Table A5-8 DeNOx cost Estimate
(700MW Boiler and Combined Cycle Power Generation)
[70% utilization, catalyst 28.6 Thousand US$/$m^3$, ammonia 57.1 US$/t, electricity 11.4 ¢/kWh, 80% DeNOx]

| | Coal Boiler | | Heavy Oil Boiler | | Gas Boiler | Gas Combined Cycle Process |
|---|---|---|---|---|---|---|
| Flue Gas (1,000$Nm^3$/h) | 2,400 | 2,250 | 2,000 | 1,900 | 1,900 | 5,400 |
| DeNOx Inlet | | | | | | |
| NOx (ppm) | 400 | 250 | 200 | 120 | 60 | 100 |
| $SO_2$ (ppm) | 1,000 | 1,000 | 1,500 | 100 | 0 | 0 |
| Dust (g/$m^3$) | 20 | 20 | 0.1 | 0.05 | 0.005 | 0 |
| $NH_3$/NOx Molar Ratio | 0.81 | 0.82 | 0.83 | 0.85 | 0.94 | 0.90 |
| Outlet $NH_3$ (ppm) | 3 | 3 | 3 | 3 | 5 | 5 |
| Catalyst | | | | | | |
| Pitch (mm) | 7 | 7 | 6 | 6 | 4 | 4 |
| SV ($h^{-1}$) | 2,000 | 2,500 | 3,800 | 5,500 | 11,000 | 9,000 |
| Volume ($m^3$) | 1,200 | 900 | 526 | 345 | 172 | 600 |
| Life (year) | 5 | 5 | 10 | 8 | 16 | 10 |
| Pressure Power Drop (mm Water Column) | 120 | 110 | 100 | 90 | 80 | 110 |
| Power Consumption (%) | 0.22 | 0.20 | 0.17 | 0.14 | 0.12 | 0.48 |
| Equipment Cost (million US$) | | | | | | |
| Catalyst (A) | 34.29 | 25.71 | 15.03 | 9.86 | 4.91 | 17.14 |
| Equipment Cost, etc. (B) | 19.05 | 18.10 | 14.29 | 13.33 | 10.48 | 19.05 |
| Sub-total (A+B) | 53.34 | 43.81 | 29.32 | 23.19 | 15.39 | 36.19 |
| US$/kW-Rated | 76.20 | 62.60 | 41.90 | 33.10 | 22.00 | 51.70 |
| Annual Cost (million US$) | | | | | | |
| Fixed Cost* | 7.12 | 6.57 | 4.50 | 3.86 | 2.80 | 5.75 |
| Catalyst** | 6.86 | 5.14 | 1.50 | 1.23 | 0.30 | 1.71 |
| Electric Power | 1.08 | 0.98 | 0.83 | 0.69 | 0.59 | 2.35 |
| Ammonia | 2.10 | 1.28 | 0.88 | 0.53 | 0.29 | 1.30 |
| Others | 1.14 | 1.05 | 0.95 | 0.95 | 0.76 | 1.43 |
| Sub-total | 18.30 | 15.02 | 8.66 | 7.26 | 4.74 | 12.54 |
| DeNOx Cost | | | | | | |
| ¢/kW | 0.43 | 0.35 | 0.20 | 0.17 | 0.11 | 0.29 |
| ¢/NOx-$m^3$ | 3.85 | 5.45 | 4.34 | 6.71 | 8.62 | 4.91 |
| ¢/NOx-t | 1.88 | 2.66 | 2.11 | 3.27 | 4.20 | 2.39 |

Notes: * 0.08A + 0.23B
** A/Life

# APPENDIX 6 Review and Introduction of Air Pollution Control Process Technology

# Appendix 6 Review and Introduction of Air Pollution Control Process Technology

In principle, the level of air pollutants removed at a particular air pollution control facility should be determined according the level of emission standards established for environmental protection of a country or an area. In Argentina, however, allowable emission levels is not so severe. Flue gas treatment facilities seemingly suitable for thermal power plants at present or in future are presented.

## 6.1 Measures to decrease pollutants emission through improvement of conversion technology

Measures for improvement in this case, are already described in the clause 4.4 in the main report.

## 6.2 Simplified measures for pollution control

A simplified air pollution control facilities will be applicable to existing small - to medium - scale thermal power plants, if some countermeasures are required in near future.

Also, the equipment costs to achieve this are estimated for thermal power plants with rate output of 120MW and the DeSOx agents are estimated for 3 month operation with fuel oil or coal, as presented below:

1) SOx reduction measures

The following two processes were selected from various alternatives.

(a) Magnesium hydrate absorption effluent method ("magnesium hydrate method") (for oil-fired and coal-fired boilers)

(b) Semi-dry type simplified desulfurization method(for coal-fired boilers)

(a) Magnesium hydrate method

The slurry containing magnesium hydroxide ($Mg(OH)_2$) is used as an absorbing agent. Magnesium sulfite produced from $SO_2$ absorption is oxidized by the air and a magnesium sulfate solution is discharged.

Because of its simplicity and low facility cost, including the cost of the absorbing agent which is much cheaper than caustic soda, the method has been increasingly used since 1980. In Japan, about 100 plants have been constructed to treat flue gas from industrial operation.

Also, more than 10 plants which previously used the soda absorption effluent method have changed the absorbing agent to magnesium hydroxide. Recently, many plants are constructed in Taiwan by using Japanese technology.

As magnesium sulfate is an ingredient of seawater, it can be safely discharged into the ocean. The method is suitable for small- to medium-scale desulfurization facilities and can be widely used in countries where power plants and factories are located near the sea.

Figure A6-1 shows the system diagram of the magnesium hydroxide absorption effluent method.

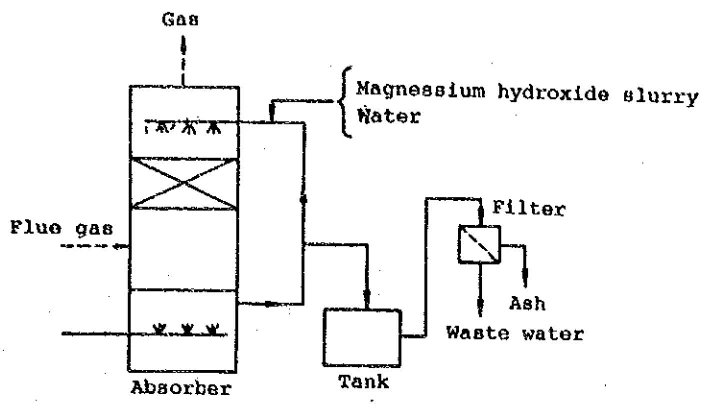



**Figure A6-1 SYSTEM DIAGRAM OF MAGNESIUM HYDROXIDE ABSORPTION EFFLUENT METHOD**

a) Reasons for selection

- Simple configuration and low cost (one third the cost for the conventional lime-gypsum process)

- High SOx reduction rate (95%)

- Ease of operation and maintenance

- Since thermal power plants are located near the ocean or the river to obtain large amounts of cooling water, the effluent discharge process can be utilized.

- Relatively low materials cost compared to other effluent processes ($Mg(OH)_2$ which is cheaper than caustic soda)

- No secondary pollution

  Basic magnesium in effluent is converted into a harmless $MgSO_4$ solution, which is discharged after pH adjustment and SS removal. $MgSO_4$ is an ingredient of seawater and thus can be safely discharged to the ocean.

- Suitable for small- to medium-scale thermal power plants

b) Plant cost

The block diagram of this process is shown in Figure A6-1. When the process is adopted to a thermal power plant with rated output of 120MW, the plant cost is estimated at 5.7 to 8 Million US dollar.

c) Magnesium hydrate cost

Since magnesium can absorb a larger amount of $SO_2$ than calcium does, the SOx reduction rate of 95% can be achieved by mole ratio of $Mg(OH)_2$ to $SO_2$ at 1:1.

Assuming that fuel oil with the 1.1% sulfur content is used, the cost of magnesium hydrate required for the 120MW plant which operates at 70% is estimated as follows:

| | |
|---|---|
| Consumption of magnesium hydrate: | 1,050 tons/3 months |
| Cost of " : | 0.62-0.67 million US$/3 months |

The process is expected to reduce $SO_2$ concentration at the inlet from 1,700mg/Nm$^3$ to 80 - 100mg/Nm$^3$ at the outlet.

While the process offers a lower operating cost than other effluent processes, the running cost is higher than the lime-gypsum method due to the use of magnesium hydrate.

Note that flue gas temperature falls to around 70°C after the process, air indirectly heated by steam may have to be injected to prevent white smoke from occurring.

(b) Semi-dry type simplified SOx reduction method

The process consists of "primary desulfurization" in which lime stone powders are blown into the furnace, and "secondary desulfurization" to spray water into flue gas.

A water-spray cooling tower is provided between the air heater and the dust collector. Lime stone powders are sprayed into the boiler at around 1,200°C with the mole ratio of 2 - 5 and pass through the spray tower for improved reactivity.

The desulfurization rate increases with decrease in gas temperature toward the dew point of steam and reaches 80% at 60°C with the mole ratio of 3.

Most of the $SO_2$ desulfurization process are done in the spray tower.

The method requires relatively small facility cost and space because of the simplified process. Also, no slurry is used to assure ease of operation and maintenance and to eliminate the need for drainage. One disadvantage is large consumption of lime stone powders.

The method is suitable for small- to medium-scale power plants located inland. The dust collector is essential. In Argentina, bag filters cannot be used because gas temperature rises in the seasons when natural gas is used (no desulfurization required) and damages bags. Thus the EP needs to be installed if this method is selected.

Figure A6-2 illustrates the system diagram of the semidry type simplified desulfurization method.

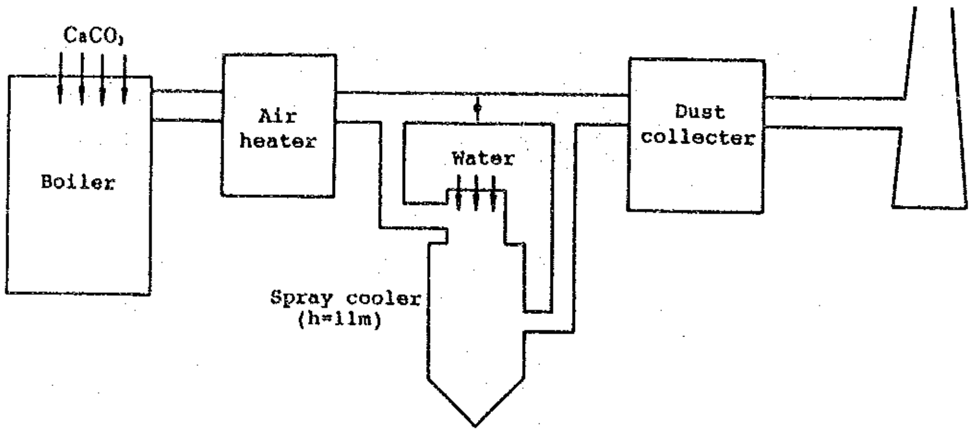



**Figure A6-2 SYSTEM DIAGRAM OF SEMI-DRY TYPE SIMPLIFIED DESULFURIZATION METHOD**

Since the process requires the EP in the downstream process, it is suitable for coal-fired boilers equipped with the EP, rather than oil-fired boilers which do not have the EP.

a) Reasons for selection

- Relatively low equipment cost compared to the magnesium hydrate method (not including the EP cost)

- Semi-dry type to eliminate effluent

- Ease of operation and maintenance because no slurry is used

- Desulfurization rate of 80% or over

b) Plant cost

The block diagram of the process is illustrated in Figure A6-2.

When installed at a coal-fired thermal power plant with rate output of 120MW, the plant cost is estimated at 5.1 - 7.1 million US$.

c) Lime stone cost

Assuming that coal contains 0.7% sulfur and the mole ratio of lime stone injected is 3, the lime stone cost required for a 120MW thermal power plant, at the operating rate of 70%, is estimated as follows:

| | |
|---|---|
| Consumption of lime stone: | 6,500 tons/3 months |
| Cost of " : | 1.2 - 1.5 million US$/3 months |

The process is capable of reducing $SO_2$ concentration from 1,700mg/$Nm^3$ at the inlet to 350mg/$Nm^3$ at the outlet.

The semi-dry type offers an advantage in not producing effluent, but a solid-gas reaction requires a large amount of lime stone, thus producing a large amount of dust and requiring a higher running cost.

2) Dust control measures

By introducing the above two processes, specific dust control measures are not required. The two processes are described in detail, as follows:

(a) Magnesium hydrate absorption effluent method

The method is of wet type, and waste gas from a boiler is cleaned by magnesium hydrate slurry and water which are sprayed from the above. In the process, $SO_2$ is absorbed and large dust particles are removed. Then, the cleaned waste gas passes through the mist eliminator located above the absorber. During elimination of mist, dust is also removed to some extent and dust concentration in the gas decreases significantly. Nevertheless, waste gas from oil-fired boilers contains 0.5-micron or smaller particles which account for 30% of total weight, so that the dust removal rate is assumed to be a conservative 70%. This means, if dust concentration of waste gas at the boiler outlet is 200mg/Nm$^3$, the concentration at the stack outlet is estimated to be 60mg/Nm$^3$.

On the other hand, coal-fired boilers produce considerably larger amounts of dust. For dust removal, the venturi type absorber is used to allow dust to contact the absorbing solution freely. The dust removal rate is more than 95%. Thus, dust concentration can be reduced from 10,000 - 30,000mg/Nm$^3$ at the absorber inlet to 500 - 1,500mg/Nm$^3$ at the outlet.

The absorbing solution is oxidized by air and is cleaned through filters which pick up dust and other solid matters for disposal outside the system.

(b) Semi-dry type simplified SOx reduction method

The process should be used at coal-fired thermal power plants equipped with electrostatic precipitators. Dust in boiler waste gas contains coal ash, gypsum powders produced through reaction, and unreacted lime stone powders. 70% - 80% of dust are removed through the spray cooler, and the remnant go through the EP.

Since dust particles produced from coal-fired boilers are relatively large - 1-micron or smaller particles account for less than 1% of total weight - the high rate of dust removal is expected. Generally, the electrostatic precipitators can eliminate dust by 98% or more. Dust concentration of 40,000mg/$Nm^3$ at the boiler outlet can be reduced to less than 600mg/$Nm^3$ at the outlet.

Prior to introduction of the process, the capacity and performance of existing electrostatic precipitators need to be reviewed.

3) NOx reduction measures

(a) Improvement measures

As part of NOx reduction measures, low excess air combustion described in proposed improvements for compliance with Grade I should be applied to Grade II.

In addition, the proposed improvement for Grade II includes the use of low NOx burners. Although the effect varies among many types of low NOx burners available, as discussed in Appendix 5(3)3)(d), the use of the burner can reduce NOx concentration by additional 100 - 200mg/$Nm^3$ compared to low excess air operation. NOx concentration under low excess air operation is estimated at 400 - 600mg/$Nm^3$ for gas, 600 - 800mg/$Nm^3$ for fuel oil, and 900 - 1,300mg/$Nm^3$ for coal, which can be reduced to 300 - 400mg/$Nm^3$, 400 - 600mg/$Nm^3$, and 700 - 1,100mg/$Nm^3$ by using the low NOx burner respectively.

(b) Low NOx burner cost

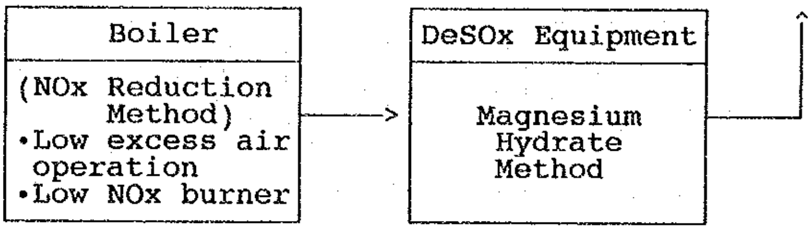
If the conventional burner is converted to the low NOx burner, two types are required, namely for natural gas and fuel oil (or coal).

The cost of installing the low-NOx burner at a thermal power plant having rated capacity of 120MW is estimated at 4.8 - 5.7 million US$.

4) Summary of proposed improvement for Grade II

(a) Magnesium hydrate absorption effluent method

a) Block diagram




a. In the case of fuel oil

(Unit: mg/$Nm^3$)

| | Boiler Outlet | Outlet of Desulfurizer |
|---|---|---|
| SOx | 1,700 | (80 - 100) |
| NOx | (400 - 600) | (400 - 600) |
| Dust | (100 - 200) | (50 - 60) |

b. In the case of coal

(Unit: mg/$Nm^3$)

| | Boiler Outlet | Outlet of Desulfurizer |
|---|---|---|
| SOx | 1,700 | (80 - 100) |
| NOx | (700 - 1,100) | (700 - 1,100) |
| Dust | (1,000 - 30,000) | (500 - 1,500) |

b) Equipment cost

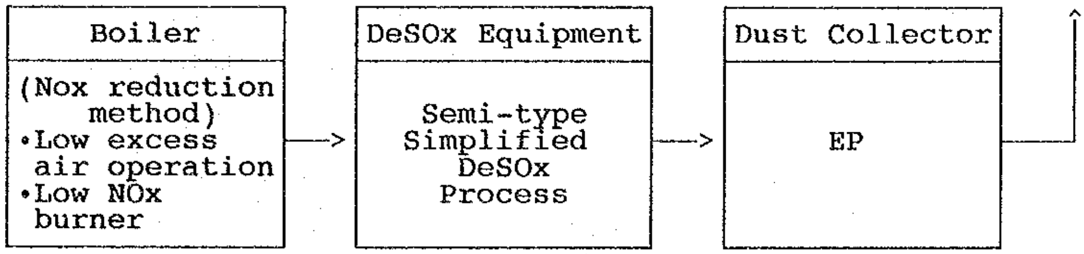
| | (Unit: million US$) |
|---|---|
| DeSOx plant | 5.7-8.0 |
| Low NOx burner | 4.8-5.7 |
| Total | 10.5-13.7 |

c) DeSOx agent cost

Magnesium hydrate: 0.62 - 0.67 million US$/3-months

(b) Semi-dry simplified SOx reduction method

a) Block diagram (coal-fired)




(Unit: mg/Nm$^3$)

| | Boiler Outlet | Outlet of Desulfurizer | EP Outlet |
|---|---|---|---|
| SOx | 1,700 | (330-380) | (330-380) |
| NOx | (700-1,100) | (700-1,100) | (700-1,100) |
| Dust | (20,000-40,000) | (6,000-12,000) | (300-600) |

b) Equipment cost

(Unit: million US$)

| | |
|---|---|
| DeSOx plant | 5.1-7.1 |
| Low NOx burner | 4.8-5.7 |
| Total | 9.9-12.8 |

c) DeSOx agent cost

Lime stone: 1.2 - 1.5 million US$/3-months

## 6.3 Indepth countermeasure for pollution control

Air pollution control facility of this grade is expected to comply with emission standards similar to those applied in industrialized countries. The equipment and other costs show below are estimated for a new thermal power plant having unit rated capacity of 500MW which uses the same fuel throughout the year.

Emission levels of major pollutants are established as follows:

(Unit: $mg/Nm^3$)

| | Coal-fired | Oil-fired | Gas-fired |
|---|---|---|---|
| SOx | 300 | 300 | - |
| NOx | 400 | 260 | 120 |
| Dust | 50 | 40 | 30 |

1) Selection of air pollution control equipment by type of pollutant

The following air pollution control equipment is selected for each type of pollutant, in consideration to the high removal rate, field-proven operating record, high reliability, and good economy in terms of plant and running costs.

(a) SOx ....... Wet-type lime-gypsum method

(b) NOx ....... Selective catalytic reduction method

(c) Dust .......Electric precipitator
Hot EP for coal
Cold EP for fuel oil

2) Proposed air pollution control equipment by type of fuel

(a) Coal-fired thermal power plants

a) Block diagram of the system

The block diagram of the air pollution control system for coal-fired thermal power plants is shown in Figure A6-3.

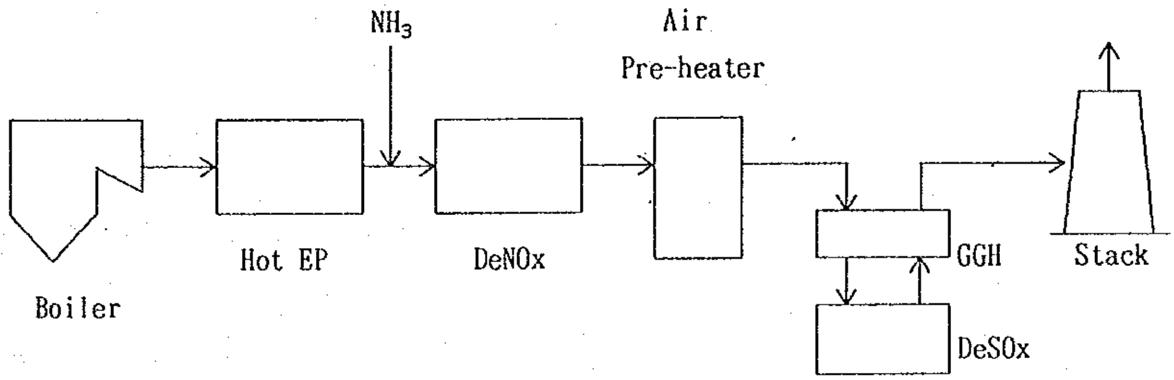



**Figure A6-3 BLOCK DIAGRAM OF AIR POLLUTION CONTROL SYSTEM FOR COAL-FIRED THERMAL POWER PLANTS**

b) Process description

Flue gas from the boiler (at around 370°C) goes through the hot EP for dust removal. The hot EP is used because coal dust's resistivity decreases at high temperature and does not cause inverse ionization. Also, the coal-fired boiler produces large amounts of dust, which should be removed on the upstream side in order to prevent the catalytic layer of the subsequent DeSOx equipment from being clogged. Flue gas leaving the EP is sprayed with ammonia, and NOx in the gas is converted to $N_2$ and $H_2O$ through the catalyst layer of the selective catalytic reduction DeNOx equipment. Then, the flue gas is cooled down to around 150°C through the air preheater and enter the gas gas heater, where it is further cooled down to 90°C through heat exchange with desulfurized clean gas. Then it enters the wet-type lime-gypsum DeSOx equipment and leaves there at 55°C. After SOx removal, the cleaned gas is heated to 105°C in the gas gas heater through heat exchange with gas at the outlet of the air preheater before release to the air through a stack.

c) Post-treatment concentrations of pollutants

Concentrations of air pollutants at the outlet of major equipment are as follows:

(Unit: $mg/Nm^3$)

| Pollutant | Boiler Outlet | Hot EP Outlet | DeNOx Equipment Outlet | DeSOx Equipment Outlet |
|---|---|---|---|---|
| SOx | (1,700-2,000) | (1,700-2,000) | (1,700-2,000) | less than 300 |
| NOx | (700-1,100) | (700-1,100) | less than 400 | less than 400 |
| Dust | (10,000-30,000) | (200-600) | (200-600) | less than 50 |

d) Plant cost

The cost of air pollution control equipment installed at a new 500MW coal-fired thermal power plant is estimated as follows:

(Unit: million yen)

| | |
|---|---|
| Desulfurizer | 71 - 95 |
| DeNOx equipment | 30 - 38 |
| Electrostatic precipitator | 19 - 24 |
| Gas gas heater | 8 - 11 |
| Total | 128 - 168 |

e) Costs of lime stone, ammonia, electricity, and gypsum

Assuming that coal with the 0.75% sulfur content is used, with NOx concentration in flue gas at 900mg/Nm$^3$, power consumption rate of 1.6%, and capacity utilization rate of 70%, the costs of lime stone, ammonia, electricity, and gypsum are estimated as follows:

| | Consumption | Cost |
|---|---|---|
| Lime stone | 28,700 tons/year | 5.5 - 6.9 mil. US$/y |
| Ammonia | 5,400 tons/year | 5.1 - 5.9 mil. US$/y |
| Electricity | 49,100 tons/year | 5.6 mil. US$/y |
| Sub-total | | 16.2 - 18.4 mil.US$/y |
| Gypsum | 42,000 tons/year | 1.1 - -1.5 mil.US$/y |
| Total | | 15.1 - 16.9 mil.US$/y |

(b) Oil-fired thermal power plants

a) Block diagram of the system

The block diagram of the pollution control system for oil-fired thermal power plants is shown in Figure A6-4.

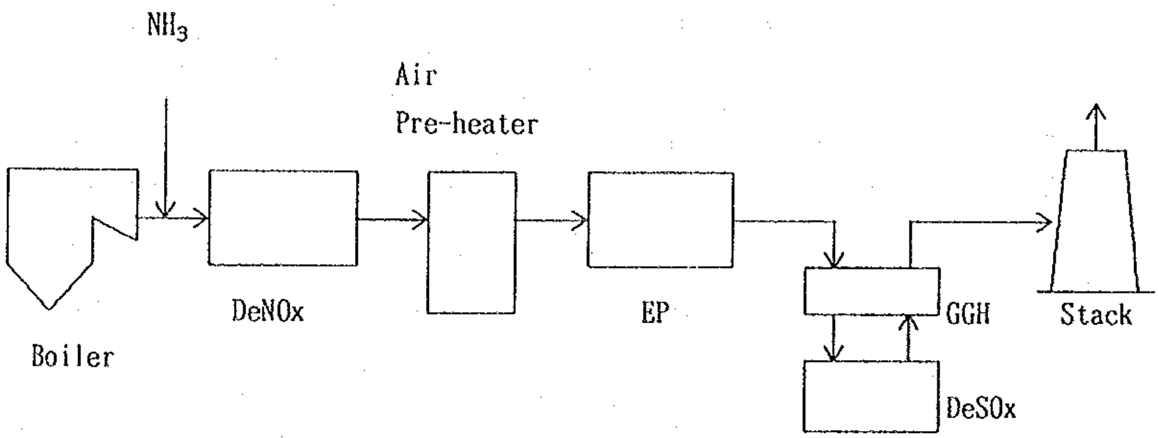



**Figure A6-4 BLOCK DIAGRAM OF POLLUTION CONTROL SYSTEM FOR OIL-FIRED THERMAL POWER PLANTS**

b) Process description

Flue gas at the boiler outlet (at around 370°C) is sprayed with ammonia and NOx in flue gas is removed through the selective catalytic reduction DeNOx equipment. Then the flue gas is cooled down in the air preheater to 150°C and enters the cold EP for dust removal. Then, it is cooled down in the gas gas heater by means of heat exchange with the desulfurized clean gas to 90°C, enters the wet-type lime-gypsum deSox equipment and leaves at 55°C after desulfurization. The cleaned gas is heated to 105°C in the gas gas heater by means of heat exchange with gas at the EP outlet, before being released to the air through a stack.

c) Post-treatment concentrations of pollutants

Concentrations of air pollutants at the outlet of major equipment are as follows:

(Unit: $mg/Nm^3$)

| Pollutant | Boiler Outlet | DeNOx Equipment Outlet | Cold EP Outlet | DeSOx Equipment Outlet |
|---|---|---|---|---|
| SOx | (1,700-2,000) | (1,700-2,000) | (1,700-2,000) | less than 300 |
| NOx | (400-600) | less than 260 | less than 260 | less than 260 |
| Dust | (100-200) | (100-200) | less than 40 | less than 40 |

d) Plant cost

The cost of air pollution control equipment installed at a new 500MW oil-fired thermal power plant is estimated as follows:

| | (Unit: million yen) |
|---|---|
| Desulfurizer | 7,500-10,000 |
| DeNOx equipment | 1,700- 2,300 |
| Electrostatic precipitator | 1,000- 1,500 |
| Gas gas heater | 800- 1,200 |
| Total | 11,000-15,000 |

e) Costs of lime stone, ammonia, electricity, and gypsum

Assuming that fuel oil with the 1.1% sulfur content is used, with NOx concentration in flue gas at $500mg/Nm^3$, power consumption rate of 1.5%, and capacity utilization rate of 70%, the costs of lime stone, ammonia, electricity, and gypsum are estimated as follows:

| | Consumption | Cost |
|---|---|---|
| Lime stone | 22,500 tons/year | 4.3 - 5.4 mil. US$/y |
| Ammonia | 2,200 tons/year | 2.1 - 2.4 mil. US$/y |
| Electricity | 46,000 tons/year | 550 mil. US$/y |
| Sub-total | | 11.6 - 13 mil. US$/y |
| Gypsum | 33,000 tons/year | -0.95 - -1.24 mil.US$/y |
| Total | | 10.7 - 11.8 mil.US$/y |

(c) Natural gas-fired thermal power plants

a) Block diagram of the system

The block diagram of the pollution control system for gas-fired thermal power plants is shown in Figure A6-5.

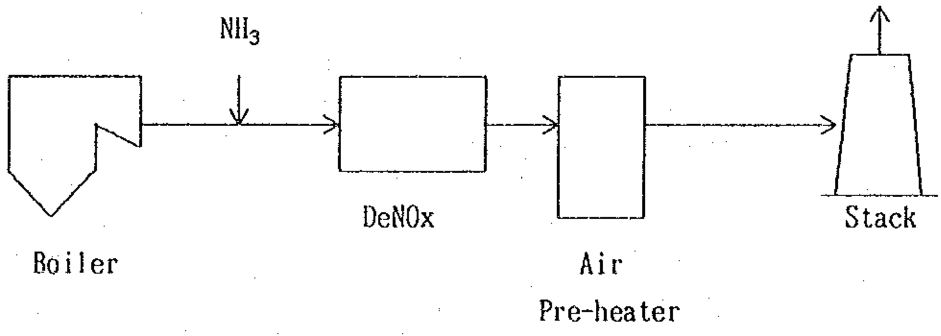



**Figure A6-5 BLOCK DIAGRAM OF POLLUTION CONTROL SYSTEM FOR GAS-FIRED THERMAL POWER PLANTS**

b) Process description

Flue gas at the boiler outlet (at around 370°C) is sprayed with ammonia, and NOx in the gas is removed through the selective catalytic reduction deNOx equipment. Subsequently, the gas is further cooled down to 150°C through the downstream air preheater and is released through a stack to the air.

c) Post-treatment concentration of pollutant

Natural gas combustion produces small amounts of SOx and dust, thus only NOx needs to be removed through the special equipment. NOx concentrations at the boiler outlet and after deNOx equipment are as follows:

(Unit: $mg/Nm^3$)

| | Boiler Outlet | Outlet of DeNOx Equipment |
|---|---|---|
| NOx | (300 - 400) | less than 120 |

d) Plant cost

The cost of deNOx equipment installed at a new 500MW gas-fired thermal power plant is estimated to be 11.5 - 12.5 million US$.

e) Ammonia and electricity costs

With NOx concentration of $350mg/Nm^3$, and plant operating rate of 70%, the costs of ammonia and electricity are estimated as follows:

| | Consumption | Cost |
|---|---|---|
| Ammonia | 2,100 tons/year | 2.0 - 2.3 mil. US$/y |
| Electricity | 4,000 MWh | 0.48 mil. US$/y |
| Total | | 2.48 - 2.78 mil.US$/y |

3) Supplemental

(a) Desulfurization process

In this report, the basic process of the wet type lime-gypsum method with the large installed base and high reliability has been selected. Another promising process is the jet bubbling reactor (JBR) process. However, the largest available unit using the JBR process is designed for a 350MW plant, and that for a 500MW plant has still to be constructed. Although the JBR process is not suitable for the project at this moment, it should be reconsidered when the system for the 500MW plant, constructed in the next few years, starts to be operated. The JBR process is superior over the basic process in terms of plant and running costs as well as the desulfurization rate.

(b) DeNOx process

This report has selected the selective catalytic reduction method because it is most widely used.

Also recommended is the in-furnace deNOx method.

In particular, it should be used in combination with various combustion management methods such as the exhaust gas mixing method, the two-stage combustion method, and the low NOx burner method. In this case, the boiler furnace is a few meters higher than ordinary furnaces. At the same time, it can achieve the reduction rate of NOx comparable to that by the selective non-catalytic reduction method using ammonia, with economy due to the use of the fuel as a reducing agent.

(c) Gas-fired thermal power plants

In this report, air pollution facilities are proposed for gas-fired thermal power plants under the assumption that they consist of the steam boiler and turbine, like oil-fired and coal-fired thermal power plants. In the future, however, it is recommended to adopt the combined cycle generation system consisting of a gas turbine and a steam turbine to a gas-fired thermal power plant. The combined cycle system can achieve overall thermal efficiency of 43% - 44%, which will be further boosted to 47% in the near future, well above the overall efficiency of 40% by a combination of the conventional boiler and the steam turbine.

The combined cycle system is most suitable for natural gas.

Although the system using the high temperature gas turbine produces more NOx, the selective catalyst reduction method can be used for effective reduction of NOx. Previously, many countries have chosen to lower combustion temperature for the purpose of reducing NOx production. However, the solution has led to the decline in thermal efficiency and the increase in $CO_2$ due to the increase in fuel consumption. Instead, reduction of NOx which produces from high temperature combustion is conducive to fuel saving, thus less $CO_2$ production.

## 6.4 Assessment of the cost impact of environment control measure

### (1) Basis of Assessment of Cost

Capital and operating costs for Paticulate Removal, Nitrogen Oxides Reduction and Flue Gas Desulfurization have been estimated for a typical 500MW Thermal Power Plant based, Heavy Fuel Oil and Natural Gas respectively as buit on a Turn Key Basis in The Republic of Argentina.

<u>Case-1: 500MW Natural Gas Power Plant</u>

| | |
|---|---|
| NOx Reduction | Selective Catalytic Reduction |

<u>Case-2: 500MW Heavy Fuel Oil based Power Plant</u>

| | |
|---|---|
| Particulate Removal | Electrostatic Precipitator |
| Nox Reduction | Selective Catalytic Reduction |
| Flue Gas Desulfurization | Limestone Gypsum Process |

<u>Emission Limits</u>

For the purpose of this study the following Emission Limits have been considered and are based on typical standards as set in the US, EC Countries and Japan.

| | |
|---|---|
| $SO_2$ | 0.576 $kg/10^6kcal$ |
| NOx | 0.288 $kg/10^6kcal$ |
| Particulates | 0.180 $kg/10^6kcal$ |

1) Natural Gas DeNOx Case

Case-1 500MW NG Based Power Plant

a. Flue Gas Clean up system Description

A brief description of the Flue Gas Clean Up System that has been considered for the 500MW NG based Thermal Power Plant as shown in Figure A6-6 is given below.

Particulate Removal

No Particulate removal system is required as Natural Gas is generally free of Particulate matter.

Nitrogen Oxides Reduction

The Boiler Flue Gas is fed to the Selective Catalytic Reduction (SCR) DeNOx unit at an appropriate temperature of about 400 deg.C where Nitrogen Oxides are removed by reacting with Ammonia in the presence of a Catalyst according to the following reactions

$$4NO + 4NH3 + O2 \rightarrow 4N2 + 6H2O$$
$$6NO2 + 8NH3 \rightarrow 7N2 + 12H2O$$

Typically the SCR Catalst is a Vanadium based catalyst with a carrier medium such as Alumina or Titanium Dioxide. In the SCR unit a NOx removal efficiency of about 50% is acheived in order to obtain a NOx concentration of 150mg/Nm3 before being discharged to the Stack.

SO2 Removal

No $SO_2$ removal system is required as the amount of Sulfur compounds in Natural Gas is generally negligible.

b. By-Products and Effluents

The only effluent issuing from the Flue Gas Clean Up System is the Stack Gas which satisfies the Emission Standards.

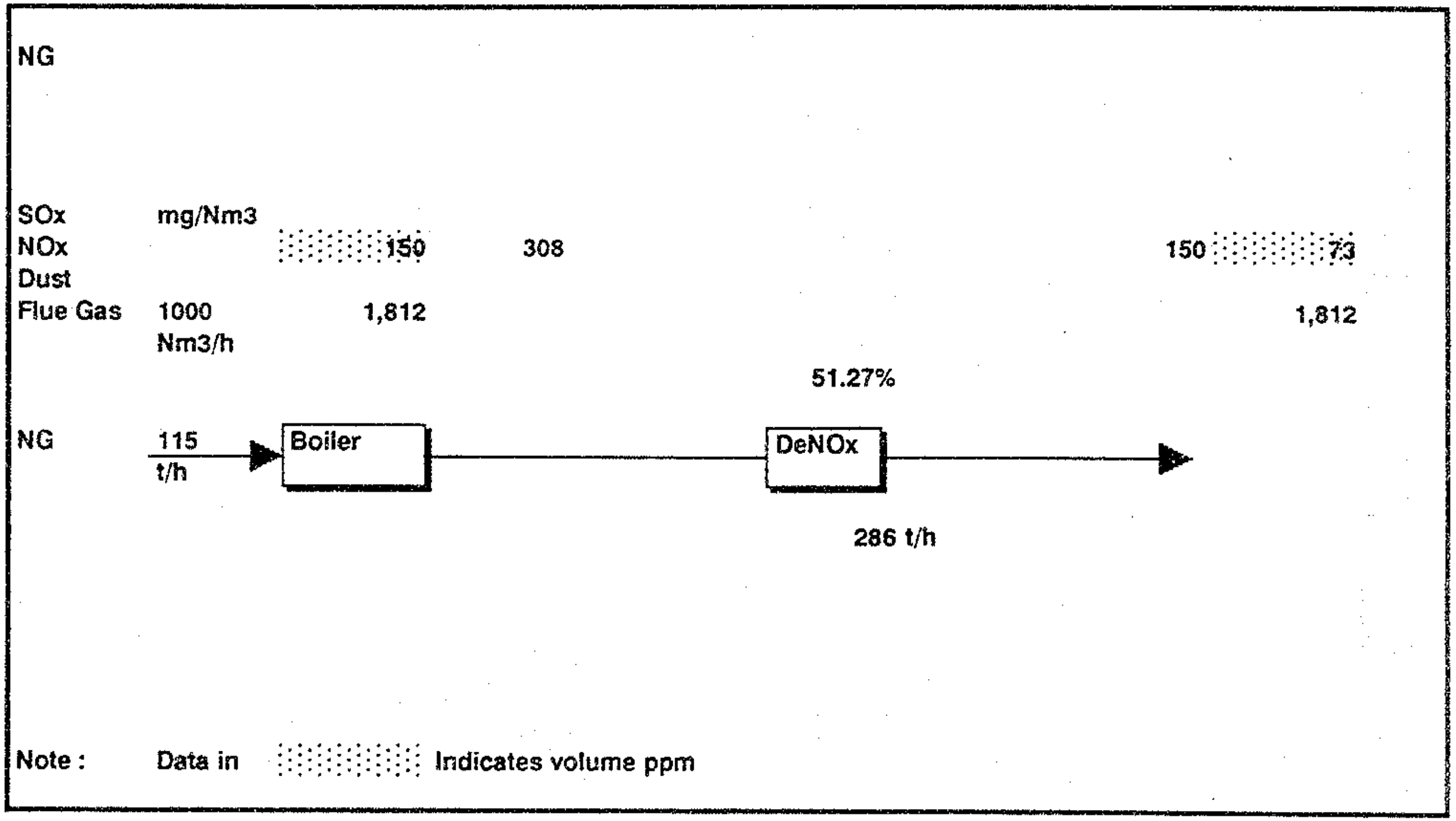



Figure A6-6 500MW GRASSROOTS POWER PLANT

c. Capital and Operating Costs

The Capital and Operating Costs are as given below. The Operating Costs are based on 8000 hours of continuous operation per year.

Capital Costs

| | MM US$ |
|---|---|
| Selective Catalytic Reduction Unit | 6.14 |
| Equipment & Materials Total | 6.14 |
| Civil & Erection | 2.62 |
| Engineering & Project Management | 1.34 |
| Overheads & Sales Expense | 0.99 |
| Indirect Field Expenses | 0.80 |
| Total Base Project Cost | 11.89 |

Operating Costs

| Raw Material | Consumption | Unit Price | Annual Cost 1,000US$ |
|---|---|---|---|
| Ammonia(100%) | 106kg/h | 1.24US$/kg | 1,050 |
| Steam | 4 T/h | 9.52US$/T | 305 |
| Industrial Water | T/h | 0.23US$/T | |
| Power | 2,500 kW | 0.048US$/kWh | 952 |
| Total | | | 2,307 |

2) Fuel Oil DeNOx, SOx, P.M. Case

Case-2 500MW Heavy Fuel Oil Based Power Plant

a. Flue Gas Clean Up system Description

A brief description of the Flue Gas Clean Up System that has been considered for the 500MW Heavy Fuel Oil based Thermal Power Plant as shown in Figure A6-7 is given below.

Particulate Removal

The Boiler flue gas is fed to a Rigid Electrostatic

Precipitator (ESP) where most of the Particulate Matter is removed before being fed to the Nitrogen Oxides Reduction Section. The ESP is designed to Operate at a Particulate Removal Efficiency of 75% where about 0.6 tons per hour of Ash is removed. The concentration of Particulates in the Stack Gas is about 100mg/Nm3.

Nitrogen Oxides Reduction

The particulate free Flue Gas is fed to the Selective Catalytic Reduction (SCR) DeNOx unit at an appropriate temperature of about 400 deg.C where Nitrogen Oxides are removed by reacting with Ammonia in the presence of a Catalyst according to the following reactions.

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$
$$6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$$

Typically the SCR Catalst is a Vanadium based catalyst with a carrier medium such as Alumina or Titanium Dioxide. In the SCR unit a NOx removal efficiency of about 66% is acheived in order to obtain a NOx concentration of 150 mg/Nm3 in the Stack Gas after removing $SO_2$ in the Flue Gas Desulfurization Unit.

SO2 Removal

The NOx depleted Flue Gas after appropriate heat recovery and reduction in temperature is fed to the Flue Gas Desulfurization Unit (FGD) for $SO_2$ removal. The FGD Process considered for this evaluation is the well established Limestone Forced Oxidation Process which results in the production of By-product Gypsum according to the following reaction.

$$CaCO_3 + SO_2 + 2H_2O + 0.5O_2 \rightarrow CaSO_4.2H_2O + CO_2$$

A $SO_2$ removal efficiency of about 82% is acheived in the FGD unit inorder to obtain a $SO_2$ concentration of 300mg/Nm3 in the Stack Gas. The By-Product Gypsum obtained in this process can be used as a building material or disposed of as Landfill.

b. FGD Process Description

A brief description of the Forced Oxidation Limestone Process that has been considered for Flue Gas Desufurization as shown in Figure A6-7 is given hereunder.

The Flue Gas after Particulate removal and NOx Reduction and being cooled to an appropriate temperature level is fed to the $SO_2$ Scrubber via a Booster Fan. In the Scrubber the $SO_2$ in the Flue Gas reacts with Limestone and Oxygen to form Gypsum according to the reaction as mentioned above. The reaction zone in the Scrubber provides for both oxidation of sulfites and crystallization of Gypsum.

The Gypsum slurry bleed stream is transfered to a Gypsum Slurry Tank. The Gypsum slurry is mechanically dewatered and sold as byproduct building material or disposed of as landfill.

The Desulfurized Flue Gas issuing from the $SO_2$ Scrubber is reheated in a reheat mix chamber where it is mixed with ambient air that has been heated in a heat exchanger with steam before being discharged to the atmosphere via a Flue Gas Stack.

c. By-Products and Effluents

The only By-Products or effluents issuing from the Flue Gas Clean Up System (other than the Stack Gas which satisfies the Emission Standards) are Ash from the ESP and Gypsum from the FGD unit. Both Ash and Gypsum can be sold to the Cement Industry and can be used for the production of building materials or disposed off as landfill material. The quality of Gypsum produced is expected to have a solids content of 80 to 90%

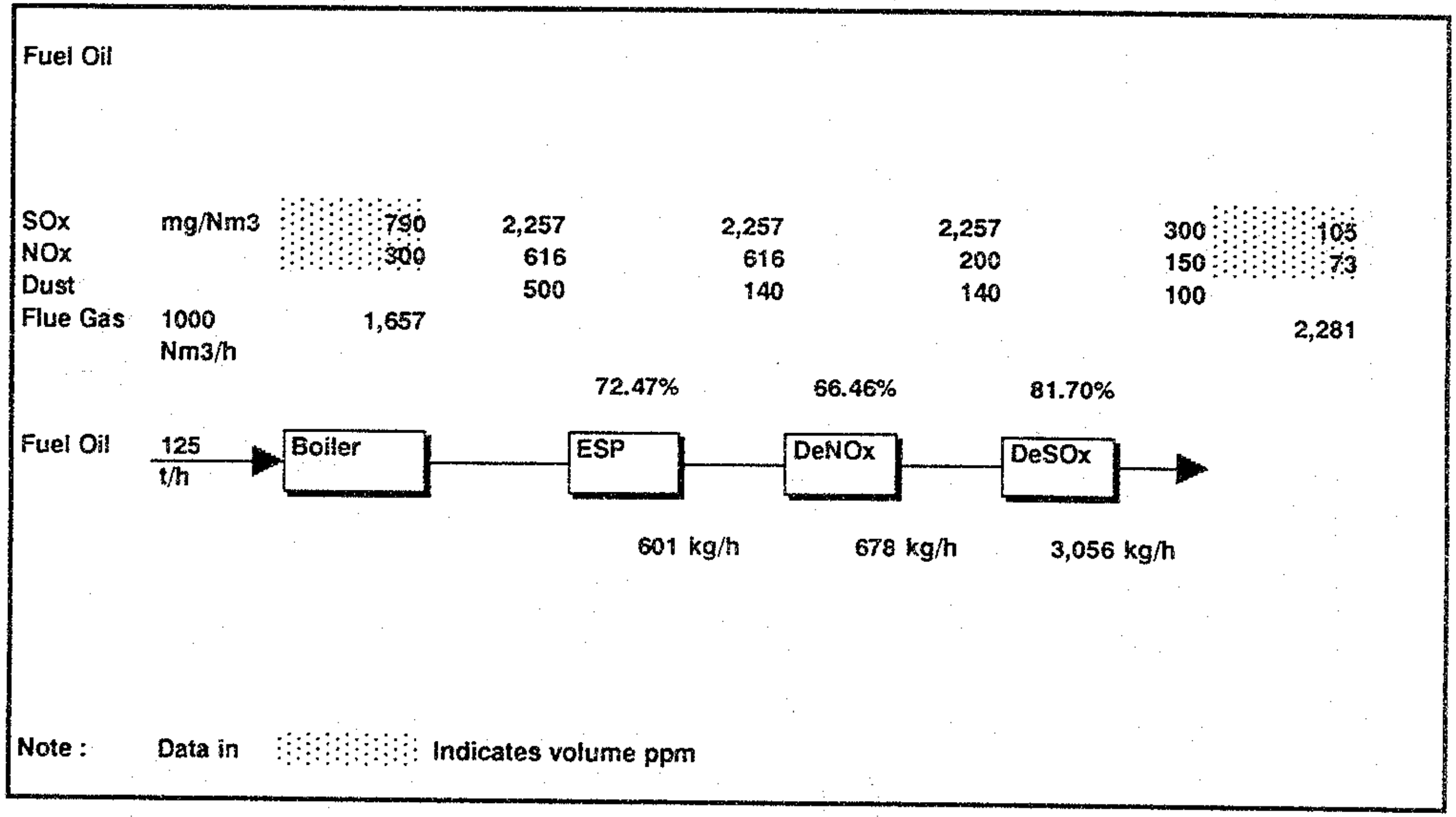



Figure A6-7 500MW GRASSROOTS POWER PLANT

d. Capital and Operating Costs

The Capital and Operating Costs are as given below. The Operating Costs are based on 8000 hours of continuous operation per year.

Capital Costs

| | MM US$ |
|---|---|
| Electrostatic Precipitator | 3.71 |
| Selective Catalytic Reduction Unit | 4.69 |
| Flue Gas Desulfurization Unit | 25.89 |
| Equipment & Materials Total | 34.29 |
| | |
| Civil & Erection | 26.97 |
| Engineering & Project Management | 10.05 |
| Overheads & Sales Expense | 6.89 |
| Indirect Field Expenses | 4.44 |
| Total Base Project Cost | 82.64 |

Operating Costs

| Raw Material | Consumption | Unit Price | Annual Cost MM US$ |
|---|---|---|---|
| Limestone | 5,015kg/h | 14.3¢/kg | 5.74 |
| Ammonia | 251kg/h | 1.24US$/kg | 2.49 |
| Steam | 44 T/h | 9.52US$/T | 3.35 |
| Industrial Water | 104 T/h | 22.8¢/T | 0.19 |
| Power | 9,100 kW | 4.8¢/kWh | 3.49 |
| Total | | | 15.26 |

| | |
|---|---|
| Gypsum | 11 T/h |
| Ash | 1 T/h |

(2) Assessment of Power Cost

1) Foreword

According to the assessment conducted this time in relation to the air pollution in the country caused by thermal power plants, it is concluded that the present pollution level of emission from thermal power plants in Buenos Aires, Rosario and Mendoza is not hazardous to the natural environment or inhabitant.

This means immediate installation of any additional counter measure to reduce pollution level will not be required in any of thermal power plant in Argentine.

However, the envisaged rapid economic development of the country will results increase of energy consumption in the country including additional fuel consumption by the transportation sector, miscellaneous industry and the thermal power plants.

Some time in future, emission of NOx and SOx from vehicles, industries and power plant will exceed the level which can not maintain the pollution level of atmosphere at satisfactory level without advanced emission control measures.

It is considered that the most likely additional thermal power plant in future in Argentine will be natural gas base power plant and some fuel oil base power plants will be required to supplement the natural gas base power plant, when and where natural gas supply is not sufficient to cover all future demand of the newly constructed thermal power plant.

In the followings, the financial impact of the installation of pollution control facilities to the power generation cost in newly built thermal power plant are described.

The case of NOx reduction by catalytic selective reduction for a natural gas base combined cycle power plant and the case of fuel oil base steam turbine power plant with DeSOx, DeNOx and De particulate material are adopted as most likely example.

2) Method of assessment of the financial impact

In order to indicate the cost impact of the pollution abatement facility to power generation cost, the cost estimation of power generation cost without abatement facility and the cost of operation of abatement facility must be estimated on the comparable bases.
The cost estimation uses "Plant Life Time Average Cost" method.
This method is utilized widely to estimate the cost of a project with long project life or to compare different type of power generation plant. The future return obtained from future operation is converted to the value at the time of initial investment is made utilizing discount cash concept. The charge of electricity through the project life is fixed at constant figure (assuming inflation effect is nil).
The present value of integrated future income will be expressed as under;

$$\sum_{i=1}^{n} KWH(i) \times A \times \left[ \frac{1}{1 + \frac{r}{100}} \right]^{i} \quad \ldots\ldots (1)$$

i = year from start up
KWH(i) = Annual sales of KWH at ith year
A = Unit price of electricity
r = Discount Rate %

The unit price normally determined to allow the investor to recover initial investment and to obtain reasonable margin which can be utilized to recover cost of capital by loan or own resources, to use for development of technical level of the plant, to develop future project, etc.

Therefore, the total income through the project life will be equivalent to the above mentioned capital recovery plus margin (Capital Cost) plus fuel cost, plus direct operating cost such as man-power cost maintenance cost, tax and other miscellaneous cost incurred for operation .

Integrated annual income through the project life converted to the present value should be equivalent to the operating cost including capital related cost as shown bellow,

$$\sum_{i=1}^{n} \{\text{Capital cost}(i)+\text{Fuel cost}(i)+\text{Operating cost}(i)\}\frac{1}{(1+\frac{r}{100})^{i}} \quad ...(2)$$

This equation indicates the break down of total income to be collected from sales of electricity.

Capital cost(i)
= recovered capital cost at ith year
Fuel cost(i)
= Fuel cost spend at ith year
Operating cost(i)
= Direct operation cost of the ith year
r = Discount Rate

From equation (1) and (2)
Unit power cost A will be defined as bellow;

$$A = \sum_{i=1}^{n} \{\text{Capital cost}(i)+\text{Fuel cost}(i)+\text{Operating cost}(i)\}\frac{1}{(1+\frac{r}{100})^{i}} \div \sum_{i=1}^{n} KWH(i)\cdot\frac{1}{(1+\frac{r}{100})^{i}}$$

For simplification, we assume the annual sales of electricity (KWH) through the project life is constant. the annual capital cost element will be considered as also constant.

The typical case of the natural gas base combined cycle power plant assuming 15 years project life, 9.2% Discount Rate for return (which equivalent 6% flat depreciation plus 6.5% flat capital recovery on initial investment), etc are shown in Table A6-1.

The additional cost for DeNOx of the combined cycle power plant based on the same procedure applied to power plant itself is also shown Table A6-1.

When the same cost calculation method is applied to a typical heavy fuel oil power plant, the impact of installation of DeNOx, DeSOx and De P.M. will be as Table A6-1.

**Table A6-1 (a) ARGENTINE ELECTRICITY**

| | | | |
|---|---|---|---|
| Combined cycle 500MW | | 15 Year Life | DeNOx Facility |
| Investment Million $ | | | |
| Direct Plant Cost | | 12.50 | |
| Indirect Const | | 1.25 | |
| Total | | 13.75 | |
| Operating Cost | | Million $/Year | |
| In-direct | | | |
| Depreciati | 6% Flat | 0.83 | 0.83 |
| (90% Invest | 15 Y Equal) | | |
| Return | 8% 1st Y | 1.10 | |
| | 6.5% Ave | 0.89 | 0.89 |
| Tax | 2.47% Ini | 0.34 | |
| | 1.8% Ave | 0.25 | 0.25 |
| ADM,MISCE | 1.36% Ini | 0.19 | |
| | 1.26 Ave | 0.17 | 0.17 |
| Direct | | | |
| Man Power | 0.42% | 0.06 | 0.06 |
| Person 16375$ | | | |
| Maintenance | 0.9% Ini | 0.12 | |
| | 1.46% Ave | 0.20 | 0.19 |
| Annual Cost | | 2.39 | 0.07 |
| Annual Cost Exclu Depre & In | | 0.67 | 0.12 |
| Other Cost | | | KWH Cost(C) |
| Ammonia 0.5 Gram/KWH | | 0.06¢us/KWH | |
| Power 0.005KWH/KWH | | 0.02¢us/KWH | |
| | | | 0.08 Plus |
| | | | 0.07 |
| | | Total: | 0.15 ¢us/KWH |

## Table A6-1 (b) ARGENTINE ELECTRICITY

Oil Steam Turbine 500MW 15 Year Life

Investment Million $ 86.80 De-Polution Unit
De SOx NOx PM

| | | | |
|---|---|---|---|
| Direct Plant Cost | | 78.12 | |
| Indirect Const | | 8.68 | |
| Total | | 86.80 | |
| Operating Cost | | Million $/Year | |
| In-direct | | | |
| Depreciati | 6% Flat | 5.21 | 5.21 |
| (90% Invest | 15 Y Equal) | | |
| Return | 8% 1st Y | 6.94 | |
| | 6.5% Ave | 5.64 | 5.64 |
| Tax | 2.47% Ini | 2.14 | |
| | 1.8% Ave | 1.56 | 1.56 |
| ADM,MISCE | 1.36% Ini | 1.18 | |
| | 1.26 Ave | 1.09 | 1.09 |
| Direct | | | |
| Man Power | 0.18% | 0.16 | 0.16 |
| Person 16375$ | | | |
| Maintenance | 0.58% Ini | 0.69 | |
| | 1.23% Ave | 0.91 | 0.91 |
| Annual Cost | | 13.85 | 0.42¢us/KWH |
| Annual Cost Exclu Depre & In | | 3.00 | 0.09¢us/KWH |

| | | | |
|---|---|---|---|
| Other Cost | | | |
| Ammonia | 0.5 Gram/KWH | 0.06¢us/KWH | 1100$/Ton |
| Power | 0.005KWH/KWH | 0.09¢us/KWH | 0.05$/KWH |
| Steam | 0.08kg/KWH | 0.04¢us/KWH | 5.0$/Ton |
| Lime | 0.01kg/KWH | 0.15¢us/KWH | 150$/Ton |
| | Sub Total: | 0.34¢us/KWH | |
| | Total: | 0.76¢us/KWH | |

## Table A6-1 (c) ARGENTINE ELECTRICITY

Combined Cycle Power Plant    Investment 312.00 Million$
Present Value Method

| | | | | |
|---|---|---|---|---|
| Operating Cost | | Million $/Year | | |
| In-direct | | | | |
| Depreciati | 6% Flat | 18.72 | 18.72 | |
| (90% Invest | 15 Y Equal) | | | |
| Interest | 8% 1st Y | 24.96 | | |
| | 6.5% Ave | 20.28 | 20.28 | 22.24 |
| Tax | 2.47% Ini | 7.71 | | |
| | 1.8% Ave | 5.62 | 1.56 | |
| ADM,MISCE | 1.36% Ini | 4.24 | | |
| | 1.26 Ave | 3.93 | 3.98 | |
| Direct | | | | |
| Man Power | 0.42% | 1.31 | 1.31 | |
| Person 16375$ | | | | |
| Maintenance | 0.9% Ini | 2.81 | | |
| | 1.46% Ave | 4.56 | 4.56 | |
| | | | +5.67 | |

Note; Interest Rate is Not Commercial Rate

| | | |
|---|---|---|
| Annual Cost | 54.41 | 1.66 |
| Annual Cost Exclu Depre & In | 15.41 | 0.47 |

| Fuel Cost (2050kcal/KWH) | | KWH Cost(c) |
|---|---|---|
| 1.0$/MMBTU 0.4¢/MKcal | 0.82¢us/KWH | 2.42 |
| 2.0$/MMBTU 0.8¢/MKcal | 1.64¢us/KWH | 3.30 |
| 3.0$/MMBTU 1.2¢/MKcal | 2.46¢us/KWH | 4.12 |

## Table A6-1 (d) ARGENTINE ELECTRICITY

| | | | | |
|---|---|---|---|---|
| | ST | 0.34 | | |
| Power Plant Oil Steam | | 500MW | | |
| Operating Cost | | Million $/Year | | |
| In-direct | | | | |
| Depreciati | 6% Flat | 29.74 | 29.74 | |
| (90% Invest | 15 Y Equal) | | | |
| Interest | 8% 1st Y | 39.65 | | |
| | 6.5% Ave | 32.22 | 32.22 | 22.24 |
| Tax | 2.47% Ini | 12.24 | | |
| | 1.8% Ave | 8.92 | 8.92 | |
| ADM,MISCE | 1.36% Ini | 6.74 | | |
| | 1.26 Ave | 6.25 | 6.25 | |
| Direct | | | | |
| Man Power | 0.26% | 1.31 | 1.31 | |
| Person 16375$ | | | | |
| Maintenance | 0.58% Ini | 2.87 | | |
| | 1.05% Ave | 5.20 | 5.20 | |
| | | | +5.67 | |

Note; Interest Rate is Not Commercial Rate

| | | |
|---|---|---|
| Annual Cost | 83.64 | 2.55 |
| Annual Cost Exclu Dep & Retu | 21.68 | 0.66 |
| | Million $ | ¢us/KWH |

| Fuel Cost (2050kcal/KWH) | | | KWH Cost(c) |
|---|---|---|---|
| 1.0$/MMBTU | 0.4¢/MKcal | 0.82¢us/KWH | 3.27 |
| 2.0$/MMBTU | 0.8¢/MKcal | 1.64¢us/KWH | 4.19 |
| 3.0$/MMBTU | 1.2¢/MKcal | 2.46¢us/KWH | 5.01 |

# APPENDIX 7 Current State of Air Pollution Control Measures at Thermal Power Plants in Japan

# Appendix 7 Current State of Air Pollution Control Measures at Thermal Power Plants in Japan

## A7.1 Management of Air Pollution Control Activities

### A7.1.1 Role of Government in Air Pollution Control

(1) Environmental Agency

Environmental Agency, established in 1971, is responsible for development, formulation, and promotion of basic policy related to environmental preservation in Japan and for overall coordination of related government agencies in environmental preservation activity.

Activities related to preservation of air quality are conducted by Planning Division, Air Pollution Control Division, and Automotive Pollution Control Division under Air Quality Bureau.

Major responsibilities of the above three divisions are summarized as follows.

1) Planning division

Overall coordination of the agency's business; overall coordination of activities related to environmental preservation of related organizations required for implementation of the agency's business; enforcement of the Clear Air Act (not including matters under jurisdiction of Air Pollution Control Division and Automotive Pollution Control Division; and enforcement of the Law for Protection of Ozone Layer through Regulation of Specific Substances.

2) Air Pollution Control Division

Establishment of emission standards, total pollutant load control standards, and fuel utilization standards, under the Clean Air Act; establishment of standards related to structure, use and management of ordinary dust emitting facilities under the Clean Air Act, and of control standards for specific dust related to specific dust emitting facilities; and monitoring required for air pollution control (not including matters under jurisdiction of Automotive Pollution Control Division).

3) Automotive Pollution Control Division

Establishment of allowable limits for automobile exhaust gas; establishment of allowable limits for automobile noise; enforcement of the Law for Control of Dust Generation from Spike Tires; monitoring required for control of air pollution and noise in connection with automobile traffic; and investigation and planning related to control of pollution produced in connection with automobile traffic.

In addition, Environmental Agency has its own research organization, National Institute for Environmental Studies, and Atmospheric Environment Department is responsible for air quality as a general.

(2) Ministry of International Trade and Industry (MITI)

The ministry deals with preservation of air quality related to industry and trade for the interest of controlling industrial pollution. Industrial Location and Environmental Protection Bureau is responsible for investigation related to policy making and planning, as well as pollution control accompanied by industrial siting. Management and supervision on operation of thermal power plants from construction to operation are conducted by Public Utilities Department under the Agency of Natural Resources, and Public Utilities Departments under Regional Trade and Industry Bureaus in 8 areas throughout the country.
Major responsibilities of bureaus and divisions related to preservation of air quality are summarized as follows.

1) MITI, Industrial Location and Environmental Protection Bureau, Environmental Policy Division

Overall management of the ministry's affairs related to pollution control and environmental preservation; development of policy and plan related to control of industrial pollution; investigation and guidance on control of industrial pollution under jurisdiction of MINI; subsidy related to control of industrial pollution under MITI's jurisdiction; enforcement of the Law Concerning Development of Pollution Control Organizations at Designated Factories; guidance and supervision of organizations related to control of industrial pollution under MITI's jurisdiction; matters related to disposal of industrial waste under MITI's jurisdiction; and enforcement of the Law Concerning Compensation for Health Damage due to Pollution.

2) Power Generation Division, Public Utilities Department of Agency of Natural Resources and Energy, and Public Utilities Departments of Regional Trade and Industry Bureaus

Construction, maintenance, and operation of turbines and auxiliary boilers at hydrowater, thermal, and nuclear power generation facilities; coordination of rights to water and land for power source development; investigation related to environmental preservation of the site for hydrowater, thermal, and nuclear power generation facilities; matters related to hydropower generation dams; commenting and recommendation on the use of hydropower to prefectural governors; contribution to cost for common facilities for power generation; investigation on hydropower development; investigation on river flow and meteorology related to power generation; flow meter calibration testing; welding inspection on thermal and nuclear power generation facilities; rationalization of use of power generation fuels (not including nuclear fuels); and matters related to geothermal power generation.

Also, MITI has its own research arm, National Institutes for Resources and Environment, and Atmospheric Environmental

Protection Department is responsible for air quality.

3) Local government organizations

Departments or bureaus related to environmental preservation and pollution control are established in 47 prefectural governments (including Tokyo Metropolitan Government) and municipalities, townships, and villages. Also, the Council on Anti-Pollution Measures is established in each prefecture, municipality, township, and village under the Fundamental Law of Environment (explained later) to work under supervision of prefectural governors,

## A7.1.2 Laws, Regulations, and Standards Related to Air Pollution

The Fundamental Law of Environmental Act, the backbone of pollution control related legislations in Japan, and the Clean Air Act which regulates air pollution are described as follows.

(1) Fundamental Law of Environmental

In Japan, with rapid economic development which started in the late 1950s, problems of air pollution, water contamination, and noise have surfaced throughout the country. In particular, a major shift of the primary energy source from coal to petroleum, accompanied by construction and operation of petrochemical complexes in major industrial areas, has created extensive atmospheric pollution by sulfur oxides, as well as new types of offensive odors. Clearly, a variety of pollution sprung up with the increase in consumption of petroleum. Furthermore, rapid concentration of population in urban areas, and the rise in standards of living have given birth to urban pollution, including noise from road traffic and construction sites, and air pollution due to exhaust gas from automobiles.

To take administrative measures against pollution, the government enacted the Factory Effluent Control Act and the Water Quality Preservation Act in 1958. However, these laws regulated concentration at an individual source and were not able to cope with the explosive increase in pollution sources and pollutants.

In recognition of the need for clearly defining basic principles and guidelines to promote environmental policy, including the scope of pollution, division of responsibility between business operators, and the central and local governments, the Basic Environmental Act was enacted in 1967.

The Fundamental Law of Environment of 1993 was enacted replacing the Basic Low for Environmental Control, with a view to providing more extensive coverage of pollution control, to coping with urban pollution and daily-life-related pollution, to applying a variety of control methods, and to reassessing fundamental socio-economic systems as well as people's behavioral patters.

1) Objectives etc.,

The objective of the Law is "to help ensure peoples healthy and cultural life at present and in the future as well as to contribute to welfare of mankind". For this objective, the Law stipulates the basic philosophy concerning environmental protection in order to promote policies for environmental preservation in an integrated and systematic manner, olefines responsibilities of the national and local governments, business entities and people, and sets forth other principles of environmental protection policies.

Incidentally according to the Law's definition, "environmental pollution" means adverse impacts on human health and life environment to be caused by extensive "air pollution", "water contamination', "soil contamination", "noise" "vibration", "land subsidence", and "offensive odor" generated by business activities and other human activities.

Basic Concepts of the Fundamental Law of Environment:

- enjoyment and inheritance of benefits of good environment
- construction of the society enabling sustained growth with minimal impact on environment
- active promotion of environmental preservation of the earth through international cooperation

The entire pollution-related legislations under the Basic Environmental Act is summarized in Figure A7-1, and the regulatory structure in Figure A7-2.

- Fundamental Law of Environment
  - Duties of Entrepreneurs
    - *Law for the Establishment of an Organization for Pollution Control in Specified Factories
    - *Law Concerning Entrepreneurs Bearing the Cost of Public Pollution Control Works
  - Control of Emissions, etc.
    - *Air Pollution Control Law
    - *Water Pollution Control Law
    - *Law Concerning Special Measures for Lake Water Quality Protection
    - *Law Concerning Special Measures for Seto Inland Sea Conservation
    - *Law Concerning the Prevention of Marine Pollution and Marine Disasters
    - *Agricultural Land Soil Pollution Prevention, etc., Law
    - *Noise Regulation Law
    - *Vibration Regulation Law
    - *Industrial Water Law (Ground subsidence)
    - *Law Concerning Regulation of Pumping-up of Ground Water for Use in Buildings (Ground subsidence)
    - *Offensive Odor Control Law
  - Installation of environmental pollution control equipment
    - *Law Concerning Emergency Measures for Improvement of Waste Disposal Equipment
    - *Waste Disposal and Public Cleaning Law
    - *Sewerage Law
  - Protection of nature
    - *Nature Conservation Law
    - *Natural Parks Law
  - Control of land use
    - *National Land Comprehensive Development Law
    - *City Planning Law
    - *Law Concerning Restriction on Industries, etc., in Built-up Districts in the National Capital Region (also for Kinki Region)
    - *Factory Siting Law
  - Aid
    - *Law Concerning Special Government Financial Measures for Pollution Control Project
    - *Environmental Pollution Control Service Corporation Law
  - Settlement
    - *Pollution Health Damage Compensation Law
    - *Law Concerning the Settlement of Environmental Pollution Disputes
  - Crimes relating to environmental pollution
    - *Law for the Punishment of Environmental Pollution Crimes Relating to Human Health

**Figure A7-1 SYSTEM CHART OF THE FUNDAMENTAL LAW OF ENVIRONMENTAL**

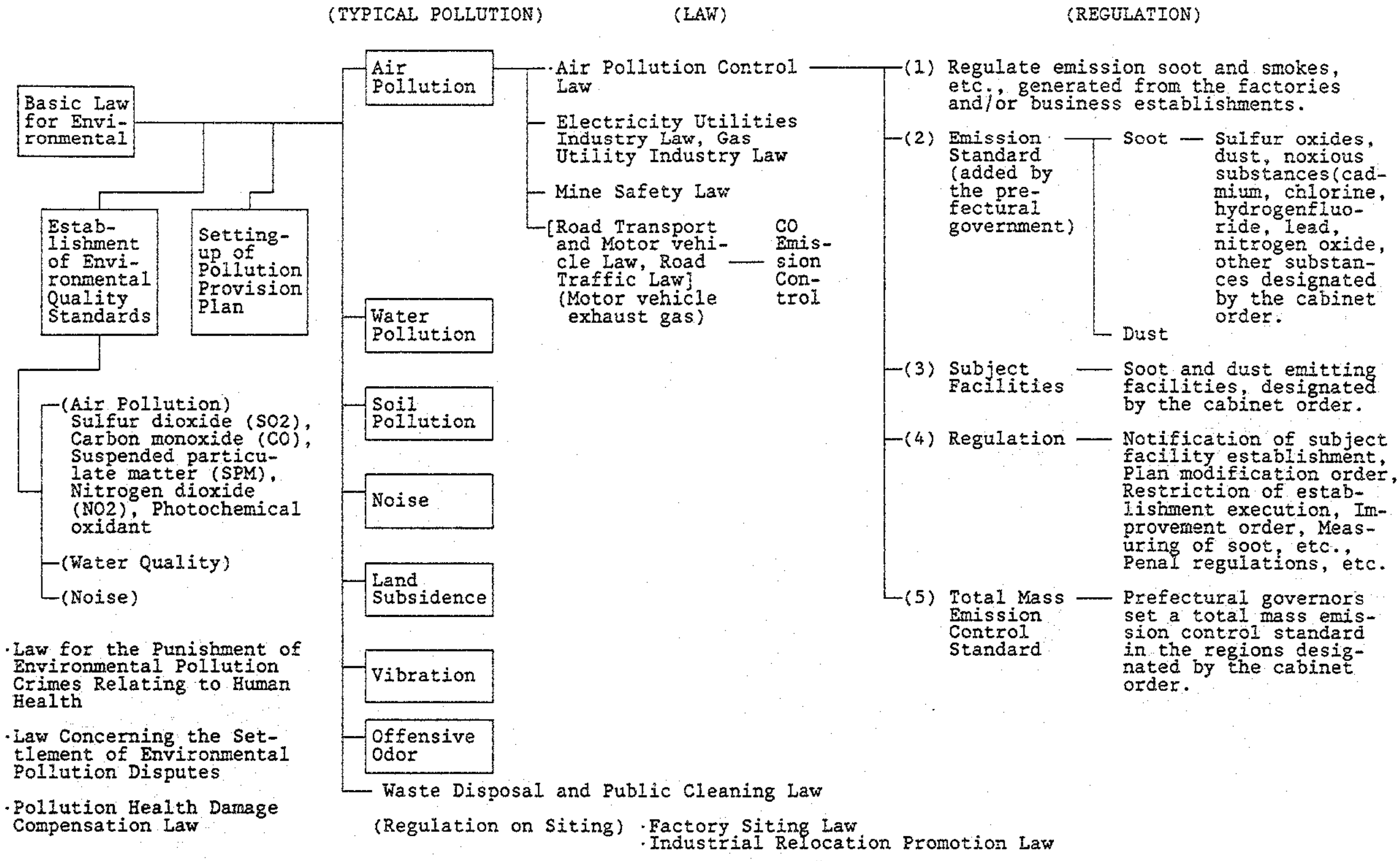



**Figure A7-2 SYSTEM OF BASIC LAW FOR ENVIRONMENTAL**

(2) The Law defines the responsibilities of national and local governments, business organizations and people. Particularly for business organizations, the following responsibilities are stipulated:

(a) to properly treat soot, polluted water, wastes etc, add, thereby, to prevent pollution and to take necessary measures to preserve natural environment properly

(b) to take necessary measures so that proper treatment will be made when products and other materials generated by business activities have turned into wastes.

(c) to make necessary efforts to reduce impact on environment to be made by products of business activities when they have turned into wastes, as well as to attempt to use such raw materials, services and so forth that help reduce impact on renewable resources and other environment.

(d) to make necessary efforts to reduce impact of business activities on environment and to preserve environment and also to cooperate with national and local governments implementing policies for environmental preservation.

Furthermore, the Law defines the following national government responsibilities pertaining to formulation and implementation of basic and integrated policies for environmental preservation of environmental preservation:

Government Responsibilities:

- to take full consideration of environmental preservation in formulating and executing policies
- to promote environmental impact assessment
- to enforce regulations for reducing obstacles for environmental preservation

- to take economic measures for reducing obstacles for environmental preservation
- to promote activities for improving facilities for environmental preservation and other activities
- to encourage use of products and materials with low impact on environment
- to promote education and learning in environmental preservation
- to take necessary measures to promote voluntary activities by private organizations and others
- to provide information
- to conduct studies
- to promote R & D
- to handle disputes related to environmental impact and to compensate for damages
- to pursue international cooperation in relation to environmental preservation of the earth and other activities
- to cooperate internationally for monitoring and observation as well as other activities
- to encourage local governments and private organizations to protect environment
- to take environmental preservation into account in implementing international cooperation and other activities

3) Current status of environmental standards

Under the law, environmental standards are established for air pollution, water contamination, noise, and soil contamination.

Table A7-1 shows environmental standards related to air pollution: those related to sulfur oxides were established in February, 1969; those covering carbon monoxide in February, 1970; and those related to suspended particulates in January, 1972. In May, 1973, environmental standards for photochemical oxidants and carbon dioxide were established and those for sulfur dioxide were revised.

Table A7-2 shows major events related to pollution and environmental policy in Japan.

### Table A7-1 Ambient Air Quality Standards

| Substance | | Sulfur Dioxide ($SO_2$) | Carbon Monoxide (CO) | Suspended[1] Particulate Matter (SPM) | Nitrogen Dioxide ($NO_2$) | Photochemical[2] Oxidants (Ox) |
|---|---|---|---|---|---|---|
| Environmental Standard | Environmental Condition | Daily average of hourly values shall not exceed 0.04 ppm, and hourly values shall not exceed 0.1 ppm. | Daily average of hourly values shall not exceed 10 ppm, and average of hourly values in eight consecutive hours shall not exceed 20 ppm. | Daily average of hourly values shall not exceed 0.10 $mg/m^3$, and hourly values shall not exceed 0.20 $mg/m^3$. | Daily avrage of hourly valuese shall be within the range between 0.04 ppm and 0.06 ppm or below. | Hourly values shall not exceed 0.06 ppm. |
| | Measuring Method | Conductometric method | Nondispersive infrared analyzer method | Weight concentration measuring methods based on filtration colleciton, or light scattering method, or piezoelectric microbalance method of β-ray attenuation method yeilding values having a linear relation with the values of the above method. | Colorimetry employing Saltzman reagent (with Saltzman's coefficient being 0.84) | Absorptiometry using nuetral potassium iodide solution, or colormetry. |

Notes: 1. Suspended particulates matter shall mean airborn particles of 10 microns or less in diameter.

2. Photochemical oxidants are oxidizing substances such as ozone and peroxiacetyl ntrate produced by photochemical reactions (only those capable of isolating iodine from neutral potassium iodide, excluding nitrogen dioxie).

Table A7-2 Brief History of Pollution and Environmental Policy in Japan

(1/2)

| Year | Major Event |
|---|---|
| 1949 | •Tokyo Metropolitan Government established the first ordinance for prevention of industrial pollution. |
| 1955 | •Air Pollution due to smoke emission from steel plants in Chiba prefecture. |
| 1956 | •Minamata disease became major public concern. |
| 1961 | •Enactment of the Smoke Control Act. |
| 1964 | •The Ministry of Welfare established Pollution Division. |
| 1967 | •Promulgation and enactment of the Basic Anti-Pollution Measures Act.<br>•The Yokkaichi air pollution trial began. |
| 1968 | •Enactment of the clean Air Act and the Noise Control Act.<br>•Establishment of K emission standard values (the first stage) for sulfur oxides. |
| 1969 | •Cabinet decision on environmental standards for sulfur oxides.<br>•Enactment of special emission standards for sulfur oxides Promulgation of the Law for Special Measures Related to Health Damage due to Pollution. |
| 1970 | •Introduction of the second-stage K emission standard value control.<br>•Establishment of environmental standards for carbon monoxide Partial amendment of Basic Anti-Pollution Measures Act and adoption of 14 pollution legislation including the Water Contamination Prevention Act. |
| 1971 | •Introduction of the third-stage K emission standard value control.<br>•Inauguration of Environmental Agency.<br>•Inauguration of Conference on Environmental Pollution Control.<br>•Establishment of fuel utilization standards. |
| 1972 | •Establishment of environmental standards for suspended particulate.<br>•Introduction of the fourth-stage K emission standard value control.<br>•Notification of '73 regulation on automobile exhaust gas. |
| 1973 | •Introduction of the fifth-stage K emission standard value control.<br>•Establishment of environmental standards for nitrogen dioxide and photochemical oxidant.<br>•Establishment of emission standards for nitrogen oxides from fixed sources. |
| 1974 | •Introduction of the sixth-stage K emission standard value control.<br>•Notification of '75 regulation on automobile exhaust gas Partial amendment of the Clean Air Act (introduction of total pollutant load control on sulfur oxides). |

| Year | Major Event |
|---|---|
| 1975 | •Notification of '75 regulation on automobile exhaust gas.<br>•Introduction of higher emission standards for nitrogen oxides from fixed sources.<br>•Introduction of the seventh-stage K emission standard value control.<br>•Designation of the second areas subject to total pollutant load control on sulfur oxides. |
| 1976 | •Introduction of the eighth-stage K emission standard value control.<br>•Notification of '78 regulation on automobile exhaust gas.<br>•Designation of the third areas for total pollutant load control on sulfur oxides. |
| 1978 | •Notification of '79 regulation on automobile exhaust gas.<br>•Revision of environmental standards for nitrogen dioxide. |
| 1979 | •Introduction of higher emixxion standards for nitrogen oxides from fixed sources.<br>•Notification of '81 regulation on automobile exhaust gas. |
| 1980 | •Notification of '82 regulation on automobile exhaust gas. |
| 1981 | •Introduction of total pollutant load control on nitrogen oxides.Conference on Environmental Pollution |
| 1985 | •Small boilers were added to the subject of regulation under the Clean Air Act. |
| 1987 | •Gas turbines and diesel engines were added to the subject of regulation under the Clean Air Act. |
| 1992 | •Proclamation of Law of NOx for Automobiles |
| 1993 | •Proclamation and Enforcement of Fundamental Law of Environment<br>•Approval on Total NOx Decreasing Plan of Emission from Automobiles |

4) Pollution control plan

The pollution control plan sets forth pollution control policy and measures to be implemented in a specific area under the recognition that regulating individual factories and other establishments is not effective enough to control pollution in a community.

The pollution control plan is prepared for polluted areas, including Tokyo, Osaka, and Yokkaichi, and potential or developing areas including Chiba, Mizushima, and Ooita. As of 1992, the pollution control plan is established for 39 areas throughout the country.

The current status of pollution control plan is summarized in Table A7-3 and Figure A7-3.

(2) Clean Air Act

1) General

The Clean Air Act was established in June, 1968 to regulate smoke emitted from factories, business establishments, and automobiles under the Basic Environmental Act, followed by enactment in December. Then, the Basic Environmental 1970, for reinforcement, including implementation of national emission standards, expansion of pollutants subject to regulation, and the establishment of fuel utilization standards.

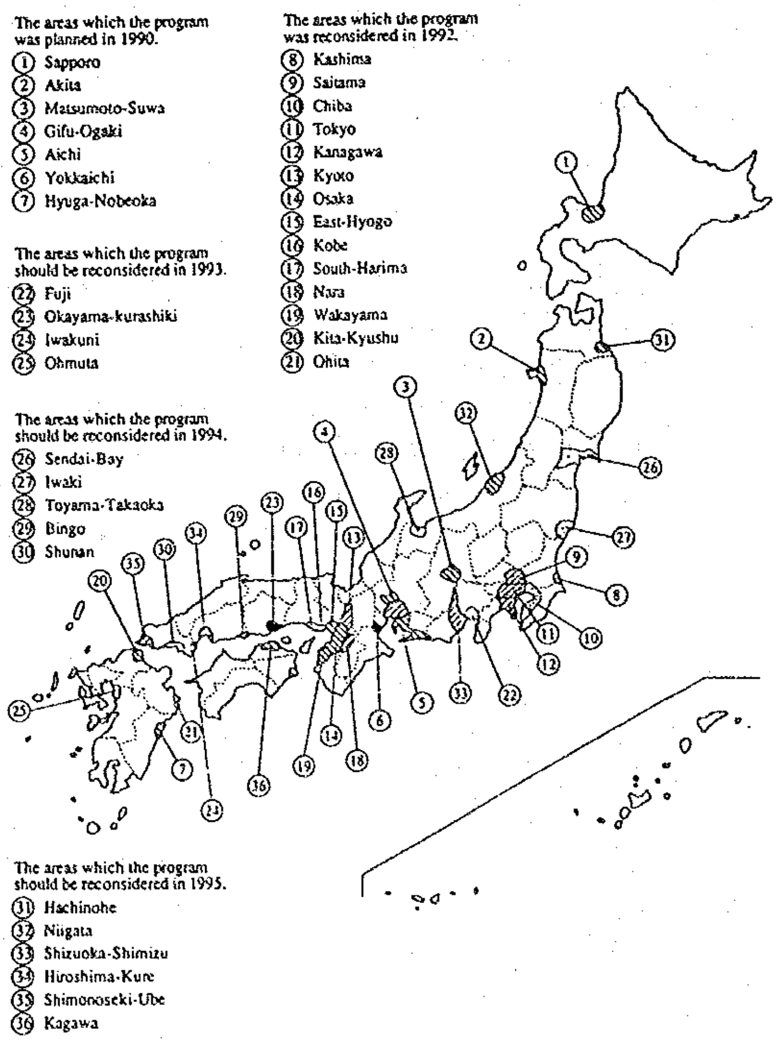
In May, 1971, smoke emission standards were reinforced to establish general emission standards according to the type and size of facility, instead of individual facility, and special emission standards were newly established. At the same time, harmful substances which were previously not subject to regulation have become the subject of control in terms of concentration for each facility. Then, in August, 1973, emission standards for nitrogen oxides produced from fixed sources were established. Subsequently, emission

## Table A7-3 Past and Present Pollution Control Programs at a Glance

| Duration of Regional Pollution Control Programs (year) | | | | | | | | | | | | | | | | | | | | | | | | | Name of area | Supplement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | Sapporo, Akita, Matsumoto-Suwa, Gifu-Ogaki, Hyuga-Nobeoka<br>Yokkaichi<br>Aichi 7 areas | The areas which the program was planned in 1990. |
| | | | | | | | | | | | | | | | | | | | | | | | | | Kagoshima, Saitama, Tokyo, Kanagawa, Kyoto, Osaka, Nara, East-Hyogo, Kita-Kyushu, Ohita<br>South-Harima<br>Chiba, Kobe<br>Wakayama 14 areas | The areas which the program was reconsidered in 1992. |
| | | | | | | | | | | | | | | | | | | | | | | | | | Okayama-kurashiki<br>Fuji, Iwakuni, Ohmuta 4 areas | The areas which the program should be reconsidered in 1993. |
| | | | | | | | | | | | | | | | | | | | | | | | | | Sendai-Bay, Iwaki, Toyama-Takaoka, Bingo, Shunan 5 areas | The areas which the program should be reconsidered in 1994. |
| | | | | | | | | | | | | | | | | | | | | | | | | | Hachinohe, Niigata, Shizuoka-Shimizu, Hiroshima-Kure, Shimonoseki-Ube, Kagawa 6 areas | The areas which the program should be reconsidered in 1995. |
| | | | | | | | | | | | | | | | | | | | | | | | | | 36 areas | |

Remarks : 1) ←→ Past programs
2) ←→ Present programs

Source : Environment Agency, "White Paper on Environment", 1992




## Figure A7-3 Map of Areas Under Regional Pollution Control Programs

standards were revised 3 times up to the fourth regulation in August, 1979. Also, the K emission standard value control for sulfur oxides, started in December, 1968, was steadily reinforced, followed by the 8th regulation in 1976.

The Clean Air Act was amended in June, 1974, and the total pollutant load control system was introduced. Sulfur oxides, designated under the total pollutant load control system, were expanded geographically under the first total pollutant load control area designated in November, 1974, followed by the second designation in December, 1975, and the first designation in November, 1974. At present, the total pollutant load control is implemented in 24 areas. Nitrogen oxides were designated under the total pollutant load control system in June, 1981, covering 3 areas.

In May, 1985, small boilers with burner combustion ability of 50 l/h were added to smoke generation facilities. Then, gas turbines and diesel engines were added in December, 1987.

In addition, regulation on exhaust gas produced from automobiles covers carbon monoxide, hydrocarbons, and nitrogen oxides.

The structure of the Clean Air Act is shown in Figure A7-4.

Basic principles of the K emission standard value control to regulate emission of sulfur oxides and total pollutant load control of sulfur oxides and nitrogen oxides.

(a) K emission standard value control

The Clean Air Act requires smoke emitting facilities which emit sulfur oxides (SOx) to establish emission standards, called K emission standard value.

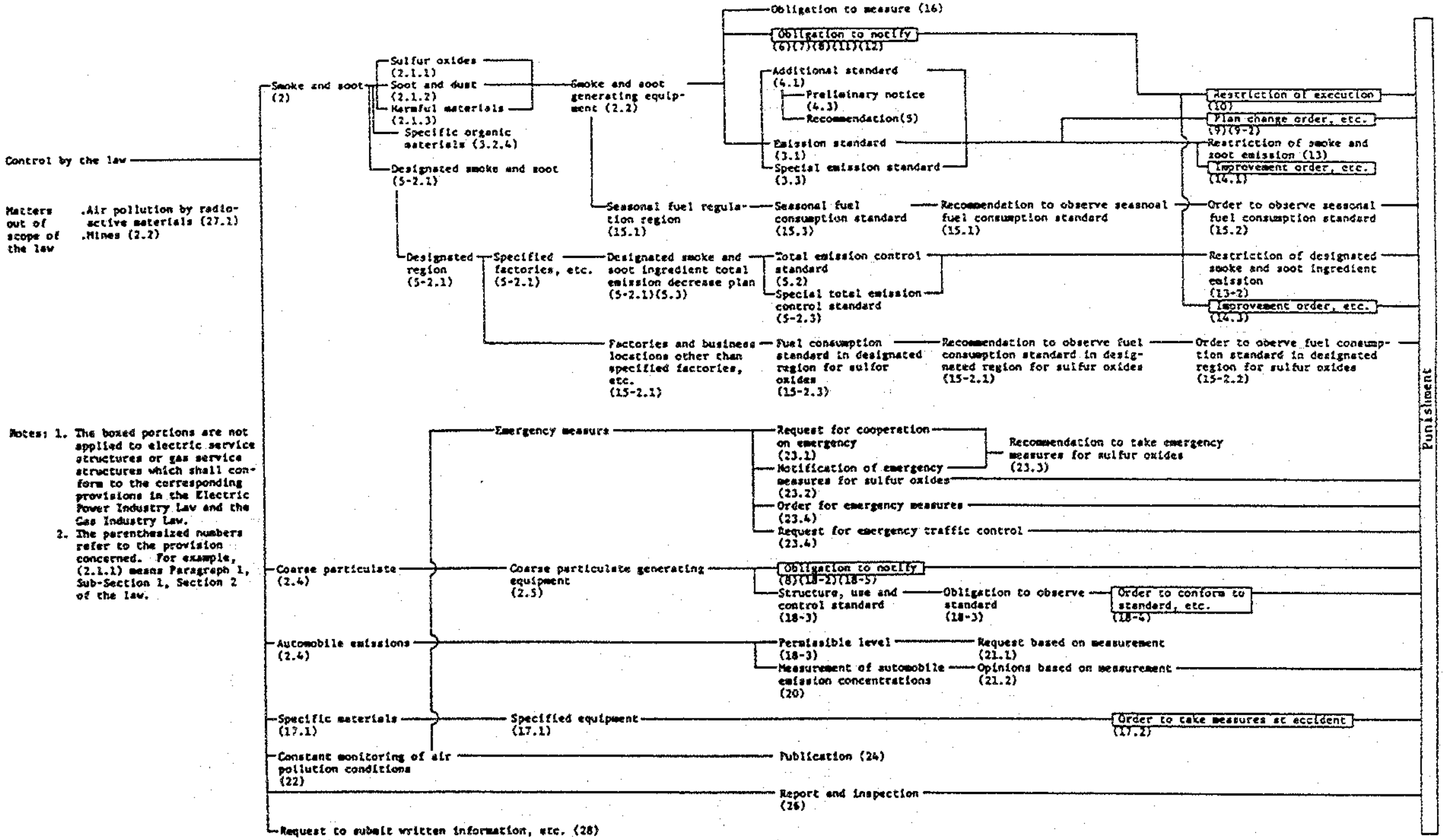



**Figure A7-4 System Chart of Air Pollution Control Law**

The K emission standard value represents the amount of SOx emission allowed according to the height of an exhaust port (stack) of each facility (effective height) in order to ensure the maximum ground level concentration of SOx emitted from the stack at the smoke emitting facility.

The allowable amount of SOx emission is determined by using the following equation:

$$q = K \times 10^{-3} He^2$$

q: Allowable amount of emission of sulfur oxides ($Nm^3/h$)
K: Factor set for each area
He: Effective height of the stack (m)

Here, the effective height of the stack (He) is determined by using the following equation:

$$He = Ho + 0.65\,(Hm + Ht)$$

$$Hm = \frac{0.795\sqrt{Q \cdot V}}{1 + \frac{2.58}{V}}$$

$$Ht = 2.01 \times 10^{-3} \cdot Q \cdot (T-288) \cdot \left(2.30 \log J + \frac{1}{J} - 1\right)$$

$$J = \frac{1}{\sqrt{Q \cdot V}}\left(1460 - 296 \times \frac{V}{T - 288}\right) + 1$$

He: Effective height of the stack (m)
Ho: Actual height of the stack (m)
Q: Amount of flue gas at 15°C ($m^3/s$)
V: Emission rate of flue gas (m/s)
T: Temperature of emission gas (K°C)

The K emission standard value control has been gradually reinforced from the first regulation enacted in December 1, 1968, through the eighth regulation in September 28, 1976. Today, the ordinary K emission values (ordinary emission standards) ranging between 3.0 - 17.5 are established for 16 types of areas throughout the country. However, in the areas where smoke emitting facilities are concentrated and intensive pollution may produce, special K emission values are established for new and additional facilities. They were also gradually reinforced between July, 1969, and April, 1974. Today, special K emission values (special emission standards) between 1.17 and 2.34 are established for 3 types of areas. (Tables A7-4 and A7-5)

**Table A7-4 Incremental Introduction of K and Special K Emission Standard Values (1968 - 1974)**

| Introduction of Month/Year | K Emission Standard Value Control (Number of Areas) | Special K Emission Standard Value Control (Number of Areas) |
|---|---|---|
| December, 1968 | 20.4 - 29.2 (21 areas + others) | Not regulated |
| July, 1969 | " | 5.26 (5 areas) |
| February, 1970 | 11.7 - 26.3 (35 areas) | " |
| June, 1971 | 11.7 - 26.3 (51 areas + others) | 5.26 (17 areas) |
| January, 1972 | 7.01 - 22.2 (70 areas + others) | 2.92 - 5.26 (17 areas) |
| January, 1973 | 6.42 - 22.2 (70 areas + others) | " |
| April, 1974 | 3.5 - 17.5 (99 areas + others) | 1.71 - 2.34 (28 areas) |
| April, 1975 | 3.0 - 17.5 (99 areas + others) | " |
| September, 1976 | 3.0 - 17.5 (120 areas + others) | " |

Table A7-5 Lank-wise K Value Areas (at 1992)

| Lank | | Area | K value |
|---|---|---|---|
| General Standards | 1 | 6 areas: Central Tokyo, Yokohama-Kawasaki, Nagoya, Yokkaichi, Osaka-Sakai, Kobe-Amagasaki | 3.0 |
| | 2 | 21 areas: Chiba, Fuji, Kyoto, Himeji, Mizushima, Kitakyushu and others | 3.5 |
| | 3 | 1 area: Sapporo | 4.0 |
| | 4 | 4 areas: Hitachi, Kashima and others | 4.5 |
| | 5 | 3 areas: Toyama-Takaoka, Kure, Tohyo | 5.0 |
| | 6 | 9 areas: Annaka, Niigata, Okayama, Shimonoseki and others | 6.0 |
| | 7 | 3 areas: Tomakomai, Hachioji, Kasaoka | 6.42 |
| | 8 | 6 areas: Sendai, Fukui, Hiroshima and others | 7.0 |
| | 9 | 8 areas: Asahikawa, Utsunomiya, Mihara, Tokushima and others | 8.0 |
| | 10 | 8 areas: Akita, Kanazawa, Otsu, Fukuoka, Nagasaki and others | 8.76 |
| | 11 | 6 areas: Takasaki, Urawa, Narita, Naha and others | 9.0 |
| | 12 | 4 areas: Shizuoka, Sasebo and others | 10.0 |
| | 13 | 15 areas: Hakodate, Gifu, Takamatsu, Minamata and others | 11.5 |
| | 14 | 6 areas: Mishima, Kurume and others | 13.0 |
| | 15 | 20 areas: Aomori, Morioka, Yamagata, Nagano, Kagoshima and others | 14.5 |
| | 16 | Others | 17.5 |
| Special Standards | 1 | 6 areas: Central Tokyo, Osaka-Sakai, Yokohama-Kawasaki, Kobe-Amagasaki, Yokkaichi, Nagoya | 1.17 |
| | 2 | 8 areas: Chiba, Fuji, Himeji, Mizushima, Kitakyushu and others | 1.75 |
| | 3 | 14 areas: Kashima, Toyama, Kyoto, Fukuyama, Ohmuta, Ohita and others | 2.34 |

Note: Special standards are applied to newly constructed facilities only.

(b) Total pollutant load control

Total pollutant load control means allocation of an allowable amount of emission to factories and business establishments of a specific size ("designated factories") to maintain the total amount of emission at an allowable level within the area where factories and business establishments are concentrated and environmental standards cannot be met only by smoke emission standards for individual factories and business establishments. Total pollutant load control is established for a certain area designated by the national government and is enforced under the total emission reduction plan prepared by each prefectural governor.

The total emission reduction plan is designed to reduce the total amount of smoke emission in the designated area (Stage 1 emission) to that required to maintain applicable environmental standards (Stage 3 emission) by establishing the target reduction (Stage 4 emission) for the total amount of emission from designated factories (Stage 2 emission). The plan also sets forth the period required to meet the reduction target and the method of achieving it.

At present, sulfur oxides and nitrogen oxides are subject to total pollutant load control. The amount of SOx emission is determined from sulfur content of raw fuels, while that of NOx emission from the concentration of NOx in flue gas.

Note that sulfur oxides are subject to total pollutant load control only for special factories, while fuel utilization standards are to be established for other factories and business establishments. Fuel utilization standards need to be complied with for various types of fuels, and regarding fuel and other petroleum-based fuels, the standards are established by prefectural governors on the basis of those established by the

Director General of Environmental Agency. Note that designated factories subject to total pollutant load control are those which consume fuels (fuel oil equivalent) at a rate of 0.1 - 1kl/hour for sulfur oxides, and at a rate of 1 - 10kl/hour for nitrogen oxides, and which are more than a certain size designated by prefectural governors.

Total pollutant load control of sulfur oxides was first designated in November, 1974 (11 areas), followed by the second designation in December, 1975 (8 areas) and the third designation in September, 1976 (5 areas). Today, 24 areas are designated. Total pollutant load control of nitrogen oxides covers 3 areas designated in June, 1981. Figure A7-5 summarizes the structure of the total pollutant load control system, and Figure A7-6 the conceptual view. Table A7-6 shows the current state of the areas designated for total pollutant load control by sulfur oxides and nitrogen oxides.

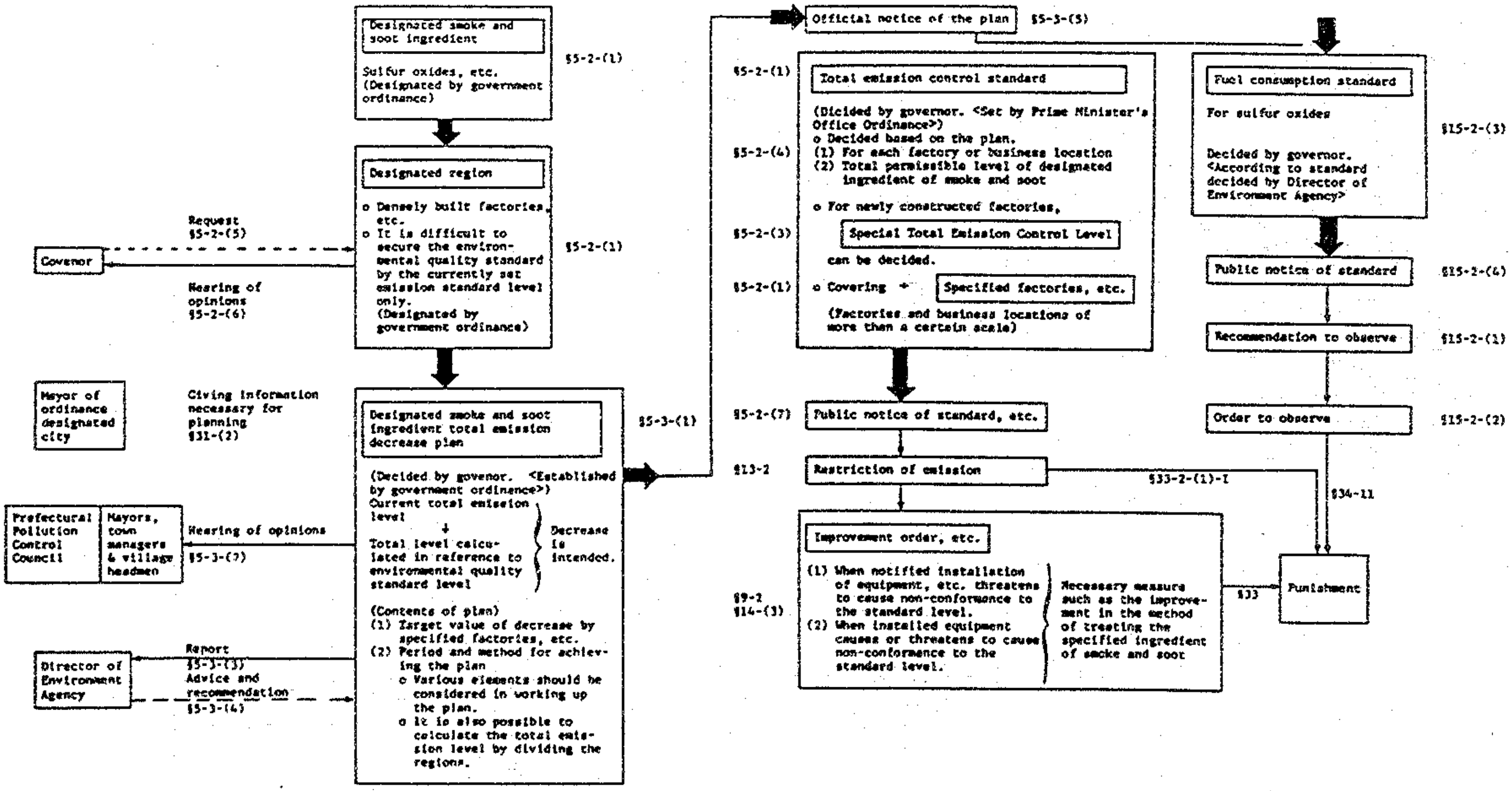
Table A7-6 Current State of the Areas Designated for Total Pollutant Load Control by Sulfur Oxides and Nitrogen Oxides

(a) Regions designated for total emission control of sulfur oxides

| First designation (Nov., 1974) | Second designation (Dec., 1975) | Third designation (Sep., 1976) |
|---|---|---|
| Chiba, Ichikawa area<br>Special Ku area<br>Yokohama & Kawasaki area<br>Fujinomiya & Fuji area<br>Nagoya area<br>Handa & Hekinan area<br>Yokkaichi area<br>Osaka area<br>Kobe & Amagasaki area<br>Kurashiki (Mizushima)<br>Kitakyushu area | Kishiwada, Ikeda area<br>Himeji, Akashi area<br>Wakayama & Kainan area<br>Kurashiki (excluding Mizushima)<br>Ube & Onoda<br>Tokuyama & Shimomatsu area<br>Iwakuni area<br>Ohmuta | Kawaguchi & Soka area<br>Kyoto area<br>Bizen<br>Fukuyama<br>Ohtake |

(b) Regions designated for total emission control of nitrogen oxides

| Jun., 1976 |
|---|
| Special Ku area<br>Yokohama & Kawasaki area<br>Osaka area |




(Remarks) In the above drawing, for example, §33-2-(1)-I expresses Paragraph I, Sub-Section 1, Section 33-2 of "Air Pollution Control Law".

**Figure A7-5 System Chart of Total Emission Control**

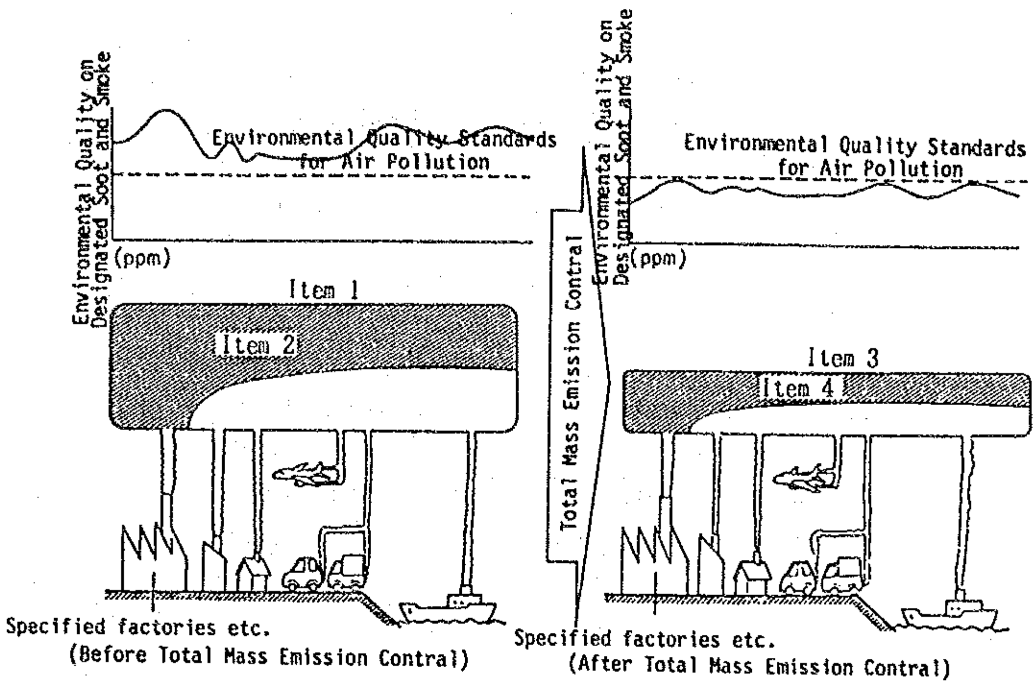



**Figure A7-6 Explanation of Total Mass Emission Contral**

Item 1 : Total mass of designated soot and smoke generated by the business activity and other activity.

Item 2 : Total mass of designated soot and smoke emitted from the specified factories, etc.

Item 3 : Total mass computed as prescribed by the order of the Prime Minister's Office regarding the designated soot and smoke generated by the business activity and other activity.

Item 4 : Objective for reduction relating to the total mass emission referred to in Item 2 above.

2) Objective

The Clean Air Act regulates emission of smoke produced from factories and other business establishments, establish allowable limits for exhaust gas from automobiles to help protect people's health from air pollution and preserveliving environment, and sets forth liability of business operators for damage to human health due to air pollution, thereby to protect victims.

In essence, the act sets forth the following matters:

- To establish smoke emission standards and total pollutant load control standards for designated dusts.
- To restrict emission of smoke.
- To report installation and modification of smoke emitting facilities.
- To issue the order to modify the plan.
- To issue the order to improve.
- To regulate fuel utilization.
- To require business operators to measure smoke and other data.
- Emergency measures
- Receiving of the report and on-site inspection

3) Substances subject to regulation

Substances subject to regulation under the Clean Air Act are smoke, dust, automobile exhaust gas, and special substances.

Among them, smoke includes sulfur oxides, soot and dust, and harmful substances (cadmium, chloride, hydrogen fluoride, and lead), while dusts are specific dusts (asbestos) and general dusts. Automobile exhaust gas includes carbon monoxide, hydrocarbons, lead compounds, nitrogen oxides, and granular substances. Finally, special substances are those which are designated under the Clean Air Act as substances which may cause damage to human health or living environment. At present, 28 substances, including phenol and pyridine, are designated.

The relationship between smoke, dust, and suspended granular substances is shown in Figure A7-7.

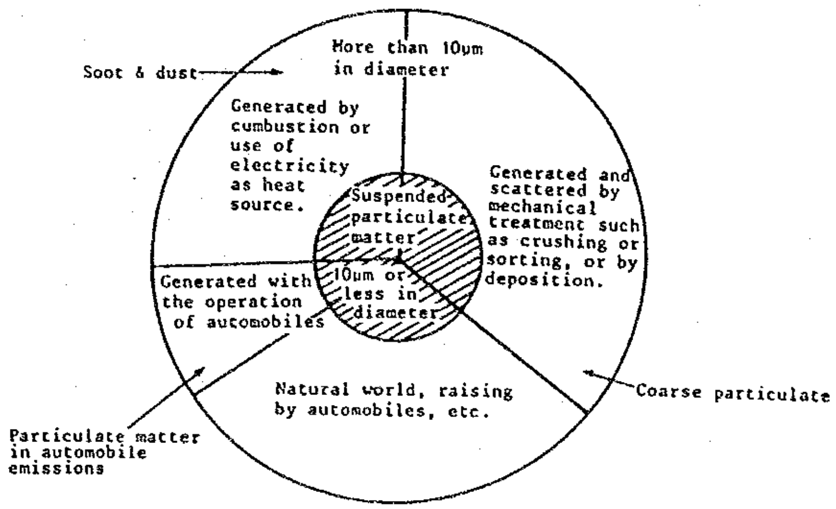



**Figure A7-7 Relationship between Smoke, Dust, and Suspended Granular Substances**

4) Control standards and measures

Control standard and measures for substances subject to regulation are shown in Table A7-7, which covers volume control, K emission control value, total pollutant load control standards, concentration control, and the order to improve, and penalties.

## Table A7-7 Control Measures, etc. of Air Pollution Control Law

| Control materials | | Examples of materials | Generation style | Generating equipment | Control standard | Control measures, etc. |
|---|---|---|---|---|---|---|
| Smoke and soot | Sulfur oxides | $SO_2$, $SO_3$ | Combustion | Smoke and soot generating equipment | Emission standard (quantity regulation, region K value method, total emission control standard) | Improvement order, direct punishment, etc. |
| | Soot and dust | Soot, etc. | ditto | ditto | Emission standard (concentration regulation for respective kinds and scales of equipment) | ditto |
| | Harmful materials | NOx, Cd, Pb, HF, $Cl_2$, HCl, etc. | Combustion, synthesis, decomposition, pressurization, etc. | ditto | Emission standard (concentration regulation for respective kinds of materials and equipment. Also total emission control standard for NOx) | ditto |
| | Specified harmful materials | (Not designated) | Combustion | ditto | Emission standard (quantity regulation, K value method) | ditto |
| Coarse particulate | | Cement dust, coal dust, iron dust, etc. | Grinding, sorting, deposition, etc. | Coarse particulate generating equipment | Structure, use and control standard | Order to conform to standard |
| Automobile emissions | | CO, HC, Pb, etc. | Operation of automobiles | Specific automobiles | Permissible levels (considered in safety standard) | Traffic control, improvement order, etc. (also by other laws) |
| Specified materials | | $C_6H_5OH$ (phenol), $C_5H_5N$ (pyridine), etc. | Accident during chemical processing such as synthesis | Specific equipment (not specified by government order, etc.) | Nil | Order to take measures at accident |

(3) Current state of emission standards

1) SOx

Emission standards for sulfur oxides set forth allowable limits for emission made from the stack, according to the height of the stack and the area classification designated under the Execution Ordinance for the Clean Air Act.

SOx emission standards are considered to be allowable limits for the area classification (K value) designated under the ordinance, according to the height of the exhaust port (effective height of the stack). K values according to area classification are summarized in Table A7-8.

2) NOx

Harmful substances are those contained in flue gas, which allowable permits are established for each type of substance and facility.

NOX emission standards by facility are shown in Table A7-9.

3) Smoke

Smoke is contained in flue gas, which allowable permits are established for each type of substance and facility.

Smoke emission standards by facility are shown in Table A7-10.

(4) Current state of emission standards for diesel generators

In 1987, the Clean Air Act was amended to add gas turbines and diesel engines consuming fuel of 50ℓ or more to smoke emitting facilities.

## Table A7-8 K VALUE BY REGION

| | Region | K Value (ppm) |
|---|---|---|
| Ordinary Emission Standard | Tokyo (A)、Yokohama、 Kawasaki、Yokosuka | 3.0 (0.005) |
| | Chiba、Kisarazu、Ichihara、Kimitsu、Futtsu<br>Fujimiya、Fuji | 3.5 (0.006) |
| | Kashima、Hitachi | 4.5 (0.008) |
| | Tokyo (B)、Iwaki | 6.0 (0.010) |
| | Utsunomiya | 8.0 (0.014) |
| | Kawagoe、Noda | 9.0 (0.015) |
| | Koriyama、Katsuta | 11.5 (0.020) |
| | Tsuchiura、Koga、Choshi | 14.5 (0.025) |
| | Others | 17.5 (0.030) |
| | Tokyo (A)、Yokohama、 Kawasaki、Yokosuka | 1.17 (0.002) |
| | Chiba、Kisarazu、Ichihara、Kimitsu、Futtsu<br>Fujimiya、Fuji | 1.75 (0.003) |
| | Kashima、Kawaguchi、Soka、Hatogaya | 2.34 (0.004) |

[Note] 1. Ordinary Emission Standard is applied to thewhole country.
2. Special Emission Standard is applied to the facilities installed after 1974. 4. 1.
3. Figures in the parenthesis are the maximum ground level concentration equivalent for K value.

## Table A7-9 Nitrogen Oxide Emission Standard (Selection)

| Type of Facility (Unit: 10,000$Nm^3$/h) | On (%) | Emission Standard Value (ppm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Date of Installation | | | | | |
| | | -73.8.9 | 73.8.10 -75.12.9 | 75.12.10 -77.6.17 | 77.6.18 -79.8.9 | 79.8.10 -83.9.9 | 83.9.10- |
| Gas Firing Boiler | 5 | | | | | | |
| 50- | | 130 | 130 | 100 | 60 | 60 | 60 |
| 10-50 | | 130 | 130 | 100 | 100 | 100 | 100 |
| 4-10 | | 130 | 130 | 130 | 100 | 100 | 100 |
| Liquid Firing Boiler | 4 | | | | | | |
| 50- | | 180 | 180 | 150 | 130 | 130 | 130 |
| 10-50 | | 190 | 180 | 150 | 150 | 150 | 150 |
| 4-10 | | 190 | 180 | 150 | 150 | 150 | 150 |
| 1-4 | | 230 | 230 | 150 | 150 | 150 | 150 |
| 0.5-1 | | 250 | 250 | 250 | 250<br>180 | 180 | 180 |
| Waste Incinerator (Continuous type) | 12 | | | | | | |
| 4- | | (300) | (300) | (300) | 250 | 250 | 250 |
| -4 | | (300) | (300) | (300) | (300) | (250) | (250) |
| Solid Material Firing Boiler | 6 | | | | | | |
| 70- | | 400 | 300 | 300 | 300 | 300 | 200 |
| 50-70 | | 420 | 300 | 300 | 300 | 300 | 250 |
| 20-50 | | 420 | 350 | 300 | 300 | 300 | 250 |
| 4-20 | | 450 | 350 | 300 | 300 | 300 | 250 |

## Table A7-10 Regulation on Dust in Air Pollution Control Law

| Type of Facility | Scale (10,000 $Nm_3/h$) | Regular Regulations General ($g/Nm^3$) | Regular Regulations Special ($g/Nm^3$) | Regular Regulations On (%) | Supplementary Regulations General ($g/Nm^3$) | Supplementary Regulations Special (g/Nm3) | Supplementary Regulations Handling of On |
|---|---|---|---|---|---|---|---|
| Gas Firing Boiler | 20 or more<br>4 to 20 | } 0.05 | } 0.03 | } 5 | | | |
| | less than 4<br>small boiler | } 0.10 | } 0.05 | 5<br>5 | Not applied for the time being. | Not applied for the time being. | |
| Fuel Oil Firing Boiler and Gas-Liquid Firing Boiler | 20 or more | 0.05 | 0.04 | 4 | 0.07 for existing boiler for the time being. | | |
| | 4 to 20 | 0.15 | 0.05 | 4 | 0.18 for existing boiler for the time being. | | |
| | 1 to 4<br>less than 1 | 0.25<br>0.30 | } 0.15 | 4<br>4 | | | |
| | Small boiler | 0.30 | 0.15 | 4 | Not applied for the time being to boiler using kerosene, light oil or fuel oil A. Not applied to existing boiler for the time being. 0.50 for boiler installed by September 10, 1990. | Not applied for the time being to boiler using kerosene, light oil or fuel oil A. Not applied to existing boiler for the time being. 0.30 for boiler installed by September 10, 1990. | Application to be postponed for the time being. |
| Coal Firing Boiler | 20 or more | 0.10 | 0.05 | 6 | 0.15 for existing boiler for the time being. | | |
| | 4 to 20 | 0.20 | 0.10 | 6 | 0.25 for existing boiler for the time being. | | |
| | less than 4 | 0.30 | 0.15 | 6 | 0.35 for existing boiler for the time being. | | |
| | Small boiler | 0.30 | 0.15 | 6 | Not applied to existing boiler for the time being. 0.50 for boiler installed by September 10, 1990. | 0.30 for boiler installed by September 10, 1990. | |

New facilities which are permanently used have been subject to control on SOx, NOx, and smoke since February, 1988. On the other hand, existing facilities are subject to control for SOx, while no control is applied for NOx for a while.

Finally, both new and existing facilities for emergency use are exempt from application for the time being.

Total pollutant load control is imposed on facilities for regular use. Emission standards for gas turbines and diesel engines are summarized in Table A7-11.

(5) Fuel utilization standards

Current state of fuel utilization standards are shown in Tables A7-12(1) and A7-12(2).

The standards are designed to reduce smoke in a particular area according to the actual condition of SOx pollution in urban areas by recommending or ordering the use of low sulfur fuel or reduction of fuel consumption.

(6) Compliance with control standards and penalties

A person who intends to install a smoke emitting facility has to report the type and construction of the facility and the method of treating smoke at least 60 days before the installation. The same reporting obligation is applied to the change in facility construction or smoke treatment method. Dust is also subject to reporting obligation.

If the facility subject to reporting hereunder does not conform to emission standards, the order to change the plan will be issued. The facility which emits smoke which does not comply with the order to improve, emission standards, and/or total pollutant load control standards is penalized.

## Table A7-11 EMISSION STANDARD FOR GAS TURBINE AND DIESEL ENGINE (1/2)

Gas Turbine

| | | Normal Use | | Emergency |
|---|---|---|---|---|
| | | Existing | New | Existing and New |
| Application of the Cabinet Order | | (Application to be) postponed for two years (1990. 2. 1~) | No application to be postponed (1998. 2. 1~) | The same as Normal Use Case |
| Emission Standard | Nitrogen Oxides $O_2$ = 16% | · Application to be postponed for the time being<br>· Total Mass Emission Contral (1991. 2. 1~) | · 70 ppm<br>However, Liquid Fuel (less than 45,000 $Nm^3/hr$)<br>Before 1989. 7.31 : 120 ppm<br>Liquid Fuel (More than 45,000 $Nm^3/hr$)<br>Before 1991. 1.31 : 100 ppm<br>Gas (Less than 45,000 $Nm^3/hr$)<br>Before 1989. 7.31 : 90ppm<br>· Total Mass Emission Contral (1989. 2. 1~) | Application of Emission Standard to be postponed for the time being |
| | Sulfur Oxides | · Ordinary Emission Standard (K Value)<br>However, no application to gas turbin emitting the gas less than 10,000 $Nm^3/hr$ for the time being.<br>· Total Mass Emission Contral, for Use of Fuel Standard (1991. 2. 1) | · Ordinary Emission (K Value)<br>· Special Emission Standard (K Value)<br>· Total Mass Emission Contral Standard for Use Fuel (1989. 2. 1~) | Application of Emission Standard to be postponed for the time being |
| | Dust $O_2$ = 13% | · Application of Emission Standard to be postponed for the time being. | · Ordinary Emission Standard : $0.05g/Nm^3$<br>· Special Emission Standard : $0.04g/Nm^3$ | Application of Emission Standard to be postponed for the time being |

## Table A7-11 EMISSION STANDARD FOR GAS TURBINE AND DIESEL ENGINE (2/2)

Diesel Engine

| | | Normal Use | | Emergency |
|---|---|---|---|---|
| | | Existing | New | Existing and New |
| Application of the Cabinet Order | | (Application to be) postponed for two years (1990. 2. 1~) | No application to be postponed (1998. 2. 1~) | The same as Normal Use Case |
| Emission Standard | Nitrogen Oxides $O_2$ = 13% | · Application of Emission Standard to be postponed for the time being<br>· Total Mass Emission Contral (1991. 2. 1~) | · 950 ppm<br>However, for the diesel engine with cylinder more than 400 mm<br>Before 1989. 7.31 1,600ppm<br>1989. 8. 1~1991. 1.31 1,400ppm<br>1991. 2. 1~ 1,200ppm<br>(after evaluation of counter-measure technologies: 950ppm)<br>· Total Mass Emission Contral (1989. 2. 1~) | Application of Emission Standard to be postponed for the time being |
| | Sulfur Oxides | · Ordinary Emission Standard (K Value)<br>However, no application to diesel engine emitting the gas less than 10,000 $Nm^3$/hr for the time being.<br>· Total Mass Emission Contral, Standard for Use of Fuel (1991. 2. 1) | · Ordinary Emission Standard (K Value)<br>· Special Emission Standard (K Value)<br>· Total Mass Emission Contral Standard for Use of Fuel (1989. 2. 1~) | Application of Emission Standard to be postponed for the time being |
| | Dust $O_2$ = 13% | · Application of to be postponed for the time being. | · Ordinary Emission Standard : 0.10g/$Nm^3$<br>· Special Emission Standard : 0.08g/$Nm^3$ | Application of Emission Standard to be postponed for the time being |

[Note] 1. The Cabinet Order is applied to the facilities with combustion capacity more than 50 liters per hour of heavy fuel oil equivalent.
2. 50 liters per hour is equivalent to the output of 150 kW.
3. 45,000 $Nm^3$/h is equivalent to the output of 2,000 kW.
4. Diesel engine with cylinder more than 400 mm is equivalent to the output more than 1,500 kW.

[Note] Total Mass Emission Contral Standard

| | Fuel Conversion Factor | Facilities Factor |
|---|---|---|
| Gas Turbine | 2.0~3.5 | New CI 5.0<br>Existing C 7.0~13.0 |
| Diesel Engine | 20.0~30.0 | New CI 40.0<br>Existing C 49.0~69.0 |

## Table A7-12 (1) TOTAL MASS EMISSION CONTRAL STANDARD FOR SULFUR OXIDES

| Region | Total Mass Emission Contral Standard<br>$Q = aW^b$<br>Q = $SO_2$ Emission Quantity ($Nm^3/h$)<br>W = Fuel Consumption (kl/h) | | | | Special Total Mass Emission Contral Standard<br>$Q = aW^b + r.a. \{(W + W_i)^b - W^b\}$<br>Wi : Fuel Consumption of New Facilities (kl/h) | | Standard for Use of Fuel | | |
|---|---|---|---|---|---|---|---|---|---|
| | Factor a | Factor b | Scale of Specified Factories, etc. W | Application Date | Factor r | Application Date | Sulfur Content (%) | Scale of Factories Applied Standard for Use of Fuel | Application Date |
| Kawaguchi, Soka and Others | 2.11 | 0.86 | 0.3 | 1978. 5.31 | 0.5 | 1978. 2.28 | 0.8 | ≧0.1 | 1978. 5.31 |
| Chiba, Ichikawa and Others | 3.3 | 0.90 (Nothern Area)<br>0.88 (Southern Area) | 0.5 | 1977. 1. 1 (New)<br>1778. 3. 1 (Existing) | 0.5 | 1976.10. 1 | 0.6<br>0.8 | 0.2≦W<0.5<br>0.05≦W<0.2 | 1977. 1. 1 (New)<br>1978. 3. 1 (Existing) |
| Central Tokyo and Others | 0.57〜3.36 | 0.80〜0.95 | 0.3 or 0.2 kl/day (More than 0.1 kl/day) | 1977.12. 1 | 0.3 | 1976. 8. 1 | 0.2〜0.8 (Exisiting)<br>0.1〜0.5 (New) | <0.3kl/day | 1977.12. 1 (Exisiting)<br>1977. 8. 1 (New) |
| Yokohama, Kawasaki and Others | 1.5 (seaside in Yokohama and Kawasaki)<br>2.5 (Others) | 0.865 | 1.0 | 1977. 4. 1 | 1/3 (Seaside in Yokohama and Kawasaki)<br>0.32 (Others) | 1975. 4. 1 | 0.3 (Seaside in Yokohama and Kawasaki)<br>0.5 (Others) | | 1977. 4. 1 (Exisiting)<br>1976. 4. 1 (New) |
| Fujimiya, Fuji and Others | 2.8 (Fuji)<br>3.0 (Others) | 0.8 | 1.0 | 1978. 4. 1 | 0.3 (Fuji)<br>0.5 (Others) | 1977. 3.31 | 0.5 (Fuji)<br>0.8 (Others) | | 1978. 4. 1 |
| Nagoya and Others | 2.37<br>1.95<br>1.54 | 0.95 | 0.5 | 1976. 4. 1<br>1976.10. 1<br>1978. 4. 1 | 1/3 | 1976. 4. 1 | 0.5 | | 1978. 4. 1 |
| Handa, Hekinan and Others | 3.69<br>3.16<br>2.63 | 0.95 | 0.5 | 1976. 4. 1<br>1976.10. 1<br>1978. 4. 1 | 0.4 | 1976. 4. 1 | 0.8 | | 1978. 4. 1 |
| Yokkaichi and Others | 4.0 | 0.819 | 0.5 | 1976. 9. 1 | 0.3 | 1976. 9. 1 | 0.8<br>1.0 | 0.1≦W<0.5<br><0.1 | 1976. 9. 1 |
| Kyoto and Others | 1.6 (Kyoto)<br>3.2 (Others) | 0.85 | 0.3 | 1978. 5. 1 | 0.3 (Kyoto)<br>0.5 (Others) | 1978. 1. 1 | 0.5 (Kyoto)<br>0.8 (Others)<br>0.8 (Kyoto)<br>1.2 (Others) | 0.1≦W<0.3<br><0.1 | 1978. 5. 1 (Existing)<br>1978. 1. 1 (New) |
| Osaka and Others | 2.0 (Osaka City and others)<br>3.0 (Others) | 0.85 | 0.3 | 1978. 3.31 | 0.3 | 1977.10. 1 | 0.35 (Osaka City and others)<br>0.8 (Others)<br>0.35 (Osaka City and others)<br>0.8 (Others) | 0.5≦W<0.8<br><0.5 | 1978. 3.31 |

## Table A7-12 (2) TOTAL MASS EMISSION CONTRAL STANDARD FOR NITROGEN OXIDES

| Region | Total Mass Emission Contral Standard | | | | | Special Total Mass Emission Contral Standard | | |
|---|---|---|---|---|---|---|---|---|
| | Calculation Formula | Factor a(K) | Factor b(l) | Scale of Specified Factories, etc. W | Application Date | Calculation Formula | Factor r | Application Date |
| Central Tokyo and Others | $Q = k\{\Sigma(C.V)\}^{1}$ | 0.51 | 0.95 | 1 | 1985. 3.31 | $Q = k\{\Sigma(C.V) + \Sigma(Ci.Vi)\}^{1}$ | - | 1982.11.30 (Existing : 1985. 3.31) |
| Yokohama, Kawasaki and Others | $Q = aW^{b}$ | 1.37 | 0.95 | 4 | 1985. 3.31 | $Q = aW^{b} + r.a\{(W + Wi)^{b} - W^{b}\}$ | 0.7 | 1987. 4. 1 (Existing : 1985. 3.31) |
| Osaka City and Others | $Q = k\{\Sigma(C.V)\}^{1}$ | 0.6 | 0.95 | 2 | 1985. 3.31 | $Q = k\{\Sigma(C.V) + \Sigma(Ci.Vi)\}^{1}$ | - | 1987.11. 1 (Existing : 1985. 3.31) |

Q : $NO_2$ Emission Quantity ($Nm^3/h$)
C : Facilities Factor
V : Emitted Gas Quantity (10,000 $Nm^3/h$)
W : Fuel Consumption (kl/h)
Ci : Facilities Factor for Newly installed Facilities
Vi : Emitted Gas Volume from New Facilities (10,000 $Nm^3/h$)
Wi : Fuel Consumption of New Facilities (kl/h)

(7) Relationship with ordinance

A local government may establish necessary regulations in the form of ordinance in addition to national control standards, if considered necessary to control pollution. Also, the local government or local residents may conclude a pollution control agreement with a specific corporation.

(8) Exception from the Clean Air Act

Exception related to mines, electrical installations, and gas installations

Among smoke emitting facilities, dust emitting facilities or special facilities installed at factories or other business establishments, mines are exempt from the Clean Air Act and electrical and gas installations are partially exempt. In addition, the provisions of the Clean Air Act does not apply to air pollution due to radioactive materials and its control.

The above facilities are regulated under respective laws, namely (1) Mine Safety Act, (2) Electricity Enterprises Act and Gas Enterprises Act, and (3) Atomic Energy Basic Act.

a) As for mines, "mines set forth in Paragraph 2, Article 2 of the Mine Safety Act" are excepted.

b) As for electrical installations and gas installations, smoke from smoke emitting facilities (dust emitting facilities or special facilities) which are also "electrical installations set forth in the Electricity Enterprises Act" or "gas installations set forth in the Gas Enterprises Act" is expected from corresponding provisions in the Electricity Enterprises Act or the Gas Enterprises Act, including facility layout, reporting of changes, the order to change the plan, and order to improve (the order to comply with standards, the order at the time of accident).

In addition, actions under the excepted provisions may be taken by the Minister of International Trade and Industry, as requested by the competent prefectural governor.

The provisions not subject to exception, such as restriction on smoke emission (penalty), action on fuel use, and emergency action, as well as related on-site inspection, are fully applicable.

### A7.1.3 Monitoring of Air Quality

#### (1) Monitoring system

##### 1) Monitoring stations

Monitoring stations are installed throughout the country to check the current state of air pollution. These stations are roughly classified into those in the national atmospheric observation network and those in the regional air pollution monitoring network.

(a) National atmospheric observation networks

15 national air pollution measuring stations and 8 national atmospheric environment measuring stations are provided throughout the country to monitor air pollution from the national perspective, and to collect basic data for establishment of environmental standards and formulation of pollution control plans. (In addition, the government operates 4 automobile exhaust gas measuring stations and 6 acid rain measuring stations.

- Air pollution measuring stations

There are 15 stations in major areas, each equipped with measuring instruments to monitor 5 substances subject to environmental standards, as well as non-methane hydrocarbons, suspended dusts, and settled particulates. Based on data collected, factors in causing air pollution are analyzed and identified.

- Atmospheric environment measuring stations

  8 stations are installed in the major plains in Japan to monitor the areas other than polluted areas. Each station is equipped with similar measuring instruments available at national air pollution measuring stations, as well as measuring instruments for hydrogen sulfide, ozone and other substances.

(b) Regional air pollution monitoring network

It is roughly divided into general atmospheric environment measuring stations (general stations) and automobile exhaust gas measuring stations (exhaust gas stations). General stations are described as follows.

The Clean Air Act established in 1968 requires prefectural governors to monitor air pollutants all the time. The objective of regular monitoring was originally emergency measures and evaluation of environmental standards themselves. Today, monitoring data, after statistical treatment, are used as basic data for formulation of air pollution control plans, as background data for environmental impact assessment, and for a wide range of purposes.

2) Current state of measuring stations

Recent changes in the numbers of municipalities and measuring stations which monitor substances subject to air pollution-related environmental standards, namely sulfur dioxide, carbon monoxide, suspended particular matters, nitrogen dioxide, and photochemical oxidant, are summarized below.

Table A7-13 Recent Changes in the Number of Measuring Stations

| Year | 1976 | | 1982 | | 1986 | | 1991 | |
|---|---|---|---|---|---|---|---|---|
| Item | (A) | (B) | (A) | (B) | (A) | (B) | (A) | (B) |
| | Number | | Number | | Number | | Number | |
| Sulfur Dioxide | 538 | 1,426 | 624 | 1,622 | 652 | 1,625 | 686 | 1,621 |
| Carbon Monoxide | 158 | 189 | 172 | 213 | 167 | 198 | 161 | 191 |
| Suspended Particulate | 98 | 187 | 134 | 286 | 437 | 906 | 641 | 1,368 |
| Nitrogen Dioxide | 435 | 859 | 562 | 1,239 | 605 | 1,331 | 653 | 1,391 |
| Photochemical Oxidant | 392 | 713 | 499 | 983 | 532 | 1,027 | 584 | 1,063 |

Notes: (A): Municipal
(B): Measuring Station

Note that most of these stations are unmanned. In addition, local governments operate air pollution monitoring cars to take measurement at desired locations, so as to supplement the permanent stations.

3) Permanent air pollution monitoring system

If comprehensive management is needed for a certain area, the permanent air pollution monitoring system is installed and two or more monitoring stations collect data and send them to the central monitoring station for data compilation. the system consists of a data transmission system and a data processing system, which have been installed in most of local governments since around 1970 when installation of monitoring stations was progressed.

(2) Management system

The management system related to monitoring of air pollution in Japan is described in the role of the government, related laws and regulations, and the monitoring system. Here, emergency measures and regulatory control on specific business establishments, such as large power plants, are described.

1) Emergency measures

Emergency means when air pollution becomes serious under the Clean Air Act or the local anti-air pollution ordinance established by prefectural governments, so that damage to human health or living environment may occur. In particular, if the concentration of any of 5 substances for which environmental standards are established may exceed or has exceeded a present level, an alarm or alert is issued in consideration to meteorological conditions, and reduction efforts are requested to users of major sources (including automobiles) in the area, followed by recommendation or order if necessary. Non-compliance with the order is penalized.

Table A7-14 Alert Levels Triggering Forced Reduction of Pollutant Emission

| Substance | Ordinery Alert | Serious Alert |
|---|---|---|
| Sulfur Dioxides | 0.2 ppm or more for consecutive 3 hours<br>0.3 ppm or more for consecutive 2 hours<br>0.5 ppm or more<br>An average of 0.15 ppm or more for consecutive 48 hours | 0.5 ppm or more for consecutive 3 hours<br>0.7 ppm or more for consecutive 2 hours |
| Suspended Particulate | 2 $mg/Nm^3$ for consecutive 2 hours | 3 $mg/Nm^3$ for consecutive 3 hours |
| Carbon Monoxide | 30 ppm or more | 50 ppm or more |
| Nitrogen Dioxide | 0.5 ppm or more | 1 ppm or more |
| Oxidant | 0.12 ppm or more | 0.4 ppm or more |

Note: All measurement is 1-hour value.

2) Regulatory control on specific business establishments

Local governments often conclude the pollution control agreement under their ordinance, with relatively large establishments, such as steel mills, petrochemical plants, paper mills, and power plants.

The agreement usually sets forth more strict control standards than national standards (surcharge strict standards) and regulate the amount of emission of pollutants.

Thermal power plants which conclude the agreement are required to report fuel consumption, concentration of pollutant on emission, the amount of emission, and other relevant data each month. Also, the planning statement specifying the compliance with the agreement in each year and pollution control measures to be implemented in the ensuing year should be submitted by the end of each year.

Furthermore, many plants send source data, including concentrations of sulfur oxides and nitrogen oxides on emission, residual oxygen concentration in waste gas, andelectricity production, by telemeter to central monitoring stations of local governments.

Finally, to verify the above data, on-site inspection is conducted once or twice per year under the attendance of MITI's and local government's officers and citizens in some cases (appointed in advance).

### A7.1.4 Monitoring of Smoke from Thermal Power Plants

(1) Measurement items

Regarding smoke emitted from boilers and other equipment used for operation of power plants, emission standards are established for SOx, NOx, and dust under the Clean Air Act and other applicable laws and regulations, with periodical measurement being required by law. In addition, many plants measure wind direction, wind speed, temperature, solar radiation, radiation balance, humidity and other meteorological data.

(2) Measuring locations

SOx, NOx, and dust are measured in the flue.

(3) Measuring method

The method of measurement is set forth in the Clean Air Act. SOx are measured according to JIS K0103, NOx JIS K0104, and dust JIS Z8808.

In addition, SOx and NOx are monitored from the central control center through continuous measuring instruments, as specified under the Electricity Enterprises Act.

Dust is regularly monitored at an interval specified in the Electricity Enterprises Act (Note) and emission at the stack outlet is always monitored by TV at many plants.

(Note: Facilities with emission of 40,000$m^3$/n or more are required to monitor once or more within 2 months. Most of thermal power plants are subject to this requirement.)

(4) Reporting

The result of smoke monitoring is reported monthly, quarterly, and annually to MITI (regional trade and industry bureau with jurisdiction) under the Electricity Enterprises Act.

In addition, thermal power plants which conclude the agreement with local governments are required to make monthly report and often send continuously monitored data to central monitoring stations of local governments by telemeter.

# APPENDIX 8 Current State and Future Outlook for the Energy Sector

## Appendix 8 Current State and Future Outlook for the Energy Sector

### A8.1 Fuel Policy of the Government of Argentine

During the past two decades, the government has pursued energy policy aiming at freeing the country from deep dependence on petroleum fuel, as seen in most of industrialized and middle-income countries worldwide. As a result, Argentina has successfully reduced the consumption of petroleum product in general and in particular fuel oil for power generation by boosting the use of natural gas, and significantly reduced consumption of kerosene for industrial, commercial, and household uses.

At present, privatization of public enterprises producing and marketing electricity, petroleum, and natural gas is under way at a rapid rate. Since future fuel supply and demand will be governed by market principles, there will be no energy production and marketing plans directly controlled by the government policy.

Nevertheless, it is expected that the privatized energy industry will continue its efforts to reduce the dependency on petroleum, as has been pursued by the government. This reflects the fact that Argentina is abundant in hydropower and natural gas resources, whereas relatively small crude oil reserves in the country will limit significant increase of domestic supply of petroleum. Also, it makes an economic sense to control consumption of petroleum-related energy which price is expected to increase in the long run. Finally, reduction of fuel oil consumption by increase use of natural gas and hydro electricity serves a purpose of reducing $CO_2$ emission to atmosphere, which is the major concern of the international community right now.

These conditions will encourage construction of hydroelectric power plants and development of natural gas resources and distribution networks provided certain incentive, which can encourage the investment of private party in this direction, is provided by the Government.

At the same time, however, the ongoing economic reform and the Government economic development program will results large investment in many sectors and to spur growth of the energy consumption. Therefore country's energy supply and demand structure will change drastically in near future. In particular, the use of crude oil, petroleum products and coal may increase significantly. That will necessitate the government to pursue a new policy serving dual purposes of preserving the environment and securing stable energy supply without harming activities of private sector enterprises.

Looking at the country's present energy supply and demand situation, the country produced primary energy as the total oil equivalent (TOE) of approximately 50 x $10^6$ tons in 1991, of which 6 x $10^6$ tons were exported as crude and petroleum products and remaining 44 x $10^6$ tons were consumed in the country. Primary energy sources are dominated by domestic oil (50% of total) and domestic natural gas (40%). Coal accounts for a scant 1% of total, including imported coal for steel production. Hydro electricity and nuclear energy supply about 3% each.

Proven recoverble reserves of crude oil are estimated at 300 x $10^6$ tons, the reserve/production ratio will be around 15 years at 1991 consumption rate even if some new discovery is made.

On the other hand, proven recoverble reserves of natural gas are estimated at 20 trillion cubic feet, and many new discoveries are anticipated. Some predict the total reserves will reach 50 trillion cubic feet. At present conditions the reserve/production ratio will be at least 30 years.

Thus, unless energy requirements increase dramatically due to rapid economic growth, the country's energy supply and demand situation will be maintained by tapping domestic sources of oil and natural gas. (Table A8-1)

Table A8-1 **ESTIMATED ENERGY RESERVES (1992) AND CONSUMPTION (1991)**
(Millions of Tons of Oil Equivalent-MMTOE)

| | Proven Reserves | | Proven and Potential Reserves | | Utilization | |
|---|---|---|---|---|---|---|
| | MMTOE | % | MMTOE | % | MMTOE | % |
| Hydropower | 1,430 *1 | 51 | 1,430 | 15 | 4.0 *3 | 9 |
| Natural Gas | 574 | 21 | 2,080 | 22 | 20.4 *2 | 28 |
| Oil | 342 | 12 | 1,093 | 12 | 25.2 | 60 |
| Coal | 132 | 5 | 4,575 | 48 | 0.2 | 1 |
| Uranium | 302 | 11 | 302 | 3 | 1.5 | 2 |
| | 2,780 | 100 | 9,480 | 100 | 50.4 | 100 |

*1 Hydroelectric potential over 25 years.
*2 Excludes flared gas.
*3 1 KWH : 2606 kcal equivalent.

Source : Energy Secretariat, Government of Argentina..pa

## A8.2 Overall Energy Demand Forecast

### A8.2.1 Energy Intensity Forecast

Energy demand forecast at a national level can be made by using a computer simulation model based on the country's industrial input/output model, the worldwide fuel distribution system, and other relevant factors. However, at present, there is not much data in Argentina to allow such approach. Instead, this study employs a macroeconomic approach to forecast overall energy demand in the country on the basis of possible scenarios for economic growth, and assessment of present and future energy intensity for unit G.D.P. generation.

Generally, GDP is believed to be closely associated with energy consumption. In the past, energy consumption grew proportionally to GDP growth. After the oil crises, however, the relation between GDP and energy consumption (intensity of energy) changed considerably. In particular, energy consumption decreased considerably in relation to GDP in Japan, due to a high energy cost in the country.

In Argentina, energy consumption per US$1,000 of real GDP has been changing during the past two decades, as shown in Figure A8-1 (TOES/GDP in Non-OECD Energy Statistics of OECD).

In general, the energy intensity in OECD countries has been declining gradually year after year after the oil crises. (Figure A8-2) However, it has been growing gradually in countries which are in the economic growth stage. (Figure A8-3) As seen in the relationship between GDP and power consumption, economic growth in industrially developing countries is fueled by the rise in standards of living and expansion of industrial activity (energy-intensive).
On the other hand, the GDP growth in the industrially developed country largely depend on the non-energy intensive sector such as electronics, computer, services etc.

To forecast GDP and energy elasticity in Argentina, trends in GDP per caput and energy intensity in OECD countries and middle-income countries including Argentina (Figure A8-4) is shown. It indicates that energy intensity has declined in most of these countries excepting Canada, New Zealand, and Scandinavian countries (all are abundant in low-cost hydroelectric power) when GDP per CAPT has exceeded US$5,000. An attempt was made to forecast energy demand growth in Argentina, based on the data of energy intensity (average) in these countries.

### A8.2.2 G.D.P. Growth Forecast

At the first step of demand forecast, the following three GDP growth patterns were assumed.

<u>Argentine Economic Growth Scenarios (1993-2010)</u>

As discussed earlier, the Argentine economy has recently moved out of stagnation in the past two decades and has started the first step of growth. The Government of Argentine published economic development plan for 1993~1995 in 1993. This plan indicated 6.5% GDP growth 1993~1995 and 5% during 1996~2000. Following three scenarios for economic growth were established as the basis of energy and electricity demand forecast.

1) High growth scenario

External debts of the government and public enterprises will decrease steadily; investment from abroad and by the private sector will reach a sufficiently high level; natural and human resources in the country will be fully utilized from now on; and the industry's international competitiveness will be improved. As a result, the economy will undergo rapid growth as it is intended by the Government development program.

Economic development achieved in various countries during the two decades after the oil crises can be divided into several patterns, when yearly growth rates were plotted against GDP/CAPT trends. (Figures A8-5)

While South Korea is an exceptional case (7.8%), annual average growth of 4.5% over relatively a long period of time, as seen in Malaysia, is feasible. Since Argentine population has been constantly growing at 1.4% to 1.6% annually, GDP needs to grow at an annual 6% (4.5% + 1.5%) to achieve 4.5% growth per caput, which is slightly lower than the Argentine Government target during 1993~1995, under the high growth scenario.

2) Standard growth scenario

According to the current long-term economic forecast estimated by World Bank, GDP of middle-income countries will grow at an average 4.5%, which is equivalent to that recorded in the Argentine between 1965 and 1973. Thus, the 4.5% growth is a rather conservative.

3) Low economic growth scenario

The above world economic forecast assumes that reconstruction of the former Soviet Union and Eastern Europe will continue and industrialized countries, particularly the U.S. and Europe will maintain free trade policy, and thus expects that the world economy will finally go out of persistent recession after the oil crises. However, if these assumptions were proved untrue, especially if the U.S. moves to trade protectionism, the Latin American economy will be adversely affected, and Argentina's economic growth will slow down.

In this case, GDP's growth rate will fall down to a level seen in the 1970s and 1980s, at around 1.5% to match with the Argentine population growth rate. For each of the above 3 cases, the country's GDP growth pattern is estimated up to 2010, as shown in Figure A8-6.

A8.2.3 Future Energy Requirement

Based on the above growth scenarios of Argentine and GDP/energy intensity trends of middle-income countries similar to Argentina, energy demand forecast was made and the result is presented in

Table A8-2. It is estimated that present energy intensity per unit G.D.P.(0.65 T.O.E.per 1,000 US$) will be decreased to 0.61 by 2010 under high growth scenario, be decreased to 0.63 under moderate growth scenario and will be the same under low growth scenario.

Under the high growth scenario, total energy requirements, estimated as 50.6 x $10^6$ (TOE) in 1993, are expected to grow to 56.3 x $10^6$ in 1995, 74.2 x $10^6$ in 2000, 97.6 x $10^6$ in 2005, and 127.4 x $10^6$ in 2010. Under medium growth scenario, total requirement (TOE) in 2000 will be 67.8 x $10^6$ and in 2010 will be 102.7 x $10^6$.

## Table A8-2 TOTAL ENERGY PROSPECT ARGENTINE

1,000$ TOE

| | High Growth Scenario (6%/Y) | | | Moderate Scenario (4.5%/Y) | | | Low Growth Scenario (1.5%/Y) | | |
|---|---|---|---|---|---|---|---|---|---|
| | G.D.P. | Elasticity | TOE | G.D.P. | Elasticity | TOE | G.D.P. | Elasticity | TOE |
| 1993 | 77.91 Million x 1.00 | 0.649 | 50.6 | 77.91 Million x 1.00 | 0.649 | 50.6 | 77.91 Million x 1.00 | 0.65 | 50.6 |
| 1995 | 77.91 Million x 1.12 | 0.645 | 56.3 | 77.91 Million x 1.09 | 0.646 | 54.9 | 77.91 Million x 1.03 | 0.65 | 52.2 |
| 2000 | 77.91 Million x 1.50 | 0.635 | 74.2 | 77.91 Million x 1.36 | 0.640 | 67.8 | 77.91 Million x 1.11 | 0.65 | 56.2 |
| 2005 | 77.91 Million x 2.01 | 0.623 | 97.6 | 77.91 Million x 1.70 | 0.633 | 83.8 | 77.91 Million x 1.20 | 0.65 | 60.8 |
| 2010 | 77.91 Million x 2.69 | 0.608 | 127.4 | 77.91 Million x 2.11 | 0.625 | 102.7 | 77.91 Million x 1.29 | 0.65 | 65.3 |

* Preliminary estimate as 1985 US$

## A8.3 Future Energy Sources in Argentine (Future of Fuels sources for Thermal Power Plants)

In the future, hydroelectric and nuclear power plants will serve as base load stations, and natural gas-based combined cycle and large/super high pressure steam turbine plants will be major middle load stations. Then, oil-fired thermal power plants, together with reservoir-type hydroelectric power generation plants, will basically serve as peak load (daily, weekly, and seasonal) stations.
The air pollution by thermal power plants will become a significant problem only when natural gas demand of the whole country exceeds the domestic supply capacity of natural gas supply, and it results extensive use of low-cost fuel by power plants. In this case, new construction or capacity expansion of thermal power plants depend on imported high sulfur oil or coal will be required. This means, high sulfur content fuel oil or coal, which can produce serious air pollution unless adequate counter measures are adopted, will be used on a continuous basis and in large quantities.

### A8.3.1 Future prospect of oil production in Argentina

Recently, Argentina Government intensively proceeding privatization of crude oil exploration and production activities to free most of them from the control of YPF, a apublic enterprise. Although this will improve the situation, judging from the history of crude oil production in Latin America and a general outlook for world crude oil prices, it is not likely that very large investment exceeds the level in the early 1980s (when exploration activities boomed worldwide) will be made in the near future. That means, it is very difficult, if not impossible, to see that present recoverable reserves of $1,570 \times 10^6$ bbl (1992) (annual consumption of $161 \times 10^6$ bbl) will increase considerably by 2010 due to the increase in newly discovered reserves greater than the present consumption level. (Figure A8-7 a,b,: Reserves of Oil Producing Countries Similar to Argentina)

For instance, the number of exploratory wells functioning during 1983-1985 exceeded one thousand, but in 1992 the number was 943 and in 1992 number was 570 (January to September).

This again suggests that it is difficult to discover new petroleum resources which allow domestic production to continue in the long run at present production level or higher, in response to growing oil demand in the near future in the country.

In the late 1980s, the country exported 2 - 4 million tons of crude oil and petroleum products partly due to the decline in consumption of oil fuels caused by the increase in use of natural gas, and partly due to faltering industrial demand.

It is expected that, however, further fuel conversion from petroleum products to natural gas is not likely because of the most of oil product will be used transportation sector.

In 1991 and 1992, the export of crude oil and petroleum product exceeded 5 million tons as the results of activation of oil sector business. In 1992 the crude oil production in Argentine exceeds 30 million tons, but the future long range supply at this level will be very difficult because of the resource limitation. Therefore, it is concluded the future domestic supply will be about 25 million ton annualy.

A8.3.2 Future prospect of natural gas supply in Argentine

The amount of proven recovable natural gas in the country is considered as 20 TCF (trillion cubic foot) (26 TCF as confirmed reserve), and there are additional 9 TCF provable reserves. The 1992 domestic production is reported as about 0.7 TCF. The present expected life is about 30 years.
Presently the Government is promoting exploration of oil/gas reserves in the country through "Argentine Exploration Plan".

However, as the remarkable recovery of economy of the country is increasing the consumption of natural gas in the country. In addition, the export of natural gas to Chile is already firmed up, and several plans to export gas to Brazil are also under way.

Under these circumstance, it is considered as unlikely that the discovery of additional gas reserve can exceed the present consumption and can results significant improvement of reserve/production ratio. (Ref: Figure A8-8 a,b,)

The replacement of petroleum and coal by natural gas will not proceed so quickly as the past as the further replacement oil by gas may be comparatively costly such as the case of seasonal fuel oil demand or compressed gas for automobile fuel.
Therefore, the future additional demand of natural gas is considered as proportional to the total fuel demand increase.

According to the forecast of fuel demand in future under the high economic development scenario, which is close to present plan of the Government, the total fuel demand will increase more than 100% of present by AD2010. The supply of natural gas in the country will have difficulty to keep up with that requirement, because the time for recovery of the investment required to increase gas production and distribution capacity normally require 10~15 years after investment is made.

As we estimated the R/P ratio of natural gas will be 30 years at best in future, and the increase of production by 100% will result the R/P as 15 years. These condition will be difficult to be justified financially. Therefore, it is concluded that the future supply of natural gas in the country will be some where around 50% more than present level.

### A8.3.3 Prospect of supply/demand of primary energy

Based on the expected capacity increase of hydro-electric power plant and nuclear power plant and the possibility of supply of oil and gas in Argentine, the supply demand balance of primary energy in AD 2010 is estimated. The results is indicated in Figure A8-9.

Depend on the development of hydro power plant, the shortage of primary energy will be about 30 million TOE in case hydro electric power plant development is low.

When expected project for hydro-power plants are realized, the shortage of energy will be 20 million TOE.

## A8.4 Future prospect of electricity demand

Introduction. In order to assess the impact of thermal power plant to the atmospheric environment of the country, the amount of fuel and its species to be used for the thermal power plant in future must be estimated.

In the following, (1) the forecast of the future demand of electricity, (2) the assessment of type of power plant and its fuel requirement, are described;

### A8.4.1 Forecast of the future demand of electricity

One of reports publicated in the country in 1993 in relation to the forecast of future electricity demand was provided by S.E.

The report forecasted future demand based on assumed G.D.P. (National Domestic Product) and macro economic model. The assumed annual G.D.P. growth in this report was 4.1% 1992~2000, 3.4% 2,000~2005, 3.0% 2005~2010.

However, the recently disclosed economic development program of the Government is indicating much higher economic growth infuture. It indicated annual G.D.P. growth 1993~1995 6.5% and 1996~2000 5.0%. The forecast mentioned above is recently revised based on the G.D.P. growth indicated in the Government program.

The study team conducted the demand forecast based on the co-relation between G.D.P. per caput and electricity intensity over G.D.P.

The G.D.P. growth of the country was assumed in the same way as described in Chapter 2 of this Appendix 8.

The high growth scenario assumes annually 6.0% G.D.P. growth up to 2010, medium growth scenario assumes 4.5% and low growth senario assums 1.5%.

The next exercise is the estimation of electricity intensity over G.D.P. per caput in the country in future. Unfortunately the past trend of the change in electricity intensity in Argentine is not applicable in future because the G.D.P/electricity relationship was negative in several years. This phenomena is not observed in the country where smooth economic development is continuing. In order to estimate future trend of Argentine, the G.D.P./electricity intensity of the countries similar to Argentine are assessed.

The results are indicated in the Figure A8-10. The co-relation between G.D.P./caput electricity intensity over G.D.P. is not very clear, but except few country where very low cost electricity is abundantly available the KWH requirement per unit of G.D.P. is definitely decreasing as the per caput G.D.P. increase.

Generally speaking KWH/G.D.P. caput in the country, where the initial industrialization and rapid electrification of the life of inhabitant is progressing, the country G.D.P./caput increasing from 300 US$ level to 2000 US$ level, show very high power consumption increase per unit G.D.P. increase, and when G.D.P./caput reaches to 2,500~3,000 U.S.Dollar level, where standard of living improved to world standard and basic heavy industries are already established, KWH increase to unit G.D.P. become taper.

Further, the economy shifted to non-energy industry such as automobile manufacturing, electronics, computer etc, the KWH/unit G.D.P. decrease to lower than 1.0.

The KWH/unit G.D.P. Argentine in these years up to 1990 had been always around 0.75~0.76, and the G.D.P. increase in 1991, 1992 was 8.9 and 8.7% against generated electricity increase 1991 6.6% and 1992 4.7% are observed.

It is concluded that under the high growth scenario the structure of industries and society of Argentine will move to the structure of high income county, where KWH/G.D.P. is around 0.6, but in case of low growth scenario present 0.75 will continue.

The estimated future demand of electricity generation are indicated in the Table A8-3 and Figure A8-9.

The electricity generation in AD2010 by high growth is estimated as 144.6 x $10^3$ GWH/Y, by medium growth 118.4 x $10^3$ GWH/Y and by low growth 75.4 x $10^3$ GWH/Y. The forecast made in the report provided S.E. in 1993 forecasted the generation in AD2010 as 132.3 x $10^3$ GWH/Y which is close to the case of high growth scenario. The recent, 1994, forecast of S.E. indicates electricity generation 98.7 x $10^3$GWH in AD2010, which is close to the case of medium growth scenario.

## Table A8-3 ELECTRICITY GENERATION (ANNUAL FORECAST) (G.D.P. BASE)

Unit: Billion KWH/Y

| | High Growth Scenario (6%) | Moderal Scenario (4.5%) | Low Growth Scenario (1.5%) |
|---|---|---|---|
| 1990 | 65.13 x ( 1.00 ) x 0.750 = 48.8 | | |
| 1993 | 77.91 B. x ( 1.00 ) x 0.749 = 58.4 | 77.91 B. x ( 1.00 ) x 0.749 = 58.4 | 77.91 B. x ( 1.00 ) x 0.750 = 58.4 |
| 1995 | 77.91 B. x ( 1.12 ) x 0.745 = 65.0 | 77.91 B. x ( 1.09 ) x 0.746 = 63.4 | 77.91 B. x ( 1.03 ) x 0.750 = 60.2 |
| 2000 | 77.91 B. x ( 1.50 ) x 0.734 = 85.8 | 77.91 B. x ( 1.36 ) x 0.739 = 78.3 | 77.91 B. x ( 1.11 ) x 0.750 = 64.9 |
| 2005 | 77.91 B. x ( 2.01 ) x 0.721 = 112.9 | 77.91 B. x ( 1.70 ) x 0.731 = 96.8 | 77.91 B. x ( 1.20 ) x 0.750 = 70.1 |
| 2010 | 77.91 B. x ( 2.69 ) x 0.704 = 147.5 | 77.91 B. x ( 2.11 ) x 0.722 = 118.7 | 77.91 B. x ( 1.29 ) x 0.750 = 75.4 |

Estimation of S.E.

| | 1993 Estimate | 1994 Estimate |
|---|---|---|
| 1995 | 59.6 | 65.2 |
| 2000 | 80.1 | 78.0 |
| 2005 | 107.5 | 88.3 |
| 2010 | 141.8 | 98.7 |

## A8.5 Assessment of the type of future power plant and its fuel requirement

### A8.5.1 The type of the power plant in future

According to the latest report, which was provided by S.E. to study team, the most likely future power supply (SEN) are predicted as follows:-

| | | | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| Supply Electricity | | | | | | |
| | SE 93 | Nuclear | 6736 | 11724 | 11724 | 11724 |
| | GWH | Hydro | 22297 | 38695 | 38695 | 38695 |
| | | Case 2 | (22297) | (38695) | (43205) | (63966) |
| | | Thermal | 26547 | 24291 | 49941 | 81911 |
| | | Case 2 | (26547) | (24291) | (45431) | (56640) |
| | | Total | 55580 | 74710 | 100360 | 132330 |
| | SE 94 | Nuclear | 6750 | 11760 | 11760 | 11760 |
| | | Hydro | 23403 | 40939 | 40939 | 40939 |
| | | Thermal | 35049 | 25274 | 35644 | 46039 |
| | | Total | 65292 | 77973 | 88343 | 98738 |

This prediction is indicating the ongoing nuclear power plant project (Atucha II) will be put on stream from some time 1996, and futher addition of nuclear power plant is not likely untill AD 2010.

The expansion of the capacity of hydraulic power plant will continue up to 1999 as it is expected in the past SE long range plan.

Further expansion of hydraulic power plant after 2000 is not yet solidified, but there is good possibility of adding 1650 MW during middle of 2000's.

Since the variable cost of hydraulic and nuclear power plant is very low comparting with that of thermal power plant based on fossil fuel, supply from these plants will be given the first priority every year.

The balance between the total demand and supply from hydro and nuclear will be met by thermal power plant.

A8.5.2 The estimated fuel requirement in future

(1) The estimated fuel requirement in future

The future electricity requirement estimated by the recent S.E. report, which is similer to the medium growth scenario of study team, and the other estimate made in 1993, which is close to the high grows scenario, are shown in the above paragraph.

The required energy to generate the above mentioned electricity based on the S.E. estimate of Hydro Power Generation and Nuclear Power Generation in future are estimated as follows:-

The use of fuel by the existing power plants in future assumed as the same that of 1992 performance.

**THERMAL POWER GENERATED 1992 25410 GWH**

| Fuel Used | Electricity Generated GWH | Fuel equivalent to Oil |
|---|---|---|
| Coal | 423 | $139 \times 10^3$ |
| Fuel Oil | 5590 | $1448 \times 10^3$ |
| Middle Disti | 1918 | $512 \times 10^3$ |
| Natural Gas | 17959 | $4778 \times 10^3$ |
| Total | 25690 | $6877 \times 10^3$ |

(2) Fuel Requirement (TOE) for Power Generation

| | | | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| Supply Electricity | | | | | | |
| | SE 93 | Nuclear | 6736 | 11724 | 11724 | 11724 |
| | GWH | Hydro | 22297 | 38695 | 38695 | 38695 |
| | | Case 2 | (22297) | (38695) | (43205) | (63966) |
| | | Thermal | 26547 | 24291 | 49941 | 81911 |
| | | Case 2 | (26547) | (24291) | (45431) | (56640) |
| | | Total | 55580 | 74710 | 100360 | 132330 |
| | SE 94 | Nuclear | 6750 | 11760 | 11760 | 11760 |
| | | Hydro | 23403 | 40939 | 40939 | 40939 |
| | | Thermal | 35049 | 25274 | 35644 | 46039 |
| | | Total | 65292 | 77973 | 88343 | 98738 |
| Energy (TOE) for Electricity Generation | | | | | | |
| TOE 1000 SE93 | | Nuclear | 1751 | 3048 | 3048 | 3048 |
| | | Hydro | 5797 | 10061 | 10061 | 10061 |
| Hydro KWH=2600KCAL | | Natu Gas | 4966 | 4470 | 10113 | 17146 |
| (Gas Oil 512 incl) | | F.O./G.O | 1960 | 1960 | 1960 | 1960 |
| | | Coal | 130 | 130 | 130 | 130 |
| | | Total | 14605 | 19669 | 25312 | 32345 |
| TOE 1000 SE94 | | Nuclear | 1755 | 3058 | 3058 | 3058 |
| | | Hydro | 6085 | 10644 | 10644 | 10644 |
| Hydro KWH=2600KCAL | | Natu Gas | 6837 | 4686 | 6968 | 9255 |
| | | F.O./G.O | 1960 | 1960 | 1960 | 1960 |
| | | Coal | 139 | 135 | 135 | 135 |
| | | Total | 16776 | 20483 | 22765 | 25052 |

This indicates that the natural gas requirement for power plants in AD2010 will be 9,255,000 TOE under the moderate economic growth case, and under very high economic growth case the requirement will be 17,146,000 TOE (20,403 million $m^3$).

(3) Primary energy supply forecast

According to the supply data of primary energy by S.E. in 1991, the avairable natural gas was 18,500 x $10^3$ (TOE), and oil production was 25.330 x $10^3$ (TOE). It is assumed that this crude oil production can be maintained up to AD 2010 and the natural gas production will be increased gradualy, annual average 2.1%, up to 150% of present supply by AD 2010.

Based on the above oil and gas production and expected hydro and nuclear energy, the likely domestic supply of primary energy are estimated as follows:-

| | | |
|---|---|---|
| 1995 | TOE/Year | 55,145,000 TOE |
| 2000 | " | 62,986,000 " |
| 2005 | " | 65,526,000 " |
| 2010 | " | 68,346,000 " |

On the other hand, the total energy requirement of the country will increase rapidly because of planned high economic growth, which require significant additional energy. (Ref: Table A8-2)

### A8.5.3 Seasonal change of fuel consumption and its impact to environment

One of the characteristic feature of fuel consumption in the country is the seasonal change.

It is well know that most of the steam turbine power plant in the country use natural gas in summer time, but the supply of natural gas to the such power plant is reduced very much in winter. Therefore almost all fuel in these plants during winter is switched from natural gas to fuel oil.

The data provided by CAMESA is shown in the Figure A8-11. The impact if power plants to the atmospheric environment must be assessed with due consideration on this condition.

It is very important to assess future fuel demand and supply situation including seasonal influence in relation to planning the most economic pollution counter measures.

### A8.5.4 Conclusion of this Chapter

As the forecast of future primary energy demand and supply indicates, there is high possibility of shortage of domestic primary energy supply in near future.

The most desirable measure for the country to maintain the selfsufficiency of energy supply in the country is the intensive development of hydro electiricity resources and natural gas resouces.

When the potential problem of green house effect of carbon dioxide in the atmospher, the effort to increase the supply of renewable energy and the lest $CO_2$ containing energy is very important not only for the Argentine but also Global Engiconment conservation.

**PRIMARY ENERGY SUPPLY IN ARGENTINE (T.O.E.$10^6$)**

| AD2010 | Case I | Case II | Case III |
|---|---|---|---|
| Natural Gas | 27.8 | 27.8 | 27.8 |
| Crude Oil | 25.0 | 25.0 | 25.0 |
| Nuclear i) | 3.0 | 3.0 | 3.0 |
| Hydro Electrocity 1)2) | 10.1 | 16.7 | 10.1 |
| Others | 2.0 | 2.0 | 2.0 |
| Total | 67.9 | 74.5 | 68.4 |

1) Case I, II : S.E. information '93
   Case III : S.E. information '94
2) Hydro Electricity 1KWH = 2,600 kcal
3) Case II assume extensive development of hydro-electricity in 2000's

| | | | |
|---|---|---|---|
| Import | 34.8 | 28.2 | 34.3 |

Import Requirement (Ref. Figure A8-12)

Energy Requirement AD2010 estimated (under moderate growth scenario)
$A^s$ 102.7 x $10^6$ TOE

**FUEL REQUIREMENT FOR ELECTRICITY GENERATION (AD2010)**

TOE $10^6$

| | Case I | Case II | Case III |
|---|---|---|---|
| Nuclear | 3.05 | 3.05 | 3.06 |
| Hydro | 10.06 | 16.65 | 10.64 |
| Natural Gas | 17.15 | 10.56 | 9.26 |
| Fuel Oil/Gas Oil | 1.96 | 1.96 | 1.96 |
| Coal | 0.13 | 0.13 | 0.13 |
| Total | 32.35 | 32.35 | 25.05 |