced by the addition of PIB. There is a little increase of HC emission, probably due to less particles (to adsorb HC) in the exhaust gas.

c) Cost Estimate

① Comparison with 4-stroke and 2-stroke engine

1) 2-stroke motorcycle: 1,800-4,000 M$/unit

2) 4-stroke motorcycle: 2,400-4,800 M$/unit

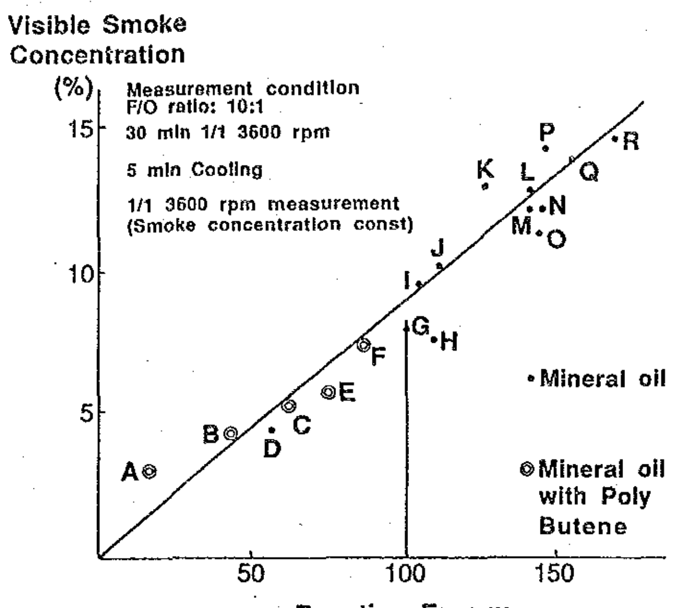
② Smokeless lube oil

Mineral oil : 14 M$/litre

Smokeless oil (mineral oil + polybutene) : 20 M$/litre

The smokeless lube oil is sold in Thailand at 50 bahts/liter, 10 ~ 20% higher than the convention mineral lube. Although the production cost of PIB is around twice of the mineral lube, the sales price may be determined by the percentages of PIB in the lube and costs for additives, packages, transport, marketing and supply-demand balances.

Fig. 9.2.10 Influence of Reaction Energy on Visible Smoke Concentration



Visible smoke--

A, B, C, D Low-smoke oil (Japan)
G, H Mineral oil (Japan)
L, M, N, O Mineral oil (ASEAN)

- Has a high correlation with reaction energy (r = 0.973).
- Is easily affected by the type of lube oil with regard to its concentration.
- Shows a low concentration when a lube oil containing poly butene additives is used.

(b) Reinforcement of Emission Regulations for Motor Cars

a) Purpose

The number of motor cars in operation in KVR are 700,000 or 43% of all registered numbers and 54.2% of those are on the road. They are a major source of air pollution, which contribute about 47% of CO, 18% of HC, 43% of NOx and 1% of SOx emissions in the Region. Also a 5.4% annual increment in these years, indicates total milages of 17 billion Km in 2005, and each annual exhaust emission will come to 0.8 for CO, 0.8 for HC, 1.6 for NOx, and 2.1 for SOx, times of that in 1992, because of the EC level's regulation will be enacted. So, advanced regulation planning (91/441/EEC) will be necessary to counter on this matter (Table .9.2.34).

Table 9.2.34 Effects on Regulation Plans for Motor Car (Petrol)

Vehicle type		Emission factor (g/unit)			
Vehicle type of census	Pollutant	Present	New regulated value (91/441/EEC)	Rate	Remarks
Motor car	HC CO NOx SOx	1.80 10.36 1.97 0.004	0.74 5.06 1.64 0.004	0.41 0.49 0.83 1.00	Oxydation catalytic converter

Note)Average travel speed⇒30km/h

b) Evaluation

The general trend in the world is to use catalytic converters to control emissions from petrol fueled motor cars, such as three ways (to convert CO, HC and NOx) or oxidation (to burn CO and HC) catalyst. Major emission reduction technologies are shown in Fig. 9.2.11.

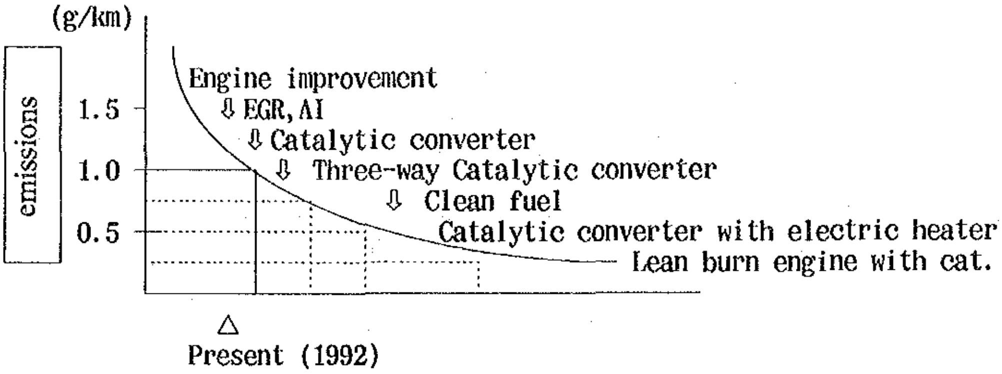


Fig. 9.2.11 Reduction Technologies for Exhaust Emission from Motor Cars

a. Technical Evaluation

About 60% of the vehicles in KVR, are produced domestically, mainly in the class of 1300-1500 cc. The new Proton model [ISWARA] has been developed to meet the ECE regulation. They are designed so that catalytic converters or other control equipments can be installed easily, so it is technically possible to equip emission control units domestically sold vehicles.

b. Cost of Control System

① Exhaust secondary air and oxidation catalyst system:
70,000yen (M$1,400)

② Effect on fuel economy : -5%

Table 9.2.35 Effect on Fuel Economy and Vehicle Price

Regulations	Country	Major exhaust emission control system	Effect on Fuel economy(%)	Increase in vehicle price(M$)
ECE. R15-04	Europe	①Engine modification Leaner air-fuel ratio Deceleration control Ignition timing control	0 ~- 5	~ 300
ECE. R83 Japan'75	Europe Japan	①Secondary air/EGR ②Oxidation catalyst	- 5 ~-10	1,200 ~1,800
US 1981 Japan'78	U.S.A Japan	①Three-way catalyst ②Three-way catalyst/EGR	0 ~+ 5	3,000 ~4,000

3) Control of Use of Very Old Vehicles
(Promotion of Low Pollution Vehicles)

(a) Purpose

There is a strong need to replace aged and overused vehicles with low polluting new ones equipped with advanced combustion control systems. In Japan, further replacement to electric or methanol vehicles are intended to alleviate NOx pollution.

As most air pollution in KVR results from HC, PM and CO, the first task will be the modernization of old vehicles, typically taxis and buses, by converting them to those equipped with new engine systems. It is recommended that the Ministry of Transport and commercial transport sectors carry out a study on trucks, buses and taxis.

Table 9.2.36 Exhaust Emission Comparison for Old/New Type Cars

Vehicle	Pollu.	Petrol (g/Km) Present	Petrol (g/Km) New type (R83)	Diesel(g/Km) Present	Diesel(g/Km) New type (R24)
Taxi	H C	2.6	0.8	0.9	0.7
	C O	15.4	8.7	4.1	2.2
	NOx	1.8	2.3	2.2	1.6
	SOx	0.004	0.004	0.8	0.6
	P M	0.04	0.04	0.44	0.19
Mini Bus	H C			5.2	2.9
	C O			9.7	5.8
	NOx			4.6	3.2
	SOx			1.7	1.4
Large Bus	H C			6.8	5.5
	C O			22.5	17.0
	NOx			19.0	15.3
	SOx			3.7	3.0
Medium Truck	H C			4.0	2.3
	C O			5.9	3.7
	NOx			3.8	2.6
	SOx			1.7	1.4
Large Truck	H C			5.0	4.2
	C O			16.5	13.0
	NOx			19.0	15.5
	SOx			3.7	3.0

Note:Average travel speed⇨ 20(km/hour)

(b) Evaluation

The following factors shall be considered in the conversion of commercial vehicles to less polluting ones:

a) Diesel taxis shall be replaced shortly by petrol vehicles to reduce PM and NOx emissions.

b) Vehicles which cannot pass emission standard tests, shall be banned from further public use.

Any diesel vehicle whose engine capacity is less than 1600 cc shall not be permitted under the new type registration. Probably 20% reduction of particle emission in KVR can be expected by implementation of these countermeasures.

There are some ways of promoting new vehicles. The first one is to force all vehicles, old or new to observe the current emission standards. The second one is to force all vehicles to keep the emission permits effective at the production year of each vehicle. For the production year without effective emission permits, a temporal standards could be additionally formulated. Conversion for commercial vehicles may be better to be assisted financially by tax benefits, low interest loans etc.

4) Fuel Control

(a) Promotion of Unleaded Petrol

It is estimated around 40 - 50% of petrol sold in KVR is unleaded petrol. The remained contains 0.15mg of tetra ethyl lead per litre of petrol. Lead increases emissions of particle and harmful matters and also poisonous to the oxidation and three way catalysts after they are applied into vehicles. It is recommended that lead fuels should be banned when the new regulation (91/441/EEC) is introduced for motor car in future.

(b) Supply of Low Sulphur Fuel

Malaysian diesel oil contains 0.323% by weight of sulphur according to the analysis. The general global trends have moved toward lower sulphur. 0.2% wt. is proposed for use in residential areas in EC. For KVR, a level identical to EC proposal is recommendable from the view of not only SOx but of SPM reduction.

(c) Supply of Oxygenated Petrol

Methanol, MTBE, ethanol, ETBE, etc. are among the compounds containing oxygen to be added to petrol. MTBE is an abbreviation of methyl tertiary butyl ether while "E" of ETBE stands for ethyl. MTBE and ETBE are produced by allowing isobutylene and methanol or ethanol to react.

The application of the oxygenated compound is shown in Fig. 9.2.12, Carbon monoxide generation decreases with increasing oxygen concentrations. However, the reduction rate of hydrocarbons decreases after reaching the peak at 10%.

The use of oxygenated petrol could be a good measure for reducing carbon monoxide in the environment until dissemination of the catalyic converters can be installed to individual motor vehicles.

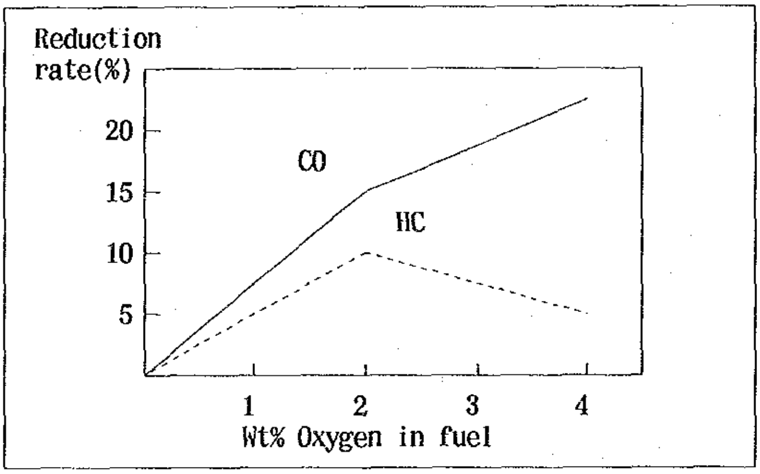


Fig. 9.2.12 Oxygen Content of Petrol and Reduction of Pollutants

(3) Organization and Institution

1) Vehicle Certification System

The vehicle certification system is composed of such items as problem research, study of technical issues, establishment of emission allowance, drafting of new standards, modification of safety standards, test for type approval, and tests for production samples. These are depicted in Table 9.2.37.

Table 9.2.37 Exhaust Emission Regulation Making Process and Vehicle Certification

Jurisdictional Body	General Procedure		
Department of Environment (Ministry of Science,Technology, and the Environment)	Study of environmental pollution problems caused by motor vehicles		
	Technical feasibility assessment of new items to be enforced		
	Work shop	⇦	Hearing from vehicle manufacturers and other parties concerned
	Notice of announcement draft of permis sible limits		
Road Transport Department (Ministry of Transport)	Drafting of environment pollution control standard	⇨	Parties concerned with moter vehicles at home and abroad
	Promulgation of amendent to Safety Regulations for Road Vehicles		Notification to GATT
	Type approval & Inspection (Initial) Registration		

2) Inspection and maintenance system

As explained in Section 9.2.6, the inspection and maintenance system can be implemented by a private inspection factory (Designated inspection & maintenance shop) authorized by the Ministry of Transport.

Anticipated number of repair service shops and inspection offices (factories) are shown in Table 9.2.38.

All vehicles, private, be they commercial, or official, shall adhere to this system. The vehicle which passes emission tests receives a certificate issued by the government and has its registration renewed.

Table 9.2.38 Anticipated Number of Repair Service Shops and Inspection Offices

Item	Model case in Japan	Klang Valley
Number of registered vehicles	60,000,000	700,000 (without motorcycle)
Number of maintained vehicles per inspector	160 units per person	Anticipated number of employees 4375
Number of employees per repair service shops	4.5	
Number of approved repair service shops	80,000	930
Number of inspection offices(No. of course)	150(300)	K.L -2(2),P.J-1(1) Klang-1(1)
Cost of inspection system M$ 1.5 million/course	———	K.L M$ 6.0 million P.J M$ 1.5 million Klang M$ 1.5 million

3) Installation and Operation of Chassis Dynamometers

SIRIM is going to install a chassis dynamometer testing system in 1995. Cooperative use of the system by DOE may be possible in the beginning. However, the system is positively needed as a tool to collect supporting data for the implementation of the car inspection system. Such data may be confirmation of emission factors selected for Malaysia, tracing the emission variations of cars in circulation with running mileage, and other.

Costs of chassis dynamometer and auxiliary equipment are in Table 9.2.39. The costs for shipping, installation, housing, foundation, taxes and others are not included.

Table 9.2.39 Cost of Chassis Dynamometer

Item	Vehicle type		
	Petrol	Diesel	Large vehicle
Chassis dynamometer	M$ 2,000,000	⇦	M$ 4,000,000
CVS system	M$ 600,000	⇦	M$ 1,000,000
Gas analyzers	M$ 1,000,000	⇦	M$ 1,000,000
Dilution tunnel	——	M$ 600,000	M$ 1,400,000
Total	M$ 3,600,000	M$ 4,200,000	M$ 7,400,000

(4) Alternative Energy

1) Introduction of CNG Taxi

(a) Purpose

The numbers of registered taxis in the Region are increasing yearly (8,500 in 1988, and 12,000 in 1992), with diesel and aged cars being the most dominant. Taxi fares are reasonable, and taxis are means popular of public transport for shopping and business. However, diesel taxis have a larger pollutant emission rate than petrol vehicles. Their increased use has had a great impact on air quality in KVR.

The conversion of taxis to LPG-fueled vehicles in large cities in Japan has contributed to the reduction of PM, HC and CO emissions. The following Table 9.2.40 estimates emission reduction through the use of CNG by taxis.

Table 9.2.40 Emission Factor Changes via Introduction of CNG Taxi

Car Type	Engine Type	Pollu-tants	Existing fuel use engine	CNG fuel use engine	Reduction rate(%)
Taxi	Petrol	C O H C NOx SOx	2.6 15.4 1.8 0.0	0.14 7.4 0.23 0.0	95 52 87 100

Note: Average travel speed⇒20km/h
Reference:JDB(Japan Development Bank) report No.165 , 1992

2) Methanol Vehicles

Although the future of methanol fueled vehicles depends upon fuel cost, the results of research and development and general car use trends, it is a theme to be discussed in relation to energy diversification and promotion of low pollution vehicles. Especially light duty trucks which will be increasingly used for transport of goods may be important factor that needs to be considered, on a long time scale of methanol conversion.

3) Palm Oil as Diesel Fuel

As no diesel vehicles are produced in Malaysia, it is difficult to restrict diesel exhaust emissions at the production. Also no sufficient reduction technology in relation to engine modification has yet been developed in the world. The current plan to use palm oil as one of the alternative under the energy substitution policy requires study for its effects on emission reduction.

(5)Traffic Volume Control

1) General

This section will discuss the reduction of traffic volume by rationalization of people and goods transported and by designing an alternative public transport system, to ultimately protect air quality before it deteriorates by emissions of HC, CO, NOx and other pollutants.

Estimated changes and emission reduction effects of a traffic volume control policy and its implementation plans are discussed below.

2) Klang Valley Transportation Plans

The Klang Valley Transportation Study proposed the following master plan for 2005, including regional development pattern and connection of routes.

(a) Public Transportation Plan

a) Mass transit railway introduction plan

b) Bus transport improvement

(b) Road Network Plan

a) Expressway

b) Primary Distributor

c) District Distributor

In our estimation of future traffic volume, this master plan is assumed to be close to implementation phase in 2005.

Fig. 9.2.13 shows the proposed MRT system plan.

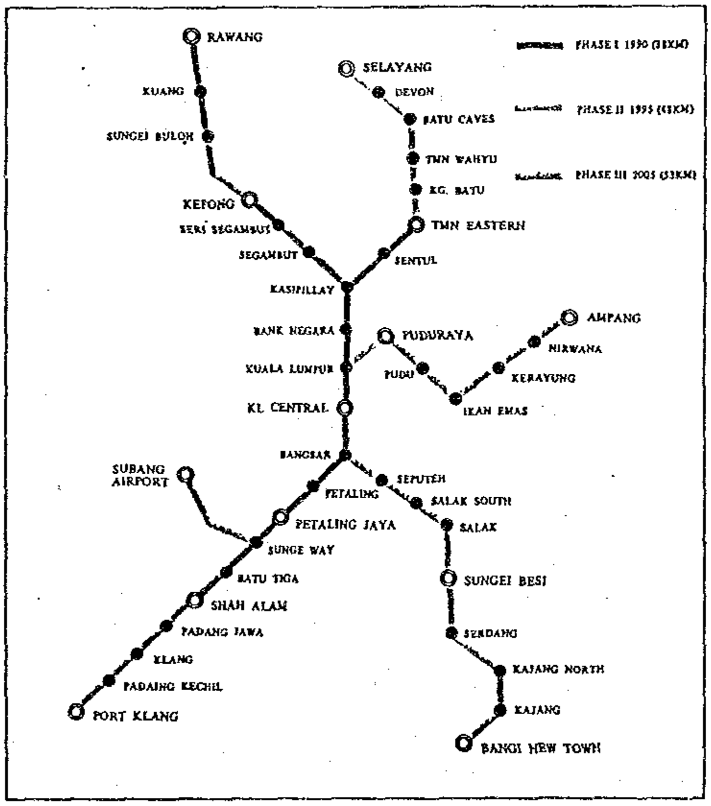


Fig. 9.2.13 Proposed MRT Plan in 2005

3) Restriction of Motor Cars in City Centre

(a) Purpose

Heavy traffic congestion on the trunk roads of Kuala Lumpur results in severe damage to the economy and air quality, and should be solved in the future. In this section, effective methods will be studied with quantitative evaluation of the results from restriction of motor cars in several zones inside the capital city. Hourly and seasonal restrictions will be handled in general.

a. Targeted vehicles : motor cars

b. Purpose of trip : home based trip

c. Number of passengers in a car : one

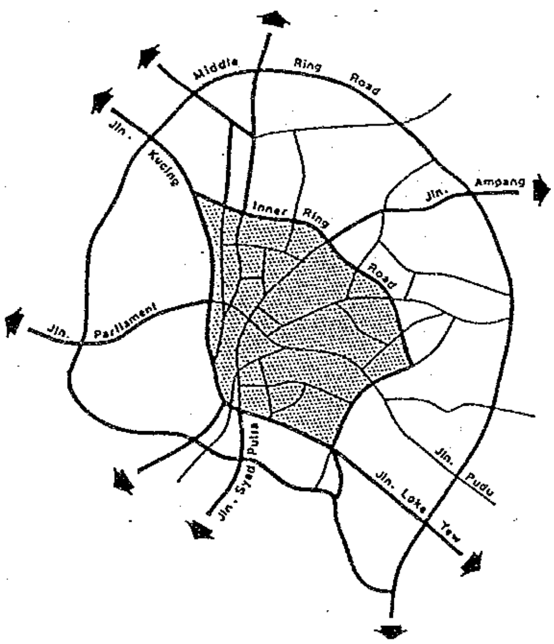


Fig. 9.2.14 Plan of Restriction Area

Fig. 9.2.14 is a traffic restrain zone proposed by a JICA Study in 1987 (#6007). The 1987 JICA Study Team estimated reduction of motor car trips in the Central Planning Area (CPA; inside of the Inner Ring Rood), as in Table 9.2.41.

Table 9.2.41 Reduction of Motor Car Trips in Central Planning Area ,1995

Purpose of Trip	Daily trips into CPA	Morning Peak(MP) (6-10am) Ratio	Trips into CPA at MP	Trip reduction rate(%) at MP	Reduced Trips	Reduction rate to daily trips(%)
To work	39,227	89	34,910	20	6,980	18
To school	1,286	74	950	20	190	15
Business	28,119	16	4,500	20	900	3
Private	42,604	20	8,520	20	1,700	4
To home	17,860	4	710	20	140	1
Subtotal	129,096	38	49,590	-	9,920	8
Taxi	29,371	20	5,870	20	1,170	4
Total	158,467	35	55,460	-	11,090	7

4) Rationalization of Goods Transport

(a) Necessity of Rationalization

Discussions of motor vehicle source pollution controls, cannot overlook trucks. They emit not only NOx and black smoke but noise. Their contributions to the overall emissions in the region are 29% of NOx and 61% of SOx for all motor vehicles, where as they comprise only 10% of all traffic volume. Although there are other transportation methods such as rail roads and ships, but the trend is to use trucks because of their flexibility and mobility. Since more vivid fluidity of down-sized goods is anticipated in the future arising from the diversifications and sophistication of consumers demands, it is important to plan appropriate countermeasures from the view of air pollution protection.

Promoting efficient operation of trucks is effective to suppress its truck traffic volume. It has to be accomplished from both the merits of air pollution control and economic advantage in business activities.

(b) Rationalization Target

The main users of trucks for commodity transport are producers, whole-sellers, department stores, retailers, transportation businesses and others.

(c) Rationalization of transport and distribution

a) Joint and collective transport

b) Efficient method of transport

c) Efficient use of trucks

d) Reduction of numbers of trucks

(d) Reasonable allocation of transport centres

(e) Information system on goods transfer

5) Introduction of Flextime System

(a) Purpose

Severely congested rush hours in the downtown last only for one to two hours in the morning and around three hours in the evening and main occupants (roughly 80%) are commuters to offices and schools. Therefore, shift of office or school hours or introduction of flextime system would be effective to reduce traffic at the rush hours. The flextime is to have the core working time, for example from ten to four o'clock, and flexible hours before and after the core to compensate the predetermined working hour. If the total working hour is 7 hours and if one starts working at 9:30, he can leave his office at 5:30 pm including one hour lunch.

(b) Effect

The effect of the flextime greatly depends on the co-operation of offices in the downtown area. The effect given in Table 9.2.42 below was obtained in Sapporo City of Hokkaido Prefecture in Japan. The rush hour vehicle traffic was reduced by 3 to 11% on the increase of 2 to 7% in the nearby hours.

Table 9.2.42 Effect of Flextime Introduction

Rate of co-operation offices (%)	Reduction rate of traffic volume at 8:00~9:00 (%)	Increase rate of traffic volume in nearby hours (%)	
		7:00 ~ 8:00	9:00 ~10:00
5	2.7	1.9	1.7
10	5.5	2.8	3.4
20	11.0	5.6	6.8

The KVR has the rush hour peak in 7 to 8 o'clock with 2 to 3% higher traffic volume than Sapporo. Therefore, greater reduction can be expected than in the above Table.

(c) Implementation

Although the flextime system can be promoted through public campaign, administrative pressures or appraisals may be necessary to have anticipated effect.

It is recommended to organize a flextime promotion committee in the City and to determine i) its introduction method and estimation of the effect, ii) its socio-economic effect, and iii) public awareness campaign.

6) Others

There are some other methods to reduce traffic in downtown areas employed in large cities.

(a) Five-Day-a-Week System

Instead of six days a week working schedule, it could be reduced to five days. Usually total working hours in a week is kept at the same by evenly allocating one day working hours into five days. Hence, one each peak in the morning and afternoon can be reduced in a week.

(b) Park and Ride System

If free public parking spaces are available near entrances of highways or major roads and people are willing to leave their cars in the parking lot and take buses to downtown, traffic in the highway and in the downtown will be greatly reduced. Public awareness of its convenience and effect on the pollution reduction is the key of the success introduction of this system. The bus fare must be cheaper than the highway tariff of a car. If the bus fare within the downtown is free, this Park'n Ride (called in Seattle, Wash. U.S.A.) system will be more effective. Governmental subsidies or financial assist to the bus companies may be needed.

(c) Car Pool System

Majority of passenger cars in the rush hour is usually occupied by one or two people. If people can use cars cooperatively together, traffic numbers of cars will be reduced. Besides public campaign, it may be helpful for the promotion of this system to change highway tariffs with numbers of people in a car entering highway. Less people in one car pay more. Thus people will tend to use car in pool. Because of traffic destination and time, co-operation in work places is beneficial.

7) Execution of Traffic Survey

(a) Purpose of Study

The views of control of air pollution and traffic congestion, traffic survey is very effective to know the control measures for motor vehicles and traffic planning.

(b) Necessary Information for Motor Vehicles

a) Traffic Census

Traffic volume information shows the utilization of existing road network and the sectional traffic concentration and situation of congestion to compare with the respective road capacities.

Information on road traffic volume, congestion rate and travel speed are anticipated.

b) Origin/Destination (O/D) Survey

O/D survey is conducted for the purpose of catching the trip of origin and destination, trip purpose and other related trip data.

The study is classified into following three types,

1) Car O/D

2) Person trip

3) Commodity movement

9.3 Effect of Control Measures on Air Pollutant Concentration

9.3.1 Reduction of Air Pollutant Emission from Factories

(1) Control Menu

SOx: To control the power plants (the major pollutor), and boilers in the districts where SOx target value would be exceeded.

NOx: To control by modifying combustion manner

Dust: To control boilers in factories by fuel conversion to lighter one and by installation of collectors in solid fuel combustors.

Sufficient combustion management should be implemented in general to reduce pollutant emissions by energy saving. Table 9.3.1 is the menu of the control measures to be implemented by 2005 in KVR.

Table 9.3.1 Control Measures against Stationary Sources

	Measures	SOx	NOx	Particle	Year
1.	Power Plants				
	(1) Fuel Conversion (natural gas)	o		o	1997
	(2) Improvement of Electr. Precip.			o	1997
2.	Factories				
	(1) Fuel conversion - natural gas	o		o	1997
	LFO	o		o	1997
	(2) Collectors - Multicyclone			o	1997
	Multicyclone			o	2005
	EP			o	1997
	(3) Revamp. of wood waste combustor			o	2005
	(4) Combustion management	o	o	o	1997
	(5) Energy saving	o	o	o	1997
3.	Particles from non-point sources			o	1997
4.	Establishment of Combustion Management System				1997
5.	Combustion Management Engineer Training				1997
6.	Supporting System				
	(1) Technology transfer from the experienced				1995
	(2) Financial support				1997

1) Control of Power Plants

(a) HFO Boiler: In 2005, SOx emission from PS-A Power Station would be around 1.5 times (30,041 tons/y) of that in 1992 (19,523 tons/y). As the air quality target value would be exceeded in the district where PS-A located, excess SOx emission should be eliminated by converting fuel to natural gas or by flue gas desulfurization plants from existing boilers.

(b) Coal Boiler: All coal burnt boilers, whichever existing or new, should be designed to emit NOx to be half of the current or designed value, in order to reduce NOx emission to be less than 1.3 times of the current emission in 2005. One boiler supposed to be installed in 1996 should be switched to natural gas instead of burning coal to reduce SOx emission.

(c) With the above controls, the SOx target value seems still exceeded slightly under the simulation study. Either #3 or #4 boiler should be converted from coal to natural gas to satisfy the value completely on the simulation.

2) Control of General Factories

(a) SOx Reduction: According to the dispersion simulation of the current(1992) conditions, few ground level SOx concentrations exceeded the target value. These sites should be controlled primarily by fuel conversion to natural gas at boilers larger than 150 kg/h fuel (oil equivalent) combustion, and other remaining sites to industrial diesel oil at boilers larger than 200 kg/h combustion.
In spite of these control measures, the vicinity of mesh No. 76-15 has the ground level SOx concentration over the target value under the simulation study. This is caused by palm waste combustors in the area. If these must be controlled, increment of stack height will be the best solution. However, it would be better to check again sulphur contents in palm waste and the necessity of the control in the sparsely populated area with equal severity should be re-considered before construction of higher stacks.

(b) Dust Control: Multicyclones should be installed at boilers burning more than 1500 kg/h of wood waste in order to remove 80% of Dust emission.

(2) Effect of Control Measures on Amount of Pollutant Emissions

Emissions in 2005 are compared in Table 9.3.2 with those in 1992, assuming that all the proposed control measures have been implemented. Also, amounts of pollutants reduced from the estimated amounts without control measures in 2005 are listed in the Table for reference.

Table 9.3.2 Reduced Amount of Pollutant Emissions from Factories (2005)

(unit: ton/year)

Year		1992	2005		
			without measures	with measures	Reduction Amount
SOx	P. Stations	19,522	30,040	12,759	17,281 (57.5)
	General Factories	11,047	11,283	5,345	5,938 (52.6)
	Total	30,569	41,323	18,104	23,219 (56.2)
NOx	P. Stations	12,792	26,038	22,758	3,280 (12.6)
	General Factories	2,979	4,415	4,364	51 (1.2)
	Total	15,771	30,453	27,122	3,331 (10.9)
Dust	P. Stations	1,969	2,423	828	1,595 (65.8)
	General Factories	7,034	8,163	5,451	2,712 (33.2)
	Total	9,003	10,586	6,279	4,307 (40.7)

Figures in parenthesis are reduction percentage.

1) SOx

The reduced amount, 23,220 tons/y, from the uncontrolled emission in 2005 is 56% in which almost equal percentages of reduction are expected from both of power stations and factories.

2) NOx

A combination of the two stage combustion and LNB, and the conversion to lighter fuel reduce NOx emission collectively at 3,330 tons/y which will be equal to around 11% of the uncontrolled amount in 2005. The amount is almost for the reduction at the power stations which is about 3,280 tons/y.

3) Dust

Total reduction is around 4,300 tons/y, within which 1,100 tons/y are removed in collectors and remaining is due to the effect of conversion to lighter and cleaner fuels.