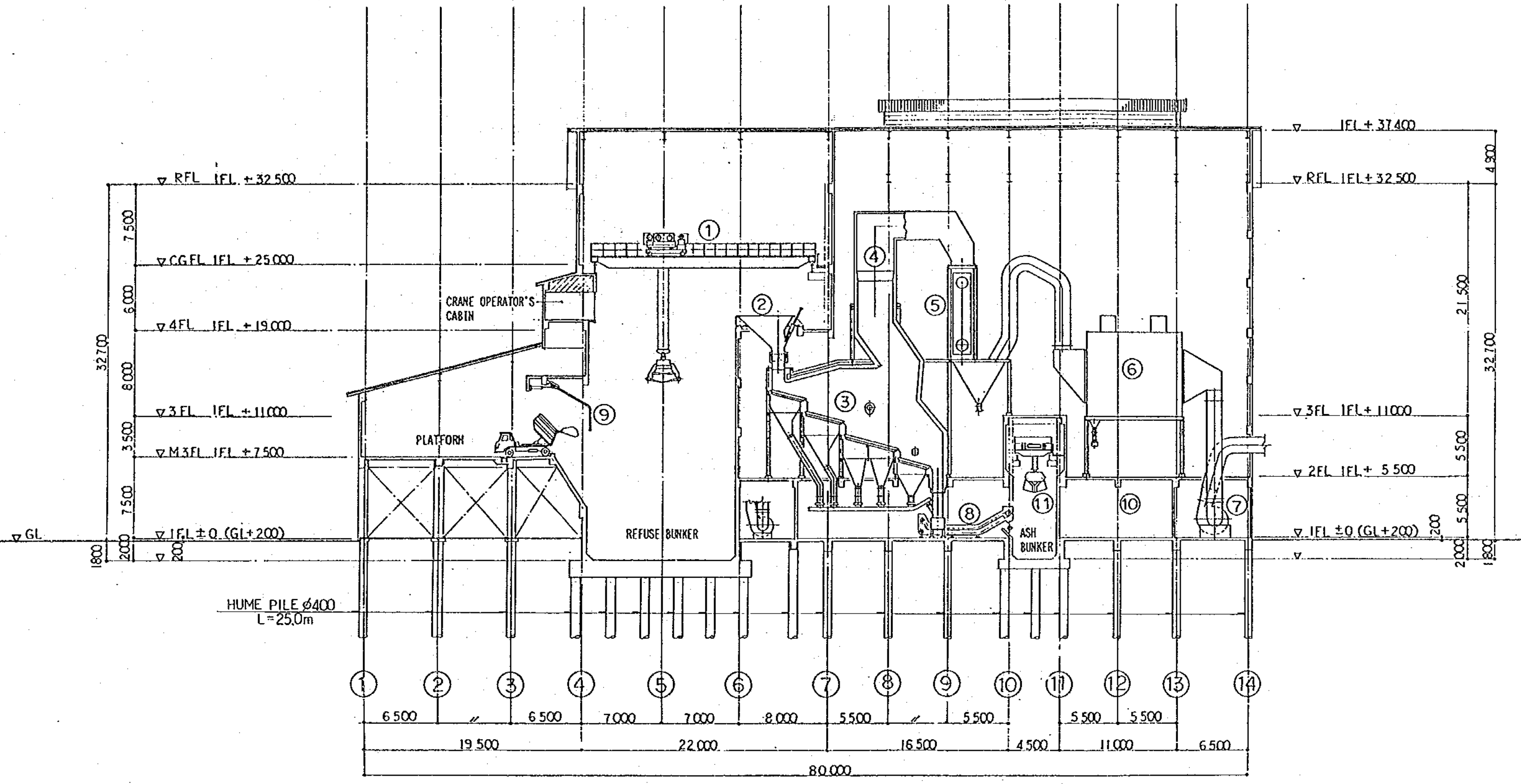


① REFUSE CRANE
② CHARGING HOPPER
③ FURNACE
④ GAS COOLER
⑤ GAS AIR HEATER
⑥ ELECTROSTATIC PRECIPITATOR
⑦ INDUCED DRAFT FAN
⑧ ASH CONVEYOR
⑨ DAMPING DOOR
⑩ WASTE WATER TREATMENT PLANT
⑪ ASH CRANE

ON NUT INCINERATION PLANT		
EQUIPMENT LAYOUT SECTION		
SCALE	DRAWING NO.	DATE
	I-7	15/12/1990
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT		
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)		

Fig 1.2-3 Section of the planned Incineration Plant

1.3 Site Conditions and Expected Environmental Impacts

1.3.1 Location and Geological Conditions

The planned site is on the south side of the existing dump site at On Nut as shown in Fig. 1.3-1. The site is flat with some swampy ponds around the site. The results of the geological survey conducted by the JICA Study Team in 1990 shows that a layer where N values are greater than 50 exist at 25m depth from the ground. A site location map is shown in Fig. 1.3-2.

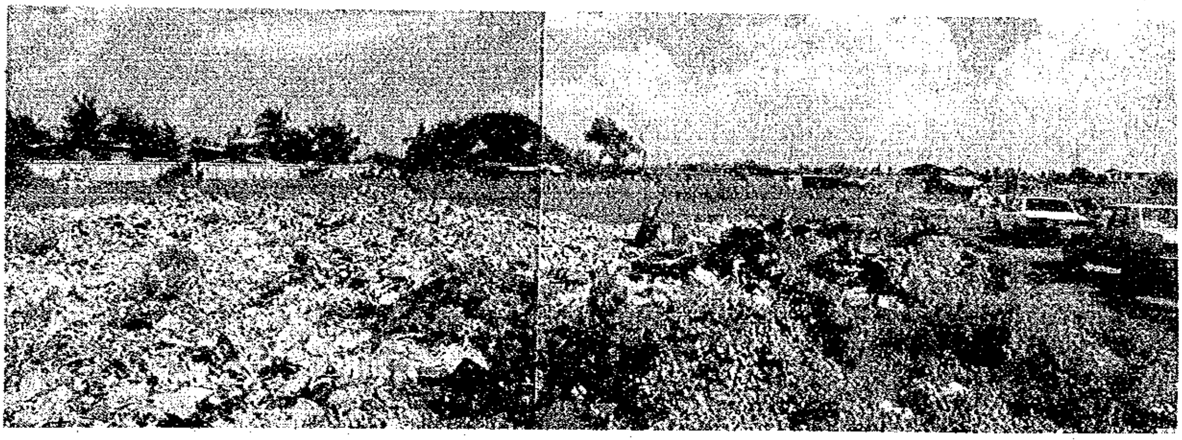


Fig. 1.3-1 Site View: A view of existing furnace attached to the compost plant at On Nut and Screening facility for fine compost.

Fig. 1.3-2 Site Location of the Planned Incineration Plant

1.3.2 Expected Environment Impacts

It is considered that the planned incineration plant will not cause any significant negative impacts on the people and the environment judging from the following:

1. The planned plant site is located within the existing disposal site.

2. There are not many people living near the site. There are no housing development plans in the neighborhood areas. The nearest school is 800m away from the site.

4. The planned incineration plant will not affect the current air quality as the plant will be equipped with measures against air pollution.

5. The planned incineration plant will not affect the surrounding public water as the plant will have a closed system whereby all the waste water generated in the waste reception pit will be put into a furnace, and sewage generated as a result of cleaning the floors and equipment will be used as cooling water.

1.4 Schedule of Construction

It is proposed that the BMA will construct an incineration plant (200 t/d/unit x 3 units) in two phases. The first furnace and common facilities for three furnaces such as a waste reception pit and water treatment facilities will be designed and constructed during the first phase 1992 - 1995. Plant operation will begin at the end of 1995. The second and third furnaces will be constructed in the second phase, and start their operation in 2000. Refer to Fig. 1.4-1 for the schedule.

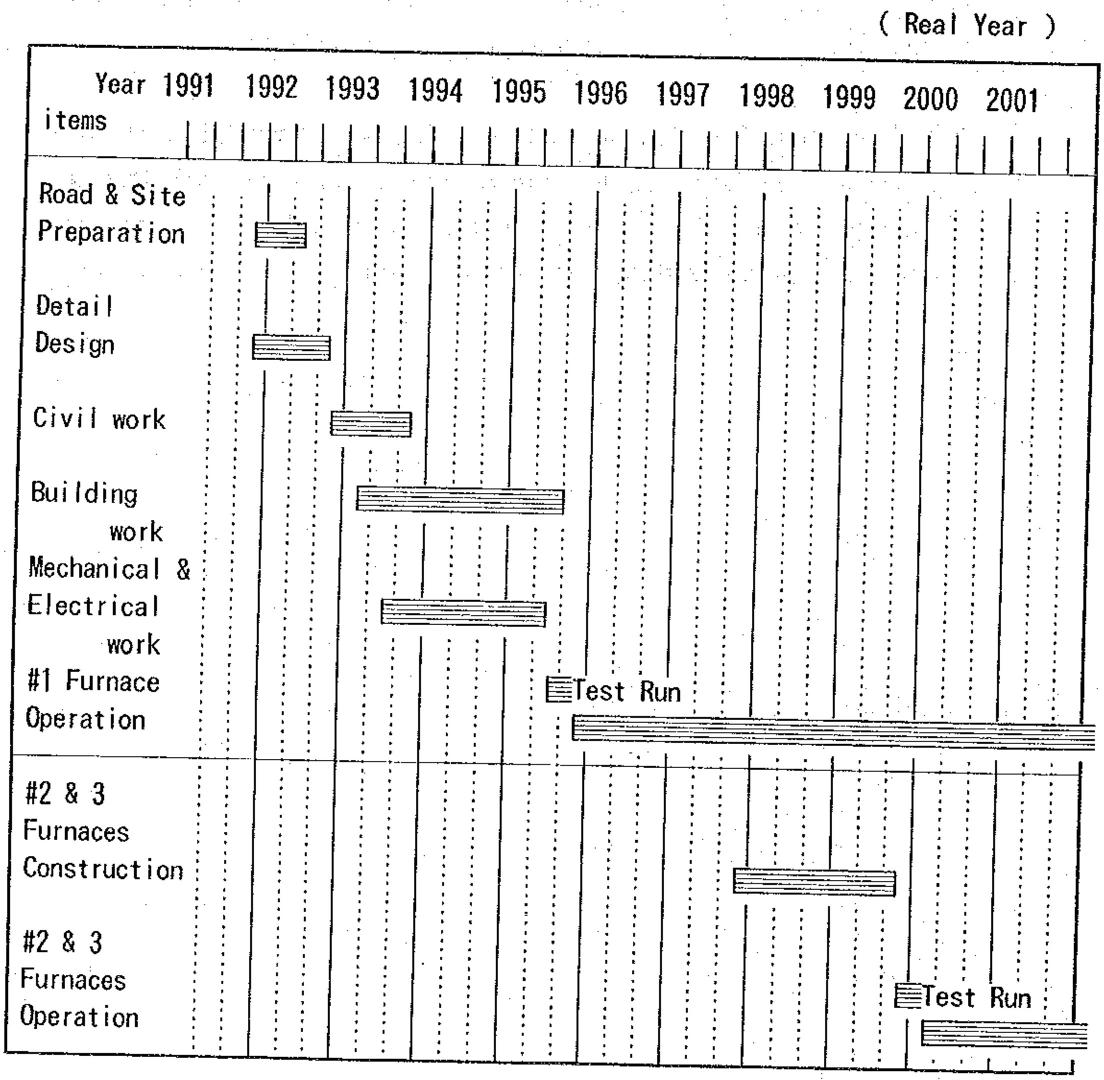


Fig 1.4-1 Construction Schedule of the Incineration Plant

1.5 Cost of Construction and Operation

The total construction cost of the planned incineration plant is estimated at 1,842 million Baht in 1990 price, of which 1,209 million Baht (66% of the total cost) will be required for the first phase 1993 - 1995 during which the first furnace and common facilities will be constructed. The remaining 633 million Baht will be needed for the second phase 1998 - 2000 during which both the second and third furnaces will be constructed.

Annual operation/maintenance costs will be 25 - 67 million Baht during 1996 - 1999, while they will be more than doubled in 2000 and afterwards. An average unit cost of operation/maintenance (without depreciation) during 19 years of operation is estimated at about 700 Baht/ton.

Table 1.5-1 Estimated Costs Required for Construction and Operation/Maintenance of the Planned Incineration Plant

(Million Baht in 1990 price)

Fiscal Year / items	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total
Construction			490	490	229	-	-	280	280	73	1,842
Operation & Maintenance											
Emolument			0.61	0.63	3.90	6.20	6.38	6.58	10.10	13.12	47.52
Utility						15.04	15.04	14.81	14.80	30.45	90.14
Parts *1						0.36	0.44	1.82	2.00	2.80	7.42
Repair*2						3.64	3.64	9.09	40.00	16.70	73.07
Subtotal			0.61	0.63	3.90	25.24	25.50	32.30	66.90	63.07	218.15
Total			491	491	233	25	26	312	347	136	2,061

*1: Parts include materials and equipment used for operation and maintenance.

*2: Repair means mainly overhaul which will be done by a contractor. Cost of minor repair to be done by the BMA is also included.

Chapter 2. Design Policy

An Incineration plant has been planned based upon the following design policy.

Policy 1. WORKABLE INCINERATOR

A proposed incinerator should be the one which can incinerate the current waste of ordinary characteristics (in terms of calorific values and waste composition) without choosing a particular waste having higher calory.

Policy 2. USE OF RELIABLE TECHNOLOGY

A proposed incinerator should be the one which employs reliable technology that has been tested and proved good in many places.

Policy 3. ECONOMICAL INCINERATOR

A proposed incinerator should be the most economical one, given the waste quality, environmental standards to be met, and other conditions.

Policy 4. PREVENTION OF THE SECONDARY POLLUTION

The prime objective of an incinerator is to dispose of waste in a sanitary manner by incinerating and reducing waste volume. It, however, may cause a secondary pollution such as air pollution if adequate measures are not taken.

A proposed incinerator should be the one with facilities necessarily for avoiding such secondary pollution. It should be the one which will meet the both the Proposed Industrial Emission Standards, and the Industrial Effluent Standards of Industrial Environment Division, Ministry of Industry."

Chapter 3. Site Conditions

3.1 Location

The planned site is located in the south part of the existing disposal site at On Nut where there are open dumping areas and two compost plants. It is flat with an area of 10.6 rai (17,000 m^2). There is an access road to the planned site. There are high voltage transmission lines near the site. The planned site location is shown in Fig. 3.1-1.

BOUNDARY POINTS

STA	N	E	ANG	DIST.	REMARKS
34				1.92	
1	1032.48	631.46	65°–41'–24"	111.42	FENCH CONER
2	922.37	634.41	51°–38'–60"	64.48	ADGE OF ROAD
3	934.70	690.49	221°–55'–53"	24.87	
4	948.00	710.65	124°–51'–38"	2.60	
5	949.69	720.65	228°–17'–53"	19.83	
6	947.08	740.31	100°–50'–33"	23.18	
7	959.06	747.62	181°–45'–06"	30.52	
8	997.71	758.13	262°–23'–38"	128.78	
9	969.73	883.84	179°–42'–05"	20.88	
10	965.30	904.24	182°–10'–39"	18.11	
11	960.79	921.78	182°–13'–02"	2.58	
12	960.05	924.25	177°–16'–43"	9.41	
13	957.79	933.38	144°–48'–24"	10.79	
14	964.60	950.83	245°–34'–25"	62.13	
15	921.21	995.35	63°–17'–51"	158.92	
16	1073.51	1040.76	183°–09'–38"	25.09	
17	1097.12	1049.23	180°–04'–28"	2.11	
18	1099.10	1049.95	182°–56'–35"	2.80	
19	1101.69	1051.03	182°–34'–25"	32.60	
20	1131.15	1064.98	66°–57'–24"	25.07	
21	1140.66	1041.78	179°–50'–06"	6.63	ELECTRIC POLE
22	1143.16	1035.64	95°–05'–11"	43.09	ADGE OF ROAD
23	1103.07	1015.02	168°–09'–26"	26.37	
24	1081.57	999.76	251°–17'–10"		

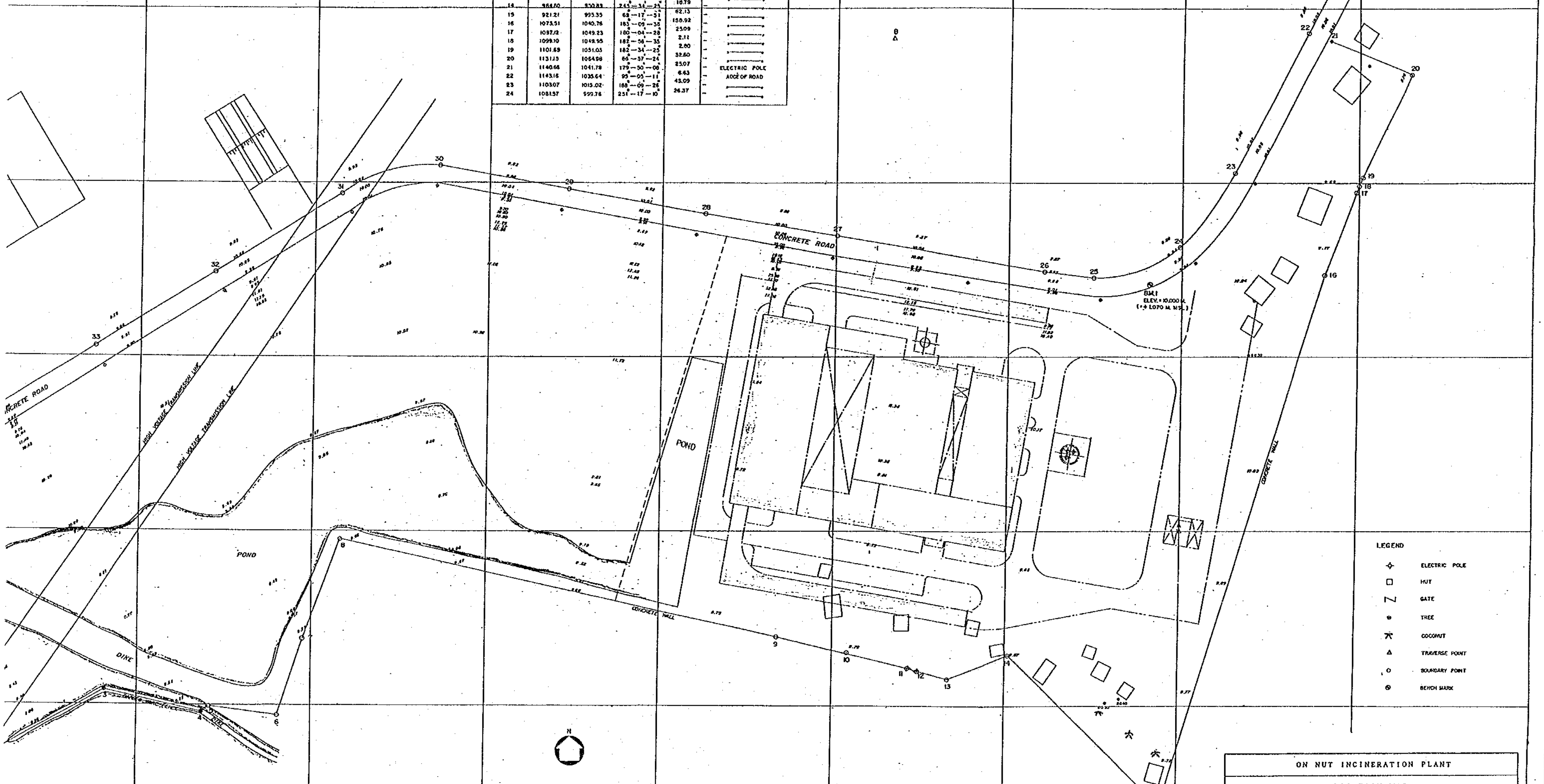
BOUNDARY POINTS

STA	N	E	ANG	DIST.	REMARKS
24				26.58	
25	1072.76	974.58	204°–03'–43"	14.78	ADGE OF ROAD
26	1074.52	960.01	182°–58'–59"	60.69	
27	1084.05	900.21	179°–34'–38"	38.58	
28	1091.14	862.14	180°–45'–16"	40.07	
29	1098.19	822.70	180°–14'–16"	37.70	
30	1104.97	785.62	153°–39'–11"	29.33	
31	1098.90	757.42	165°–03'–03"	42.78	
32	1074.28	721.11	180°–11'–24"	40.50	
33	1052.57	686.66	179°–38'–46"	39.34	
34	1032.07	653.33	224°–12'–07"		

AREA = 29 – 1 – 30 RAI

TRAVERSE POINT

STA	N	E
A	1000.000	1000.000
B	1141.239	958.598
C	1000.007	644.495



NOTES

1. NORTH IS MAGNETIC NORTH
2. CO-ORDINATE IS ASSUMED TO BE N.1000 / E.1000 AT POINT A
3. ELEVATION IS ASSUMED TO BE 10.000 M. AT BM.1 WHICH IS CONCRETE NAIL ON THE ADGE OF CONC. ROAD (= + 1.070 M. MSL.)

LEGEND

- ELECTRIC POLE
- HUT
- GATE
- TREE
- COCONUT
- TRAVERSE POINT
- BOUNDARY POINT
- BENCH MARK

ON NUT INCINERATION PLANT		
LOCATION MAP		
SCALE	DRAWING NO.	DATE
	1 – 0	15/12/1990
THE STUDY ON BANGKOK SOLID WASTE MANAGEMENT		
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)		

E 700 E 750 E 800 E 850 E 900 E 950 E 1000 E 1050

Fig 3.1-1 Site Location Map for the Planned Incineration Plant in On Nut

3.2 Environmental Conditions

3.2.1 Physical Resources

1) Climate

Thailand has a tropical climate with wet and dry seasons. The dry season can be divided into cool and hot seasons. Such seasonal changes occur as a result of changes in monsoon wind directions.

Temperatures, humidity and rainfall recorded between 1956 and 1985 in Bangkok by Meteorological Department are shown in Fig. 2.2-1. Annual mean temperature is about 28°C. The highest monthly mean temperature is 30°C in April, and the lowest monthly mean temperature is 26°C in December. Monthly mean humidity ranges from approximately 70% to 80%.

In Bangkok, average annual rainfall is about 1500 mm. Mean maximum monthly rainfall is over 200 mm in September and October, and mean minimum monthly rainfall is less than 10 mm in December and January. The heaviest daily rainfall was 167.3 mm (June 1979).

In Bangkok wind is not strong, mean wind speed is 1.7 m/s. Most frequent wind direction is south to southwest in February through August and north to northeast in October through December according to data recorded between 1951 - 1980.

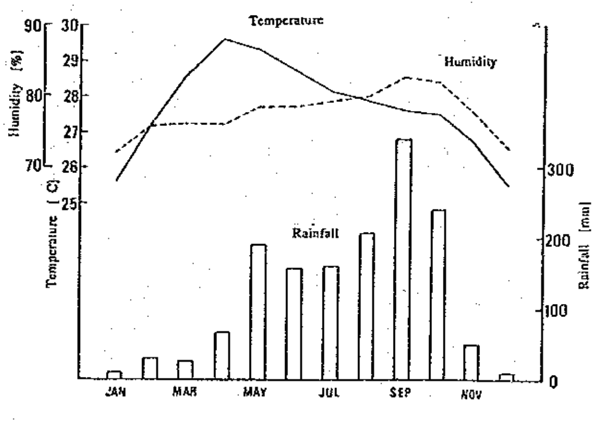


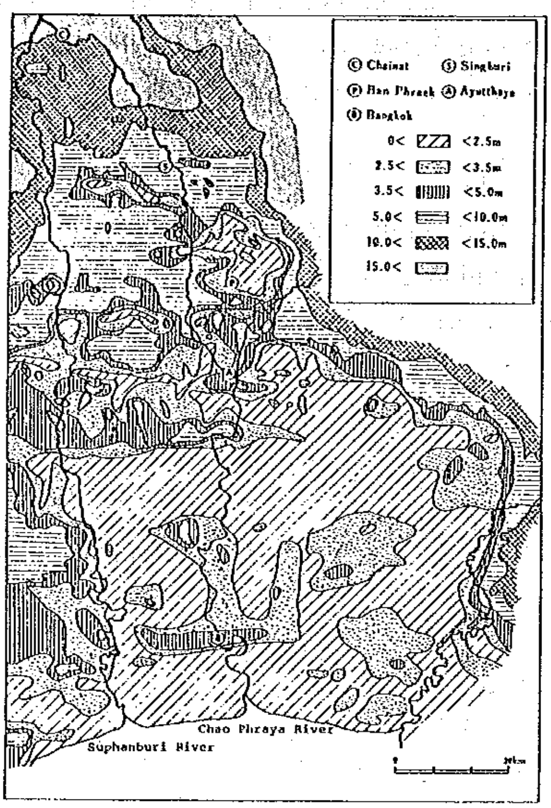
Fig. 3.2-1 Average Monthly Climate in Bangkok (1956 - 1985)
Source : Ministry of Communication

2) Topography

Bangkok is situated in Bangkok Plain which is a southern part of Central Plain. The Bangkok Plain is part of the alluvial delta of the Chao Phraya river basin. The quaternary alluvial deposit in this plain reach to a 300 m depth in the Bangkok area. The surface layers of the Bangkok Plain are composed of recent and semi-recent alluvial deposits.

The elevation of Bangkok is less than 5 m, and there is little slope. The contour map of the Chao Phraya delta is shown in Fig. 3.2-2. The inner districts of Bangkok have been subsiding at a rate of 5 to 10 cm a year.

The planned incinerator site is in the existing disposal site in On Nut. The ground level is about M.S.L. + 1 m. And there is a pond at western part of the site, where there is standing water which is about 2.5 m deep.

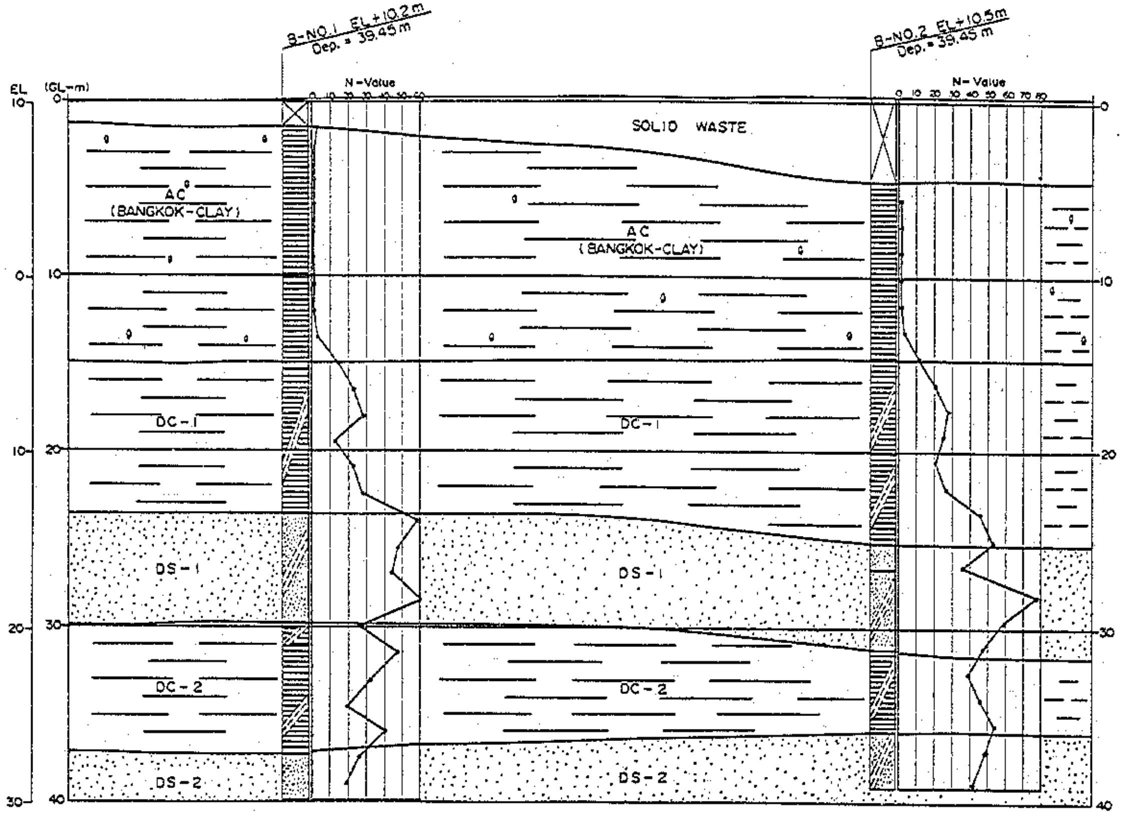


Source : Y. Tanaka (Agricultural Development of Tropical Delta)

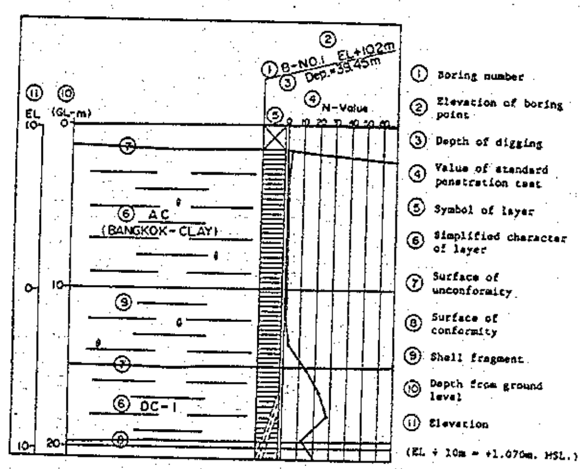
Fig. 3.2-2 Contour Map of the Chao Phraya Delta

3) Geology

Fig. 3.2-3 shows geological logs and cross section of the site, which were prepared based upon the field investigation. The result of logs and detailed information of investigation are shown in Chapter 6 of Volume 4 Supporting Report. The report shows that alluvium and dilluvium deposits are distributed over the site area. The alluvium deposit is a very soft clay commonly called as Bangkok Clay. It has about 15m thickness and low N-values. Therefore, all structures need pile foundations. A supporting layer of the pile foundation exist at about 25m depth form original ground level. However, in the case that a light structure is built by using friction pile foundations, the length of pile can be shorter than 25m.



LEGEND



Time classification	Simplified character	Symbol	Characteristic
—	SOLID WASTE		Plastic, organic matter, black, soft
Alluvium	AC		Clay trace shell fragment, greenish gray, soft (CH), Bangkok clay.
Diluvium	DC-1		Silty clay trace fine sand, grayish brown, stiff to hard. (CH)
	DS-1		Silty fine sand trace medium sand, brownish gray, dense to very dense. (SM)
	DC-2		Silty clay trace fine sand, grayish brown, hard. (CH)
	DS-2		Silty fine sand trace medium sand, brown, dense. (SM)

Fig. 3.2-3 Geological Logs and Cross Section of the On Nut site

4) Surface Water

There is a Khlong around the planned On-Nut site. At present, the Khlong is used for drainage of treated leachate from the On Nut disposal site. This Khlong is connected to another large Khlong.

The JICA team analyzed the water quality of the Khlong in the rainy season (September 1990), and it was observed that this Khlong has a lower level concentration of organic matter than a Khlong near On Nut, and it has a slow current. However, dissolved oxygen is lower than that observed in the Khlong near On Nut. Results of the observation are shown in Table 3.2-2. Sample collection points are shown in Fig. 3.2-4.

The ONEB of Ministry of Science, Technology and Energy has the classification of water by quality as shown in Table 3.2-1. The water of the Khlong near the planned site may fall into Class 4 or 5 judging from results of the analysis of organic matter contained in the water.

Table 3.2-1 Classification of Water by Quality

Classification	Objectives/Conditions & Beneficial Usages
Class 1	Extra clean fresh surface water resources used for: (1) conservation. Not necessary to pass through water treatment processes, require only ordinary processes for pathogenic destruction (2) ecosystem conservation which basic living organisms can breed naturally
Class 2	Very clean fresh surface water resources used for: (1) consumption which requires the ordinary water treatment process (2) aquatic organism conservation for living and assisting for fishery (3) fishery (4) recreation
Class 3	Medium clean fresh surface water resources used for: (1) consumption after an ordinary treatment process (2) agriculture
Class 4	Fairly clean fresh surface water resources used for: (1) consumption after special water treatment process (2) industry (3) other activities
Class 5	The resources which are not classified in class 1-4 and used for: (1) navigation

Source : Notification of the Ministry of Science,Technology and Energy, 1985

Table 3.2-2 Quality of Surface Water near the Planned On Nut Site

Item\ Station		O-1	O-2	O-3	O-4
pH	(-)	7.3	7.2	7.2	7.0
DO	(mg/l)	0.3	0.4	0.5	0.8
BOD	(mg/l)	5	13	9	7
COD	(mg/l)	23	25	25	16
SS	(mg/l)	10	14	17	22
T-N	(mg/l)	1.6	4.9	4.4	3.3
T-P	(mg/l)	0.39	0.55	0.25	0.29
HEM	(mg/l)	2.0	1.6	1.4	1.0
Number of Coliform Group	(MPN/1 ml)	1.7×10^3	$>2.4 \times 10^6$	1.7×10^6	2.2×10^2
Number of Fecal Coliform Group	(MPN/1 ml)	9.0×10^2	$>2.4 \times 10^6$	$<1.7 \times 10^6$	1.1×10^2
Cd	(μg/l)	0.1	0.1	0.3	0.1
CN	(mg/l)	<0.02	-	-	<0.02
Pb	(μg/l)	6	6	38	5
Cr	(μg/l)	2.7	3.3	11	3.7
As	(μg/l)	1.5	-	-	<0.1
Cu	(μg/l)	31	38	98	6
Zn	(μg/l)	120	200	210	70
Mn	(mg/l)	0.8	0.8	1.0	0.8
T-Hg	(μg/l)	<0.1	-	-	0.4
R-Hg	(μg/l)	<0.5	-	-	<0.5
Org-P	(μg/l)	<1.0	-	-	<10.1
PCB	(μg/l)	<0.05	-	-	<0.05

Sampling Date: September 21, 1990
HEM: Hexane Extraction Method

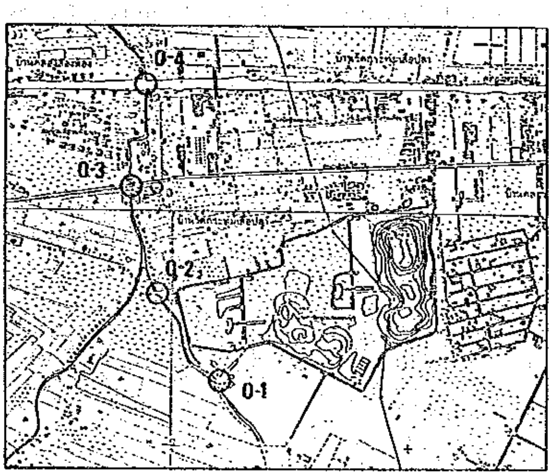


Fig. 3.2-4 Water Sample Collection Points

5) Ground Water (Refer to Page 13 of Part I)

6) Air Quality (Refer to Page 14 Part I)

3.2.2 Land Use and Transportation

1) Land Use

Land use of Phra Khanong district where the planned site is located, and of the whole Bangkok are shown in Table 3.2-3, and land use map of Phra Khanong district is shown in Fig. 3.2-5. Phra Khanong district has an area of approximately 140km^2. Major land use components are empty space (60%), residential area (12%) and agriculture area (12%).

Table 3.2-3 Land Use in Phra Khanong District

Area		Residential	Commercial	Industry	Ware House	Government Institute	Education Institute	Religion	Recreation
Phra Khanong District	area (km^2)	17.72	1.77	3.92	1.02	4.08	1.51	0.42	0.11
	%	12.34	1.23	2.73	0.71	2.84	1.05	0.29	0.08
Bangkok	area (km^2)	180.99	17.84	22.25	6.86	41.73	13.10	7.08	4.00
	%	11.54	1.14	1.42	0.44	2.66	0.83	0.45	0.25

Area		Public Utility	Road, Soil	Space	Agriculture	River Canal	Other	Total
Phra Khanong District	area (km^2)	0.20	3.89	85.10	17.21	2.30	4.31	143.56
	%	0.14	2.71	59.29	11.99	1.60	3.00	100.00
Bangkok	area (km^2)	4.29	38.45	623.87	543.13	54.36	10.80	1,568.75
	%	0.29	2.45	39.77	34.62	3.47	0.69	100.00

Source: BMA

2) Transportation

(1) Road

Sukhumvit Road 77 is the main access road to the planned site in On Nut. This road is a two-way road, with one lane for each way. See Fig. 3.2-6 for road network in the vicinity of the planned site.

(2) Traffic Noise

Traffic noise observed at the access road to the On Nut site and background noise observed around the site are shown in Tables 3.2-4 and 3.2-5

Table 3.2-4 Traffic Noise and Traffic Volume Observed at the Road Side of Sukhumvit Road Soi 77

STATION	RT-1	
TIME	14:28	13:39
L_{eq}	79.7	79.0
L_{50}	75	74
L_{max}	99	100
Traffic Volume Small Size	204	173
Large Size	44	44

Sampling Data: 27 September 1990
Time of Survey: 10 minutes

Table 3.2-5 Background Noise Level Observed at On-Nut

STATION	O-1	O-2
TIME	15:10	15:27
L_{eq}	55.4	60.9
L_{50}	55	54

Sampling Data: 27 September 1990

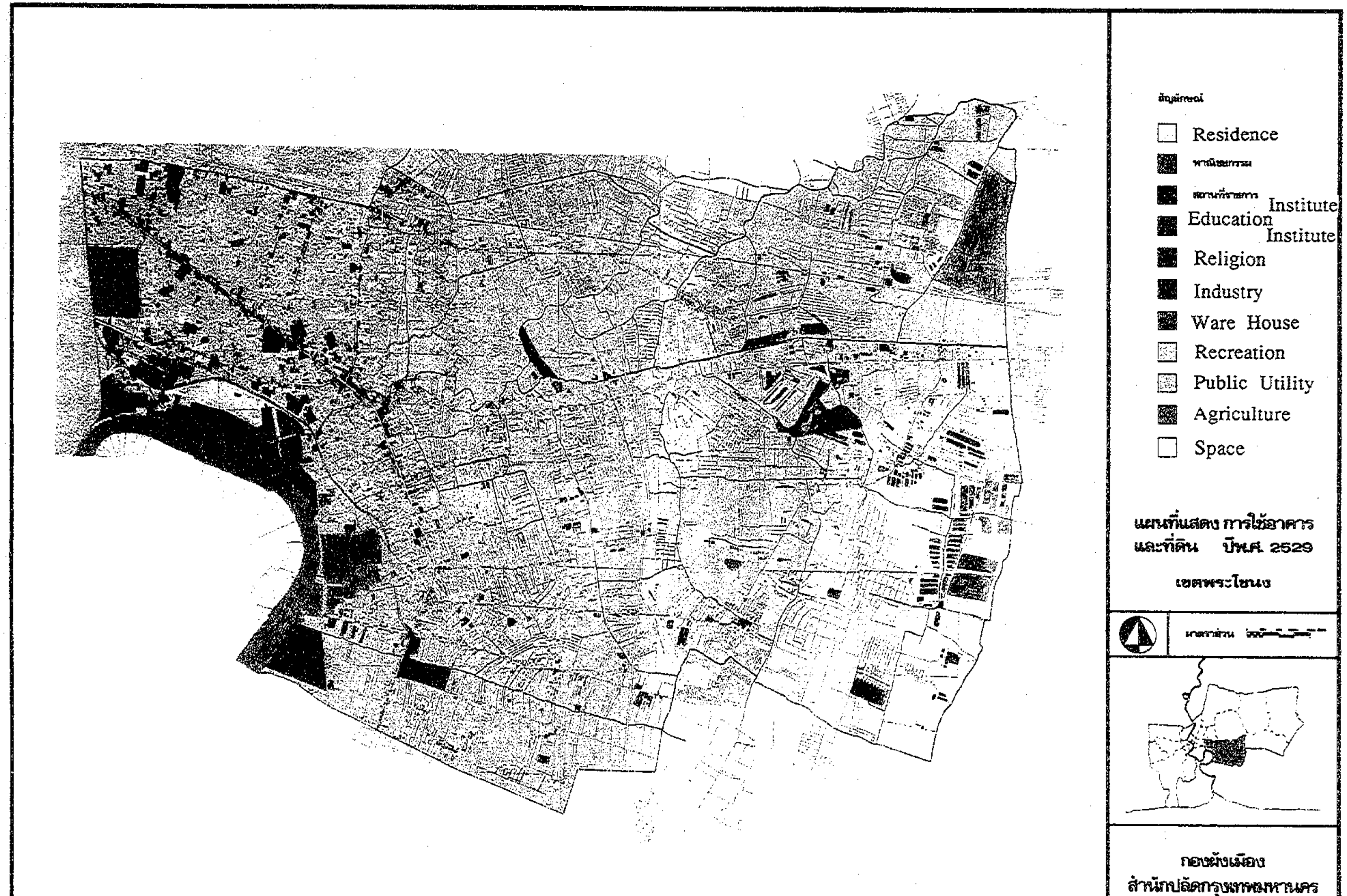


Fig 3.2-5 Land Use Map of Phra Khnong District

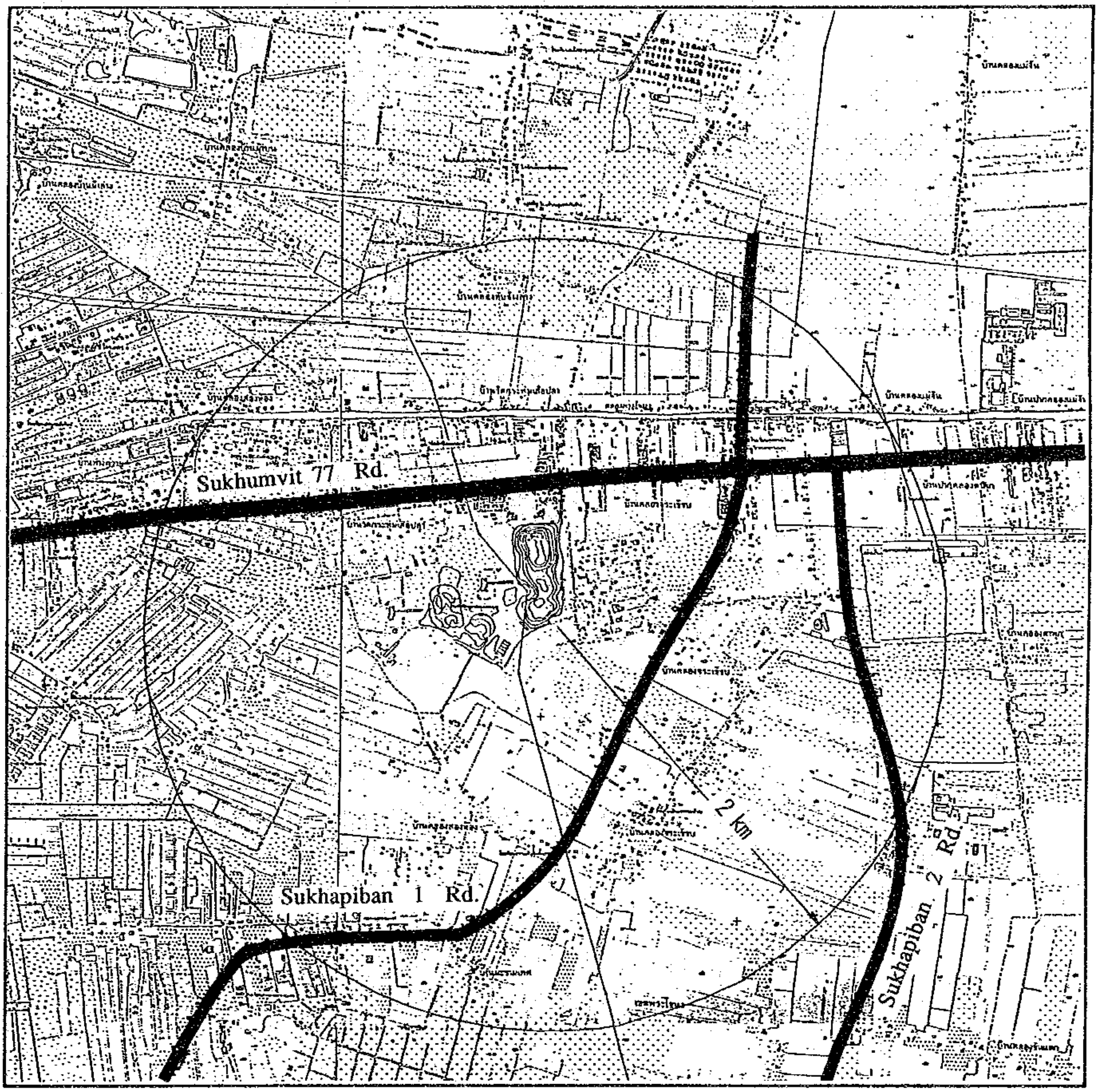


Fig. 3.2-6 Road Network at On Nut

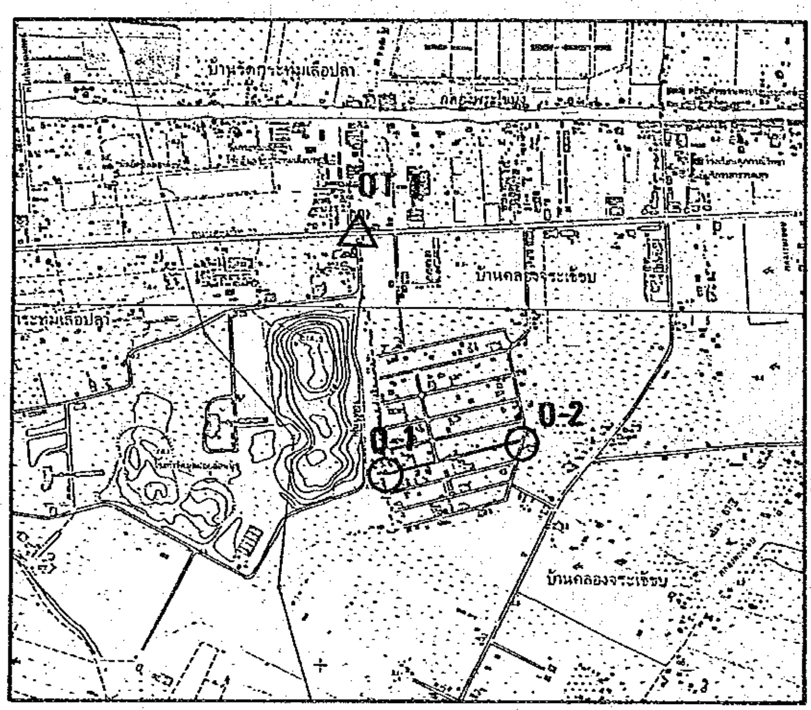


Fig. 3.2-7 Noise Level Observation Points around the On Nut Site

3) Recreation

There is no large scale recreation facility such as a park within a 2 km radius of the candidate site.

3.2.3 Social Culture Values

1) Cultural Facilities

Location of cultural facilities around the On Nut site is shown in Table 3.2-6 and Fig. 3.2-8. There are five schools and three temples in the area around the candidate site within 2 km radius.

Public Elementary School	C-1,2
Private Elementary School	C-3
High School	C-4
Religion School	C-5
Buddhist Temple	T-1,2
Indian Temple	T-3

Fig. 3.2-8 Location of Cultural Facilities

Table 3.2-6 Culture Facility

ITEM	NUMBER OF FACILITIES
Public Elementary School	2
Private Elementary School	1
High School	1
Religion School	1
Buddhist Temple	2
Indian Temple	1

2) Archaeology

There is no historical site within a 2 km radius of the On-Nut site.

Chapter 4. Major Specifications of the Incinerator

4.1 Definition of Garbage to be Incinerated

Fig. 4.1-2 shows the Low Heat Values (LHV) of waste estimated through the three different surveys. The estimated LHV values vary greatly: the lowest is 600 kcal/kg, and the highest is 1,400 kcal/kg. Further details are shown in Tables 4.1-1(1), 4.1-1(2) and 4.1-1(3).

The average LHV is estimated at 1,120 kcal/kg in 1990 with a technical adjustment though a simple average was around 1,000 kcal/kg. Based upon this estimation (average LHV = 1,120 kcal/kg), the future average LHV was projected as indicated by the broken line shown in Fig. 4.1-2.

It is considered that actual waste to be taken to an incinerator would contain a high water content than sampled waste. Therefore, further modifications were made to estimate a more realistic average LHV. The final-adjusted future LHV is estimated at 1,100 kcal/kg in 1996 (commencement year of operation of the planned incinerator), and 1,200 kcal/kg in 2010 as indicated by the lowest line in Fig. 4.1-2. The process of the adjustment is shown in the Technical Note.

It is determined that design LHV values for the incinerator is 750 kcal/kg to 1,500 kcal/kg based upon the policy for designing an economical and workable incineration.

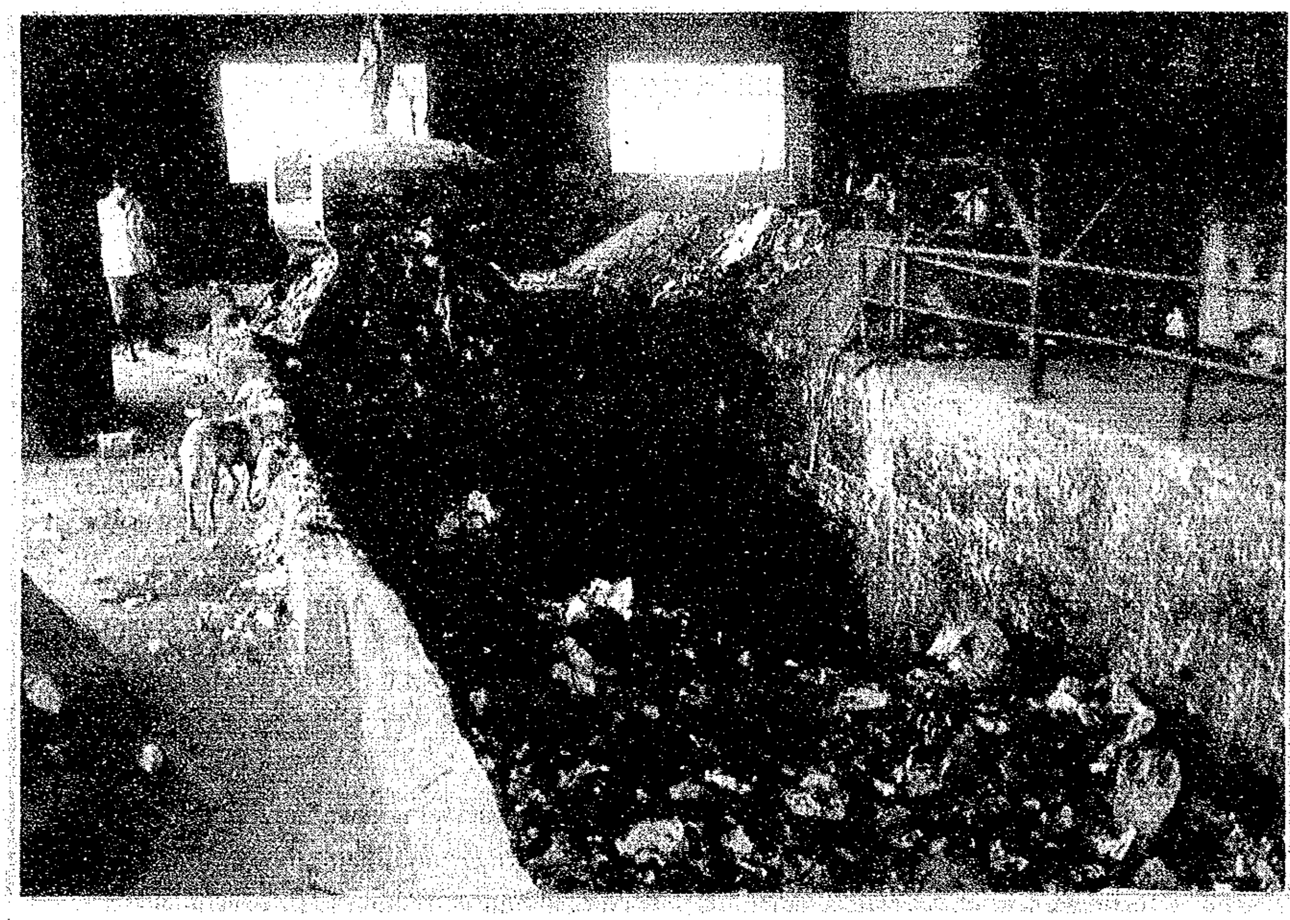


Fig. 4.1-1 Garbage Sampling for Analysis

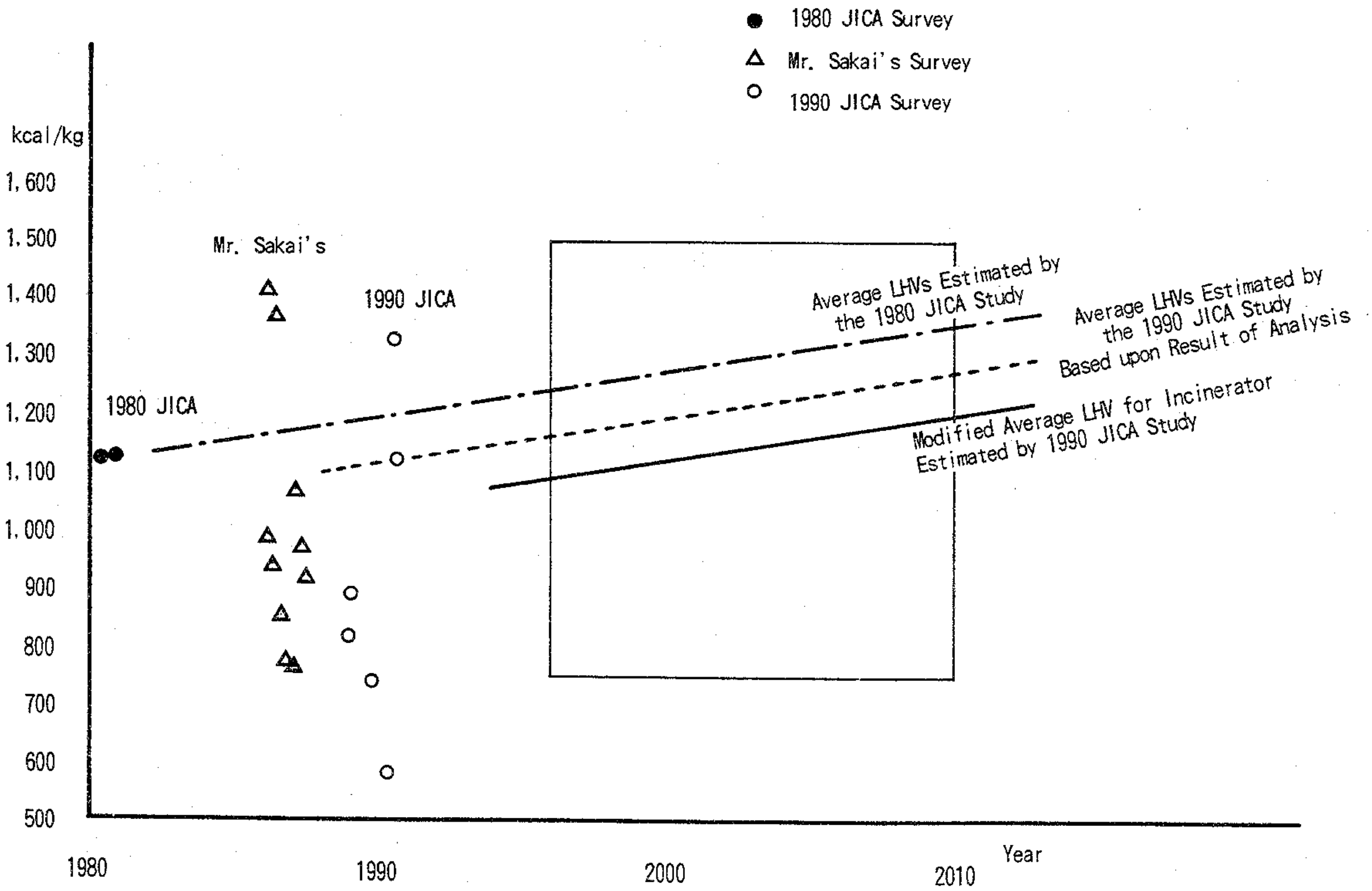


Fig. 4.1-2 Designed on Heat Value for the Incinerator

Table 4.1-1 (1) Composition of Solid Waste in 3 Element and Calorific Value

Sampling Date		Moisture %	Combustible %	Ash %	Total %	Estimated Calory kcal/kg
1) The Previous JICA Study						
Rainy Season	1980	57.5	27.8	14.7	100	1,133
Dry Season	1980	56.7	26.8	16.5	100	1,134
2) The Study by a JICA Expert						
May	1986	53.2	26.8	20.0	100	989
June	1986	47.4	36.5	16.1	100	1,420
July	1986	55.7	26.9	17.4	100	939
September	1986	60.5	23.7	15.8	100	776
October	1986	60.2	25.2	14.6	100	856
November	1986	46.0	34.0	20.0	100	1,377
December	1986	62.0	24.4	13.6	100	765
July	1987	57.4	29.2	13.4	100	1,073
August	1987	56.8	32.0	11.2	100	1,171
August	1987	58.9	27.7	13.4	100	970
October	1987	51.8	26.2	22.0	100	913
3) The Current JICA Study						
March	1989	62.7	24.6	12.7	100	816
July	1989	59.4	25.5	15.1	100	886
November	1989	60.2	22.4	17.4	100	738
May	1990	59.7	19.4	20.9	100	578
23 August	1990	55.4	35.0	9.6	100	1,331
80 August	1990	56.9	32.3	10.8	100	1,133

Table 4.1-1 (2) Chemical Composition of Solid Waste in Absolute Analysis

(Unit: % Volatile)

Sampling Date		C	H	O	N	S	Cl	Total
1) The Previous JICA Study								
Rainy Season	1980	54.96	8.23	34.38	1.40	0.25	0.79	100
Dry Season	1980	53.28	11.07	33.49	1.12	0.15	0.89	100
2) The Current JICA Study								
23 August	1990	51.88	7.56	38.02	1.82	0.02	0.70	100
30 August	1990	53.13	6.56	38.01	1.91	0.06	0.33	100

Table 4.1-1 (3) Physical Composition of Solid Waste (Unit: % Dry Base)

Sampling Date		Paper	Garbage	Cloth	Wood	Plastic	Rubber	Metal	Glass	Others	Total
1) The Study by a JICA Expert											
May	1986	19.8	24.3	3.1	3.2	14.0	4.1	2.2	15.4	13.9	100
June	1986	12.8	14.3	6.2	4.7	8.3	18.3	2.1	0.6	32.7	100
July	1986	9.2	-	7.1	22.7	7.9	0.0	5.1	7.6	54.6	100
September	1986	21.8	7.1	5.9	11.2	9.9	0.6	3.9	4.7	34.9	100
October	1986	11.9	5.1	6.5	17.1	13.8	0.9	1.3	6.3	37.1	100
November	1986	14.9	6.3	14.1	5.6	15.8	0.0	2.5	0.9	39.9	100
December	1986	18.5	8.2	4.4	10.0	6.9	0.2	3.4	8.4	40.0	100
July	1987	21.2	13.7	3.9	11.7	15.8	2.1	5.5	7.6	18.5	100
August	1987	21.6	9.6	6.2	21.7	11.7	3.3	4.0	1.1	20.8	100
August	1987	15.0	7.4	2.5	20.0	14.9	1.1	2.9	3.0	33.2	100
October	1987	13.8	3.8	7.6	10.0	5.4	2.0	2.9	3.3	51.2	100
2) The Study by the JICA Team											
March	1989	14.3	16.3	4.7	5.2	9.9	0.3	3.1	3.5	42.7	100
July	1989	15.7	9.0	5.3	18.3	10.7	0.4	3.3	3.3	34.0	100
November	1989	17.6	9.7	4.7	9.1	11.8	1.1	5.8	8.6	31.6	100
May	1990	15.7	13.9	4.4	2.9	9.1	0.2	3.1	9.9	40.8	100
23 August	1990	15.9	10.9	6.1	8.0	13.5	5.0	3.6	7.4	29.6	100
30 August	1990	17.0	16.3	3.1	3.9	10.1	0.2	5.7	5.6	38.1	100

Technical Note

Some water vaporized and spilled out of the sample waste in the process of sample taking and analysis. Therefore, some adjustments were made to estimate a more realistic water content and calory through the following assumptions and calculations:

$$\frac{A \times B/100 + C}{A + C} = \frac{60\text{ kg} \times 55.4/100 + 3\text{ kg}}{60\text{ kg} + 3\text{ kg}} = 57.5\%$$

where

A: Amount of waste sample taken to a dryer

B: Water content estimated

C: Estimated amount of water evaporated or spilled out in the process of sampling

(It is assumed that the amount of the water reduction is 5% of the amount of the sample water.)

The water content is estimated at 57.5% after the adjustment, a 2.1% increase over the original water content. It is estimated that this change will cause the LHV of waste to decrease by 80 - 90 kcal/kg.

Case 1

Modified Data by Water Content Aug. 23, 1990 (Unit: %)

Moisture wet%	Ash wet%	Combustible wet%	C'	H'	N'	Cl'	S'	O'	Total'
57.5	9.2	33.3	17.28	2.52	0.61	0.23	0.01	12.66	33.3
			C	H	N	Cl	S	O	Total
	Dry base Combustible		51.88	7.56	1.82	0.70	0.02	38.02	100

Ho = 8100 x C + 34000 {H-O/8} + 2500 x S

= 8100 x 0.5188 + 34000 {0.0756 - 0.3802/8} + 2500 x 0.0002

= 5,157 kcal/kg

LHV modified = Ho x Volatile - 6000 (9 x H' + Moisture)

= 5157 x 0.33 - 600 (9 x 0.0252 + 0.575) = 1,236 kcal/kg

Original Data 23 Aug., 1990

Moisture wet%	Ash wet%	Combustible wet%	C'	H'	N'	Cl'	S'	O'	Total'
55.4	9.6	35.0	17.28	2.68	0.64	0.25	0.01	13.31	35.0
			C	H	N	Cl	S	O	
	Dry Base Combustible		51.88	7.56	1.82	0.70	0.02	38.02	100

Ho = 5,162 kcal/kg

LHV original = 1,331 kcal/kg

LHV original - LHV modified = 1,331 - 1,236 = 95 kcal/kg

Case 2

Modification of water content 30 Aug, 1990

Moisture wet%	Ash wet%	Combustible wet%	C'	H'	N'	Cl'	S'	O'	Total'
59.0	10.3	30.7	16.31	2.01	0.59	0.10	0.02	11.67	30.7
			C	H	N	Cl	S	O	Total
	Dry Base Combustible		53.13	6.56	1.91	0.33	0.06	38.01	100

Ho = 4,920 kcal/kg

LHV modified = 1,048 kcal/kg

Original Data 30 Aug., 1990

Moisture wt%	Ash wt%	Combustible wet%	C'	H'	N'	Cl'	S'	O'	Total'
56.9	10.8	32.3	17.16	2.12	0.62	0.11	0.02	12.28	32.3
			C	H	N	Cl	S	O	Total
	Dry Base Combustible		53.13	6.56	1.91	0.33	0.06	38.01	100

Ho = 4,920

LHV original = 1,133

LHV original - LHV modified = 1,133 - 1,048 = 85 kcal/kg

4.2 Heat Recovery System

There are three typical heat recovery systems as shown in Table 4.2-1.

Table 4.2-1 Typical Heat Recovery Systems

No.	FACILITY REQUIRED	PURPOSE
1	Hot Water Boiler	Hot water use for shower, both, etc.
2	Steam Boiler	Steam generation for vehicle washing
3	High Pressure Steam Boiler + Turbine + Electric generator	Power generation

It is judged that the hot water use with hot water boiler (Item 1 in the above table) is the most appropriate system for the planned incineration plant considering 1) the low calory of waste in Bangkok, and 2) cost-effectiveness.

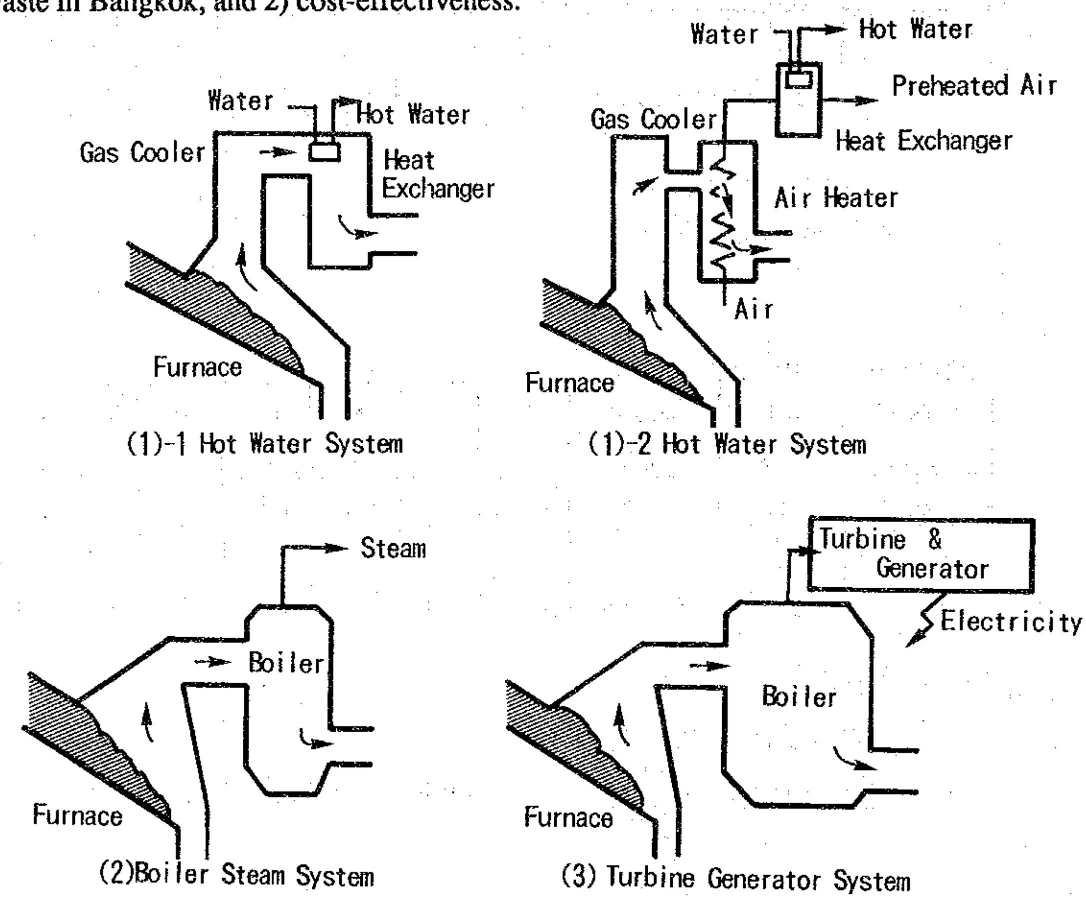


Fig. 4.2-1 Heat Recovery System

Assuming that the total generated heat is 2.5 x 10^7 kcal/h, it is estimated that the net amount of heat to be recovered for the purpose other than operating the plant itself is estimated at 0.12 x 10^7 kcal/h, less than 5% of the total generated heat. More than 95% of the heat generated is lost or used for drying garbages. With the net heat recovery of 0.12 x 10^7 kcal/h, the hot water generation with the boiler is the only heat recovery system applicable to the planned incinerator as shown in Table 4.2-2.

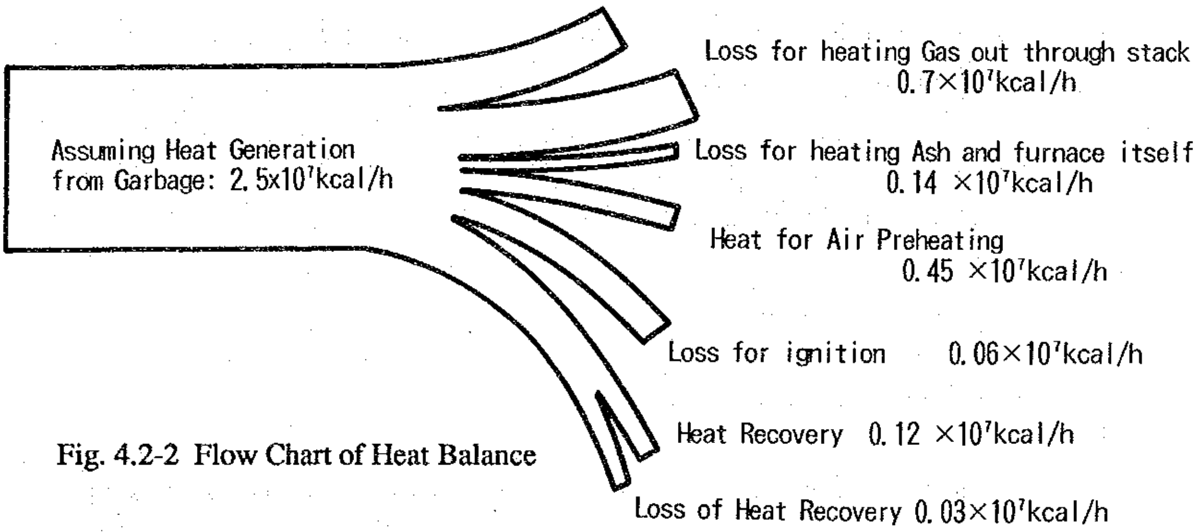


Fig. 4.2-2 Flow Chart of Heat Balance

Table 4.2-2 Heat Use and Its Heat Requirement

Heat Use	Heat required x 107 kcal/h	Note
Turbine - Generator		Contain loss of steam to the air from the system
200 kw	2	
500 kw	4	
1000 kw	8	
1500 kw	12	
Turbine		Contain loss of steam to the air from the system
Fan Drive 200 kw	1	
Fan Drive 500 kw	2	
Steam washing for vehicles	0.6	100 vehicle 60,000 kcal/vehicle
Hot water shower	0.1	5 m^3/h 10°C --> 60°C
Pool	0.5	25m x 10m x 2m 24°C
Skate link	2.2	1200m^2

Reasons for Not Recommending Steam Generation with Steam Boiler

1) Calory of waste in Bangkok is too low to constantly generate steam of constant pressure.
2) It is not economical because the system requires a large sized boiler and auxiliary equipment for steam use.

Reasons for Not Recommending Boiler-Turbine-Generator System

1) Calory of waste in Bangkok is too low to generate sufficient high pressure steam required for power generation.

2) Variation of calory of waste in Bangkok is too great to maintain steam pressure at a constant level as required for power generation.

3) It is not economical because:

a. This system itself is very costly

b. Operation/maintenance of this system requires a very high level of technology

c. This system will not be workable at all during the first several years after the commencement of the operation because of the low calory waste in Bangkok.

4.3 Reception Pit, Furnace and Air-preheater

Reception pit, furnace and air-preheater should be designed considering the fact that the calory content of waste in Bangkok is low.

1) Reception Pit

A reception pit should be large enough to store incoming waste for 3 consecutive days so that waste can be dried by using the heat generated through the waste decomposition process. (It would be necessary to allow for about 3 days for adequate drying of waste.) Mixing of waste is also important to make waste even in terms of calories. (For enabling self-combustion, calory of waste should be increased over 900 kcal/kg.)

2) Furnace

For effective combustion, there are three(3) important points in design a furnace:

(1) The gas-outlet should be planned in a head position to make combustion gas contact waste for long time.(The longer the contact time, the more heat can be given to waste, which is helpful for drying waste.)

(2) The ceiling of the furnace should be low to utilize a heat reflection, which is helpful for drying waste.

(3) The bed of the furnace should be long to make longer the drying area where turn-over equipment is provided.

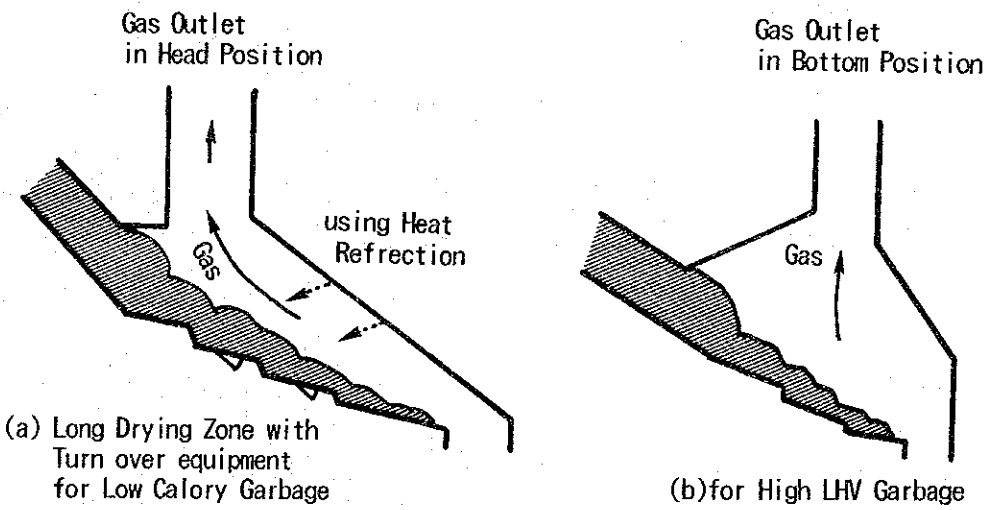


Fig. 4.3-1 Structures of the Furnaces for Low & High calory Garbage

3) Air-preheater

Air-preheater should have a large capacity to supply adequate amount of hot air for waste drying, and for maintaining a stable combustion.

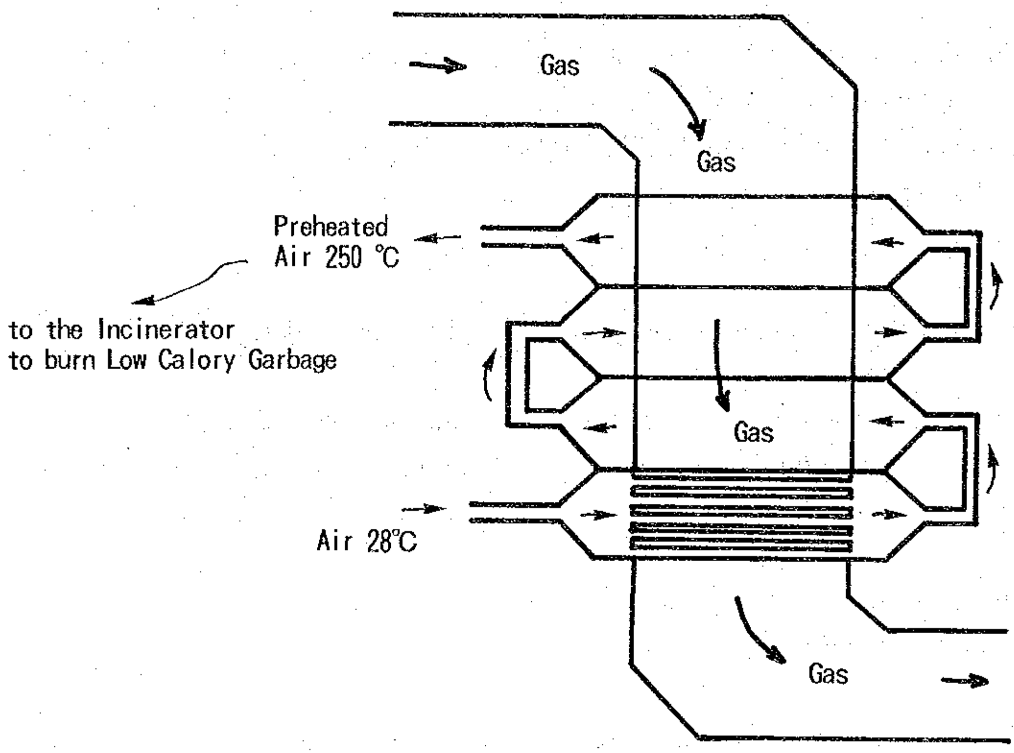


Fig. 4.3-2 Structure of Air-preheater

The above-explained facilities have been used by many local authorities in Japan, and proved to be reliable, economical and easy to operate.

4.4 Gas Cooling System

4.4.1 Introduction

A gas cooling system is required to lower the gas temperature, and avoid corrosion of incineration equipment. Combustion gas temperature is 500°C - 1,000°C at an outlet of the furnace. The temperature must be lowered to 250°C - 300°C. Fig. 4.4-1 shows the relationship between the gas temperature and corrosion.

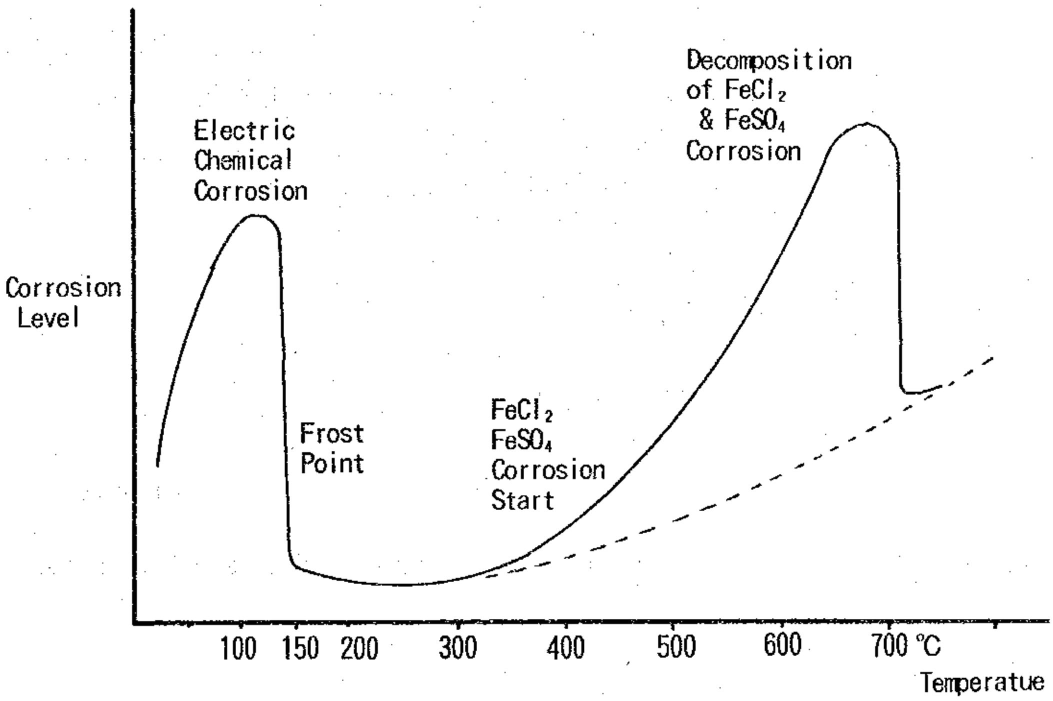


Fig. 4.4-1 Relationship Between Gas Temperature and Corrosion

4.4.2 Selection of Water Injection System

There are two types of gas cooling systems for incinerators:

(1) Water injection system
(2) High pressure steam boiler system

A water injection system is recommendable for the planned incinerator judging from the caloric content of waste in Bangkok and cost-effectiveness.

A high pressure boiler system aims at both heat recovery and gas cooling. However, heat recovery from the incineration of waste of Bangkok is not feasible as the caloric content of the waste is too low. Moreover, the boiler system is much more costly than the water injection system. Therefore, the boiler system is not feasible for the planned incinerator.

Fig. 4.4-2 shows the relationship between the waste calory (low heat value) and suitable gas cooling system.

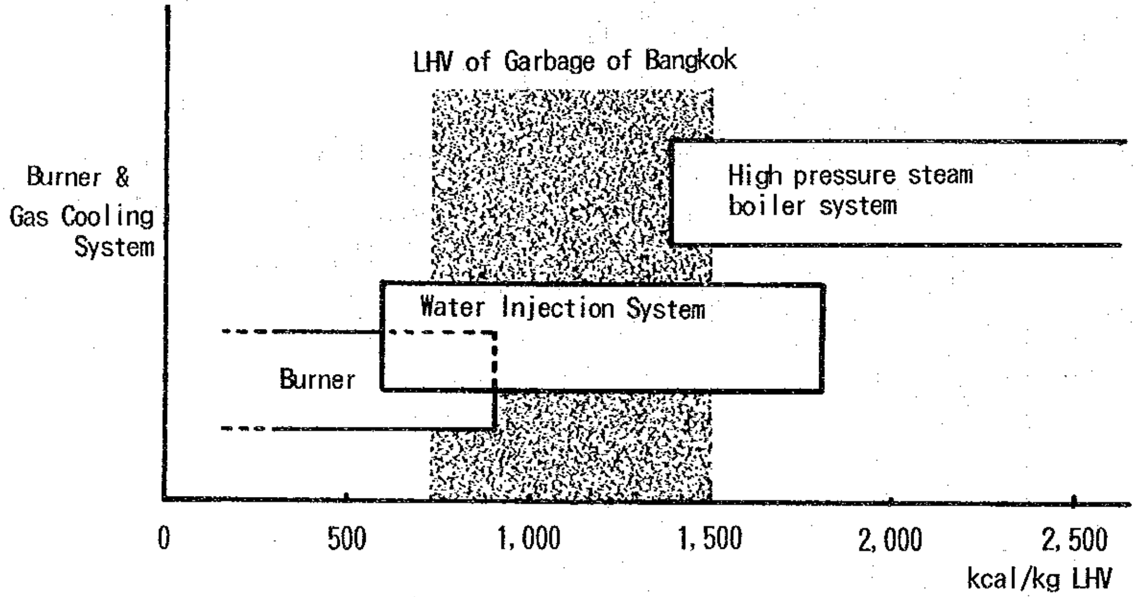


Fig. 4.4-2 Relationship between Waste Calory (Low Heat Values) and Appropriate Gas Cooling System

Technical Note on Water Injection System

The system uses the vaporization of water for cooling the gas. 400 kcal/kg of heat can be taken out at the time of conversion of water into vapor. Construction of this system is simple and easy. Examples of the system are shown in Fig. 4.4-3. Fig. 4.4-4 shows an entire incinerator system with the water injection system.

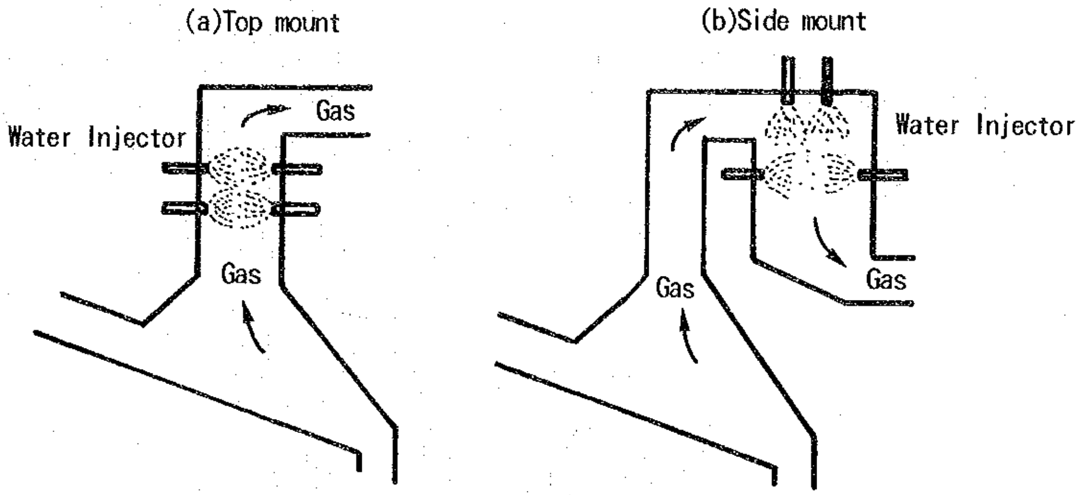


Fig. 4.4-3 Water Injection System

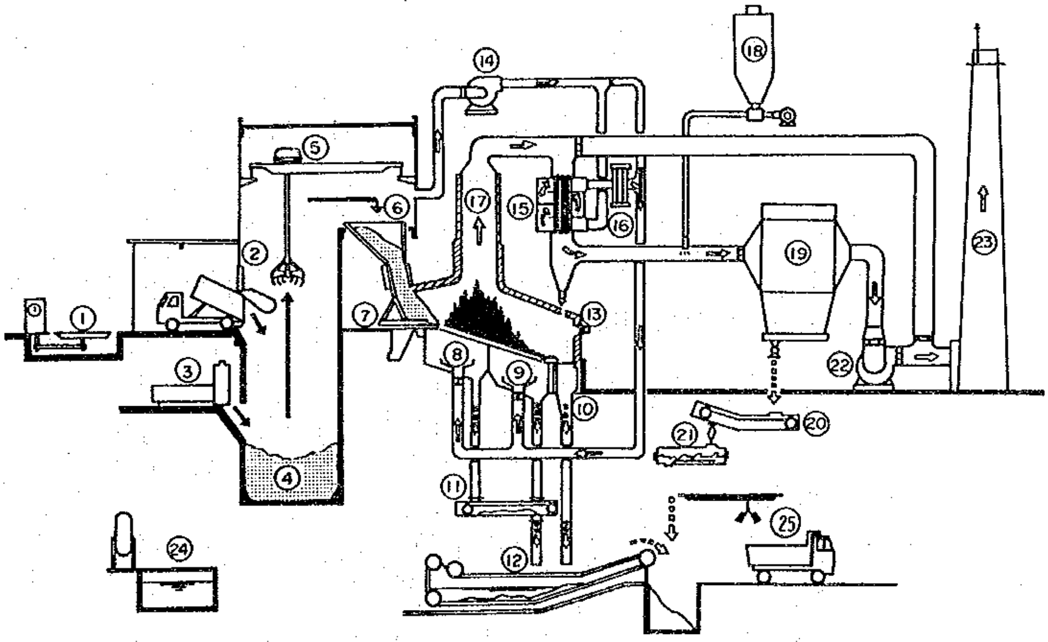


Fig. 4.4-4 Incinerator with Water Injection System

Technical Note on Boiler System

A typical boiler system is shown in Fig. 4.4-5. The boiler system is at least 1.3 times more costly than the water injection system, and is economically feasible only for waste with high calory. Power generation using steam generated with a boiler is not feasible in Bangkok because the power generation requires a higher calory waste for stable and constant generation of steam.

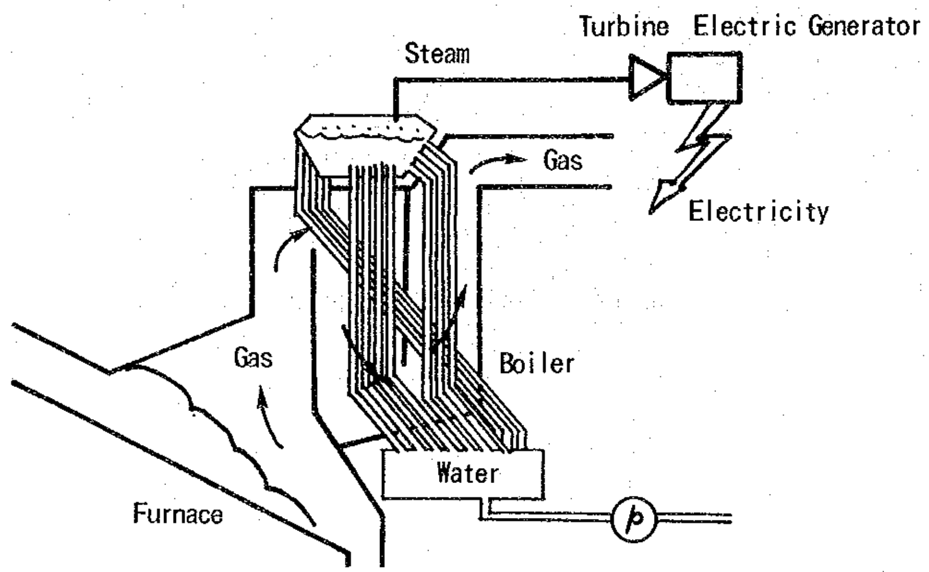


Fig. 4.4-5 Boiler System

Fig. 4.4-6 below shows the example of boiler system, (11) is boiler.

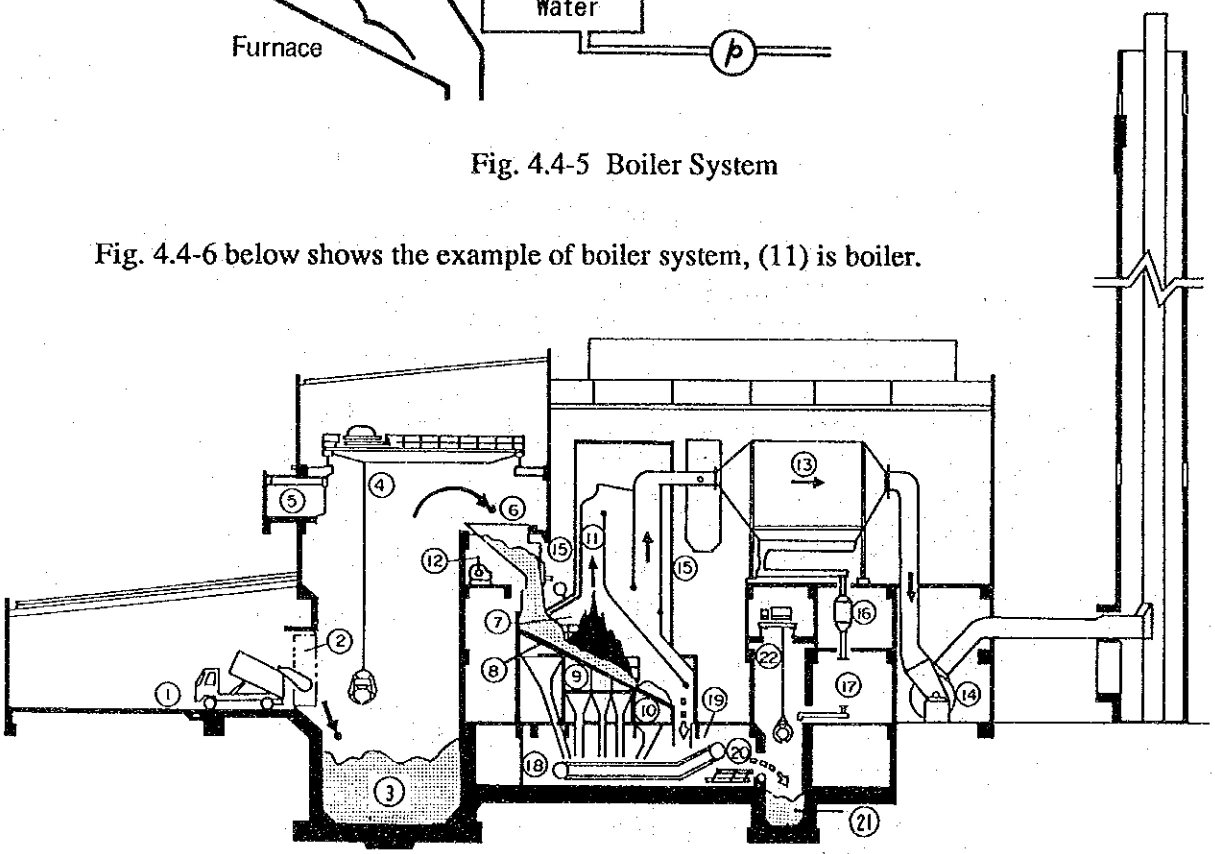


Fig. 4.4-6 Incineration Plant with Boiler System

4.5 Air Pollution Control System

Air pollution control systems are required to remove pollution such as HCl and particles contained in the combustion gas.

Amounts of respective pollutants contained in the gas were estimated as shown in Table 4.5-1, based upon the chemical composition analysis made on 30 August 1990.

The table below shows that the estimated amounts of HCl and particulate matter exceed the Emission Standards proposed by Ministry of Industry. Therefore, some air pollution control systems are required.

Table 4.5-1 Chemical Analysis and Gas Balance

CHEMICALS	%	ESTIMATED GAS BALANCE		PROPOSED INDUSTRIAL EMISSION STANDARDS	
C	53.13	CO_2	8.7%		-
H	6.56	H_2O	25.7%		-
O	38.01	O_2	6.7%		-
N	1.91	N_2	59.0%		
		NOx	100 mg/m^{3}N	NOx	1000 mg/m^{3}N
S	0.06	SO_2	31.1 ppm	SOx	400 ppm
Cl	0.33	HCl	251 mg/m^{3}N	HCl	200 mg/m^{3}N
Total	100		100%		-
Particles			10 g/m^{3}N		0.5 g/m^{3}N

Note 1. NOx is caused by high temperature combustion.
2. Air ratio is assumed at 1.7 in calculation.
3. SOx, HCl values are converted by using 12% O_2 gas base.
4. Gas emission volume is 30,802 m^{3}N/h furnace.

Removal of Particle

There are the following three major systems for removal of particles.

1. Electrostatic precipitator
2. Multi-cyclone
3. Bagfilter system (not widely used)

The electrostatic precipitator is recommended for the planned incinerator because it is capable of removing smaller particles much more effectively than the Multi-cyclone system. Multi-cyclone system is almost useless for removing particles smaller than 1 micron.

Removal of HCl

There are following two methods for removal of HCl.

1. Dry $Ca(OH)_2$ powder spray before EP
2. Spray of semi-wet $Ca(OH)_2$ before EP

$Ca(OH)_2$ dry powder method is recommended for the planned incinerator in view of easy construction, operation and maintenance of the spray unit. Although the spray of $Ca(OH)_2$ semi-dry method is more effective in removing HCl, it causes maintenance problems such as choking and chipping of nozzle, and damages the spray conveyance pipes.

Technical note on Removal of Particles

A typical electrostatic precipitator and a multi-cyclone are shown in Fig. 4.5-1. Fig. 4.5-2 shows HCl removal performance of electrostatic precipitation and multi-cyclone respectively. A broken line in the figure shows a distribution of particles by size (in terms of a curve of accumulated percentages).

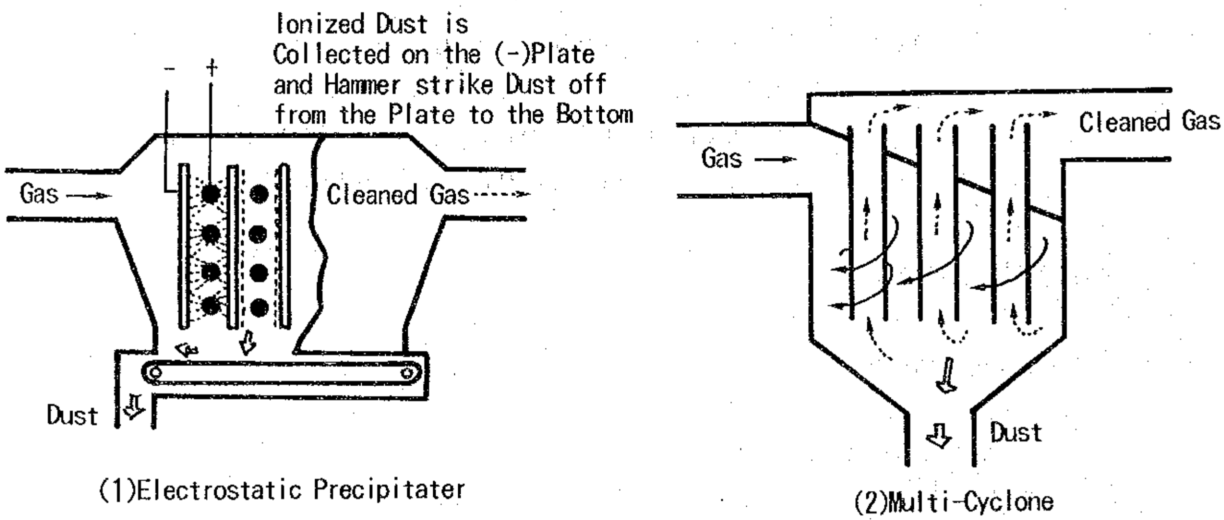


Fig. 4.5-1 Typical Structure of Electrostatic Precipitator and Multi-Cyclone System

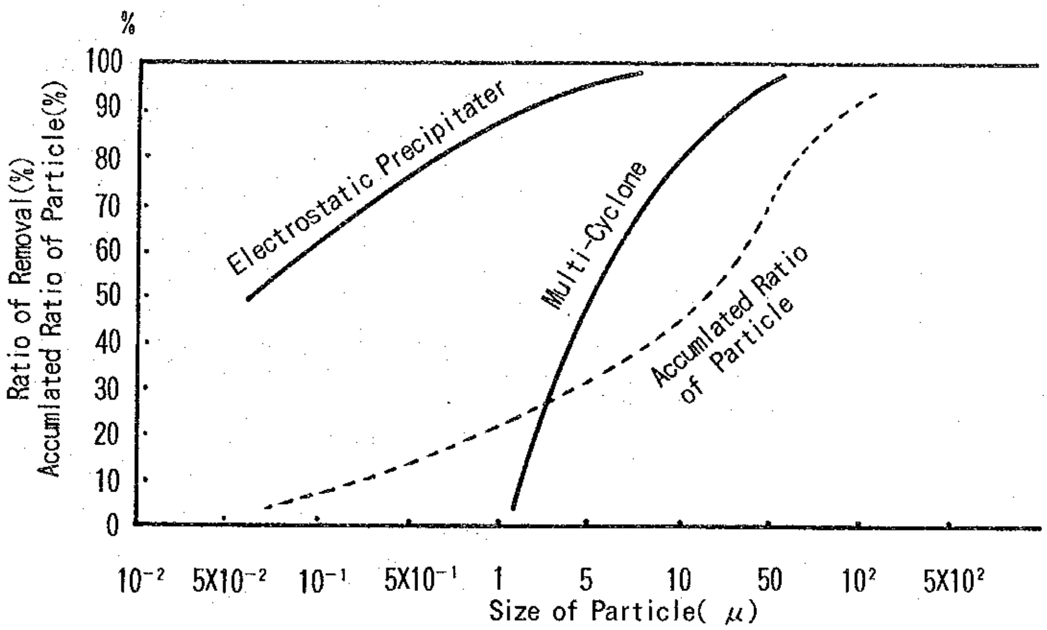


Fig. 4.5-2 Removal Efficiency by 2 Types

Technical Note on Dry $Ca(OH)_2$ Powder Method

It is estimated that the combustion gas generated in the incinerator will contain 660 mg/Nm^3 of HCl on average of the maximums. On the other hand, the Proposed Industrial Emission Standards require that HCl should be reduced to 200 mg/Nm^3 or less. It is therefore necessary for the planned incinerator to have a HCl removal which is capable of reducing HCl by 70% or more in order to meet the proposal Standards.

Fig. 4.5-3 tells that the use of 2 mol of dry $Ca(OH)_2$ powder spray (per 1 mol of HCl) is enough to reduce HCl by more than 70%. The chemical process of HCl removal is: $2HCl + Ca(OH)_2$ --- $CaCl_2 + 2H_2O$. Particles of $CaCl_2$ will be removed by an electrostatic precipitator.

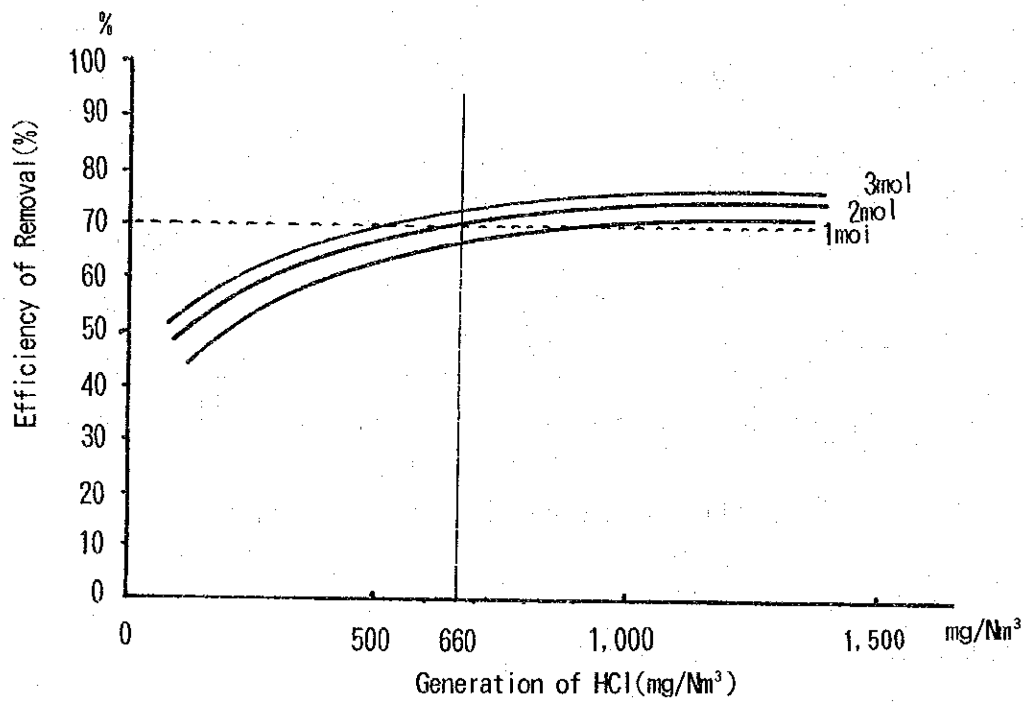


Fig. 4.5-3 HCl Removal Efficiency by Amounts of the Use of $Ca(OH)_2$ Dry

4.6 Incineration Control System

The planned incineration plant will not be equipped with highly advanced automation operation control systems in view of that (1) the planned incinerator is the first one of this scale in Bangkok, and (2) those advanced systems may cause serious problems if they were not handled by very experienced and skillful operators.

The planned incinerator will be provided with the following automatic control systems:

1. Semi-automatic crane control
2. Automatic control of gas temperature
3. Automatic control of air pressure in the furnace
4. Automatic water treatment system

<u>1) Semi-Automatic Crane Control</u>

A certain set of movements of a crane is programmed. With pressing a button "AUTO," the crane will move to a hopper, release waste into the hopper, and return to a programmed place.

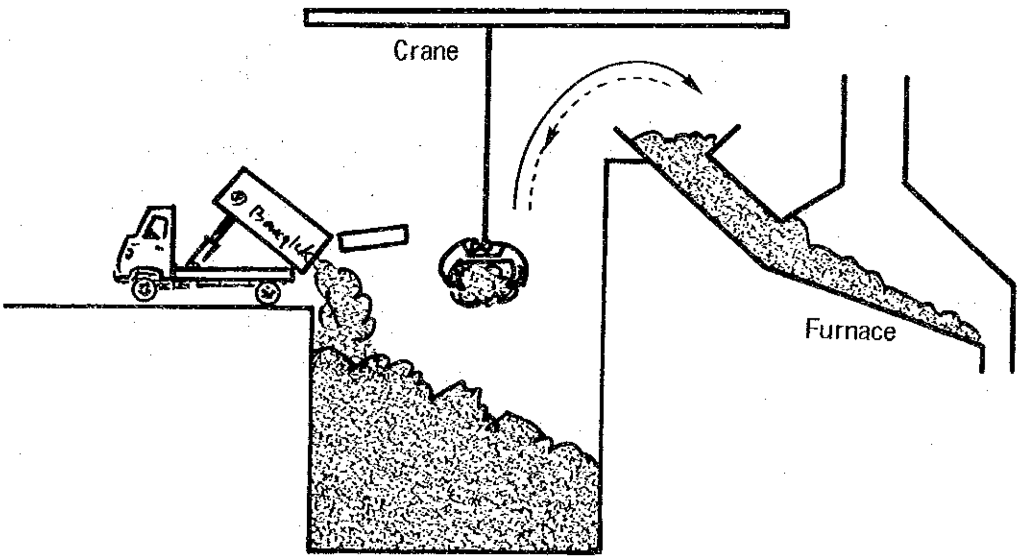


Fig. 4.6-1 Semi-Automatic Crane Control

2) Automatic Control of Gas Temperature at the Outlet of Gas Cooler

If the temperatures of gas increase, water valves will be automatically opened and the water injection amount will increase. Then temperature of gas will decrease to an appropriate level.

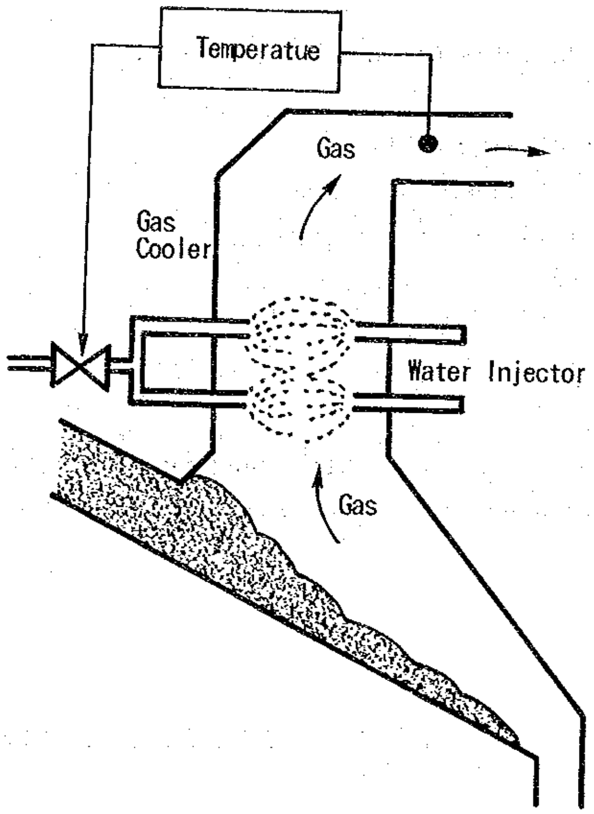


Fig. 4.6-2 Gas Temperature Control Diagram

3) Automatic Control of Air Pressure in the Furnace

Air pressure inside the furnace will be automatically kept at a constant level (lower than ambient air pressure) for effective combination.

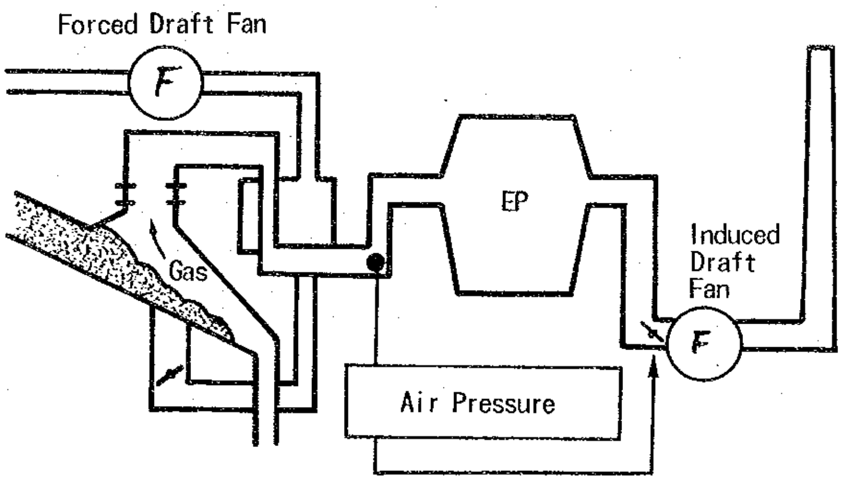


Fig. 4.6-3 Air Pressure Control Diagram

4) Automatic Water Treatment System

This system controls water treatment process automatically. The system will give warning signals when there are something wrong with the treatment facilities.

Chapter 5. Scale of the Incinerator

This chapter explains why an incinerator with the capacity of 600 tons/day (200 tons/day/unit x 3 units) was proposed.

Reasons for Proposing an Incinerator with 600 tons/day Capacity

1. An incinerator with the capacity of over 600 tons/day is not feasible in view of:

   a. The planned site of 10.6 rai is too small considering requirements for size of auxiliary facilities such as the waste reception pit.

   b. Required investment is very large relative to the BMA's budget.

2. An incinerator with the capacity of less than 600 tons/day is not adequate since:

   a. Future increases in disposal are estimated at 8,700 tons/day in 2000

   b. Future needs for training the BMA personnel for operation of large incinerators which may be increasingly necessary in the future.

Reasons for Proposing a Furnace of 200 tons/day/unit

Given the total capacity being 600 tons/day, and calorific values of waste of Bangkok, 3 units of 200 tons/day/unit is judged the most suitable because:

1. A gas cooling system should be of a water injection type judging from the quality (calory) of waste in Bangkok.

2. Given that a water injection system is applied, the maxim capacity of a furnace is 200 tons/day/unit. As shown in Fig. 5-1, if a furnace is bigger than 200 tons/day/unit, it does not function properly because injected water cannot reach the center of gas cooler vessel.

3. A unit capacity can be larger than 200 ton/day if a boiler system is applied as a gas cooling system. The installation of a boiler system is economically feasible only if used for power generation. This however is not feasible in Bangkok

due to the low calory waste. (Refer to Fig. 5-2 for the costs of incinerator with water injection system and those with boiler-turbine-generator system.)

Thus, it is concluded that an incinerator with a capacity of 600 tons/day (200 tons/day/unit x 3 units) with a water injection system is the most suitable from both technical and economical viewpoints.

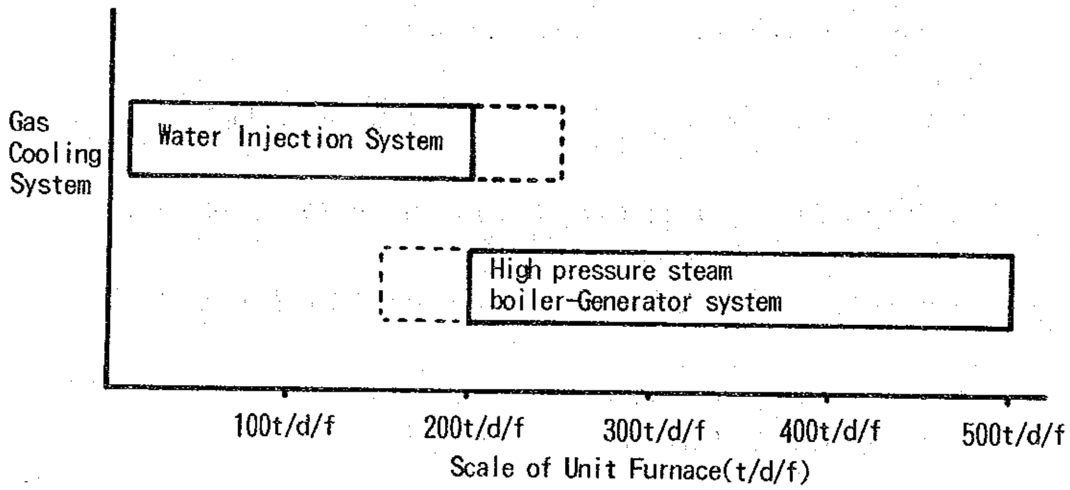


Fig. 5.1 Appropriate Gas Cooling System by Size of Furnace

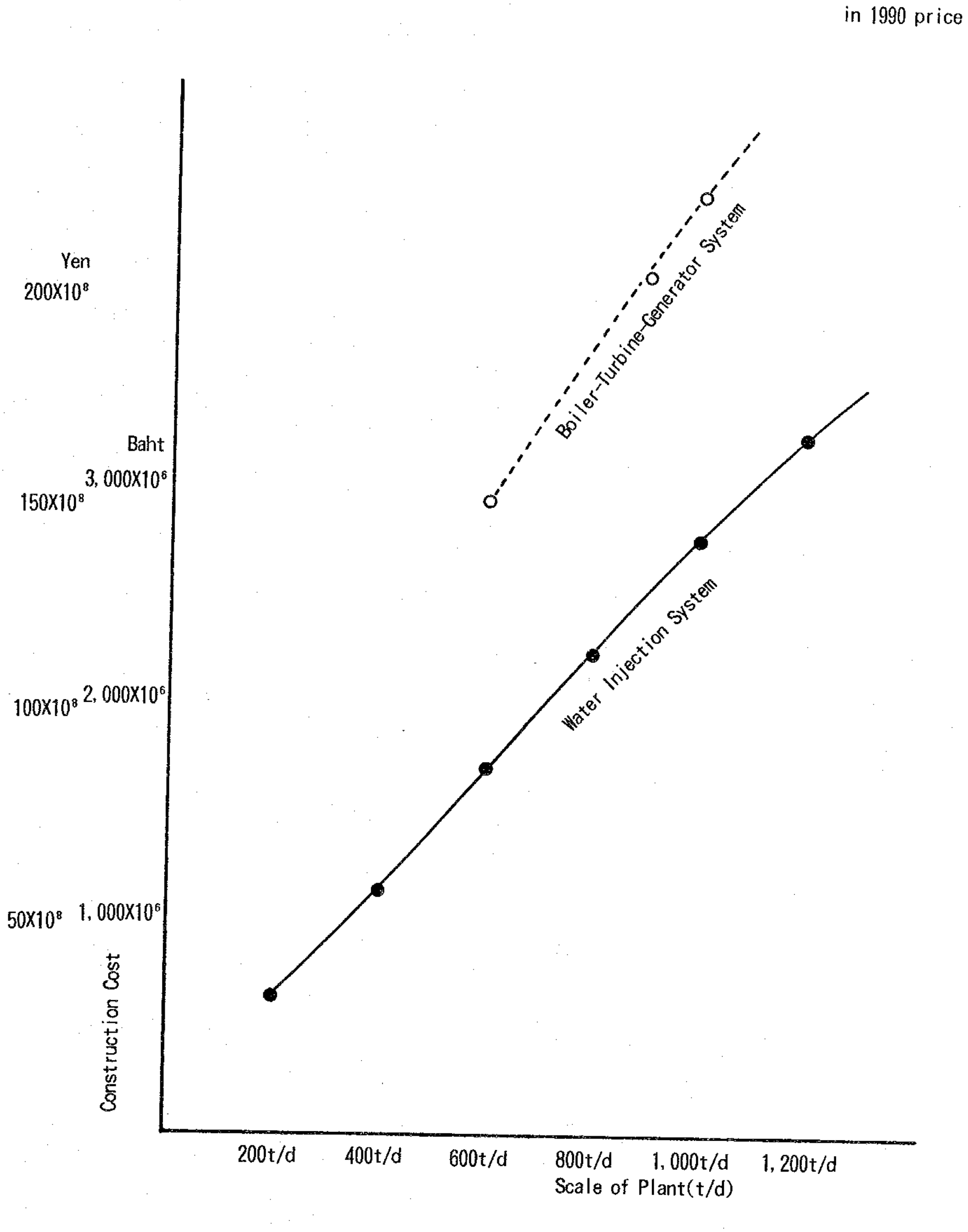


Fig.5-2 Price of Incinerators by Capacity

Chapter 6. Layout of the Incineration Plant

A layout plan has been planned considering traffic safety, operational efficiency and convenience, and shape and area of the site. In particular, due consideration was given to the following points:

1. An administration office shall be provided in the same building as the one in which the incinerator is installed.

2. All on-site roads shall be of one way traffic without sharp turning points in order to avoid vehicle accidents.

3. Sufficient space shall be provided between the gate and weigh bridge so that collection vehicles can stop and wait for their turn for measurement inside the site when necessary.

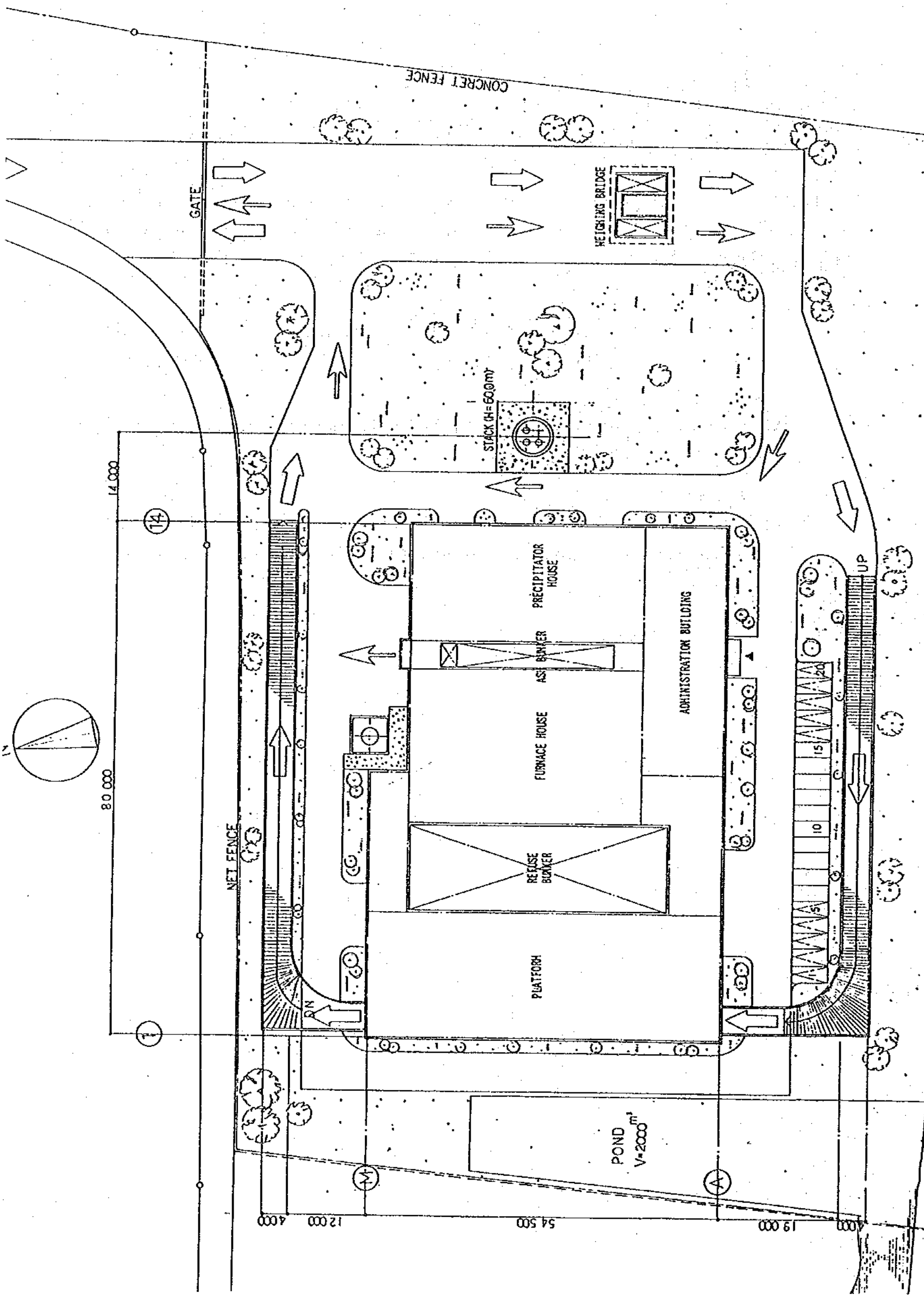


Fig. 6-1 Layout Plan for the Planned Incineration Plant

Chapter 7. Operation and Maintenance

7.1 Manpower Required

It is estimated that a total of 85 persons will be required for the operation and maintenance of the planned incineration plant.

Table 7.1-1 Estimated Manpower Required for the Operation/Maintenance of the Planned Incineration Plant

PERSONNEL	MANPOWER REQUIRED
Plant Manager	1 (1)
Engineers	
- Mechanical	2 (1)
- Electrical	2 (1)
Equipment Controller	2 (1)
Operator	
- Crane	12 (8)
- Incinerator	12 (8)
- Weight Bridge	8 (4)
Maintenance Crew	24 (8)
Cleansing Men	6 (4)
Guardmen	12 (8)
Clerk Chief	1 (1)
Assistant	3 (1)
Total	85 (46)

Note: Figures in parenthesis indicate number of persons required for the operation/maintenance of the incinerator with capacity of 200 tons/day during 1996 - 1999.

7.2 Training Plan

It is advisable that the BMA should send operation and maintenance crew to oversea's facilities for on-the-job training for 6 - 8 months before the commencement of operation of the first furnace.

An additional crew will be required for the operation of the second and third furnaces. They can be trained through the on-the-job training at the first plant.

Table 7.2-1 shows personnel to be trained and the training duration.

Table 7.2-1 Personnel to be Trained and Training Duration

PERSONNEL	OVERSEAS TRAINING DURATION FOR THE FIRST FURNACE	TRAINING DURATION FOR THE 2ND & 3RD FURNACES
Equipment Controllers	6 - 10 months	4 months
Operators	6 - 10 months	4 months
- Crane	6 - 10 months	4 months
- Incinerator	6 - 10 months	4 months
- Weight Bridge	6 months	4 months
Maintenance Crew	8 months	4 months

7.3 Special Instructions for the Plant Operation

Success of the plant operation much depends on the skill, experience, and care of the operators. It is possible that the plant life would be shortened and incineration performance drop drastically due to the inappropriate operation of the facilities.

The following points are particularly important in the day-to-day operation of the plant:

1. Waste Mixing by Crane Operators

   a. Mixing of wet low calory waste with high calory waste is a must for the successful combustion.
   b. Incoming waste must to be kept in the pit for more than 24 hours before incineration.
   c. When a crane operator puts waste of abnormally high or low calory into furnace, he must inform the furnace operator so that the furnace operator can take necessary measures.

2. Combustion Control by Furnace Operators

   a. When waste with large calory variations were put into furnace, a furnace operator must make very careful operational adjustments of such factors as incineration speed, amount of preheated air to be sent to the furnace, and temperature and pressure inside the furnace.

b. Furnace operators must always know the on-going combustion conditions by using monitoring televisions.

3. Coping with Abnormal Conditions

a. Operation and maintenance crews must quickly and carefully cope with abnormal conditions such as the case when smooth flow of preheated air or incineration ash is disturbed.
b. Failures in the coping with abnormal conditions will result in the damage of equipment and the shortening of plant life.

7.4 Maintenance

Smooth plant operation requires regular maintenance. Some equipment needs daily check, while some other equipment needs periodic check. Required maintenance and its frequency are shown in Table 7.4-1.

Table 7.4-1 Required Maintenance

CHECK ITEMS	RESPONSIBLE PERSONS	FREQUENCY
Daily Check	Operators and maintenance crew	Everyday (at a fixed time of the day)
Periodical Check		
- Water injection nozzle	Maintenance crew	More than once a month
- Fan	Maintenance crew	More than 3 times a month
- Air preheater	Maintenance crew	More than once a month
- Gas cooler	Maintenance crew	More than once a month
- Hopper under stoker	Maintenance crew	More than 3 times a month
- Inside the furnace	Maintenance crew	More than 3 times a year
- Electrostatic precipitator	Maintenance crew	More than 2 times a year
- Others	Maintenance crew	To be decided by equipment
Check of Abnormal Conditions Eg. Abnormality in Pressure inside the Furnace and IDF dumper position	Operators and maintenance crew	All the time
Overhaul	Maintenance crew and suppliers	Once a year
Calibration of instruments	Suppliers	Once a year at least

Chapter 8. Construction Schedule

The planned incineration plant will be constructed in two phases: the first phase during 1993 - 1995 and the second phase during 1998 - 2000 as shown in Fig. 8-1. Although a single phased construction requires a less investment cost than the two phased construction, the latter is recommended from the following reasons.

1. To avoid the concentration of large expenditures in a short period

2. To allow a time for training of plant operators. (The first furnace can be operated by fewer number of operators. During the operation period of the first furnace, additional operators and maintenance crew can be trained for the operation of the second and third furnaces.)

3. It is possible to improve design of the second and third furnaces by modifying any deficient or inconvenient parts of the incinerator which might be found during the operation of the first furnace.

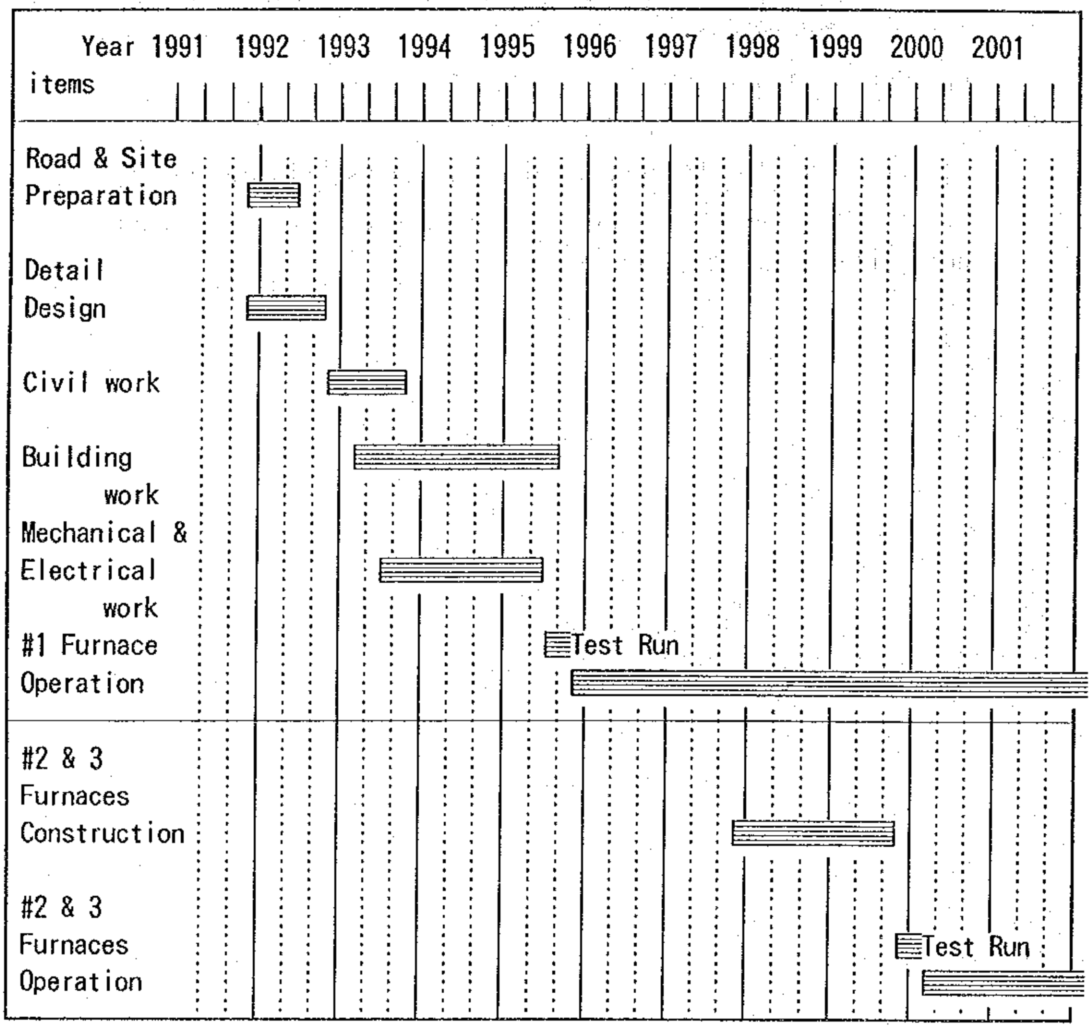


Fig. 8-1 Construction Schedule for the Planned Incineration Plant

Chapter 9. Construction and Operation Costs

9.1 Total Project Cost

It is estimated that a total cost required for construction and operation/maintenance during the Master Plan period till 2000 will be 2,061 million Baht, of which the construction will require a total of 1,842 million Baht and the remaining 219 million Baht for the operation/maintenance which will start in 1996 with the capacity of 200 tons/day. Table 9.1-1 summarizes the estimated costs required for the planned incineration plant.

Table 9.1-1 Estimated Costs Required for Construction and Operation/Maintenance of the Planned Incineration Plant

Unit: Million Baht in 1990 Price

	1993 - 2000 MASTER PLAN PERIOD	2001 - 2014	1993 - 2014
	A	B	C=A+B
1. Construction	1,842	0	1,842 (658 Baht/ton)
a. First Phase (1993 - 1995)	(1,209)		
b. Second Phase (1998 - 2000)	(633)		
2. Operation & Maintenance	219	1,746	1,965 (713 Baht/ton)
3. Total (1+2)	2,061	1,746	3,807 (1,371 Baht/ton)

Note: The above operation costs include an estimated 5.14 million Baht required for training during 1993 - 1995. The plant operation will start in 1996.

9.2 Annual Costs

Annual costs required for construction and operation/maintenance are shown in Table 9.2-1.

Table 9.2-1 Annual Costs Required for the Planned Incineration Plant

Unit: Million Baht in 1990 Price unless otherwise indicated

YEAR	CONSTRUCTION	OPERATION/ MAINTENANCE	TOTAL	WASTE AMOUNT INCINERATED (ton/day)
	A	B	C=A+B	D
1991	-	-	-	-
1992	-	-	-	-
1993	490.00	0.61	490.61	-
1994	490.00	0.63	490.63	-
1995	229.00	3.90	232.90	-
1996		25.24	25.24	150
1997		25.50	25.50	150
1998	280.00	32.30	312.30	150
1999	280.00	66.90	346.90	150
2000	73.00	63.07	136.07	470
Total 1993-2000	1,842.00	219.00	2,061.00	-
2001		64.54	64.54	470
2002		80.20	80.20	470
2003		195.89	195.89	470
2004		81.29	81.29	470
2005		86.18	86.18	470
2006		92.56	92.56	470
2007		263.69	263.69	470
2008		88.61	88.61	470
2009		94.00	94.00	470
2010		100.35	100.35	470
2011		298.07	298.07	470
2012		93.97	93.97	470
2013		101.45	101.45	450
2014		106.35	106.35	450
Total 2001-2014	0	1,747.15	1,747.15	-
Grand Total 1993-2014	1,842	1,965.30	3,807.00	2,777,650 tons
Share	48 %	52 %	100 %	

9.3 Construction Costs

The construction of the planned incineration plant requires 1,209 million Baht in the first phase (1993 - 1995), and 633 million Baht in the second phase (1998 - 2000), totaling 1,842 million Baht, of which details are shown in Table 9.3-1.

Table 9.3-1 construction Costs Required for the Planned Incineration Plant

Unit: Million Baht in 1990 Price

WORK ITEMS	#1 FURNACE 1993-1995	#2,3 FURNACE 1998-2000FY	TOTAL
1. Mechanical and Electrical Work			
1.1 Equipment			
1) Waste Reception System	124.00	20.00	144.00
2) Incineration System	74.00	140.00	214.00
3) Gas Cooling System	9.00	10.00	19.00
4) Gas Treatment System	30.00	37.00	67.00
5) Water Supply System	10.00	10.00	20.00
6) Waste Water Treatment System	15.00	4.00	19.00
7) Heat Utilization System	1.00	1.00	2.00
8) Air Preheating System	35.00	50.00	85.00
9) Ash Handling System	32.00	20.00	52.00
10) Electrical Equipment	34.00	20.00	54.00
11) Measuring and Control System	28.00	30.00	58.00
12) Auxiliary Equipment	4.00	1.00	5.00
Sub Total	396.00	343.00	739.00
1.2 Freightage	20.00	25.00	45.00
1.3 Installation Work	100.00	115.00	215.00
2. Civil and Building Work			
1) Civil Work	5.00	1.00	6.00
2) Building	547.00	94.00	641.00
3) Stack	44.00	0	44.00
Sub Total	596.00	95.00	691.00
3. Supplementary Work	2.00	1.00	3.00
4. Insurance	15.00	6.00	21.00
Total	1,129.00	585.00	1,714.00
5. Tax			
1) Custom	19.00	17.00	36.00
2) Business & Stamp Tax (3.3+0.1%)	41.00	22.00	63.00
3) Labor Tax (3% on local portion)	20.00	9.00	29.00
Sub Total	80.00	48.00	128.00
Total	1,209.00	633.00	1,842.00

9.4 Training and Operation/Maintenance Costs

An estimated 219 million Baht will be required for the training and the operation and maintenance of the plant during 1993 - 2000, and another 1,746 million Baht will be needed during 2001 - 2014, amounting to 1,965 million Baht in total, of which details are shown in Table 9.4-1.

Annual average cost of operation/maintenance is estimated at about 103 million/year during the operation period 1996 - 2014. Average unit operation/maintenance cost is estimated at 713 Baht/ton.

Further details of respective components costs for operation/maintenance are shown in Tables 9.4-2, 9.4-3 and 9.4-4. Assumed unit costs and quantities used for preparing those tables are shown in Tables 9.4-5 and 9.4-6.

Table 9.4-1 Training and Operation Maintenance Cost Required for the Planned Incineration Plant

Unit: Million Baht in 1990 Price

YEAR	PARTS & REPAIR	EMOLUMENT	UTILITIES	TOTAL OPERATION/ MAINTENANCE
	A	B	C	D=A+B+C
1991				-
1992				-
1993		0.61		0.61
1994		0.63		0.63
1995		3.90		3.90
1996	4.00	6.20	15.04	25.24
1997	4.08	6.38	15.04	25.50
1998	10.91	6.58	14.81	32.30
1999	42.00	10.10	14.80	66.90
2000	19.50	13.12	30.45	63.07
Total 1993-2000	80.49	47.52	90.14	219.00
2001	21.27	13.52	29.75	64.54
2002	36.68	13.93	29.59	80.20
2003	152.41	14.34	29.14	195.89
2004	36.59	14.77	29.93	81.29
2005	41.22	15.22	29.74	86.18
2006	47.15	15.67	29.74	92.56
2007	217.81	16.14	29.74	263.69
2008	42.24	16.63	29.74	88.61
2009	47.13	17.13	29.74	94.00
2010	52.97	17.64	29.74	100.35
2011	250.15	18.17	29.74	298.07
2012	45.52	18.71	29.74	93.97
2013	52.97	19.28	29.20	101.45
2014	57.30	19.85	29.20	106.35
Total 2001-2014	1,101.42	231.00	414.73	1,747.15
Grand Total 1993-2014	1,181.91	278.52	504.87	1,965.30
Share	60 %	14 %	26 %	100 %

Table 9.4-2 Detailed Costs of Parts and Repair

Unit: Million Baht in 1990 Price

FISCAL YEAR	#1 FURNACE		#2,#3 FURNACES		TOTAL		
	PARTS	REPAIR	PARTS	REPAIR	PARTS	REPAIR	SUM
	A	B	C	D	E=A+C	F=B+D	G=E+F
1996	0.36	3.64	0.00	0.00	0.36	3.64	4.00
1997	0.44	3.64	0.00	0.00	0.44	3.64	4.08
1998	1.82	9.09	0.00	0.00	1.82	9.09	10.91
1999	2.00	40.00	0.00	0.00	2.00	40.00	42.00
2000	2.12	9.42	0.68	7.28	2.80	16.70	19.50
2001	3.06	10.10	0.84	7.28	3.89	17.38	21.27
2002	3.55	11.40	3.46	18.18	7.01	29.58	36.59
2003	3.61	65.00	3.80	80.00	7.41	145.00	152.41
2004	3.71	10.10	4.03	18.84	7.74	28.94	36.68
2005	3.83	11.40	5.80	20.20	9.62	31.60	41.22
2006	3.90	13.70	6.75	22.80	10.65	36.50	47.15
2007	3.95	77.00	6.86	130.00	10.81	207.00	217.81
2008	3.99	11.00	7.05	20.20	11.04	31.20	42.24
2009	4.05	13.00	7.28	22.80	11.33	35.80	47.13
2010	4.16	14.00	7.41	27.40	11.57	41.40	52.97
2011	4.65	84.00	7.51	154.00	12.16	238.00	250.16
2012	4.94	11.00	7.58	22.00	12.52	33.00	45.52
2013	5.27	14.00	7.70	26.00	12.97	40.00	52.97
2014	5.40	16.00	7.90	28.00	13.30	44.00	57.30
Total	64.80	427.49	84.63	604.98	149.44	1,032.47	1,181.91
Annual Average	3.41	22.50	4.45	31.84	7.87	54.34	62.17

Notes: 1. "Parts" include materials and equipment used for operation and maintenance.

2. "Repair" means mainly overhaul which will be done by a contractor. Cost of minor requires to be done by the BMA is also included.

Table 9.4-3 Detailed Costs of Emolument

Unit: Million Baht in 1990 Price

PERSONNEL	FISCAL YEAR								
	1993	1994	1995	1996	1997	1988	1999	2000	2001
Manager	0.20	0.21	0.21	0.22	0.23	0.23	0.24	0.25	0.26
Engineer									
- Mechanical	0.20	0.21	0.21	0.22	0.23	0.23	0.24	0.25	0.26
- Electric	0.20	0.21	0.21	0.22	0.23	0.23	0.24	0.25	0.26
Equi. Controller			0.11	0.15	0.15	0.16	0.16	0.33	0.34
Operator									
- Crane			0.96	1.18	1.22	1.25	1.82	1.99	2.05
- Incinerator			0.96	1.18	1.22	1.25	1.82	1.99	2.05
- Weigh Bridge			0.29	0.59	0.61	0.63	1.18	1.33	1.37
Maintenance Crew			0.76	1.18	1.22	1.25	3.02	3.99	4.11
Cleansing Men				0.30	0.30	0.31	0.32	0.50	0.51
Guardmen				0.59	0.61	0.63	0.65	1.00	1.03
Clerk Chief			0.17	0.22	0.23	0.23	0.24	0.25	0.26
Assistant				0.15	0.15	0.16	0.16	0.50	0.51
Total	0.61	0.63	3.90	6.20	6.38	6.58	10.10	13.12	13.52

Table 9.4-4 Detailed Costs of Utilities

Unit: Million Baht in 1990 Price

ITEMS	FISCAL YEAR 1996	1997	1998	1999	2000	2001	2002	2003	2004	2005-2014 (Each year)
Electricity	10.37	10.37	10.37	10.37	18.66	18.66	18.66	18.66	18.66	18.66
Water	0.26	0.26	0.28	0.36	0.96	1.02	1.15	1.22	1.28	1.34
Fuel	2.30	2.30	2.05	1.54	3.07	2.30	1.54	1.02	0.51	0.26
$Ca(OH)_2$	1.92	1.92	1.92	2.40	7.20	7.20	7.68	7.68	7.92	7.92
Coagulant	0.02	0.02	0.02	0.02	0.05	0.05	0.05	0.05	0.05	0.05
Polymer	0.07	0.07	0.07	0.07	0.22	0.22	0.22	0.22	0.22	0.22
Lubrication	0.01	0.01	0.01	0.01	0.04	0.04	0.04	0.04	0.04	0.04
Grease	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Others	0.06	0.06	0.06	0.06	0.19	0.19	0.19	0.19	0.19	0.19
Total	15.04	15.04	14.81	14.80	30.45	29.75	29.59	29.14	28.93	28.74

Table 9.4-5 Assumed Annual Emolument Rates and Manpower Required

MANPOWER	YEARY EMOLUMENT (Baht/year)	MANPOWER REQUIRED (PERSONS) 1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Manager	180,000			1	1	1	1	1	1	1	1
Engineer	180,000										
Mechanical	180,000			1	1	1	1	1	1	1	2
Electric	180,000			1	1	1	1	1	1	1	2
Equi, Controller	120,000					0.8	1	1	1	1	2
Operator											
Crane	120,000					6.7	8	8	8	11.3	12
Incinerator	120,000					6.7	8	8	8	11.3	12
Weigh Bridge	120,000					2	4	4	4	7.3	8
Maintenance Crew	120,000					5.3	8	8	8	18.7	24
Cleansing men	60,000						4	4	4	4	6
Guardsmen	60,000						8	8	8	8	12
Clerk Chief	180,000					0.8	1	1	1	1	1
Assistant	120,000						1	1	1	1	3
Total				3	3	25	46	46	46	47	85

Table 9.4-6 Assumed Unit Costs and Quantities of Utilities

ITEMS	Unit	Unit Cost	FISCAL YEAR 1996	1997	1998	1999	2000	2001	2002	2003	2004	5-14 (Each year)
Electricity	kWh	2.7B/kWh	500	500	500	500	900	900	900	900	900	900
Water	m^3/d	$4B/m^3$	200	200	220	240	750	800	900	950	1000	1050
Fuel	l/d	8B/l	900	900	800	600	1200	900	600	400	200	100
$Ca(OH)_2$	t/d	7,500B/t	0.8	0.8	0.8	1.0	3.0	3.0	3.2	3.2	3.3	3.3
Coagulant	kg/d	7B/kg	7	7	7	7	20	20	20	20	20	20
Coagulant aid	kg/d	8B/kg	7	7	7	7	20	20	20	20	20	20
Polymer	kg/d	225Bkg	1	1	1	1	3	3	3	3	3	3
Lubrication	kg/y	50B/kg	250	250	250	250	750	750	750	750	750	750
Grease	kg/y	175B/kg	50	50	50	50	75	75	75	75	75	75
Others	/d	200B/d	1	1	1	1	3	3	3	3	3	3

Chapter 10. Evaluation of the Project

10.1 Technical Evaluation

It is judged that the planned incineration plant is technically feasible in terms of both the systems themselves and the ease of the plant operation due to the reasons given below:

1. The planned incineration plant is the one which employes reliable technologies that have been tested and proved good by many local authorities in Japan.

2. The planned incineration plant employs a water injection system (as a cooling system) and a furnace with a stoker bed, with which the BMA/DPC is familiar. (The same systems are applied to the existing incineration plants of the BMA.) So, the BMA will not have difficulties in the operation of those systems.

Note on the Difference between the Planned Incinerator and the Existing Ones, and Necessity for Training

The planned incineration plant is different from the existing ones of the BMA in terms of capacity, draft fan system and operation control system. The planned incineration plant has much larger incineration capacity. It has both forced draft fans and an induced funs, while the existing ones have only forced fans. The planned plant has an automatic control system for air pressure inside the furnace. It also has a semi-automatic crane operation system.

It will be necessary for the BMA to let responsible engineers and operators have a sufficient training during the time of installation and commissioning. With such training, it is considered that the BMA/DPC will have no significant difficulties in the plant operation.

10.2 Environmental Evaluation

10.2.1 Source of Potential Impacts

The environmental pollution factors related to an incineration plant are shown in Table 10.2-1.

Table 10.2-1 Pollution Factors of Incineration Plant

ENVIRONMENTAL FACTOR / ENVIRONMENTAL IMPACT ELEMENT	AIR POLLUTION	WATER POLLUTION	ODOR	NOISE	TRANSPOR-TATION	FAUNA-FLORA
Vehicle	Δ			Δ	O	
Stack	O					
Plant		Δ	Δ	O		O
Office etc.		Δ				O

O: Important Factor, Δ: Minor Factor

10.2.2 Forecast and Evaluation of Environmental Impact

1) Air Pollution

It is considered that the planned incineration plant will not cause significant impacts on ambient air judging from the results of the forecasts of the degree of concentration of NOx, SOx, SPM and HCl as shown in Fig. 10.2-1 (1) and (2). Refer to Technical Note which explains calculation models used, and conditions of forecast.

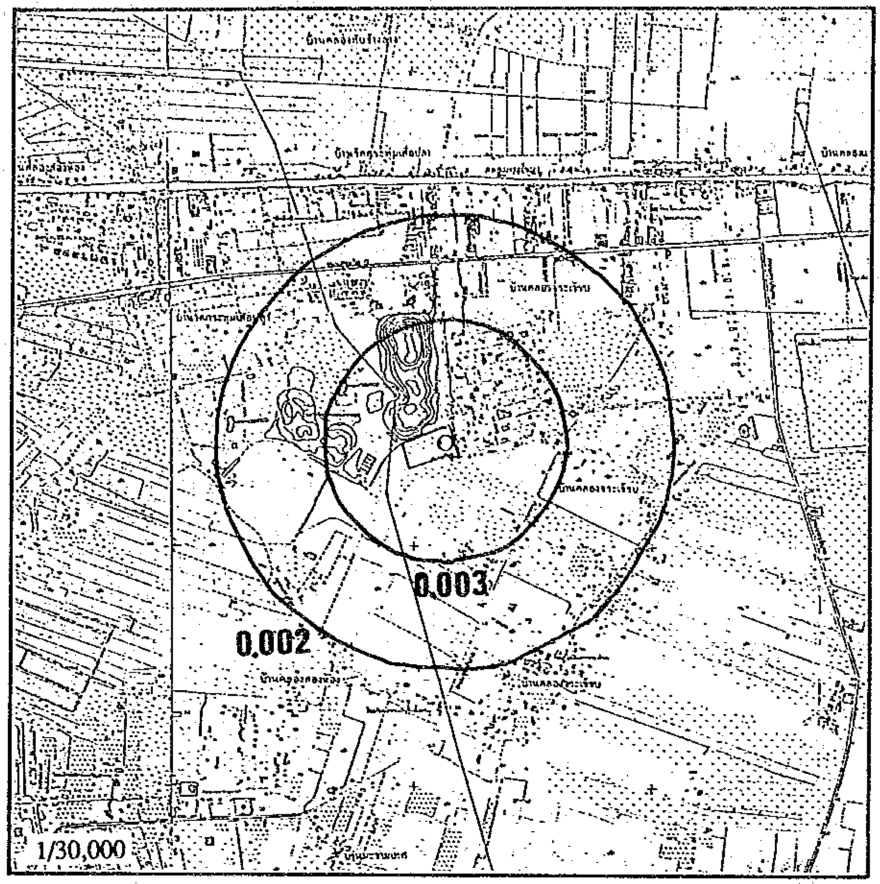
As shown in Table 10.2-2, degree of maximum concentration of those gas is very low as compared to those observed in the actual air by the ONEB, and also to the National Ambient Air Quality Standards.

Table 10.2-2 Forecasted Maximum Concentration in Comparison with the Actual Air Quality and the National Ambient Air Quality Standards (NAAQS)

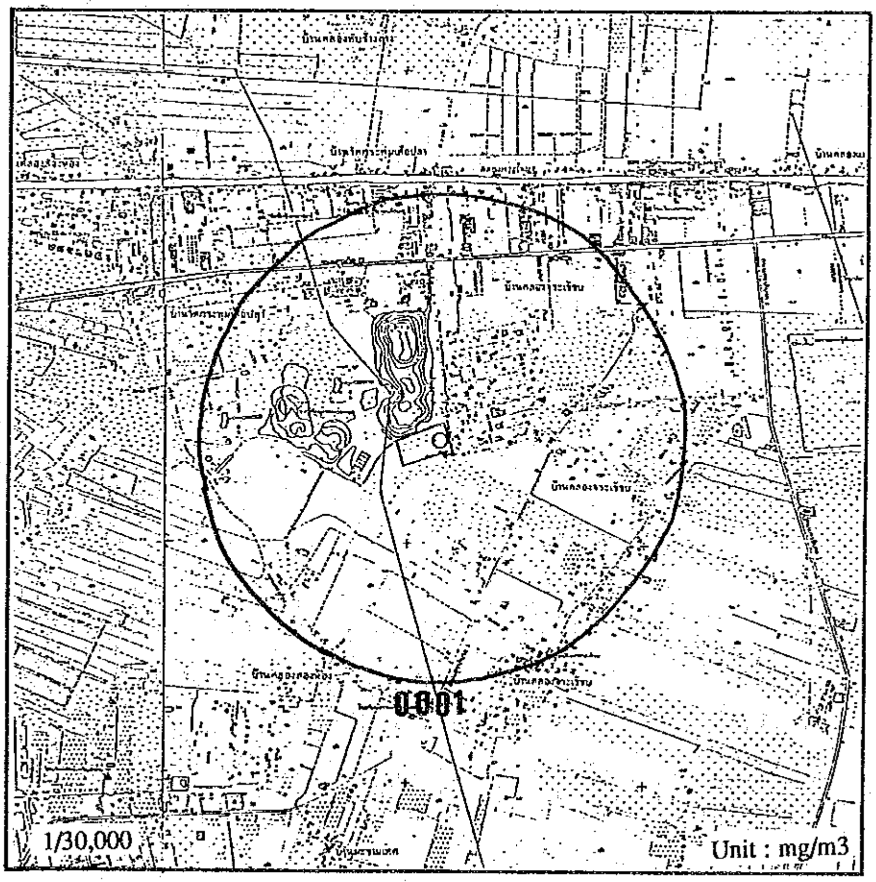
Item	NOx (ppm)	SOx (ppm)	SPM (mg/m^3)	HCl (ppm)
Maximum Forecast Level	0.004	0.002	0.002	0.003
Actual Air Quality Monitored*-1	0.2(NO_2)	0.02(SO_2)	0.11	-
NAAQS*-2	0.1(NO_2)	0.10(SO_2)	0.10	-

*-1 NOx: Urban residential area, 1987 - 89
SOx: Urban residential area, 1988, 89
SPM: Suburban residential area, 1983 - 89

*-2 NOx: 1 hour average
SOx: 24 hour average
SPM: 1 year average

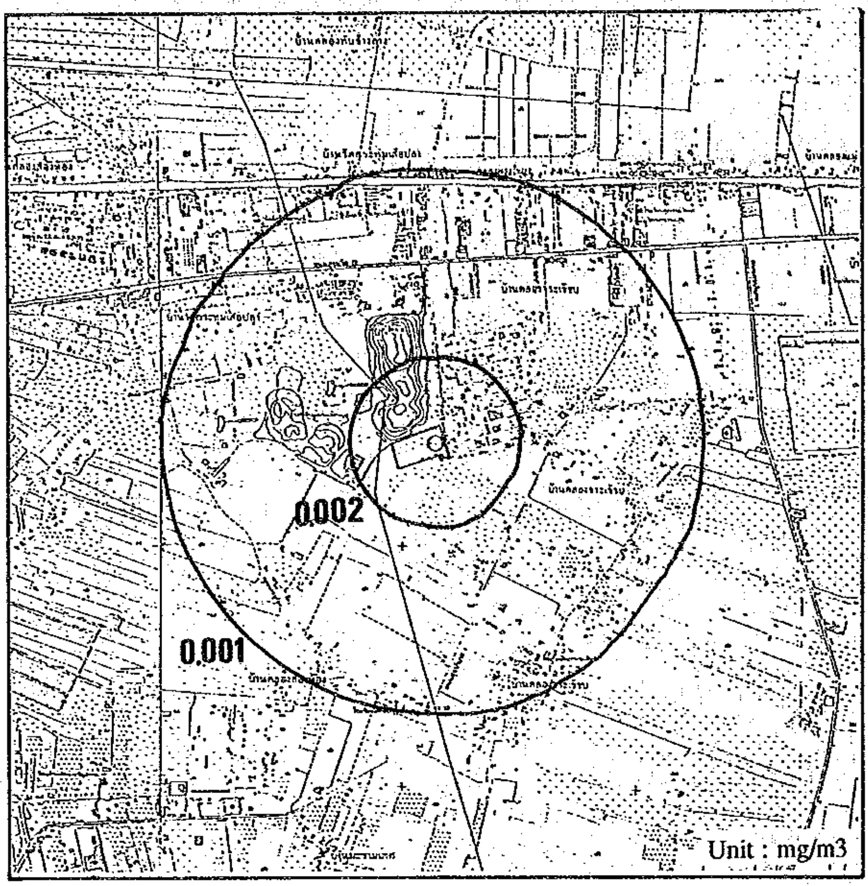


NOx

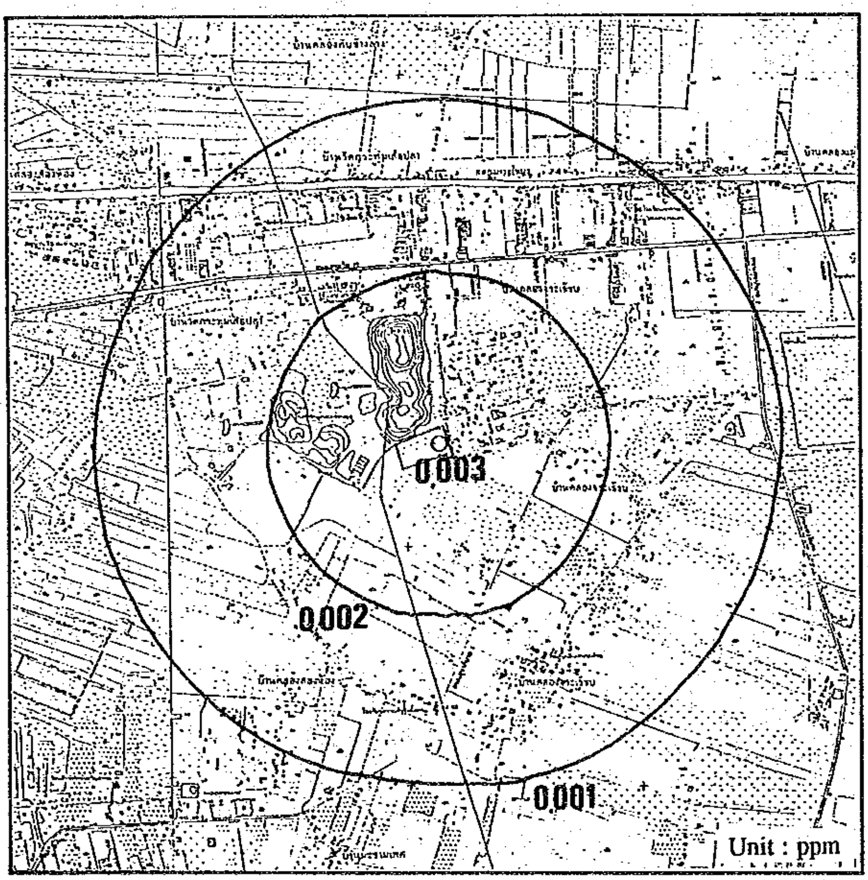


SOx

Fig. 10.2-1 Forecast of Air Pollution by Emission Gas (1)



SPM



HCl

Fig. 10.2-1 Forecast of Air Pollution by Emission Gas (2)