In the second place, the flow rate QR^o under designed conditions of rotar meter was calculated by regression Equation III-3-15 and obtained corrected flow rate $QG^o_a i\text{-}1$ and $QG^o_b i$.

where;

$QG^o_a i\text{-}1$: corrected flow rate under designed condition after adjustment at (i-1) patrol (l/min)

$QG^o_b i$: flow rate under designed condition before adjustment at (i) patrol.

Further, corrected flow rate under designed conditions was corrected with temperature at monitoring by the Equation III-3-18.

$$QGai\text{-}1 = \frac{273 + Temp}{273 + To} \times QG^o_a i\text{-}1$$

$$QGbi = \frac{273 + Temp}{273 + To} \times QGbi$$

Equation III-3-18

where;

QGai-1: flow rate after adjustment at (i-1) patrol under temperature at monitoring (l/min)

QGbi: flow rate before adjustment at (i) patrol under temperature at monitoring (l/min)

To: temperature at designed condition (20°C)

Temp: temperature at monitoring (°C)

Air sucking volume Ri during (i-1) patrol and (i) patrol was obtained by multiplying elapsing time t_2 with the average value of flow rate after adjustment at (i-1) patrol and flow rate before adjustment at (i) patrol.

$$Ri = \frac{QGai\text{-}1 + GQbi}{2} \times t_2 \times \frac{1}{1000}$$

Equation III-3-19

where;

R_1: air sucking volume during (i-1) patrol and (i) patrol (m^3)

t_2: time elapsed during (i-1) patrol to (i) patrol (min)

An example of calculation results of sucking air volume by this method is shown in Table III-3-27 (all the results are shown in part of reference).

Table III-3-27 An example of calculation results of air sucking volume of Andersen sampler

ANDERSEN SAMPLER AIR VOLUME CALCULATION

SITE NO. 1 ROTOR NO. F00320

DATE	TIME		LAPSE TIME (MIN)	STOP TIME (MIN)	ROTOR METER (L/MIN)	PRESSURE DIFFERENCE (MM-HG)	CORRECTED FLOW RATE (L/MIN)	CALIBRATED FLOW RATE (L/MIN)	FLOW VOL. (M**3)
12 9	9 46		0	0	21.4	51.0	21.2	29.4	
12 9	16 47	B	421	0	21.0	51.0	20.8	28.9	12.3
12 9	16 47	F	0	0	21.4	52.0	21.2	29.4	
12 10	12 20	B	1173	0	21.4	52.0	21.2	29.4	34.5
12 10	12 20	F	0	0	21.4	52.0	21.2	29.4	
12 10	16 57	B	277	0	21.2	50.0	21.0	29.2	8.1
12 10	16 57	F	0	0	21.4	50.0	21.2	29.4	
12 11	12 26	B	1169	0	22.0	55.0	21.7	30.1	34.8
12 11	12 26	F	0	0	21.4	54.0	21.1	29.3	
12 12	11 43	B	1397	0	21.8	50.0	21.6	29.9	41.4
12 12	11 43	F	0	0	21.4	50.0	21.2	29.4	
12 12	16 48	B	305	0	21.4	54.0	21.1	29.3	9.0
12 12	16 48	F	0	0	21.4	54.0	21.1	29.3	
12 13	11 6	B	1098	0	21.2	55.0	20.9	29.1	32.1
12 13	11 6	F	0	0	21.4	55.0	21.1	29.3	
12 14	12 3	B	1497	0	21.7	55.0	21.4	29.7	44.2
12 14	12 3	F	0	0	21.4	55.0	21.1	29.3	
12 14	16 30	B	267	0	21.4	55.0	21.1	29.3	7.8
12 14	16 30	F	0	0	21.4	55.0	21.1	29.3	
12 15	12 21	B	1191	0	21.4	56.0	21.1	29.3	34.9
12 15	12 21	F	0	0	21.4	56.0	21.1	29.3	
12 15	16 25	B	244	0	21.4	56.0	21.1	29.3	7.2
12 15	16 25	F	0	0	21.4	56.0	21.1	29.3	
12 16	12 15	B	1190	0	21.9	56.0	21.6	29.7	35.3
12 16	12 15	F	0	0	21.4	56.0	21.1	29.3	
12 16	16 35	B	260	0	21.4	56.0	21.1	29.3	7.6
12 16	16 35	F	0	0	21.4	56.0	21.1	29.3	
12 17	11 30	B	1135	0	21.4	57.0	21.1	29.3	33.3
12 17	11 30	F	0	0	21.4	57.0	21.1	29.3	
12 17	14 24	B	174	0	21.4	57.0	21.1	29.3	5.1
12 17	14 24	F	0	0	21.4	59.0	21.1	29.2	
12 18	11 58	B	1294	0	21.2	59.0	20.9	29.0	37.7
12 18	11 58	F	0	0	21.4	59.0	21.1	29.2	
12 19	12 3	B	1445	0	21.8	58.0	21.5	29.8	42.6
12 19	12 3	F	0	0	21.4	58.0	21.1	29.3	
12 19	17 2	B	299	0	21.8	58.0	21.5	29.8	8.8
12 19	17 2	F	0	0	21.4	58.0	21.1	29.3	
12 20	11 52	B	1130	0	21.4	58.0	21.1	29.3	33.1
12 20	11 52	F	0	0	21.4	58.0	21.1	29.3	
12 20	16 37	B	285	0	21.4	57.0	21.1	29.3	8.3
12 20	16 37	F	0	0	21.4	57.0	21.1	29.3	
12 21	13 8	B	1231	0	21.3	58.0	21.0	29.1	36.0

The total air sucking volume is obtained as the sum of air sucking volume during each patrolling time.

$$V = \sum_{i=1}^{N} Ri$$

Equation III-3-20

where;

V: Total air sucking volume (m^3)

N: Number of patrols (excluding the time of commencement of monitoring, and including the time of completing of monitoring)

(3) Calculation of particulate matter concentration by Andersen sampler

The concentration of particulate matter was calculated from the (1) weighed values (before and after monitoring) of polyethylene sheets and back-up filters placed in each stage of Andersen sampler and (2) total air sucking volume, using Equation III-3-21.

$$C = \frac{We - Ws}{V} \times 10^3 \qquad \text{Equation III-3-21}$$

where;

We: weight after collection (of particulate matter) of polyethylene sheet and backup filter (mg)

Ws: weight before collection (of particulate matter) of polyethylene sheet and backup filter (mg)

V: total air sucking volume (m^3)

C: concentration of particulate matter ($\mu g/m^3$)

III-3-3-3 Results of monitoring of particulate size distribution

The results of monitoring of particulate concentration by Andersen sampler based on the calculation methods described in III-3-3-2 are shown in Table III-3-28.

Table III-3-28-(1) Results of monitoring of particulate concentration by Andersen sampler (1st Field Survey)

SITE-NO. 1 ROTOR NO. FB0320 1983 12/ 9 - 12/21

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	1-0	258.17	260.55	2.38	4.6	40.0
1	7.0 -- 11.	1-1	276.51	277.71	1.20	2.3	35.3
2	4.7 -- 7.0	1-2	265.86	267.92	2.06	4.0	33.0
3	3.3 -- 4.7	1-3	253.88	255.73	1.85	3.6	29.0
4	2.1 -- 3.3	1-4	254.94	256.14	1.20	2.3	25.4
5	1.1 -- 2.1	1-5	273.96	276.57	2.61	5.1	23.1
6	.65 -- 1.1	1-6	276.10	277.00	0.90	1.8	18.0
7	.43 -- .65	1-7	277.05	277.53	0.48	0.9	16.2
8	-- .43	1-8	425.25	433.11	7.86	15.3	15.3

SAMPLING TIME = 291.4 (H)
AIR VOLUME = 513.9 (M**3)
TOTAL CONC. = 40.0 (UG/M**3)

SITE-NO. 2 ROTOR NO. FB0320A 1983 12/ 9 - 12/21

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	2-0	275.62	276.59	0.97	1.9	29.4
1	7.0 -- 11.	2-1	279.07	279.64	0.57	1.1	27.5
2	4.7 -- 7.0	2-2	276.92	277.85	0.93	1.8	26.3
3	3.3 -- 4.7	2-3	260.73	262.18	1.45	2.8	24.5
4	2.1 -- 3.3	2-4	266.01	267.11	1.10	2.2	21.7
5	1.1 -- 2.1	2-5	273.22	274.41	1.19	2.3	19.5
6	.65 -- 1.1	2-6	278.94	280.44	1.50	2.9	17.2
7	.43 -- .65	2-7	278.52	280.13	1.61	3.2	14.2
8	-- .43	2-8	422.03	427.69	5.66	11.1	11.1

SAMPLING TIME = 288.2 (H)
AIR VOLUME = 510.3 (M**3)
TOTAL CONC. = 29.4 (UG/M**3)

SITE-NO. 6 ROTOR NO. FB0320B 1983 12/ 9 - 12/21

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	6-0	266.97	268.14	1.17	2.3	33.2
1	7.0 -- 11.	6-1	273.97	274.55	0.58	1.1	30.9
2	4.7 -- 7.0	6-2	256.78	258.16	1.38	2.7	29.7
3	3.3 -- 4.7	6-3	277.62	279.94	2.32	4.5	27.0
4	2.1 -- 3.3	6-4	280.64	281.96	1.32	2.6	22.5
5	1.1 -- 2.1	6-5	263.43	264.85	1.42	2.8	19.9
6	.65 -- 1.1	6-6	264.06	265.42	1.36	2.7	17.1
7	.43 -- .65	6-7	255.17	257.21	2.04	4.0	14.5
8	-- .43	6-8	430.99	436.33	5.34	10.5	10.5

SAMPLING TIME = 288.8 (H)
AIR VOLUME = 510.6 (M**3)
TOTAL CONC. = 33.2 (UG/M**3)

Table III-3-28-(2). Results of monitoring of particulate concentration by Andersen sampler (2nd Field Survey)

SITE-NO. 1 ROTOR NO. FD0320 1984 3/ 8 - 3/20

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	1-0	259.04	261.34	2.30	4.9	49.4
1	7.0 -- 11.	1-1	276.41	277.21	0.80	1.7	44.4
2	4.7 -- 7.0	1-2	254.48	255.92	1.44	3.1	42.7
3	3.3 -- 4.7	1-3	263.46	266.17	2.71	5.8	39.6
4	2.1 -- 3.3	1-4	277.40	279.42	2.02	4.3	33.8
5	1.1 -- 2.1	1-5	259.12	260.75	1.63	3.5	29.5
6	.65 -- 1.1	1-6	272.60	273.65	1.05	2.3	26.0
7	.43 -- .65	1-7	269.29	271.78	2.49	5.3	23.7
8	-- .43	1-8	444.69	453.26	8.57	18.4	18.4

SAMPLING TIME = 288.5 (H)
AIR VOLUME = 466.0 (M**3)
TOTAL CONC. = 49.4 (UG/M**3)

SITE-NO. 2 ROTOR NO. FD0320A 1984 3/10 - 3/20

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	2-0	276.97	278.01	1.04	2.7	39.6
1	7.0 -- 11.	2-1	274.13	274.73	0.60	1.5	36.9
2	4.7 -- 7.0	2-2	265.87	266.93	1.06	2.7	35.4
3	3.3 -- 4.7	2-3	271.87	272.78	0.91	2.3	32.6
4	2.1 -- 3.3	2-4	274.95	276.47	1.52	3.9	30.3
5	1.1 -- 2.1	2-5	253.47	254.57	1.10	2.8	26.4
6	.65 -- 1.1	2-6	264.27	264.77	0.50	1.3	23.5
7	.43 -- .65	2-7	277.98	278.70	0.72	1.9	22.2
8	-- .43	2-8	422.96	430.87	7.91	20.4	20.4

SAMPLING TIME = 234.6 (H)
AIR VOLUME = 387.9 (M**3)
TOTAL CONC. = 39.6 (UG/M**3)

ANDERSEN AIR SAMPLER DATA

SITE-NO. 6 ROTOR NO. FD0320D 1984 3/ 6 - 3/20

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	6-0	271.76	274.00	2.24	4.4	52.6
1	7.0 -- 11.	6-1	260.03	261.00	0.97	1.9	48.3
2	4.7 -- 7.0	6-2	271.65	273.37	1.72	3.3	46.4
3	3.3 -- 4.7	6-3	272.92	276.12	3.20	6.2	43.0
4	2.1 -- 3.3	6-4	274.75	276.94	2.19	4.3	36.8
5	1.1 -- 2.1	6-5	279.77	282.28	2.51	4.9	32.6
6	.65 -- 1.1	6-6	277.28	278.71	1.43	2.8	27.7
7	.43 -- .65	6-7	260.96	264.75	3.79	7.4	24.9
8	-- .43	6-8	450.39	459.42	9.03	17.5	17.5

SAMPLING TIME = 334.2 (H)
AIR VOLUME = 514.8 (M**3)
TOTAL CONC. = 52.6 (UG/M**3)

Table III-3-28-(3) Results of monitoring of particulate concentration by Andersen sampler (3rd Field Survey)

SITE-NO. 1 ROTOR NO. F00320 1984 6/21 - 7/ 4

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	1-0	248.35	249.98	1.63	3.3	40.3
1	7.0 -- 11.	1-1	257.40	258.43	1.03	2.1	37.0
2	4.7 -- 7.0	1-2	272.37	274.22	1.85	3.8	34.9
3	3.3 -- 4.7	1-3	250.84	252.58	1.74	3.5	31.2
4	2.1 -- 3.3	1-4	271.68	274.20	2.52	5.1	27.6
5	1.1 -- 2.1	1-5	257.50	259.10	1.60	3.2	22.5
6	.65 -- 1.1	1-6	264.75	265.28	0.53	1.1	19.3
7	.43 -- .65	1-7	270.77	271.89	1.12	2.3	18.2
8	-- .43	1-8	428.33	436.17	7.84	15.9	15.9

SAMPLING TIME = 312.3 (H)
AIR VOLUME = 492.8 (M**3)
TOTAL CONC. = 40.3 (UG/M**3)

SITE-NO. 2 ROTOR NO. F00320A 1984 6/21 - 7/ 4

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	2-0	267.80	268.74	0.94	1.8	32.3
1	7.0 -- 11.	2-1	254.23	254.91	0.68	1.3	30.5
2	4.7 -- 7.0	2-2	262.24	263.64	1.40	2.7	29.2
3	3.3 -- 4.7	2-3	265.53	268.05	2.52	4.8	26.5
4	2.1 -- 3.3	2-4	252.69	254.57	1.88	3.6	21.7
5	1.1 -- 2.1	2-5	262.12	263.44	1.32	2.5	18.2
6	.65 -- 1.1	2-6	264.17	264.79	0.62	1.2	15.6
7	.43 -- .65	2-7	269.27	271.11	1.84	3.5	14.5
8	-- .43	2-8	427.30	433.04	5.74	10.9	10.9

SAMPLING TIME = 310.8 (H)
AIR VOLUME = 524.3 (M**3)
TOTAL CONC. = 32.3 (UG/M**3)

SITE-NO. 6 ROTOR NO. F00320B 1984 6/21 - 7/ 4

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	6-0	261.08	263.48	2.40	4.7	47.8
1	7.0 -- 11.	6-1	251.25	252.42	1.17	2.3	43.1
2	4.7 -- 7.0	6-2	270.69	272.85	2.16	4.2	40.8
3	3.3 -- 4.7	6-3	264.03	267.49	3.46	6.7	36.6
4	2.1 -- 3.3	6-4	264.14	266.66	2.52	4.9	29.9
5	1.1 -- 2.1	6-5	269.24	271.15	1.91	3.7	25.0
6	.65 -- 1.1	6-6	262.58	263.63	1.05	2.0	21.3
7	.43 -- .65	6-7	261.88	264.71	2.83	5.5	19.2
8	-- .43	6-8	427.01	434.08	7.07	13.7	13.7

SAMPLING TIME = 310.8 (H)
AIR VOLUME = 514.5 (M**3)
TOTAL CONC. = 47.8 (UG/M**3)

Table III-3-28-(4) Results of monitoring of particulate concentration by Andersen sampler (4th Field Survey)

SITE-NO. 1 ROTOR NO. FU0320 1984 9/13 - 9/25

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	1-0	25945.00	26125.00	1.80	3.8	45.3
1	7.0 -- 11.	1-1	25398.00	25473.00	0.75	1.6	41.5
2	4.7 -- 7.0	1-2	26041.00	26184.00	1.43	3.0	39.9
3	3.3 -- 4.7	1-3	26360.00	26602.00	2.42	5.1	36.9
4	2.1 -- 3.3	1-4	26217.00	26398.00	1.81	3.8	31.8
5	1.1 -- 2.1	1-5	27128.00	27311.00	1.83	3.8	28.0
6	.65 -- 1.1	1-6	26298.00	26433.00	1.35	2.8	24.2
7	.43 -- .65	1-7	25078.00	25286.00	2.08	4.4	21.4
8	-- .43	1-8	42373.00	43181.00	8.08	17.0	17.0

SAMPLING TIME = 287.5 (H)
AIR VOLUME = 475.7 (M**3)
TOTAL CONC. = 45.3 (UG/M**3)

SITE-NO. 2 ROTOR NO. FU0320A 1984 9/14 - 9/25

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	2-0	26544.00	26635.00	0.91	2.1	31.8
1	7.0 -- 11.	2-1	27059.00	27093.00	0.34	0.8	29.7
2	4.7 -- 7.0	2-2	25958.00	26056.00	0.98	2.3	28.9
3	3.3 -- 4.7	2-3	27245.00	27334.00	0.89	2.1	26.6
4	2.1 -- 3.3	2-4	26512.00	26665.00	1.53	3.6	24.5
5	1.1 -- 2.1	2-5	27555.00	27669.00	1.14	2.7	21.0
6	.65 -- 1.1	2-6	25262.00	25321.00	0.59	1.4	18.3
7	.43 -- .65	2-7	25818.00	25872.00	0.54	1.3	17.0
8	-- .43	2-8	43092.00	43767.00	6.75	15.7	15.7

SAMPLING TIME = 259.6 (H)
AIR VOLUME = 429.8 (M**3)
TOTAL CONC. = 31.8 (UG/M**3)

SITE-NO. 6 ROTOR NO. FU0320B 1984 9/13 - 9/25

STAGE	DIAMETER (UM)	FILTER NO.	BEFORE WEIGHT (MG)	AFTER WEIGHT (MG)	DUST WEIGHT (MG)	DUST CONC. (UG/M**3)	ACC.DUST CONC. (UG/M**3)
0	11. --	6-0	25942.00	26111.00	1.69	3.6	39.1
1	7.0 -- 11.	6-1	26893.00	26958.00	0.65	1.4	35.5
2	4.7 -- 7.0	6-2	26702.00	26821.00	1.19	2.5	34.1
3	3.3 -- 4.7	6-3	25615.00	25819.00	2.04	4.4	31.5
4	2.1 -- 3.3	6-4	26274.00	26431.00	1.57	3.4	27.2
5	1.1 -- 2.1	6-5	27685.00	27845.00	1.60	3.4	23.8
6	.65 -- 1.1	6-6	27634.00	27740.00	1.06	2.3	20.4
7	.43 -- .65	6-7	25805.00	26054.00	2.49	5.3	18.1
8	-- .43	6-8	41874.00	42475.00	6.01	12.8	12.8

SAMPLING TIME = 288.0 (H)
AIR VOLUME = 468.4 (M**3)
TOTAL CONC. = 39.1 (UG/M**3)

CHAPTER 4 LONG TERM FIELD SURVEY

The long term field survey has been conducted during from December 7th 1983 to December 6th 1984, and the particulate matter, sulfur oxide, wind direction & velocity, solar and net radiation and temperature have been automatically and continuously monitored through the year.

During the period of one year monitoring, the daily maintenance of the instruments have been undertaken by Singapore side, and the calibration of instruments and so on have been carried out by Japanese team who stayed in Singapore for short term field survey.

Table III-4-1 shows monitoring items by station in long term field survey. Further the details on measuring principles and handling methods for sulfur oxide, wind direction & velocity and solar & net radiation and so on have already been described in the previous report on air quality. In this report, therefore, only the particulate matter is taken up.

Table III-4-1 Monitoring items in long term field survey by stations

Station	Name of station	Monitored item	Instrument
MP-1	Jurong Town Hall	Suspended P.M. (SPM) Sulfur Dioxide (SO_2) Wind direction and velocity Temperature	Beta ray analyser SO_2 analyser Propeller type-anemometer Thermometer
MP-2	National University of Singapore	SPM SO_2 Wind direction and velocity	Beta ray analyser SO_2 analyser Anemometer
MP-4	Boon Lay Apartment	SO_2 Wind direction and velocity	Beta ray analyser Anemometer
MP-6	Nanyang Technological Institute (NTI)	SPM SO_2 Wind direction and velocity	Beta ray analyser SO_2 analyser Anemometer
MP-7	Bukit Panjang Police Post	SO_2 Wind direction and velocity	SO_2 analyser Anemometer
MP-14	Kallang Flatted Factory	SO_2 Wind direction and velocity	SO_2 analyser Anemometer

Table III-4-1 Monitoring items in long term field survey by stations (Cont'd)

Station	Name of station	Monitored item	Instrument
MP-20	Singapore offshore Petroleum Services	SO_2 Wind direction and velocity	SO_2 analyser Anemometer
Changi Airport		Solar radiation Net radiation	EPRI solar meter Differential net radiation meter

III-4-1 Monitoring of SPM by Beta Ray Dust Analyser

Monitoring methods of particulate matter have been described in Chapter 3 of Part II. In this study, Beta ray analyser has been employed as the instrument to monitor one hour average values of SPM concentration through the year.

The reasons why Beta ray analyser was employed in this study are (a) filtration method and particle separation method are only applicable for 24 hours monitoring and they require man power to replace the filter and to check the flow rate while operation, and (b) they are not able to monitor short time concentration due to their sensibility. Filter contamination method is (c) not able to indicate the concentration as the direct weight concentration. Further light scattering method, Beta ray analyzing method and Piezo-balance method which are the methods for monitoring short time concentration are considered and compared. The light scattering method is the relative concentration monitoring method, and Piezo-balance method is too complicated in its maintenance although it is the direct method. Due to the above reasons, the Beta ray analyser was employed.

III-4-1-1 Beta ray dust analyser

(1) Measuring principle and its structure

The Beta ray analyser is the instrument based on the principle that the absorption rate of Bata ray increases depending on quality and quantity of the substance when the Beta ray of low energy is irradiated onto the substance. From this principle, Beta ray is irradiated on the particulate matter collected on the filter and by measuring transmitted Beta ray, the quality and quantity of particulate matter are identified.

The relation between the transmitted intensity of Beta ray and quality & quantity of the particulate matter is obtained by the following equation.

$$I = Io \exp(-um.Xm)$$ Equation III-4-1

where;

I: Beta ray intensity transmitted through filter and particulate matter

Io: Beta ray intensity transmitted only through filter

um: Mass absorption coefficient (cm^2/g)

Xm: Mass of particulate matter (g/cm^2)

From the above equation, mass of the particulate matter are;

$$Xm = \frac{1}{um} l_n \frac{Io}{I}$$ Equation III-4-2

And concentration of particulate matter is;

$$C = \frac{S}{V} . Xm = \frac{S}{V} . \frac{1}{um} . l_n \frac{Io}{I}$$ Equation III-4-3

where;

C: concentration of particulate matter (mg/m^3)

S: collecting area (cm^2)

V: air sucking volume (m^3)

In this study, DKK (Denki Kagaku KK) GRH-76 type Beta ray analyser was employed. As shown in Fig. III-4-1 and Picture III-4-1, Beta ray analyser is installed in SO_2 analyser which is also used in this study. Through cyclon separater, air is sucked at the constant flow rate of 18 liter per minute, and SPM is collected on the glass fibre filter rolled on reel, and mass concentration of SPM is output by automatic calculation. The results of monitoring are recorded on the chart together with SO_2 values every one hour in terms of one hour average concentration value.

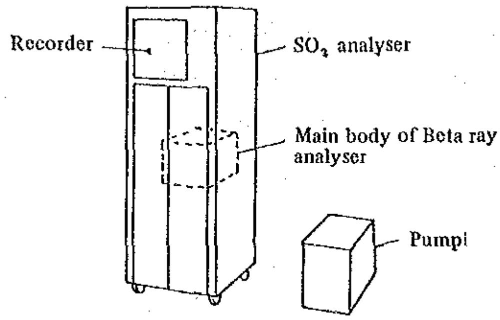


Fig. III-4-1 Outside view of Beta ray dust analyser

The detecting part of the instrument is designed as Beta ray route and sampled air are crossed in acute angle and the filter is placed at the cross. The detecting part is divided into two, and in the upper part of radiation cell, Beta ray source (Promethium 147, ^{147}Pm) is installed. In the lower part, semi conductor detector (Silicon loaded particle detector) is installed. (Fig. III-4-2)

Due to this mechanical structure, blank monitoring, collection and detection are designed to be carried out at one point. Therefore, the error by misplacement of filter is minimized and monitoring of low concentration area can be conducted in high sensibility.

According to the instruction of programme time chart, processes (a) filter forwarding, (b) blank monitoring and (c) air flow monitoring are repeated which make possible to monitor automatically, as shown in Fig. III-4-3. Table III-4-2 shows the specifications of the instrument, and Fig. III-4-4 shows flow chart of monitoring processes.

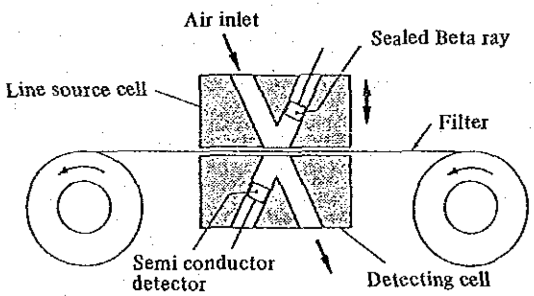


Fig. III-4-2 Structure of detecting part

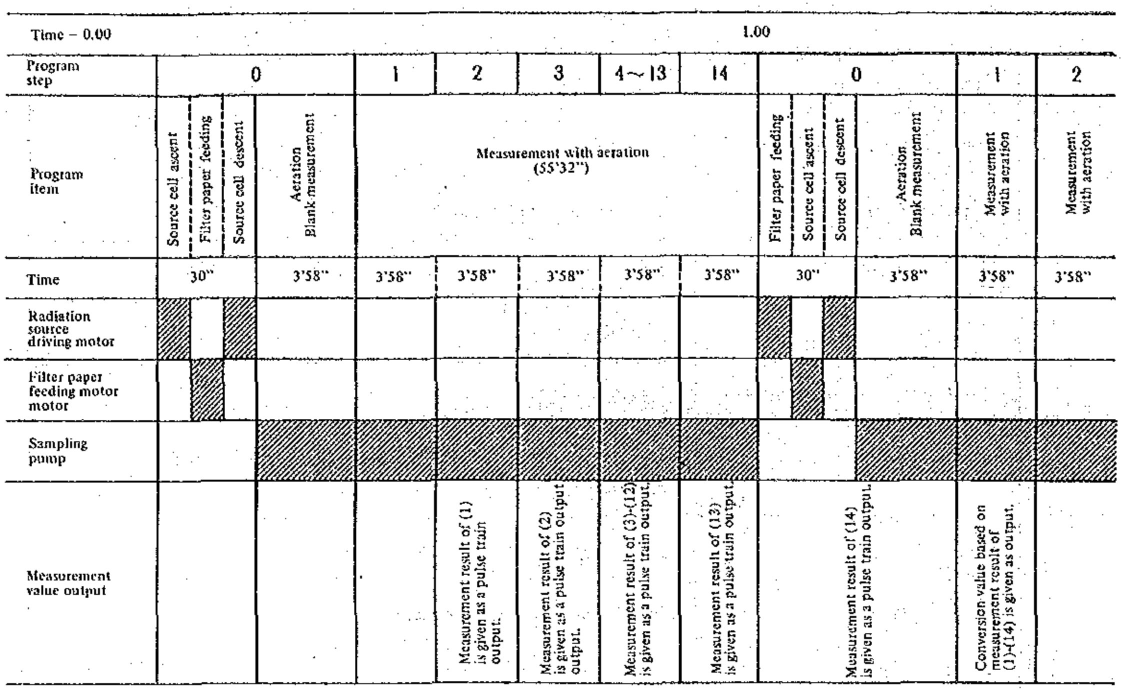


Fig. III-4-3 Programme time chart

Table III-4-2 Specifications of Beta ray dust analyser

Type	DUB type (DKK)
Monitoring range	0 - 15 mg/m^3
Precision	10 μg/mg or ±10%
Ray source	147 Pm
Filter	glass fibre
Collection method	filteration
Air flow rate	18 liter per minute (constant flow rate regulated)
Detecter	semi conducting detecter
Calibration	equivalent membrane
Indication	time (hr min) readings corresponding sequence check at manual operation results of calibration
Recording	DC 0 - 1 V
Output of telemeter	Pulse 0 - 5 x 10^3 C.P.H. DC 0 - 1 V
Telemeter signal	input (reset, stop monitoring)
Power source	AC 100 V ±10%, 50/60 Hz
Power consumption	about 150 VA
Size	main body: 270W x 410D x 250H pump unit: 225W x 285D x 270H
Weight	main body: about 20 kg pump: about 10 kg
Temperature range	-10 to 40°C
Type combined with SO_2 analyser	GRH - 76 M type

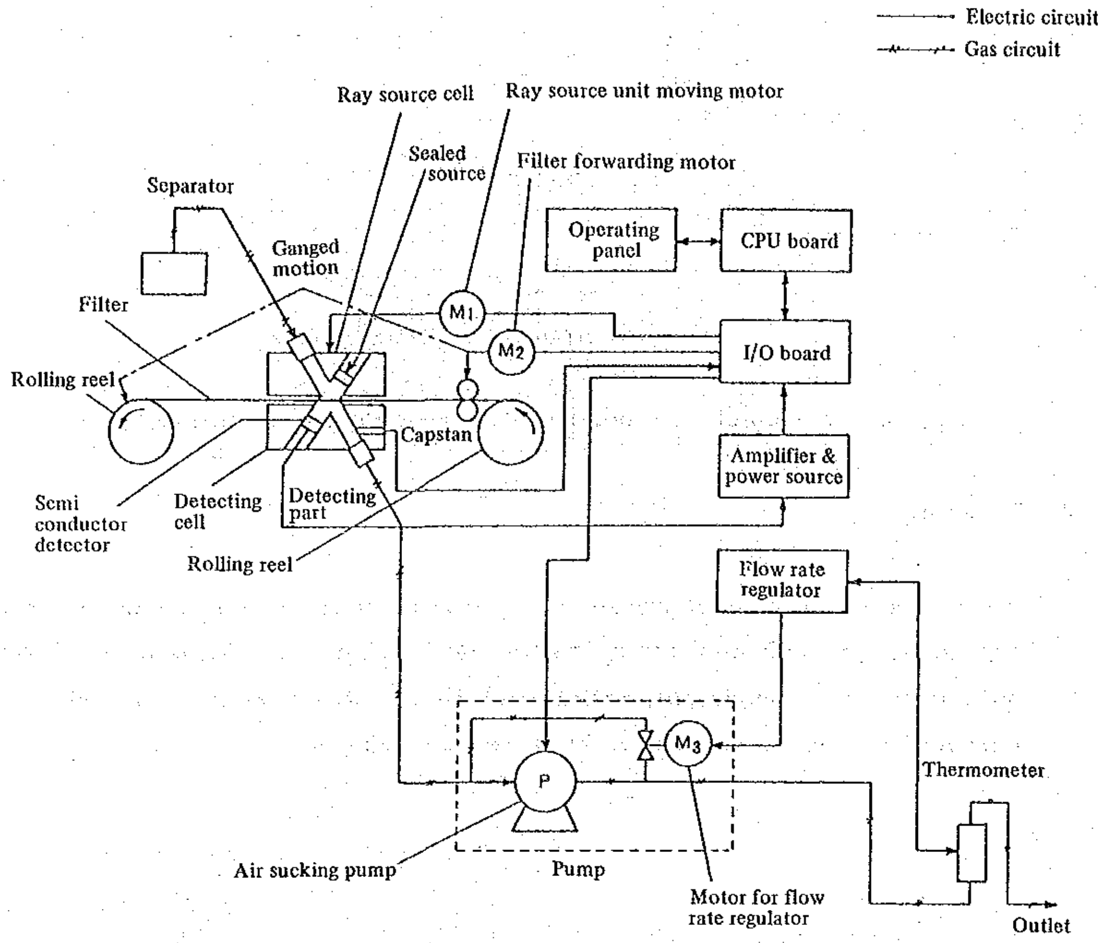


Fig. III-4-4 Flow chart of Beta ray dust analyser

Beta ray source is Promethium 147 of about 100 microcurie and designed that the radioactive isotope may not permeate and leak. But it is not permitted to take out the sealed ray source. In Japan, no qualification, permit and registration are required for handling this radioactive substance.

The half life of Promethium 147 is about 2.6 years and as shown in Fig. III-4-5, the gap of zero point by time elapse are found in small. So it can work more than 7 years.

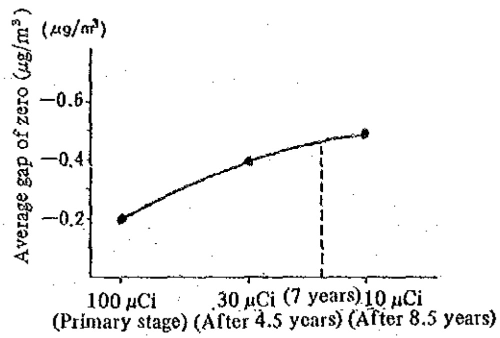


Fig. III-4-5 Gap of zero point by different ray source intensity

(2) Handling

For operation, key panel installed in the front part of the instrument (shown in Fig. III-4-6) is adjusted by operation mode shown in Table III-4-3, by which automatic monitoring, calibration and time correction are carried out. The detailed key operation is shown in attached catalogue.

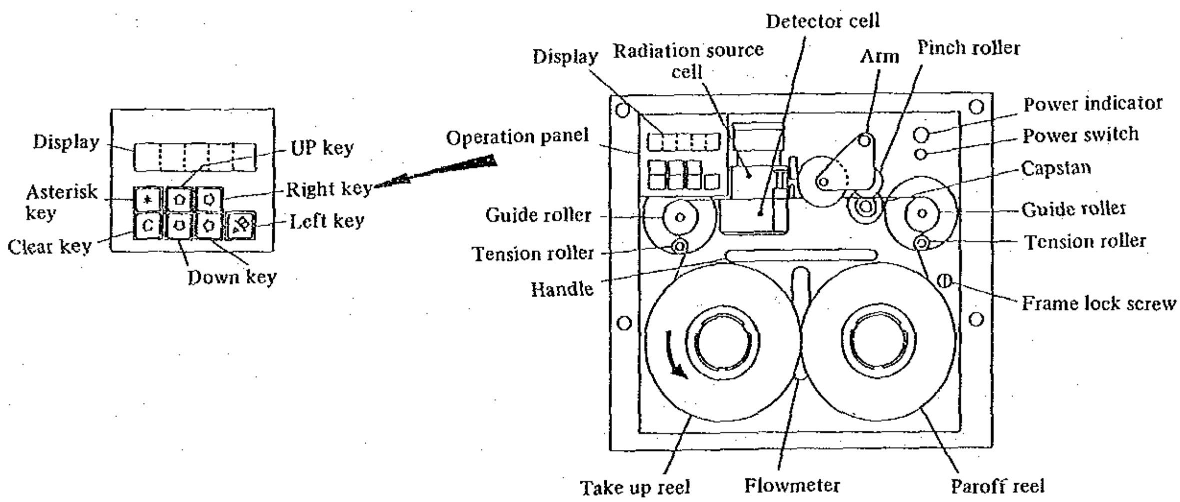


Fig. III-4-6 Operation board of front part

Table III-4-3 Operation mode

Indicater	Mode	Objective
00-00 (In case of time mode blinking at a second inverval)	Automatic monitor	Normally indicating time (flash 1 sec) alarm signal indicating at abnormal
1	Manual handling	Moving ray source, filter forwarding, ON/OFF of pump, flow rate regulation
2	Equivalent membrane value	Recording and indicating of membrane value
3	Calibration	Blank monitoring, membrane monitor, calibration
4	Span coefficient	Recording and indicating of span coefficient
5	Time	Time correction and indication
6	Month and Day	Correction of month and day
7	Year	Correction of year
8	Station number	Recording of station number
9	Judgement	Confirmation of ROM, recording of corrected number, printing data, confirmation of installed watch
A	Corrected Value A	Recording and indicating of numerical values for zero point adjustment, without changing membrane
b	Corrected Value B	Recording and indicating of numerical values for adjustment of sensibility without changing membrane
c	Transmittance test	Output selecting 10 divided sensibility of 0-1000 pulse/hour

(3) Calibration

The calibration of Beta ray analyser is conducted as follows;

(a) place the equivalent membrane made by plastic film on the filter of detecter previously measured blank value, as shown in Fig. III-4-7,

(b) Beta ray is absorbed into membrane and output the weight concentration corresponding to the thickness of the film,

(c) and confirmation of equivalent membrane value or alteration of membrane value is conducted by operating or adjusting key panel.

Fig. III-4-8 shows the results of monitoring by several types of materials and from the figure, the straight line character is found among substances of different density.

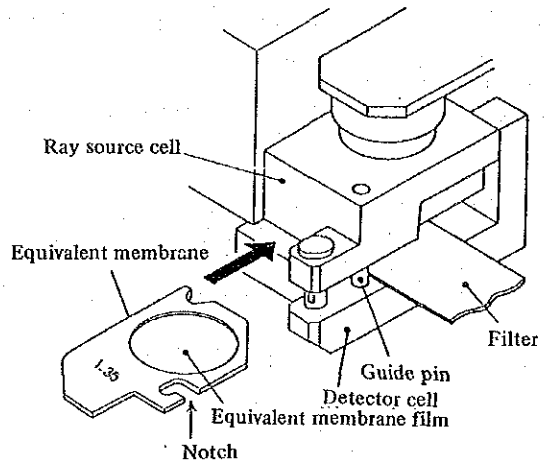


Fig. III-4-7 Installation of equivalent membrane

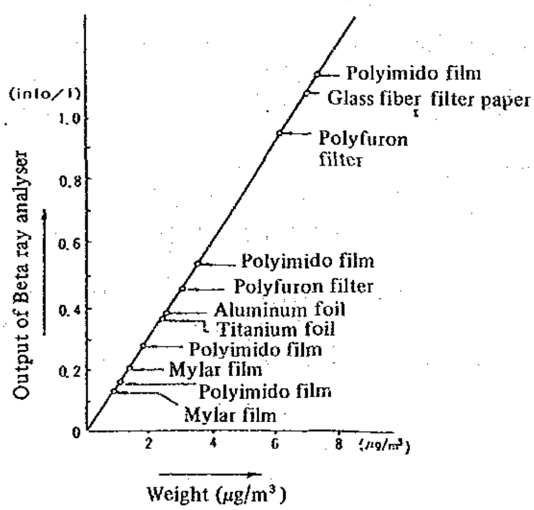


Fig. III-4-8 Relation of output by various types of membrane and Beta ray analyser

(4) Maintenance

The maintenance works are to be carried out as shown in Table III-4-4 in order to operate the instrument in order and to keep maintaining the designed capacity and function.

In this study, replacement of filter (once a month), calibration by equivalent membrane and daily check were conducted by Singapore counter part. Other maintenance works have been carried out by Japanese team during their stay in Singapore for the fields survey (2nd to 4th field survey). Picture III-4-1 shows calibration work of Beta ray analyser.

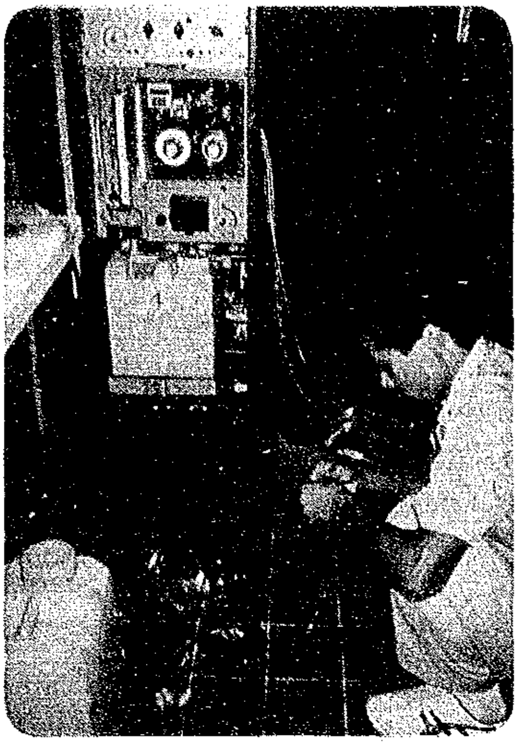
Table III-4-4 Maintenance work of Beta ray dust analyser

	Maintenance item		Maintenance cycle							Reference
	Object	Work contents	1 week	2 weeks	1 months	2 months	3 months	6 months	Year	
1.	Filter	Replace with new one			□					7.3
2.	Separater	Cleansing of inside					Δ			7.4
3.	Air sucking pump	Diaphragm replace						□		7.5
		Valve heat replace							□	7.8
4.	Internal tubes connection	Cleansing of tube					Δ			7.7
		Replace with new one						□		
5.	Ray cell	Cleansing inside						Δ		7.6
6.	Air inlet tube	Cleansing inside					Δ			
		Replace with new one							□	
7.	Calibration	Calibration by equivalent membrane			O					5.2

O : check normal operation, adjust at specified value

Δ : cleansing of specified parts

□ : replacement of specified parts for maintaining good condition



Picture III-4-1 Outside view of Beta ray dust analyser installed in SO_2 analyser

III-4-1-2 Results of monitoring

The effective monitoring hours for suspended particulate matter at MP-1, 2 and 6 are shown in Table III-4-5.

The effective monitoring hours mean the total monitoring hours excluding the time for calibration, instrumental troubles and so on. In Japan, it is defined that annual monitoring hours should exceed 6,000 hours for effective monitoring.

As shown in the table, all the stations have exceeded 6,000 hours.

Table III-4-5 Effective monitoring hours

Monitoring station	Effective hours	Monitoring rate
MP-1	7,642 hours	87.0%
MP-2	8,166	93.0%
MP-6	7,618	86.7%

Remarks: December 7th 1983 to December 6th 1984 = 8,784 hours

Data on one hour average values of SPM at each monitoring stations are shown in Table III-4-6. The concentration of annual, by monsoon and by day and night at each monitoring station are shown in Table III-4-7. Further the analysis of these monitored data is described in Part V of the report.

Table III-4-6 An example of monitoring results of suspended particulate matter

*** ﾒ ｲ ｻ ｲ ｹﾞｯ ﾎﾟｳ *** PAGE - 4

1984 ﾈﾝ 1 ｶﾞﾂ ｺｳﾓｸ (106) SPM ｸﾌﾞﾝ 0 ｷﾖｸ (1) (MP1) J.T.C. HALL (UG/M3)

.ｼﾞ ﾆﾁ.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	MIN	MAX	AVE	HOUR	TOTAL
1	20	18	10	10	10	8	10	20	4	4	8	10	5	8	5	10	2	2	10	10	16	30	20	28	2	30	12	24	288
2	12	10	10	10	10	30	45	54	78	38	30	10	10	12	0	10	10	8	14	8	12	24	30	38	0	78	21	24	513
3	30	55	40	40	38	32	22	20	38	20	10	10	14	10	20	12	25	15	6	10	12	12	4	10	4	55	21	24	505
4	10	10	24	20	20	20	35	30	35	30	28	20	50	32	20	20	40	40	30	10	20	40	54	40	10	54	28	24	678
5	60	55	30	50	40	50	50	60	80	54	30	30	25	20	22	15	20	20	25	25	25	38	30	30	15	80	37	24	884
6	22	30	10	10	25	15	18	20	30	34	34	32	30	10	14	10	10	20	20	30	20	24	25	40	10	40	22	24	533
7	54	30	18	20	30	15	12	40	50	20	20	20	20	20	10	5	10	8	10	10	30	25	20	20	5	54	22	24	517
8	25	40	10	24	12	10	5	2	12	10	10	20	10	10	10	10	20	35	35	22	45	30	18	10	2	45	18	24	435
9	10	10	20	20	15	10	20	25	35	30	40	20	20	5	5	24	24	25	40	50	25	40	30	30	5	50	24	24	573
10	20	30	30	50	30	28	50	70	65	80	50	45	40	10	40	32	25	22	40	30	40	40	28	35	10	80	39	24	930
11	35	30	38	30	30	30	30	50	45	50	45	60	30	44	50	60	54	60	80	98	60	40	35	26	26	98	46	24	1110
12	10	4	10	10	10	10	10	10	62	40	45	10	24	28	40	25	28	30	30	25	10	10	15	30	4	62	22	24	526
13	55	50	20	20	40	38	20	20	32	30	20	10	20	20	20	20	28	40	70	48	32	20	30	30	10	70	31	24	733
14	30	20	18	12	20	10	10	18	20	30	2	18	12	10	20	20	30	30	20	30	40	20	28	20	2	40	20	24	488
15	12	18	15	20	8	20	30	12	20	30	15	10	4	10	0	14	10	6	10	24	36	40	35	30	0	40	18	24	429
16	40	30	26	30	40	50	50	60	80	85	65	60	50	30	35	30	25	20	2	12	22	32	16	12	2	85	38	24	902
17	5	5	10	5	5	10	14	14	18	18	10	20	15	10	10	10	4	10	10	14	4	20	20	10	4	20	11	24	271
18	16	10	18	20	20	18	12	58	72	70	54	38	22	20	38	20	50	68	40	40	45	34	24	15	10	72	34	24	822
19	10	16	22	15	18	22	35	40	42	40	55	50	40	24	28	28	25	22	30	18	15	12	32	20	10	55	27	24	659
20	20	8	10	10	5	10	15	10	20	35	45	20	40	38	50	60	****	****	****	****	****	****	****	****	5	60	25	16	396
21	****	****	****	****	****	****	****	****	****	****	****	****	30	38	68	40	50	38	50	25	20	30	20	10	10	68	35	12	419
22	10	10	5	10	18	20	24	40	40	20	14	18	20	34	38	28	25	20	28	32	38	28	45	38	5	45	25	24	603
23	34	50	30	24	25	15	15	10	14	15	25	20	10	20	24	20	40	60	55	54	72	54	20	10	10	72	30	24	716
24	10	5	6	10	5	10	10	10	10	25	35	65	45	54	70	36	20	45	18	30	38	20	20	40	5	70	27	24	637
25	20	30	40	30	20	30	55	90	70	50	50	30	20	28	10	10	22	58	20	20	20	15	20	14	10	90	32	24	772
26	10	10	5	10	10	5	10	25	65	88	64	80	28	34	26	18	50	55	25	25	30	26	48	38	5	88	33	24	785
27	30	30	48	20	24	20	10	18	28	30	15	30	4	4	10	15	5	6	10	15	22	40	12	4	4	48	19	24	450
28	10	20	10	10	5	8	5	5	5	5	10	28	40	16	10	24	20	20	20	25	14	34	24	40	5	40	17	24	408
29	18	20	10	10	6	8	8	10	18	40	40	40	34	32	20	22	20	20	20	4	18	32	40	28	4	40	22	24	518
30	10	10	30	60	30	10	18	4	5	12	24	24	20	5	5	18	50	8	12	12	25	30	30	54	4	60	21	24	506
31	30	30	30	15	12	18	22	45	52	40	20	5	2	8	20	20	24	10	10	24	24	26	16	25	2	52	22	24	528
MIN	5	4	5	5	5	5	5	2	4	4	2	5	2	4	0	5	2	2	2	4	4	10	4	4	0				
MAX	60	55	48	60	40	50	55	90	80	88	65	80	50	54	70	60	54	68	80	98	72	54	54	54		98			
AVE	23	23	20	21	19	19	22	30	38	36	30	28	24	21	24	22	26	27	26	26	28	29	26	26			26		
HOUR	30	30	30	30	30	30	30	30	30	30	30	30	31	31	31	31	30	30	30	30	30	30	30	30				724	
TOTAL	688	694	603	625	581	580	670	890	1145	1073	913	853	734	644	738	686	766	821	790	780	830	866	789	775					18534

Table III-4-7 Concentration of SPM by Beta ray analyser by annual, season, and day & night

($\mu g/m^3$)

Monitoring station	S. monsoon (4-10)			N. monsoon (11-3)			Annual		
	Day	Night	Total	Day	Night	Total	Day	Night	Total
(1) J.T.C. HALL	20.0	26.3	23.4	26.1	29.0	27.7	22.6	27.4	25.2
(2) N.U.S.	23.8	31.2	27.8	29.1	32.5	30.9	26.0	31.8	29.1
(3) NANYANG.T.I	20.7	32.4	27.1	19.8	30.8	25.8	20.4	31.8	26.6

III-4-2 Monitoring of SO_2, Wind Direction & Velocity, Solar & Net Radiation, and Temperature

For one year from December 7th 1983 to December 6th 1984, automatic and continuous monitoring of SO_2, wind direction & velocity, solar & net radiation, and temperature have been conducted in terms of one hour average value at monitoring points as shown in Table III-4-1.

III-4-2-1 Instruments

In this study, the same instruments which were used at the previous short term field survey on air quality have been used, after overhauling and calibration. The specifications of the instruments employed in this study are shown in Table III-4-8 to Table III-4-12.

(1) SO_2 analyser

Table III-4-8 Specifications of SO_2 analyser

Name	Measuring instrument of ambient SO_2 concentration
Manufacturer	Denki Kagaku Keiki, KK
Type	GRH - 72
Objective pollutant	Ambient SO_2
Principle	Solution conductmetry
Measurement range	0-0.05, 0.1, 0.2, 0.5, 1 ppm 5 range automatic/manual change
Measurement cycle	60 minutes (switchable to 30 min.)
Recording	Saw-tooth dotted recording. Starting from zero and end of cycle indicates one hour average value
Sampling rate	1 liter/min.
Reagent quantity	20 ml
Reagent tank capacity	20 liter
Recording unit	Output ; 0-1 VDC Recording ; dotted saw-tooth recording, 25 mm/h Chart ; folded strip, 180 mm width
Output voltage	DC 0-1 V
Power requirements	AC 100 V ±10%, 50 Hz or 60 Hz
Weight	about 110 kg (including 20 liter of reagent)
Dimension	460 (W) x 1580 (H) x 500 (D)
External colour	Munsell N4

(2) Anemometer

Table III-4-9 Specifications of anemometer

Name	:	Low-threshold anemometer
Manufacturer	:	KOSHIN DENKI KOGYO Co. Ltd.
Type	:	MV-110B
Wind direction and velocity sensor		
Wind velocity sensor	:	4-blade propeller type
Electrical signal	:	D.C. Generator
Wind direction sensor	:	Light weight reinforced plastic tailfin type
Electrical signal	:	Torque synchro transmitter
Accuracy	:	Wind direction; within $\pm 3^\circ$ at wind velocity 0.4 m/s Wind velocity; within ± 0.3 m/s at wind velocity from 0.4 to 2 m/s or within $\pm 3\%$ at wind velocity from 2 to 20 m/s
Maximum wind velocity	:	60 m/s
Cable for remote transmission	:	Up to 1,000 m, 0.75 mm^2, 8-cond. cable, between sensor/transmitter and recorder or averaging device
Weight	:	Approx. 5 kg.
Recorder		
Type	:	Self-balancing, 2-pen system
Measurement range	:	Wind direction; All azimuths, with $540^\circ/360^\circ$ shifting Wind velocity; 0.4 to 20 m/s
Chart feeding velocity	:	30 mm/H
Chart	:	Effective width-180 mm (speed-100 mm, direction-70 mm) length-23 m (corresponding to 1 month's recording at speed of 30 mm/H)
Power supply	:	AC 100 V $\pm 10\%$, both for 50 and 60 Hz
Weight	:	Approx. 28 kg.
External casing	:	For both flush mounting and desk-top mounting

Table III-4-9 Specifications of anemometer (Cont'd)

Averaging device		
Electrical signal for recording	:	Manual switch between average and instantaneous values
Output signal	:	Average direction (0-540°) 0-1 V impedance 100Ω Average velocity (0-10 m/s) 0-1 V impedance 100Ω
Averaging method	:	10 minutes sequential average by electrical integration
Power supply	:	AC 100 V ±10%, both for 50 and 60 Hz
Weight	:	Approx. 20 kg.
External casing	:	For both flush mounting and desk-top mounting

(3) Solar radiation meter

Table III-4-10 Specifications of solar radiation meter

Sensitivity	7 mV/cal cm^{-2} $min.^{-1}$
Internal resistance	100Ω
Response speed	3.8 s. (63.2%)
Error by temperature fluctuation	-0.1%/°C
Cosin characteristics	2%
Directional function	all round
Weight	2.31 kg

(4) Net radiation meter

Table III-4-11 Specifications of net radiation meter

Power	25 mV/cal. Cm^{-2} $min.^{-1}$
Sensitivity difference	within 3%
Internal resistance	80Ω
Response speed	20 s.
Wave range	0.3 to 100μ over
Temperature range	-15°C to +40°C
Sensor dimension	38 mm x 38 mm
Polyethylene dome	0.1 mm thick

(5) Thermometer

Table III-4-12 Specifications of thermometer

Name	Platinum resistance thermometer
Manufacturer	KOSHIN DENKI KOGYO Co. Ltd.
Type	KTM
Sensing body Sensing device Measuring range Currency	 Platinum resistance 100Ω at 0°C 0°C to +60°C accuracy ±0.5°C 5 mA
Ventilating tube Type Flow speed Materials Painting Fan motor	 Double tube with ventilation 5 - 6 m/s anti-corrosion aluminium casting anti-corrosion alumina-alloy silver color melanin fuse painting Type :FC-100B AC100 V 50/60 Hz Currency : 0.15/0.18 A

III-4-2-2 Maintenance of instruments

Among works for maintenance of instruments, Singapore side has conducted daily maintenance works such as replacement of chart and so on, and Japanese team have carried out the calibration, replacement of mechanical parts and so on during their stay in Singapore for the short term field survey. The maintenance items and frequency are shown in Table III-4-13 to III-4-16. Picture III-4-2 shows maintenance work by Japanese team.

(1) SO_2 analyser

Table III-4-13 Maintenance items and frequency of SO_2 analyser

No.	Item for maintenance			Frequency							
	Item		Contents	1 w.	2 w.	1 m.	2 m.	3 m.	4 m.	6 m.	1 y.
1	Air sampling tube		1) dirt, leakage, damage, disconnection			x					
			2) rinsing of tube inside					x			
			3) replacement of tube								x
2	Air passage except sampling tube		1) dirt, leakage, damage, disconnection	x							
			2) rinsing of connector & inside tube					x			
			3) replacement of tube								x
			4) test for gas leakage					x			
3	Solution passage		1) dirt, leakage, damage, disconnection		x						
			2) rinsing of connector & inside tube					x			
			3) replacement of tube								x
4	Flow meter		1) dirt & dust of inside, position of float	x							
			2) adjustment to 1.0 liter/min.	x							
			3) rinsing of inside and float					x			
			4) check indication of flow rate							x	
5	Flow rate adjustment valve		1) check of flow rate adjustment range	x							
			2) rinsing of needle and inside					x			
6	Filter(1)	Element	1) replacement of element	x							
		Case	2) rinsing of inside and connector					x			
			3) replacement of filter case								x
7	Absorbing solution		preparation of solution and replacement		x						

Table III-4-13 Maintenance items and frequency of SO_2 analyser (Cont'd)

No.	Item for maintenance			Frequency							
	Item		Contents	1 w.	2 w.	1 m.	2 m.	3 m.	4 m.	6 m.	1 y.
8	Gas absorbing system		1) dirt, bubbling	x							
			2) rinsing of inside and electrode					x			
9	Air absorbing pump		1) abnormal noise and vibration, check of flow rate			x					
			2) rinsing of diaphragm, valve & joint					x			
			3) replacement of diaphragm and valve								x
10	Solenoid valve		check of opening & closing operation					x			
11	Solution charging pump		1) abnormal noise and vibration		x						
			2) check of flow rate			x					
12	Solution in impinger		1) check solution quantity as 20±0.4 ml					x			
			2) adjustment of electrode for level detector					x			
13	Calibration by equivalent solution		calibration of each range by equivalent solution				x				
14	Recorder	Chart	1) proper advance	x							
			2) check of chart slip	x							
			3) replacement of chart			x					
		Ink	4) shade of ink	x							
			5) supply of ink		x						
		Indicator	6) zero adjustment								x
15	Timer		check of time gap	x							
16	Power source, earth		check loosing, disconnection, brokage		x						
17	Adjustment of electronic circuit		adjustment of slide, range, balance, D/A								x
18	Filter(2)	by-path filter	replacement of element								x

Note: w.: week, m.: month y.: year

(2) Anemometer

Table III-4-14 Maintenance item and frequency of anemometer

Maintenance and Inspection		Frequency			
Item	Contents	Daily	Week	Month	3 M.
Pole	Inspection : confirmation of vertical erection and stretch of stay	x			
Sensor	Inspection : confirmation of rotation	x			
Recorder	Inspection : confirmation of chart advance, time deviation and ink shade	x			
	Replacement : chart replacement			x	
	Supply : ink supply		x		
Adjustment	Adjustment : adjustment of N of sensor and recorder adjustment of wind velocity zero				x x
Power cable and its connection	Inspection : confirmation of loose and disconnection	x			

(3) Solar and net radiation meter

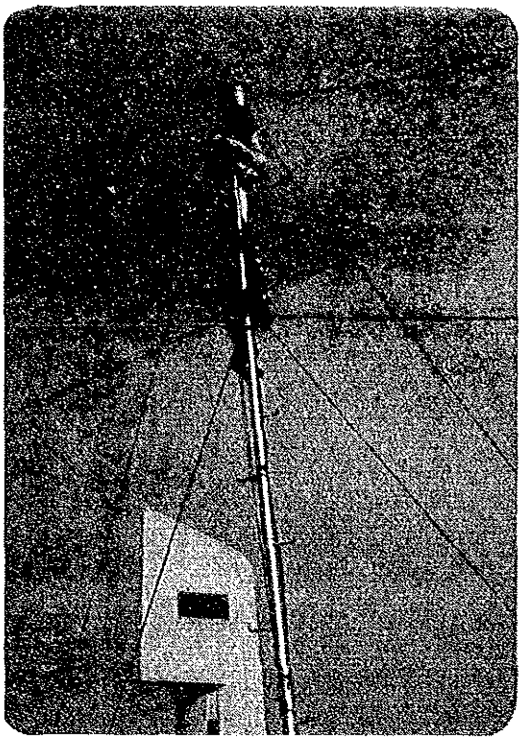
Table III-4-15 Maintenance item and frequency of solar and net radiation meter

Items			Frequency			
	Objective	Contents	Daily	Weekly	Month	Whenever necessary
Pyrano-meter	1) pole	confirm vertical erection	x			
	2) glass dome	blur or damage	x			
	3) silicagel	supply or replacement				x
Net radia-tion meter	1) pole	confirm vertical erection	x			
	2) polyethylene dome	blur or damage	x			
		tension of dome surface	x			
		replacement of dome			x	
	3) air pump	confirm flow rate	x			
		replacement of silicagel				x
Re-corder	1) recorder	confirm chart advance	x			
		confirm time slip of chart	x			
		check ink shade	x			
		replacement of chart			x	
		supply of ink		x		
	2) power supply & connection	confirm loose and discon-nection	x			

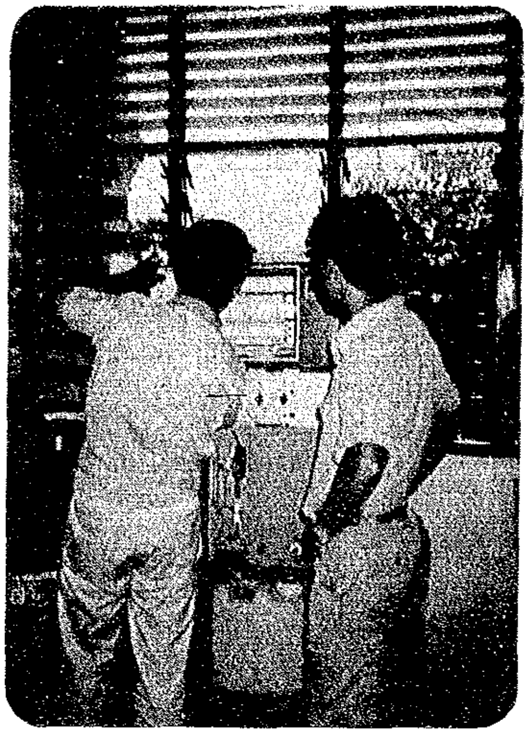
(4) Thermometer

Table III-4-16 Maintenance item and frequency of thermometer

Items		Frequency				
	Items & contents	Day	Week	1 Month	3 Month	Year
Sensor	(1) abnormal noise of air pump	x				
	(2) cleaning of shelter					x
Recorder	(1) chart advance, time slip of chart, ink shade	x				
	(2) replacement of chart			x		
	(3) ink supply		x			
Calibra-tion	Adjustment after comparison by Assmann thermometer				x	
Power & cable	loose and or disconnection of cable	x				



Calibration of anemometer (MP-1)



Calibration of SO_2 analyser (MP-20)

Picture III-4-2 Maintenance work of instruments

III-4-2-3 Results of monitoring

(1) Effective monitoring time

The effective monitoring hours of SO_2, wind direction & velocity, solar & net radiation and temperature at each station are shown in Table III-4-17 to III-4-20. From the tables, the monitoring hours are all exceeding that of effective stations in Japan.

Table III-4-17 Effective monitoring hours of SO_2

Station	Effective monitoring hours	Monitored (%)
MP-1	8011 hours	91.2
MP-2	7645 hours	87.0
MP-4	8229 hours	93.7
MP-6	7515 hours	85.6
MP-7	8302 hours	94.5
MP-14	8011 hours	91.2
MP-20	8445 hours	96.1

Table III-4-18 Effective monitoring hours of anemometer

Station	Effective monitoring hours		Monitored (%)	
	Wind direction	Velocity	Direction	Velocity
MP-1	8,376	8,164	95.4	92.9
MP-2	8,195	8,080	93.3	92.0
MP-4	8,400	8,327	95.6	94.8
MP-6	8,006	8,006	91.1	91.1
MP-7	8,447	8,316	96.2	94.7
MP-14	8,180	8,128	93.1	92.5
MP-20	7,759	8,197	88.3	93.3

Table III-4-19 Effective monitoring hours of solar & net radiation

Station	Effective monitoring hours		Monitored (%)	
	Solar radiation	Net radiation	Solar	Net radiation
Changi airport	8,737	8,431	99.5	96.0

Table III-4-20 Effective monitoring hours of temperater

Station	Effective monitoring hours		Monitored (%)	
	1.5 m from ground	30 m from ground	1.5 m	30 m
MP-1	8,121	7,994	92.5	91.0

(2) SO_2

The average concentration of SO_2 by year, N monsoon, S monsoon and day/night are shown in Table III-4-21.

Yearly average SO_2 concentration is high in sequence of
MP4 MP1 MP6 MP7 MP2 & MP14 MP20.

Further an example of the results of monitoring of respective station is shown in Table III-4-22, and all results are shown in the part of reference of this report. The results of analysis of SO_2 concentration are described in Part V of the report.

Table III-4-21 Results of SO_2 monitoring

(ppb)

Station	S. Monsoon (4-10)			N. Monsoon (11-3)			Yearly average		
	Day	Night	Through	Day	Night	Through	Day	Night	Through
(1) J.T.C. HALL	20.6	16.0	18.1	21.3	16.0	18.4	20.9	16.0	18.2
(2) N.U.S.	15.4	12.2	13.7	17.2	12.0	14.4	16.2	12.1	14.0
(4) Boon Lay Apartment	35.0	16.0	24.7	22.3	15.4	18.5	30.1	15.7	22.3
(6) Nanyang.T.I.	21.1	12.7	16.5	15.1	9.2	11.9	18.9	11.4	14.8
(7) Bukit Panjang P.P.	21.6	10.5	15.6	18.7	8.6	13.2	20.4	9.7	14.6
(14) Kallang.F.F.	16.7	12.9	14.6	15.9	11.0	13.2	16.4	12.1	14.0
(20) Singapore offshore P.S.	14.7	9.3	11.7	13.0	8.5	10.5	14.0	9.0	11.3

S. Monsoon: April to October
N. Monsoon: November to March
Day: 07:00 to 17:59
Night: 18:00 to 06.59

Table III-4-22 An example of results of monitoring of SO_2 (one hour average)

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1984 ﾈﾝ 1 ｶﾞﾂ ｺｳﾓｸ (101) SO2 ｸﾌﾞﾝ 0 ｷﾖｸ (1) (MP1) J.T.C. HALL (PPB)

ｼﾞ / ﾆﾁ.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	MIN	MAX	AVE	HOUR	TOTAL
1	42	9	8	20	24	30	16	20	25	13	14	12	13	12	13	14	22	17	14	13	19	12	17	19	8	42	17	24	418
2	14	9	9	17	24	19	22	37	31	13	18	17	16	28	15	15	20	40	24	21	20	13	11	21	9	40	20	24	474
3	14	19	21	19	17	14	10	11	26	14	11	12	12	16	13	12	13	12	11	14	13	12	11	11	10	26	14	24	338
4	19	24	28	17	26	24	23	17	22	12	12	12	17	18	36	40	70	36	19	33	29	13	9	12	9	70	24	24	568
5	20	18	14	24	16	14	23	22	22	****	40	37	23	23	12	23	12	10	10	10	9	10	25	11	9	40	19	23	428
6	9	17	18	29	35	20	13	30	44	16	31	65	29	35	17	12	13	17	14	10	26	17	19	22	9	65	23	24	558
7	20	14	54	28	20	26	12	22	8	8	9	9	15	24	12	9	9	9	9	8	8	8	24	54	8	54	17	24	419
8	30	35	32	10	22	29	10	10	8	11	8	14	9	19	8	9	9	9	8	8	12	9	9	9	8	35	14	24	337
9	9	9	21	20	21	14	17	30	21	82	66	28	51	28	11	15	19	13	23	43	76	26	18	20	9	82	28	24	681
10	18	11	17	15	11	13	17	19	16	39	68	47	29	34	15	14	14	26	17	17	17	18	11	16	11	68	22	24	519
11	11	17	16	16	14	16	16	17	11	14	13	14	49	33	34	23	22	12	10	12	12	7	7	6	6	49	17	24	402
12	14	12	14	25	22	10	6	6	7	7	7	8	8	9	9	9	11	22	18	8	8	36	28	15	6	36	13	24	319
13	32	15	15	15	10	9	8	7	6	8	9	53	23	59	81	23	43	61	27	13	10	9	7	7	6	81	23	24	550
14	8	6	6	6	6	6	5	6	7	7	11	18	24	14	12	31	19	24	18	10	7	6	6	6	5	31	11	24	269
15	6	7	7	9	7	6	6	7	7	8	9	25	30	13	15	20	18	18	13	16	9	8	8	8	6	30	12	24	280
16	8	8	9	13	22	26	14	18	27	16	19	43	40	38	43	37	18	16	14	14	17	12	9	17	8	43	21	24	498
17	43	10	9	9	12	9	9	8	17	26	34	55	60	52	49	31	41	20	11	10	8	9	8	11	8	60	23	24	551
18	9	9	8	9	7	7	8	18	21	23	108	56	18	15	30	32	47	51	15	9	10	7	7	13	7	108	22	24	537
19	7	8	6	5	6	7	7	6	7	19	****	83	25	14	19	33	25	22	21	19	44	42	29	24	5	83	21	23	478
20	10	7	9	8	10	9	8	7	9	10	17	31	55	24	39	33	****	****	****	****	****	****	****	****	7	55	18	16	286
21	****	****	****	****	****	****	****	****	****	****	****	****	53	44	36	33	31	24	28	34	38	25	16	8	8	53	31	12	370
22	6	6	5	6	5	5	5	7	10	7	90	94	54	27	23	15	12	12	15	16	15	9	8	8	5	94	19	24	460
23	8	8	11	7	10	9	8	9	10	11	16	17	26	24	22	19	24	24	20	16	16	14	10	7	7	26	14	24	346
24	7	6	8	10	19	10	7	8	15	52	132	190	59	67	53	****	28	14	13	27	13	8	9	12	6	190	33	23	767
25	18	16	18	18	9	6	24	26	15	7	7	7	6	6	7	8	6	13	11	18	7	17	8	5	5	26	12	24	283
26	40	14	11	8	5	28	26	10	19	15	18	43	21	43	13	12	9	12	18	7	6	17	25	9	5	43	18	24	429
27	15	13	20	9	11	6	6	5	5	12	12	11	10	10	10	10	9	11	11	10	11	15	10	9	5	20	10	24	251
28	19	16	13	10	6	20	10	6	6	8	19	21	21	11	10	10	10	9	7	6	10	9	17	21	6	21	12	24	295
29	16	13	5	5	5	5	4	4	4	6	5	7	6	9	8	6	8	17	10	11	8	14	13	16	4	17	9	24	205
30	5	6	22	19	14	5	5	4	11	10	11	46	60	28	26	30	20	13	8	7	15	10	16	21	4	60	17	24	412
31	8	13	7	4	4	4	4	14	12	11	31	16	7	9	11	17	36	11	10	10	16	31	13	8	4	36	13	24	307
MIN	5	6	5	4	4	4	4	4	4	6	5	7	6	6	7	6	6	9	7	6	6	6	6	5	4				
MAX	43	35	54	29	35	30	26	37	44	82	132	190	60	67	81	40	70	61	28	43	76	42	29	54		190			
AVE	16	13	15	14	14	14	12	14	15	17	29	36	28	25	23	20	21	20	15	15	17	15	14	14			18		
HOUR	30	30	30	30	30	30	30	30	30	29	29	30	31	31	31	30	30	30	30	30	30	30	30	30				721	
TOTAL	485	375	441	410	420	406	349	411	449	485	845	1091	869	786	702	595	638	595	447	450	509	443	408	426					13035

(3) Wind direction and velocity

Yearly appearance frequency of wind direction at each monitoring station is shown in Fig. III-4-9 as wind rose. The average wind velocity by season and time is shown in Table III-4-23. The results of analysis of wind direction and velocity are described in Part V of this report.

An example of monitoring results of wind direction and velocity are shown in Table III-4-24 and all the results are shown in the part of reference of this report.

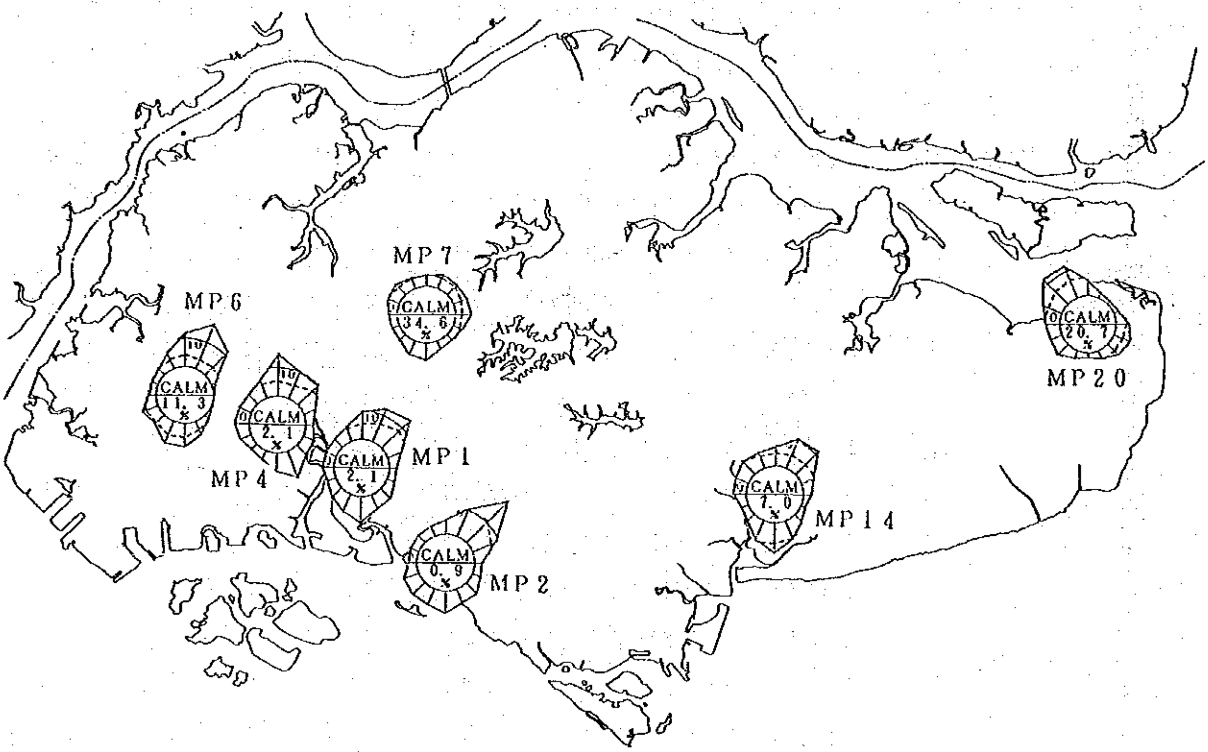

Fig. III-4-9 Results of monitoring of wind direction (appearance frequency of wind direction)

Table III-4-23 Results of monitoring of wind velocity

(m/sec)

Station	S. Monsoon (4-10)			N. Monsoon (11-3)			Yearly average		
	Day	Night	Through	Day	Night	Through	Day	Night	Through
(1) J.T.C. HALL	2.5	1.7	2.1	2.6	2.1	2.3	2.6	1.8	2.2
(2) N.U.S.	3.0	2.1	2.5	3.1	2.8	2.9	3.0	2.4	2.7
(4) BOON LAY APART	3.0	1.9	2.4	2.3	1.7	2.0	2.7	1.8	2.2
(6) NANYANG.T.I.	1.3	0.8	1.1	1.2	1.1	1.1	1.3	0.9	1.1
(7) BUKIT PANJANG P.P.	1.4	0.6	0.9	1.2	0.5	0.8	1.3	0.5	0.9
(14) KALLANG.F.F.	2.3	1.3	1.8	2.0	1.3	1.6	2.2	1.3	1.7
(20) SINGAPORE O.P.S.	1.2	0.7	0.9	2.2	1.5	1.8	1.6	1.0	1.3

Table III-4-24-(1) An example of monitoring results (hourly value) of wind direction

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1984 ネン 1 ガツ コウモク (1) フウコウ クブン 0 キヨク (1) (MP1) J.T.C. HALL

ジ ニチ	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	HOUR
1	NNE	NE	NNE	NNE	NNE	NNE	NNE	NE	NNE	NNE	N	NNE	N	NNE	N	N	NE	NNE	N	NNE	NNE	NNE	N	N	24
2	NNE	NNE	NNE	N	N	N	N	N	N	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NE	NE	NNE	NNE	NNE	NNE	NNE	24
3	N	NNW	NNE	N	N	NNE	NNE	N	N	N	NNE	N	NNE	NNE	NNE	N	N	N	N	N	N	NNE	NNE	N	24
4	N	N	N	N	N	N	N	N	N	NNE	N	N	NNE	NNE	NNE	NNE	NNE	NNE	NE	NNE	NE	NE	NNE	NNE	24
5	NNE	NNE	NNE	NNE	NNE	NNE	N	N	N	NNE	NNE	NNE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	24
6	NE	NNE	NNE	NE	NNE	NNE	NNE	NNE	N	N	NNE	NE	NNE	NE	NE	NE	NE	NE	NE	NE	NE	NNE	N	NNW	24
7	NNW	NNE	NNE	N	NNE	NNE	NNE	NE	NE	NE	NE	NE	NNE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NNE	NNE	24
8	NNE	NE	NE	NE	NNE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	24
9	NE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	N	24
10	NNW	NNW	N	NNE	NNE	NNE	N	NNW	NNE	NNE	N	NNE	NE	NE	N	N	NNE	NNE	NNE	N	N	NNE	NNE	NNE	24
11	NNE	N	N	N	N	N	N	NNW	NNW	N	NNE	NNE	NE	NNE	NNE	NNE	N	ENE	N	NNE	ESE	ESE	E	ENE	24
12	NE	NNE	NNE	NE	NNE	NNE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	ENE	NE	NE	NE	NNE	NNE	NNE	24
13	N	NNE	NE	NE	ENE	ENE	NNE	NE	NE	NE	NE	NE	NE	NNE	NE	NNE	NNW	WSW	W	ENE	ENE	ENE	NE	NE	24
14	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	ENE	NE	NE	NNW	W	C	ENE	NE	NE	NE	NE	24
15	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NNE	NE	NE	NNE	NNW	NNW	NNE	NE	NE	NE	ENE	NNE	24
16	NE	NE	NE	NNE	NNE	NNE	NE	NNE	NNE	NNE	NE	NE	NE	NNE	NE	ENE	ENE	NE	NE	NNE	NE	NE	NE	NE	24
17	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NNE	NNE	NNE	NNE	NE	NE	NE	NE	NE	NE	NE	NE	NE	24
18	NNE	NE	NE	ENE	NE	NE	NNE	NW	N	NNE	NE	N	NNE	NNE	ESE	NE	C	NNW	NNE	NNW	NE	ENE	ENE	ENE	24
19	ENE	NE	NE	NE	NE	NE	ENE	NE	NE	NNE	NE	NNE	N	NNE	WSW	SSW	SSW	E	ESE	ENE	ENE	ENE	ENE	NE	24
20	ENE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NNE	NNE	SW	SSW	***	***	***	***	***	***	***	***	16
21	***	***	***	***	***	***	***	***	***	***	***	***	ENE	S	S	S	S	ESE	NNE	ENE	ENE	ENE	NE	ENE	12
22	NE	NE	NNE	NNE	NE	NE	NE	NNE	NNE	NE	NNE	NNE	NNE	SSW	S	ESE	ESE	E	NNW	N	NNE	***	***	***	21
23	***	***	***	***	***	***	***	***	***	***	NNE	NE	ENE	S	NNW	WSW	NE	NE	NNE	ENE	ENE	NE	NE	NE	14
24	NNE	NNE	NNE	NE	NNE	NE	NNE	NNE	NNE	NNE	NNE	N	N	NNE	SSW	WSW	W	N	N	N	NNE	NNE	NNE	NNE	24
25	N	N	NNW	NW	NW	NNW	N	N	NW	NW	***	***	NW	ENE	S	ESE	NNE	N	NNE	NE	NNE	NE	ENE	NE	22
26	NE	NNE	ENE	NE	NE	NE	N	NNW	N	NNE	NNE	NNE	NNE	NE	WSW	NE	NE	NE	NE	NE	NE	NNE	N	NNE	24
27	NNE	N	NNW	N	NNW	NNW	NNW	NNW	N	N	N	N	NNE	NNE	N	N	NNE	N	N	NNE	N	NNE	NNE	NNE	24
28	NE	NNE	NNE	NNE	NNE	NE	NE	NE	NE	NNE	NNE	NNE	NNE	NNE	N	N	NNE	NNE	NE	NNE	NE	NNE	N	N	24
29	NNE	NNW	NNW	NW	NW	NNW	NW	NNW	NNW	NE	N	N	N	N	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNW	N	NNW	24
30	NNW	N	N	N	NNW	NNW	NNW	NNW	N	N	NNE	NNE	NNE	NNE	N	SW	E	WNW	NE	NNE	NNE	N	N	N	24
31	NNE	NNW	NNW	NNW	NW	NW	NNE	N	N	NNE	NNE	NE	NE	NE	ESE	SSW	SSE	ENE	NE	NNE	NE	NE	NE	NE	24
HOUR	29	29	29	29	29	29	29	29	29	29	29	29	31	31	31	31	30	30	30	30	30	29	29	29	709

Table III-4-24-(2) An example of monitoring results (hourly value) of wind velocity

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1984 ﾈﾝ 1 ｶﾞﾂ ｺｳﾓｸ (2) ﾌｳｿｸ ｸﾌﾞﾝ 0 ｷｮｸ (1) (MP1) J.T.C. HALL (0.1M/S)

ﾋ ﾆﾁ.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	MIN	MAX	AVE	HOUR	TOTAL
1	24	24	24	22	12	32	33	32	37	29	34	28	34	35	40	37	28	31	26	27	21	26	29	24	12	40	29	24	689
2	21	21	20	15	13	11	16	17	21	28	34	41	45	40	41	38	43	45	50	33	27	36	26	23	11	50	29	24	705
3	14	14	17	20	24	17	20	18	18	28	40	32	44	38	30	45	33	37	37	30	35	37	29	25	14	45	28	24	682
4	29	20	24	22	23	19	27	26	27	39	39	29	41	30	43	35	38	43	43	31	20	17	13	13	13	43	29	24	691
5	14	10	12	16	17	21	18	17	17	35	52	30	32	42	54	44	61	60	57	46	38	34	37	33	10	61	33	24	797
6	24	28	25	41	25	26	30	22	20	30	35	46	40	48	49	51	66	58	49	42	36	25	17	16	16	66	35	24	849
7	15	19	23	19	21	25	25	32	32	31	43	46	35	38	53	52	49	52	45	56	31	27	39	37	15	56	35	24	845
8	31	36	32	29	23	21	34	36	35	43	51	60	53	54	50	43	50	52	52	45	49	47	43	35	21	60	42	24	1004
9	37	29	24	25	19	16	23	28	38	43	46	36	40	41	36	30	38	36	35	35	38	28	24	15	15	46	32	24	760
10	12	8	13	15	18	18	13	12	13	23	26	30	27	44	26	22	34	33	31	26	24	17	18	22	8	44	22	24	525
11	17	12	17	16	15	14	15	13	11	21	13	20	26	22	21	15	11	8	9	6	11	12	10	28	6	28	15	24	363
12	27	29	26	21	20	18	23	31	30	35	41	45	47	58	52	49	53	47	45	36	25	32	30	19	18	58	35	24	839
13	15	17	18	17	18	15	26	28	32	32	31	25	17	21	23	22	7	16	10	8	29	39	28	25	7	39	22	24	519
14	26	24	27	27	30	29	27	28	29	41	41	43	27	32	24	31	22	13	3	20	34	32	31	28	3	43	28	24	669
15	26	22	27	29	18	11	14	17	20	24	35	32	21	26	15	16	20	14	12	28	25	29	30	21	11	35	22	24	532
16	24	19	21	15	20	13	10	13	11	10	24	31	25	22	22	42	45	34	38	27	31	41	33	29	10	45	25	24	600
17	30	31	32	25	26	21	21	24	32	44	44	35	27	29	27	33	37	35	38	30	29	31	23	26	21	44	30	24	730
18	17	13	19	27	23	26	14	7	6	12	29	19	15	14	25	21	3	9	16	19	23	27	25	24	3	29	18	24	433
19	25	27	31	22	19	21	22	23	34	35	37	27	18	16	14	37	25	17	10	28	36	28	24	24	10	37	25	24	600
20	23	23	28	25	18	21	27	24	27	26	36	29	23	18	27	35	*****	*****	*****	*****	*****	*****	*****	*****	18	36	26	16	410
21	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0	0	0	0	0
22	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0	0	0	0	0
23	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0	0	0	0	0
24	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	0	0	0	0	0
25	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	11	8	19	12	12	23	32	27	26	30	29	19	8	32	21	12	248
26	18	18	14	23	27	23	19	13	18	17	21	20	28	26	16	9	34	30	40	29	27	27	22	28	9	40	23	24	547
27	22	17	21	28	26	21	25	15	19	27	29	38	36	44	32	34	25	31	33	30	18	21	30	37	15	44	27	24	659
28	27	24	26	26	25	28	28	28	32	28	30	31	29	35	30	34	20	24	21	26	22	23	19	18	18	35	26	24	634
29	18	20	14	16	16	18	14	11	13	14	19	18	26	26	25	32	36	34	29	21	10	7	11	21	7	36	20	24	469
30	18	11	13	10	12	10	15	8	20	21	26	28	22	30	7	34	21	11	29	15	14	17	17	19	7	34	18	24	428
31	20	15	13	10	11	12	7	24	25	27	37	29	28	18	20	12	14	34	32	15	28	26	30	38	7	38	22	24	525
MIN	12	8	12	10	11	10	7	7	6	10	13	18	11	8	7	9	3	8	3	6	10	7	10	13	3				
MAX	37	36	32	41	30	32	34	36	38	44	52	60	53	58	54	52	66	60	57	56	49	47	43	38		66			
AVE	22	20	22	22	20	20	21	21	24	29	34	33	30	32	30	32	32	32	32	28	27	28	26	25			27		
HOUR	26	26	26	26	26	26	26	26	26	26	26	26	27	27	27	27	26	26	26	26	26	26	26	26				628	
TOTAL	574	531	561	561	519	507	546	547	617	743	893	848	817	855	821	865	825	827	822	736	707	716	667	647					16752

(4) Solar and net radiation

Daily variation pattern of solar and net radiation monitored at Changi Airport Observatory is shown in Fig. III-4-10. (yearly average value of same hour)

The results of analysis are described in Part V of the report. Further all the results of monitoring of one hour average values are processed and shown in the part of reference of the report.

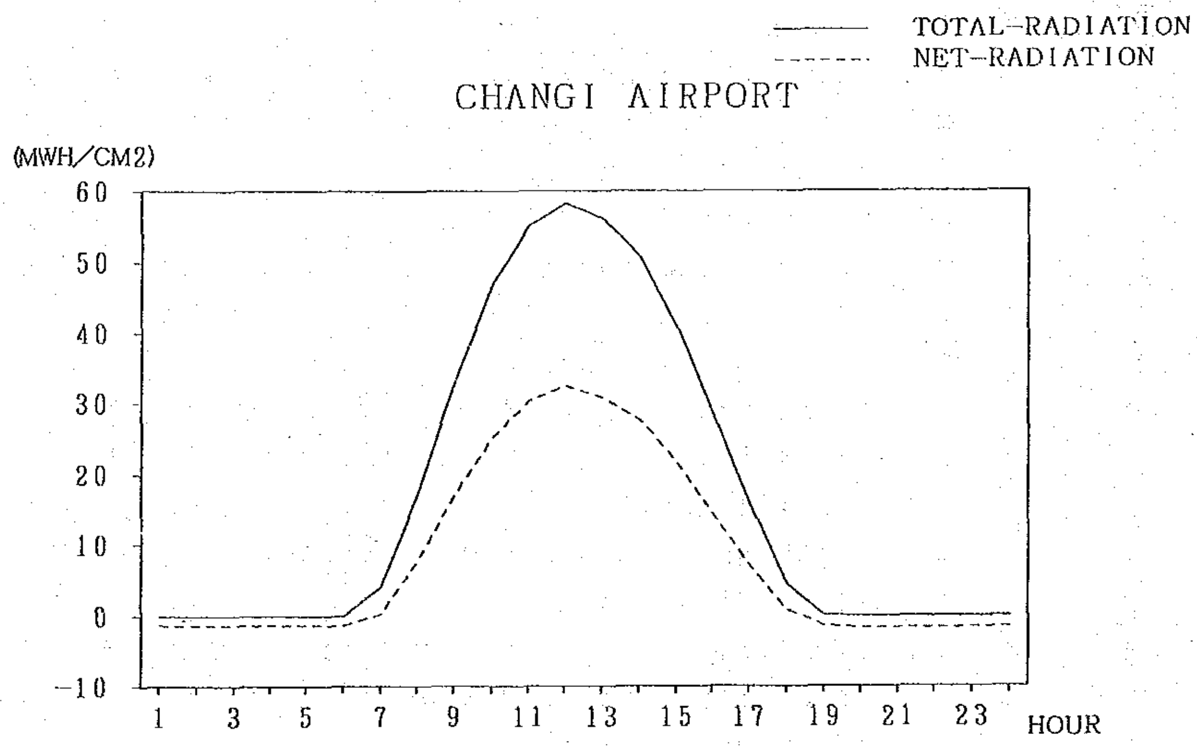

Fig. III-4-10 Results of monitoring of solar and net radiation (Daily variation pattern)

Table III-4-25-(1) An example of results of monitoring of solar radiation (one hour average value)

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1984 ﾈﾝ 1 ｶﾞﾂ ｺｳﾓｸ (3) ﾆｯｼｬﾘｮｳ ｸﾌﾞﾝ 1 ｷｮｸ (30) CHANGI AIRPORT (W/M2)

ｼﾞ / ﾆﾁ.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	MIN	MAX	AVE	HOUR	TOTAL
1	0	0	0	0	0	0	41	240	475	614	666	761	868	707	607	470	263	41	0	0	0	0	0	0	0	868	240	24	5753
2	0	0	0	0	0	0	30	118	390	574	695	811	697	503	429	271	143	55	1	0	0	0	0	0	0	811	197	24	4717
3	0	0	0	0	0	0	21	113	281	425	233	321	344	309	199	163	97	38	0	0	0	0	0	0	0	425	106	24	2544
4	0	0	0	0	0	0	25	195	236	428	524	533	418	415	313	231	143	65	1	0	0	0	0	0	0	533	147	24	3527
5	0	0	0	0	0	0	33	157	388	419	338	864	694	698	690	408	279	82	2	0	0	0	0	0	0	864	211	24	5052
6	0	0	0	0	0	0	36	192	356	390	550	613	623	623	642	417	315	83	2	0	0	0	0	0	0	642	202	24	4842
7	0	0	0	0	0	0	29	90	213	351	494	361	486	321	534	455	286	46	1	0	0	0	0	0	0	534	153	24	3667
8	0	0	0	0	0	0	23	92	233	399	351	369	52	360	213	202	83	33	0	0	0	0	0	0	0	399	100	24	2410
9	0	0	0	0	0	0	29	182	319	357	310	219	242	277	397	374	92	49	1	0	0	0	0	0	0	397	119	24	2848
10	0	0	0	0	0	0	26	140	424	491	506	269	289	555	597	232	101	35	1	0	0	0	0	0	0	597	153	24	3666
11	0	0	0	0	0	0	14	66	71	100	202	139	110	127	189	80	12	2	0	0	0	0	0	0	0	202	46	24	1112
12	0	0	0	0	0	0	34	141	294	317	544	525	467	401	299	207	198	97	2	0	0	0	0	0	0	544	147	24	3526
13	0	0	0	0	0	0	23	166	379	544	684	790	717	740	645	518	317	72	1	0	0	0	0	0	0	790	233	24	5596
14	0	0	0	0	0	0	20	114	380	492	693	881	878	892	558	272	185	85	3	0	0	0	0	0	0	892	227	24	5453
15	0	0	0	0	0	0	24	285	285	540	687	712	889	807	691	509	302	65	1	0	0	0	0	0	0	889	242	24	5797
16	0	0	0	0	0	0	20	115	199	249	497	611	802	479	457	370	257	75	2	0	0	0	0	0	0	802	172	24	4133
17	0	0	0	0	0	0	39	205	422	638	805	865	890	828	485	435	347	108	3	0	0	0	0	0	0	890	253	24	6070
18	0	0	0	0	0	0	32	181	361	618	512	686	608	702	537	315	182	70	4	0	0	0	0	0	0	702	200	24	4808
19	0	0	0	0	0	0	32	199	422	634	788	821	931	620	398	451	107	34	2	0	0	0	0	0	0	931	227	24	5439
20	0	0	0	0	0	0	18	127	245	433	642	780	740	435	335	142	50	4	0	0	0	0	0	0	0	780	165	24	3951
21	0	0	0	0	0	0	13	103	258	513	467	646	732	638	535	429	157	45	0	0	0	0	0	0	0	732	189	24	4536
22	0	0	0	0	0	0	27	195	410	612	755	843	472	445	634	267	194	38	1	0	0	0	0	0	0	843	204	24	4893
23	0	0	0	0	0	0	18	121	398	601	740	869	873	436	46	50	64	51	2	0	0	0	0	0	0	873	178	24	4269
24	0	0	0	0	0	0	13	93	273	228	495	375	736	644	99	29	71	45	1	0	0	0	0	0	0	736	129	24	3102
25	0	0	0	0	0	0	26	190	235	525	394	204	129	26	59	47	30	10	0	0	0	0	0	0	0	525	78	24	1875
26	0	0	0	0	0	0	****	****	332	566	652	506	281	664	430	55	82	53	3	0	0	0	0	0	0	664	165	22	3624
27	0	0	0	0	0	0	25	80	219	211	328	410	295	315	500	362	192	15	0	0	0	0	0	0	0	500	123	24	2952
28	0	0	0	0	0	0	6	28	77	159	283	369	452	452	231	165	157	56	2	0	0	0	0	0	0	452	102	24	2437
29	0	0	0	0	0	0	3	20	57	102	67	120	93	40	46	32	57	37	3	0	0	0	0	0	0	120	28	24	677
30	0	0	0	0	0	0	41	129	254	506	649	546	462	657	245	137	116	41	3	0	0	0	0	0	0	657	158	24	3786
31	0	0	0	0	0	0	15	40	234	573	769	913	833	783	561	361	232	63	3	0	0	0	0	0	0	913	224	24	5380
MIN	0	0	0	0	0	0	3	20	57	100	67	120	52	26	46	29	12	2	0	0	0	0	0	0	0				
MAX	0	0	0	0	0	0	41	285	475	638	805	913	931	892	691	518	347	108	4	0	0	0	0	0		931			
AVE	0	0	0	0	0	0	25	137	294	439	526	572	552	513	406	273	165	51	1	0	0	0	0	0			165		
HOUR	31	31	31	31	31	31	30	30	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31				742	
TOTAL	0	0	0	0	0	0	736	4117	9120	13609	16320	17732	17103	15899	12601	8456	5111	1593	45	0	0	0	0	0					122442

Table III-4-25-(2) An example of results of monitoring of net radiation (one hour average value)

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1984 ﾈﾝ 1 ｶﾞﾂ ｺｳﾓｸ (13) ﾎｳｼｬﾘｮｳ ｸﾌﾞﾝ 1 ｷｮｸ (30) CHANGI AIRPORT (W/M2)

ｼﾞ / ﾆﾁ	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	MIN	MAX	AVE	HOUR	TOTAL
1	-15	-15	-9	-6	-12	-21	-3	86	281	294	327	385	447	363	310	233	128	24	-5	-19	-13	-11	-14	-21	-21	447	113	24	2714
2	-21	-20	-17	-26	-22	-22	-5	42	174	276	342	409	351	250	212	134	60	10	-11	-12	-15	-17	-17	-4	-26	409	85	24	2051
3	0	0	0	0	0	0	-3	46	125	202	123	164	177	160	105	85	46	0	-7	-5	0	-11	-14	-18	-18	202	49	24	1175
4	-19	-17	-19	-10	-11	-11	-1	70	99	227	330	331	278	273	216	103	54	16	-12	-7	-7	-8	-15	-12	-19	331	77	24	1848
5	-6	-5	-1	-13	-14	-17	-8	54	170	199	164	441	347	349	345	182	116	14	-18	-29	-30	-24	-29	-32	-32	441	90	24	2155
6	-17	-16	-19	-23	-13	-11	0	56	158	183	267	302	307	305	316	197	140	19	-24	-26	-19	-13	-15	-10	-26	316	85	24	2044
7	-3	-5	-4	-1	-1	-2	-3	39	106	176	243	191	251	164	271	231	140	2	-2	-4	-11	-7	-4	-3	-11	271	74	24	1764
8	-9	-7	-10	-6	-1	-5	-5	35	108	200	180	184	106	83	99	87	27	4	-15	-23	-18	-15	-15	-20	-23	200	40	24	964
9	-14	-15	-15	-13	-10	-14	-7	59	135	165	145	101	116	133	203	179	39	8	-16	-21	-18	-16	-17	-16	-21	203	45	24	1091
10	-17	-8	-10	-13	-20	-21	-15	45	187	225	243	124	129	272	292	109	36	4	-10	-14	-10	-11	-10	-7	-21	292	63	24	1500
11	-6	-4	-5	-6	-6	-8	-6	11	21	35	91	60	42	49	80	24	-3	-9	-10	-1	-2	-4	-5	-7	-10	91	14	24	331
12	-12	-18	-16	-14	-15	-22	-10	35	68	148	268	265	231	199	149	97	81	31	-13	-12	-26	-24	-28	-27	-28	268	56	24	1335
13	-21	-20	-17	-4	-14	-30	-1	55	161	249	325	639	374	377	322	247	139	28	-25	-27	-25	-25	-26	-27	-30	639	111	24	2654
14	-24	-24	-23	-22	-19	-12	-16	11	133	189	423	612	626	628	366	151	82	18	-28	-27	-26	-27	-26	-26	-28	628	122	24	2939
15	-26	-27	-23	-32	-25	-25	-13	73	299	385	505	542	670	598	506	362	209	20	-9	-12	-13	-16	-23	-36	-36	670	162	24	3889
16	-32	-16	-12	-18	-12	-10	5	72	144	178	362	455	604	359	338	256	168	24	-27	-34	-36	-36	-35	-31	-36	604	111	24	2666
17	-30	-25	-19	-24	-22	-26	0	114	279	446	584	638	673	607	373	315	247	52	-25	-24	-25	-24	-24	-22	-30	673	168	24	4038
18	-21	-23	-24	-26	-23	-25	-15	102	254	451	372	512	463	538	404	234	127	37	-8	-10	-10	-5	-5	0	-26	538	137	24	3299
19	-16	-19	-33	-34	-33	-28	-7	97	270	432	557	597	684	444	274	306	42	-4	-37	-39	-35	-41	-37	-38	-41	684	138	24	3302
20	-22	-34	-36	-32	-24	-23	0	59	149	350	391	566	539	320	240	91	19	-25	-1	-4	-5	-4	-6	-7	-36	566	104	24	2501
21	-8	-9	-7	-3	-5	-9	-1	50	160	365	340	461	546	465	386	307	108	25	-13	-30	-30	-36	-32	-37	-37	546	125	24	2993
22	-32	-29	-27	-21	-23	-21	-10	104	273	430	547	633	354	325	464	191	129	13	-3	-12	-15	-20	-11	-10	-32	633	135	24	3229
23	-7	-13	-18	-18	-19	-9	-6	63	261	436	524	633	638	312	26	36	39	26	-11	-24	-18	-27	-32	-36	-36	638	115	24	2756
24	-31	-26	-24	-25	-21	-18	-6	47	128	223	367	289	570	551	83	24	53	23	0	0	0	0	0	0	-31	570	92	24	2207
25	-3	-19	-16	-15	-17	-20	1	104	165	392	295	153	95	16	43	31	13	-1	-7	****	****	-12	-13	-33	-33	392	52	22	1152
26	-7	-9	-7	-13	-13	-18	-24	58	232	423	494	376	197	500	323	37	48	27	-7	-13	-11	-4	-10	-19	-24	500	107	24	2560
27	-8	-1	-2	-1	0	0	-1	59	162	157	244	316	226	230	370	264	137	-3	-1	-10	-14	-10	-9	-7	-14	370	87	24	2098
28	0	0	0	-3	0	0	0	9	44	109	207	281	350	346	178	115	97	27	0	-1	0	0	0	0	-3	350	73	24	1759
29	0	0	-1	0	0	-1	0	15	41	73	51	93	73	29	39	29	39	14	-10	-9	-11	-16	-10	-11	-16	93	18	24	427
30	-19	-16	-11	-9	-8	-11	-15	71	155	347	474	394	325	486	172	87	70	16	10	-14	-20	-26	-16	-8	-26	486	101	24	2434
31	-12	-18	-15	-15	-8	-1	-1	9	151	400	601	691	640	600	421	253	146	17	-28	-27	-16	-7	-6	-5	-28	691	157	24	3770
MIN	-32	-34	-36	-34	-33	-30	-24	9	21	35	51	60	42	16	26	24	-3	-25	-37	-39	-36	-41	-37	-38	-41				
MAX	0	0	0	0	0	0	5	114	299	451	601	691	684	628	506	362	247	52	10	0	0	0	0	0		691			
AVE	-15	-15	-14	-14	-13	-14	-6	56	164	270	335	382	369	333	256	161	90	15	-12	-16	-16	-16	-16	-17			94		
HOUR	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	30	30	31	31	31				742	
TOTAL	-458	-458	-440	-446	-411	-441	-176	1750	5093	8365	10386	11838	11429	10331	7926	4997	2776	457	-373	-490	-479	-497	-504	-530					69645

(5) Temperature

The results of monitoring of temperature, monitored at 1.5 m and 30 m from the ground of MP-1 (Town Hall) are shown in Fig. III-4-11. The results of analysis of temperature are shown in the part of reference of the report and one example is shown in Table III-4-26.

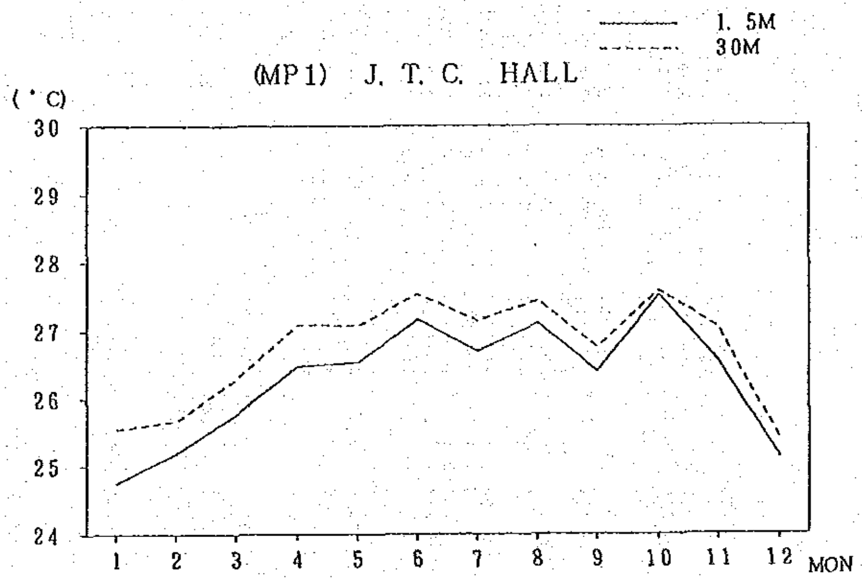

Fig. III-4-11 Results of monitoring of temperature (monthly variation pattern)

Table III-4-26 An example of results of monitoring of temperature (one hour average value)

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1984 ﾈﾝ 2 ｶﾞﾂ ｺｳﾓｸ (7) ｷｵﾝ1.5M ｸﾌﾞﾝ 0 ｷﾖｸ (1) (MP1) J.T.C. HALL (0.1°C)

.ｼﾞ ﾆﾁ.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	MIN	MAX	AVE	HOUR	TOTAL
1	235	235	235	230	230	230	230	236	248	260	270	268	275	280	255	260	270	260	254	250	250	240	240	240	230	280	249	24	5981
2	238	240	228	220	210	220	218	214	212	218	220	222	225	228	228	230	232	228	228	225	220	224	222	221	210	240	224	24	5371
3	220	222	220	220	220	225	225	222	226	242	260	270	280	285	288	290	280	270	260	250	248	246	244	240	220	290	248	24	5953
4	239	240	240	240	240	236	235	235	245	256	268	270	280	282	258	230	240	246	245	245	235	235	235	236	230	282	246	24	5911
5	240	240	235	230	230	230	230	235	250	255	270	265	270	265	245	258	265	264	258	250	240	244	240	232	230	270	248	24	5941
6	234	235	230	228	226	224	224	230	240	260	270	280	285	290	298	298	285	276	266	259	250	250	259	248	224	298	256	24	6145
7	248	248	248	248	240	240	236	240	250	260	266	270	270	250	255	248	240	238	235	236	236	236	236	236	235	270	246	24	5910
8	236	236	238	236	238	238	234	239	255	268	272	268	254	241	249	246	240	240	240	238	238	235	234	234	234	272	244	24	5847
9	230	226	228	228	229	229	230	232	242	260	270	274	290	270	270	270	266	270	268	250	248	238	235	235	226	290	250	24	5988
10	235	234	230	230	228	229	230	232	242	260	270	280	290	295	290	290	234	230	240	230	238	240	240	240	228	295	248	24	5957
11	238	238	240	238	238	238	234	238	250	265	280	284	306	300	300	308	298	284	270	265	252	250	248	246	234	308	263	24	6308
12	246	245	242	240	240	240	240	245	260	270	276	290	290	302	304	310	286	272	260	260	250	250	250	248	240	310	263	24	6316
13	249	248	245	244	242	245	240	241	250	260	270	285	302	285	285	275	264	255	252	250	244	244	240	242	240	302	257	24	6157
14	242	242	244	240	240	240	238	240	260	274	278	286	300	315	260	245	234	238	238	238	236	232	232	232	232	315	251	24	6024
15	235	240	238	230	232	238	236	238	250	260	270	280	280	280	286	282	280	284	270	265	254	244	242	240	230	286	256	24	6154
16	238	236	238	235	234	234	230	240	256	265	270	278	289	290	238	240	241	238	235	230	235	240	239	239	230	290	246	24	5908
17	235	234	232	230	230	230	230	235	245	260	265	276	290	288	294	290	240	***	***	***	***	***	***	***	230	294	253	17	4304
18	***	***	***	***	***	***	***	***	***	250	265	280	280	285	284	269	278	282	245	234	230	222	228	229	222	285	257	15	3861
19	228	228	231	232	226	224	222	228	240	250	255	269	278	280	270	265	250	242	240	242	240	240	240	238	222	280	244	24	5858
20	234	230	232	232	230	230	226	230	244	258	275	265	240	265	270	276	250	236	230	230	230	***	***	***	226	276	243	21	5113
21	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	0	0	0	0	0
22	***	***	***	***	***	***	***	***	***	***	***	***	305	280	280	260	268	268	264	252	252	250	245	240	240	305	264	12	3164
23	238	235	230	235	234	234	228	230	254	255	270	288	294	288	290	290	282	290	280	252	246	240	240	240	228	294	257	24	6163
24	240	234	234	230	230	228	230	234	250	270	275	294	288	290	298	290	295	292	288	260	260	250	244	242	228	298	260	24	6246
25	238	238	236	234	230	230	230	238	256	270	285	295	290	290	250	255	260	275	265	254	248	248	246	244	230	295	254	24	6105
26	240	240	234	238	234	235	238	240	254	***	***	***	***	***	***	270	274	284	272	260	255	250	250	244	234	284	251	18	4512
27	245	246	240	242	240	238	238	238	250	268	284	292	298	305	310	310	302	298	280	268	258	250	245	240	238	310	266	24	6385
28	240	240	238	235	240	238	232	238	260	275	***	300	310	***	***	***	***	***	***	***	***	***	***	***	232	310	254	12	3046
29	***	***	***	***	***	***	***	***	***	***	292	292	302	280	295	284	270	270	264	260	255	248	242	242	242	302	271	14	3796
MIN	220	222	220	220	210	220	218	214	212	218	220	222	225	228	228	230	232	228	228	225	220	222	222	221	210				
MAX	249	248	248	248	242	245	240	245	260	275	292	300	310	315	310	310	302	298	288	268	260	250	259	248		315			
AVE	238	237	235	234	232	233	231	235	248	260	270	278	284	281	275	272	264	263	256	248	244	242	241	239			252		
HOUR	25	25	25	25	25	25	25	25	25	25	25	26	27	26	26	27	27	26	26	26	26	25	25	25				613	
TOTAL	5941	5930	5886	5845	5811	5823	5784	5868	6189	6489	6746	7221	7661	7309	7150	7339	7124	6830	6647	6453	6348	6046	6016	5968					154424

CHAPTER 5 ANALYSIS OF CHEMICAL COMPONENTS CONTAINED IN PARTICULATE MATTER

For identifying chemical components contained in the particulate matter, TPM sampled on polyphlone filter by high volume sampler for one day during the short term field survey from each station have been brought back Japan for analysis of metal elements and anion by neutron activation method, X ray fluorescence analysis, and ion chromatography.

Besides the above, the samples collected in another one day during the short term field survey by quartz filter have also been brought back Japan for analysis of total carbon and non-volatile carbon by differential thermal method.

Further for estimation of contribution rate by soil, 3 typical types of soil of Singapore have also been analyzed.

Table III-5-1 shows the date of sample collection in each field survey (sampling day). Table III-5-2 shows the chemical components analyzed in the study.

Table III-5-1 Sampling date for chemical analysis

	1st survey (MP1-20)	2nd survey (MP1-20)	3rd survey (MP1-20)	4th survey (MP1-20)
Metal elements & anion (Polyphlone)	Dec/19-20	Mar/19-20	Jul/3-4	Sept/25-26
Total carbon & nonvolatile carbon (Quartz)	Dec/14-15	Mar/14-15	Jun/26-27	Sept/20-21

Table III-5-2 Analyzed chemical components

Analyzing method	Analyzed chemical components
Neutron activation analysis	Ag (Silver), Al (aluminum), As (Arsenic), Ba (Barium), Br (Bromine), Ca (Calcium), Cd (Cadmium), Ce (Cerium), Cl (Chlorine), Co (Cobalt), Cr (Chromium), Cs (Cesium), Cu (Copper), Fe (Iron), Hf (Hafnium), K (Potassium), La (Lanthanum), Lu (Lutetium), Mn (Manganese), Na (Sodium), Ni (Nickel), Sb (Antimony), Sc (Scandium), Se (Selenium), Sm (Samarium), Th (Thorium), Ti (Titanium), V (Vanadium), W (Wolfram) Zn (Zinc)
X ray fluorescence analysis	Cd (Cadmium), Pb (Lead), S (Sulfur), Si (Silicon)
Ion chromatography	Cl^- (Chloride), $NO_3{}^-$ (Nitrate), $SO_4{}^{2-}$ (Sulfate)
Differential thermal analysis	Total Carbon, Non Volatile Carbon

III-5-1 Analysis of Metal Elements by Neutron Activation Method

III-5-1-1 Principle of analysis

When the sample is placed in the reactor, thermal neutron generated by fission of ^{235}U impacts to atomic nuclear contained in the sample and neutron fission is produced. In the result, the formed nuclei is produced which is quite different from the original one. The formed nuclei is radioactive and after certain time, it radiates Beta ray and Gamma ray, and it is disintegrated to daughter of nuclide. The energy of Gamma ray is measured, and identification of metal elements contained in the original sample comes possible. Also number of Gamma ray energy is proportional to the number of metal elements, and so the quantity of elements is possible to be identified.

In actual neutron activation analysis, many types of metal elements are coexisted in the sample and their half life are also varied (sec, min, hour, day order) or (more than one month). So selecting cooling period properly, nuclides of various half life are measured.

As described in the above, neutron activation method does not require complicated chemical pretreatment and it makes possible to analyze many types of metal elements simultaneously even though the samples contain very fine quantity of metal elements. From these reasons, this method is highlighted recently as the most advanced and scientific analysis.

III-5-1-2 Analyzing method

The samples are placed n the reactor of TRIGA II type furnace of Atomic Energy Research Laboratory, Musashi Institute of Technology, and irradiates thermal neutron. Thus the various radioactive isotopes generated are measured by semi conductor detector and multichannel analyser together with mini-computer. The irradiation of thermal neutron on the sample is conducted in two ways; short and long term.

Short term irradiated sample is measured by Gamma ray using semi conductor detector. Long term irradiated sample is cooled for several days to several weeks in the laboratory, and then Gamma ray is measured by semi conductor detector. Fig. III-5-1 shows atomic furnace and its sectional view. Picture III-5-1 shows outview of instrument for neutron activation analysis.

Thermal neutron flux is $5 \times 10^{11} \sim 1.5 \times 10^{12}$ n/cm^2-S.

Semi conductor detector is 8,100 type of Canberra Industries Inc., and it has the capacity of detector efficiency, 10%, and detector resolution, 2.0 KeV at 1333 KeV.

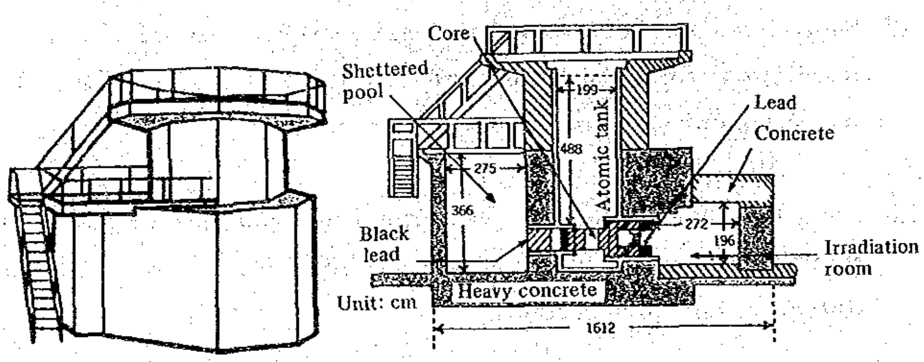
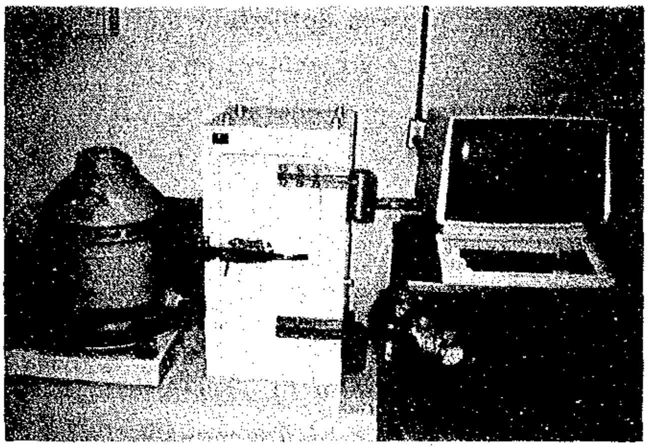
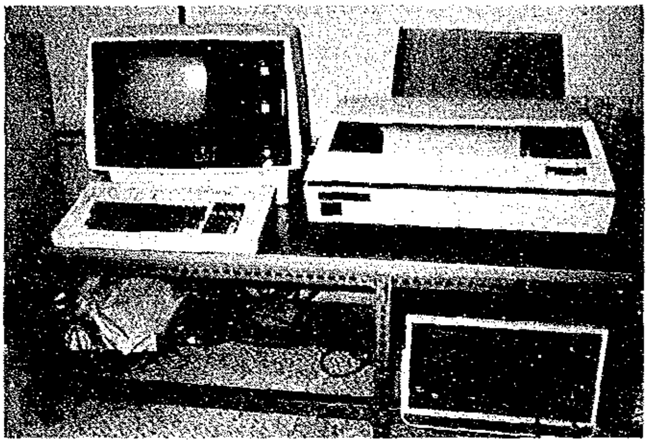


Fig. III-5-1 Outview and section of TRIGA II type furnace





Picture III-5-1 Instruments for neutron activation analysis

Analyzing conditions by respective nuclides are as follows;

(i) Short lived nuclides -- At thermal neutron flux of ($1.5 \times 10^{12} n/cm^2$-sec), irradiation for 1 minute, and after cooling for about 3 - 4 minutes, measurement or detection for 300 seconds.

(ii) Long lived nuclides (a) -- At thermal nuetron flux of ($1.5 \times 10^{12} n/cm^2$-sec), irradiation for 5 hours, and after cooling for several days, measurement or detection for 1,000 seconds.

(iii) Long lived nuclides (b) -- After cooling long lived nuclides (a) for several weeks, measurement or detection for 4,000 seconds.

Table III-5-3 shows analyzing elements by nuclides and analyzing conditions.

Table III-5-3 Elements by nuclides and analyzing conditions

Classification	Element	Target nuclear species	Isotope ratio (%)	Nuclides generated	Half life period	Gamma ray energy (KeV)	Analyzing conditions		
							Irradiation time	Cooling time	Measurement time
Short lived nuclides	Al	^{27}Al	100	^{28}Al	2.31 minutes	1778.9	1 minute	3-4 minutes	300 seconds
	Br	^{79}Br	50.5	^{80}Br	17.6 minutes	617.0	1 minute	3-4 minutes	300 seconds
	Ca	^{48}Ca	0.185	^{49}Ca	8.8 minutes	3083	1 minute	3-4 minutes	300 seconds
	Cl	^{37}Cl	24.5	^{38}Cl	37.3 minutes	1642.0	1 minute	3-4 minutes	300 seconds
	Cu	^{65}Cu	30.9	^{66}Cu	5.1 minutes	1039.0	1 minute	3-4 minutes	300 seconds
	Mn	^{55}Mn	100	^{56}Mn	2.58 hours	846.9, 1810	1 minute	3-4 minutes	300 seconds
	Ti	^{50}Ti	5.34	^{51}Ti	5.79 minutes	320.0	1 minute	3-4 minutes	300 seconds
	V	^{51}V	99.8	^{52}V	3.76 minutes	1434.4	1 minute	3-4 minutes	300 seconds
Long lived nuclides (a)	As	^{75}As	100	^{76}As	26.3 hours	559.2	5 hours	Several days	1000 seconds
	Cd	^{114}Cd	28.9	^{115}Cd	2.32 days	528	5 hours	Several days	1000 seconds
	K	^{41}K	6.88	^{42}K	12.5 hours	1524.7	5 hours	Several days	1000 seconds
	La	^{139}La	99.9	^{140}La	1.68 days	1595.4	5 hours	Several days	1000 seconds
	Na	^{23}Na	100	^{24}Na	15 hours	1368.4	5 hours	Several days	1000 seconds
	Sb	^{121}Sb	57.3	^{122}Sb	2.75 days	564.0	5 hours	Several days	1000 seconds
	Sm	^{152}Sm	26.7	^{153}Sm	1.96 days	103.2	5 hours	Several days	1000 seconds
	W	^{186}W	28.4	^{187}W	24.0 hours	685.7	5 hours	Several days	1000 seconds
Long lived nuclides (b)	Ag	^{109}Ag	48.7	^{110}Ag	253 days	657.8	5 hours	Several weeks	4000 seconds
	Ba	^{130}Ba	0.101	^{131}Ba	11.5 days	496	5 hours	Several weeks	4000 seconds
	Ce	^{140}Ce	88.5	^{141}Ce	32.5 days	145.4	5 hours	Several weeks	4000 seconds
	Co	^{59}Co	100	^{60}Co	5.24 years	1332.4	5 hours	Several weeks	4000 seconds
	Cr	^{50}Cr	100	^{51}Cr	27.8 days	320.0	5 hours	Several weeks	4000 seconds
	Cs	^{133}Cs	100	^{134}Cs	2.07 years	795.8	5 hours	Several weeks	4000 seconds
	Fe	^{58}Fe	0.33	^{59}Fe	45.1 days	1098.6	5 hours	Several weeks	4000 seconds
	Hf	^{180}Hf	35.2	^{181}Hf	44.6 days	482.2	5 hours	Several weeks	4000 seconds
	Lu	^{176}Lu	2.59	^{177}Lu	6.7 days	208.4	5 hours	Several weeks	4000 seconds
	Ni	^{58}Ni	67.9	^{58}Co	71.3 days	810.3	5 hours	Several weeks	4000 seconds
	Sc	^{45}Sc	100	^{46}Sc	83.9 days	889.4	5 hours	Several weeks	4000 seconds
	Se	^{74}Se	0.87	^{75}Se	121 days	264.6	5 hours	Several weeks	4000 seconds
	Th	^{232}Th	100	^{233}Pa	27.0 days	311.8	5 hours	Several weeks	4000 seconds
	Zn	^{64}Zn	48.9	^{65}Zn	245 days	1115.4	5 hours	Several weeks	4000 seconds

(a) Preparation of sample and production of standard sample

As shown in Fig. III-5-2, 1/9 of the Polyphlone filter is cut, and 1/2 of the remaining filter is cut and contained in the polyethilene bag of double layers which are used for short and long term irradiation.

For production of standard samples, appropriate reagent dissolved solution for each element is produced, and these standard solution is dropped on the filter, Toyo N_o5A, in constant quantity which is used for analysis as multi-element-standard.

Table III-5-4 shows the reagent used for production of standard sample for elements contained. In the table, Gamma ray counting rate of the standard samples is shown in terms of CPS (counts per sec.)/μg. The standard samples have been used repeatedly and an example is shown in table.

Table III-5-4 An example of standard sample and Gamma ray counting rate

Classification	Element	Standard		Gamma ray counting rate (CPS/μg)
		Reagent	Load of element (μg)	
Short lived nuclides	Al	Al	99.7	6.30
	Br	KBr	6.71	1.97
	Ca	$CaCO_3$	423	0.00565
	Cl	KCl	238	0.0384
	Cu	Cu	100	0.588
	Mn	Mn	1.86	6.51
	Ti	Ti	48.9	0.321
	V	V	6.21	55.9
Long lived nuclides (a)	As	As_2O_3	2.78	39.7
	Cd	Cd	10.0	0.293
	K	KCl	502	0.266
	La	La_2O_3	0.734	10.7
	Na	Na_2CO_3	220	12.9
	Sb	Sb	0.280	17.5
	Sm	Sm_2O_3	0.0404	524
	W	W	0.704	27.9
Long lived nuclides (b)	Ag	Ag_2SO_4	0.695	0.341
	Ba	$BaCl_2 \cdot 2H_2O$	37.7	0.0258
	Ce	$Ce(SO_4)_2 \cdot 2(NH_4)_2 \cdot SO_4 \cdot 2H_2O$	0.724	0.871
	Co	$CoCl_2 \cdot 6H_2O$	0.484	0.626
	Cr	Cr	3.69	0.431
	Cs	Cs	0.394	1.49
	Fe	Fe	800	0.00212
	Hf	Hf	0.115	2.77
	Lu	$LuCl_3 \cdot 6H_2O$	0.0241	115
	Ni	Ni	130	0.0150
	Sc	Sc_2O_3	0.158	17.7
	Se	H_2SeO_3	1.39	0.390
	Th	$Th(NO_3)_4 \cdot 4H_2O$	0.0544	6.03
	Zn	Zn	109	0.0271

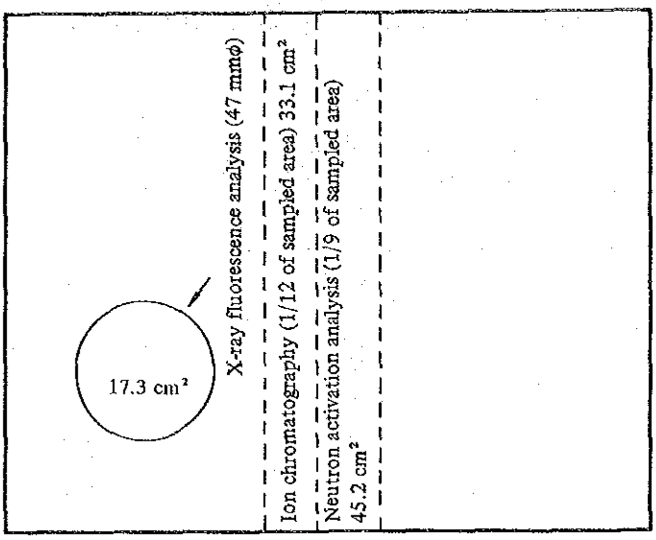


Fig. III-5-2 Cutting of sampled filter for analysis

(b) Sequence order of analysis

Pretreated sample and standard sample are placed in the irradiation capsule, and under the analyzing conditions shown in Fig. III-5-3, irradiation of thermal neutron, cooling, and measurement of Gamma ray are conducted. The area of Gamma ray peak of each element is calculated and compared with the area of standard sample from which element volume contained in the samples is obtained.

Following to the above, and after deducting blank value of the filter previously weighed, the ambient element concentration is obtained, dividing by air sucking flow rate.

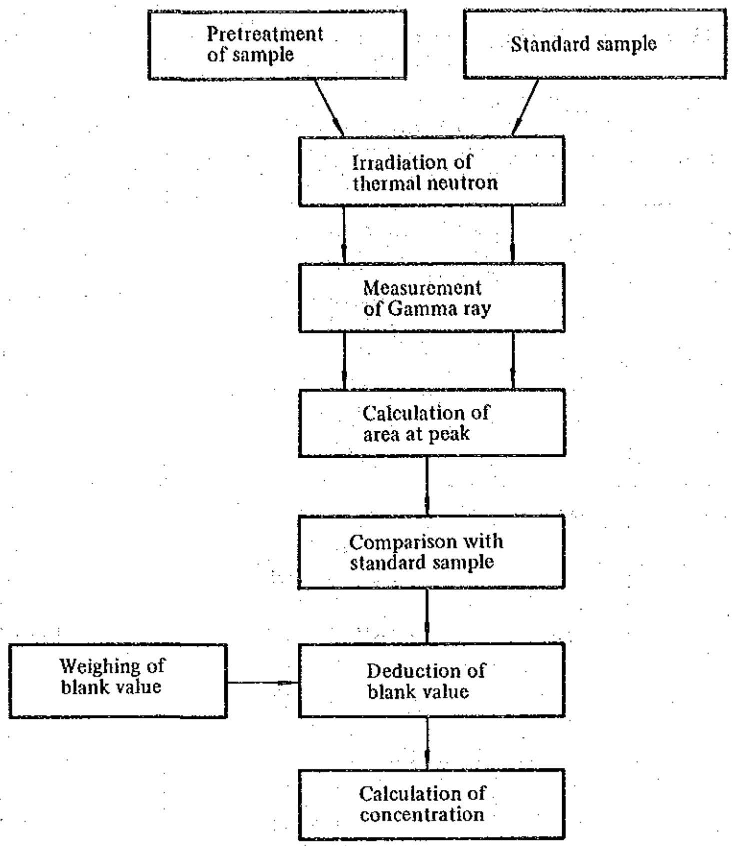


Fig. III-5-3 Analyzing sequence of neutron activation analysis

III-5-1-3 Analysis of ambient air standard sample

In order to evaluate the analyzing methods, standard sample AS-1 of concentration known particulate matter was analyzed. The results of such analysis are shown in Table III-5-5. The elements well correlated with analyzed values were Al, Mn, Ti, V, As, La, Na, W, Cr, Ni, Sc and Zn. Other elements are also within the deviation range of literature values.

Table III-5-5 Analyzing results of ambient air standard sample (AS-1)

Classification	Element	Standard sample (AS-1) of particulate matter	
		Analyzed value (ppm)	Literature value (ppm)*
Short lived nuclides	Al	57000 (3)	50000 ±7000
	Br	300 (5)	340 ±9
	Ca	62000 (2)	56000 ±5000
	Cl	43000 (2)	31000 ±4000
	Cu	600 (10)	400 ±140
	Mn	1300 (2)	1200 ±100
	Ti	3800 (7)	4200 ±1100
	V	270 (3)	230 ±70
Long lived nuclides (a)	As	36 (5)	43 ±13
	Cd	<100	19**
	K	12000 (10)	9700
	La	18 (10)	18 ±2
	Na	15000 (1)	14000 ±1000
	Sb	53 (3)	39 ±6
	Sm	3.0 (3)	3.4
	W	23 (11)	21 ±13
Long lived nuclides (b)	Ag	<5	3
	Ba	590 (17)	410
	Ce	36 (7)	30
	Co	19 (7)	26 ±4
	Cr	350 (2)	240 ±30
	Cs	2.5 (22)	4.0**
	Fe	41000 (2)	45000 ±3000
	Hf	3.5 (12)	3.4**
	Lu	0.27 (27)	0.3**
	Ni	210 (30)	200 ±30
	Sc	11 (1)	11 ±1
	Se	<6	9 ±6
	Th	4.5 (7)	5.1**
	Zn	3000 (2)	3400 ±500

Table in bracket is counting error.

III-5-1-4 Limit of determination and filter blank

Average limit of determination at analysis of particulate matter in the ambient and filter blank values (PF-1 filter) are shown in Table III-5-6.

Table III-5-6 Average limit of determination and filter blank value

Classification	Element	Limit of determination (μg)	Filter blank (ng/cm^2)			
			1st field survey	2nd field survey	3rd field survey	4th field survey
Short lived nuclides	Al	1	60	60	70	80
	Br	0.2	1	0.9	0	0
	Ca	20	400	400	0	200
	Cl	3	700	200	0	500
	Cu	1	0	0	0	0
	Mn	0.02	0.6	0.8	0	1
	Ti	2	0	0	0	0
	V	0.02	0	0	0	0.3
Long lived nuclides (a)	As	0.03	0	0	0	0
	Cd	0.5	0	0	0	0
	K	20	0	0	0	0
	La	0.02	0	0	0	0
	Na	0.1	5000	2000	2000	3000
	Sb	0.005	0	0	0	0
	Sm	0.002	0	0	0	0
	W	0.05	0	0	0	0
Long lived nuclides (b)	Ag	0.04	2	0.7	0.7	1
	Ba	2	0	0	0	0
	Ce	0.02	0	0	0	0
	Co	0.005	0	0	0	0
	Cr	0.05	2	1	0.9	1
	Cs	0.005	0	0	0	0
	Fe	20	0	0	0	0
	Hf	0.02	0	0	0	0
	Lu	0.005	0	0	0	0
	Ni	1	0	0	0	0
	Sc	0.002	0	0	0.01	0
	Se	0.05	0	0	0	0
	Th	0.01	0	0	0	0
	Zn	0.5	10	10	6	4

III-5-1-5 Calculation method of metal elements and so on

The weight of metal elements on the filter is calculated from the peak area of Gamma ray by the following Equation III-5-1.

$$E_W = \left(\frac{Stw}{StYa} \cdot SYa\right) - Fbw \qquad \text{Equation III-5-1}$$

where;

E_W: Weight of element in analyzed sample (μg)

Stw: Weight of element in standard sample (μg)

StYa: Peak area of Gamma ray in standard sample

SYa: Peak area of Gamma ray in analyzed sample

Fbw: Filter blank value (μg)

The metal element concentration in the ambient is obtained from the following Equation III-5-2.

$$Ce = \frac{Ew}{V} \cdot \frac{Fa}{Sa} \times 1{,}000 \qquad \text{Equation III-5-2}$$

where;

Ce: Element concentration in the ambient (ng/m^3)

Ew: Element weight in analyzed sample (μg)

V: Air sucking flow rate (m^3)

Fa: Total area of filter (406 cm^2)

Sa: Filter area of analyzed sample (22.6 cm^2)

Further, peak area of Gamma ray is calculated as follows; the Gamma ray peak peculiar to the element is analyzed by multichannel analyser which has detector resolution of around 1 KeV and spectrum data are indicated by channel number of multi channel analyser and count number of Gamma ray corresponding to each channel is indicated. The spectrum data are the results of measuring number of dispersed Gamma ray in the channel box corresponding to energy.

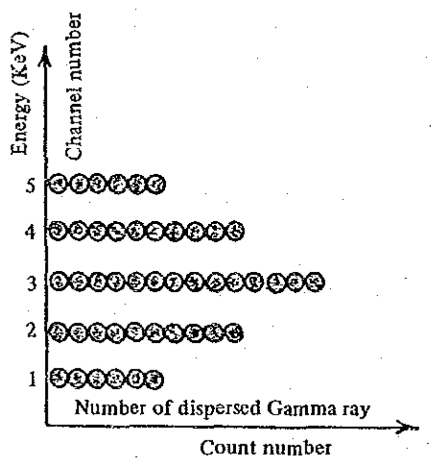


Fig. III-5-4 Spectrum data (dispersion of Gamma particle)

The spectrum data indicate the dispersion curve as shown in Fig. III-5-5, and so-called background portion and peak area of spectrum data are overlapped. When total count number around peak is T, background is B and net peak area is N, net peak area is obtained by the following Equation III-5-3.

$$N = T - B \qquad \text{Equation III-5-3}$$

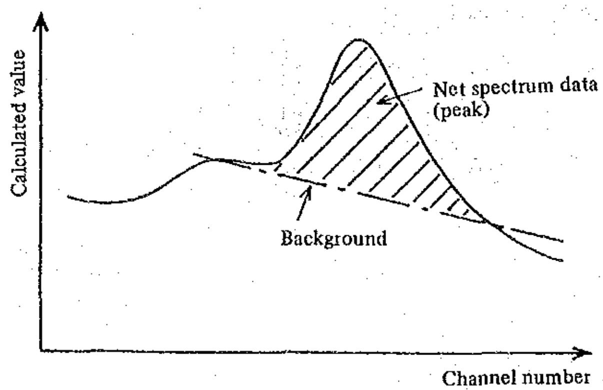


Fig. III-5-5 Spectrum data and background

Further, measured value by detectors in certain time period is the value with statistical dispersion, and its dispersion behaviour is according to poisson dispersion. Calculated value C is the one near to precise value in the range of calculation error $\pm\sqrt{C}$. Net peak area N calculated by Equation III-5-3 has calculation error σ_N(%). σ_N is obtained by following equation.

$$\sigma_N = \frac{\sqrt{N + (n - \frac{1}{2})B}}{N} \times 100 \qquad \text{Equation III-5-4}$$

where; n: number of channel

(in this study, each 3 channels before and after which makes 7 channels in total are used. So it comes, n = 3)

III-5-1-6 Gamma ray Spectrum

Fig. III-5-6 to III-5-8 show an example (1st field survey at MP-1) of Gamma ray spectrum.

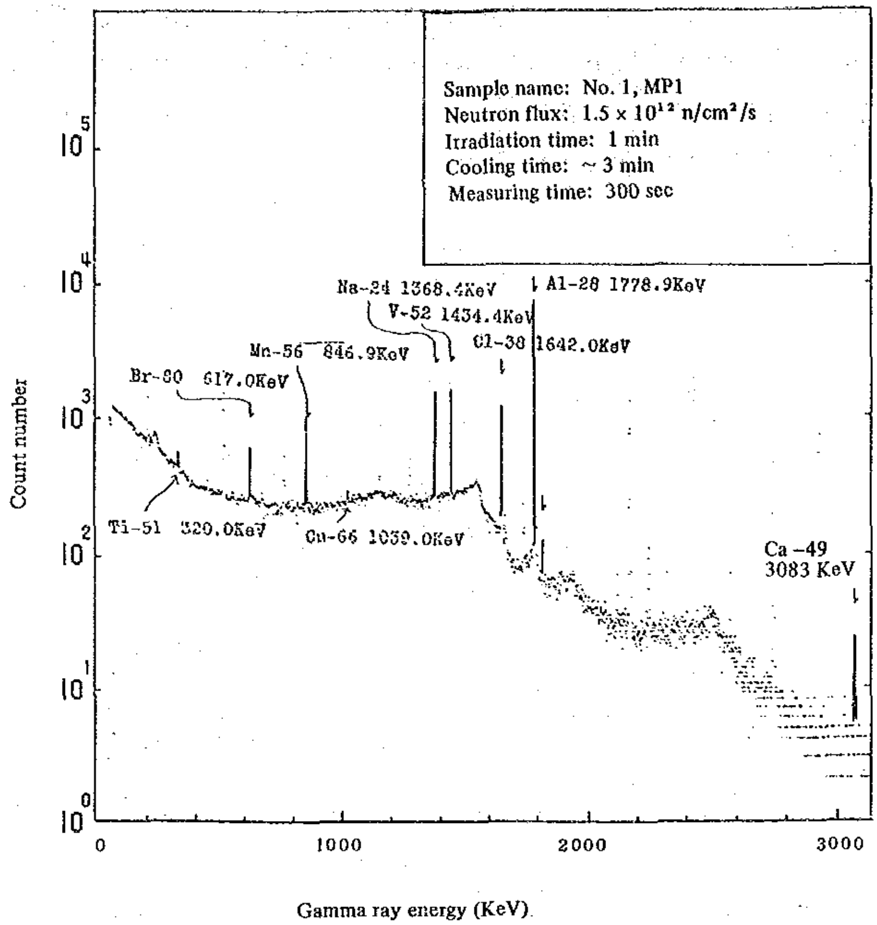


Fig. III-5-6 An example of Gamma ray spectrum (short lived nuclides)

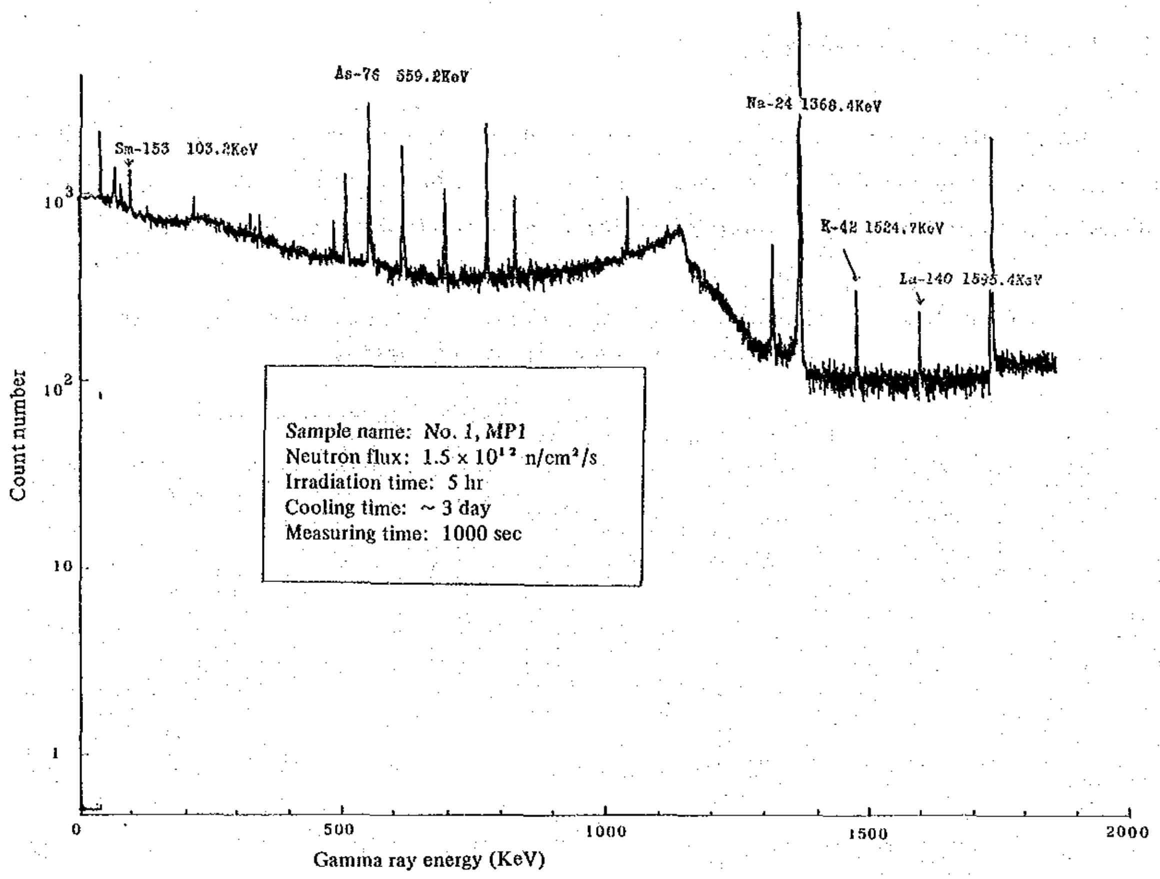


Fig. III-5-7 An example of Gamma ray spectrum (long lived nuclides (a))

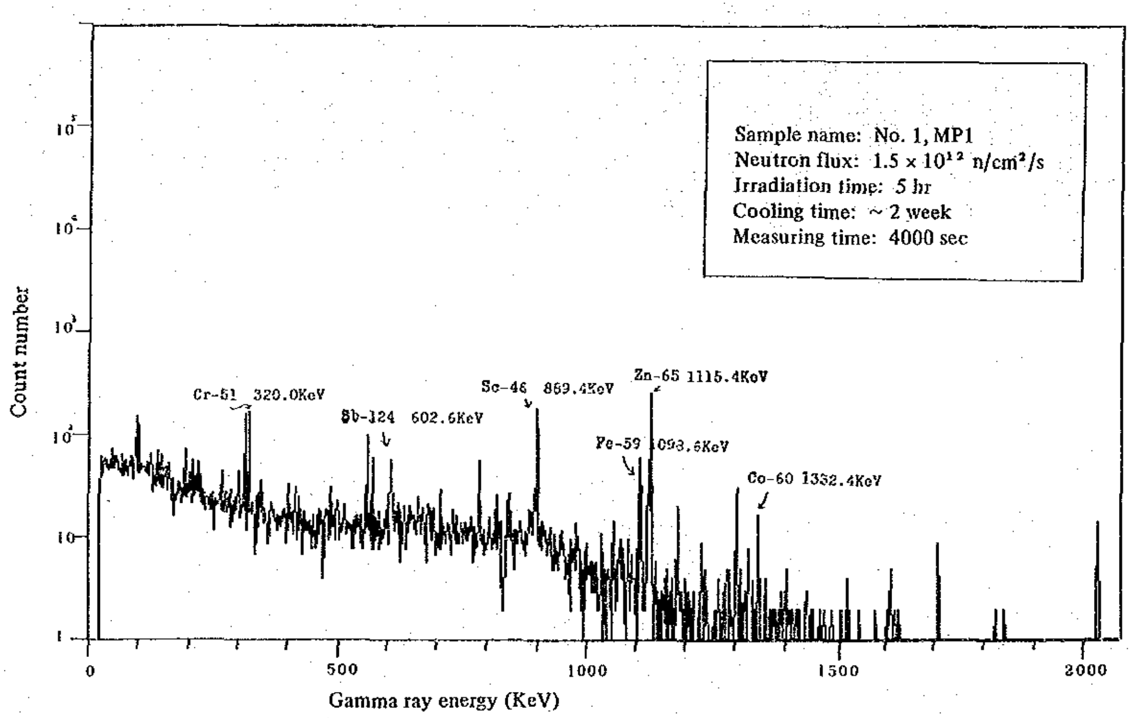


Fig. III-5-8 An example of Gamma ray spectrum (long lived nuclides (b))

III-5-1-7 Results of measurement

The results of measurement of metal elements and so on are shown in Table III-5-7. In the table, the results of measurement of Cd, Pb, S, and Si by X-ray fluorescence analysis, and results of anion analysis by ion chromatography are also shown.

Table III-5-7-(1) Results of measurement of metal elements by neutron activation analysis (1st field survey)

	ホウシャカブンセキ(NG/M3)																		
	AG	AL	AS	BA	BR	CA	CD	CE	CL	CO	CR	CS	CU	FE	HF	K	LA	LU	MN
MP 1	<0.70	2800	2.60	<20	43	1400	<40	3.50	5800	0.23	5.40	<0.090	<50	880	0.200	<900	<0.90	0.025	17.0
MP 2	<0.50	530	0.96	<10	47	480	<30	0.43	4500	0.13	0.97	<0.060	42	150	<0.050	<700	<0.60	<0.007	5.3
MP 3	<0.60	670	3.90	<20	110	820	<30	0.73	4000	0.19	3.00	0.094	18	430	<0.070	<800	<0.60	<0.020	6.7
MP 4	<0.70	3900	30.00	27	49	3600	29	3.80	5100	0.54	6.60	0.350	23	1300	0.190	<900	0.93	0.022	21.0
MP 5	<0.60	2400	7.90	23	50	1900	<30	1.80	6900	0.49	4.70	0.180	51	840	<0.080	1400	<0.70	<0.020	21.0
MP 6	<0.60	890	18.00	18	25	800	<40	1.10	4800	<0.20	7.00	<0.080	23	360	<0.060	<900	<0.70	0.012	8.6
MP 7	<0.90	4800	9.50	<20	250	1400	<50	3.50	4300	0.87	6.20	0.360	220	1900	0.220	<900	<0.90	0.022	21.0
MP 8	<0.50	570	6.70	17	59	720	<40	<0.40	4800	<0.20	0.69	0.094	180	270	0.079	<900	<0.70	<0.009	4.8
MP 9	<0.50	770	1.90	13	48	600	34	0.72	4400	<0.20	1.30	<0.060	98	310	0.051	<900	<0.60	<0.009	8.3
MP10	<0.70	1300	5.00	<20	37	980	<30	0.91	2900	<0.20	<0.80	0.092	77	560	0.075	1300	<0.70	<0.010	6.7
MP11	<0.70	1600	2.00	<9	63	<300	<40	1.30	3500	<0.09	1.70	<0.090	62	590	0.140	<900	1.20	<0.020	11.0
MP12	<0.80	990	2.90	<30	130	1800	<40	1.60	6300	0.29	5.80	<0.200	<40	610	<0.090	<900	<0.90	<0.020	16.0
MP13	<0.60	760	3.70	<30	82	670	<30	0.91	3800	0.35	3.10	<0.090	<20	490	<0.090	<900	<0.70	<0.020	8.3
MP14	<0.70	990	8.80	<30	71	1500	<40	0.73	6000	0.35	10.00	<0.090	57	580	0.140	<900	<0.70	<0.020	15.0
MP15	<0.70	940	<0.90	<20	68	1100	<40	1.00	5600	0.29	<0.90	<0.090	51	290	0.067	<900	<0.80	0.015	6.4
MP16	<0.50	470	11.00	<9	31	350	<30	0.49	3900	0.27	6.00	0.064	30	240	0.063	<900	<0.50	<0.009	6.0
MP17	<0.70	3600	14.00	<20	370	2100	<50	2.90	4100	0.31	12.00	0.200	42	1600	0.310	1300	1.10	0.023	23.0
MP18	<0.50	720	<0.70	22	51	590	<20	0.64	4900	0.21	1.30	<0.200	33	250	<0.040	<800	<0.50	<0.008	5.0
MP19	<0.60	2200	3.80	22	100	1100	<30	1.90	4600	<0.20	4.90	0.150	<40	510	<0.070	<800	1.30	<0.020	9.0
MP20	<0.60	2400	1.50	150	26	1200	<30	2.10	4600	0.26	1.80	0.120	53	590	0.160	<800	0.91	0.020	16.0

	ホウシャカブンセキ(NG/M3)											ケイコウXセンブンセキ(NG/M3)				イオンクロマト(NG/M3)			TPM
	NA	NI	SB	SC	SE	SM	TH	TI	V	W	ZN	CD	PB	S	SI	CL-	NO3-	SO4--	(UG/M3)
MP 1	1200	18.0	1.00	0.340	1.00	0.220	0.460	140	24.00	2.2	47	4.5	52	1000	12000	4100	750	2400	52.7
MP 2	1000	<7.0	0.46	0.056	0.72	0.040	0.120	<60	26.00	<1.0	38	2.1	110	900	1700	3000	470	1900	25.3
MP 3	720	15.0	1.20	0.081	<0.60	0.034	0.140	<70	34.00	<2.0	49	<2.0	130	1100	2700	2900	500	2200	35.0
MP 4	1000	<20.0	1.20	0.470	1.50	0.310	1.100	250	52.00	2.1	43	4.4	<40	2000	19000	4200	840	5500	89.2
MP 5	2000	52.0	2.90	0.230	2.30	0.170	0.480	210	81.00	<2.0	64	2.0	130	2600	12000	4900	780	6700	83.0
MP 6	430	13.0	0.91	0.100	0.59	0.050	0.180	58	17.00	<2.0	73	3.5	81	940	3700	3100	650	2900	40.0
MP 7	600	<20.0	3.00	0.630	1.10	0.250	0.950	200	25.00	<2.0	120	3.6	390	1300	19000	3200	510	2600	98.7
MP 8	2100	10.0	<0.50	0.064	4.40	<0.040	0.130	64	9.30	<2.0	32	3.6	170	870	2300	3000	530	2400	35.6
MP 9	2100	13.0	0.85	0.064	0.59	0.029	0.200	<80	31.00	<2.0	29	<2.0	180	1200	2800	2900	560	4000	39.4
MP10	1500	<8.0	0.87	0.120	0.66	0.075	0.510	110	4.80	<2.0	22	<2.0	<50	720	3800	2200	390	1400	34.6
MP11	<200	<9.0	0.74	0.130	1.20	0.093	0.660	<200	6.50	<2.0	64	2.6	190	560	4500	2400	310	1500	34.7
MP12	890	<20.0	6.70	0.140	1.40	0.068	0.260	140	5.10	<2.0	120	2.9	670	1100	4500	4100	700	2300	47.7
MP13	<200	13.0	0.89	0.090	<0.60	0.059	0.170	<80	50.00	<2.0	53	3.9	94	1300	2400	2500	400	2400	34.5
MP14	700	13.0	7.00	0.110	1.90	0.081	0.260	75	7.10	4.4	120	<2.0	<40	890	3700	3800	490	2100	44.0
MP15	2700	<20.0	1.10	0.110	<0.70	0.055	0.200	<90	1.30	<2.0	20	3.2	75	760	4300	3900	620	1700	31.4
MP16	860	<9.0	<0.30	0.037	0.95	<0.030	0.140	41	17.00	<0.9	24	3.8	65	890	2300	2900	340	2000	28.2
MP17	430	<20.0	5.70	0.420	<0.80	0.200	1.300	160	9.60	<2.0	160	4.8	1000	1700	17000	3100	490	2800	103.4
MP18	730	6.3	<0.30	0.060	0.35	0.059	0.180	<60	0.97	<0.8	18	<2.0	77	590	3000	3300	340	1400	25.5
MP19	2000	13.0	1.40	0.190	<0.50	0.190	0.450	<200	2.10	<2.0	35	3.0	240	840	9200	3500	570	1700	45.6
MP20	2100	<20.0	<0.30	0.200	0.87	0.160	0.320	140	2.60	<2.0	26	<2.0	140	770	11000	3200	360	1500	42.4

Table III-5-7-(2) Results of measurement of metal elements by neutron activation analysis (2nd field survey)

	ﾎｳｼｬｶﾌﾞﾝｾｷ(NG/M3)																		
	AG	AL	AS	BA	BR	CA	CD	CE	CL	CO	CR	CS	CU	FE	HF	K	LA	LU	MN
MP 1	<0.60	1800	11.00	44	110	2900	<30	2.30	2500	0.54	7.60	0.130	100	1400	0.140	1100	1.20	<0.020	36.0
MP 2	<0.60	2000	1.90	< 20	110	3600	<30	2.20	1900	0.51	3.50	<0.080	87	910	0.160	< 800	1.20	<0.020	19.0
MP 3	<0.40	350	< 0.80	< 20	63	420	<30	0.37	1900	0.24	0.77	<0.060	120	220	<0.050	< 800	<0.50	<0.020	5.3
MP 4	0.79	1500	2.70	20	150	1700	<40	1.70	2100	0.30	2.80	0.130	54	660	<0.080	2100	<0.80	<0.020	12.0
MP 5	0.51	1400	2.00	26	140	760	<40	1.10	2200	0.21	3.10	<0.080	92	520	0.096	2200	<0.70	0.015	9.4
MP 6	<0.60	4100	4.80	79	37	1800	<30	3.50	1500	0.94	4.70	<0.200	130	1400	0.280	< 800	1.20	<0.020	20.0
MP 7	<2.00	8900	20.00	< 40	260	8900	<40	5.50	2600	1.30	18.00	0.300	130	4000	0.510	2400	2.50	0.035	82.0
MP 8	0.83	6100	14.00	43	31	1900	<30	4.60	1900	0.41	8.70	0.300	180	2700	0.300	2100	2.30	0.034	38.0
MP 9	<0.70	4700	23.00	23	76	1800	<30	3.10	2400	< 0.30	10.00	0.330	75	1100	0.270	1300	1.00	<0.020	28.0
MP10	<0.70	2300	6.60	< 30	63	1800	<30	2.70	930	< 0.30	4.70	0.190	230	980	<0.090	< 900	1.10	0.016	29.0
MP11	<0.60	4600	7.00	< 30	60	1600	<30	2.90	1000	0.62	4.60	0.270	100	1500	0.250	1700	1.70	<0.020	27.0
MP12	1.50	2600	14.00	43	130	3800	<40	2.60	2600	0.71	12.00	<0.200	110	2100	0.190	< 900	2.00	0.022	51.0
MP13	0.61	1400	3.20	< 20	220	1100	<30	0.77	1200	< 0.20	3.90	0.120	61	780	0.180	< 700	<0.60	0.013	16.0
MP14	1.10	1200	2.70	< 20	96	1200	<30	1.90	1500	0.27	4.40	<0.200	84	770	0.120	1000	0.71	0.012	17.0
MP15	0.91	1900	14.00	< 30	55	1700	<30	1.90	2400	0.85	9.90	<0.200	68	880	0.110	1100	<0.60	<0.020	31.0
MP16	0.99	3200	6.40	< 30	62	1700	<40	3.10	2100	0.95	10.00	<0.200	< 50	1500	<0.090	< 900	1.20	0.021	30.0
MP17	<0.60	2100	3.10	< 20	160	1800	45	1.90	1500	0.25	3.40	<0.080	240	900	0.180	< 800	0.78	0.020	19.0
MP18	<0.50	770	1.80	< 30	120	630	<30	0.89	1700	< 0.30	1.80	<0.080	90	390	<0.080	< 800	<0.60	<0.020	7.7
MP19	<0.80	1800	12.00	35	87	7900	<30	3.10	3100	1.30	21.00	<0.200	170	4600	0.240	1600	2.10	<0.020	190.0
MP20	<0.60	1400	2.50	< 20	120	2400	<30	1.70	2100	0.59	6.00	<0.080	59	850	0.100	< 800	0.73	<0.020	16.0

	ﾎｳｼｬｶﾌﾞﾝｾｷ(NG/M3)											ｹｲｺｳXｾﾝﾌﾞﾝｾｷ(NG/M3)				ｲｵﾝｸﾛﾏﾄ(NG/M3)			TPM
	NA	NI	SB	SC	SE	SM	TH	TI	V	W	ZN	CD	PB	S	SI	CL-	NO3-	SO4--	(UG/M3)
MP 1	960	24.0	2.60	0.280	2.20	0.180	0.500	130	63.00	4.0	190	4.4	250	2100	8400	1800	2000	5800	74.9
MP 2	1200	14.0	0.70	0.250	<0.60	0.120	0.330	81	31.00	1.4	56	4.1	380	1600	8600	1600	1400	3400	36.6
MP 3	1200	9.8	< 0.40	0.050	0.69	<0.030	0.100	45	13.00	< 2.0	23	3.0	100	610	1400	1400	780	2100	51.4
MP 4	2700	17.0	0.89	0.150	0.79	0.120	0.500	160	21.00	1.7	56	7.8	320	1400	6500	1100	1500	3700	82.7
MP 5	2500	16.0	1.40	0.160	0.78	0.070	0.330	51	23.00	< 2.0	53	5.4	260	1200	6800	1200	1300	3700	95.3
MP 6	700	<20.0	0.55	0.410	1.30	0.300	0.630	110	22.00	< 0.8	73	1.9	170	2000	13000	1100	1800	4800	69.7
MP 7	740	<30.0	13.00	1.600	2.10	0.400	1.500	510	33.00	5.1	230	6.6	610	4000	26000	2100	2000	6200	176.4
MP 8	2200	<20.0	2.80	0.650	3.00	0.290	1.100	< 90	26.00	1.4	110	7.8	85	2800	18000	1200	2000	4600	100.8
MP 9	2100	15.0	3.10	0.460	1.50	0.230	1.100	230	22.00	2.7	140	2.9	150	2600	17000	1400	2300	4600	105.3
MP10	2000	<20.0	16.00	0.300	1.30	0.140	0.510	120	38.00	< 0.9	130	2.1	200	1200	8200	500	1200	3800	61.6
MP11	330	<20.0	3.20	0.450	1.40	0.260	1.600	160	26.00	2.3	100	3.0	230	1100	13000	690	1600	4000	82.8
MP12	1100	<20.0	6.00	0.400	4.20	0.210	0.830	170	39.00	10.0	340	3.1	430	2000	9900	1700	2300	7100	72.8
MP13	370	<20.0	2.70	0.170	0.88	0.100	0.360	110	21.00	< 2.0	84	< 2.0	550	900	4600	750	1200	3800	52.8
MP14	720	13.0	2.50	0.130	1.00	0.056	0.300	46	25.00	1.9	79	< 2.0	370	990	4300	940	1200	3300	49.4
MP15	690	<20.0	4.20	0.260	4.30	0.160	0.450	93	39.00	5.4	150	2.2	230	1600	6800	1600	2200	6100	29.0
MP16	1000	<20.0	3.70	0.360	2.10	0.130	0.620	250	21.00	6.4	130	< 2.0	220	1200	10000	1500	2300	4800	77.5
MP17	960	<20.0	2.50	0.220	0.79	0.110	0.460	130	22.00	< 2.0	70	1.9	460	1100	7100	980	1400	4000	62.8
MP18	1400	13.0	1.20	0.098	0.83	0.055	0.160	49	15.00	< 2.0	34	< 2.0	310	730	2600	1100	1100	2600	61.5
MP19	1300	33.0	5.50	0.340	4.30	0.190	0.510	160	53.00	4.4	640	6.4	310	4700	7000	2100	1300	8800	46.9
MP20	1400	<20.0	1.50	0.200	<0.70	0.090	0.350	56	36.00	1.7	49	< 2.0	310	1100	5600	1500	2100	3100	74.0

Table III-5-7-(3) Results of measurement of metal elements by neutron activation analysis (3rd field survey)

	ﾎｳｼｬｶﾌﾞﾝｾｷ(NG/M3)																		
	AG	AL	AS	BA	BR	CA	CD	CE	CL	CO	CR	CS	CU	FE	HF	K	LA	LU	MN
MP 1	<0.40	< 8	21.00	< 20	44	1400	<30	0.62	3300	0.31	18.00	<0.080	23	400	0.130	430	0.67	<0.008	13.0
MP 2	<0.30	280	1.40	< 8	18	510	<30	0.30	3300	0.14	0.92	<0.040	43	220	<0.040	440	<0.60	<0.005	3.0
MP 3	<0.50	950	1.80	< 20	44	2200	<30	0.94	3300	0.50	3.80	0.095	74	760	0.110	710	<0.60	<0.020	15.0
MP 4	0.82	780	4.90	35	41	3300	<30	0.80	3900	0.68	13.00	<0.060	< 40	1400	0.150	470	<0.70	<0.020	60.0
MP 5	<0.60	1100	3.90	< 20	27	5300	<30	2.20	4500	0.94	10.00	<0.200	160	4100	<0.080	430	<0.60	<0.020	140.0
MP 6	<0.60	2100	12.00	57	31	5400	<30	1.60	3600	0.44	15.00	0.190	110	1300	0.160	1200	0.91	0.025	46.0
MP 7	<0.80	6400	8.50	< 30	300	2300	<40	3.50	3800	0.59	12.00	0.360	63	3000	0.210	1300	<0.80	<0.020	46.0
MP 8	<0.60	2600	6.70	32	69	380	<30	1.90	2400	0.32	3.90	0.190	< 40	1400	0.092	630	1.60	<0.020	17.0
MP 9	<0.60	3600	14.00	31	150	< 400	<40	3.30	2300	0.50	8.70	0.310	46	1500	0.120	1100	0.92	<0.020	36.0
MP10	<0.50	780	2.10	23	72	700	<30	0.53	1700	< 0.20	1.60	<0.050	< 30	440	0.053	390	<0.70	0.009	7.1
MP11	<0.60	1900	4.60	< 30	180	1500	<50	4.90	2900	0.24	4.60	<0.090	47	730	<0.090	820	1.60	<0.020	19.0
MP12	<0.60	1200	1.20	< 20	53	1600	<40	1.30	3500	0.30	4.40	<0.080	< 40	690	<0.070	580	<0.80	0.015	16.0
MP13	<0.50	910	< 0.90	< 20	400	< 400	<50	0.92	1800	< 0.30	3.20	<0.090	59	470	<0.090	< 500	<0.90	<0.020	6.5
MP14	1.10	1300	1.60	19	97	1500	<40	2.10	2900	0.29	3.20	<0.090	31	650	0.096	< 500	1.50	<0.020	12.0
MP15	<0.40	110	< 0.60	< 6	11	< 500	37	0.34	4600	< 0.09	< 0.60	0.044	18	< 50	<0.040	< 500	<0.70	<0.005	< 0.9
MP16	<0.50	1900	< 0.90	< 20	180	1700	<30	1.70	2500	0.41	11.00	<0.090	88	1000	0.130	< 300	1.00	<0.009	28.0
MP17	<0.50	1100	1.10	< 20	140	350	<30	1.00	2200	< 0.20	2.00	0.066	88	490	0.085	< 800	<0.60	<0.020	8.7
MP18	<0.40	1500	< 0.80	< 9	61	870	<30	0.80	2500	0.14	1.60	0.081	31	610	0.091	< 400	<0.60	<0.009	6.6
MP19	<0.40	860	< 0.60	< 8	45	780	<20	1.40	2700	0.22	3.30	<0.060	19	420	0.061	< 300	1.10	<0.008	7.2
MP20	<0.50	2200	< 0.80	600	78	3200	<30	2.00	2200	0.22	2.90	0.120	63	970	0.140	680	1.30	<0.020	24.0

	ﾎｳｼｬｶﾌﾞﾝｾｷ(NG/M3)											ｹｲｺｳXｾﾝﾌﾞﾝｾｷ(NG/M3)				ｲｵﾝｸﾛﾏﾄ(NG/M3)			TPM
	NA	NI	SB	SC	SE	SM	TH	TI	V	W	ZN	CD	PB	S	SI	CL-	NO3-	SO4--	(UG/M3)
MP 1	2000	< 8.0	0.98	0.100	0.66	0.061	0.160	< 60	15.00	< 0.8	27	< 2.0	96	1100	4800	2200	680	1800	37.9
MP 2	1700	5.9	< 0.50	0.025	0.35	<0.020	0.055	< 30	7.70	< 0.8	11	< 2.0	77	730	1800	2200	490	1200	24.1
MP 3	2200	< 8.0	1.20	0.110	<0.60	0.080	0.170	< 70	21.00	< 0.8	35	< 2.0	71	1400	6400	2000	670	2000	40.6
MP 4	2500	<20.0	2.50	0.120	<0.60	0.081	0.240	< 70	40.00	4.7	200	3.0	140	2300	5300	2400	580	3700	52.4
MP 5	2700	<20.0	2.40	0.180	1.40	0.110	0.290	98	26.00	3.0	450	9.6	140	2800	6600	3000	1000	4200	56.3
MP 6	1900	<20.0	3.50	0.280	1.20	0.120	0.410	130	15.00	4.8	250	5.8	180	2600	15000	2000	1100	2600	66.0
MP 7	1800	18.0	1.60	1.100	<0.80	0.220	1.100	300	26.00	< 0.8	130	< 2.0	660	1700	33000	2700	670	2700	122.4
MP 8	900	11.0	2.70	0.280	1.00	0.120	0.530	160	12.00	1.4	140	5.0	190	1000	12000	1300	750	1900	65.1
MP 9	970	< 9.0	2.40	0.430	0.73	0.240	1.000	240	25.00	3.1	130	3.2	300	1500	27000	1700	940	2900	104.7
MP10	770	15.0	1.10	0.076	<0.40	<0.040	0.150	< 70	11.00	< 0.9	28	3.7	110	650	3600	590	360	1400	37.3
MP11	920	< 9.0	2.20	0.180	<0.60	0.170	0.640	180	14.00	< 0.9	110	3.1	340	950	11000	1800	670	2100	71.1
MP12	2000	15.0	0.72	0.180	0.81	0.120	0.280	72	1.20	1.4	51	4.1	160	1300	10000	2300	590	1800	45.1
MP13	1100	< 9.0	3.60	0.092	<0.60	<0.050	0.170	71	23.00	< 2.0	58	6.0	900	1100	5300	970	511	1700	53.1
MP14	1900	< 9.0	1.10	0.150	0.65	0.095	0.220	110	7.10	2.3	42	2.2	290	920	7800	1800	640	1300	42.8
MP15	2500	4.7	< 0.50	0.011	0.34	<0.030	0.024	< 70	4.00	< 0.9	< 5	3.6	< 50	590	450	2800	570	1100	21.0
MP16	930	< 9.0	1.60	0.160	<0.60	0.042	0.420	260	19.00	4.2	88	< 2.0	460	1300	9800	1600	690	1900	67.9
MP17	920	< 8.0	1.30	0.120	0.57	0.048	0.230	39	9.30	< 2.0	45	4.3	330	830	6300	1000	560	1400	40.0
MP18	1000	< 7.0	< 0.40	0.110	<0.40	0.049	0.360	81	3.80	< 0.9	34	6.1	190	600	8900	1500	400	1000	42.0
MP19	1200	< 6.0	1.90	0.082	0.49	0.057	0.190	53	4.00	< 0.8	22	3.4	77	690	5200	1700	590	1100	41.7
MP20	850	< 9.0	1.10	0.240	<0.60	0.130	0.480	110	4.00	< 0.9	41	< 2.0	180	1000	15000	1600	860	1500	56.7

Table III-5-7-(4) Results of measurement of metal elements by neutron activation analysis (4th field survey)

	ホウシャカブンセキ(NG/M3)																		
	AG	AL	AS	BA	BR	CA	CD	CE	CL	CO	CR	CS	CU	FE	HF	K	LA	LU	MN
MP 1	<0.40	810	2.80	< 20	85	860	<40	0.82	4200	0.34	3.70	<0.090	17	330	<0.060	< 400	<0.90	<0.009	6.9
MP 2	<0.40	510	< 0.70	< 8	47	480	<40	0.34	4500	0.25	0.80	0.069	< 30	290	0.100	< 400	<0.80	<0.008	< 2.0
MP 3	0.50	2400	< 0.70	< 10	79	1200	42	2.80	4200	0.22	3.80	0.100	< 40	670	0.150	560	0.88	0.023	9.0
MP 4	<0.60	940	13.50	< 20	77	2500	<40	1.10	3500	0.30	11.00	<0.080	54	790	<0.080	600	<0.80	<0.008	27.0
MP 5	<0.60	1100	16.00	< 20	65	9200	<40	1.40	5000	0.56	13.00	0.200	50	1700	0.120	820	<0.80	<0.020	50.0
MP 6	<0.60	1400	17.00	24	37	2000	<40	1.20	4200	0.63	9.40	<0.090	43	720	0.091	690	<0.90	<0.020	20.0
MP 7	<2.00	16000	22.00	79	260	3800	<50	5.90	2900	1.10	19.00	0.420	< 90	5300	0.480	1000	1.90	0.038	51.0
MP 8	<0.70	3500	17.00	70	65	1900	<40	2.10	3700	0.66	16.00	<0.200	140	2200	0.310	1000	1.70	<0.020	41.0
MP 9	<0.70	4500	24.00	< 20	110	810	<30	2.80	2700	0.38	13.00	0.340	87	1400	0.120	1600	1.70	0.030	19.0
MP10	<0.50	710	< 0.90	29	70	260	<30	0.43	1500	0.14	2.30	0.074	46	270	<0.060	< 900	<0.60	<0.020	3.5
MP11	<0.70	5900	5.90	< 30	140	3400	<40	4.70	3400	0.34	5.30	0.260	130	2400	0.300	< 900	3.00	0.042	21.0
MP12	<0.40	1500	1.60	29	61	1900	<30	1.20	5000	0.34	3.90	0.080	24	700	0.140	1300	<0.60	0.017	15.0
MP13	<0.40	980	1.50	18	220	800	<40	0.54	2800	< 0.09	2.00	<0.060	< 40	440	0.068	< 900	<0.60	<0.020	5.9
MP14	0.44	1500	1.30	30	89	1100	<40	1.30	4400	0.57	3.80	<0.080	52	530	0.060	< 800	0.92	<0.020	8.4
MP15	<0.30	420	< 0.80	17	17	< 400	<30	0.63	6700	< 0.09	< 0.70	<0.040	41	190	<0.040	< 900	<0.70	<0.009	1.9
MP16	<0.70	3200	2.20	< 50	100	2600	<40	2.50	5100	0.38	4.80	<0.200	56	1300	<0.200	< 800	<0.80	<0.050	17.0
MP17	<0.60	2000	< 2.00	< 30	210	830	<40	1.40	3400	0.17	3.90	<0.090	110	780	0.110	< 900	0.95	<0.030	9.6
MP18	<0.50	720	< 1.00	34	79	470	<40	0.86	4200	0.15	1.30	<0.090	17	290	<0.060	1700	<0.80	<0.020	4.1
MP19	<0.50	1000	< 0.80	< 20	110	910	<40	0.72	4300	0.17	2.00	<0.070	< 30	440	<0.070	<2000	<0.80	<0.020	7.6
MP20	<0.90	3300	2.30	190	67	17000	<40	4.50	4100	16.00	32.00	0.260	33	1200	0.700	1400	1.80	<0.040	36.0

	ホウシャカブンセキ(NG/M3)										ケイコウXセンブンセキ(NG/M3)				イオンクロマト(NG/M3)			TPM
	NA	NI	SB	SC	SE	SM	TH	TI	V	W	ZN	CD	PB	S	SI	CL-	NO3-	SO4--	(UG/M3)
MP 1	2300	14.0	0.82	0.100	0.77	<0.030	0.170	< 80	9.60	< 0.9	31	< 2.0	230	1200	6000	2800	1300	2400	56.9
MP 2	2600	14.0	< 0.50	0.064	0.52	<0.030	0.110	< 60	7.90	< 0.8	18	5.6	67	1200	3600	3000	1300	2300	44.2
MP 3	2400	<10.0	< 0.50	0.290	0.81	0.110	0.460	44	7.40	< 0.7	29	4.4	160	1200	15000	3300	1400	2300	94.2
MP 4	1800	17.0	2.20	0.130	1.20	<0.030	0.220	74	52.00	< 0.8	120	6.0	141	2400	6900	2500	1600	4200	82.0
MP 5	2100	<20.0	3.20	0.210	1.30	0.053	0.270	68	43.00	1.5	320	7.5	120	5700	8700	4000	2300	9500	85.2
MP 6	2000	< 9.0	4.70	0.210	2.00	0.045	0.270	< 90	21.00	2.8	96	2.0	< 20	1800	10000	2700	1700	3900	64.2
MP 7	1400	<30.0	3.00	2.100	1.60	0.330	2.400	560	24.00	< 2.0	120	10.0	680	2200	63000	2100	1500	3500	215.5
MP 8	1100	<20.0	5.40	0.410	1.50	0.096	0.860	170	24.00	2.6	190	7.0	190	2000	19000	2500	1600	4200	100.6
MP 9	1400	15.0	2.80	0.490	1.30	0.190	1.000	160	12.00	< 2.0	77	4.6	230	1300	21000	1900	1500	3200	117.6
MP10	980	9.4	1.90	0.085	0.52	<0.030	0.130	< 70	5.60	< 0.9	18	2.5	89	700	3300	910	940	1900	42.5
MP11	1400	<20.0	9.10	0.550	1.40	0.230	2.800	< 90	10.00	< 2.0	83	6.9	410	1600	26000	2100	1800	3000	137.8
MP12	2700	11.0	1.10	0.210	1.10	0.082	0.300	< 80	1.70	< 2.0	64	3.8	98	1700	12000	3500	1300	2800	55.5
MP13	1600	< 7.0	2.60	0.110	0.97	0.050	0.240	< 70	3.80	< 2.0	38	3.4	550	990	5700	1800	1200	2100	121.4
MP14	2500	< 8.0	1.20	0.140	0.90	0.058	0.360	< 80	5.00	< 2.0	38	3.9	190	1100	8900	3000	1400	2100	65.6
MP15	3500	< 3.0	< 0.40	0.065	0.66	0.041	0.065	< 70	4.10	< 2.0	11	3.6	< 40	980	3300	5000	1200	2100	40.4
MP16	2000	<20.0	42.00	0.390	2.20	0.150	0.650	180	4.90	< 2.0	96	3.4	170	1200	17000	4100	1600	2500	94.1
MP17	1800	<20.0	3.90	0.230	<0.70	0.110	0.440	120	4.20	< 2.0	78	< 2.0	390	1100	12000	2400	1200	2100	107.7
MP18	2200	6.5	0.76	0.073	0.97	0.049	0.170	64	3.80	< 2.0	35	5.5	< 50	830	5600	2500	1000	2000	74.2
MP19	2200	< 8.0	< 0.60	0.110	1.20	<0.030	0.200	39	5.90	< 2.0	53	< 2.0	210	1100	8100	3400	1500	2300	98.3
MP20	2000	84.0	0.95	0.400	1.40	0.220	0.650	210	6.50	10.0	60	7.9	56	3500	20000	3000	1800	5600	107.2

III-5-2 Analysis of Metal Elements by X-ray Fluorescence Analysis

Elements (Pb, Si) which cannot be analyzed by neutron activation method and elements (Cd, S) which is quite low in analyzing sensibility, have been analyzed by X-ray fluorescence method.

III-5-2-1 Principle of measurement

When the sample is irradiated by primary X-ray produced from X-ray generator, characteristic secondary X-ray is generated from the sample. The fluorescence of X-ray has intensity distribution of energy corresponding to the elements component, and so X-ray intensity of energy corresponding to the elements to be determined is measured by dispersing X-ray. And it is compared with X-ray intensity with the standard sample which has previously measured. Thus the containing quantity of the proposed element is determined.

Fig. III-5-9 shows principle of X-ray fluorescence analyzing instrument.

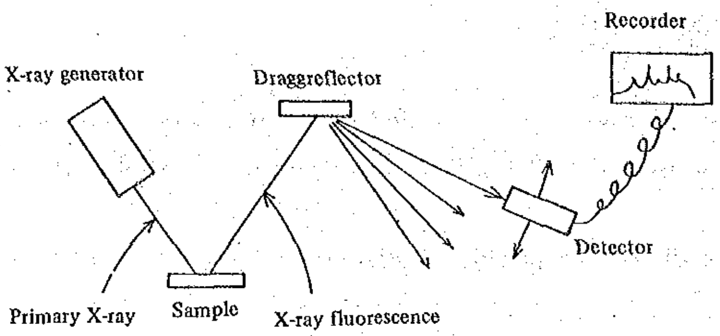
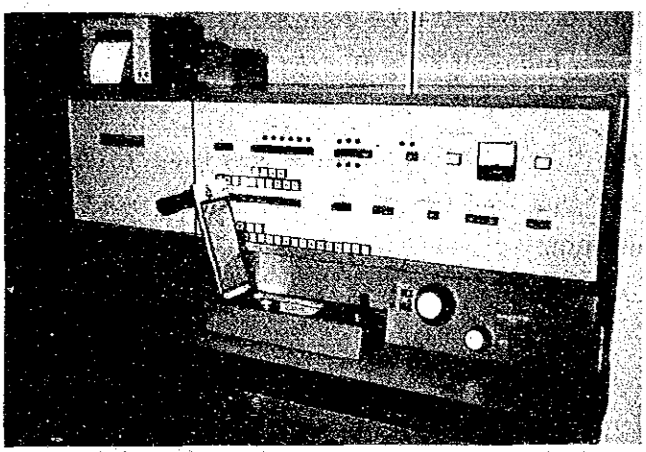


Fig. III-5-9 Principle of X-ray fluorescence analyzing instrument

III-5-2-2 Analyzing methods

As shown in Fig. III-5-2, sampled filter for analysis (PF-1) is cut into round shape of 47 mm and it is placed on the X-ray fluorescence analyzing instrument, Gigerflex of RIGAKU DENKI KK, (Picture III-5-2) for analysis. The instrument is set on sample stand as shown in Fig. III-5-10.



Picture III-5-2 Analyzing instrument of X-ray fluorescence

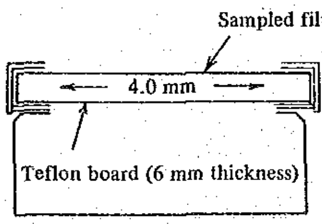


Fig. III-5-10 Sample stand

(a) Analyzing conditions

Table III-5-8 shows the classified items of X-ray tube, Bragy reflector, detector, analyzing line, measuring time and so on which used in this study.

Table III-5-8 Analyzing conditions of X-ray fluorescence analysis

Element	X-ray tube	Bragy reflector	Detector	Analytical line	Measuring time
Si	Chromium tube	EDDT*	Flow proportional counter	K α line (7.126 A)	100S
S	Chromium tube	Ge	Flow proportional counter	K α line (5.373 A)	100S
Cd	Chromium tube	EDDT*	Flow proportional counter	L α line (3.960 A)	200S
Pb	Tungsten tube	LiF	Scintillation counter	L β line (0.982 A)	200S

Notes: * EDDT: Ethylenediamine ditartrate
** Chromium tube: 40 KV - 35 mA
Tungsten tube: 50 KV - 40 mA

Among X-ray tubes, Chromium tube was used for analysis of Si, S and Cd, and Tungsten tube was used for Pb. This is due to the fact that the relative intensity of Chromium tube at over 2.5 Å is superior and below 2.5 Å, relative intensity of Tungsten tube is superior, as shown in Fig. III-5-11.

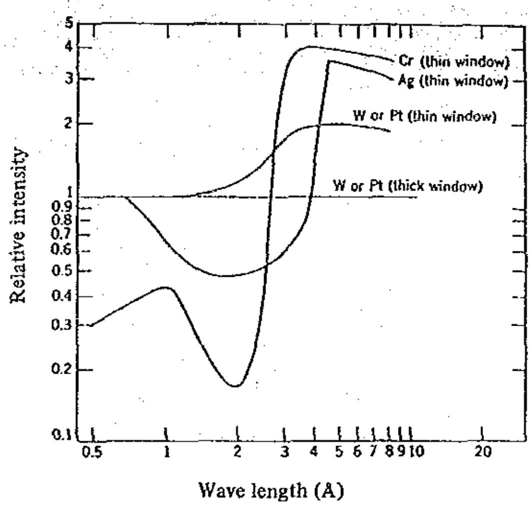


Fig. III-5-11 Character of X-ray tubes

For Bragy reflector used for X-ray reflection, EDDT for Si and Cd, Ge for S, and LIF for Pb were employed. This is due to that applicable range of Bragy reflector corresponding to the analytical line of each element has been limited as shown in Fig. III-5-12. (Oblique line)

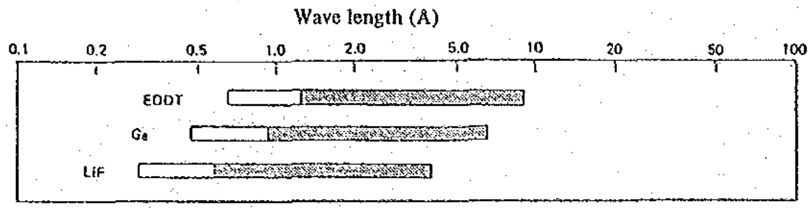


Fig. III-5-12 Applicable range of Bragy reflectors

Further Fig. III-5-13 shows the relative intensity of flow proportional counter employed.

In this study, Argon has been employed.

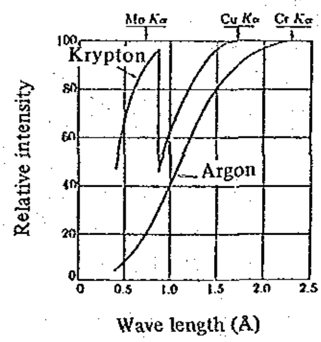
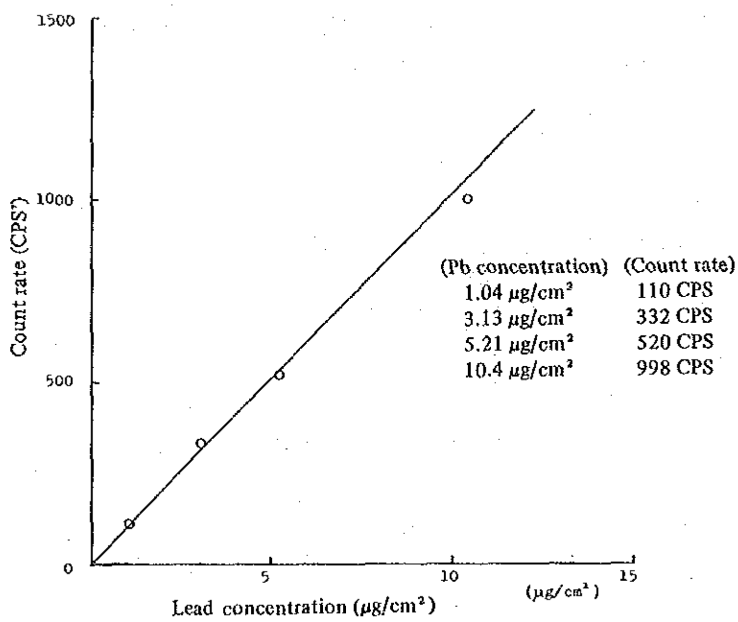


Fig. III-5-13 Relative intensity of flow proportional counter

(b) Drawing of analytical line

(i) Pb, Cd (Filtration method of precipitate by coprecipitation with iron)
Into the solution containing 300 μg of Iron (Fe^{3+}), a certain fixed quantity of Lead (Pb^{2+}) and Cadmium (Cd^{2+}) are added. Adjusting Ph at 9.3 by Sodium Borate solution and 0.1N Hydrogen Chloride, precipitation is coagulated while heating, and the precipitates are collected on the filter after filtration. The above procedures are repeated changing quantity of Lead and Cadmium stage by stage for production of standard samples for drawing the analytical line.

Fig. III-5-14 shows the analytical line.



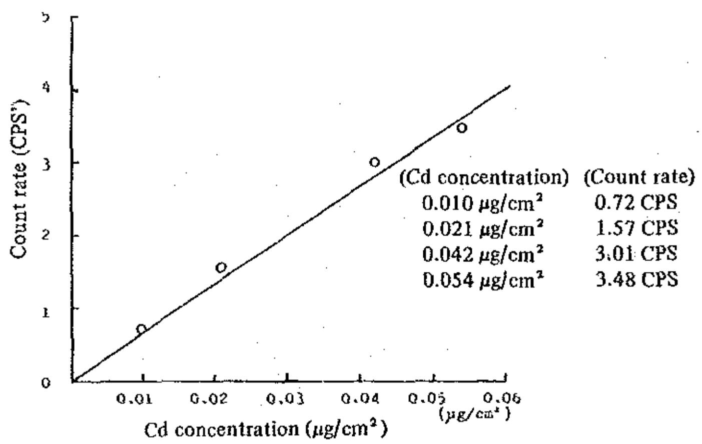
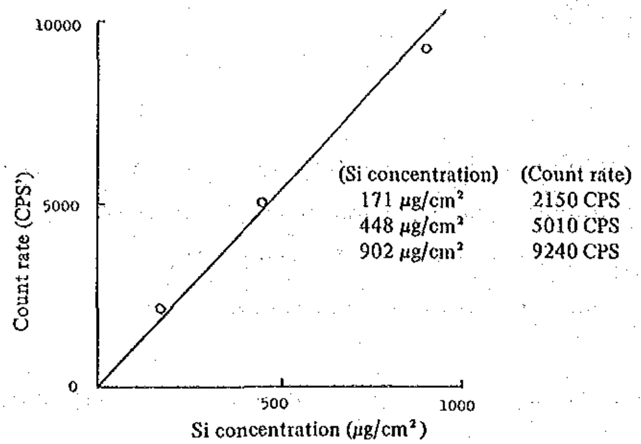


Fig. III-5-14 Analytical line of Lead and Cadmium

ii) Si, S (filtration method of powder)

Silicon and Sulpher content-know-powder (fly ash) are fully grinded in the agate mortar, and the powder is dispersed by air. The dispersed powder is collected on the filter after filtration under reduced pressure. From the weight of filter weighed before and after sampling, and concentration of Silicon and Sulpher, the contents of 2 elements are obtained. The filters contained different volumes of powder are produced as the standard samples for drawing the analytical lines. Fig. III-5-15 shows the analytical line.



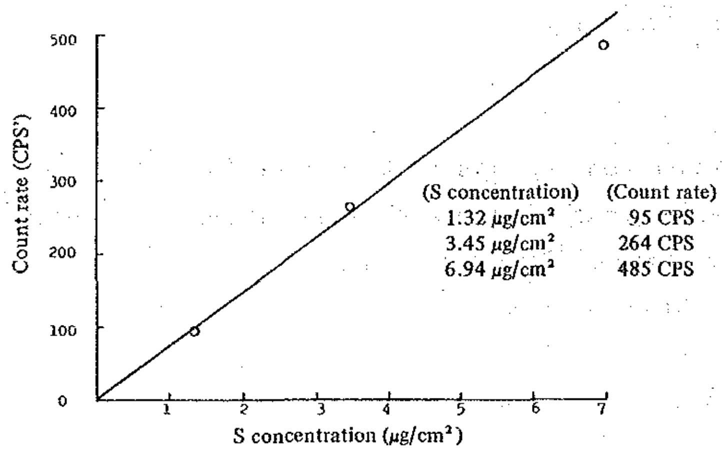


Fig. III-5-15 Analytical line of Silicon and Sulpher

III-5-2-3 Determination limit

The average determination limit values of the samples of ambient particulate matter are as follows which are obtained by X-ray fluorescence analysis. The blank values of filters are not usually obtained quantitatively.

Cd: 0.02 $\mu g/cm^2$
Pb: 0.05 $\mu g/cm^2$
Si: 0.2 $\mu g/cm^2$
S: 0.2 $\mu g/cm^2$

III-5-2-4 Calculation method of metal elements concentration

The weight of elements on the filter were calculated from X-ray's peak (CPS) by the following equation.

$$Ew = \frac{Stw}{St_{CPS}} \cdot S_{CPS}$$ Equation III-5-5

where;

Ew:	Element weight contained in sample at unit area ($\mu g/cm^2$)
Stw:	Element concentration in standard sample ($\mu g/cm^2$)
St_{CPS}:	Count rate in standard sample (CPS)
S_{CPS}:	Count rate of analyzed sample (CPS)

Elements concentration in the ambient are calculated by the following Equation III-5-6.

$$Ce = \frac{Ew \cdot Fa}{V} \times 1{,}000$$ Equation III-5-6

where;

Ce: Element concentration in the ambient (ng/m^3)

Ew: Element weight in analyzed sample at unit area ($\mu g/cm^2$)

Fa: Total area of filter (406 cm^2)

V: Air flow rate (m^3)

III-5-2-5 Spectrum of X-ray fluorescence

Fig. III-5-16 shows an example of spectrum of X-ray fluorescence (1st Field Survey).

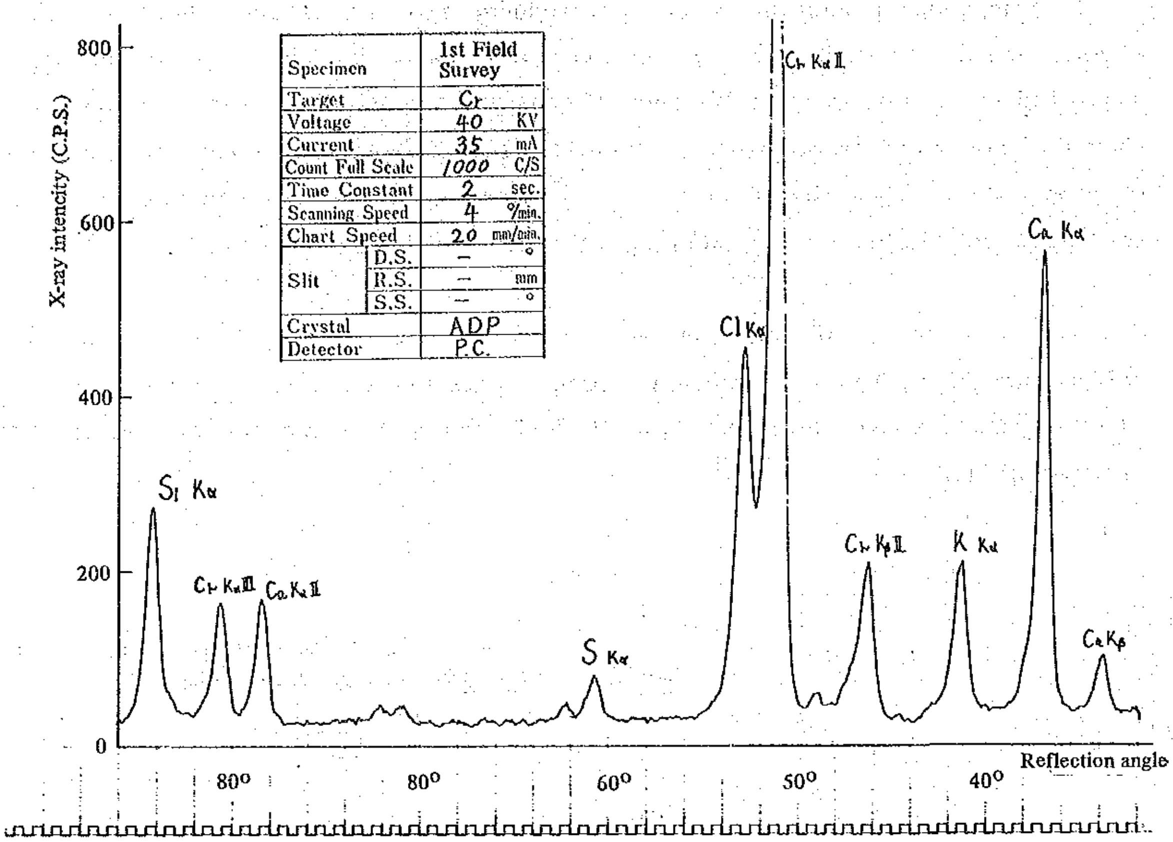


Fig. III-5-16 Spectrum of x-ray fluorescence

III-5-2-6 Results of measurement

Table III-5-7 shows the results of measurement of metal elements in particulate matter analyzed by X-ray fluorescence method.

III-5-3 Analysis of Anion by Ion Chromatography

III-5-3-1 Principle of analysis

Ion chromatography method is a kind of column ion chromatography using ion exchange resin as fixed phase.

Sample solution containing ion is introduced into separation column together with eluent, and ion is collected by ion exchange resin. By eluent development, ion is separated selectively by the difference of separation constant between ion and resin. And they are introduced to suppressor column and eluent from separation column is removed or nuetralized. Thus the objective ion is flowing in electric conductivity cell from separation column one by one, and respective types of ion are measured.

The instrument of ion chromatography is composed by eluent tank, solution forwarding pump, sample injection pump, separation column, suppressor column and electric conductivity detector. Fig. III-5-17 shows the outline of analysis by ion chromatography.

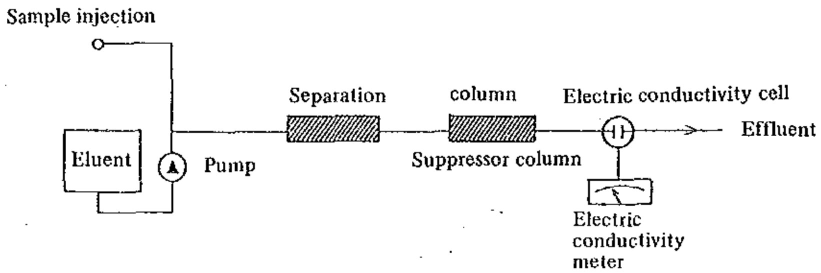
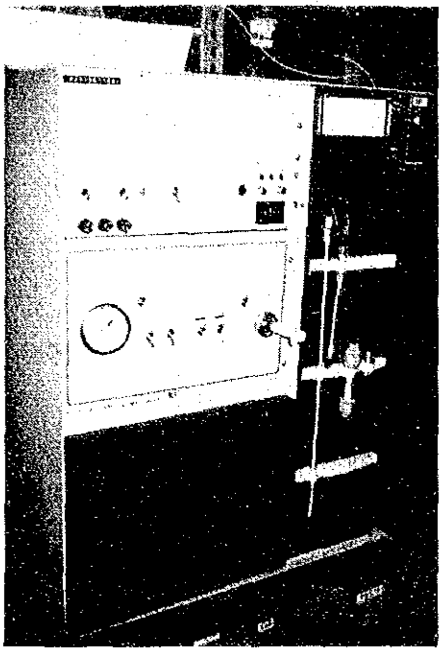


Fig. III-5-17 Outline of analysis of ion chromatography

III-5-3-2 Analyzing method

The filter (PF-1) is cut into 1/12 as shown in Fig. III-5-2, and adding 100 ml of eluent, vibrated about 90 minutes which is used as standard sample. The analysis in this study has been conducted by Chromatography Model 10 of Dionex Co. Ltd. Picture III-5-3 shows the instrument of ion chromatography.



Picture III-5-3 Instrument of ion chromatography

(1) Analyzing conditions

The analysis has been carried out by the following conditions.

Separation column:	3 mm × 150 mm × 3 mm × 500 mm anion exchange resin
Suppressor column:	6 mm × 250 mm
Sample volume:	200 μℓ
Eluent:	0.0024M Na_2CO_3/0.003M $NaHCO_3$
Eluent flow rate:	138 ml/hr

(2) Drawing of analytical line

4 ml of 1000 mg/l chloride ion standard solution, 30 ml of 1000 mg/l nitric acid standard solution and 50 ml of 1000 mg/l sulfuric acid standard solution are kept in the volume tric flask of 1 liter, and eluent is added upto the marked line (constant volume) which is used as standard stock solution. This standard stock solution is diluted in sequence upto 100 magnifications which are used as standard solution for analytical line. This solution is injected into ion chromatography under same conditions with sample solution, and analytical line is drawn.

Fig. III-5-18 shows analytical line and it is an example of analytical lines drawn once a day.

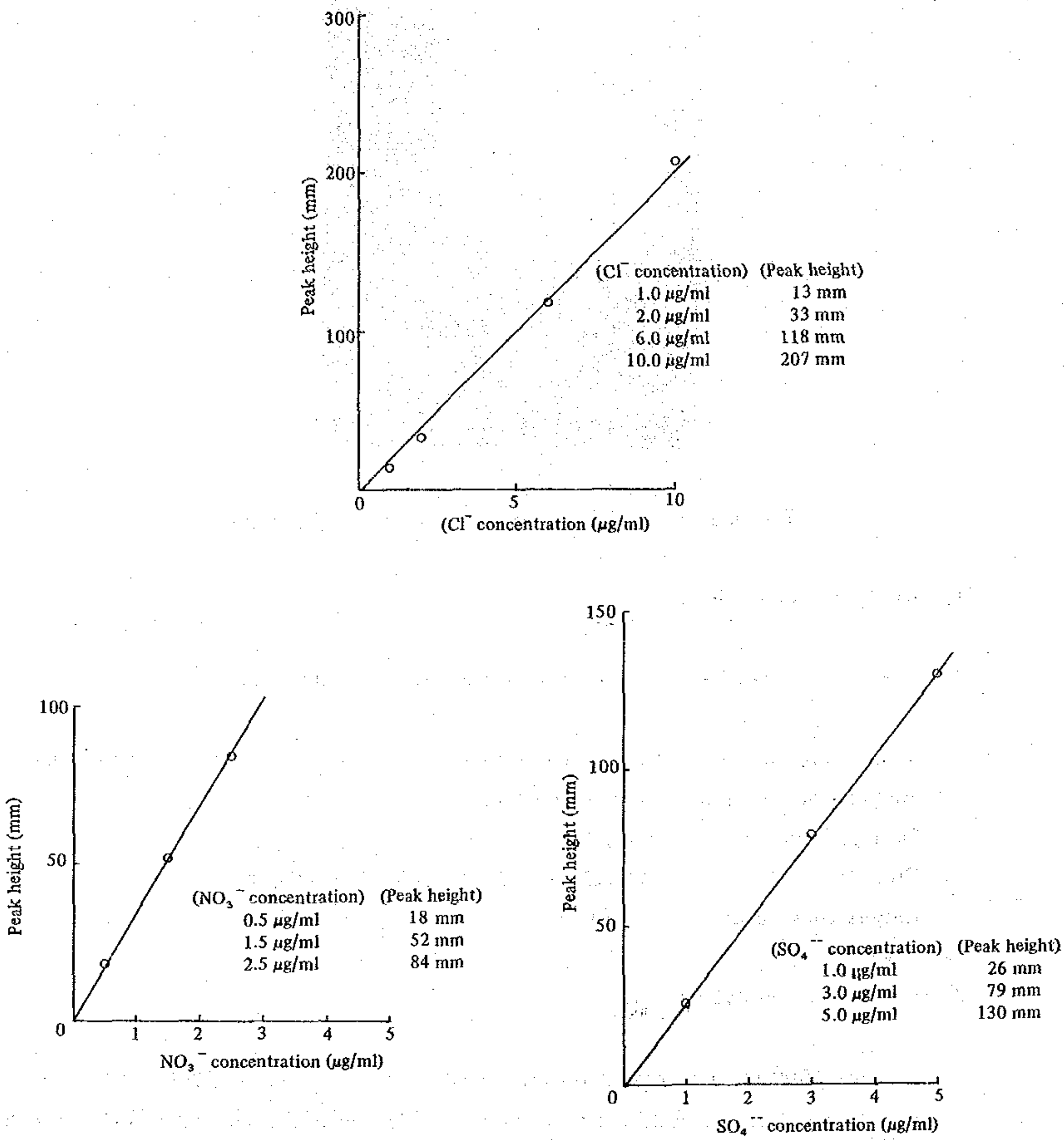


Fig. III-5-18 Analytical line of Cl^-, NO_3^- and SO_4^{2-}

III-5-3-3 Determination limit and blank value of filter

Full scale of electric conductivity in this analysis is 30 μs/cm for Cl^-, and 3 μs/cm for NO_3^- and SO_4^{2-}. The low marginal limit of determination is shown as solution concentration in Table III-5-9, and blank value of Polyphlone filter (PF-1) is also shown in the table at the unit of ng/cm^2.

Table III-5-9 Determination limit and blank value of filter

Analyzed item	Determination limit (g/ml)	Blank value of filter (ng/cm^2)			
		1st F.s.	2nd F.s.	3rd F.s.	4th F.s.
Cl^-	0.1	0	0	0	0
NO_3^-	0.1	0	0	0	0
SO_4^{--}	0.1	300	0	0	0

III-5-3-4 Calculation method of anion concentration

The anion concentration of sample is calculated as follows;

(1) Ion concentration of analyzed solution

$$Soul_I = \frac{CSti - Hsoul}{Hst}$$ Equation III-5-7

where;

$Soul_I$: Ion concentration of analyzed solution (μg/ml)

CSti: Ion concentration of standard solution (μg/ml)

Hsoul: Peak height of analyzed solution (mm)

Hst: Peak height of standard solution (mm)

(2) Anion concentration in the ambient

$$C_I = \frac{Soul_I \cdot V_L \cdot Sa}{Fa \cdot V} \times 1,000$$ Equation III-5-8

where;

C_I: Anion concentration in the ambient ($\mu g/m^3$)

$Soul_I$: Ion concentration of analyzed solution (μg/ml)

V_L: Extracted solution volume (ml)

Sa: Total area of filter (406 cm^2)

Fa: Filter area of analyzed sample (17.3 cm^2)

V: Air sucking flow rate (m^3)

III-5-3-5 Ion Chromatogram

Fig. III-5-19 shows the typical example of ion chromatogram (1st Field Survey). Horizontal axis is the time after sample injection, and vertical axis represents peak height. Further the peak height used for calculation of concentration is the height from the base-line connected flat part around the peak.

Eluent : 0.0024M Na_2CO_3/ 0.003 $NaHCO_3$
Separator Column : 3 × 150 mm + 3 × 500 mm
Suppressor Column : 6 × 250 mm
Injection Volume : 200 ul
Conductivity Meter Setting : 30 μS/ cm
Flow Rate : 138 ml/ hr.
Recorder Speed : 5 mm/ min.

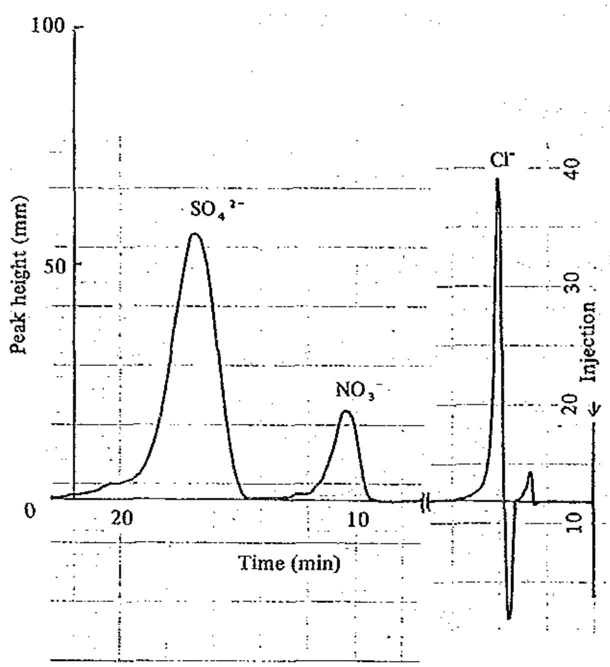


Fig. III-5-19 Ion chromatogram

III-5-3-6 Results of measurement

The anion concentration in the particulate matter by ion chromatography analysis is shown in Table III-5-7.

III-5-4 Analysis of Total Carbon and Non-volatile Carbon by Differential Thermal Analyzing Method

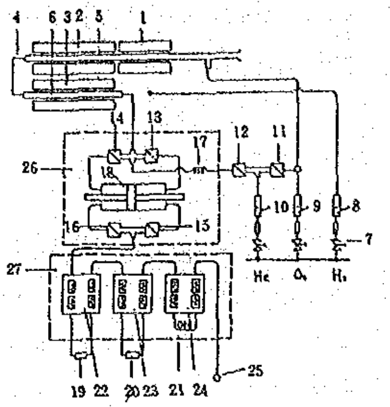
III-5-4-1 Principle of Analysis

Particulate matter sampled on the quartz filter is treated thermally and is classified into organic carbon and elemental carbon. After complete oxidization to CO_2, they are introduced into differential thermal conductivity meter which has CO_2 absorbing tube. The heat generated by absorption of CO_2 is output as disproportional signal for determination.

Further, in this study the sample was treated in Nitrogen current at 400°C and volatile carbon was removed for determining non-volatile carbon, and the sample not thermally treated was used for analysis of total carbon.

The outline of the instrument is shown in Fig. III-5-20, and it is composed by the decomposition furnace, flow rate regulating pump and detector.

From the combustion tube fully charged with He carrier gas, the sample is inserted on Nickel board. The sample is decomposed by high temperature and then completely oxidized with catalysis of oxide copper. The gases generated from samples except CO_2, H_2O, and N_2 are removed by oxidation furnace and reduction furnace. The gases mixed by CO_2, H_2O and N_2 are introduced into differential thermal conductivity meter which has the absorbing tubes for H_2O and CO_2 respectively, and then concentration of C, N, and H are obtained from the disproportional electric signal (count number).



1. Decomposition furnace
2. Oxidization furnace
3. Reduction furnace
4. Thermostat connecting tube
5. Combustion tube
6. Reduction tube
7. Pressure regulator
8-10. Flow rate meter
11-16. Electromagnetic valve
17. Preheater
18. Pump
19. H_2O absorbing tube
20. CO_2 absorbing tube
21. Delay coil
22-24. T.C.D.
25. EXT
26. Pump thermostat
27. Detector thermostat

Fig. III-5-20 Outline of carbon analyzing instrument

III-5-4-2 Analyzing methods

As shown in Fig. III-5-21, the Quartz filter was cut to circle pieces of 1 cm diameter (2 pcs.) as samples for analysis. For the analysis of total carbon, no pretreatment has been given, but for the analysis of non-volatile carbon, the sample pieces were thermally pretreated (400°C in Nitrogen current) as described.

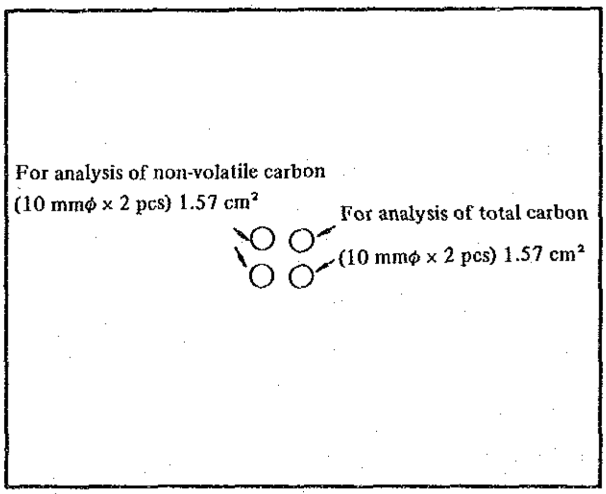
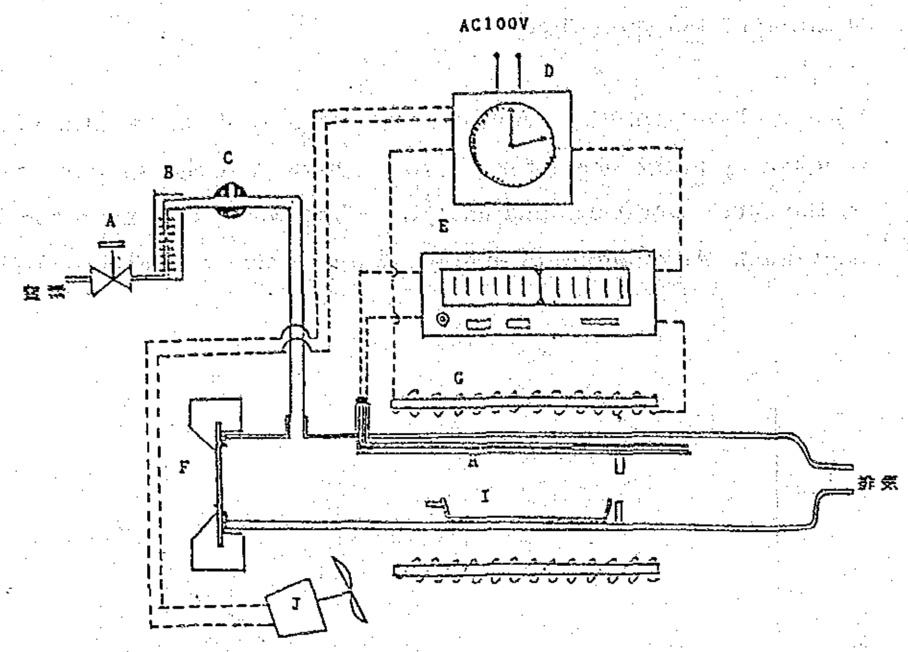


Fig. III-5-21 Division of sampled filter for carbon analysis



A: Pressure meter for Nitrogen
B: Flow rate meter for Nitrogen
C: Change-over cock
D: Sample heating and cooling sequence timer
E: Temperature regulator for heating furnace
F: Inlet of sample
G: Heating furnace
H: CA
I: Quartz sample board
J: Cooling fan

Fig. III-5-22 Outline of pretreatment facility for analysis of elemental carbon

(1) Analyzing conditions

The analysis of carbon has been carried out under the following conditions.

Sample decomposition temperature:	950°C
Temperature of oxidization furnace:	850°C
Temperature of reduction furnace:	550°C
Temperature of pump thermostat:	55°C
Temperature of detector thermostat:	100°C
Flow rate of Helium:	200 ml/min
Flow rate of Oxigen gas:	20 ml/min
Bridge Current:	65 mA

(2) Drawing of analytical line

Para-Amino Demethyl Aniline was employed as a standard substance and weighed by micro-scale for 0.1 to 2.5 mg. And the samples were also analyzed by the same conditions and analytical line was drawn from the volume of carbon contained. An example of analytical line is shown in Fig. III-5-23.

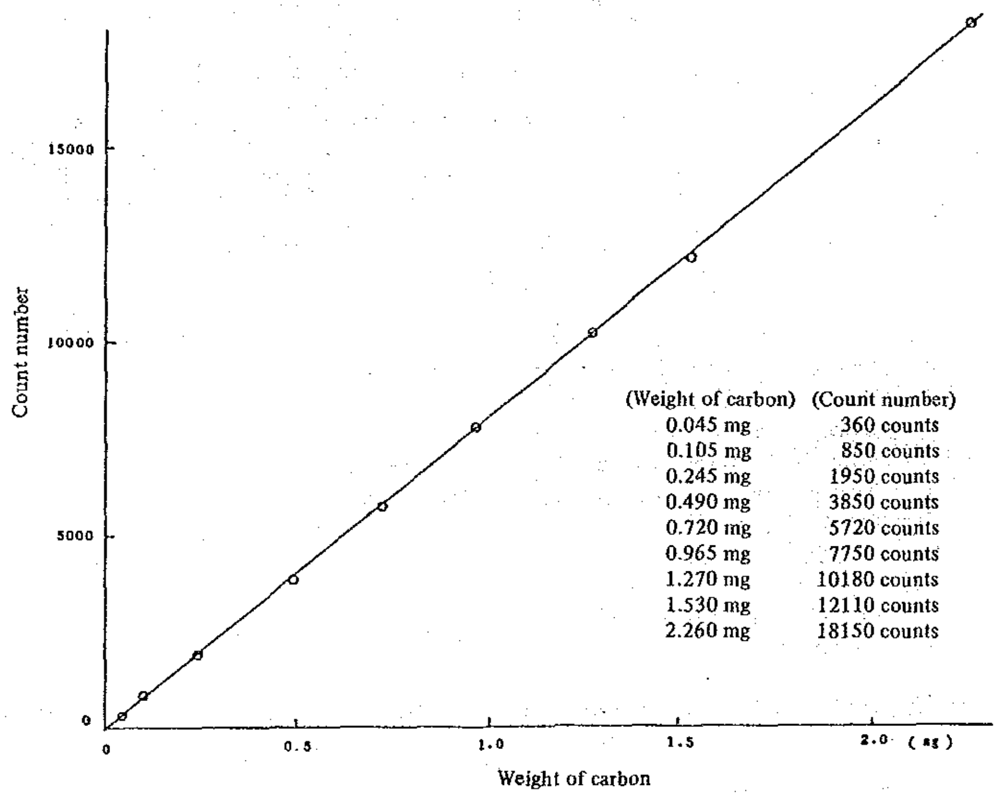


Fig. III-5-23 Analytical line of carbon

III-5-4-3 Limit of determination and blank value of filter

The limit of determination at analysis of ambient particulate matter by Differential Thermal Analysis is shown in Table III-5-10, and the blank value of the filter is also shown in the same table.

Table III-5-10 Limit of determination and blank value of filter

Item	Limit of determination *	Filter blank value			
		1st	2nd	3rd	4th
Total Carbon	5 μg	11	9	6	5
Non-volatile carbon	5 μg	5	3	2	2

Remarks: μg for 2 pieces filter of 1 cm

III-5-4-4 Calculation methods of carbon concentration

Carbon weight on the filter is calculated from count number of differential thermal conductivity meter by the following Equation III-5-9.

$$Cw = \left(\frac{Stw}{St_{count}} \cdot S_{count}\right) - Fbw \qquad \text{Equation III-5-9}$$

where;

Cw: Carbon weight in analyzed sample (μg)

Stw: Carbon content in standard sample (μg)

St_{count}: Count number of standard sample

S_{count}: Count number of analyzed sample

Fbw: Blank value of filter (μg)

Further, concentration of carbon in the ambient is calculated by the following Equation III-5-10.

$$Cc = \frac{Cw \cdot Fa}{V \cdot Sa} \qquad \text{Equation III-5-10}$$

where;

Cc: Carbon concentration in the ambient ($\mu g/m^3$)

Cw: Carbon weight in analyzed sample (μg)

V: Air flow rate (m^3)

Fa: Total area of filter (406 cm^2)

Sa: Filter area of analyzed sample (1.57 cm^2)

III-5-4-5 Results of analysis

The results of analysis of carbon concentration in the ambient air by differential thermal analysis are shown in Table III-5-11. In the table, the volatile carbon is represented by organic carbon, and non-volatile carbon is represented by elemental carbon. Also TPM concentration and the ratio of TPM to carbon are enumerated in the table.

Table III-5-11-(1) Results of analysis of carbon (1st survey)

Monitoring point	Elemental carbon μg/m³ (%)	Organic carbon μg/m³ (%)	Total carbon μg/m³ (%)	TPM μg/m³
MP 1	11.4 (17.1)	3.1 (4.6)	14.5 (21.7)	66.7
MP 2	9.3 (15.1)	3.0 (4.9)	12.3 (20.0)	61.4
MP 3	10.8 (20.3)	3.2 (6.0)	14.0 (26.4)	53.1
MP 4	14.0 (14.8)	5.1 (5.4)	19.1 (20.2)	94.4
MP 5	14.6 (16.0)	3.4 (3.7)	18.0 (19.8)	91.1
MP 6	12.7 (14.6)	5.1 (5.8)	17.8 (20.4)	87.2
MP 7	26.9 (18.2)	11.1 (7.5)	38.0 (25.7)	148.0
MP 8	11.3 (14.6)	4.0 (5.2)	15.3 (19.7)	77.5
MP 9	13.1 (16.6)	4.3 (5.4)	17.4 (22.0)	79.1
MP10	10.4 (16.1)	3.7 (5.7)	14.1 (21.8)	64.6
MP11	11.2 (15.1)	3.9 (5.3)	15.1 (20.4)	74.0
MP12	10.9 (19.6)	3.5 (6.3)	14.4 (25.9)	55.5
MP13	11.9 (20.6)	3.9 (6.7)	15.8 (27.3)	57.8
MP14	10.2 (19.0)	3.1 (5.8)	13.3 (24.7)	53.8
MP15	5.3 (10.8)	2.1 (4.3)	7.4 (15.0)	49.2
MP16	11.5 (17.8)	3.6 (5.6)	15.1 (23.3)	64.7
MP17	27.9 (23.0)	7.7 (6.4)	35.6 (29.4)	121.1
MP18	7.3 (14.7)	1.7 (3.4)	9.0 (18.2)	49.5
MP19	8.8 (12.8)	2.4 (3.5)	11.2 (16.3)	68.8
MP20	7.4 (13.7)	2.5 (4.6)	9.9 (18.4)	53.9

Table III-5-11-(2) Results of analysis of carbon (2nd survey)

Monitoring point	Elemental carbon µg/m³ (%)	Organic carbon µg/m³ (%)	Total carbon µg/m³ (%)	TPM µg/m³ (%)
MP 1	20.2 (17.1)	3.3 (2.8)	23.5 (19.9)	118.2
MP 2	15.8 (24.2)	2.6 (4.0)	18.4 (28.2)	65.2
MP 3	18.8 (23.2)	3.8 (4.7)	22.6 (27.9)	81.1
MP 4	25.0 (21.4)	3.8 (3.3)	28.8 (24.7)	116.8
MP 5	25.6 (22.2)	5.2 (4.5)	30.8 (26.7)	115.2
MP 6	21.4 (19.9)	5.6 (5.2)	27.0 (25.1)	107.6
MP 7	43.0 (24.4)	10.7 (6.1)	53.7 (30.5)	176.0
MP 8	15.0 (20.1)	3.2 (4.3)	18.2 (24.4)	74.7
MP 9	23.5 (25.2)	8.4 (9.0)	31.9 (34.2)	93.3
MP10	14.8 (22.3)	5.2 (7.8)	20.0 (30.2)	66.3
MP11	17.2 (22.8)	5.1 (6.8)	22.3 (29.5)	75.5
MP12	15.6 (17.1)	2.0 (2.2)	17.6 (19.3)	91.1
MP13	17.0 (22.2)	4.1 (5.3)	21.1 (27.5)	76.7
MP14	13.8 (17.9)	3.4 (4.4)	17.2 (22.3)	77.3
MP15	7.7 (14.4)	1.0 (1.9)	8.7 (16.3)	53.3
MP16	16.0 (18.6)	5.7 (6.6)	21.7 (25.3)	85.8
MP17	33.1 (25.2)	9.7 (7.4)	42.8 (32.6)	131.3
MP18	13.5 (21.6)	3.1 (5.0)	16.6 (26.6)	62.5
MP19	12.2 (19.4)	2.5 (4.0)	14.7 (23.4)	62.8
MP20	7.6 (17.2)	1.2 (2.7)	8.8 (19.9)	44.2

Table III-5-11-(3) Results of analysis of carbon (3rd survey)

Monitoring point	Elemental carbon µg/m³ (%)	Organic carbon µg/m³ (%)	Total carbon µg/m³ (%)	TPM µg/m³ (%)
MP 1	6.2 (13.9)	1.4 (3.1)	7.6 (17.0)	44.7
MP 2	4.1 (8.8)	0.5 (1.1)	4.6 (9.9)	46.6
MP 3	8.0 (15.2)	1.6 (3.0)	9.6 (18.2)	52.7
MP 4	12.2 (16.3)	1.8 (2.4)	14.0 (18.7)	74.8
MP 5	6.5 (8.1)	1.6 (2.0)	8.1 (10.0)	80.6
MP 6	7.0 (10.1)	2.6 (3.8)	9.6 (13.9)	69.1
MP 7	32.7 (18.8)	11.7 (6.7)	44.4 (25.6)	173.6
MP 8	15.1 (14.5)	4.9 (4.7)	20.0 (19.2)	104.3
MP 9	23.7 (18.4)	8.7 (6.8)	32.4 (25.2)	128.6
MP10	6.5 (13.7)	2.9 (6.1)	9.4 (19.7)	47.6
MP11	15.8 (20.8)	7.9 (10.4)	23.7 (31.1)	76.1
MP12	10.6 (17.3)	1.9 (3.1)	12.5 (20.5)	61.1
MP13	13.3 (22.9)	4.2 (7.2)	17.5 (30.2)	58.0
MP14	7.8 (13.6)	2.2 (3.8)	10.0 (17.4)	57.5
MP15	2.8 (6.9)	1.2 (3.0)	4.0 (9.9)	40.6
MP16	10.8 (13.8)	4.3 (5.5)	15.1 (19.3)	78.4
MP17	7.6 (14.8)	3.3 (6.4)	10.9 (21.2)	51.4
MP18	8.6 (16.4)	3.0 (5.7)	11.6 (22.1)	52.4
MP19	4.4 (8.8)	2.8 (5.6)	7.2 (14.3)	50.2
MP20	8.6 (12.8)	3.2 (4.8)	11.8 (17.6)	67.1

Table III-5-11-(4) Results of analysis of carbon (4th survey)

Monitoring point	Elemental carbon μg/m³ (%)	Organic carbon μg/m³ (%)	Total carbon μg/m³ (%)	TPM μg/m³ (%)
MP 1	15.5 (21.7)	3.6 (5.0)	19.1 (26.8)	71.3
MP 2	11.1 (22.9)	2.6 (5.4)	13.7 (28.2)	48.5
MP 3	15.6 (24.5)	5.7 (8.9)	21.3 (33.4)	63.8
MP 4	14.2 (24.9)	3.4 (6.0)	17.6 (30.8)	57.1
MP 5	12.1 (18.9)	3.4 (5.3)	15.5 (24.2)	64.0
MP 6	11.3 (18.4)	4.9 (8.0)	16.2 (26.3)	61.5
MP 7	26.9 (18.8)	12.4 (8.6)	39.3 (27.4)	143.4
MP 8	16.1 (17.0)	5.2 (5.5)	21.3 (22.5)	94.6
MP 9	22.3 (18.8)	12.4 (10.4)	34.7 (29.2)	118.9
MP10	11.9 (27.0)	3.2 (7.3)	15.1 (34.3)	44.0
MP11	21.0 (24.1)	6.9 (7.9)	27.9 (32.1)	87.0
MP12	14.3 (18.1)	4.3 (5.4)	18.6 (23.5)	79.2
MP13	16.4 (27.0)	4.4 (7.2)	20.8 (34.2)	60.8
MP14	16.3 (24.2)	4.1 (6.1)	20.4 (30.3)	67.3
MP15	10.2 (20.3)	2.5 (5.0)	12.7 (25.3)	50.2
MP16	19.9 (21.5)	6.5 (7.0)	26.4 (28.5)	92.5
MP17	20.1 (25.5)	5.0 (6.3)	25.1 (31.9)	78.8
MP18	17.1 (19.5)	8.3 (9.5)	25.4 (29.0)	87.6
MP19	14.2 (21.7)	3.7 (5.7)	17.9 (27.4)	65.4
MP20	15.4 (19.5)	4.0 (5.1)	19.4 (24.6)	78.9

III-5-5 Analysis of Metal Element, Anion and Carbon in Soil by Neutron Activation Analysis, X-ray Fluorescence Analysis and Differential Thermal Analysis

3 typical types of surface soil of Singapore have been supplied by Soil Investigation Unit of JTC and their metal elements, anion and carbon content have been analyzed.

The methods of analysis are almost same with the previously described for ambient particulate matter, but some processes of pretreatment being different, the followings are supplemented.

The sample soil has been naturally dried and impurities such as small stones are eliminated. After grinded by agate mortar, they were used as analytical sample.

The weighing of sample has been carried out after desication for several days with Silicagel. The quantity of samples for various analyses are as follows;

(a) Neutron activation analysis

About 15 mg for short term irradiation and about 30 mg for long term irradiation are sealed in double layers Polyethylene bags of 5 x 7 cm respectively.

(b) X-ray Fluorescence Analysis

About 100 mg of soil samples are equally distributed on the filter for analysis.

(c) Ion Chromatography Analysis

Adding 100 ml of eluent in 1 gram of soil sample, and vibrating about 90 minutes for extraction, the sample solution are obtained after filteration of impurities.

(d) Carbon Analysis

2 to 5 mg of soil sample are weighed on the nickel board and they are used for analysis of total carbon and non-volatile carbon.

Table III-5-12 shows the results of analysis.

Table III-5-12 Results of analysis of soil components

Name of sample		No. 1	No. 2	No. 3	Average
Method	Item/unit	ppm	ppm	ppm	ppm
Neutron activation analysis	Ag	<4	<4	<3	<4
	Al	120000 (1)	70000 (1)	170000 (1)	120000
	As	17 (7)	11 (9)	170 (2)	66
	Ba	660 (9)	260 (20)	<100	310
	Br	<30	<30	<10 (34)	<30
	Ca	<2000	<2000	<3000	<2000
	Cd	<70	<70	<70	<70
	Ce	81 (2)	120 (2)	24 (6)	75
	Cl	2200 (13)	<1000	<1000	<1000
	Co	<0.7	1.5 (26)	0.94 (28)	0.84
	Cr	22 (11)	50 (5)	57 (4)	43
	Cs	3.9 (11)	2.5 (16)	2.8 (13)	3.1
	Cu	<400	<300	<500	<400
	Fe	25000 (2)	43000 (2)	31000 (2)	33000
	Hf	7.4 (4)	8.9 (4)	7.4 (4)	7.9
	K	37000 (8)	4300 (46)	11000 (15)	17000
	La	54 (4)	56 (4)	20 (7)	43
	Lu	0.68 (5)	0.53 (7)	0.10 (29)	0.44
	Mn	34 (6)	38 (5)	44 (5)	39
	Na	2400 (6)	2000 (3)	790 (27)	1700
	Ni	<80	<80	<70	<80
	Sb	8.8 (5)	1.7 (19)	7.7 (5)	6.1
	Sc	18 (1)	13 (1)	10 (1)	14
	Se	<4	<4	3.9 (45)	<4
	Sm	6.5 (1)	11 (1)	2.0 (2)	6.5
	Th	20 (1)	14 (2)	35 (1)	23
	Ti	3700 (5)	3800 (7)	4700 (8)	4100
	V	60 (4)	100 (3)	71 (5)	77
	W	7.4 (22)	<3	7.9 (16)	5.2
	Zn	43 (27)	<30	28 (39)	25
X-ray fluorescence analysis	Cd	1.3	0.6	0.7	0.9
	Pb	61	70	75	69
	S	190	170	270	210
	Si	310000	300000	190000	270000
Ion Chromatography analysis	Cl^-	870	41	230	380
	NO_3^-	12	<7	<7	<7
	$SO_4^{=}$	46	100	18	55
Differential thermal analysis	Elemental carbon	850	710	530	697
	Organic carbon	1310	140	740	730
	Total carbon	2160	850	1270	1427

Remarks: Numerical value in bracket is analytical error (%).

PART IV
EMISSION SOURCE

PART IV EMISSION SOURCE

In this study, the monitored values of each monitoring station obtained through the field survey are assumed to be the values of the future (1990). On the above condition, the proposed dispersion concentration of particulate matter from coal firing power stations and integrated steel mill are added, and such values are assumed to be the ambient concentration of the particulate matter of the future (1990).

The monitored values mean or are defined as the ambient concentration of all emission sources such as natural background, sources from human activities and secondary particles.

In this PART IV, the assumption of emission volumes from coal firing power stations and integrated steel mill are conducted which are necessary for future dispersion calculation.

CHAPTER 1 ASSUMPTION OF EMISSION VOLUME OF PARTICULATE MATTER

For setting up the assumption of emission volume from the new sources, the agreement between Singapore and Japanese Authorities has been obtained, and so the basis of calculation or assumption is described in this part of the report.

IV-1-1 Coal Firing Power Stations

IV-1-1-1 Pulau Seraya power station

The proposed Australlian coal's ash content is assumed to be 15% judging from its high caloric value (6,450 Kcal/kg) and all ash are introduced to electrostatic precipitator.

Wet emission gas volume is 9.1 Nm^3/kg-coal. When Hydrogen content of coal is 5%, dry emission gas volume is 8.5 Nm^3/kg-coal ($9.1 - \frac{22.4}{2} \times 0.05 = 8.5$). As the ash content of coal is 15%, ash per 1 kg coal is 0.15 kg/kg-coal. So ash concentration in dry gas is 0.15 kg/8.5 Nm^3 which is equal to 18 g/Nm^3-dry gas.

When the efficiency of electrostatic precipitator is 99.7%, concentration at the exit is calculated as 0.05 g/Nm^3-dry gas. Therefore the particulate concentration discharged into the ambient comes 124 kg/hr. (0.05 g/Nm^3-dry gas x $\frac{8.5}{9.1}$ x 2,650,000 Nm^3/hr-wet gas - 1,000).

Taking the deviation of efficiency of EP into consideration, particulate emission volume is assumed to be 130 kg/hr.

IV-1-1-2 Pulau Tekong power station

When concentration of EP exit is 0.05 g/Nm^3-dry gas, same as Pulau Seraya, the particulate emission volume is calculated as 115 kg/hr from wet gas emission volume 2,470,000 Nm^3/hr.

Taking the deviation of EP efficiency into calculation, the particulate emission volume is assumed as 120 kg/hr.

IV-1-2 Integrated Steel Mill

IV-1-2-1 Grate Kiln

Referring to Japanese experiences of sintering processes which is comparatively high in concentration of particulate, the concentration at the inlet of EP is assumed to be 2 g/Nm^3. When the efficiency of EP is 91% (due to greater deviation of dust concentration lower efficiency rate is applied) the particulate concentration at the exit of EP is calculated to be 0.18 g/Nm^3. The particulate volume discharged into the ambient from EP is obtained by multiplying emission volume of Grate Kiln (5 x 10^6 Nm^3/hr) which is 900 kg/hr.

IV-1-2-2 Reheating furnace

Referring to Japanese experiences, the particulate concentration of reheating furnace is assumed as 0.1 g/Nm^3. As EP is supposed to be not installed, the emission volume to the ambient is obtained just multiplying 6.3 x 10^4 Nm^3/hr, which makes 6.3 = 6 kg/hr.

IV-1-2-3 Electric arc furnace

The steel making requires a large volume of thermal power, but 100 t/charge UHP furnace (Ultra High Power) of transformer capacity 60 MVA is employed which requires short time for steel making processes. When one cycle of steel making by UHP furnace is 2 hours, it comes 12 charges per day. So one day production comes 100 x 12 = 1,200 t/day. On the other hand, annual production of Molten steel is 1.037×10^6 t and so the daily treatment of 3,457 t (1.037×10^6/12 months x 25 days) is required. From these data, the required numbers of UHP furnace is 3,450 t/1,200 = 3 furnaces.

Referring to the standard emission gas volume of 100 t furnace in Japan, one set of 100 t/charge is assumed to discharge 600,000 Nm^3/hr. Among gas volume, 80% is induced from the ceiling and 20% is directly induced from the furnace. All volume of gases are assumed to be introduced into EP. (Because of generation of CO, bag house is usually used instead of EP for safety). The particulate concentration at the inlet of EP is 5 g/Nm^3, and efficiency of bag house is 96.5%. On these conditions, particulate concentration at the exit of bag house is calculated to be 0.18 g/Nm^3. The total gas volume discharged into the ambient is 0.18 g/Nm^3 x 600,000 Nm^3/hr x 3 furnaces = 324 kg/hr.

Particulate volume discharged from the above mentioned facilities are summed up as shown in Table IV-1-1.

Table IV-1-1 Particulate volume by plants and facilities

Names of plant and facilities	Particulate volume (kg/hr)
Pulau Seraya Power Station	130
Pulau Tekong Power Station	120
Tekong Integrated Steel Mill Tekong Integrated Steel Grate Kiln Tekong Integrated Steel Reheating Furnace Tekong Integrated Steel Electric Arc F.	 900 6 324

The particulate matter discharged into the ambient is fallen down to the place near to the sources when they are heavy in weight, and is dispersed long far away when they are light. These phenomena are put into dispersion model and it is scheduled to calculate the ambient concentration of the particulate matter, but precipitating velocity of the particulate is calculated by the following Stokes formula IV-2-1.

$$Vs = \frac{2r^2 Psg}{9\nu Pa} \qquad \text{Formula IV-2-1}$$

where;

r: radius of particulate (m)

Ps: density of particulate (g/m^3)

Pa: density of air (g/m^3)

ν: coefficient of kinematic viscosity of air (m^2/s)

g: acceleration (m/s^2)

Vs: falling velocity of particulate (m/s)

In the Stokes formula, final velocity of particulate largely depends on the size of particulate and for calculation of particulate dispersion by all sizes and falling velocity, tremendous number of calculation are needed. So in this study, the particle size is classified into 4 categories as shown in Table IV-2-1, taking into consideration the fact that the size distribution in the ambient is drawn in two mountains curve at 2 microns and below 10 microns of SPM.

Table IV-2-1 Classification of particulate size

0 - 1.9 μm
2 - 9.9 μm
10 - 19.9 μm
Over 20 μm

Size distribution of particulate by the facilities has been assumed, referring to the monitored values in Japan.

In this chapter, size distribution by facilities and ratio of particulate size by classified rank are described.

IV-2-1 Boiler of Power Plant (Coal Firing Boiler)

For size distribution of particulate emitted from power stations of Pulau Seraya and Pulau Tekong, the average of monitored values for 4 coal firing stations in Japan were adopted. The results are shown in Fig. IV-2-1 of the next page.

In the figure, horizontal axis represents size of particulate and vertical axis is cumulative frequency, and it is expressed by logarithmic scale. And the size distribution is drawn in straight line (Rosin-Ramler distribution). Rosin-Ramler distribution is generally used for distribution exponent of the particulate matter generated from industrial activities. Residual rate (R) is expressed by the following equation.

$$R = 100 \times \exp(-\beta d_p^n) \qquad \text{Equation IV-2-2}$$

where;

R: residual rate (%)

d_p: particle size (μm)

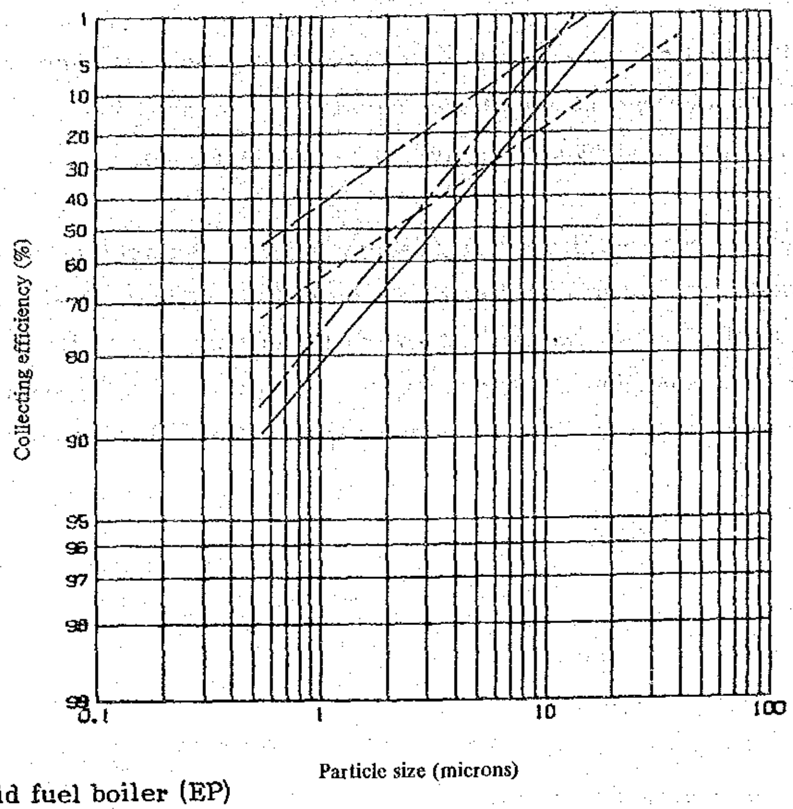
β: distribution factor

n: distribution exponent

Distribution factor and distribution exponent are constant determined by particulate character and these values are shown in Table IV-2-2 together with values of other facilities. In the table, size ratio by classified particulate sizes are shown which have already enumerated in Table IV-2-1.

Table IV-2-2 Distribution factor β, distribution exponent n and size ratio by classified size

Facilities	n	β	Medium diameter (μm)	Size ratio (%)			
				0.0-1.9	2.0-9.9	10.0-19.9	Over 20
Boiler for generator	1.029	0.206	3.3	34.3	54.6	10.0	1.1
Grate kiln	0.562	0.454	2.1	48.9	32.1	10.4	8.6
Reheating furnace	0.550	0.911	0.6	73.7	22.4	3.1	0.8
Electric Arc F.	1.065	0.270	2.4	43.2	52.5	4.2	0.1



——— Solid fuel boiler (EP)
- - - - - Grate Kiln (EP)
—·—·— Electric Arc furnace (EP)
— — — Liquid fuel boiler (no-EP)

Fig. IV-2-1 Size distribution of particulate by facilities

IV-2-2 Grate Kiln

For setting up the size distribution of particulate matter of Tekong integrated steel mill, the average values referred to Japanese sintering furnace of 4 steel mills have been applied. The results of this assumption are shown in Fig. IV-2-1. And distribution factor β, distribution exponent n and size ratio by the classified particulate size are shown in Table IV-2-2.

IV-2-3 Reheating Furnace

The integrated steel mill of Tekong is not installed with EP, and so reference had to be applied to 32 facilities in Japan which are not equipped with EP. Those figures are shown in Fig. IV-2-1. And distribution factor β, distribution exponent n, and size ratio by the classified particulate size are shown in Table IV-2-2.

IV-2-4 Electric Arc Furnace

Size distribution of the particulate matter emitted from Tekong integrated steel mill are estimated from the monitored values of 6 electric arc furnace operating in Japan.

Those values are shown in Fig. IV-2-1, and distribution factor β, distribution exponent n, and size ratio by the classified particulate size are shown in Table IV-2-2.

IV-2-5 Particulate Emission Volume by Size

The particulate volume by size, factories and facilities are shown in Table IV-2-3 together with other emission factors.

Table IV-2-3 Particulate volume by size

Plant & facility		Plant number	Stack number	Stack height (m)	Outlet diameter (m)	Gas velocity (m/s)	Gas temperature (°C)	Emission gas volume (Nm^3/hr)	Particulate volume (Kg/hr)	Particulate volume by size (Kg/H)			
										below 2 μm	2-10	10-20	Over 20
SERAYA POWER STATION		63	2	183	7.62	25	150	2,650,000	130	44.6	71.0	13.0	1.4
TEKONG POWER STATION		64	1	183	7.36	25	150	2,470,000	120	41.2	65.5	12.0	1.3
TEKONG INTEGRATED STEEL MILL	Grate Kiln	65	1	170	8.97	30	100	5,000,000	900	440.1	288.9	93.6	77.4
	Reheating Furnace	65	2	70	1.45	30	500	63,000	6	4.4	1.3	0.2	0.1
	Electric Arc Furnace	65	3	120	6.0	25	120	1,800,000	324	140.0	170.1	13.6	0.3