V; the sampling volume (m^3)

The list of TSP concentrations is shown in Table 4-37. Flow (1) Flow (2) represent air sampling volume obtained by Equation (4-20) and (4-24).

Table 4-37 TSP concentration measured by Low volume sampler

(unit μg/m³) (FLOW#1)]

Survey		Monitoring Station				
		MS 1	MS 2	MS 3	MS 4	MS 5
№1 (First Survey) 1/17 ~ 1/30	Quartz	57.9	52.1	82.6	67.5	50.6
	Polyflone	61.5	53.0	78.7	63.1	57.5
№2 1/30 ~ 2/14	Quartz	46.0	36.3	61.3	47.2	30.1
	Polyflone	48.8	38.9	60.7	44.2	35.0
№3 2/14 ~ 2/29	Quartz	51.6	52.7	75.3	69.3	47.0
	Polyflone	52.4	49.8	70.8	66.6	53.8
№4 2/29 ~ 3/10	Quartz	39.7	42.8	64.2	53.7	40.9
	Polyflone	41.8	42.9	65.6	49.5	45.1
№5 (Second Survey) 3/11 ~ 3/24	Quartz	33.1	33.8	46.0	34.5	25.4
	Polyflone	33.6	36.4	54.4	36.3	27.2
№6 4/1 ~ 4/29	Quartz	42.3	36.5	45.4	48.4	31.9
	Polyflone	42.3	39.3	49.9	46.4	34.3
№7 5/2 ~ 5/16	Quartz	23.2	21.8	46.1	46.7	19.6
	Polyflone	21.7	25.1	49.0	40.9	23.9
№8 5/16 ~ 5/31	Quartz	45.3	31.5	41.2	42.5	25.2
	Polyflone	47.9	32.9	45.3	41.2	25.4
№9 5/31 ~ 6/15	Quartz	47.4	29.8	35.3	33.1	17.2
	Polyflone	55.7	29.6	41.4	37.7	20.2
№10 6/15 ~ 7/1	Quartz	52.4	32.2	38.6	36.7	26.4
	Polyflone	62.9	33.1	47.5	42.3	28.3
№11 7/1 ~ 7/12	Quartz	47.1	33.0	34.1	45.4	31.2
	Polyflone	54.8	33.0	39.4	45.4	28.5
№12 (Third Survey) 7/13 ~ 7/26	Quartz	38.9	28.8	37.9	41.3	25.8
	Polyflone	41.3	28.3	39.8	39.6	26.0
№13 7/26 ~ 8/15	Quartz	50.7	35.2	42.7	39.4	22.5
	Polyflone	53.9	36.2	47.4	41.0	26.2
№14 8/15 ~ 8/31	Quartz	26.8	23.6	54.1	44.9	25.8
	Polyflone	30.1	28.0	51.2	40.9	38.6
№15 8/31 ~ 9/16	Quartz	40.1	28.3	47.3	49.6	31.7
	Polyflone	43.0	30.2	49.7	46.8	44.1
№16 9/16 ~ 9/30	Quartz	39.3	39.9	49.8	58.6	24.7
	Polyflone	38.3	39.2	51.9	56.3	33.5
№17 9/30 ~10/17	Quartz	73.0	40.3	39.3	49.2	33.1
	Polyflone	77.8	39.5	49.1	53.8	38.5
№18 10/17 ~10/31	Quartz	60.8	50.6	68.2	80.4	31.3
	Polyflone	65.3	66.1	76.5	85.5	39.4
№19 10/31 ~11/16	Quartz	73.3	90.5	84.4	130.0	77.4
	Polyflone	85.0	87.6	85.5	149.4	86.2
№20 11/16 ~11/30	Quartz	84.3	104.8	115.6	114.1	92.1
	Polyflone	84.8	100.6	107.9	118.3	104.2
№21 11/30 ~12/16	Quartz	53.5	66.3	66.9	92.9	52.9
	Polyflone	62.2	64.0	66.6	106.7	69.7
№22 12/16 ~ 1/ 3	Quartz	79.3	79.8	92.8	94.4	89.2
	Polyflone	86.6	83.4	94.8	104.1	96.5

(unit μg/m³) (FLOW#2)]

Survey		Monitoring Station				
		MS 1	MS 2	MS 3	MS 4	MS 5
№1 (First Survey) 1/17 ~ 1/30	Quartz	62.8	59.4	86.9	73.6	55.5
	Polyflone	66.1	58.2	84.3	66.9	62.1
№2 1/30 ~ 2/14	Quartz	50.1	41.0	64.5	51.7	32.9
	Polyflone	52.8	41.5	66.8	47.2	38.4
№3 2/14 ~ 2/29	Quartz	55.8	59.6	79.4	75.5	51.6
	Polyflone	55.9	51.9	77.5	69.8	58.6
№4 2/29 ~ 3/10	Quartz	43.0	48.7	68.6	59.3	45.1
	Polyflone	45.6	45.3	72.0	53.3	49.2
№5 (Second Survey) 3/11 ~ 3/24	Quartz	34.4	38.1	48.8	38.2	28.0
	Polyflone	36.8	40.1	59.6	38.9	29.6
№6 4/1 ~ 4/29	Quartz	43.9	39.7	46.0	52.6	33.6
	Polyflone	43.6	41.5	52.6	47.8	36.3
№7 5/2 ~ 5/16	Quartz	24.1	23.7	46.7	50.9	20.5
	Polyflone	22.2	26.4	51.1	41.2	25.6
№8 5/16 ~ 5/31	Quartz	46.5	34.1	41.7	45.8	26.5
	Polyflone	48.7	34.2	47.1	41.8	26.2
№9 5/31 ~ 6/15	Quartz	49.3	31.9	35.7	36.0	19.5
	Polyflone	57.4	30.7	42.5	38.3	21.6
№10 6/15 ~ 7/1	Quartz	53.6	34.8	39.0	39.9	27.5
	Polyflone	63.3	34.8	49.0	43.3	28.8
№11 7/1 ~ 7/12	Quartz	48.2	35.7	34.3	47.3	32.5
	Polyflone	56.1	34.2	40.9	45.9	29.3
№12 (Third Survey) 7/13 ~ 7/26	Quartz	40.0	31.2	38.4	43.3	27.0
	Polyflone	42.7	29.6	41.6	40.7	26.7
№13 7/26 ~ 8/15	Quartz	52.4	38.1	43.2	41.2	23.7
	Polyflone	54.4	37.9	49.4	42.0	27.0
№14 8/15 ~ 8/31	Quartz	27.9	25.5	54.8	47.0	27.3
	Polyflone	30.9	29.4	54.0	42.6	39.9
№15 8/31 ~ 9/16	Quartz	41.5	33.2	47.6	51.8	33.2
	Polyflone	43.8	34.2	51.6	48.4	45.4
№16 9/16 ~ 9/30	Quartz	40.8	43.1	50.6	61.5	32.0
	Polyflone	39.0	40.8	54.0	57.5	42.8
№17 9/30 ~10/17	Quartz	75.5	43.7	40.0	51.7	34.6
	Polyflone	80.2	41.6	51.2	55.3	39.6
№18 10/17 ~10/31	Quartz	63.2	54.8	68.6	83.4	32.9
	Polyflone	66.9	66.6	79.8	87.8	40.5
№19 10/31 ~11/16	Quartz	76.3	97.1	84.8	136.6	82.0
	Polyflone	85.7	91.8	86.4	153.9	89.8
№20 11/16 ~11/30	Quartz	87.7	114.3	118.3	120.6	97.6
	Polyflone	88.1	106.2	112.1	121.9	107.6
№21 11/30 ~12/16	Quartz	56.1	71.6	68.1	98.0	55.8
	Polyflone	63.7	66.6	69.6	107.5	72.1
№22 12/16 ~ 1/ 3	Quartz	83.1	87.6	95.2	99.9	98.5
	Polyflone	88.4	86.5	98.6	105.7	105.9

4.2 Meteorological observations

4.2.1 Monitoring of wind direction and wind velocity

The meteorological conditions of the survey area are thought very important for estimation of the smoke diffusion behaviors. Among many of them, the wind pattern is one most influential in the calculation of atmospheric concentration of pollutants.

In this study, two variables, wind direction and its velocity were thought important and thus were monitored at three stations by using the instruments of continuous and automatic moving type. To maintain the desirable condition of such instruments, weekly inspection and scheduled maintenance by once every three months were done throughout the whole one year survey period.

(1) Monitoring of wind direction, its velocity and turbulency

The instruments to be used for monitoring both wind direction and velocity have long been a target of developments simply because they are such fundamental ones among meteorological variables. Today the following three types are commonly in use.

① Anemometer with a cup-type wind velocity meter and an arrow-type direction monitor combined

② Propeller type anemometer

③ Supersonic anemometer

Among these three types, one most commonly employed for monitoring atmospheric pollutants is one of the type ① which is improved in its windmill blade and in tail fin such that measurement can cover a low velocity range. The type is sometimes called the windmill type anemometer and detects the wind velocity in term of output of a DC generator which is directly connected to the propeller facing the wind. On the other hand, the wind direction is measured by the instrument because it constitutes itself an arrow-type direction monitor. The type ③ is a newly developed one, very sensitive which utilizes a phenomenon that the propagation speed of an ultrasonic wave differs between down- and up-stream side of the wind and has no moving part in it. Thus the meter is featured by a wind measurement at near-zero velocity, a good response, and a good performance for air turbulency monitoring. The type ① is today no longer popular.

(2) Anemometer employed in this survey

The two dimensional ultrasonic anemometer was used in the monitoring stations MS2 through MS5 and one of three dimensional type in MSl for monitoring of wind velocity, direction and turbulency. As stated, those ultrasonic types utilizes a principle that the sound propagates differently depending upon the relative position of the meter and wind blowing direction.

When two heads, one for ultrasonic pulse transmission and the other for receiving, are positioned at a distance facing each other as shown in Figure 4- 27, and the pulse signal is sent from one to the other alternately at a fixed time interval, there are two pulse propagation times to be recorded, t_1 and t_2. The relationship among t_1, t_2 and wind velocity is then expressed by the following equation.

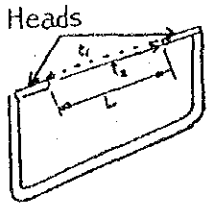

Figure 4-27 Propagation of pulse signal

$$\left.\begin{aligned} t_1 &= L/(C + Vx) \\ t_2 &= L/(C - Vx) \end{aligned}\right\} \quad \cdots\cdots (4\text{-}26)$$

where

Vx;Wind velocity vector in the direction of the ultrasonic propagation

C; *Sound velocity in the air*

L; the distance between heads (span)

The equation (4-26) is then converted into Equation (4-27) which gives the wind velocity vector as a function of t_1, t_2 and L.

$$\left.\begin{aligned} L/t_1 - Vx &= L/t_2 + Vx \\ 2Vx &= (t_2L - t_1L)/t_1 . t_2 \\ Vx &= (L/2)\,((t_2 - t_1)/t_1 . t_2) \end{aligned}\right\} \quad \cdots\cdots (4\text{-}27)$$

To measure Vy vector, a wind velocity in the Y direction, the same head arrangement is required in the direction at right angle against those stated above.

Now combining Vx and Vy, the wind velocity will be calculated by the Equation (4-28).

$$\left.\begin{aligned} V &= (Vx^2 + Vy^2)^{1/2} \\ \Theta &= \tan^{-1}(Vx/Vy)) \end{aligned}\right\} \quad \cdots\cdots (4\text{-}28)$$

As for three dimensional ultrasonic anemometer, W directional vector is added to Vx and Vy vectors. Thus probe heads are arranged in the W direction as well. The instrument can monitor not only horizontal vectors of blowing wind but its vertical vector.

The type of two dimensional anemometer used in this survey is one made by Koshin Denki Kogyo Co., Ltd. and the three dimensional one is manufactured by Kaijo Denki Co., Ltd. model S-2003, specifications of which are listed in Table 4-38. This instrument is such that it detects not only wind velocity vectors in three directions, X, Y, W but gives the standard deviations of them σx, σy and σw.

Table 4-38 (1) Specifications of the three dimensional ultrasonic anemometer

Description	Specifications
(Processing mode)	
Mean value of horizontal wind velocity (U)	Active low pass filter vector averaging
Mean value of horizontal wind direction (Θ)	Active low pass filter vector averaging
Mean value of vertical wind velocity (W)	Active low pass filter
Standard deviation of σ_u horizontal wind velocity	Square feedback rms detection
Standard deviation of σ_θ horizontal wind direction	Arc sine processing of turbulent intensity
Standard deviation of σ_w vertical wind velocity	Square feedback rms detection
(Recording range)	
Mean value of horizontal wind velocity (U)	0–30 m/sec, or 0–60 m/sec
Mean value of horizontal wind direction (Θ)	0–540°
Mean value of vertical wind direction (W)	0–plus/minus 10 m/sec, 0–plus/minus 20 m/s
Standard deviation of horizontal wind velocity (σ_u)	0–15 m/sec, or 0–30 m/sec
Standard deviation of horizontal wind direction (σ_θ)	0–60°
Standard deviation of vertical wind velocity	0–5 m/sec or 0–10 m/sec
Wind velocity measuring mode	Ultrasonic pulse transmission (time sharing of transmission/receiving)
Recorder	Electric
Chart	Folding type, 250 mm width
Chart consumption	One month/chart based on 30 mm/hr
Power supply	50 Hz/60 Hz, approx. 100VA AC 100V (115, 220 V OK) plus/minus 10%
Service temp. range	Probe and junction box −10°C – +50°C

Table 4-38 (2) Two dimensional ultrasonic anemometer specifications

(1) System measurement operation	1-head time division transmitting/receiving switching system Frequency differential system through pulse propagation time
(2) Measuring range wind velocity wind direction	 0–20 m/sec 540°/360° automatic shifting
(3) Accuracy wind velocity wind direction	 within plus/minus 5% within plus/minus 5° (at wind speed of 0.8 m/sec)
(4) Resolution	plus/minus 1/10 %
(5) Measuring cycle	38 cycles/sec
(6) Response	voltage output=0.05 sec

(3) Measurement and calibration

If the instrument is properly installed, the need for frequent additional calibrations does not arise. In this servey, calibration was performed by transmitting a standard signal (in term of voltage) to the meter. The detail of operation procedures and calibration is as described in brochures.

(4) Inspection

Major inspection points associated with the meteorological observations are the confirmation of whether or not the supporting pole being kept vertical, if data recorders are properly run and time correction. Those jobs were done by ONHB staff once every week. In addition, calibration by feeding a standard signal into the meter and probe/recorder position check (at N point) were practiced once every three months by Japanese and ONEB staffs.

(5) Measurement

The summary of measurements made by each station (MS1, MS2, MS5) is shown in Table 4-39. When those effective measuring hours being reviewed, all of monitoring stations satisfy the minimum required for an effective monitoring station in Japan. Also noted is a comparatively lower availability of MS1, being about 85%. This is mainly because of downtime for one month period caused by lightning.

Table 4-39 Effective measuring hours for wind velocity, direction *and air turbulency*

Variables	Station	Effective hours	Availability (%)
Wind direction	MS1	7,530	85.7
	MS2	8,629	98.2
	MS5	8,569	97.6
Wind velocity	MS1	7,524	85.7
	MS2	8,629	98.2
	MS5	8,488	96.6
Vertical wind vel.	MS1	7,540	85.8
Std. dev. wind vel.	MS1	7,542	85.9
Std. dev. wind dir.	MS1	7,542	85.9
Std. dev. vertical wind vel.	MS1	7,527	85.7

Total hours for the period of Jan.17,1988 through Jan.16,1989 is 8,784 hrs.

An example of hourly recorded data is shown in Table 4-40 and all others and discussion are to be referred to Appendix and Chapter III respectively.

Table 4-40 (1) An example of meteorological measurements (wind direction)

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1988YEAR 2 MONTH ITEM (1) W.D. ST. (2) (HS2) POWER PLANT

HOUR. DAY.	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	SSE	SSE	SSE	SSE	S	S	S	S	SSE	SSE	S	S	S	SSW	SSW	S	SSW	S	S	S	S	S	S	S	24
2	S	S	SSE	S	SSE	SSE	SSW	SSW	S	S	S	SSW	SSW	SSW	SSW	SSW	SSW	SSW	S	SSW	S	SSE	S	S	24
3	SSE	S	S	S	S	S	S	S	S	SSE	S	SSE	S	S	SSW	S	S	S	SSE	SE	SSE	S	SSW	S	24
4	SSW	S	SSE	SSE	SSE	SE	SE	SSE	SSE	SSE	SSE	SSE	S	S	S	S	S	SSE	SSE	SE	S	S	S	S	24
5	S	S	S	SSE	S	S	S	S	S	S	SSW	SSW	SSW	SSW	S	S	S	SSE	SSE	SSE	SSE	SSE	SSE	SSE	24
6	S	SSE	SSE	SSE	SSE	SSW	SSE	NE	NE	SE	SSW	S	S	SSW	S	SSW	S	S	SSW	S	S	S	S	S	24
7	S	S	SSW	SSW	SSE	NE	NE	ENE	E	SSE	SSE	SSE	SSE	S	S	S	S	S	SE	SSE	S	SSW	S	S	24
8	S	S	SSE	SSE	SE	SE	SSE	SE	SSE	SSE	S	S	S	S	S	S	S	SSE	SSE	SSE	SSE	SSE	SSE	SSE	24
9	S	S	S	S	SSE	SE	SSE	SSE	SSE	SE	SSE	SSE	S	S	S	SSE	SE	SE	SSE	SSE	SSE	SE	S	S	24
10	SSW	SSW	SSW	S	SW	ESE	SSE	SSW	SSE	SSE	SSE	S	SSE	S	S	SSE	SSE	SSE	SE	SSE	S	SE	ESE	ENE	24
11	NE	NE	NE	NNE	NE	NNE	NE	ENE	ENE	E	SE	SSE	SSE	SSE	SSE	SSE	SSE	SSE	SE	SSE	SSE	SE	ESE	SSE	24
12	E	ESE	WSW	WSW	WSW	WSW	WNW	NE	NE	NE	E	NE	W	SSW	SW	SSW	SSW	SSW	SSW	SSW	SSW	SSW	SSW	SSW	24
13	SSW	SSW	SSW	SSW	SSW	SSW	S	S	S	S	S	S	S	S	S	S	SSE	S	S	S	S	S	S	S	24
14	S	S	SSE	SSE	SSE	SSE	SSE	S	S	S	S	S	S	SSW	S	S	S	S	SSE	SSE	SSW	S	SSW	S	24
15	S	S	S	SSE	SSE	SSE	SSE	SE	SSE	S	S	S	S	S	S	SSE	ESE	E	SE	SSE	SE	SE	SE	S	24
16	S	E	NNE	NNE	NE	NE	NE	E	ENE	E	ESE	SSE	SSE	S	SSE	SSE	SSE	SE	SE	SSE	SSE	S	SSE	SSE	24
17	S	S	SSE	SSE	S	SE	SE	S	SSE	SSE	S	SSW	SSE	WSW	NW	SE	ENE	ENE	ENE	WNW	WNW	N	W	WSW	24
18	SW	NNW	N	N	N	N	N	NNE	NNE	NNE	NNE	NE	ENE	E	E	E	ENE	NNE	NE	NNE	NE	E	E	ENE	24
19	NNE	NNE	N	N	N	NNE	NNE	NE	NE	ENE	NE	NE	ENE	ENE	NE	ENE	ENE	ENE	NNE	NNE	ENE	NE	ENE	E	24
20	ESE	E	ENE	NE	NE	NNE	N	NNE	NNE	NE	NNE	N	NNW	N	NNE	N	NE	SE	E	E	ESE	ENE	ENE	ENE	24
21	NE	NNE	NE	NNE	NNE	NNE	NNE	NNE	NE	NE	NE	NE	NE	ENE	ENE	E	E	ENE	N	NNW	NW	NE	E	E	24
22	ENE	NE	NNE	N	NNE	NNE	NNE	NNE	NE	ENE	ENE	ENE	ENE	ENE	ENE	ENE	E	ENE	NNE	NNW	SSW	WSW	E	E	24
23	ENE	ENE	NE	ENE	ENE	NNE	NNE	NNE	ENE	SE	E	E	E	ESE	SE	S	SSW	SSW	SW	SW	S	SSW	S	SSE	24
24	SE	SE	SE	SSE	SSE	SSE	SSE	SSE	S	SSE	S	S	S	S	S	S	S	S	S	S	S	S	S	S	24
25	S	S	SSW	SSW	SSW	SSW	SSW	SSW	S	SSE	SSE	SSE	S	S	S	S	S	S	S	SSE	SSE	SSE	SSE	SSE	24
26	S	S	S	SE	SE	SSE	SSE	S	S	S	S	SSW	SSW	SSW	S	S	SSE	SSE	SSE	SSE	SSE	SSE	SSE	S	24
27	S	S	S	SSE	SSE	SSE	SSW	SSW	S	S	SSW	S	S	S	S	S	S	S	S	SSE	SSE	S	S	S	24
28	S	S	S	S	S	S	SSE	SSE	S	SSE	S	S	S	S	S	S	S	S	S	S	S	S	S	S	24
29	S	S	S	S	S	S	SSE	SSE	SSE	S	SSE	SSE	S	S	S	S	S	S	S	S	S	S	S	S	24
HOUR	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	696

Table 4-40 (2) An example of meteorological measurements (wind velocity)

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1988YEAR 2 MONTH ITEM (2) W.S. ST. (2) (HS2) POWER PLANT (0.1M/S)

HOUR DAY.	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	32	29	25	30	31	29	23	25	32	34	36	35	46	38	41	44	41	40	34	32	33	36	34	34	23	46	34	24	814
2	27	31	29	19	14	16	16	21	20	31	29	29	31	33	36	30	33	30	25	25	18	18	24	30	14	38	26	24	623
3	31	26	30	31	30	26	25	25	32	28	32	31	33	37	35	34	37	37	23	18	19	26	33	32	18	37	30	24	711
4	34	26	20	24	25	21	21	23	37	37	36	42	46	50	55	57	55	43	34	38	35	36	41	44	20	57	37	24	880
5	37	33	33	29	31	35	31	33	42	43	42	44	43	43	47	49	50	40	34	31	29	32	27	23	23	50	37	24	881
6	33	22	22	17	16	21	9	12	13	10	15	30	33	34	34	39	41	36	28	29	28	28	33	34	9	41	26	24	617
7	32	29	20	15	6	5	7	9	11	15	17	16	21	33	40	31	28	18	16	15	31	37	42	38	5	42	22	24	532
8	33	30	23	23	20	21	21	23	31	29	39	33	30	34	35	38	40	37	40	36	40	38	36	30	20	40	32	24	760
9	35	28	29	22	19	18	16	20	29	28	34	33	38	41	48	33	37	33	25	23	24	20	34	35	16	48	29	24	702
10	34	29	20	22	23	23	16	24	16	24	27	40	30	34	40	34	30	19	17	17	18	15	12	10	10	40	24	24	574
11	5	8	7	11	9	9	10	13	16	16	18	24	27	23	27	23	15	16	13	20	21	21	31	18	5	31	17	24	401
12	6	14	19	17	10	15	9	11	11	15	11	17	19	22	22	26	21	17	24	28	30	29	31	27	6	31	19	24	459
13	25	22	25	22	20	18	13	11	15	17	24	28	28	33	31	24	23	27	30	34	38	35	35	34	11	38	26	24	612
14	31	28	21	25	22	18	15	17	28	33	32	34	33	33	32	39	30	31	25	23	29	32	33	32	15	39	28	24	676
15	31	30	27	26	27	25	20	22	32	40	45	47	43	37	44	42	35	36	36	17	14	16	14	11	11	47	30	24	715
16	15	10	9	15	20	13	11	10	7	11	15	25	30	35	32	24	20	21	18	22	25	20	18	18	7	35	19	24	452
17	19	20	22	17	17	14	14	10	10	14	15	18	23	26	30	12	35	19	17	8	8	9	10	16	8	35	17	24	403
18	13	12	13	13	20	17	17	18	23	25	23	19	23	23	19	19	18	11	10	8	12	9	10	9	8	25	16	24	384
19	10	5	7	7	9	11	12	15	22	30	29	32	29	25	22	21	20	15	10	9	11	14	14	20	5	32	17	24	399
20	17	15	12	8	14	15	14	23	25	24	21	23	21	25	24	25	17	11	5	4	5	5	17	16	4	25	16	24	386
21	10	13	11	10	10	10	8	14	21	28	28	28	22	25	18	17	21	10	9	16	12	10	11	12	8	28	16	24	374
22	10	6	8	11	12	12	15	17	19	18	21	24	25	22	22	22	20	20	11	0	8	13	11	8	6	25	15	24	352
23	13	14	6	7	7	5	11	12	7	10	22	24	25	10	15	14	21	19	14	15	20	10	16	10	5	25	14	24	343
24	15	18	18	19	21	26	27	25	28	33	35	30	38	45	49	47	48	39	36	35	36	35	38	32	15	49	33	24	781
25	32	31	28	22	18	20	21	24	26	27	27	35	34	36	48	55	55	53	48	44	34	34	29	29	18	55	34	24	810
26	40	35	21	15	20	20	24	25	30	41	39	32	35	36	43	39	39	37	30	31	33	33	34	39	15	43	32	24	779
27	44	30	26	16	15	19	24	19	34	32	34	37	37	35	35	39	47	39	33	32	28	32	37	43	15	47	32	24	772
28	41	41	34	31	30	26	24	23	39	39	41	38	39	30	40	40	48	44	34	35	41	39	38	41	23	48	37	24	884
29	44	40	38	34	27	25	19	21	27	23	29	30	38	45	47	44	44	45	42	35	32	31	28	32	19	47	34	24	820
MIN	5	5	6	7	6	5	7	9	7	10	11	16	19	18	15	12	15	10	5	4	5	5	8	9	4				
MAX	44	41	38	34	31	35	31	33	42	43	45	47	46	50	55	57	55	53	48	44	41	39	42	44		57			
AVE	26	23	21	19	19	18	17	19	24	26	28	31	32	33	35	33	33	29	25	24	25	25	26	26			26		
HOUR	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29				696	
TOTAL	749	675	603	558	551	533	493	553	691	755	816	806	920	959	1011	967	967	834	718	688	717	726	768	760					17896

4.2.2 Measurement of solar radiation and net radiation

In order to forecast the pollution status of any specified area, the diffusion coefficient in turbulent state to be applied to such area is thought utmost important and must be properly evaluated. In other words, calculation of pollutant concentrations in the down-stream side of wind requires a means to quantify the spread of smoke and the degree of air stability associated with that. The atmospheric stability is defined in term of the vertical distribution of air temperature but the monitoring of such distribution up to 1,000 m high level for a long period on continuous base is thought practically prohibitive. Furthermore, the spread of smoke will be influenced not only by the vertical temperature profile but by such factors as wind velocity, solar radiation, etc. Accordingly, Pasquill developed a method to classify the degree of atmospheric stability into groups A through F depending upon such factors as wind velocity, solar radiation, cloud volume (or radiation balance) and has been employed by the Meteorological Department of English Government.

In compliance with this method, measured at 7 (seven) stations were solar radiation, net radiation of the survey area and wind velocities, which are then converted into hourly values to show atmospheric stability. Monitoring continued from January 17, 1988 until January 16, 1989 for one year period by automatic and continuous instruments, which were subject to both weekly inspections and scheduled maintenance once every three months.

(1) Methods to measure solar radiation and net radiation balance

The major part of radiation energy from the sun is in the wave range of under 4 micron meter and the instrument to be used measure such solar radiation is usually called pyrheliometer or pyranometer. The former is designed to measure the energy of solar radiation directly reaching the ground through atmosphere, and avoids the indirect radiation by scattering and reflection from the ground. The instrument is also equipped with a tracer for sun movement. The pyranometer is designed to monitor total solar radiation, both direct and indirect, whereas the diffuse radiation meter is designed to measure the radiation by scattering excluding the direct solar radiation. Accordingly the pyranometer is usually used for the purpose of evaluating air stability. Some of typical examples in this group are those developed by Robitzsch, Moll and Eppley, all of which are based on the principle to detect a temperature difference between white and black plates that absorb the solar radiation by means of bimetal or thermocouple.

The use of bimetal and thermocouple gives readings in terms of a mechanical displacement and an electromotive force respectively. As for the net radiation meter, it measures the difference between upward radiation from the ground and downward radiation from the sky.

(2) Instruments used to measure solar radiation and net radiation balance

1) Solar radiation meter

The type of radiation meter applied for this survey is a pyranometer of Eppley type widely in use in Japan that was made by EKO Instruments Trading Co., Ltd. type MS-42. Specifications of the instrument are shown in Table 4-41 and its probing head in Figure 4-28.

Table 4-41 Specifications of pyranometer used in this study

(a) Sensitivity	:	abt. 5mV/cal.cm^{-2}.mm^{-1} 7mV/kW m^{-2}
(b) Internal resistance	:	abt. 500 Ω
(c) Responce speed	:	abt. 3.8 sec. (63.2%)
(d) Coefficient of Temp.	:	abt. -0.1%/°C
(e) Cosine eooro	:	abt. 2% (angle 45° against sensing plate)
(f) Aziumth error	:	No
(g) Weight	:	2 Kg
(h) Length of lead wire	:	10 m (additional lead cable shall be prepared by user)

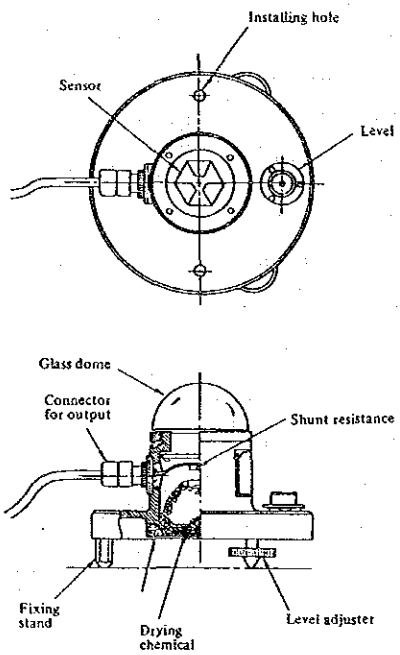


Figure 4-28 Probing part of the pyranometer

As seen in Figure 4-28, white and black plates are arranged radially about the center and the intensity of solar radiation is measured in term of a temperature difference between them. The probing head is made of 39 copper/ constantan thermocouples and white plates of barium sulphate highly reflective and moisture resistant and black plates coated by Parsons Opticals Black. In order to avoid the influences of a sudden temperature change and wind, the upper part of probing head is covered by a transparent glass made dome and is maintained as sealed. The silicagel was put inside the dome cover to avoid the blur of the dome glass.

The radiation measured is converted into both instantaneous value ($cal \cdot cm^{-2} \cdot min^{-1}$) and one hour cumulative value ($cal \cdot cm^{-2} \cdot hr^{-1}$) and then recorded.

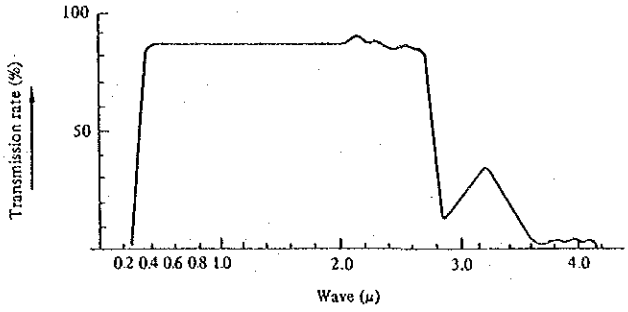


Figure 4-29 Transmission characteristics of dome glass of the pyranometer

2) Net radiation meter

A net radiation meter manufactured by EKO Instruments Trading Co., Ltd. type CN-11 was applied for this survey since it enable the observer to monitor radiation energy in the wide range of from short to long wave length. Specifications of the instrument are listed in Table 4-42 and its external appearance is shown in Figure 4-30.

Table 4-42 Specifications of the net radiation meter used

1)	1-1	Sensitivity	:	35mV/kW.m^{-2} 25mV/cal.cm^{-2}.min^{-1}
	1-2	Internal resistance	:	about 90Ω
	1-3	Response speed	:	about 20 sec.
	1-4	Temperature range	:	-15° to 40°C
	1-5	Accuracy	:	±5%
	1-6	Wave length region	:	0.3 ~ 30μm or more
	1-7	Size of sensing plate	:	38 x 38 (mm)
	1-8	Painting of sensing plate	:	Parson Optical Black
	1-9	Polyethylene dome	:	Special polyethylene dome
		As to its transmissivity see attached Fig. 7		
2)	Main body			
	2-1	Size	:	640^{L} x 220^{W} x 220^{H}(mm)
	2-2	Weight	:	about 7.6 kg
	2-3	Power source	:	AC 100V/220V ±10% 50/60Hz
	2-4	Power consumption	:	about 55W
	2-5	Fuse	:	2A
	2-6	Coating	:	Manssel N-6

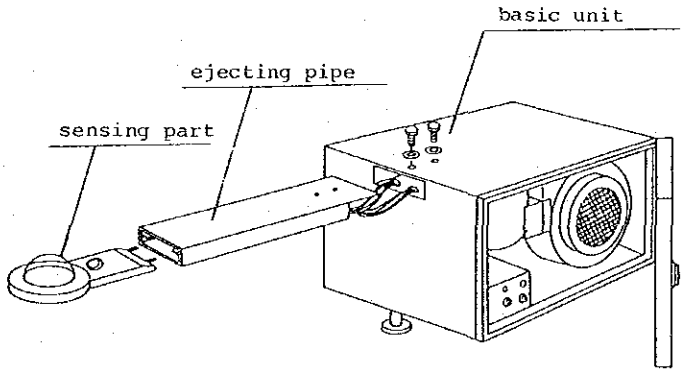


Figure 4-30 The external appearance of net radiation meter

The probing part of the instrument (as shown in Figure 4-31) is covered by a polyethylene made dome with transmission characteristics to cover a wide range of wave length, consists of 250 compensating type thermocouples which detect radiation coming downward and upward. The dew on the surface of dome gives an appreciable impact on transmission characteristic of radiation in long wave length range and thus a provision was made to blow onto the outer surface of dome by a blower installed and also to supply a dry air stream inside the dome through a dehumidifier of thermoelectric cooling type. The net radiation measured by the instrument is again converted into both instantaneous value ($cal \cdot cm^{-2} \cdot min^{-1}$) and one hour cumulative value ($cal \cdot cm^{-2} \cdot h^{-1}$) and then is recorded together with pyranometer readings.

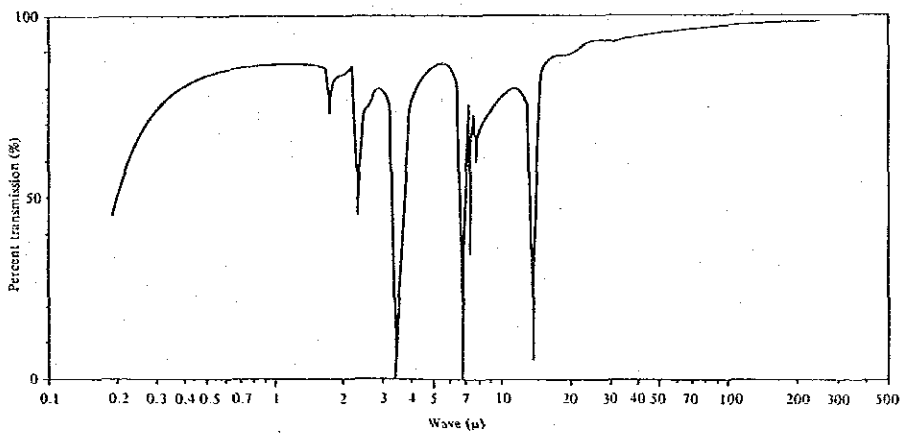


Figure 4-31 Transmission characteristics of polyethylene dome

(3) Measurement

Prior to the start of measurements, the recording part was set at one hour cumulative value by the cumulative recording selector and recording pens were set at the starting time. Thus both the radiation and radiation balance value were continuously and automatically monitored as instantaneous as well as one hour cumulative values.

(4) Calibration

The sensing parts of both pyranometer and net radiation meter had been calibrated at shop before they were delivered to the monitoring sites such that additional calibrations were not required. The instruments are thought serviceable so long as they don't show abnormal readings but it is thought desirable that they receive once a year inspection by the maker to assure the sensitivity.

(5) Inspections

Those listed in Table 4-43 are inspections practiced to maintain the reliable performances of pyranometer and net radiation meter for a longterm period.

Table 4-43 Inspections done on the pyranometer 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			

(6) Measurement results

Table 4-44 summarizes the effective measuring hours of MS1 monitoring station with respect to both instruments, which shows the station satisfying a minimum required for an effective station in Japan.

Table 4-44 Effective measuring hours of the pyranometer and net radiation meter

Measurement	Effective measuring hrs	Availability
Radiation	8,654	98.5
Net radiation flux	8,558	97.4

Total hours for the period of Jan.17,1988 through Jan.16,1989 are 8,784.

The hourly means of radiation and met radiation observed are exemplified in Table 4-45 and Table 4-46 but complete set of data are enclosed in Appendix and discussions are included in the succeeding chapters.

Table 4-45 An example of measurements of solar radiation

********** MONTHLY REPORT ********** PAGE - 3

1988YEAR 2 MONTH ITEM (3) SUN ST. (1) (HS1) ONEB STATION (W/M2)

HOUR DAY.	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	0	39	180	310	365	720	700	489	491	396	262	83	0	0	0	0	0	0	0	720	168	24	4035
2	0	0	0	0	0	0	0	40	182	323	438	573	530	548	476	455	243	70	0	0	0	0	0	0	0	573	162	24	3878
3	0	0	0	0	0	0	0	80	196	269	528	710	799	219	623	448	313	82	0	0	0	0	0	0	0	799	201	24	4825
4	0	0	0	0	0	0	0	75	224	393	526	690	664	704	600	475	272	65	0	0	0	0	0	0	0	704	195	24	4686
5	0	0	0	0	0	0	0	67	240	364	700	597	802	688	647	490	299	76	0	0	0	0	0	0	0	802	207	24	4978
6	0	0	0	0	0	0	0	84	248	435	651	718	766	779	630	519	311	76	0	0	0	0	0	0	0	779	217	24	5217
7	0	0	0	0	0	0	0	61	256	475	578	585	707	651	627	475	284	82	0	0	0	0	0	0	0	707	198	24	4761
8	0	0	0	0	0	0	0	72	187	423	540	729	790	745	640	482	292	88	0	0	0	0	0	0	0	798	208	24	4996
9	0	0	0	0	0	0	0	62	204	251	463	693	726	709	535	334	261	121	0	0	0	0	0	0	0	726	182	24	4359
10	0	0	0	0	0	0	0	30	250	179	205	291	134	360	472	451	185	54	0	0	0	0	0	0	0	472	109	24	2611
11	0	0	0	0	0	0	0	42	80	287	484	540	575	632	528	432	254	79	0	0	0	0	0	0	0	632	164	24	3933
12	0	0	0	0	0	0	0	23	105	307	389	357	500	372	286	248	160	54	0	0	0	0	0	0	0	500	117	24	2801
13	0	0	0	0	0	0	0	66	245	432	382	725	773	718	567	455	183	70	0	0	0	0	0	0	0	773	192	24	4616
14	0	0	0	0	0	0	0	74	161	390	564	700	759	705	622	498	253	78	0	0	0	0	0	0	0	759	196	24	4696
15	0	0	0	0	0	0	0	54	225	422	513	678	727	670	591	435	247	74	0	0	0	0	0	0	0	727	193	24	4636
16	0	0	0	0	0	0	0	25	54	300	470	590	691	690	480	265	224	73	0	0	0	0	0	0	0	691	161	24	3870
17	0	0	0	0	0	0	0	65	223	390	433	319	363	314	65	453	87	72	0	0	0	0	0	0	0	453	116	24	2702
18	0	0	0	0	0	0	0	33	116	209	304	280	602	488	555	431	209	69	0	0	0	0	0	0	0	602	141	24	3376
19	0	0	0	0	0	0	0	80	258	456	633	693	794	756	644	483	288	68	0	0	0	0	0	0	0	794	215	24	5151
20	0	0	0	0	0	0	0	91	281	476	627	706	734	708	590	375	249	64	0	0	0	0	0	0	0	734	204	24	4901
21	0	0	0	0	0	0	0	96	288	494	664	776	802	757	654	495	306	68	0	0	0	0	0	0	0	802	225	24	5400
22	0	0	0	0	0	0	0	90	288	496	657	767	816	768	653	487	292	73	0	0	0	0	0	0	0	816	224	24	5387
23	0	0	0	0	0	0	0	91	279	476	645	777	801	780	603	525	313	67	0	0	0	0	0	0	0	801	227	24	5432
24	0	0	0	0	0	0	3	93	272	430	575	597	658	657	696	516	327	73	10	0	0	0	0	0	0	696	204	24	4907
25	0	0	0	0	0	0	0	88	301	366	519	644	724	756	663	521	264	63	11	0	0	0	0	0	0	756	205	24	4920
26	0	0	0	0	0	0	21	108	250	324	425	615	665	644	581	364	185	85	13	0	0	0	0	0	0	665	178	24	4280
27	0	0	0	0	0	0	0	21	145	313	682	857	722	686	702	688	522	293	90	12	0	0	0	0	0	857	239	24	5733
28	0	0	0	0	0	0	0	56	130	238	467	689	813	846	796	697	539	303	93	9	0	0	0	0	0	846	237	24	5676
29	0	0	0	0	0	0	0	30	156	333	493	682	752	786	816	605	437	297	90	11	0	0	0	0	0	816	229	24	5488
MIN	0	0	0	0	0	0	0	23	54	179	205	280	134	314	65	248	87	54	0	0	0	0	0	0	0				
MAX	0	0	0	0	0	0	56	156	333	682	857	813	846	816	697	539	327	121	13	0	0	0	0	0		857			
AVE	0	0	0	0	0	0	5	74	223	390	536	633	687	659	572	446	260	76	2	0	0	0	0	0			190		
HOUR	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29				696	
TOTAL	0	0	0	0	0	131	2148	6455	11319	15554	18357	19928	19119	16597	12924	7536	2200	66	0	0	0	0	0	0					132334

Table 4-46 An example of net radiation flux measurements

********** MONTHLY REPORT ********** PAGE - 10

1988YEAR 2 MONTH ITEM (13) NET ST. (1) (HS1) ONEB STATION (W/M2)

HOUR DAY.	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	-30	-38	-39	-38	-38	-38	-36	-4	100	198	235	475	454	292	292	217	123	-11	-66	-66	-66	-63	-58	-57	-66	475	72	24	1738
2	-60	-56	-57	-53	-53	-53	-52	-15	85	196	287	369	328	334	276	263	104	-13	-63	-62	-61	-63	-57	-63	-63	369	61	24	1459
3	-65	-62	-59	-64	-52	-47	-45	14	104	162	306	472	531	457	375	251	157	-16	-72	-69	-66	-65	-60	-54	-72	531	88	24	2113
4	-54	-54	-49	-45	-45	-46	-43	1	124	254	348	465	445	461	363	251	109	-43	-87	-61	-60	-58	-53	-49	-87	465	86	24	2074
5	-41	-41	-36	-50	-37	-44	-45	4	131	233	476	390	528	434	400	292	152	-6	-67	-67	-69	-63	-64	-65	-69	528	98	24	2345
6	-61	-60	-54	-55	-49	-52	-53	6	135	270	423	453	476	494	385	292	148	-22	-72	-73	-74	-71	-68	-68	-74	494	94	24	2250
7	-68	-66	-58	-50	-45	-48	-46	10	149	304	360	361	439	402	378	273	135	-13	-74	-70	-74	-71	-69	-64	-74	439	83	24	1995
8	-61	-61	-60	-54	-48	-43	-45	8	109	287	351	465	502	462	387	273	134	-10	-63	-61	-61	-57	-57	-54	-63	502	93	24	2243
9	-53	-53	-50	-42	-39	-44	-39	2	109	155	304	464	476	457	336	189	144	42	-54	-54	-50	-35	-29	-29	-54	476	88	24	2107
10	-28	-36	-41	-43	-31	-9	-13	5	179	133	150	224	92	270	344	319	111	-1	-29	-45	-42	-45	-44	-43	-45	344	57	24	1377
11	-32	-36	-35	-34	-29	-28	-27	4	40	201	343	385	410	441	351	278	137	6	-52	-51	-29	-27	-23	-21	-52	441	91	24	2172
12	-26	-26	-27	-28	-25	-25	-22	-5	63	221	200	255	359	249	187	147	74	-14	-57	-53	-32	-42	-30	-29	-57	359	58	24	1394
13	-31	-47	-45	-36	-37	-47	-44	6	149	291	261	510	545	492	366	276	81	-11	-62	-57	-55	-50	-52	-45	-62	545	98	24	2358
14	-42	-59	-55	-58	-53	-52	-46	14	77	264	390	482	517	478	411	244	133	2	-64	-63	-54	-46	-37	-40	-64	517	98	24	2343
15	-44	-47	-51	-51	-49	-46	-44	-1	131	288	350	466	493	444	382	258	120	6	-34	-49	-57	-53	-48	-49	-57	493	96	24	2315
16	-51	-44	-36	-33	-39	-39	-46	-18	12	195	317	412	480	475	323	160	128	12	-41	-55	-47	-42	-33	-31	-55	480	82	24	1959
17	-39	-36	-35	-44	-41	-42	-36	11	132	259	295	215	247	206	29	320	53	18	-39	-37	-39	-45	-49	-41	-49	320	53	24	1262
18	-29	-24	-30	-29	-35	-28	-37	-6	65	143	215	199	454	358	397	292	163	-9	-56	-60	-56	-50	-52	-59	-60	454	71	24	1713
19	-57	-57	-54	-50	-53	-50	-46	6	148	306	444	484	548	511	429	303	156	-11	-61	-50	-45	-49	-49	-58	-61	548	110	24	2665
20	-62	-57	-61	-60	-61	-60	-61	6	150	303	422	479	494	474	302	215	120	-18	-65	-65	-61	-61	-60	-64	-65	494	93	24	2229
21	-65	-62	-61	-58	-52	-53	-50	14	163	329	460	538	542	504	426	300	161	-16	-61	-60	-58	-57	-58	-58	-65	542	111	24	2668
22	-57	-57	-56	-57	-58	-56	-59	2	148	308	424	505	533	504	417	288	148	-16	-58	-56	-65	-61	-59	-62	-65	533	104	24	2500
23	-62	-63	-58	-57	-56	-57	-52	19	157	308	434	527	540	516	434	311	159	-24	-66	-65	-63	-64	-59	-57	-66	540	108	24	2602
24	-57	-54	-51	-53	-54	-54	-49	12	145	261	382	396	439	421	441	299	161	-34	-53	-50	-52	-49	-47	-48	-57	441	94	24	2252
25	-47	-45	-52	-48	-39	-46	-41	19	178	231	353	445	497	513	438	329	163	-2	-39	-45	-43	-41	-42	-44	-52	513	107	24	2572
26	-47	-50	-45	-43	-47	-47	-28	-45	155	215	292	424	456	432	327	166	86	-33	-41	-52	-55	-53	-53	-53	-55	456	78	24	1883
27	-51	-50	-50	-47	-41	-42	-47	-33	117	248	326	447	493	466	472	451	231	14	-48	-55	-55	-53	-53	-49	-55	493	108	24	2591
28	-46	-44	-44	-46	-44	-38	-36	13	68	144	323	491	542	595	555	467	341	173	-17	-47	-51	-52	-52	-51	-52	595	131	24	3149
29	-51	-53	-53	-54	-55	-49	-47	-29	68	207	335	464	505	530	547	461	334	162	-9	-53	-63	-62	-62	-51	-63	547	122	24	2922
MIN	-68	-66	-61	-64	-61	-60	-61	-45	12	133	150	199	92	206	29	147	53	-43	-87	-73	-74	-71	-69	-68	-87				
MAX	-26	-24	-27	-28	-25	-9	-13	19	179	329	476	538	548	595	555	467	341	173	-9	-37	-29	-27	-23	-21		595			
AVE	-49	-50	-48	-48	-45	-44	-43	1	117	238	344	423	461	437	374	282	146	5	-54	-57	-55	-54	-51	-50			91		
HOUR	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29				696	
TOTAL	-1438	-1417	-1402	-1380	-1305	-1283	-1235	20	3391	6914	9966	12262	13368	12672	10850	8105	4266	132	-1651	-1570	-1556	-1603	-1482	-1454					63230

5. Short term field survey

The short term field survey addressed that of particle distribution of suspended particulate matter and was made in three times, firstly during January 6, 1988 through February 2, 1988, secondly during the period of March 3 1988 through March 27 1988 and thirdly (lastly) during the period of July 4, 1988 through July 28, 1988. During each period the atmospheric air was continuously aspirated by Andersen samplers for 13 days and the trapped dust samples were subject to size distribution analyses. In addition, the particulate sample trapped by filters was brought back in Japan and was subject to chemical, elemental and ion analyses after the sample was screened into two parts, fine part (<2.1 micron m) and coarse part (>2.1 micron m).

As for the chemical analysis, samples trapped by Low volume samplers during the same period were also subject to analysis together with other soil samples representative in Samut Prakarn, a road dust, two types of gasoline. Furthermore, the sulphur content of 10 fuels including gasoline and heavy oil in use in Thailand were measured by the chemical analysis.

5.1 Measurement of particle distribution about the dust sample collected by Andersen samplers

5.1.1 Outline of the survey

The Andersen samplers pre-calibrated and loaded with filters were installed at each monitoring station and were switched on at 11:00 AM of the starting day by members grouped in five teams. Then the atmospheric air was aspirated by each sampler at the flow rate of 28.3 liter per minute. After the instruments commissioned in this way, they were kept under inspection of patrols, twice a day in morning and in afternoon. Table 5-1 shows the format of a recording chart used and Table 5-2 the work schedule of each survey period.

Weighing of filters loaded with suspended particulate matter was practiced by precision chemical balances at Ishikawajima Inspection & Instrumentation Co., Ltd. after filters were desiccated in the thermohygrostat. The recording chart used here is shown Table 5-3. The atmospheric concentration was back-calculated by knowing the difference of weight between before and after measurement and air volume aspirated.

Table 5-1 Recording chart of Andersen sampler

Monitoring Station		Instrument No.		Sampling Time: Hours minutes (1) Total minutes	Person in charge
Monitoring Period	From 198 . . . Morning, Afternoon hour min			(2) Average Flow Rate (ℓ/min)	
	To 198 . . . Morning, Afternoon hour min			(1)×(2)/1000 Total Absorbed Volume(m³)	

Date Month Day	Hour Min	Flow Meter Scale	Pressure (mmHg)	Date Month Day	Hour Min	Flow Meter Scale	Pressure (mmHg)	Date Month Day	Hour Min	Flow Meter Scale	Pressure (mmHg)	Classified Stage (μm)	Filter Number
Start						a)				a)		>11	
						b)				b)		11-7.0	
		a)*				a)				a)		7.0-4.7	
		b)*				b)				b)		4.7-3.3	
		a)				a)				a)		3.3-2.1	
		b)				b)				b)		2.2-1.1	
		a)				a)				a)		1.1-0.65	
		b)				b)				b)		0.65-0.43	
		a)				a)				a)		<0.43	
		b)				b)				b)		Remarks:	
		a)				a)				a)			
		b)				b)				b)			
		a)				a)				a)			
		b)				b)				b)			
		a)				a)				a)			
		b)				b)				b)			
		a)				a)				a)			
		b)				b)				b)			
		a)				a)				a)			
		b)				b)				b)			
		a)				a)				a)			
		b)				b)				b)			

a)* : before adjustment
b)* : after adjustment
Flow Rate : ℓ/min

Table 5-2 Work schedule of each field survey

1st field survey			2nd field survey			3rd field survey		
Date	Monitoring of TPM	Size distribution of TPM	Date	Monitoring of TPM	Size distribution of TPM	Date	Monitoring of TPM	Size distribution of TPM
1988 Jan.9	Setting up	Setting up	1988 Mar.8	Setting up	Setting up	1988 Jul.12	Setting up	Setting up
10			9			13	started	started
11			10			14		
12			11	started	started	15		
13			12			16		
14			13			17		
15	Techinical training	Techinical training	14			18		
16			15			19		
17	started	started	16			20		
18			17			21		
19			18			22		
20			19			23		
21			20			24		
22			21			25		
23			22			26		
24			23					
25			24					
26								
27								
28								
29								
30								

Monitoring of TPM
• : Flow rate arranged
○ : Filter set
△ : Flow rate check and adjustment
▲ : TPM monitoring completed
◎ : Filter replace, Flow rate check and adjustment
■ : Installation of Low volume samplers

Monitoring of size distribution of TPM
• : Flow rate arranged
○ : Filter set
△ : Flow rate check and adjustment
▲ : TPM monitoring completed, withdraval of Andersen samplers
■ : Installation of Andersen samplers

Table 5-3 Recording chart of Andersen samplers

Monitoring Station		Instrument No.	
Monitoring Period	From: 198 , , , , .		
	To: 198 , , , , .		
Incubating Time Before Sampling	From: 198 , , , , .		
	To: 198 , , , , .		
Incubating Time After Sampling	From: 198 , , , , .		
	To: 198 , , , , .		

Absorbing Time	(1) min	Incubating time before sampling	min.	Incubating time after sampling	min.
Average Flow Rate	(2) 1/min.	Total Flow Rate (1)x(2)	(3) m^3		

Classified Stage (m)	Filter No.	Weight(mg) After sampling	Weight(mg) Before Sampling	Sampled Volume (mg)	Particulate Conc. by Size(mg/m^3)	Remarks
>11				(4)		
11 - 7.0				(5)		
7.0 - 4.7				(6)		
4.7 - 3.3				(7)		
3.3 - 2.1				(8)		
2.1 - 1.1				(9)		
1.1 - 0.65				(10)		
0.65 - 0.43				(11)		
< 0.43				(12)		
Total Sampled Particulate(mg) (4)+ ------(12)				(13)		Temperature of laboratory °c
Total Particulate Conc.(mg/m^3) (13)/(3)						Humidity of laboratory %
Remarks:						

5.1.2 Instrument and Handling Methods

(1) Andersen sampler

Andersen samplers employed in this study was a SIBATA Model AN-200 which was equipped with multi-layer jet nozzles and is designed to monitor size distribution of suspended particulate matter by impacter system. The samplers consist of size separating body, rotameter, pressure gage, pump and shelter.

The instrument is made of 8 layers stage corrosion resistant aluminum alloy and each stage has 800, 400 and 200 numbers of jet nozzles and, in the bottom of the stages, stainless steel made round collector plate is installed. The diameters of the jet nozzles are designed such that they get smaller from the top stage to the bottom one in descending order and so when the constant flow rate of air is aspirated from the upper inlet, the jet air velocity increases as it goes into the lower stages. As shown in Fig. 5-1, the size of particulates decreases as stage goes from top to bottom.

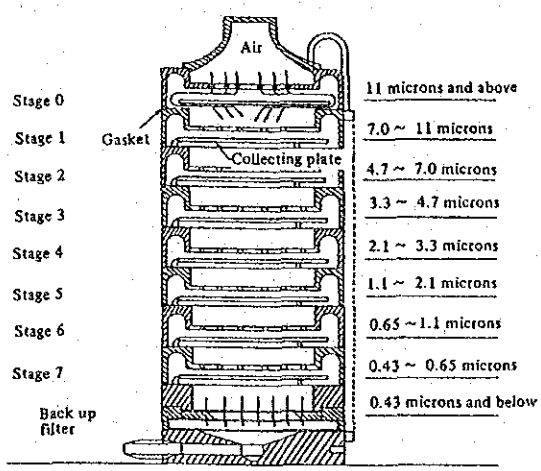


Fig. 5-1 Structure of Andersen sampler

Generally the inertial impaction parameter of impacter is defined by a functioning of the ratio of particulate size, flow velocity of particulate and section area of nozzle. According to Ranz and Wong, such relation between them can be expressed by the following equation.

$$\psi = \frac{C \cdot p \cdot Vc \cdot dp^2}{18\,\mu Dc} \quad \cdots\cdots \text{Equation (5-1)}$$

where,

C; Conningham slip correction factor $= 1.00 + \frac{0.16 \times 10^{-4}}{dp}$

dp; size (cm) of particulate matter

μ; air viscosity (1.84×10^{-4} g/cm. sec)

p; density of particulate matter (g/cm^3)

Vc; air velocity passing through jet nozzles (cm/sec)

Dc; diameter of jet nozzle (cm)

ψ; non dimensional inertial impaction parameter

(when impaction efficiency 50%, $\psi_{50} = 0.14$)

When air sampling volume Q (cm^3/min), number of jet nozzles of the stage N, Vc is obtained by the following equation:

$$Vc = \frac{Q}{60\,\pi(Dc/2)^2 N} \quad \cdots\cdots \text{Equation (5-2)}$$

When the Equation (5-2) is substituted by Equation (5-1), 50% aerodynamic particle size dp_{50} can be obtained from the following equation:

$$dp_{50} = \sqrt{\frac{18\mu\psi_{50} N\pi \times 60 Dc^3}{4CQ}} \quad \cdots\cdots \text{Equation (5-3)}$$

Where, Q = 28,317 cm^3/min = 28.3 ℓ/min. Geometrical particle size is obtained as $\sqrt{dp^2/p}$.

By the Equation (5-3), the particle sizes of particulate matter collected at the respective stages are obtained and the ranges of the particles size are shown in Table 5-4. The collection efficiency by the size is shown in Fig. 5-2.

Table 5-4 50% cut-off values of each stage

Stage	Nozzle diameter	Number of nozzle	Jet velocity	50% cut-off value	Catalogue value
0	1.18 mm	800	0.54 ms^{-1}	10.0μm	11.0μm
1	1.18	400	1.07	7.0	7.0
2	0.91	400	1.85	4.7	4.7
3	0.71	400	2.98	3.3	3.3
4	0.53	400	5.34	2.1	2.1
5	0.34	400	13.0	1.03	1.1
6	0.25	400	24.0	0.62	0.65
7	0.25	200	48.0	0.42	0.43

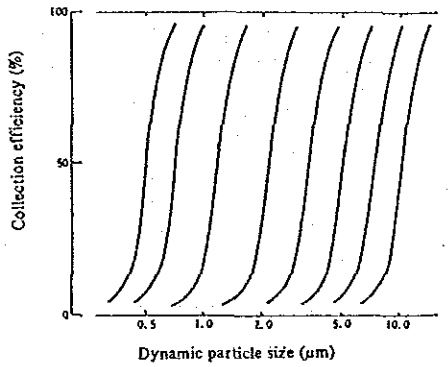


Fig. 5-2 Classification (sieving) characteristic of impactor

Table 5-5 shows the specifications of Andersen sampler and Fig. 5-3 shows external view of Andersen sampler.

Table 5-5 Specifications of Andersen sampler

Sampler main body: 8 layer stages, size classification sampler of suspended particulate matter

Pump: Rotary compressor, HITACHI
200 W RC-20S type
Max. pressure 0.5 kg/cm^2
Operation pressure: 0.4 kg/cm^2
Air supply: 55 Nl/min (at operating)
Output: 200 W
Voltage: 100 V

Piping: Flow meter (float-type area flow meter)
Tokyo Keiki KK
Scale: 4–40 l/min
Elbow and Hitting: brass, nickel plated
Connecting tube: Nylon 11 3/8″ (inner diameter)

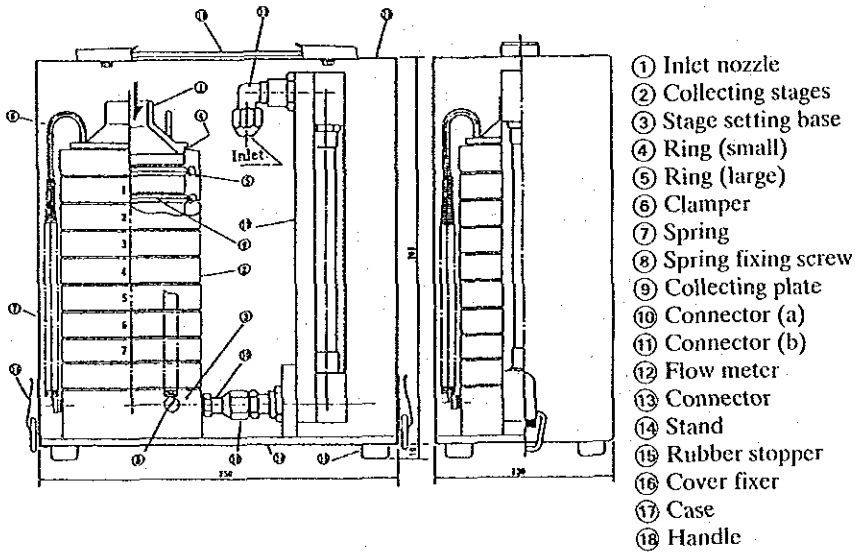


Fig. 5-3 Outside view of main body of Andersen sampler

The handling methods of Andersen sampler are as follows.

① Preparatory work

The collection plates of the respective stages are all completely cleaned and dried. (In this study, supersonic cleaning was employed as described later.)

Collection plates (Polyethylene sheets) and back-up filters are weighed prior to assembly.

② Procedure

(i) Remove the key of the bottom part of the case, and take out the main body from the case. Then the flow meter is connected to the pump by tube.

(ii) The back-up filters are placed on the back-up holder.

(iii)Install collection plates on the seiving stages.

(iv) Remove the cover of air inlet located in the upper part of sampler, and then switch on the power. Adjust the flow rate by valve of the pump, and fix the rate at 28.3 ℓ/min by reading the previously calibrated rotameter and pressure meter.

(v) Through patrols 2 or 3 times a day, confirm that the flow rate is kept exactly at 28.3 ℓ/min. If not kept right, adjust the rate by the valve of the pump.

(vi) After the measurement is completed (in this study, for the period of about 13 days), transfer the collection plates and back-up filters into the air-conditioned room for desiccation for about 24 hours. Then they are weighed by the precision chemical balance which has a sensitivity of weighing 0.01 mg.

③ Maintenance

After the monitoring is completed, all the stages are cleaned by a supersonic cleaner by using the neutral detergent, and are dried up. They are kept in the assembly case.

(2) Supersonic cleaner

A supersonic cleaner is used for cleansing of classified stages collection plates of Andersen sampler. In this study, a SHARP UTB-152 supersonic cleaner was employed.

The supersonic cleaner was designed to generate pressure waves in cleaning tank, produced countless number of fine bubbles, and removes all the dirts mechanically.

The Table 5-6 shows the specifications of the supersonic cleaner and Fig. 5-4 shows its outside view.

Table 5-6 Specifications of supersonic cleaner

Size of main body	350×425×360 mm
Size of cleaning bath	220×220×140 mm
Output	150 W
Bath capacity	6.0 liter
Weight	28 kg

Prior to starting the cleaner, pour detergent solution into the tub, and soak collecting plates of Andersen sampler using an attached service rack. It takes about 10 to 15 minutes to complete cleaning.

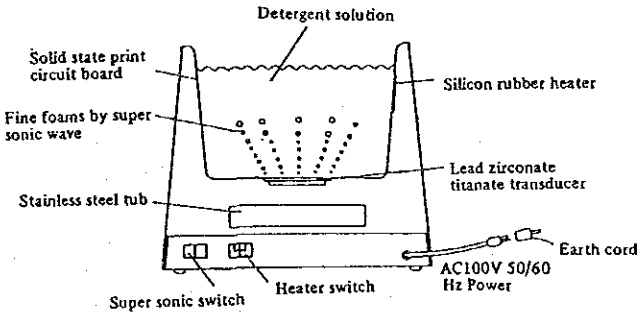


Fig. 5-4 Outside view of supersonic cleaner

(3) Filters

In this study, polyethylene sheet and polyfrone filter were used to analyze elements of particulate matter. The polyethylene sheets were placed on the 0~8 stage collecting plates of Andersen samplers while the polyfrone filter was used as back-up holder.

5.1.3 Calculations of TSP Size Distribution

(1) Calibration of Andersen sampler

The wet-type gas meter, bypass, pressure gage, rotameter, and suction pump were connected in series as shown in Fig. 5-5.

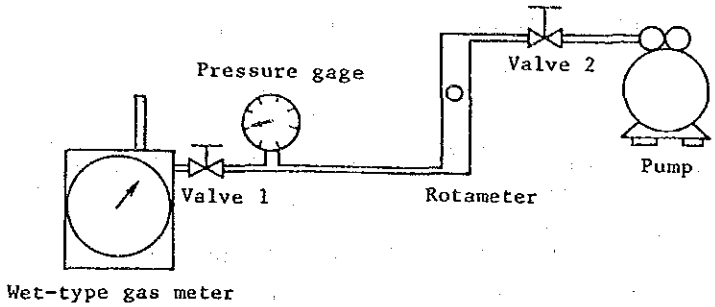


Fig. 5-5 Calibration of rotameter for Andersen sampler

① The flow rate reading indicated in rotameter was fixed at about 30 ℓ/min and also the pressure loss was adjusted at about 55 mmHg by controlling the valve of bypass 1.

② The pressure reading indicated in pressure gage were recorded when flow rate of rotameter were adjusted at 30, 25, 20 and 15 ℓ/min respectively, and the measurement time were recorded when the air volumes aspirated into the wet-type gas meter were 20 or 30 ℓ/min respectively. An example of the results is shown in Table 5-7, and all results are shown in the Appendix.

Table 5-7 An example of calculation results of rotameter for Andersen sampler

No200522 MS1

Pressure ΔP <mmHg>	Flow Meter Scale	Total Sampling Volume<L>	Sampling Time <sec>	Wet Gas Meter Temp<℃>	Flow Val.Qg0 <L/min>	Ave. Qg0	Flow Val.Qr0 <L/min>
15	15	10	37.75	24.4	15.6589	15.67	14.74
15	15	10	37.75	24.4	15.6589		
15	15	10	37.65	24.4	15.7005		
25	20	20	57.55	24.6	20.5291	20.52	19.52
25	20	20	57.57	24.6	20.5220		
25	20	20	57.57	24.6	20.5220		
38	25	20	46.60	24.5	25.3616	25.39	24.18
38	25	20	46.46	24.5	25.4380		
38	25	20	46.60	24.5	25.3616		
55	30	20	39.30	24.4	30.0828	30.08	28.68
55	30	20	39.34	24.4	30.0520		
55	30	20	39.27	24.4	30.1056		

③ The flow rate calculated from the required time for aspirating the prescribed amount was corrected to that at the designed temperature (20°C) of rotameter by the Equation (5-4). An example of the results is shown in Table 5-7.

$$Qg_0 = \frac{273+T_0}{273+Temp.} \times V \times \frac{60}{t} \quad \text{..... Equation (5-4)}$$

where,

Qg_0; flow rate of wet-type gas meter at 20°C (ℓ/min)

Temp.; temperature of wet-type gas meter during calibration (°C)

T_0; designed temperature of rotameter (20°C)

V; measured air volume of wet-type gas meter (ℓ)

t; necessary time for sucking the volume V (S)

④ Flow rate Qr_0 at the designed condition of rotameter was obtained by using the Equation (5-5) by correcting the reading value of rotameter (Qr). An example of the results is shown in Table 5-7.

$$Qr_0 = Qr \times \sqrt{\frac{273+T_0}{273+Temp.}} \times \sqrt{\frac{760-\Delta P}{P_0}} \quad \text{..... Equation (5-5)}$$

where,

Qr_0; flow rate of rotameter at the designed condition (ℓ/min)

Qr; reading value of rotameter (ℓ/min)

P_0; designed pressure of rotameter (760 mmHg)

ΔP; reading value of pressure gage (mmHg)

T_0; designed temperature of rotameter (20°C)

Temp.; temperature at calibration (°C)

⑤ The relationship between Qg_0 [flow rate of wet-type gas meter calculated by the Equation (5-4)] and Qr_0 [flow rate of rotameter calculated by the Equation (5-5)] can be expressed by the Equation (5-6).

$$Qg_0 = a\,(Qr_0) + b \quad \text{..... Equation (5-6)}$$

In above equation, a and b are regression coefficients. An example of calculation by the Equation (5-6) is shown in Fig. 5-6, and all other results are shown in the Appendix.

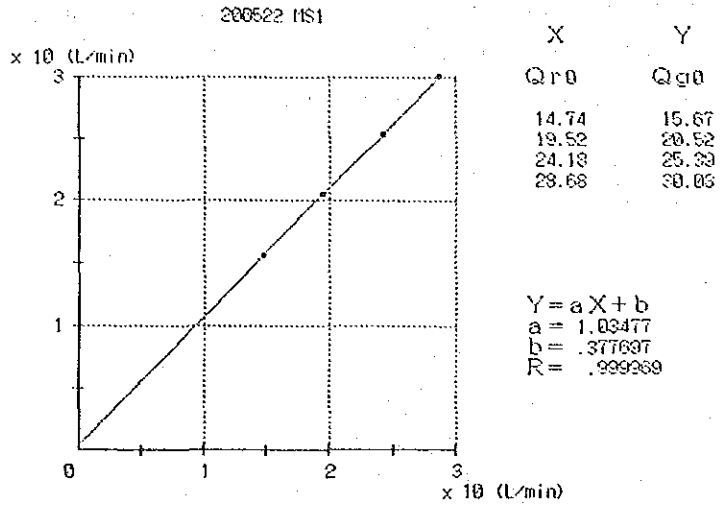


Fig. 5-6 An example of relation between flow rate of wet-type gas meter and rotameter

⑥ Flow rate of rotameter was calculated by Equation (5-6) when the Qg_0 is 28.3 ℓ/min, and then Qr values were estimated by the Equation (5-7) when the pressure losses were 40, 25 and 15 mmHg respectively. An example of the results is shown in Fig. 5-7, and all results are shown in the Appendix.

Those figures were posted on the inside-door of the shelter at each monitoring station.

$$Qr = \frac{Qrs_0}{\sqrt{\frac{273+T_0}{273+Temp.}} \times \sqrt{\frac{760-\Delta P}{P_0}}} \quad \text{..... Equation (5-7)}$$

where,

Qr; reading value of rotameter (ℓ/min)

Qrs_0; flow rate of rotameter calculated by Equation (5-6) when the Qg_0 is 10 ℓ/min (ℓ/min)

P_0; designed pressure of rotameter (760 mmHg)

ΔP; reading value of pressure gage (mmHg)

T_0; designed temperature of rotameter (20°C)

Temp.; average estimation temperature (°C)

(average temperature which is estimated at actual-site survey)

Jan. to Feb.: 27.0°C

Mar. to Apr.: 29.8°C

May to Jun.: 29.4°C

Jul. to Aug.: 28.6°C

Sept. to Oct.: 28.1°C

Nov. to Dec.: 26.6°C

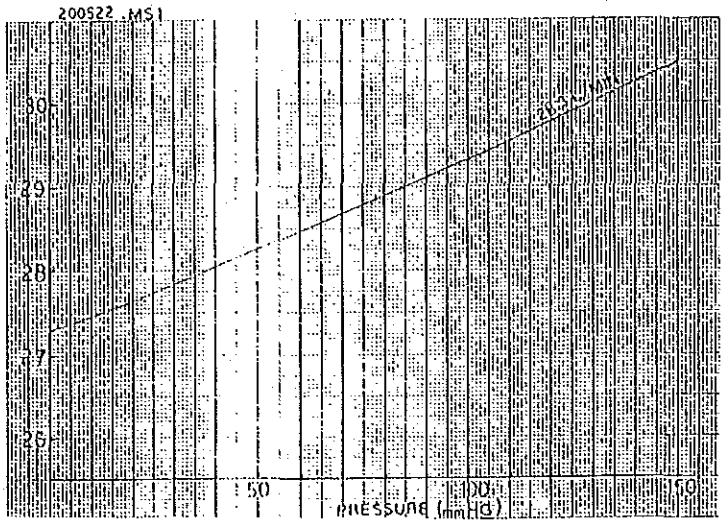


Fig. 5-7 The relation between reading value of rotameter and pressure value indicated in pressure gage when aspiration air volume is 28.3 ℓ/min

(2) Air aspiration volume of Andersen sampler

The total air aspiration volume of Andersen sampler was calculated by obtaining air sucking volume R_i between (i−1) patrol and (i) patrol, and by summing of them.

① Firstly, the flow rate of rotameter before and after the adjustment at patrols was corrected into the flow rate of rotameter at the designed condition (20°C, 760 mmHg) by using Equation (5-8) and (5-9).

$$Qra_{0i-1} = \sqrt{\frac{760-\Delta Pa_{i-1}}{P_0}} \times \sqrt{\frac{273+T_0}{273+Temp.}} \times Qra_{i-1} \quad \cdots\cdots\cdots\cdots \text{ Equation (5-8)}$$

$$Qrb_{0i} = \sqrt{\frac{760-\Delta Pb_i}{P_0}} \times \sqrt{\frac{273+T_0}{273+Temp.}} \times Qrb_i \quad \cdots\cdots\cdots\cdots \text{ Equation (5-9)}$$

where,

Qra_{0i-1}; designed condition flow rate after adjustment at (i−1) patrol (ℓ/min)

Qrb_{0i}; designed condition flow rate before adjustment (i) patrol (ℓ/min)

Qra_{i-1}; rotameter reading value after adjustment at (i−1) patrol (ℓ/min)

Qrb_i; rotameter reading value before adjustment at (i) patrol (ℓ/min)

T_0; designed condition temperature of rotameter (20°C)

Temp.; average temperature which is estimated at monitoring (°C)

P_0; designed pressure of rotameter (760 mmHg)

ΔPa_{i-1}; reading value of pressure gage after adjustment at (i−1) patrol (mmHg)

ΔPb_i; reading value of pressure gage before adjustment at (i) patrol (mmHg)

② Secondly, the flow rate Qr_0 at designed condition of rotameter was corrected into wet-type gas meter flow rate Qg_0 at 20°C by using Equation (5-10).

$$\left.\begin{aligned} Q^0_{gi-1} &= a\,(Q^0_{ri-1})+b \\ Q^0_{gi} &= a\,(Q^0_{ri}) + b \end{aligned}\right\} \quad \cdots\cdots \text{Equation (5-10)}$$

where,

Q^0_{gi-1}; corrected flow rate at designed condition at (i−1) patrol (ℓ/min)

Q^0_{gi}; corrected flow rate at designed condition at (i) patrol (ℓ/min)

③ Air sucking volume Ri during (i−1) patrol and (i) patrol were obtained by multiplying lapse time t and the mean value of flow rate after adjustment at (i−1) patrol and that before adjustment at (i) patrol.

$$R_i = \frac{Q^0_{gi-1} + Q^0_{gi}}{2} \times t \times \frac{1}{1000} \quad \cdots\cdots \text{Equation (5-11)}$$

where,

R_i; air sucking volume during (i−1) patrol and (i) patrol (m^3)

t; lapse time during (i−1) patrol to (i) patrol (min)

④ The total air sucking volume at the designed temperature was obtained as the sum of air sucking volume during each patrolling time, and then the corrected total air sucking volume at field condition was estimated by the following Equation (5-12).

$$V_1 = \sum_{i=1}^{n} R_i \frac{273+Temp}{273+T_0} \quad \cdots\cdots \text{Equation (5-12)}$$

where,

V_1; Total air sucking volume under the temperature at monitoring (m^3)

n; number of patrols (excluding the time of commencement of monitoring, and including the time of completing of monitoring)

T_0; designed temperature of rotameter (20°C)

Temp.; average estimation temperature (°C)

An example of calculation results of sucking air volume by this method is shown in Table 5-8, and all results are shown in the Appendix.

In case accidental power failure occurs during monitoring, the estimated air sucking volume by this method becomes inaccurate. So, in this study, the power failure time was calculated by the charts of automatic and continuous instruments and the count values of integrated flow meter installed in Low-volume sampler. Power failure times are shown as follows.

Table 5-8 An example of calculation results of air sucking volume of Andersen sampler

MS1 ROTOR NO.200522 TEMP(℃) 27.0

DATE	TIME		LAPSE TIME (MIN)	STOP TIME (MIN)	ROTOR METER (L/min)	PRESSURE DIFFERENCE (mmHg)	CORRECTED FLOW RATE (L/min)	CALIBRATED FLOW RATE (L/min)	FLOW VOL (m3)
1 /17	11 : 0		0		28.1	43.0	28.2	29.6	
1 /17	15 :44	B	284	0	28.0	43.0	28.1	29.5	8.4
1 /17	15 :44	F	0		28.1	43.0	28.2	29.6	
1 /18	9 :50	B	1086	0	26.5	40.0	26.7	28.0	31.3
1 /18	9 :50	F	0		28.2	45.0	28.3	29.6	
1 /18	14 :45	B	295	0	28.3	45.0	28.4	29.7	8.8
1 /18	14 :45	F	0		28.3	45.0	28.4	29.7	
1 /19	9 :55	B	1150	0	29.0	48.0	29.0	30.4	34.6
1 /19	9 :55	F	0		28.2	47.0	28.2	29.6	
1 /19	15 :21	B	326	0	28.0	45.0	28.1	29.4	9.6
1 /19	15 :21	F	0		28.3	46.0	28.4	29.7	
1 /20	10 :54	B	1173	0	28.2	47.0	28.2	29.6	34.8
1 /20	10 :54	F	0		28.2	47.0	28.2	29.6	
1 /20	16 : 1	B	307	0	28.2	48.0	28.2	29.6	9.1
1 /20	16 : 1	F	0		28.2	48.0	28.2	29.6	
1 /21	10 :11	B	1090	0	28.3	55.0	28.2	29.5	32.2
1 /21	10 :11	F	0		28.4	56.0	28.3	29.6	
1 /22	10 : 0	B	1429	0	28.3	60.0	28.1	29.4	42.2
1 /22	10 : 0	F	0		28.6	61.0	28.4	29.7	
1 /23	10 :28	B	1468	0	28.4	67.0	28.0	29.4	43.4
1 /23	10 :28	F	0		28.6	68.0	28.2	29.6	
1 /24	8 :57	B	1349	0	28.6	73.0	28.1	29.5	39.8
1 /24	8 :57	F	0		28.7	74.0	28.2	29.6	
1 /25	10 :45	B	1548	0	28.2	76.0	27.7	29.0	45.3
1 /25	10 :45	F	0		28.2	76.0	27.7	29.0	
1 /26	10 :40	B	1435	0	28.7	82.0	28.0	29.4	41.9
1 /26	10 :40	F	0		28.7	82.0	28.0	29.4	
1 /27	15 :40	B	1740	0	28.5	84.0	27.8	29.1	50.9
1 /27	15 :40	F	0		28.2	87.0	28.4	29.8	
1 /28	14 :13	B	1353	0	29.0	90.0	28.2	29.5	40.1
1 /28	14 :13	F	0		29.0	90.0	28.2	29.5	
1 /29	10 :59	B	1246	0	28.0	86.0	27.3	28.6	36.2
1 /29	10 :59	F	0		29.2	95.0	28.2	29.6	
1 /30	11 : 0	B	1441	0	29.8	98.0	28.8	30.1	43.0
	TOTAL		18720 (min)					TOTAL	564.8 (m3)

Regression coefficients; a = 1.035
b = 0.378

Table 5-9 Power failure time

Date	Monitoring station	Power failure time (minute)	Remarks
11:50 17/1, 1988 13:25 18/1, 1988	MS3	1535	Accident of suction pump
16:40–16:50 20/1, 1988	MS2	10	Power failure
12:45–13:05 21/1, 1988	MS5	20	Checking of suction pump
15:45–16:35 21/1, 1988	MS5	50	Checking of suction pump
9:10–11:10 18/7, 1988	MS5	120	Power failure

(3) Calculation of particulate matter on the each stage of Andersen sampler

The concentration of particulate matter on the each stage was calculated by weighing polyethylene sheets placed on the each plates before and after samplings and that of polyfluoro-carbon filter placed on the back-up holder. The ambient concentration of each stage was calculated by the Equation (5-13).

$$C_i = \frac{We_i - Ws_i}{V} \times 10^3 \quad \text{..... Equation (5-13)}$$

where,

Ci; concentrations of particulate matter on the each stage (stage 0 to 7) and back-up holder ($\mu g/m^3$)

We_i; weight of polyethylene sheets and polyfluorocarbon filter after sampling (mg)

Ws; weight of polyethylene sheets and polyfluorocarbon filter before sampling (mg)

V; sampling volume (m^3)

The list of particulate concentration classified by particle size is shown in Table 5-10.

Table 5-10 (1) Results of particulate concentration classified by particle size

THE FIRST FIELD SURVEY

STATION NO.1 ROTOR NO. 200522

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS1-S1-1	3.93	7.0	79.7
1	11-7.0	MS1-S2-1	3.36	5.9	72.7
2	7.0-4.7	MS1-S3-1	5.99	10.6	66.7
3	4.7-3.3	MS1-S4-1	5.64	10.0	56.1
4	3.3-2.1	MS1-S5-1	4.19	7.4	46.2
5	2.1-1.1	MS1-S6-1	3.95	7.0	38.7
6	1.1-0.65	MS1-S7-1	4.36	7.7	31.7
7	0.65-0.43	MS1-S8-1	4.22	7.5	24.0
8	<0.43	MS1-BF-1	9.35	16.6	16.6

AIR VOLUME (m3) = 564.8
TOTAL CONC.(μg/m3)= 79.7

STATION NO.2 ROTOR NO. 200523

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS2-S1-1	3.56	6.2	70.6
1	11-7.0	MS2-S2-1	2.85	5.0	64.3
2	7.0-4.7	MS2-S3-1	4.7	8.2	59.3
3	4.7-3.3	MS2-S4-1	4.68	8.2	51.1
4	3.3-2.1	MS2-S5-1	3.78	6.6	42.8
5	2.1-1.1	MS2-S6-1	3.72	6.5	36.2
6	1.1-0.65	MS2-S7-1	4.6	8.1	29.7
7	0.65-0.43	MS2-S8-1	3.43	6.0	21.6
8	<0.43	MS2-BF-1	8.88	15.6	15.6

AIR VOLUME (m3) = 569.8
TOTAL CONC.(μg/m3)= 70.6

STATION NO.3 ROTOR NO. 200525

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS3-S1-1	4.16	8.0	98.0
1	11-7.0	MS3-S2-1	1.74	3.3	90.0
2	7.0-4.7	MS3-S3-1	3.59	6.9	86.7
3	4.7-3.3	MS3-S4-1	6.57	12.6	79.8
4	3.3-2.1	MS3-S5-1	4.62	8.8	67.2
5	2.1-1.1	MS3-S6-1	4.8	9.2	58.4
6	1.1-0.65	MS3-S7-1	7.05	13.5	49.2
7	0.65-0.43	MS3-S8-1	9.32	17.8	35.7
8	<0.43	MS3-BF-1	9.32	17.8	17.8

AIR VOLUME (m3) = 522.3
TOTAL CONC.(μg/m3)= 98.0

STATION NO.4 ROTOR NO. 200526

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS4-S1-1	8.54	15.1	82.6
1	11-7.0	MS4-S2-1	4.47	7.9	67.5
2	7.0-4.7	MS4-S3-1	4.88	8.6	59.6
3	4.7-3.3	MS4-S4-1	5.36	9.5	51.0
4	3.3-2.1	MS4-S5-1	3.84	6.8	41.6
5	2.1-1.1	MS4-S6-1	3.42	6.0	34.8
6	1.1-0.65	MS4-S7-1	4.1	7.2	28.7
7	0.65-0.43	MS4-S8-1	2.79	4.9	21.5
8	<0.43	MS1-BF-1	9.39	16.5	16.6

AIR VOLUME (m3) = 566.5
TOTAL CONC.(μg/m3)= 82.6

STATION NO.5 ROTOR NO. 200549

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS5-S1-1	5.35	9.5	72.5
1	11-7.0	MS5-S2-1	4.13	7.4	62.9
2	7.0-4.7	MS5-S3-1	6.69	11.9	55.6
3	4.7-3.3	MS5-S4-1	5.9	10.5	43.7
4	3.3-2.1	MS5-S5-1	3.23	5.8	33.2
5	2.1-1.1	MS5-S6-1	2.13	3.8	27.4
6	1.1-0.65	MS5-S7-1	3.43	6.1	23.6
7	0.65-0.43	MS5-S8-1	2.84	5.1	17.5
8	<0.43	MS5-BF-1	7	12.5	12.5

AIR VOLUME (m3) = 561.6
TOTAL CONC.(μg/m3)= 72.5

Table 5-10 (2) Results of particulate concentration classified by particle size

THE SECOND FIELD SURVEY

STATION NO.1 ROTOR NO. 200522

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS1-S1-3	3.67	6.4	38.1
1	11-7.0	MS1-S2-3	2.19	3.8	31.7
2	7.0-4.7	MS1-S3-3	3.45	6.0	27.9
3	4.7-3.3	MS1-S4-3	2.9	5.1	21.9
4	3.3-2.1	MS1-S5-3	1.86	3.2	16.8
5	2.1-1.1	MS1-S6-3	0.85	1.5	13.6
6	1.1-0.65	MS1-S7-3	1.06	1.8	12.1
7	0.65-0.43	MS1-S8-3	2.11	3.7	10.2
8	<0.43	MS1-BF-3	3.76	6.6	6.6

AIR VOLUME (m3) = 573.1
TOTAL CONC.(μg/m3)= 38.1

STATION NO.2 ROTOR NO. 200523

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS2-S1-3	1.78	3.1	41.3
1	11-7.0	MS2-S2-3	2.14	3.7	38.2
2	7.0-4.7	MS2-S3-3	3.24	5.6	34.6
3	4.7-3.3	MS2-S4-3	2.93	5.0	29.0
4	3.3-2.1	MS2-S5-3	1.9	3.3	24.0
5	2.1-1.1	MS2-S6-3	1.3	2.2	20.8
6	1.1-0.65	MS2-S7-3	1.97	3.4	18.5
7	0.65-0.43	MS2-S8-3	3.56	6.1	15.1
8	<0.43	MS2-BF-3	5.28	9.0	9.0

AIR VOLUME (m3) = 583.6
TOTAL CONC.(μg/m3)= 41.3

STATION NO.3 ROTOR NO. 200525

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS3-S1-3	3.17	5.5	50.5
1	11-7.0	MS3-S2-3	2.06	3.6	45.0
2	7.0-4.7	MS3-S3-3	3.74	6.5	41.4
3	4.7-3.3	MS3-S4-3	3.58	6.2	34.9
4	3.3-2.1	MS3-S5-3	1.01	1.8	28.6
5	2.1-1.1	MS3-S6-3	2.53	4.4	26.9
6	1.1-0.65	MS3-S7-3	3.13	5.4	22.5
7	0.65-0.43	MS3-S8-3	2.97	5.2	17.0
8	<0.43	MS3-BF-3	6.81	11.9	11.9

AIR VOLUME (m3) = 574.5
TOTAL CONC.(μg/m3)= 50.5

STATION NO.4 ROTOR NO. 200526

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS4-S1-3	5.69	9.9	44.0
1	11-7.0	MS4-S2-3	2.81	4.9	34.1
2	7.0-4.7	MS4-S3-3	3.78	6.6	29.2
3	4.7-3.3	MS4-S4-3	3.06	5.3	22.6
4	3.3-2.1	MS4-S5-3	1.57	2.7	17.2
5	2.1-1.1	MS4-S6-3	0.73	1.3	14.5
6	1.1-0.65	MS4-S7-3	1.36	2.4	13.2
7	0.65-0.43	MS4-S8-3	1.75	3.1	10.8
8	<0.43	MS1-BF-3	4.44	7.8	7.8

AIR VOLUME (m3) = 572.0
TOTAL CONC.(μg/m3)= 44.0

STATION NO.5 ROTOR NO. 200549

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS5-S1-3	2.23	3.9	28.2
1	11-7.0	MS5-S2-3	1.31	2.3	24.4
2	7.0-4.7	MS5-S3-3	2.41	4.2	22.1
3	4.7-3.3	MS5-S4-3	1.98	3.5	17.9
4	3.3-2.1	MS5-S5-3	1.29	2.3	14.4
5	2.1-1.1	MS5-S6-3	0.5	0.9	12.2
6	1.1-0.65	MS5-S7-3	0.78	1.4	11.3
7	0.65-0.43	MS5-S8-3	1.94	3.4	9.9
8	<0.43	MS5-BF-3	3.75	6.5	6.5

AIR VOLUME (m3) = 573.2
TOTAL CONC.(μg/m3)= 28.2

Table 5-10 (3) Results of particulate concentration classified by particle size

THE THIRD FIELD SURVEY

STATION NO.1 ROTOR NO. 200522

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS1-S1-7	2.88	5.3	54.1
1	11-7.0	MS1-S2-7	2.32	4.3	48.8
2	7.0-4.7	MS1-S3-7	3.86	7.1	44.6
3	4.7-3.3	MS1-S4-7	4.04	7.4	37.5
4	3.3-2.1	MS1-S5-7	3.81	7.0	30.0
5	2.1-1.1	MS1-S6-7	2.60	4.8	23.0
6	1.1-0.65	MS1-S7-7	1.61	3.0	18.2
7	0.65-0.43	MS1-S8-7	1.40	2.6	15.3
8	<0.43	MS1-BF-7	6.89	12.7	12.7

AIR VOLUME (m3) = 543.3
TOTAL CONC.(μg/m3)= 54.1

STATION NO.2 ROTOR NO. 200523

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS2-S1-7	1.62	2.9	32.7
1	11-7.0	MS2-S2-7	1.17	2.1	29.7
2	7.0-4.7	MS2-S3-7	2.12	3.9	27.6
3	4.7-3.3	MS2-S4-7	2.54	4.6	23.8
4	3.3-2.1	MS2-S5-7	2.60	4.7	19.1
5	2.1-1.1	MS2-S6-7	1.69	3.1	14.4
6	1.1-0.65	MS2-S7-7	1.25	2.3	11.3
7	0.65-0.43	MS2-S8-7	1.48	2.7	9.1
8	<0.43	MS2-BF-7	3.51	6.4	6.4

AIR VOLUME (m3) = 550.3
TOTAL CONC.(μg/m3)= 32.7

STATION NO.3 ROTOR NO. 200525

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS3-S1-7	2.10	3.8	47.7
1	11-7.0	MS3-S2-7	1.77	3.2	43.9
2	7.0-4.7	MS3-S3-7	3.00	5.5	40.7
3	4.7-3.3	MS3-S4-7	3.14	5.7	35.2
4	3.3-2.1	MS3-S5-7	3.16	5.8	29.5
5	2.1-1.1	MS3-S6-7	2.48	4.5	23.7
6	1.1-0.65	MS3-S7-7	2.52	4.6	19.2
7	0.65-0.43	MS3-S8-7	2.08	3.8	14.6
8	<0.43	MS3-BF-7	5.89	10.8	10.8

AIR VOLUME (m3) = 547.6
TOTAL CONC.(μg/m3)= 47.7

STATION NO.4 ROTOR NO. 200526

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS4-S1-3	5.32	9.8	53.8
1	11-7.0	MS4-S2-3	2.69	5.0	44.0
2	7.0-4.7	MS4-S3-3	4.00	7.4	39.0
3	4.7-3.3	MS4-S4-3	3.64	6.7	31.6
4	3.3-2.1	MS4-S5-3	2.91	5.4	24.9
5	2.1-1.1	MS4-S6-3	1.94	3.6	19.5
6	1.1-0.65	MS4-S7-3	1.70	3.1	15.9
7	0.65-0.43	MS4-S8-3	1.22	2.3	12.7
8	<0.43	MS1-BF-3	5.66	10.5	10.5

AIR VOLUME (m3) = 540.2
TOTAL CONC.(μg/m3)= 53.8

STATION NO.5 ROTOR NO. 200549

STAGE	DIAMETER (μm)	FILTER NO.	DUST WEIGHT (mg)	DUST CONC. (μg/m3)	ACC.DUST CONC. (μg/m3)
0	>11	MS5-S1-3	4.07	7.5	33.9
1	11-7.0	MS5-S2-3	1.83	3.4	26.4
2	7.0-4.7	MS5-S3-3	3.11	5.7	23.1
3	4.7-3.3	MS5-S4-3	2.96	5.4	17.4
4	3.3-2.1	MS5-S5-3	2.18	4.0	11.9
5	2.1-1.1	MS5-S6-3	1.02	1.9	7.9
6	1.1-0.65	MS5-S7-3	0.49	0.9	5.1
7	0.65-0.43	MS5-S8-3	0.64	1.2	5.2
8	<0.43	MS5-BF-3	2.17	4.0	4.0

AIR VOLUME (m3) = 544.5
TOTAL CONC.(μg/m3)= 33.9

5.2 Analysis of chemical components contained in particulate matter

In order to analyze chemical components contained in the particulate matter, samples of particulate matter collected on filter papers by low-volume and Andersen samplers during the short term field survey from each station have been brought back to Japan for analysis of elements and anion & cation by instrumental neutron activation analyses (INAA), X-ray fluorescence (XRF), ion chromatography (IC), atomic absorption spectrometry (AAS), flame photometry (FP) and spectrophotometry (SP).

Samples on stage 0–7 and on a back up filter of Andersen sampler were divided into two groups and analyzed. One is coarse particle (over 2.1 μm; stages 0–4 stages of Andersen sampler) and the other is fine particle (under 2.1 μm; stages 5–7 and of back up filter of Andersen sampler).

Beside the above stated, additional analysis for the samples collected by Low-volume sampler with a quartz-fiber filter was conducted by pyrolysis of total carbon and non-volatile carbon (inorganic carbon).

Table 5-11 shows the chemical components analyzed in this study.

Table 5-11 Chemical components analyzed in this study

Analyzing method	Analyzed chemical components
INAA	Ag (Silver), Al (Aluminum), As (Arsenic), Ba (Barium), Br (Bromine), Ca (Calcium), Ce (Cerium), Cl (Chlorine), Co (Cobalt), Cr (Chromium), Cs (Cesium), Cu (Copper), Fe (Iron), Hf (Hafnium), K (Potassum), Mg (Magnesium), 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 (Tungsten), Zn (Zinc)
XRF	Cd (Cadmium), Pb (Lead), S (Sulfur), Si (Silicon)
IC	Cl^- (Chloride), NO_3^- (Nitrate), SO_4^{2-} (Sulfate)
AAS	Mg^{2+} (Magnesium ion), Ca^{2+} (Calcium ion)
FP	Na^+ (Sodium ion), K^+ (Potassium ion)
SP	NH_4^+ (Ammonium ion)
Pyrolysis	Total carbon, Non-volatile carbon

5.2.1 Analysis of Elements by Instrumental Neutron Activation Analysis

(1) Principle of analysis

When the sample is placed in the reactor, the thermal neutron generated by fission of 235_U collides with atomic nucleas in the sample materials and causes neutron fission. As the result, the product nuclei is produced which is different from the original one. The product nuclei is radioactive and emits Beta ray and Gamma ray, and changes into daughter nuclide after a certain period. The energy of Gamma ray is particular to the type of atomic nucleas. Thus measurement of γ-ray energy enables us to identify elements contained in the original sample. Also the number of Gamma ray is proportional to the number of elements, and thus determination of amount of elements become possible.

In actual neutron activation analysis, various types of elements coexist in the sample and their half lives vary in the range of from second to day order or even to more than one month. So by selecting cooling period properly, nuclides with various half lives can be measured.

As described above, neutron activation method does not require a complex chemical pretreatment and makes it possible to analyze many types of elements simultaneously in non-destructive way even though the sample contains a very small amount of elements. For these reasons and others, this method is highlighted recently as one of the most advanced and sensitive analyses.

(2) Analyzing method

The samples are placed in the TRIGA II type reactor of Atomic Energy Research Laboratory, Musashi Institute of Technology, and are irradiated by thermal neutron beam. Then the various radioactive isotopes generated are measured by a semiconductor detector and multichannel analyzer coupled with a mini-computer. The irradiation of thermal neutron on the sample is conducted in two ways; for a short-term and for a long-term.

The irradiated sample for a short-term is measured in term of Gamma ray using a semiconductor detector. The irradiated sample for a long-term is cooled for varying time of several days to several weeks in the laboratory, and then Gamma ray is measured. Fig. 5-8 shows atomic furnace and its sectional view.

Thermal neutron flux is keep at 1.5×10^{12} $cm^{-2}.s^{-1}$.

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

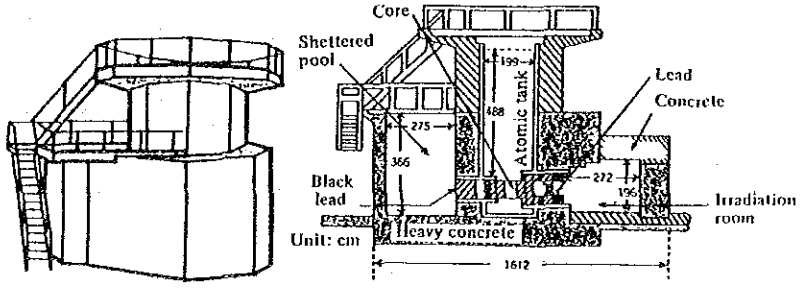


Fig. 5-8 External view and section of TRIGA II type reactor

① Analyzing conditions

(i) Short lived nuclides—At thermal neutron flux of (1.5×10^{12} $cm^{-2}.s^{-1}$), 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 neutron flux of (1.5×10^{12} $cm^{-2}.s^{-1}$), 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 3,000 seconds.

Table 5-12 shows analysis conditions of elements by nuclides.

Table 5-12 Elements by nuclides and analyzing conditions

Classification	Element	Target nuclear species	Isotope radio (%)	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
	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	^{153}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	^{110m}Ag	253 days	657.8	5 hours	Several weeks	3000 seconds
	Ba	^{130}Ba	0.101	^{131}Ba	11.5 days	496	5 hours	Several weeks	3000 seconds
	Ce	^{140}Ce	88.5	^{141}Ce	32.5 days	145.4	5 hours	Several weeks	3000 seconds
	Co	^{59}Co	100	^{60}Co	5.24 years	1332.4	5 hours	Several weeks	3000 seconds
	Cr	^{50}Cr	100	^{51}Cr	27.8 days	320.0	5 hours	Several	3000 seconds
	Cs	^{133}Cs	100	^{134}Cs	2.07 years	795.8	5 hours	Several weeks	3000 seconds
	Fe	^{58}Fe	0.33	^{59}Fe	45.1 days	1098.6	5 hours	Several weeks	3000 seconds
	Hf	^{180}Hf	35.2	^{181}Hf	44.6 days	482.2	5 hours	Several weeks	3000 seconds
	Lu	^{176}Lu	2.59	^{177}Lu	6.7 days	208.4	5 hours	Several weeks	3000 seconds
	Ni	^{58}Ni	67.9	^{58}Co	71.3 days	810.3	5 hours	Several weeks	3000 seconds
	Sc	^{45}Sc	100	^{46}Sc	83.9 days	889.4	5 hours	Several weeks	3000 seconds
	Se	^{74}Se	0.87	^{75}Se	121 days	264.6	5 hours	Several weeks	3000 seconds
	Th	^{232}Th	100	^{233}Pa	27.0 days	311.8	5 hours	Several weeks	3000 seconds
	Zn	^{64}Zn	48.9	^{65}Zn	245 days	1115.4	5 hours	Several weeks	3000 seconds

② Preparation of sample and production of standard sample

As shown in Fig. 5-9, the filter from low-volume and Andersen sampler were cut in two parts, and 1/2 of the each filter were again cut into two parts and contained in the polyethylene bag of double layers which are then subject to short and long term irradiation. To prepare standard samples, the solution with appropriate reagent dissolved for each element is produced, and these standard solution is dropped on the filter, TOYO-ROSHI PF040, in constant quantity which is used in analysis as multi-element-standard.

Table 5-13 shows the reagent used for production of the 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 the table.

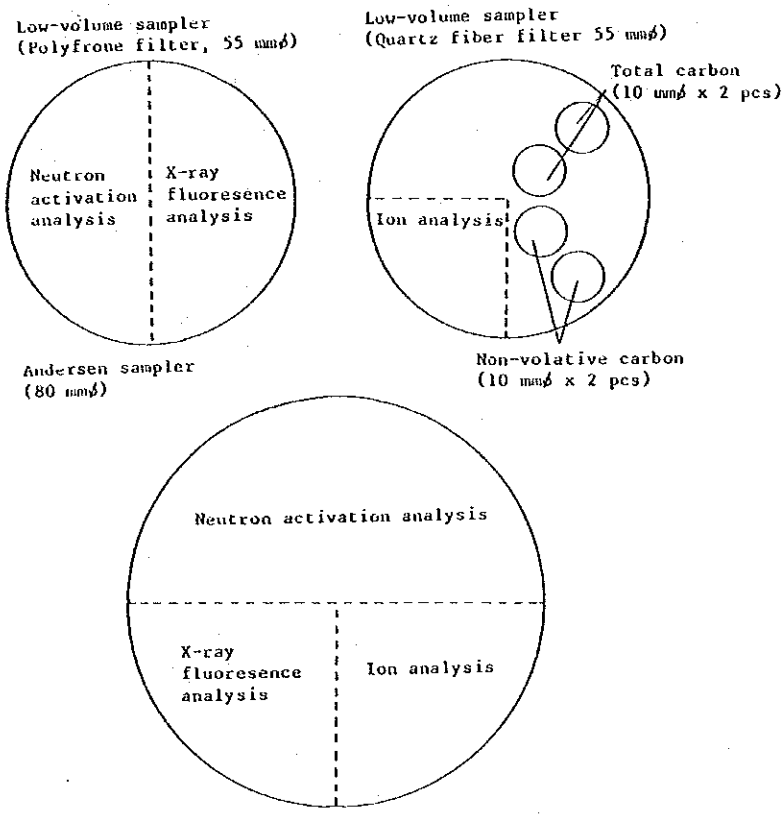


Fig. 5-9 Cutting of sampled filters for analysis

Table 5-13 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	199	6.80
	Br	KBr	7.69	1.97
	Ca	$CaCO_3$	212	0.00609
	Cl	KCl	179	0.0385
	Cu	Cu	100	0.564
	Mn	Mn	14.4	6.31
	Ti	Ti	48.9	0.289
	V	V	6.21	58.7
Long lived nuclides (a)	As	As_2O_3	2.78	43.7
	K	KCl	197	0.271
	La	La_2O_3	0.734	11.2
	Na	Na_2CO_3	201	11.6
	Sb	Sb	0.134	21.0
	Sm	Sm_2O_3	0.0404	576
	W	W	0.704	30.7
Long lived nuclides (b)	Ag	Ag_2SO_4	0.695	0.307
	Ba	$BaCl_2 \cdot 2H_2O$	37.7	0.0231
	Ce	$Ce(SO_4)_2 \cdot 2(NH_4)_2 \cdot SO_4 \cdot 2H_2O$	0.724	0.784
	Co	$CoCl_2 \cdot 6H_2O$	1.01	0.356
	Cr	Cr	2.02	0.358
	Cs	Cs	0.394	1.34
	Fe	Fe	301	0.00141
	Hf	Hf	0.115	2.40
	Lu	$LuCl_3 \cdot 6H_2O$	0.0241	103
	Ni	Ni	100	0.0178
	Sc	Sc_2O_3	0.158	13.6
	Se	H_2SeO_3	1.39	0.353
	Th	$Th(NO_3)_4 \cdot 4H_2O$	0.0544	6.93
	Zn	Zn	100	0.0185

③ Sequence order of analysis

Pretreated sample and standard sample are placed in the irradiation capsule, and under the analyzing conditions shown in Table 5-12, 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 the amount of element contained in the samples is evaluated.

Following the above, and after substracting blank value of the filter previously measured, the ambient element concentration is obtained, by dividing with air sucking flow rate. Analyzing sequence of neutron activation analyses are shown in Fig. 5-10.

(3) Analysis of ambient air standard sample

In order to evaluate the analyzing methods, standard sample AS-1 of known concentration of particulate matter was analyzed. The results of such analysis are shown in Table 5-14. The elements which showed a good agreement with analyzed values were Al, Ca, Cu, Mn, Ti, V, As, K, La, Na, Sm, Co, Fe, Ni, Sc, Se and Zn.

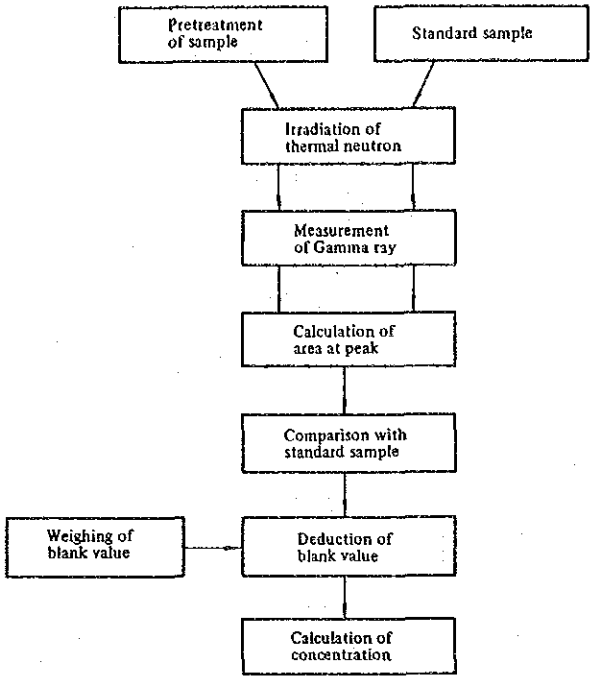


Fig. 5-10 Procedures of neutron activation analysis

Table 5-14 Analysis data 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	48000 (2)	50000±7000
	Br	250 (5)	340±9
	Ca	53000 (2)	56000±5000
	Cl	37000 (1)	31000±4000
	Cu	430 (18)	400±140
	Mn	1200 (7)	1200±100
	Ti	4500 (5)	4200±1100
	V	240 (2)	230±70
Long lived nuclides (a)	As	40 (6)	43±13
	K	10000 (25)	9700**
	La	17 (13)	18±2
	Na	14000 (2)	14000±1000
	Sb	62 (2)	39±6
	Sm	3.5 (3)	3.4**
	W	30 (11)	21±13
Long lived nuclides (b)	Ag	9 (37)	3**
	Ba	970 (17)	410**
	Ce	40 (8)	30**
	Co	29 (7)	26±4
	Cr	350 (2)	240±30
	Cs	3.5 (20)	4.0±**
	Fe	48000 (3)	45000±3000
	Hf	3.9 (14)	3.4**
	Lu	0.06 (25)	0.3**
	Ni	200 (31)	200±30
	Sc	12 (2)	11±1
	Se	9 (44)	9±6
	Th	3.7 (9)	5.1**
	Zn	3200 (3)	3400±500

Table in bracket are counting error.
* T. Otoshi and J. Omi, Bulletin of JESC, No.3, 58 (1976).
** Noncertified values

(4) Limit of measurement and filter blank

Average limit of determination at analysis of particulate matter in the ambient and filter blank values are shown in Table 5-15.

Table 5-15 Average limit of measurement and filter blank value

Classification	Element	Limit of determination (μg)	Filter blank (ng/cm²)		
			Poly-ethylene sheet	Poly-ethylene sheet + Back-up filter	Poly-frone filter
Short lived nuclides	Al	1	200	200	400
	Br	0.2	0	0	0
	Ca	20	0	0	0
	Cl	3	0	0	1000
	Cu	1	0	0	0
	Mn	0.02	0.4	0	4
	Ti	2	0	0	0
	V	0.02	1	0.3	3
Long lived nuclides (a)	As	0.03	0	0	0
	K	20	0	0	0
	La	0.02	0	0	0
	Na	0.1	100	100	800
	Sb	0.005	0	0	0
	Sm	0.002	0	0	0
	W	0.05	0	0	0
Long lived nuclides (b)	Ag	0.04	0	0	0
	Ba	2	0	0	0
	Ce	0.02	0	0	0
	Co	0.005	0	0	0
	Cr	0.05	0	0.4	1
	Cs	0.005	0	0	0
	Fe	20	0	0	0
	Hf	0.02	0	0	0
	Lu	0.005	0	0	0
	Ni	1	0	0	0
	Sc	0.002	0	0	0
	Se	0.05	0	0	0
	Th	0.01	0	0	0
	Zn	0.5	0	2	0

(5) Calculation method of elements and others

The weight of metal elements on the filter is calculated from the peak area of Gamma ray by the following Equation (5-14).

$$E_W = \left(\frac{Stw}{St\gamma a} \cdot S\gamma a\right) - Fbw \quad \text{..... Equation (5-14)}$$

where;

E_W: Weight of element in analyzed sample (μg)

Stw: Weight of element in standard sample (μg)

$St\gamma a$: Peak area of Gamma ray in standard sample

$S\gamma a$: Peak area of Gamma ray in analyzed sample

Fbw: Filter blank value (μg)

The metal element concentration in the ambient air is obtained from the following Equation (5-15).

$$Ce = \frac{Ew}{V} \cdot \frac{Fa}{Sa} \times 1{,}000 \quad \text{..... Equation (5-15)}$$

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 (cm^2)

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

Peak area of Gamma ray is calculated as follows; the Gamma ray peak specific to the element is analyzed by multichannel analyser which has detector resolution of around 1 KeV and spectrum data shown as Fig. 5-11 are indicated by channel number of multichannel 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.

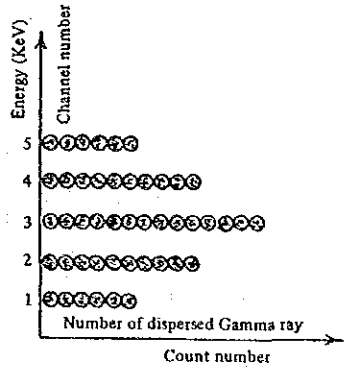


Fig. 5-11 Spectrum data (dispersion of Gamma particle)

The spectrum data indicate the dispersion curve as shown in Fig. 5-12, in which the noise portion 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 (5-16).

$$N = T - B \quad \text{..... Equation (5-16)}$$

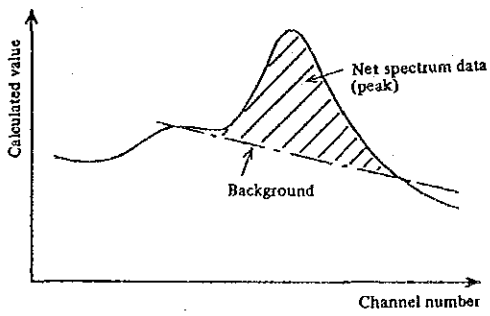


Fig. 5-12 Spectrum data and background

Furthermore, the measured value by detectors in certain time period has a statistical dispersion, and its dispersion behaviour conforms to poison distribution. Calculated value C is significant value in the range of calculation error $\pm\sqrt{C}$. Net peak area N calculated by Equation III-5-3 has calculation error $\sigma_N(\%)$. σ_N is obtained by following equation.

$$\sigma_N = \frac{\sqrt{N+(n-\frac{1}{2})\cdot B}}{N} B\times 100 \quad \text{..... Equation (5-17)}$$

where; n: number of channel

(in this study, of the neighboring makes 7 channels in total were used. So n = 3)

(6) Gamma ray Spectrum

Fig. 5-13 through 5-15 show some examples (3rd field survey at MS1 on coarse particle) of Gamma ray spectrum.

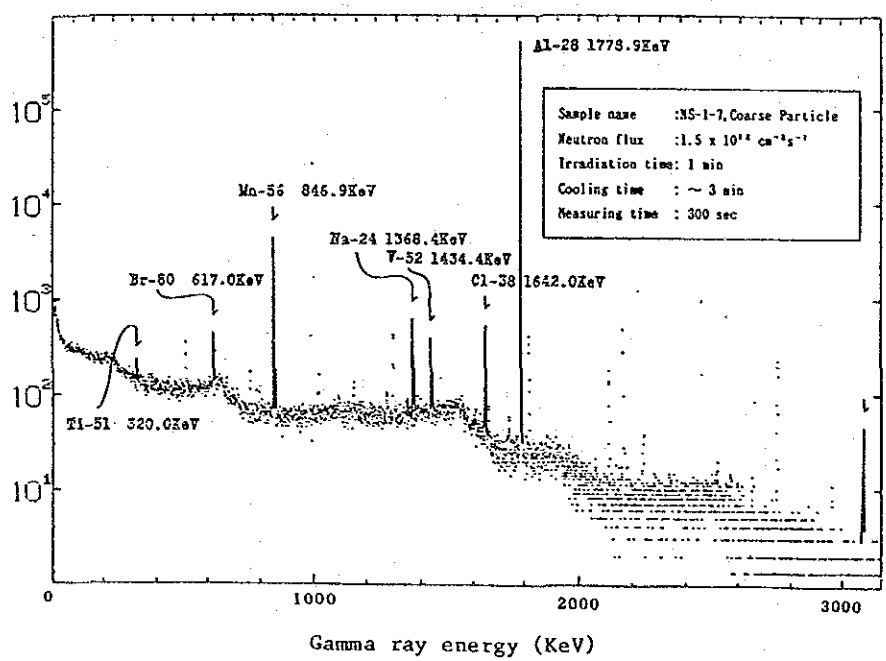


Fig. 5-13 An example of Gamma ray spectrum (short lived nuclides)

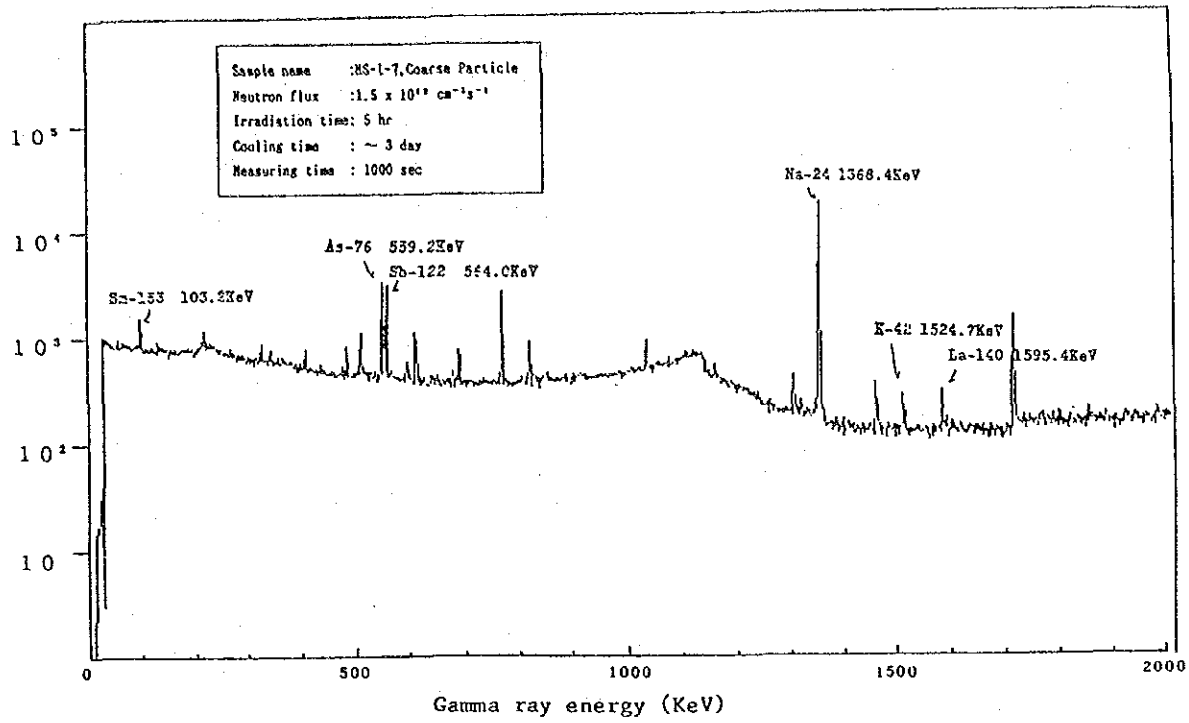


Fig. 5-14 An example of Gamma ray spectrum (long lived nuclides (a))

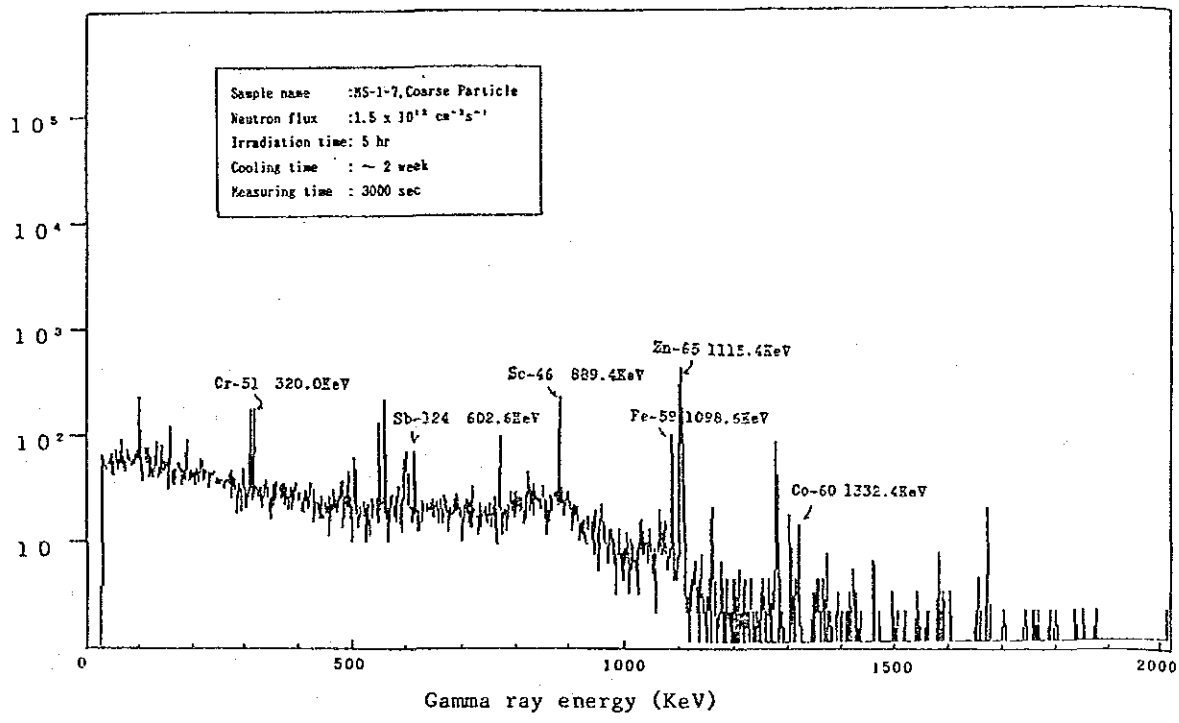


Fig. 5-15 An example of Gamma ray spectrum (long lived nuclides (b))

(7) Results of measurement

The results of analysis of elements by Instrumental Neutron Activation Analysis are shown in Table 5-16. In this table also shown are the results of measurement of Cd, Pb, S, and Si by X-ray fluorescence analysis, results of anion & cation by Ion chromatography, atomic absorption spectrometry, flame photometry and spectrophotometry, and results of total and non-volatile carbon by pyrolysis.

Table 5-16 (1) Results of element concentration contained in particulate matter by instrumental neutron activation analysis (Low-volome sampler)

unit; ng/m^3

		AG	AL	AS	BA	BR	CA	CE	CL	CO	CR	CS	CU	FE	HF	K
SURVEY1	MS1	0.60>	1300	8.00	40>	42.0	2100	3.10	1200	0.900	6.50	0.220	48	1700	0.100>	1300
	MS2	0.70>	810	12.00	50>	17.0	1200	1.40	2000	0.530	7.30	0.200>	30>	1300	0.200>	1100
	MS3	1.50	1100	11.00	50>	31.0	2600	2.50	2700	1.300	11.00	0.320	40>	4700	0.200>	1700
	MS4	0.60>	1400	5.20	30>	37.0	1600	2.10	1900	0.460	5.10	0.100>	40>	1700	0.100>	1200
	MS5	0.40>	2200	3.00	20>	18.0	2100	3.10	950	0.660	3.30	0.370	30>	1100	0.110	2000
SURVEY2	MS1	0.40>	760	4.20	20>	14.0	750	0.76	1100	0.200>	3.70	0.094	30>	700	0.080>	640
	MS2	0.30>	310	1.40	10>	9.0	800>	1.30	3100	0.360>	10.00	0.220	60>	420	0.050>	350
	MS3	0.80>	490	11.00	40>	19.0	2000	0.80>	4100	1.700	10.00	0.200>	60>	2000	0.210	1300
	MS4	0.30>	650	3.30	20>	11.0	1600	0.99	2100	0.200>	2.90	0.120	30>	400	0.060>	750
	MS5	0.20>	570	0.81	10>	12.0	500>	1.10	930	0.200>	0.77	0.140	70>	260	0.047	540
SURVEY3	MS1	0.60>	770	11.00	20>	26.0	1700	1.10	1200	0.680	7.90	0.100>	20>	1200	0.100>	800>
	MS2	1.00	410	11.00	20>	4.5	800	1.20	1000	0.750	7.90	0.220	20>	840	0.100>	1400
	MS3	0.60>	410	10.00	20>	9.5	1300	1.30	1800	1.200	7.30	0.200>	30>	1700	0.100>	1100
	MS4	0.50>	820	11.00	20>	15.0	1500	2.50	1000	0.560	4.50	0.210	20>	940	0.090>	800>
	MS5	0.40>	740	3.80	19	7.2	1300	1.40	700	0.560	5.00	0.100	20>	450	0.080>	980>

		LA	LU	MG	MN	NA	NI	SB	SC	SE	SM	TH	TI	V	W	ZN
SURVEY1	MS1	1.00	0.0400>	980	60.00	1100	19.0	29.00	0.2000	0.90>	0.160	0.290	67.0	12.0	0.60>	720
	MS2	0.50>	0.0500>	500>	58.00	1700	20.0>	64.00	0.1300	1.00>	0.096	0.180	86.0	16.0	0.70>	960
	MS3	1.20	0.0400>	500>	360.00	1400	47.0	17.00	0.1900	2.00>	0.170	0.250	130.0	35.0	1.40	3700
	MS4	1.10	0.0300>	940	73.00	1500	10.0>	17.00	0.2000	0.80>	0.160	0.250	140.0	7.4	0.60>	760
	MS5	1.60	0.0200>	720	41.00	1100	8.0>	5.40	0.2300	0.96	0.280	0.390	150.0	5.0	0.50>	140
SURVEY2	MS1	0.30>	0.0230	800	50.00	1400	7.0>	5.10	0.1100	1.10	0.063	0.140	97.0	6.4	0.49	250
	MS2	0.50	0.0200>	540	11.00	2800	19.0	1.40	0.0540	51.00	0.025	0.082	96.0	26.0	0.60>	82
	MS3	0.40>	0.0400>	430	280.00	2100	55.0	6.50	0.0780	1.50	0.066	0.0860>	57.0	63.0	1.20	2900
	MS4	0.30>	0.0100>	940	24.00	1900	6.0	1.70	0.0760	0.50	0.067	0.110	100.0>	4.5	0.40	100
	MS5	0.30>	0.0100>	700	15.00	1800	6.0>	0.47	0.0710	0.95	0.065	0.140	82.0	2.1	0.40>	18
SURVEY3	MS1	1.10	0.0030>	220	71.00	780	10.0>	5.60	0.1300	1.70	0.100	0.210	62.0	8.7	0.90>	960
	MS2	0.37	0.0040>	550	23.00	1000	22.0	32.00	0.1100	1.00>	0.056	0.070	40.0>	13.0	0.90>	370
	MS3	0.56	0.0030>	300>	72.00	840	18.0	10.00	0.1000	0.80>	0.077	0.069	66.0	22.0	1.50	1100
	MS4	0.85	0.0020>	610	34.00	1100	10.0>	4.10	0.1400	0.70>	0.140	0.190	59.0	6.3	1.00>	370
	MS5	0.40>	0.0020>	460	21.00	790	15.0	3.10	0.1500	0.80>	0.120	0.160	51.0	3.4	2.80	160

		CD	PB	S	SI	NA+	K+	CA++	MG++	NH4+	CL-	NO3-	SO4--	T-C	E-C	O-C
SURVEY1	MS1	1	450	2180	6300	1300	1100	560	100>	120	520	600	5700	24000	15300	8700
	MS2	1	1590	1610	4200	1800	1200	370	110	300	1000	840	7700	19300	13500	5800
	MS3	3	780	2550	4900	1600	1700	830	150	160	1700	840	9400	27200	16400	10800
	MS4	3	290	2060	6100	1900	1200	1200	140	100>	1300	1800	5800	25700	16200	9400
	MS5	2	30	1010	9100	990	850	550	100>	100>	330	990	4000	13200	9500	3700
SURVEY2	MS1	2	50	730	3900	1100	650	100>	100>	140	140	860	3300	11800	7500	4300
	MS2	1>	20	1380	1900	2100	780	290	150	270	230	710	7300	11500	7500	4000
	MS3	2	380	1930	2300	1500	1100	240	120	490	1800	1300	6400	16700	11500	5300
	MS4	1>	50	870	3500	1500	630	250	100>	100>	800	1400	3600	17300	11500	5800
	MS5	1>	10>	490	2200	880	420	100>	100>	100>	140	630	2300	10400	6200	4100
SURVEY3	MS1	1>	220	1000	4100	870	470	220	100>	100>	1000	470	3300	13300	10600	2700
	MS2	1>	1100	930	1400	1200	510	100>	100>	100>	250	100>	5700	7500	5500	2000
	MS3	3	230	1160	2100	1600	700	370	100>	230	1000	360	6000	11300	8100	3200
	MS4	1>	140	780	3900	1200	560	700	120	100>	1600	560	3000	13600	9700	4000
	MS5	1	40	340	2900	840	200	200	100>	100>	880	300	1800	5900	4000	2000

Table 5-16 (2) Results of element concentration contained in particulate matter by instrumental neutron activation analysis (Andersen sampler, fine particle)

unit; ng/m^3

		AG	AL	AS	BA	BR	CA	CE	CL	CO	CR	CS	CU	FE	HF	K
SURVEY1	MS1	0.30>	71	4270	10>	26.0	95	0.76	220	0.200>	1.70	0.120	14	110	0.080>	650
	MS2	0.40>	73	7.50	20>	12.0	85	0.50	360	0.200>	2.50	0.097	10>	140	0.090>	720
	MS3	0.65	120	6.80	20>	18.0	250	1.10	890	0.670	11.00	0.100>	26	1300	0.080>	1000
	MS4	0.50>	73	3.60	20>	24.0	90>	0.73	220	0.250	1.90	0.100>	14	130	0.090>	760
	MS5	0.20>	120	1.80	10>	16.0	100>	0.20>	160	0.100>	0.75	0.080	10>	150	0.040>	830
SURVEY2	MS1	0.24	85	2.90	8>	10.0	100>	0.27	270	0.100>	0.93	0.060>	10>	110	0.040>	410
	MS2	0.65	65	1.50	6>	6.4	74	0.40>	190	0.200>	9.70	0.150	10>	87	0.033	430
	MS3	0.50>	79	8.80	20>	14.0	100>	0.40>	1100	1.000	4.00	0.100>	21	690	0.080>	780
	MS4	0.12	58	1.80	7>	9.0	70	0.40	220	0.070>	0.63	0.040>	10>	79	0.030>	440
	MS5	0.16	65	0.44	7>	11.0	79	0.20>	230	0.059	0.54	0.034	10>	30>	0.022	400
SURVEY3	MS1	0.42	120	7.50	10>	15.0	110	0.56	510	0.100>	3.30	0.090>	21	310	0.060>	610
	MS2	0.39	98	8.50	10>	4.1	100>	0.24	370	0.390	5.50	0.084	10>	150	0.070>	1100
	MS3	0.40>	100	7.80	10>	8.4	86	0.10>	560	0.390	3.60	0.120	10>	590	0.070>	540
	MS4	0.20>	100	6.70	8>	13.0	170	0.28	280	0.100>	2.00	0.070>	10>	280	0.040>	500>
	MS5	0.20>	110	2.00	6>	2.6	90>	0.24	210	0.100>	1.40	0.040>	9>	180	0.030>	630

		LA	LU	MG	MN	NA	NI	SB	SC	SE	SM	TH	TI	V	W	ZN
SURVEY1	MS1	0.34	0.0100>	180	21.00	220	7.0>	19.00	0.0100>	0.60>	0.019	0.040>	20.0>	6.4	0.20>	350
	MS2	0.10>	0.0100>	100>	17.00	350	8.0>	32.00	0.0100>	1.30	0.015	0.050>	20.0>	9.4	0.20>	420
	MS3	0.24	0.0200>	200>	160.00	470	10.0>	8.60	0.0200>	0.92	0.034	0.040>	40.0>	22.0	0.53	1400
	MS4	0.23	0.0200>	200>	21.00	440	10.0>	16.00	0.0200>	1.10	0.020	0.050>	20.0>	3.9	0.34	1100
	MS5	0.18	0.0100>	170	8.60	240	4.0>	4.90	0.0180	0.46	0.014	0.020>	20.0>	2.1	0.20>	79
SURVEY2	MS1	0.23	0.0060>	400	19.00	250	4.0>	4.10	0.0150	0.53	0.010	0.020>	20.0>	4.7	0.20>	170
	MS2	0.20>	0.0080>	200>	3.30	800	7.8	1.10	0.0110	66.00	0.007>	0.020>	20.0>	21.0	0.20>	48
	MS3	0.10>	0.0210	200>	80.00	410	17.0	1.90	0.0200>	0.74	0.006>	0.040>	12.0	47.0	0.64	1400
	MS4	0.14	0.0080>	100	7.00	360	3.0>	1.60	0.0068	0.44	0.019	0.020>	11.0	2.6	0.21	65
	MS5	0.10>	0.0070>	200>	0.82	330	3.0>	0.35	0.0084	0.45	0.011	0.010>	20.0>	1.3	0.20>	39
SURVEY3	MS1	0.20>	0.0010>	100>	37.00	400	7.0>	3.90	0.0280	1.00	0.021	0.030>	20.0>	6.7	0.50>	560
	MS2	0.20>	0.0020>	200>	6.70	540	6.0>	19.00	0.0240	0.60>	0.010>	0.040>	31.0	9.6	0.40>	220
	MS3	0.20	0.0020>	200>	39.00	480	9.0>	8.70	0.0240	1.10	0.029	0.046	20.0>	17.0	0.40>	740
	MS4	0.27	0.0010>	280	10.00	660	5.0>	2.80	0.0170	0.40>	0.030	0.030>	20.0>	4.5	0.30>	190
	MS5	0.21	0.0010>	200>	6.20	280	4.0>	2.40	0.0170	0.46	0.018	0.020>	6.8	1.9	0.30>	97

		CD	PB	S	SI	NA+	K+	CA++	MG++	NH4+	CL-	NO3-	SO4--
SURVEY1	MS1	4>	290	1590	300>	330	670	100>	100>	570	100>	120	3600
	MS2	4>	890	1180	300>	440	770	100>	100>	690	170	200	4100
	MS3	4>	540	1140	400>	500	940	100>	100>	700	450	400	4800
	MS4	4>	200	1360	400>	400	670	100>	100>	480	100	190	3400
	MS5	4>	40>	900	400>	230	590	100>	100>	430	100>	190	2600
SURVEY2	MS1	3>	50	780	300>	270	350	100>	100>	460	150	220	2400
	MS2	3>	40>	1700	300>	760	430	100>	100>	1400	120	160	7600
	MS3	3>	190	880	300>	400	650	100>	100>	1100	450	220	6100
	MS4	3>	60>	920	300>	310	330	100>	100>	460	150	180	2500
	MS5	3>	30>	730	300>	250	310	100>	100>	100>	100>	160	2200
SURVEY3	MS1	4>	140	1070	400>	310	290	100>	100>	230	160	150	1900
	MS2	4>	660	1230	400>	360	250	100>	100>	660	120	120	3100
	MS3	4>	130	840	400>	460	390	180	100>	510	210	150	2700
	MS4	4>	80	1190	400>	470	310	100>	100>	100>	100	140	1400
	MS5	4>	40>	1020	400>	150	100>	100>	100>	100>	100>	150	960

Table 5-16 (3) Results of element concentration contained in particulate matter by instrumental neutron activation analysis (Andersen sampler, coarse particle)

unit; ng/m^3

	AG	AL	AS	BA	BR	CA	CE	CL	CO	CR	CS	CU	FE	HF	K
SURVEY1															
MS1	0.40>	1400	2.40	28	12.0	2100	1.80	1200	0.770	5.30	0.110	20>	1200	0.070>	550
MS2	0.40>	890	3.50	20>	6.2	1200	1.20	2300	0.400	4.70	0.150	20>	1000	0.130	240
MS3	0.56	820	1.70	20>	5.8	1400	1.50	1200	0.660	13.00	0.220	20>	2200	0.082	440
MS4	0.40>	1700	2.10	25	11.0	2900	2.50	2200	0.540	5.10	0.100	20>	1300	0.070>	440
MS5	0.50>	2300	1.70	27	3.0>	2300	3.30	1200	0.350	2.80	0.100>	20>	930	0.080>	930
SURVEY2															
MS1	0.20>	950	1.60	10	3.2	1500	1.00	2000	0.280	3.30	0.091	10>	630	0.078	300
MS2	0.20>	330	0.51	7>	3.5	610	0.97	3400	0.570	1.60	0.050>	10>	440	0.040>	430
MS3	0.50>	430	2.80	20>	5.4	1200	1.00	2700	0.730	7.00	0.100>	10>	1600	0.080>	350
MS4	0.20>	860	1.60	9>	5.3	2200	1.70	2800	0.280	3.90	0.074	10>	660	0.054	370
MS5	0.20>	810	0.24	7>	3.4	1100	1.20	2700	0.210	1.10	0.056	20>	320	0.046	330
SURVEY3															
MS1	0.30>	810	1.70	16	12.0	1900	1.00	1200	0.370	4.90	0.080>	20>	800	0.050>	1100
MS2	0.30>	440	1.60	10>	2.0>	800	0.32	1700	0.210	2.10	0.050>	20>	610	0.065	500>
MS3	0.30>	400	1.00	17	4.5	1200	0.39	1600	0.290	4.60	0.110	20>	880	0.052	640
MS4	0.30>	1200	1.60	10>	7.9	2000	1.30	1600	0.360	2.90	0.082	20>	620	0.078	640
MS5	0.20>	910	1.90	8>	4.5	1900	1.30	1600	0.340	3.20	0.160	20>	500	0.044	500>

	LA	LU	MG	MN	NA	NI	SB	SC	SE	SM	TH	TI	V	W	ZN
SURVEY1															
MS1	0.78	0.0080>	440	34.00	810	7.0>	5.90	0.2200	0.50>	0.120	0.310	90.0	4.2	0.36	210
MS2	0.34	0.0100>	510	35.00	1100	8.0>	20.00	0.1400	0.70>	0.047	0.150	74.0	4.8	0.40	310
MS3	0.51	0.0100>	670	130.00	720	10.0>	2.40	0.1100	0.60>	0.074	0.120	69.0	9.1	0.96	1100
MS4	0.76	0.0120	820	59.00	1000	7.0>	2.00	0.2500	0.50>	0.130	0.340	100.0	3.8	0.30>	290
MS5	1.10	0.0190	1100	37.00	860	10.0>	0.88	0.2900	0.50>	0.240	0.630	120.0	3.4	0.28	830
SURVEY2															
MS1	0.31	0.0059	390	26.00	1100	5.0>	0.35	0.1300	0.44	0.071	0.180	75.0	2.6	0.30>	53
MS2	0.33	0.0060>	350	9.50	2100	5.0>	0.25	0.0530	1.00	0.037	0.069	20.0>	3.7	0.40>	110
MS3	0.40	0.0100>	470	100.00	1600	10.0>	4.70	0.0750	0.70>	0.044	0.081	41.0	17.0	1.10	1400
MS4	0.35	0.0060>	660	21.00	1500	6.0>	0.45	0.1400	0.55	0.100	0.230	53.0	2.1	0.48	63
MS5	0.32	0.0064	340	14.00	1300	5.0>	0.10>	0.0830	0.55	0.061	0.130	69.0	1.5	0.30>	19
SURVEY3															
MS1	0.70	0.0010>	430	40.00	560	6.0>	0.99	0.1300	0.60>	0.090	0.140	68.0	3.5	0.60>	250
MS2	0.39	0.0020>	320	15.00	820	5.0>	8.40	0.0810	0.50>	0.065	0.060	34.0	3.6	0.50>	91
MS3	0.30	0.0010>	440	38.00	650	7.0>	1.00	0.0770	0.40>	0.047	0.070	40.0>	5.3	0.85	330
MS4	0.86	0.0021	820	28.00	810	5.0>	0.61	0.1300	0.30>	0.130	0.260	75.0	2.6	0.57	86
MS5	0.57	0.0018	840	18.00	700	4.0>	0.32	0.1300	0.50>	0.120	0.200	49.0	2.0	2.40	41

	CD	PB	S	SI	NA+	K+	CA++	MG++	NH4+	CL-	NO3-	SO4--
SURVEY1												
MS1	4>	170	730	3900	610	140	670	100>	100>	600	910	790
MS2	4>	660	1140	1500	980	170	370	100>	100>	1200	1000	2600
MS3	5>	240	1460	2300	740	220	380	100>	100>	680	940	1500
MS4	4>	90	1050	5200	970	250	1000	100>	100>	1200	1100	1300
MS5	4>	40>	680	6400	640	120	650	100>	100>	580	920	720
SURVEY2												
MS1	4>	30	780	3000	1200	110	530	100>	100>	1100	1100	1200
MS2	4>	40>	1340	1300	1900	180	290	150	100>	2400	1100	1800
MS3	4>	150	2120	1200	1300	240	440	190	100>	1600	1100	3400
MS4	4>	40>	1220	3300	1400	160	930	260	100>	1400	1200	1500
MS5	4>	40>	560	2300	1000	100>	410	100>	100>	1100	1100	510
SURVEY3												
MS1	4>	50	790	2700	580	100>	330	100>	100>	620	280	750
MS2	4>	380	1140	1200	780	150	200	100>	100>	730	280	1200
MS3	5>	40>	1390	1300	630	140	340	100>	100>	750	290	1200
MS4	5>	50>	1120	4400	710	120	610	100>	100>	860	310	1100
MS5	5>	50>	1250	3100	630	100>	350	100>	100>	790	280	660

Table 5-16 (4) Results of element concentration contained in particulate matter by instrumental neutron activation analysis (Andersen sampler, fine + coarse)

unit; ng/m^3

	AG	AL	AS	BA	BR	CA	CE	CL	CO	CR	CS	CU	FE	HF	K
SURVEY1															
MS1	0.35	1471	7.10	33	38.0	2195	2.56	1420	0.870	7.00	0.230	24	1310	0.075	1200
MS2	0.40	963	11.00	20	18.2	1283	1.70	2680	0.500	7.20	0.247	15	1140	0.175	960
MS3	1.19	940	8.50	20	23.8	1650	2.60	2090	1.550	24.00	0.270	36	3500	0.122	1440
MS4	0.45	1773	5.70	35	35.0	2945	3.25	2420	0.790	7.00	0.150	24	1430	0.080	1200
MS5	0.35	2420	3.50	32	17.5	2350	3.60	1360	0.400	3.55	0.130	15	1080	0.060	1760
SURVEY2															
MS1	0.34	1035	4.70	14	13.2	1550	1.27	2270	0.330	4.25	0.121	10	740	0.098	710
MS2	0.75	415	2.01	7	9.9	684	1.17	3590	0.670	11.30	0.175	10	527	0.053	860
MS3	0.50	509	11.60	20	19.6	1250	1.20	3800	1.730	11.00	0.100	26	2290	0.050	1150
MS4	0.22	918	3.40	8	14.5	2270	2.10	3020	0.315	4.53	0.096	10	739	0.069	810
MS5	0.26	875	0.48	7	14.4	1179	1.30	2930	0.269	1.44	0.090	15	335	0.068	730
SURVEY3															
MS1	0.57	930	9.20	21	27.0	2010	1.56	1710	0.420	8.20	0.085	31	1110	0.055	1710
MS2	0.54	538	10.30	10	5.1	850	0.76	2070	0.600	7.60	0.109	15	760	0.100	1350
MS3	0.35	500	8.80	22	10.9	1284	0.44	2160	0.680	8.20	0.230	15	1470	0.087	1180
MS4	0.25	1300	8.50	9	20.9	2170	1.58	1860	0.410	4.90	0.117	15	990	0.098	890
MS5	0.20	1020	3.90	7	7.1	1945	1.34	1810	0.390	4.60	0.180	15	680	0.061	850

	LA	LU	MG	MN	NA	NI	SB	SC	SE	SM	TH	TI	V	W	ZN
SURVEY1															
MS1	1.12	0.0090	620	55.00	1030	7.0	24.90	0.2250	0.55	0.139	0.330	100.0	10.6	0.46	560
MS2	0.39	0.0100	560	52.00	1450	8.0	52.00	0.1450	1.65	0.082	0.175	84.0	14.2	0.50	730
MS3	0.77	0.0150	770	290.00	1190	10.0	11.00	0.1200	1.22	0.108	0.140	89.0	31.1	1.49	2500
MS4	0.99	0.0220	920	80.00	1440	8.5	18.00	0.2600	1.35	0.150	0.365	110.0	7.7	0.49	1390
MS5	1.28	0.0240	1270	45.60	1100	7.0	5.78	0.3080	0.71	0.254	0.640	150.0	5.5	0.38	909
SURVEY2															
MS1	0.56	0.0089	790	45.00	1350	6.5	4.65	0.1450	0.97	0.081	0.190	85.0	7.3	0.25	223
MS2	0.45	0.0060	450	12.80	2900	10.5	1.35	0.0640	67.00	0.041	0.079	20.0	24.7	0.30	158
MS3	0.45	0.0260	570	180.00	2010	22.0	4.60	0.0850	1.09	0.067	0.105	55.0	64.0	1.74	2800
MS4	0.49	0.0070	760	28.00	1860	9.5	1.85	0.1660	0.99	0.119	0.240	64.0	4.7	0.49	108
MS5	0.37	0.0079	440	14.82	1630	5.0	0.40	0.0914	0.78	0.072	0.155	79.0	2.8	0.25	58
SURVEY3															
MS1	0.80	0.0010	480	77.00	960	6.5	4.89	0.1580	1.20	0.111	0.175	78.0	10.2	0.55	810
MS2	0.49	0.0020	420	23.70	1360	5.5	27.40	0.1050	0.55	0.070	0.080	65.0	13.2	0.43	311
MS3	0.50	0.0015	540	77.00	1130	8.0	9.70	0.1010	1.30	0.076	0.116	30.0	25.3	1.05	1090
MS4	1.13	0.0026	1100	36.00	1470	5.0	3.41	0.1670	0.35	0.160	0.255	85.0	7.1	0.82	278
MS5	0.78	0.0023	940	24.20	980	4.0	2.72	0.1470	0.61	0.138	0.230	55.8	3.9	2.55	138

	CD	PB	S	SI	NA+	K+	CA++	MG++	NH4+	CL-	NO3-	SO4--
SURVEY1												
MS1	4	480	2320	4050	940	810	720	100	620	650	1030	4390
MS2	4	1550	2320	2650	1420	940	420	100	740	1370	1200	6700
MS3	5	780	2620	2500	1240	1160	430	100	750	1130	1360	6300
MS4	4	290	2410	5400	1370	920	1050	100	530	1300	1290	4700
MS5	4	40	1580	6600	870	710	730	100	480	630	1110	3320
SURVEY2												
MS1	4	80	1560	3150	1470	660	600	100	510	1250	1320	3600
MS2	4	40	3040	1450	2660	610	340	200	1450	2520	1260	9400
MS3	4	340	3000	1350	1700	890	490	240	1150	2030	1320	9500
MS4	4	40	2540	3450	1710	690	980	310	510	1750	1380	4000
MS5	4	35	1290	2450	1250	560	460	100	100	1150	1260	2710
SURVEY3												
MS1	4	190	1860	2900	890	540	380	100	280	780	430	2650
MS2	4	1040	2370	1400	1140	600	250	100	510	850	600	4300
MS3	5	150	2230	1500	1090	530	520	100	560	960	440	3900
MS4	5	105	2510	4600	1180	630	660	100	100	980	450	2500
MS5	5	45	2270	3300	780	100	400	100	100	840	430	1420

Note; When concentration of elements are under the confidence, 1/2 of such the values are counted into calculation.

5.2.2 Analysis of Elements by X-ray Fluorescence

Elements (Pb, Si) which cannot be analyzed by neutron activation method and elements (Cd, S) in low sensitivity, were been analyzed by X-ray fluorescence method.

(1) Principle of measurement

When the sample is irradiated by primary X-ray produced from X-ray generator, secondary X-ray characteristic of elements in such sample generates from the sample. The fluorescence of X-ray has an intensity distribution corresponding to the element components, and so X-ray intensity corresponding to the elements is measured by spectro analysis of X-ray. The X-ray intensity corresponding to the standard sample was first measured and then it was compared with that of sample to be measured. Thus the amount of target element become known. Fig. 5-16 shows principle of X-ray fluorescence analyzing instrument.

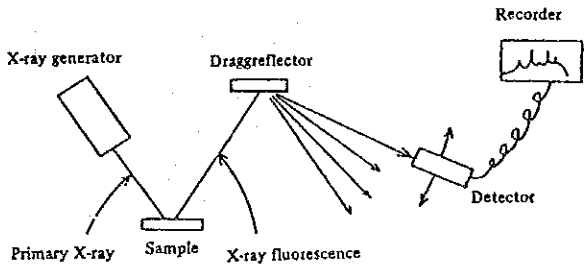


Fig. 5-16 Principle of X-ray fluorescence analyzing instrument

(2) Analyzing methods

As shown in Fig. 5-9, sampled filters for analysis are cut into a round shape of 47 mmϕ, which is then placed on the X-ray fluorescence analyzing instrument, Gigerflex of RIGAKU DENKI KK. The instrument is set on sample stand as shown in Fig. 5-17.

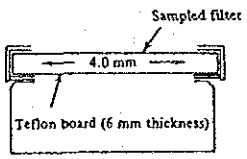


Fig. 5-17 Sample stand

① Analyzing conditions

Table 5-17 shows the type of X-ray tube, Bragy reflector, detector, analyzing line, measuring time applied to this study.

Table 5-17 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	Kα line (7.126 A)	40 sec
S	Chromium tube	Ge	Flow proportional counter	Kα line (5.373 A)	40 sec
Cd	Chromium tube	Ge	Flow proportional counter	Lα line (3.960 A)	80 sec
Pb	Tungsten tube	LiF	Scintillation counter	Lβ line (0.982 A)	40 sec

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, while 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, it is the other way around as shown in Fig. 5-18.

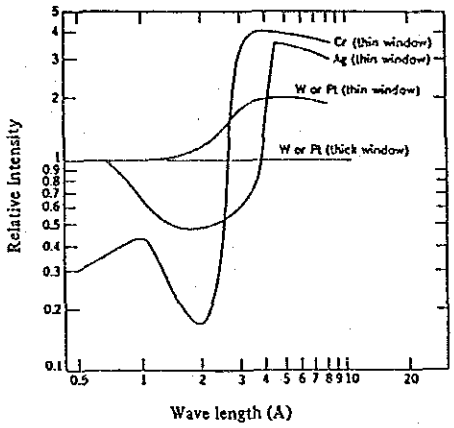


Fig. 5-18 Character of X-ray tubes

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 being limited as shown in Fig. 5-19. (Shaded line)

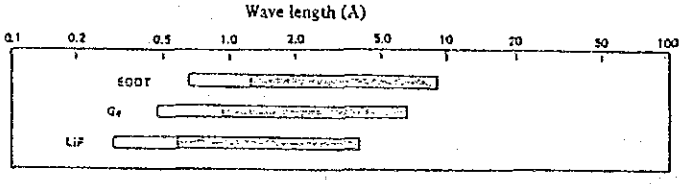


Fig. 5-19 Applicable range of Bragy reflectors

Furthermore Fig. 5-20 shows the relative intensity of flow proportional counter employed.

In this study, Argon has been employed.

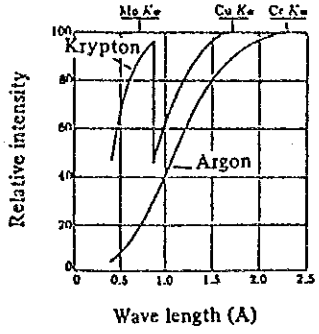


Fig. 5-20 Relative intensity of flow proportional counter

② Preparation of analytical line

(i) Pb, Cd (Filtration method of precipitate coprecipitated with iron)

A predetermined quantity of lead (Pb^{2+}) and cadmium (Cd^{2+}) are added into the solution containing 300 μg of iron (Fe^{3+}). Adjusting pH at 9.3 by sodium borate solution and 0.1N hydrogen chloride, precipitate is coagulated while heating, and was collected on a filter. The above procedures are repeated by changing quantity of lead and cadmium at each stage for production of standard samples to be used for developing the analytical line. Fig. 5-21 shows the analytical line.

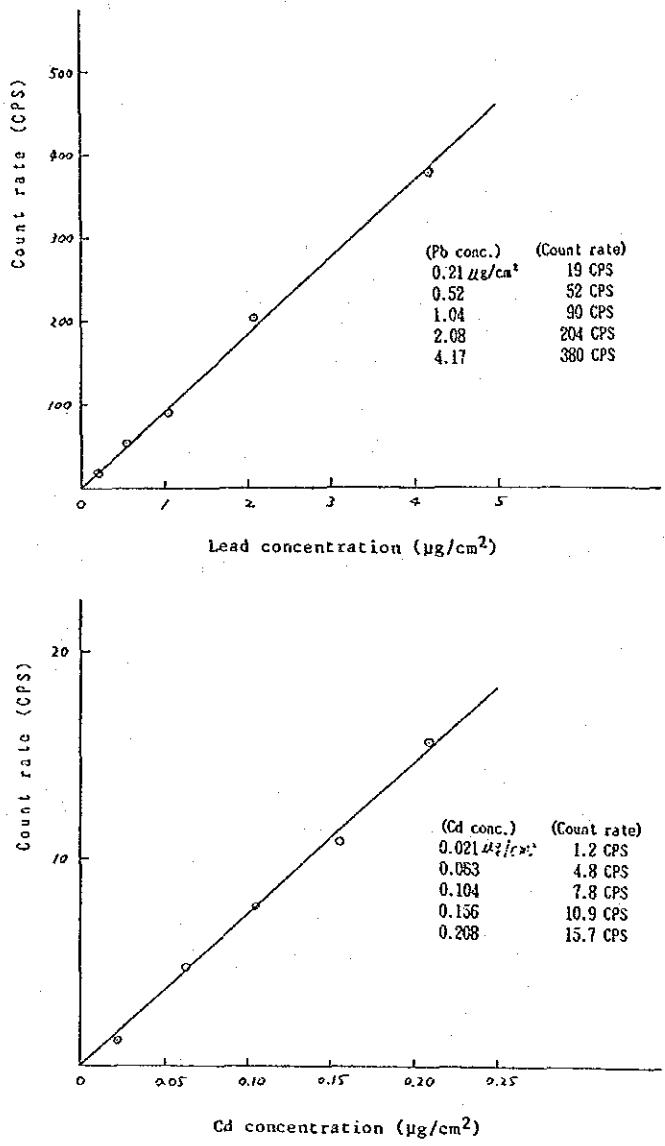


Fig. 5-21 Analytical line of lead and cadmium

(ii) Si, S (filtration method of powder)

Fly ash samples of known content of Si and S are fully ground in an 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 having varying amounts of powder are produced as the standard samples for developing the analytical lines. Fig. 5-22 shows the analytical line.

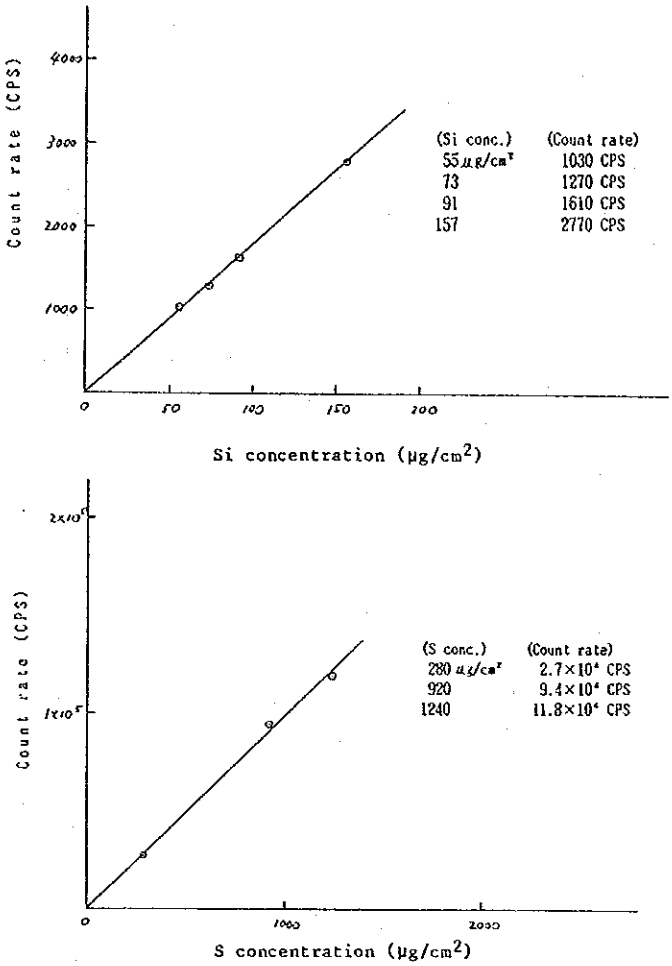


Fig. 5-22 Analytical line of silicon and sulpher

(3) Determination limit

The average detection limits of the elements in ambient particulate matter by X-ray fluorescence analysis are as follows. The blank values of filters are not usually obtainable.

Cd:0.01 $\mu g/cm^2$
Pb: 0.1 $\mu g/cm^2$
Si: 1 $\mu g/cm^2$
S: 1 $\mu g/cm^2$

(4) Calculation method of elements concentration

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

$$E_w = \frac{St_w}{St_{CPS}} \cdot S_{CPS} \quad \text{..... Equation (5-18)}$$

where;

E_w: Element weight contained in sample on unit area ($\mu g/cm^2$)

St_w: 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 air are calculated by the following Equation (5-19).

$$C_e = \frac{Ew \cdot Fa}{V} \times 1{,}000 \quad \text{..... Equation (5-19)}$$

where;

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

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

Fa: Total area of filter (cm^2)

V: Air flow rate (m^3)

(5) Spectrum of X-ray fluorescence

Fig. 5-23 shows an example spectrum of X-ray fluorescence about Road dust.

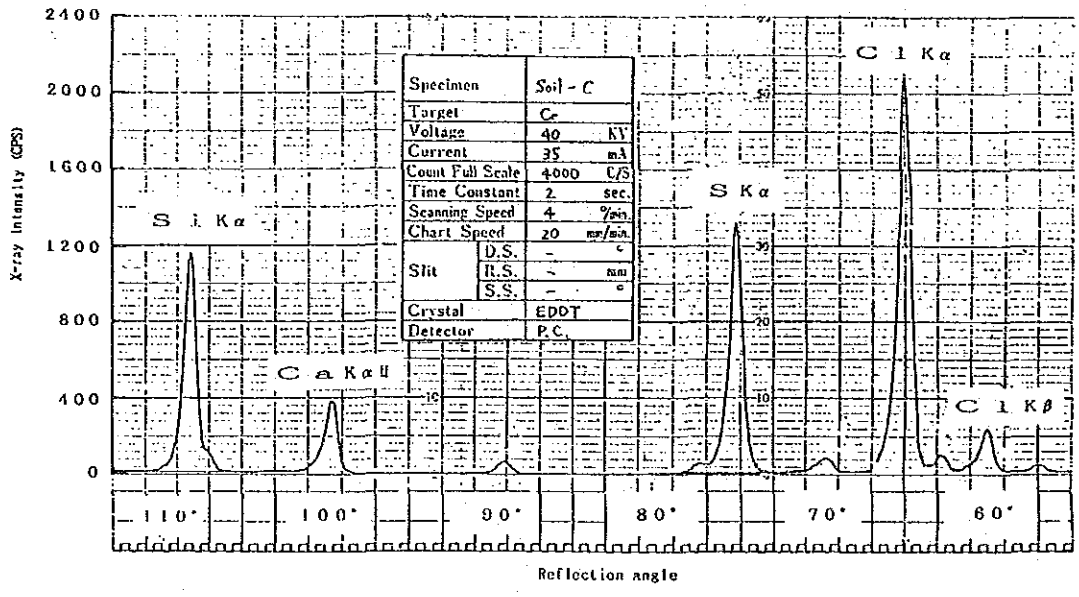


Fig. 5-23 An example of spectrum of X-ray fluorescence

(6) Results of measurement

Table 5-16 shows the results of element analysis done on particulate matter by X-ray fluorescence.

5.2.3 Analysis of Anion by Ion Chromatography

(1) Principle of analysis

Ion chromatography is a kind of column chromatography that uses an ion exchange resin as trapping phase.

A sample solution containing ions is introduced into a separation column together with an eluent, and ions are collected by ion exchange resin in the column. Due to eluent effect, each ion is separated selectively depending on its separation constant between ion and resin. Then they are led to a micro membrame suppressor where the eluent from separation column is removed or is neutralized. The target ions flows into an electric conductivity cell from the separation column one after another.

The instrument of ion chromatography consists of such components as eluent tank, solution transfer pump, sample injection valve, separation column, micro membrame suppressor and electric conductivity detector. Fig. 5-24 shows the outline of analysis by ion chromatography.

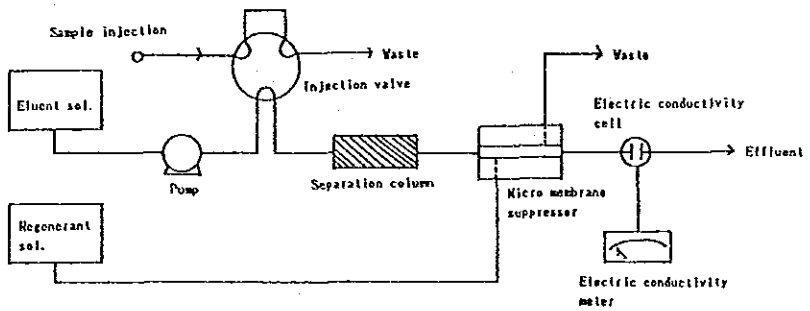


Fig. 5-24 Outline of ion chromatography

(2) Analyzing method

The filter was cut into 1/4 as shown in Fig. 5-9. A piece of the cut filter was dropped into the beaker containing 50 mℓ of deionized water and the solution was shaked about 90 minutes for extraction. The analysis was conducted by using Chromatography Model 10 of Dionex Co., Ltd.

① Analyzing conditions

The analysis has been carried out under the following conditions.

Separation column:	4 mm×50 mm + 4 mm×250 mm
Suppressor column:	Micro membrame suppressor
Sample volume:	100 $\mu\ell$
Eluent:	0.0025M Na_2CO_3/0.0022M $NaHCO_3$
Eluent flow rate:	138 mℓ/hr

② Development of analytical line

Standard stock solutions containing 1000 mg/ℓ each of chloride ion, nitrate ion and sulfate ion were prepared. This standard stock solution was adequately diluted prior to application for the preparation of analytical line. These solutions were flown into the separation column under the same conditions as applied to the sample solution, and analytical line was developed. Fig. 5-25 shows analytical line of Cl^-, NO_3^- and SO_4^{2-}.

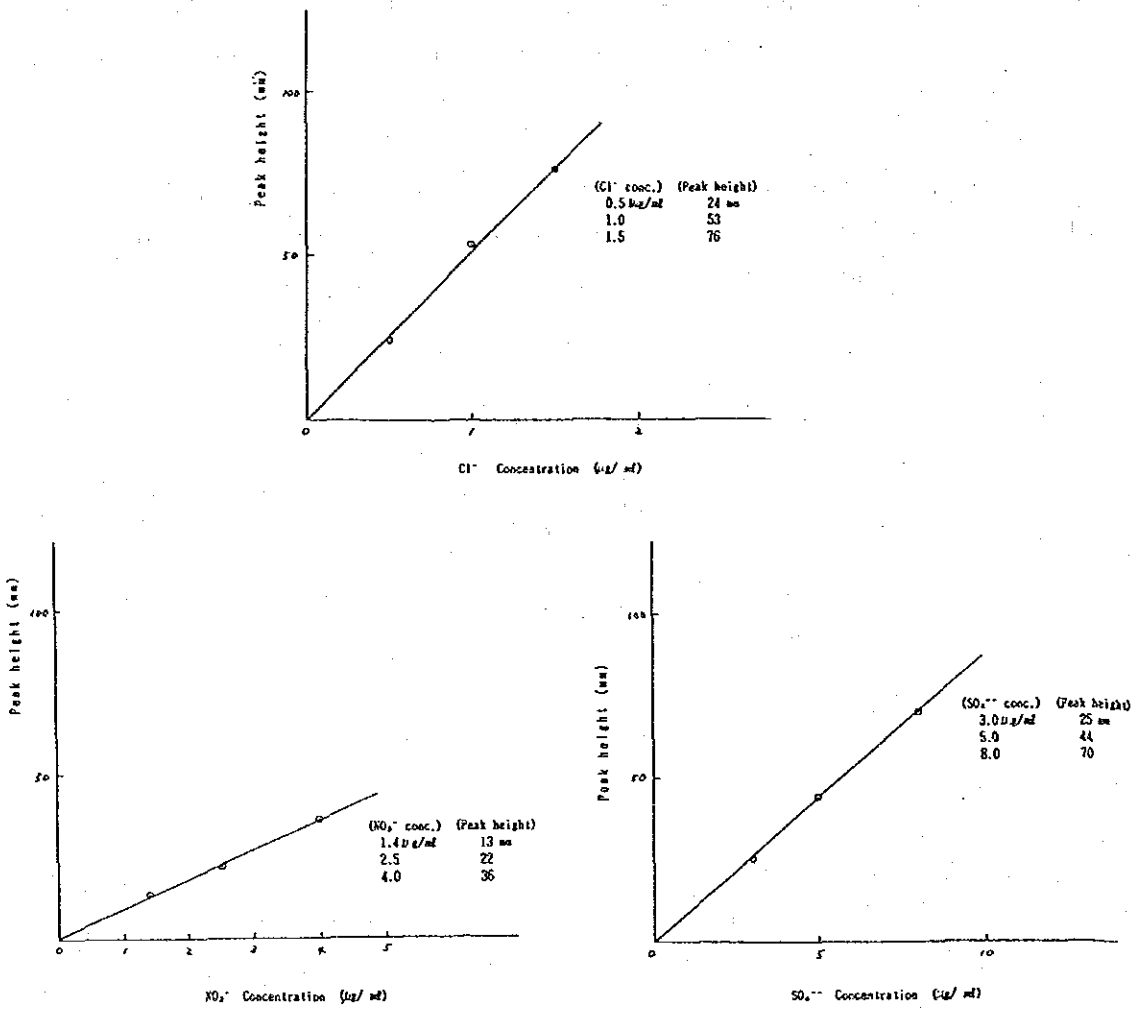


Fig. 5-25 Analytical lines of Cl^-, NO_3^- and SO_4^{2-}

(3) Determination limit and blank value of filter

The full scale of electric conductivity in this analysis is 30 μS/cm. The limits of determination and tare value of the filters are shown in Table 5-18.

Table 5-18 Determination limit and blank value of filter

Analyzed item	Determination limit ($\mu g/m\ell$)	Tare value of filter (ng/cm^2)		
		Polyethylene sheet	Polyethylene sheet + back up filter	Polyfluarocarbon filter
Cl^-	0.1	100	40	1000
NO_3^-	0.1	0	0	0
SO_4^{2-}	0.1	300	0	0

(4) Calculation method of anion concentration

The anion concentration of sample is calculated as follows;

(a) Ion concentration of analyzed solution

$$C_{sol} = C_{std} \cdot \frac{H_{sol}}{H_{std}} \quad \text{..... Equation (5-20)}$$

where;

C_{sol}: Ion concentration of analyzed solution ($\mu g/m\ell$)

C_{std}: Ion concentration of standard solution ($\mu g/m\ell$)

H_{sol}: Peak height of analyzed solution (mm)

H_{std}: Peak height of standard solution (mm)

(b) Anion concentration in the ambient air

$$C_I = \frac{C_{sol} \cdot V_L \cdot Sa}{Fa \cdot V} \quad \text{..... Equation (5-21)}$$

where;

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

C_{sol}: Ion concentration of analyzed solution ($\mu g/m\ell$)

V_L: Extracted solution volume ($m\ell$)

Sa: Total area of filter (cm^2)

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

V: Air aspiration flow rate (m^3)

(5) Ion Chromatogram

Fig. 5-26 shows the typical example of ion chromatogram (MS1, Coarse particle). Abscissa is the time after sample injection, and ordinate represents peak height. The peak height used for calculation of concentration is the height from the base-line connected flat part around the peak.

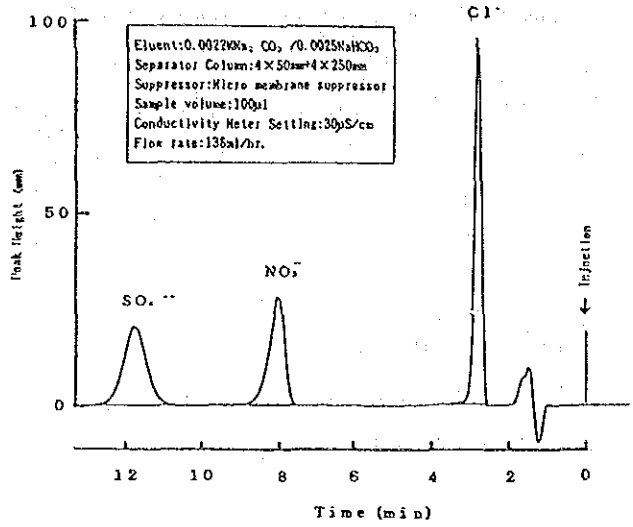


Fig. 5-26 An example of ion chromatogram

(6) Results of measurement

The anion concentration in the particulate matter measured by ion chromatography is shown in Table 5-16.

5.2.4 Analysis of Cation (Ca^{2+}, Mg^{2+}) by Atomic Absorption Spectrometry

(1) Principle of analysis

When a light beam of a specific wave length passes through the vapor of element, the atom in the ground state absorbs this light. Atomic absorption spectrophotometry is an analytical method based on this phenomenon. A sample solution containing a metal ion is introduced into flame, where the solution vaporizes and the metal atom contained in the solution changes into atmoic state by heat of the flame. The light beam emitted from a hollow cathode lamp is made to pass this vapor and its absorbance is measured. The concentration of the metal element can be calculated from decrease of the absorbance.

(2) Analyzing method

The solution sample which is described in (2) of 5.2.3 is used for analysis. The analysis in this study was carried out by HITACHI 170-50A atomic absorption sectrometer.

① Analyzing conditions

The analyses were carried out under the following conditions

Analysis line: Ca^{2+}, 422.7 nm

Mg^{2+}, 285.2 nm

Flame: Acethylene-air

② Development of analytical line

Standard stock solutions containing each 1000 $\mu g/m\ell$ of calucium ion and Magnesium ion were prepared. This standard stock solutions were properly diluted before it is used as

standard solutions for the preparation of analytical lines. The solution was poured into instrument of atomic absorption spectrometry under the same conditions as applied to sample solution. Fig. 5-27 shows analytical line of Ca^{2+} and Mg^{2+}.

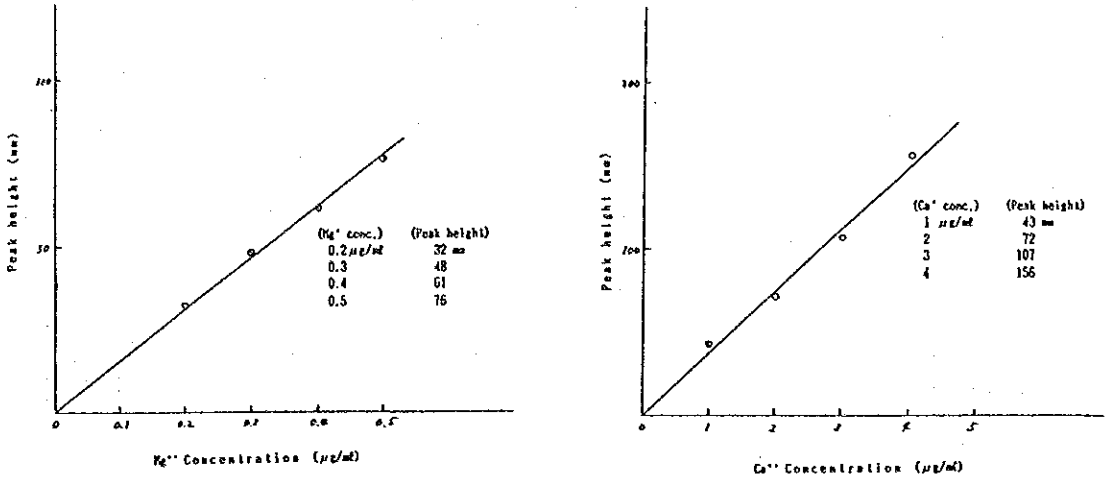


Fig. 5-27 Analytical line of Ca^{2+} and Mg^{2+}

(3) Determination limit and tare value of filter

The limit of determination and tare value of the filters are shown in Table 5-19.

Table 5-19 Determination limit and blanks value of filters

Analyzed item	Determination limit ($\mu g/m\ell$)	Tare value of filter (ng/cm^2)		
		Polyethylene sheet	Polyethylene sheet + back up filter	Polyfluarocarbon filter
Ca^{2+}	0.03	900	500	6000
Mg^{2+}	0.01	300	100	800

(4) Calculation method of Ca^{2+} and Mg^{2+} concentration

The cation (Ca^{2+}, Mg^{2+}) concentration of sample is calculated as follow;

① Ion concentration of analyzed solution

$$C_{sol} = C_{std} \cdot \frac{H_{sol}}{H_{std}} \quad \text{..... Equation (5-22)}$$

where;

C_{sol}: Ion concentration of analyzed solution ($\mu g/m\ell$)

C_{std}: Ion concentration of standard solution ($\mu g/m\ell$)

H_{sol}: Peak height of analyzed solution (mm)

H_{std}: Peak height of standard solution (mm)

② Cation concentration in the ambient air

$$C_I = \frac{C_{sol} \cdot V_L \cdot Sa}{Fa \cdot V} \quad \text{..... Equation (5-23)}$$

where;

C_I: Cation concentration in the ambient air ($\mu g/m^3$)
C_{sol}: Cation concentration of analyzed solution ($\mu g/m\ell$)
V_L: Extracted solution volume ($m\ell$)
Sa: Total area of filter (cm^2)
Fa: Filter area of analyzed sample (cm^2)
V: Air sucking flow rate (m^3)

(5) Results of analysis

The cation (Ca^{2+} and Mg^{2+}) concentration in the particulate matter obtained by atomic absorption spectrometry is shown in Table 5-16.

5.2.5 Analysis of Cation (Na^+ and K^+) by Flame Photometry

(1) Principle of analysis

The concentration of an element is determined by spraying the sample solution into flame and by measuring the emission intensity of the element at specific wave length. This method is effective in case of the analysis of alkali and alkali earth elements.

(2) Analyzing method

The sample solution which is described in (2) of 5.2.3 is used for analysis. The analysis was carried out by using HITACHI 170-50A flame photometer.

① Analysis conditions

The analysis were carried out under the following condition

Analysis line: Na^+, 589.3 nm
K^+, 766.6 nm
Flame: Acethylene-air

② Development of analytical line

Standard stock solutions containing each 1000 $\mu g/m\ell$ of sodium ion and potassium ion were prepared. This standard stock solution was properly diluted before it is used for the preparation of analytical lines. The solution was poured into the flame photometer under the same conditions as applied to sample solution and analytical line is drawn. Fig. 5-28 shows analytical line of Na^+ and K^+.

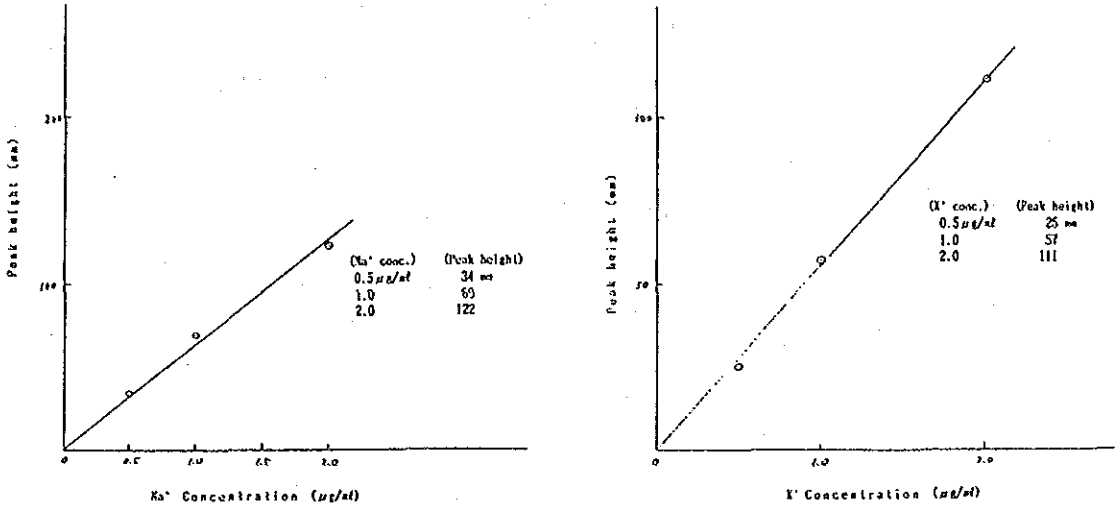


Fig. 5-28 Analytical line of Na^+ and K^+

(3) Determination limit and blank value of filter

The limit of determination and tare value of the filters are shown in Table 5-20.

Table 5-20 Determination limit and blank value of filter

Analyzed item	Determination limit ($\mu g/m\ell$)	Tare value of filter (ng/cm^2)		
		Polyethylene sheet	Polyethylene sheet + back up filter	Polyfluarocarbon filter
Na^+	0.02	200	200	1500
K^+	0.02	100	80	300

(4) Calcuation method of Na^+ and K^+ concentration

The calculation method for ion concentration of the analyzed solution and cation concentration in the ambient air are the same as those applied to cation by atomic absorption spectrometry.

(5) Results of analysis

The concentration of cation (Na^+ and K^+) in the particulate matter measured by flame photometry is shown in Table 5-16.

5.2.6 Analysis of Cation (NH_4^+) by Spectrophotometry (Method of indephenol)

(1) Principle of analysis

Ammonium ion in a sample solution is made to react with phenol in the presence of sodium hypochlorite and the absorbance of developed color of indephenol is measured by spectrophotometry.

(2) Analyzing method

A 5-mℓ sample solution described in (2) of 4.3 was transferred into a stoppered test tube, and

25 mℓ of phenol-sodium nitroprusside solution was added. After shaking, 2.5 mℓ of sodium hypochlorite solution was added, and the solution was gently mixed. The solution was kept at 30°C for 2 hr to wait color development. This solution was used for analysis. The analysis was carried out by using SHIMAZU UV-240 spectrophotometer. Analysis line is 640 nm.

Preparation method for reagents is as follows:

① Phenol-sodium nitroprusside solution

Dissolve 5 g phenol and 25 mg sodium nitroprusside in distilled water and dulite up to 500 mℓ.

② Sodium hypochloride solution

Dissolve 15 g NaOH in ammonia-free water, add 100 mℓ sodium hypochloride solution containing 3 to 10% Cl^- and dulite up to 1000 mℓ.

Developed analytical line is as follows:

Standard stock solution containing 100 μg/mℓ of ammonium ion is prepared. This standard solution is properly diluted before it is used for the preparation of analytical line. Absorbance of the solution is measured with spectrophotometer under the same conditions as applied to those of sample solution. Fig. 5-29 shows analytical line of NH_4^+.

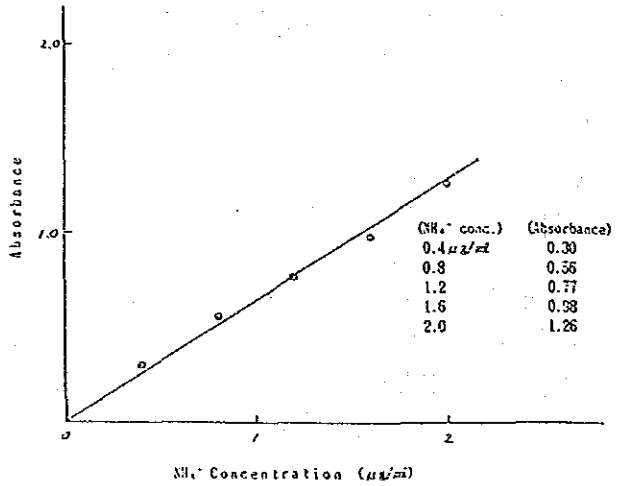


Fig. 5-29 Analytical line of NH_4^+

(3) Determination limit and blank value of filters

The limit of determination and blank value of the filters are shown in Table 5-21.

Table 5-21 Determination limit and tare value of filters

Analyzed item	Determination limit (μg/mℓ)	Tare value of filter (ng/cm²)		
		Polyethylene sheet	Polyethylene sheet + back up filter	Polyfluarocarbon filter
NH_4^+	0.02	0	0	0

(4) Calculation method of NH_4^+ concentration

Calcuation method for NH_4^+ concentration in analyzed solutions and concentration of NH_4 in the ambient air are the same as those for analysis of cation by atomic absorption spectrometry.

(5) Results of analysis

The concentration of NH_4^+ in the particulate matter measured by spectrophotometry is shown in Table 5-16.

5.2.7 Analysis of total carbon and non-volatile carbon contained in particulate mater by differential thermal analysis

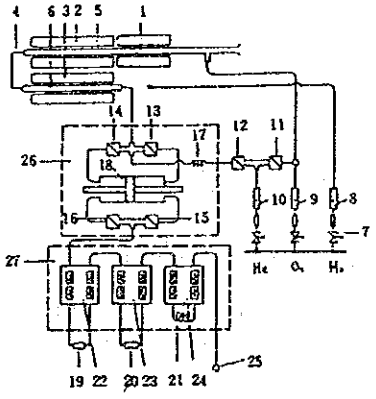
(1) Principle of analysis

Particulate matter sampled on the quartz-fiber filter is treated thermally and is classified into organic carbon and elemental carbon. After such carbons completely oxidized to CO_2, they are introduced into differential thermal conductivity meter which has a CO_2 absorbing tube. The heat generated by absorption of CO_2 is detected as the output signal of a differential electronic signal.

In this study the sample was heat-treated in nitrogen stream at 400°C and the volatile carbon was driven off to determine non-volatile carbon, and the sample not thermally treated was used for analysis of the total carbon.

The schematic of the instrument is shown in Fig. 5-30. It consists of the decomposition furnace, a constant flow pump to intake the combustion gas sample, and a detector.

Through the inlet part of the combustion tube filled with He carrier gas, the sample is inserted on a plutinum board. The sample is decomposed in the high temperature atmosphere and then completely oxidized in the presence of copper oxide catalyst. The gaseous components generated from the sample excluding CO_2, H_2O, and N_2 are removed by the oxidation furnace and reduction furnace. The gas mix of CO_2, H_2O, N_2 and He are then led to the differential thermal conductivity meter which has the H_2O and CO_2 absorbing tubes for. The concentrations of C, N, and H are evaluated in term of differential 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. 5-30 Outline of carbon analyzing instrument

(2) Analyzing methods

As shown in Fig. 5-9, the quartz-fiber filter was cut into circle pieces in 1 cm diameter (2 pcs.) as samples for analysis. For the analysis of total carbon, no pretreatment was required, but for the analysis of non-volatile carbon, the sample pieces were pretreated (at 400°C in nitrogen stream) for 4 minutes as shown in Fig. 5-31, and the volatile carbon compounds were driven off prior to analysis.

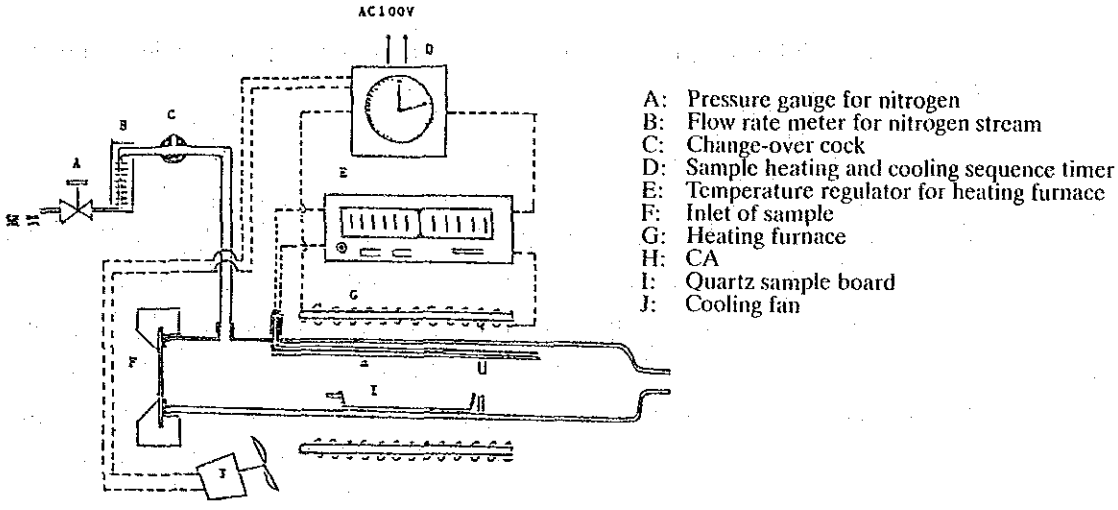


Fig. 5-31 Outline of pretreatment facility for analysis of elemental carbon

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 oxygen gas:	20 mℓ/min
Bridge current:	65 mA

② Drawing of analytical line

o-Nitroaniline was employed as a standard substance and by a micro-balance 0.1 to 2.5 mg was weighed as sample. And the sample was also analyzed under the same conditions and analytical line was developed by measuring the volume of carbon contained. The analytical line is shown in Fig. 5-32.

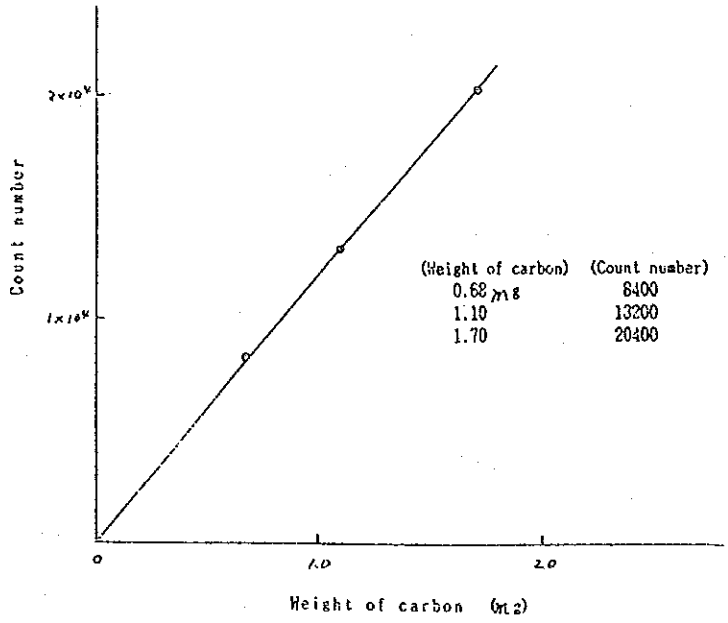


Fig. 5-32 Analytical line of carbon

(3) Limit of determination and tare value of filter

The limit of determination applied to analysis of ambient particulate matter by DTA is shown in Table 5-22, and the tare value of the filter is also shown in the same table.

Table 5-22 Limit of determination and blank value of filter

Item	Limit of determination	Filter blank value (quartz-fiber filter)
Total carbon	5 μg	38
Non-volatile carbon	5 μg	9

* Remarks: μg for 2 pieces filter of 1 cmϕ

(4) Calculation methods of carbon concentration

Weight of carbon on the filter is calculated from count number of differential thermal conductivity meter by the following Equation 5-24.

$$Cw = \left(\frac{Stw}{St_{count}} \cdot S_{count} \right) - Fbw \quad \text{..... Equation (5-24)}$$

where;

Cw: Weight of carbon in analyzed sample (mg)

Stw: Weight of carbon in standard sample (mg)

St_{count}: Count number of standard sample

S_{count}: Count number of analyzed sample

Fbw: Blank value of filter (mg)

Concentration of carbon in the ambient air is calculated by the following Equation 5-25.

$$Cc = \frac{Cw \cdot Fa}{V \cdot Sa} \quad \text{..... Equation (5-25)}$$

where;

Cc: Concentration of carbon in the ambient air (mg/m^3)
Cw: Weight of carbon in analyzed sample (mg)
V: Air flow rate (m^3)
Fa: Total area of filter (cm^2)
Sa: Filter area of analyzed sample (cm^2)

(5) Results of analysis

The results of analysis of carbon concentration in the ambient air by DTA are shown in Table 5-16. In the table, the volatile carbon is represented by organic carbon, and non-volatile carbon is represented by elemental carbon.

5.3 Analysis of Chemical Components in Soil, Road Dust and Fuel Gasoline

Two typical types of ground soil and one type of road dust in Samut Praharn Industrial District have been sampled by ONEB and elements, anion, cation and carbon content of the samples have been analyzed by INAA, XRF, IC, AAS, FP, SP and DTA. The location of the sampling points are shown in Fig. 5-33.

As for gasoline, two types of fuel gasolines (Regular and Premium) commonly used in Thailand described in Chapter 5 were sampled and their elements were analyzed by INAA and XRF.

The method of analysis for soil, road dust and fuel gasoline are almost identical to one previously applied to particulate matter in a ambient air, but some steps of pretreatment are different.

5.3.1 Soil and road dust

The sample of soil and road dust were weather dried and impurities such as small stones were eliminated. After ground with a gate mortar, the sample were used as sample for analysis. The weighing of the samples was carried out after desiccation for several days with silicagel. The specified volume of the samples applied to the analysis are shown as follows.

(1) INAA

About 15 mg of the samples for short term irradiation and about 30 mg for long term irradiation were sealed in double layer polyethylene bags of 5×7 cm respectively.

(2) XRF

About 100 mg of the samples were equally distributed over membrane filters.

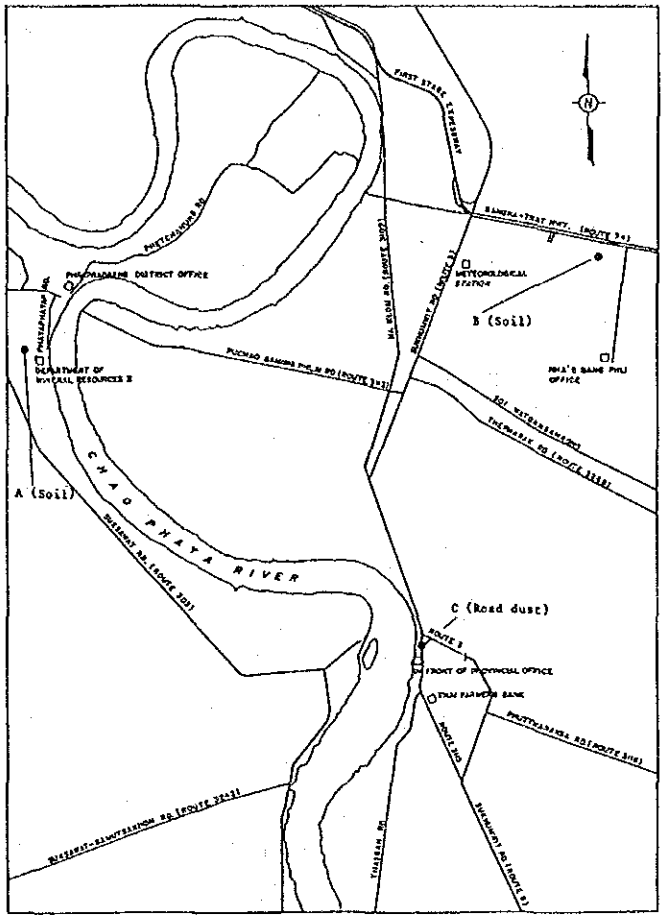


Fig. 5-33 Location of the sampling points for soil and road dust

(3) IC, AAS, FP and SP

Adding 100 mℓ of eluent in 1 g of the samples and shaking about 90 minutes for extraction, the sample solution are prepared after filteration of impurities.

(4) Differential Thermal Analysis

The samples (2~5 mg) were weighted on a platinum board and they were used for analysis of total carbon and non-volative carbon.

5.3.2 Fuel gasoline

(1) INAA

About each 50 mℓ of sample for short term and long term irradiation was sealed in polyethylene beakers. The sample for short term irradiation was irradiated by thermal neutron beam for 5 minutes and the sample for long term irradiation was irradiated with thermal neutron for 5 hours. The thermal neutron flux was 5×10^{11} $cm^{-2}.s^{-1}$. After irradiation, the sample was transferred into a new polyethylene beaker, and then Gamma ray was measured.

(2) XRF

A 0.6-mℓ gasoline sample was titrated on a 47 mmϕ membrane filter made by nitrocellulose, and was then dried up.

5.3.3 Results of analysis

The results of analysis of chemical components in soil, road dust and fuel gasoline are shown in Table 5-23.

Table 5-23 (1) Results of analysis of soil and road dust components

Unit: ppm

Item \ Name of sample	A	B	C
INAA			
Short lived nuclides			
Al	45000(1)	66000(1)	50000(2)
Br	<30	<40	150(5)
Ca	<2000	2500(22)	26000(5)
Cl	<1000	2000(16)	7300(6)
Cu	<200	<300	<300
Mg	<4000	7600(28)	1200(18)
Mn	270(12)	460(2)	610(2)
Ti	3000(7)	2400(10)	2300(5)
V	41(5)	30(5)	46(4)
Long lived nuclides (a)			
As	7.7(8)	19(5)	51(2)
K	21000(6)	42000(5)	21000(7)
La	22(5)	64(3)	22(5)
Na	4900(1)	8100(1)	7200(1)
Sb	2.8(10)	<0.7	3.4(9)
Sm	5.0(1)	14(1)	4.7(1)
W	8.6(15)	3.2(42)	4.1(24)
Long lived nuclides (b)			
Ag	<3	<3	<3
Ba	380(17)	410(19)	360(17)
Ce	54(4)	150(2)	47(3)
Co	6.9(13)	3.8(22)	6.3(12)
Cr	31(8)	24(13)	33(8)
Cs	3.6(12)	8.6(7)	3.8(10)
Fe	12000(5)	12000(5)	18000(4)
Hf	2.0(14)	14(3)	5.9(5)
Lu	0.21(20)	0.58(12)	0.69(7)
Ni	<60	<60	<50
Sc	4.5(2)	4.4(2)	4.5(2)
Se	6.4(24)	12(20)	6.1(26)
Th	12(2)	55(1)	11(2)
Zn	<30	<40	130(15)
XRF			
Cd	1.2	1.8	1.8
Pb	60	80	130
S	180	480	4700
Si	390000	320000	310000
IC, AAS, FP and SP			
Na^+	600	780	1500
K^+	410	790	360
Ca^{2+}	33	190	460
Mg^{2+}	55	98	160
NH_4^+	400	990	3400
NO_3^-	4	26	30
SO_4^{2-}	58	240	2000
Pyrolysis			
T - C	1900	6600	17500
E - C	1400	5100	16900
O - C	500	1500	600

Remarks: Figures in parenthesis are analytical error (%)

Table 5-23 (2) Results of analysis of fuel gasoline

Unit: ppb

Item	Premium	Regular	Gemetrical average *
Al	<200	<200	<200
Br	86000(7)	82000(7)	84000(7)
Ca	<4000	<3000	<4000
Cl	190000(4)	190000(4)	190000(4)
Cu	<1000	<700	<800
Mg	<10000	<10000	<10000
Mn	<5	<5	<5
Ti	<5000	<5000	<5000
V	<10	<10	<10
As	<40	<40	<40
K	<10000	<10000	<10000
La	<20	<20	<20
Na	<200	<200	<200
Sb	<20	<20	<20
Sm	<2	<2	<2
W	<50	<50	<50
Ag	<0.4	<0.2	<0.3
Ba	<40	<40	<40
Ce	<0.8	<0.9	<0.8
Co	<0.2	<0.2	<0.2
Cr	<1	<1	<1
Cs	<0.06	<0.05	<0.05
Fe	<50	<40	<50
Hf	<0.09	<0.09	<0.09
Lu	<0.08	<0.09	<0.08
Ni	<10	<7	<8
Sc	<0.01	<0.01	<0.01
Se	<0.7	<0.7	<0.7
Th	<0.06	<0.06	<0.06
Zn	39(20)	8.0(47)	22(34)
Cd	<200	<200	<200
Pb	15000	7000	11000
S	12000	4000	7600
Si	<20	<20	<20

Remarks: Figures in parenthesis are analytical error (%)
* : Premium: Regular = 45.6 : 54.4 (%)

5.4 Analysis of sulfur content in fuels for normal uses in Thailand

Ten samples of fuels as shown in Table 5-24 were brought back to Japan and were subject to analysis to determine sulfur content in fuels. Those fuels are commercially available and sold in Thailand for normal commercial applications. The Japanese Industrial Standard, JIS K2541, was applied to the analysis of sulfur content in the fuels. Results are shown in Table 5-24.

Details of analytical procedure are shown in the Appendix.

Table 5-24 Results of sulfur content in fuels

Sample No.	Kind of fuels	Sulfur content (%)	Testing method
1	Fuel oil No. 1 (Shell)	1.98	1
2	Fuel oil No. 4 (Shell)	2.58	1
3	Fuel oil No. 5 (PTT)	3.04	1
4	Fuel oil No. 6 (Shell)	1.88	1
5	Diesel oil (Shell)	0.65	1
6	Diesel oil (Esso)	0.46	1
7	Gasoline Regular (Shell)	47 ppm	2
8	Gasoline Regular (Esso)	<1 ppm	3
9	Gasoline Premium (Shell)	316 ppm	2
10	Gasoline Premium (Esso)	<1 ppm	3

1: Bomb-combustion, gravimetry
2: Micro-coulometry
3: H_2-O_2 flame combustion, dimethylsulfonazo III - Volumetry

PART III ANALYTICAL STUDY ON CURRENT ATMOSPHERIC POLLUTANT CONCENTRATIONS AND METEOROLOGICAL VARIABLES

The pollutant concentration and meteorological data monitored were subject to analytical study such that the reporter can develop a better picture about the pollution status of the Samut Prakarn industrial district. The obtained data were grouped into two parts depending on the survey period (short term and long term). The former field survey was carried out during the periods of January, March and July in 1988 to measure the distribution and concentration of total particulate matter, while the latter continued for one year throughout 1988 to monitor ambient pollutant concentrations and meteorological variables.

1. Analysis of Long-Term Field Survey Data

In the long-term field survey, the hourly values of wind direction, wind velocity, atmospheric turbulence, solar radiation, net radiation, SO_2, NO_2, NO_x and SPM by β-ray dust meter were measured for a period of one year. These hourly data were used to make meteorological analysis, environmental concentration analysis, and analysis of the correlation between meteorological factors and the environmental concentrations. The measurement period was from January 17, 1988 to January 16, 1989, and the monthly average value for January was calculated as the mean of the same month in both 1988 and 1989.

1.1 Meteorological Analysis

Pollutants emitted from factories are transported and dispersed by wind. Accordingly, meteorological conditions, such as wind direction, wind velocity and atmospheric turbulence will have large effects on the environmental concentration, together with the emitted volume of pollutants. Therefore, analysis of meteorological data in the addressed area is essential not only for simply determining meteorological conditions but also for predicting the future environmental concentration. Accordingly, in this survey, analysis of meteorological factors was made by using the measured data of wind direction, wind velocity, atmospheric turbulence, solar radiation and net radiation, which were obtained in the survey of the target area.

1.1.1 Seasonal and Hourly Classification

The predictive simulation applied to this survey was the "yearly average concentration prediction model", where predictions were made based on calculated hourly concentration values corresponding to each meteorological condition (combination of wind direction, wind velocity and atmospheric stability). Then, the yearly average concentrations calculated by taking the weight-averaging of such hourly values while the occurence frequency of meteorological conditions were taken into consideration. The approach thus cannot avoid some difficulty of reproducing the pollutant concentrations accurately for each meteorological condition because of restrictions existing in the diffusion model itself and the available volume of sourcing and meteorological data. To overcome such ambiguity, the reporter first made the statistical analyses on daily and seasonal changes of source activities, meteorological conditions and ambient concentrations (as shown in Fig. 1-1 and Fig. 1-2)

and then two time scales, hourly and seasonal, were selected to test the conformity of calculated concentrations with measured ones as shown in Table 1-1. In accordance, the study on meteorological variables has to be made with respect to same time scales.

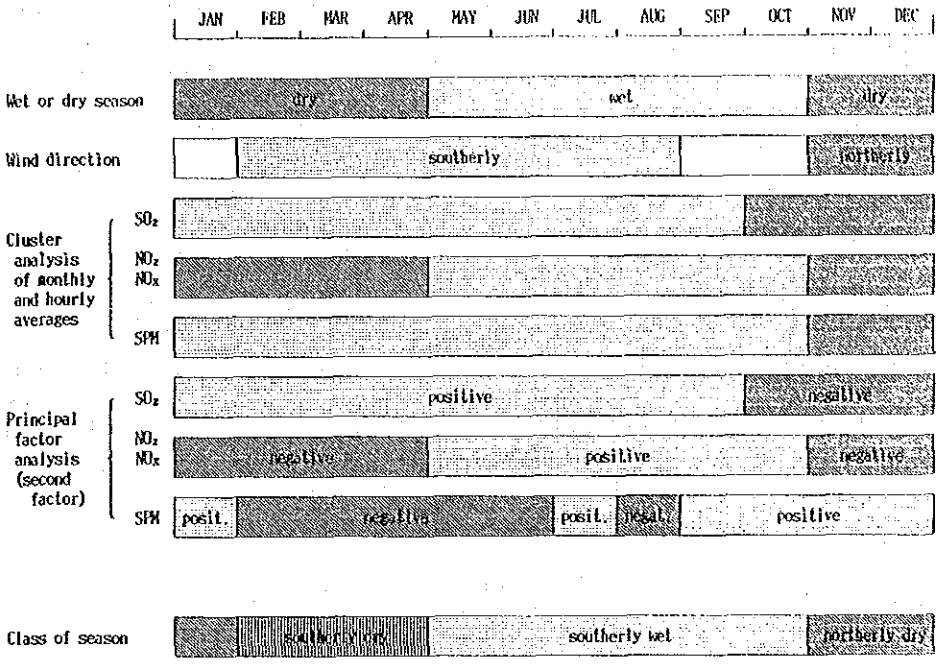


Fig. 1-1 Monthly Variations of Meteorological Conditions and Ambient Pollutant Concentration

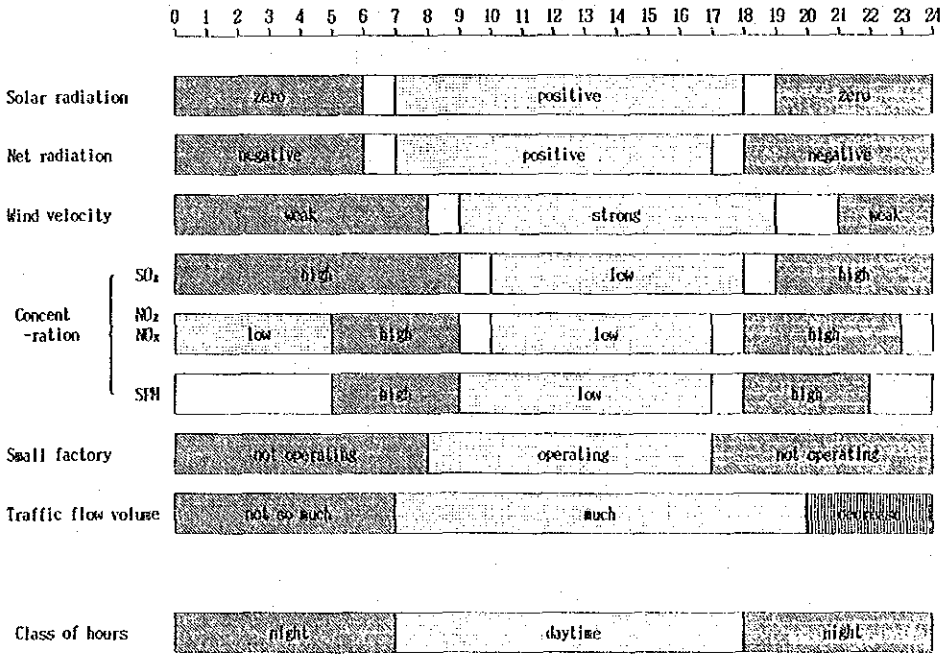


Fig. 1-2 Hourly Variations of Meteorological Conditions and Ambient Pollutant Concentration

Table 1-1 Seasonal and Hourly Classification

Season / Hours	Rainy May to Oct.	Dry Nov. to Jan.	Mid-term Feb. to Apr.
Daytime	7:00~17:59	7:00~17:59	7:00~17:59
Nighttime	18:00~ 6:59	18:00~ 6:59	18:00~ 6:59

1.1.2 Monthly and Hourly Average Wind Velocity

The monthly average and hourly average of wind velocity are shown in Fig. 1-3 and Fig. 1-4, respectively. Table 1-2 shows the daytime and nighttime averages of wind velocity for each observation site for three seasons.

When monitoring stations are compared, wind velocity changes in the descending order of MS1, MS2 and MS5, for both the monthly and hourly basis. With respect to monthly variations, although large differences are not seen throughout the year, the relatively strong wind in March is noteworthy. As for hourly variations, winds are strong in daytime and weak in nighttime. The trend is true for every monitoring station.

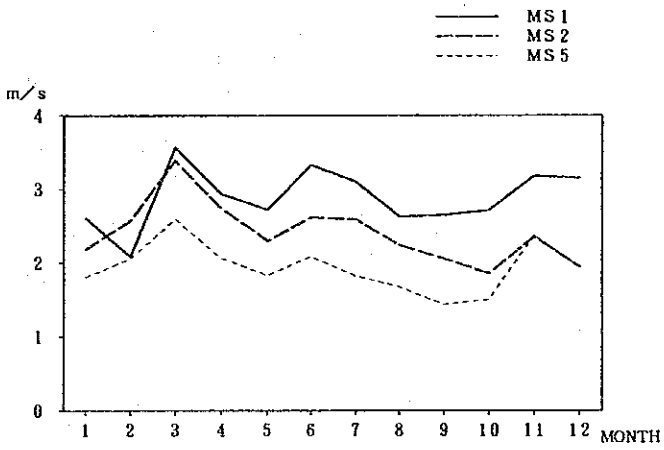


Fig. 1-3 Monthly Variations of Wind Velocity

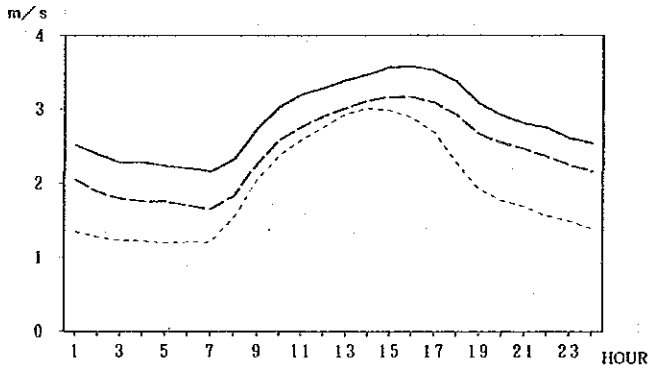


Fig. 1-4 Hourly Variations of Wind Velocity

Table 1-2 Average Wind Velocity for Each Season and Day and Night

Unit; m/s

Season	Rainy May to Oct.			Dry Nov. to Jan.			Mid-term Feb. to Apr.			Annual		
Hours	MS1	MS2	MS5	MS1	MS2	MS5	MS1	MS2	MS5	MS1	MS2	MS5
Daytime	3.2	2.8	2.3	3.4	2.5	2.8	3.0	3.2	2.9	3.2	2.8	2.5
Nighttime	2.3	1.9	1.3	2.6	1.8	1.4	2.7	2.7	1.7	2.5	2.1	1.4
All day	2.7	2.3	1.7	3.0	2.2	2.0	2.9	2.9	2.2	2.8	2.4	1.9

1.1.3 Occurance Frequency of Wind by Velocity Rank

The frequency distribution of wind velocity for a one year period is shown in Fig. 1-5, which shows that MS1 and MS2 have a gentle peak in the neighborhood of a 2 m/s wind velocity range while MS5 has a peak around 1 m/s, and the frequency is the highest between 1 to 5 m/s.

In formulating a model for meteorological analysis, wind velocity is classified into several wind velocity ranks. In doing so, it is thought necessary to take account of the appearance frequency distribution of wind velocity as well as the sensitivity of the diffusion calculating equation with respect to wind velocity. In this survey wind velocity has been classified into 6 ranks of 1) 0–0.4 m/s, 2) 0.5–0.9 m/s, 3) 1.0–1.9 m/s, 4) 2.0–2.9 m/s, 5) 3.0–4.9 m/s and 6) 5.0 m/s or more. The occurrence frequency of wind by velocity rank, as classified above, is shown in Table 1-3.

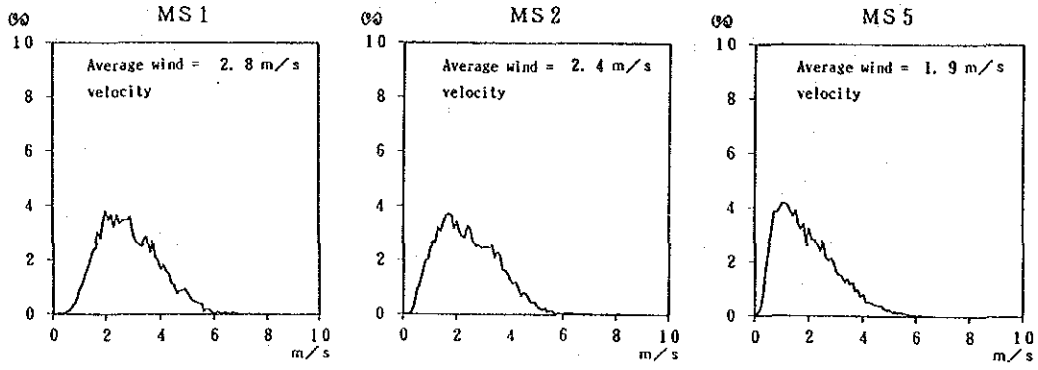


Fig. 1-5 Frequency Distribution of Wind Velocity

Table 1-3 Appearance Frequency of Wind by Velocity Rank

Wind Velocity Rank (m/s)	Appearance Frequency of Wind Velocity (%)		
	(MS1) ONEB STATION	(MS2) POWER PLANT	(MS5) H. & I. ESTATE
0–0.4	0.07	0.41	2.92
0.5–0.9	1.49	7.53	17.38
1.0–1.9	21.39	31.74	36.56
2.0–2.9	35.19	29.00	25.05
3.0–4.9	37.56	29.73	16.75
5.0–	4.31	1.60	1.34

1.1.4 Wind Rose

Annual wind rose and monthly wind rose at each monitoring station are shown in Fig. 1-6 and Fig. 1-7, respectively. Fig. 1-8 shows the wind rose of daytime and nighttime for each season.

With respect to annual wind rose, the most frequent wind directions are the S and SSE directions at MS1, the S direction at MS2 and the SSW direction at MS5, respectively, thereby indicating that winds of the S direction are dominant at every station. Furthermore, a difference in average wind velocity by wind direction can be hardly seen.

With respect to monthly wind rose, winds of the S direction are frequent during a period from January to August, and winds of the N to NE direction increase in velocity in November through December. These trends are seen at every station.

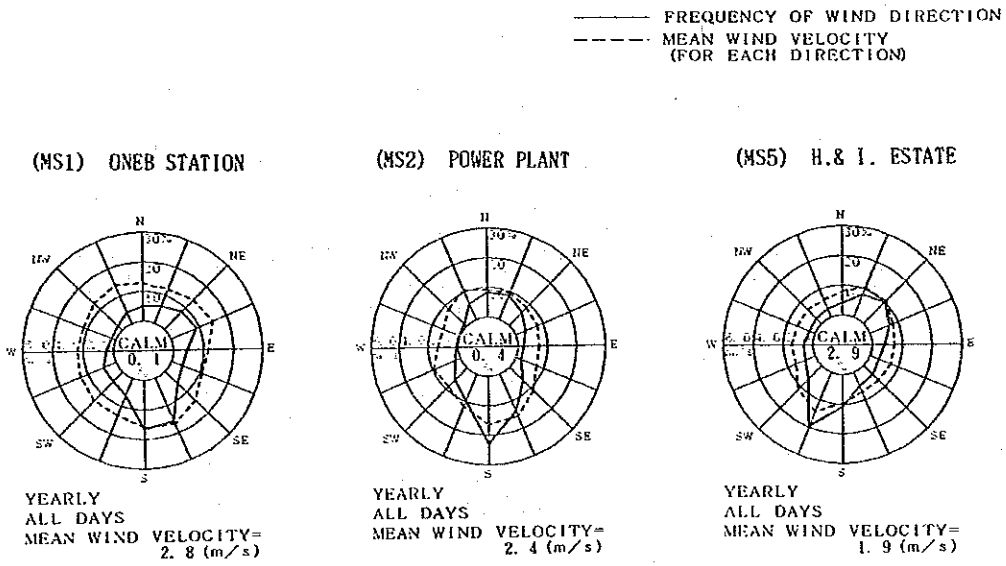


Fig. 1-6 Wind Rose at Each Monitoring Station (Annual)

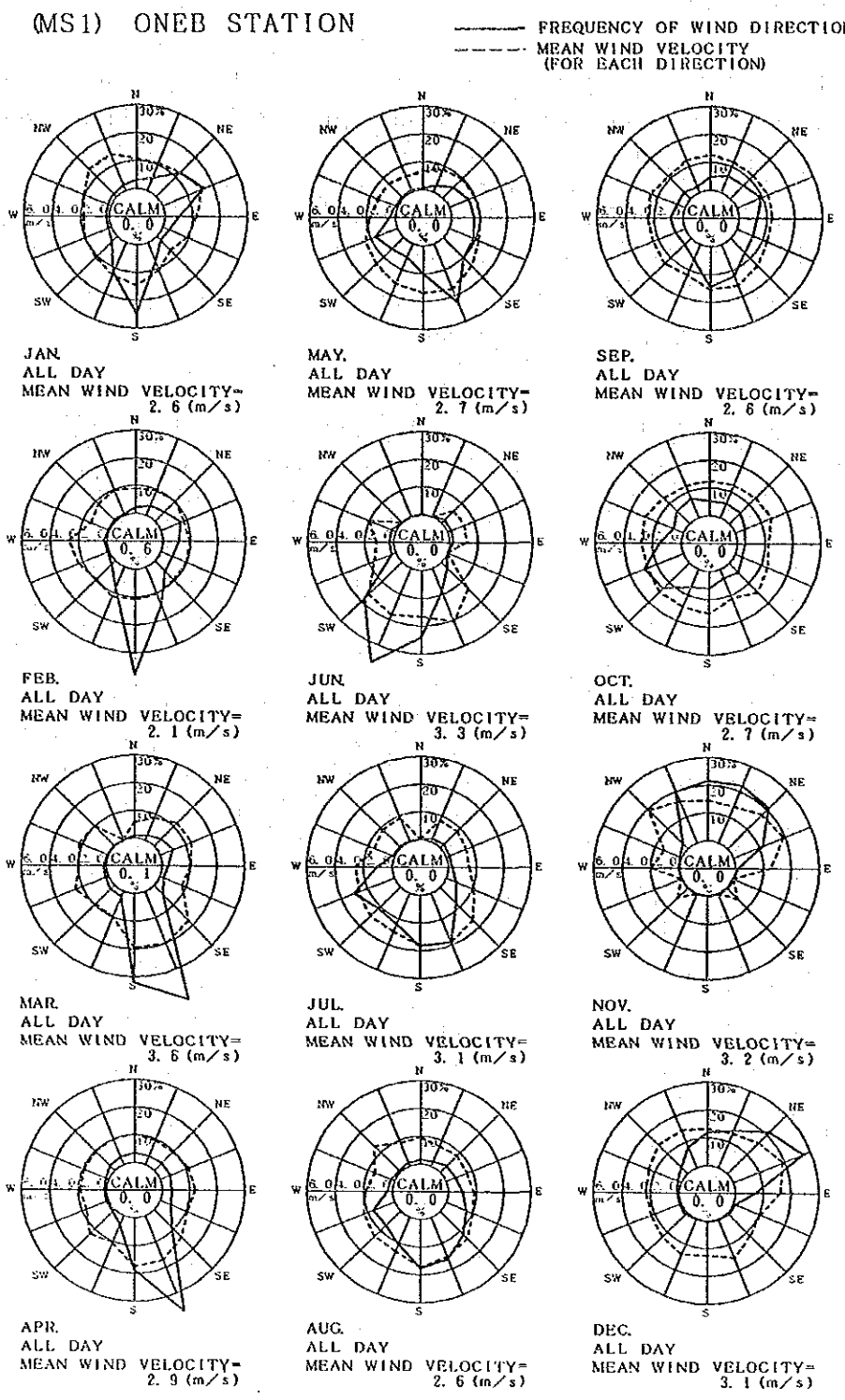


Fig. 1-7 (1) Monthly Wind Rose at Each Monitoring Station

(MS2) POWER PLANT

——— FREQUENCY OF WIND DIRECTION
– – – – – MEAN WIND VELOCITY (FOR EACH DIRECTION)

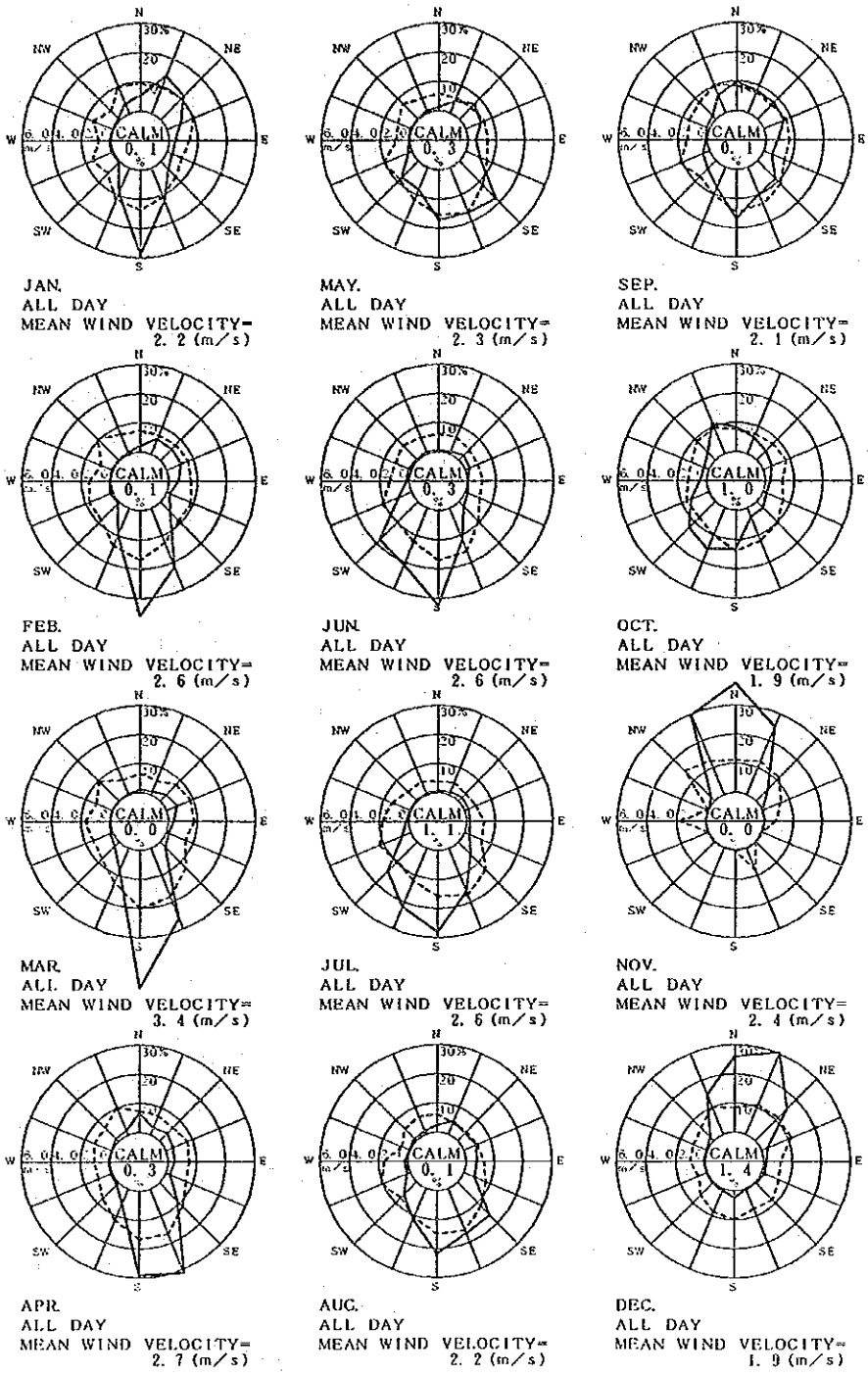


Fig. 1-7 (2) Monthly Wind Rose at Each Monitoring Station

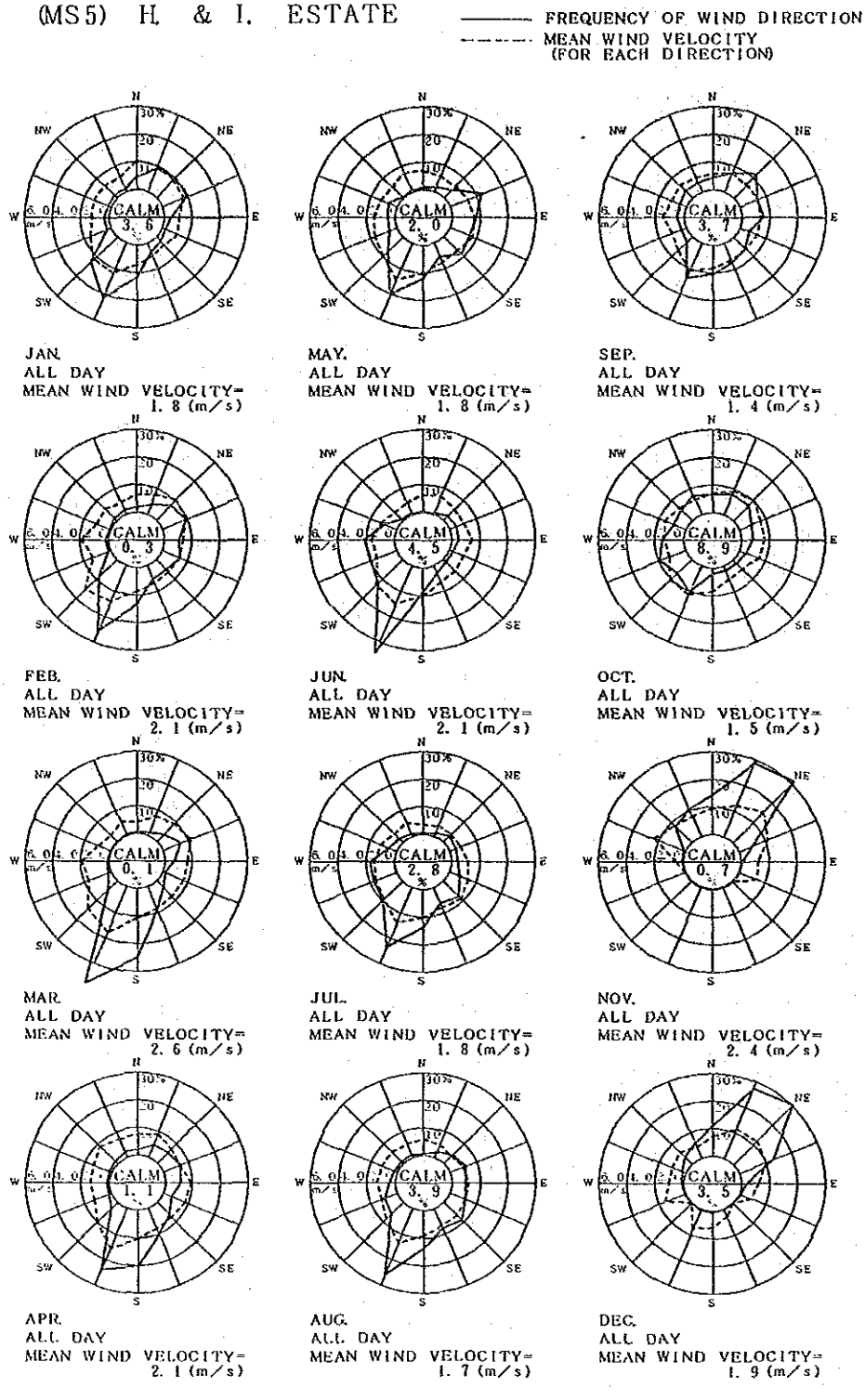


Fig. 1-7 (3) Monthly Wind Rose at Each Monitoring Station

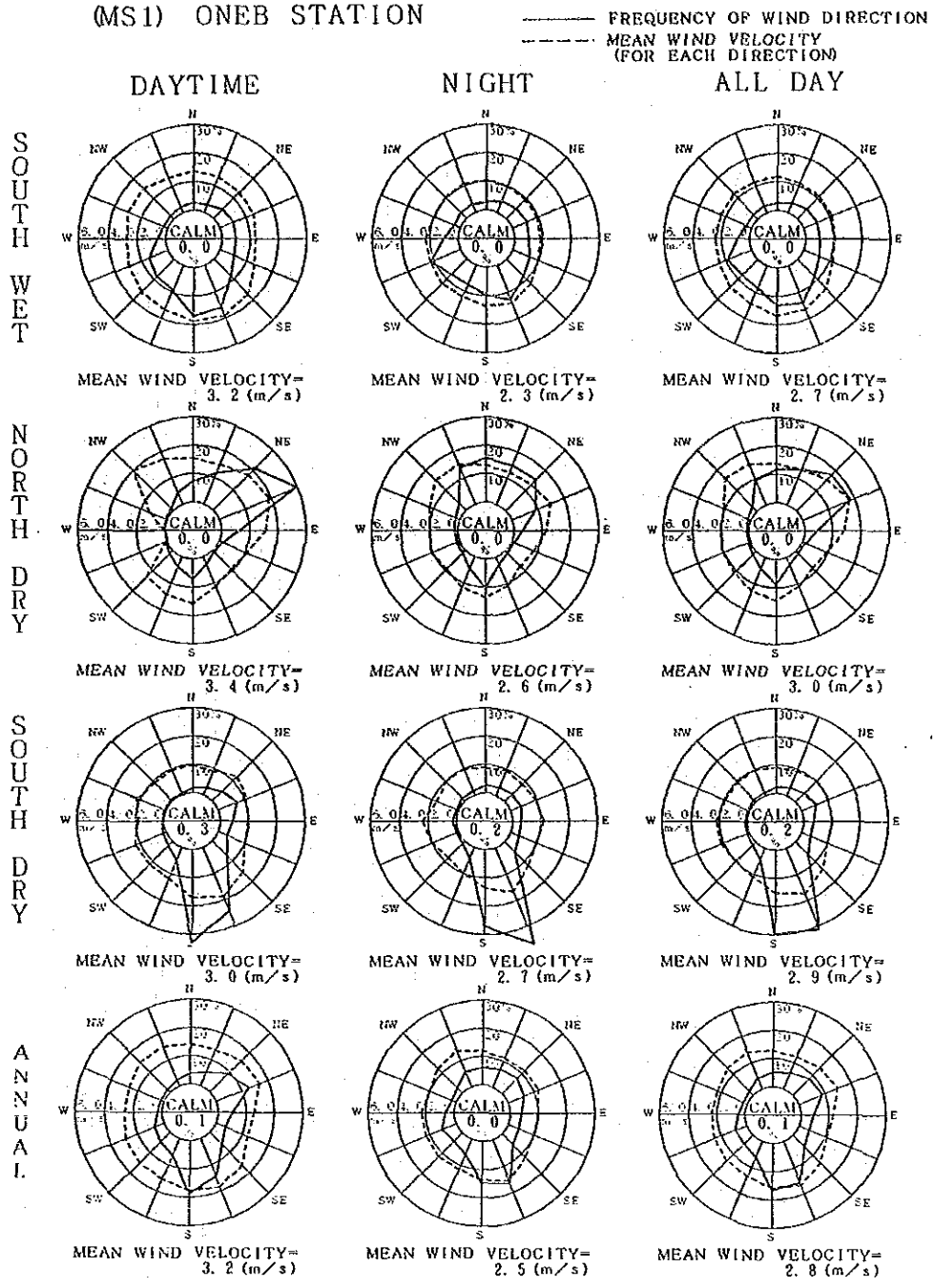


Fig. 1-8 (1) Wind Rose of Daytime and Nighttime for Each Season

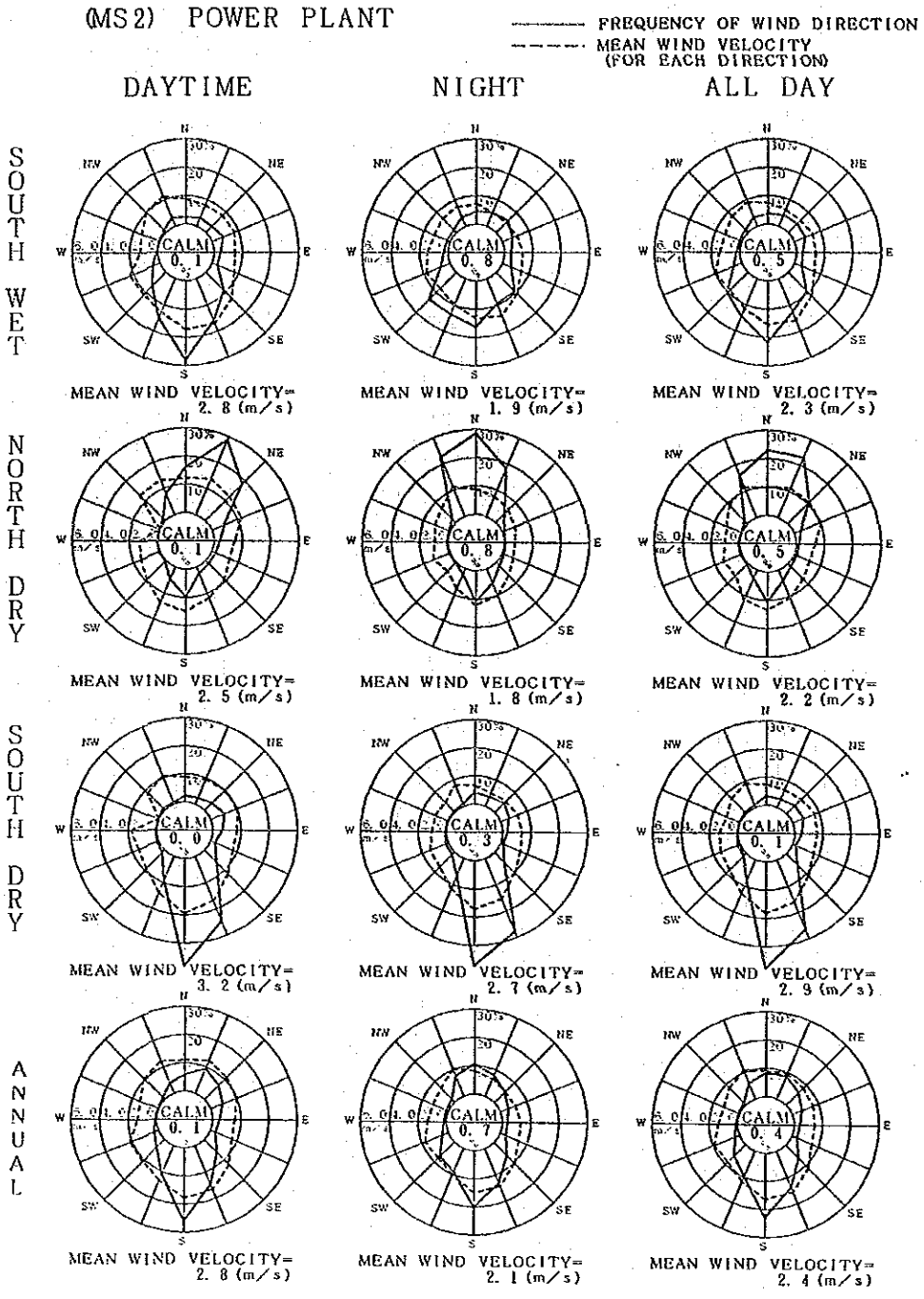


Fig. 1-8 (2) Wind Rose of Daytime and Nighttime for Each Season

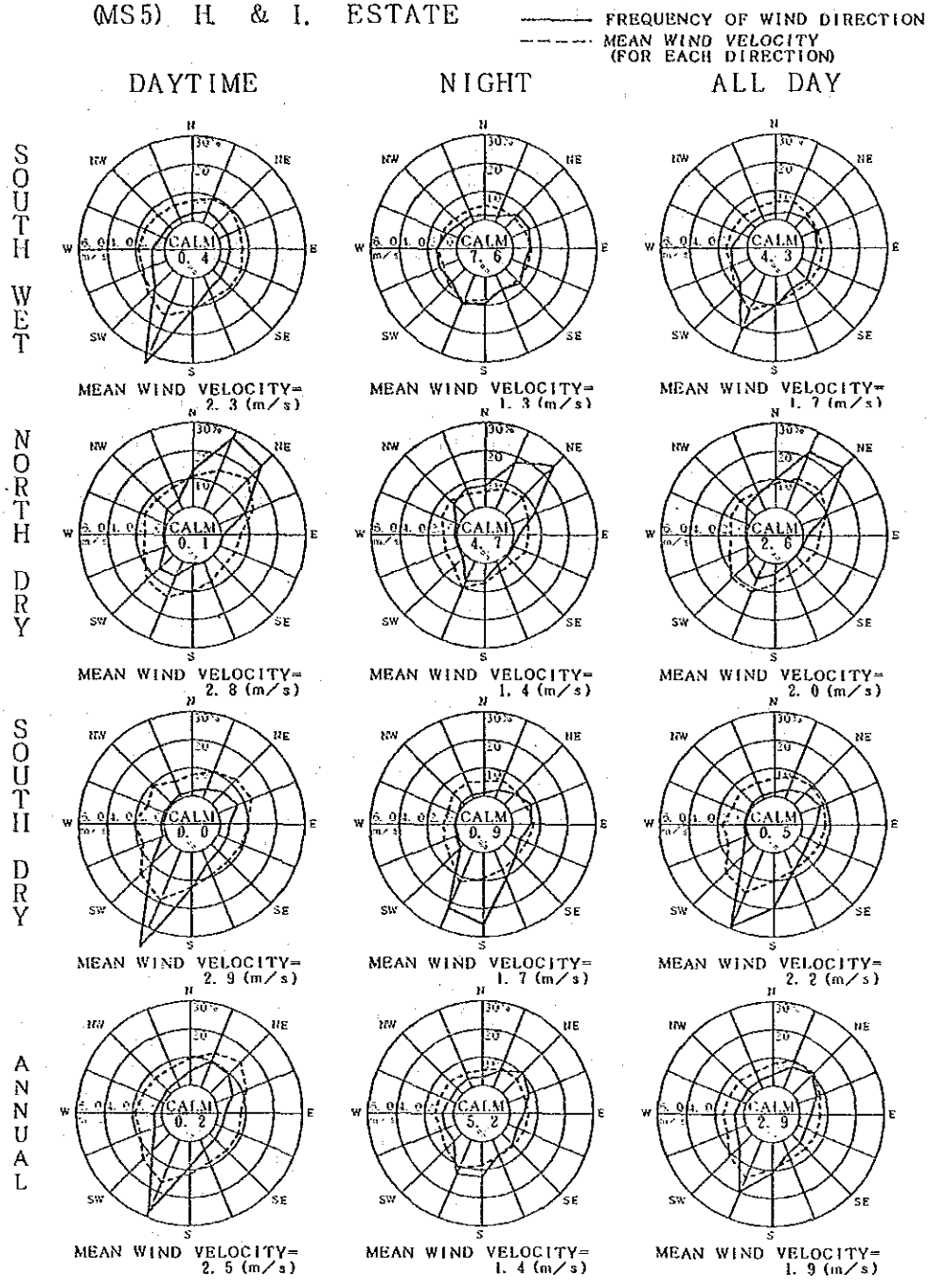


Fig. 1-8 (3) Wind Rose of Daytime and Nighttime for Each Season

1.1.5 Correlation Coefficient of Wind Direction and Wind Velocity Vectors

Based on the measurement data of hourly wind direction and velocity at each monitoring station, the degree of resemblance of wind among measurement points was examined.

As an index for the degree of resemblance of wind direction and velocity among measurement points, an approximate correlation coefficient, which is calculated by the following method, is frequently used.

The θ i, which is the angle between V_{Ai} and V_{Bi}, at time i (i = 1, 2 ... N) is obtained from the observed values V_{A1}, V_{A2}, ... V_{AN} of the wind vector at measurement point A and the wind vectors V_{B1}, V_{B2}, ... V_{BN} simultaneously measured at point B. From these, the correlation coefficients of the wind between measurement point A and B can be obtained by the following equation.

$$r(A, B) = \frac{\sum_i V_{Ai} V_{Bi} \, COS\theta_i}{\sum_i V_{Ai} V_{Bi}} \quad \cdots\cdots \quad (1\text{-}1)$$

Where, V_{Ai} and V_{Bi} are the wind velocity at time i at measurement point A and B, respectively.

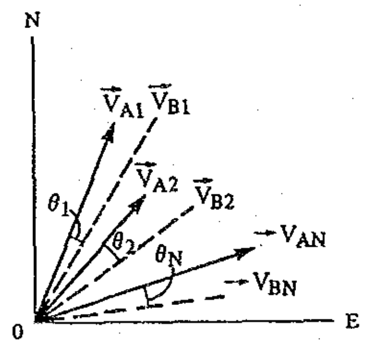


Fig. 1-9 Wind Vectors between Point A and B

Correlation coefficients of wind direction and wind velocity vectors between each measurement point obtained in the above manner are as shown in Table 1-4. In reviewing the table, correlation coefficients of yearly wind direction and wind velocity vectors are 0.909 between MS1 and MS2, 0.838 between MS2 and MS5, and 0.853 between MS1 and MS5, thereby indicating a significant correlation. Also, when correlation coefficients of monthly wind direction and wind velocity vectors are reviewed, most of the values found are 0.8 or more. Therefore, it is understood that meteorological conditions in the target area are nearly uniform. This may be due to a nearly flat configuration of the ground in the area.

Table 1-4 Correlation Coefficients of Wind Direction and Wind Velocity Vectors

	MS1 -MS2	MS2 -MS5	MS5 -MS1
Jan.	0.899	0.824	0.828
Feb.	0.925	0.826	0.848
Mar.	0.960	0.880	0.843
Apr.	0.950	0.826	0.846
May.	0.924	0.804	0.836
Jun.	0.953	0.855	0.924
Jul.	0.929	0.861	0.909
Aug.	0.904	0.814	0.849
Sep.	0.831	0.747	0.755
Oct.	0.856	0.756	0.812
Nov.	0.923	0.884	0.929
Dec.	0.818	0.850	0.865
Yearly	0.909	0.838	0.853

1.1.6 Monthly and Hourly Solar Radiation and Net Radiation

Monthly solar radiation and net radiation flux are shown in Fig. 1-10, and hourly solar radiation and net radiation flux in Fig. 1-11. When hourly variations are reviewed, it is found that both solar radiation and net radiation flux increase from around 07:00 hour, reache the peak value at around 13:00, and thereafter decline until around 19:00. Furthermore, monthly solar radiation and net radiation flux do not show any significant variation throughout the year.

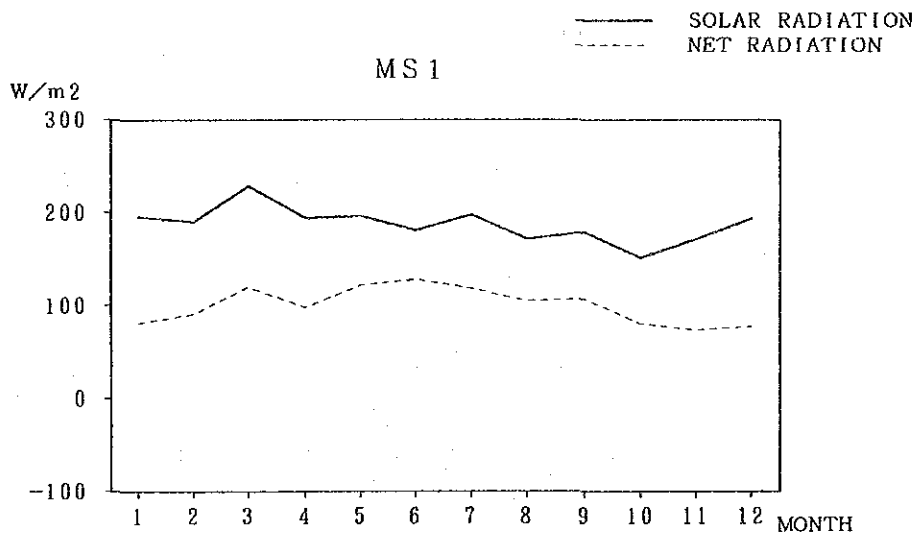


Fig. 1-10 Monthly Variations of Solar Radiation and Net Radiation Flux

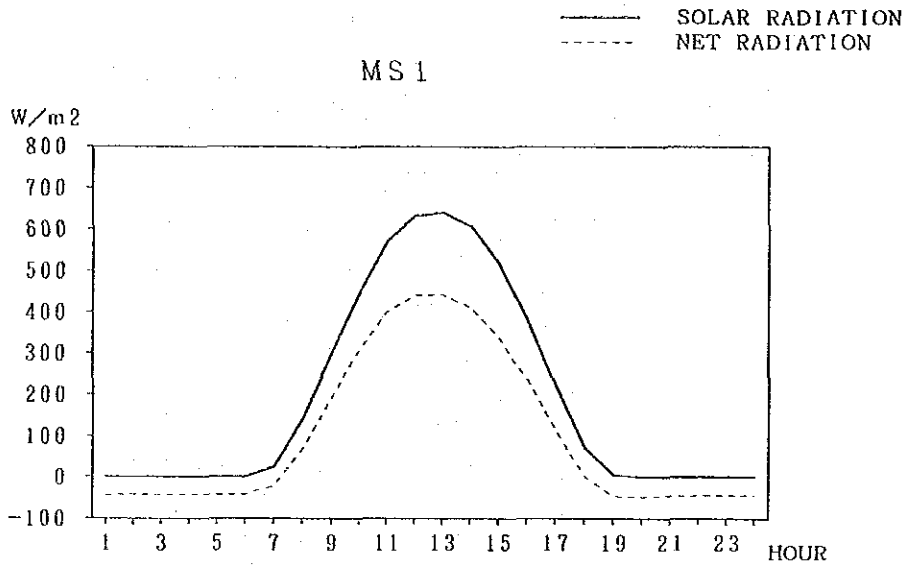


Fig. 1-11 Hourly Variations of Solar Radiation and Net Radiation Flux

1.1.7 Atmospheric Stability

Atmospheric stability is an index to show stability of the atmosphere, and is closely related to the vertical distribution of the air temperature. Under an unstable condition, air temperature in the upper level is lower than that approximated by the dry adiabatic decreasing rate (0.98℃/100 m), thereby generating a convection current due to the difference of the density of air between the upper and lower layers and thus resulting in large air turbulence. On the other hand, under a stable condition, the temperature increases with increasing level, thereby resulting in a state where turbulence is suppressed. These phenomena are indicated in a graph as shown in Fig. 1-12.

Characteristics of plume diffusion corresponding to each of the above atmospheric stabilities are as shown in Fig. 1-13. Atmospheric stability also serves as an index for determining smoke plume diffusion width.

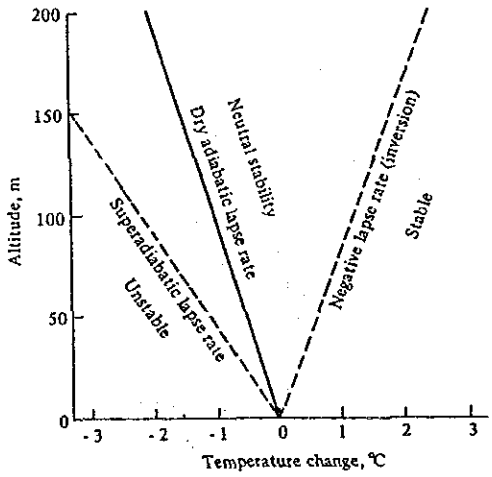


Fig. 1-12 Atmospheric Temperature Lapse Rates

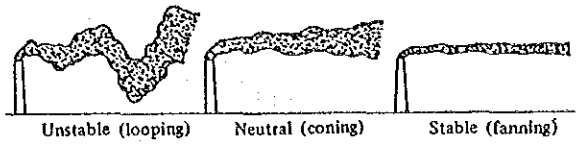


Fig. 1-13 Smoke Plume Diffusion Conditions by Atmospheric Stability

Atmospheric stability is classified by the vertical profile of atmospheric temperature as described above. However, it is difficult to make continuous measurements (up to an altitude of 1000 m above the ground) of the vertical distribution of atmospheric temperature. Also, smoke plume diffusion is greatly influenced not only by the vertical distribution of atmospheric temperature but also by wind velocity, and is related to other factors as well. Therefore, Pasquill[1] proposed a method of classifying the atmospheric stability into A through F, from simple meteorological observations, with respect to wind velocity, solar radiation and cloud amount, and this method had been adopted by the Meteorological Agency of England. Pasquill's stability classification is shown in Table 1-5.

Table 1-5 Pasquill's Stability Classification

Surface wind speed (m/sec)	Key to stability categories: Insolation			Night	
	Strong	Moderate	Slight	Thinly overcast or ≥4/8 low cloud	≤ 3/8 cloud
< 2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

(for A-B take average of values for A and B etc.)

Strong insolation corresponds to sunny midday in midsummer in England, slight insolation to similar conditions in midwinter. Night refers to the period from 1 hr before sunset to 1 hr after dawn. The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night, and for any sky conditions during the hour preceding or following night as defined above.

In Pasquill's stability classifications, solor radiation was not given quantitatively and nighttime classifications were dependent on the cloud volume. But recently due to the rapid progress made in measuring instruments, solar radiation and net radiation flux are easily obtainable, and Pasquill's stability classification was thereby greatly improved.

In this survey, based on Pasquill's classification of atmospheric stability, the reporter calculated the appearance frequency of atmospheric stability, where hourly atmospheric stability was obtained in compliance with the atmospheric stability classification (Table 1-6) of the Ministry of International Trade and Industry (MITI) which uses net radiation in place of cloud amount. The results are shown in Table 1-7 and Table 1-8.

Table 1-6 Classification of Atmospheric Stability (MITI's Method)

Wind Velocity (m/s) (About 10 meters above ground)		Solar Radiation				Net Radiation	
		Upper: (cal/cm²·hr), Lower: (W/m²)					
Range of Wind Velocity	Representative Wind Velocity	~50	49~25	24~13	12~0	0~-2.9	-3.0~
		~580	579~290	289~151	150~0	0~-34	-35~
0.0~0.3	0.0	CA	CB	CC	CC	CC	CD
0.4~0.9	0.6	A	B	B	D	E	F
1.0~2.9	2.0	B	B	C	D	E	F
3.0~4.9	4.0	B	C	C	D	D	E
5.0~7.9	6.5	C	D	D	D	D	D
8.0~	10.0	D	D	D	D	D	D

From the Manual for Predicting Environmental Concentration in Atmosphere in the comprehensive preliminary investigation of industrial pollution.

Table 1-7 Appearance Frequency of Atmospheric Stability

(Unit : %)

Monitoring stations	Calm				Windy					
	CA	CB	CC	CD	A	B	C	D	E	F
(MS1) ONEB STATION	0.03	0.01	0.00	0.03	0.09	18.21	16.42	15.11	23.62	26.48
(MS2) POWER PLANT	0.00	0.00	0.04	0.33	0.04	22.13	13.65	12.57	22.60	28.60
(MS5) H.& I.ESTATE	0.00	0.01	1.04	1.88	0.13	23.36	12.74	10.45	16.26	34.13

Table 1-8 Appearance Time of Atmospheric Stability by Wind Velocity Rank and Solar Radiation and Net Radiation Flux Rank

(MS1) ONEB STATION

Wind velocity (m/s)	Solar radiation (W/m²)								Net radiation (W/m²)				Total
	T≧580		580 >T ≧290		290 >T ≧151		151 >T ≧ 0		Q≧-34		-34 >Q		
0.0 - 0.4	CA	2	CB	1	CC	0	CC	0	CC	0	CD	2	5
0.5 - 0.9	A	7	B	13	B	10	D	10	E	16	F	56	112
1.0 - 1.9	B	71	B	157	C	113	D	145	E	413	F	713	1612
2.0 - 2.9	B	193	B	305	C	184	D	244	E	501	F	1218	2645
3.0 - 4.9	B	617	C	591	C	232	D	285	D	242	E	842	2809
5.0 -	C	112	D	94	D	28	D	30	D	19	D	37	320
Total	1002		1161		567		714		1191		2868		7503

(MS2) POWER PLANT

Wind velocity (m/s)	Solar radiation (W/m²)								Net radiation (W/m²)				Total
	T≧580		580 >T ≧290		290 >T ≧151		151 >T ≧ 0		Q≧-34		-34 >Q		
0.0 - 0.4	CA	0	CB	0	CC	1	CC	2	CC	3	CD	28	34
0.5 - 0.9	A	3	B	19	B	37	D	46	E	201	F	336	642
1.0 - 1.9	B	93	B	265	C	187	D	268	E	626	F	1243	2682
2.0 - 2.9	B	398	B	449	C	205	D	219	E	328	F	826	2425
3.0 - 4.9	B	600	C	515	C	203	D	211	D	216	E	745	2490
5.0 -	C	38	D	49	D	11	D	15	D	7	D	15	135
Total	1132		1297		644		761		1381		3193		8408

(MS5) H.& I. ESTATE

Wind velocity (m/s)	Solar radiation (W/m²)								Net radiation (W/m²)				Total
	T≧580		580 >T ≧290		290 >T ≧151		151 >T ≧ 0		Q≧-34		-34 >Q		
0.0 - 0.4	CA	0	CB	1	CC	1	CC	7	CC	78	CD	156	243
0.5 - 0.9	A	11	B	56	B	51	D	84	E	391	F	858	1451
1.0 - 1.9	B	171	B	306	C	242	D	335	E	604	F	1379	3037
2.0 - 2.9	B	385	B	468	C	226	D	200	E	207	F	593	2079
3.0 - 4.9	B	500	C	418	C	110	D	122	D	72	E	146	1368
5.0 -	C	60	D	39	D	2	D	7	D	2	D	3	113
Total	1127		1288		632		755		1354		3135		8291

1.1.8 Analysis of Horizontal Wind Fluctuation σ_A and Vertical Wind Fluctuation σ_E

(1) The relationship between air turbulency and diffusion width

The dispersion of emission substances in the atmosphere is closely associated with the randam movement of ambient air and air turbulence as the driver. Countless numbers of eddy currents existing in the air are grouped into two, one mechanically driven by buildings and trees and the other caused by the temperature difference in air layers along the vertical direction. The degree of air turbulence is called "atmospheric stability." Parameters used to express such atmospheric stability include the Richardson number, Stability-length by Monin-Obukhov, and Barad's stability ratio, in which a factor commonly required for their approximation is the measurement of wind and temperature profiles in air layers of high level above ground. In other words, it is thought not appropriate to introduce these parameters in any practical method to be applied for estimation of diffusion width.

1) Horizontal diffusion width σ_y

The estimation of horizontal diffusion width σ_y is subject to either of the following two methods.

(i) Empirical equation or diagram developed by using experimental data

(ii) Modeling equation obtainable based on Taylor's statistical theory with parameters to be empirically set

According to Taylor's statistical theory,[2] the horizontal diffusion width σ_y can be estimated by knowing the wind velocity fluctuation σ_v when diffusion time is small (being close to the emission source) and air turbulence is kept consistent and thus in the vicinity of the emission source, σ_y *increases in proportion to diffusion time* T.

$$\sigma_y(T)^2 = \sigma_v^2 \cdot T^2 \quad \cdots\cdots (1\text{-}2)$$

In Figure 1-14, the horizontal diffusion width σ_y divided by the wind velocity fluctuation σ_v (horizontal wind velocity standard deviation), σ_y/σ_v, is plotted against diffusion period T in the Log-Log scale diagram. From the graph, it is known that the diffusion width increases for up to 2-3 hours proportionally to the 1st order of the time lapse. Accordingly, by applying wind fluctuation σ_A in place of σ_v ($\sigma_v/u \fallingdotseq \tan \sigma_A$) and the downflow distance x ($x=u.T$) instead of diffusion time T, the horizontal diffusion width σ_y can be expressed as Equation (1-3). According to Yokoyama-Yamamoto[3] the constant which is $\sigma_y/\sigma_A \cdot x$ was estimated to be 0.018 whereas Draxler[4] gave the value as a function of diffusion time T and Lagrangian time scale T_L, and Pasquill[5] as a function of downflow distance x.

$$\sigma_y = \text{const} \cdot \sigma_A \cdot x \quad \cdots\cdots (1\text{-}3)$$

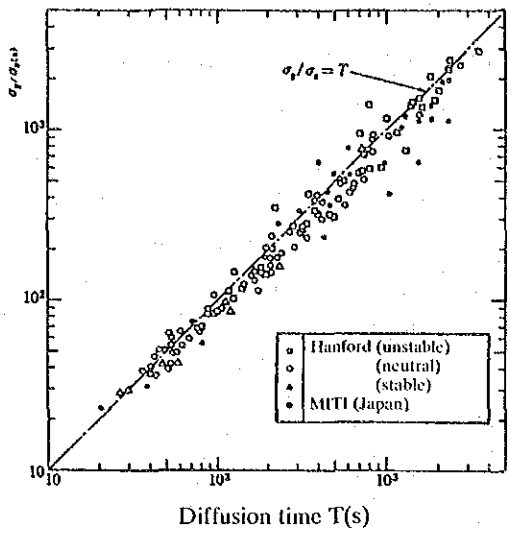


Fig. 1-14 The Relationship Between Horizontal Diffusion Width and Diffusion Time

2) Diffusion width in the vertical direction

There are a few methods for estimation of the vertical diffusion width as shown below.

(i) a method to estimate σ_z by using wind velocity fluctuation σ_w which is closely associated with the former or vertical fluctuation of wind direction $\sigma_E \fallingdotseq (\sigma_w/u)$ through field observation

(ii) a method to estimate from meteorological data such as the temperature profile of the high altitude level

(iii) a method which uses ground level observation data such as wind velocity, solar radiation, cloud volume, etc.

Among methods shown above, the method (i) was found most reliable and has options such as one proposed by Yamamoto-Yokoyama[3] and the other by Draxler[4]. The method (ii) has TVA diagram[6] and the method (iii) has such options as the P-G diagram[7] and Turner diagram[8].

The relation between σ_z and σ_E can be expressed as Equation (1-4), where the constant k varies according to the degree of atmospheric stability as such treated by Yamamoto-Yokoyama or Draxler gave the value, k, as a function of diffusion time T and Lagrangian time scale T_L.

$$\sigma_z = k\sigma_E \cdot x \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (1\text{-}4)$$

(2) Calculation of σ_A, σ_E

Based on the hourly measurement data of air turbulence by means of the three dimensional ultrasonic anemometer, hourly average of fluctuation of horizontal wind direction σ_A and vertical fluctuation of wind direction σ_E were calculated by the following equations.

$$\sigma_A = \sqrt{\frac{1}{6}\sum_{i=1}^{6} SA_{i(10)}^2 + \frac{1}{6}\sum_{i=1}^{6} (WD_{i(10)} - WD)^2} \quad \cdots\cdots (1\text{-}5)$$

where

$SA_{i(10)}$; Reading value of $\sigma\theta$ at an interval of 10 minutes (degree)

$\sigma\theta$; 10 minutes running average value of standard deviation of horizontal wind direction

$\frac{1}{6}\sum_{i=1}^{6} SA_{i(10)}$; 1 hour value of standard deviation of horizontal wind direction (degree)

$WD_{i(10)}$; Reading value of $\bar{\theta}$ at an interval of 10 minutes (degree)

$\bar{\theta}$; 10 minutes running average value of horizontal wind direction

WD; 1 hour average value of horizontal wind direction (degree)

$$WD = \frac{1}{6}\sum_{i=1}^{6} WD_{i(10)}$$

$$\sigma_E = \frac{180}{\pi}\sqrt{\frac{1}{6}\sum_{i=1}^{6}\left\{\tan^{-1}\frac{SW_{i(10)}}{U_{i(10)}}\right\}^2 + \frac{1}{6}\sum_{i=1}^{6}\left\{\tan^{-1}\frac{W_{i(10)} - W}{U}\right\}^2} \quad \cdots\cdots (1\text{-}6)$$

where

$SW_{i(10)}$; Reading value of σ_w at an interval of 10 minutes (m/s)

σ_w; 10 minutes running average value of standard deviation of vertical wind velocity (m/s)

$U_{i(10)}$; Reading value of $\bar{U}$ at an interval of 10 minutes (m/s)

$\bar{U}$; 10 minutes running average value of horizontal wind velocity

$W_{i(10)}$; Reading value of $\bar{W}$ at an interval of 10 minutes (m/s)

$\bar{W}$; 10 minutes running average value of vertical wind velocity

W; 1 hour average value of vertical wind velocity (m/s)

$$W = \frac{1}{6}\sum_{i=1}^{6} W_{i(10)}$$

U; 1 hour average value of horizontal wind velocity (m/s)

$$U = \frac{1}{6}\sum_{i=1}^{6} U_{i(10)}$$

The calculated hourly values of σ_A and σ_E are exemplified in Table 1-9 and the complete set of data is enclosed in the Data File.

Table 1-9 (1) Example of Air Turbulence Measurement Result (σ_A)

********** MONTHLY REPORT ********** PAGE - 1

1988YEAR 2 MONTH ITEM (9) SIGAZIH ST. (1) (MS1) ONEB STATION (0.1°)

HOUR DAY	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	116	113	108	105	103	99	109	177	231	155	143	190	153	201	155	181	163	128	127	130	122	130	138	131	99	231	142	24	3408
2	124	120	113	111	150	111	266	102	226	361	196	259	241	200	209	214	209	184	173	123	94	97	111	97	94	361	170	24	4089
3	127	125	111	121	119	92	84	130	148	146	133	****	165	181	179	156	114	120	108	80	****	112	102	119	80	181	126	22	2772
4	112	115	101	97	91	151	122	120	130	156	136	158	171	137	156	170	164	166	153	124	123	121	119	124	91	171	134	24	3217
5	127	119	134	115	138	130	146	147	128	169	198	213	159	215	170	192	186	128	130	117	113	131	120	126	113	215	148	24	3549
6	107	99	206	143	277	293	319	136	**********			425	203	217	197	178	167	142	122	110	109	104	135	119	99	425	181	21	3803
7	116	109	153	190	243	156	105	123	175	265	**********			320	157	140	145	134	113	109	110	129	126	124	105	320	153	21	3222
8	123	123	112	104	139	119	126	145	268	166	213	192	214	193	172	181	153	144	133	131	140	128	128	119	104	268	153	24	3664
9	120	117	118	128	192	111	247	243	349	170	143	154	144	155	152	141	123	138	130	140	150	255	146	155	111	349	163	24	3921
10	160	141	145	131	499	1640	****	143	454	127	135	178	125	153	169	161	195	150	125	762	479	323	242	130	125	1640	294	23	6767
11	247	110	121	136	100	199	124	166	168	136	280	233	219	228	173	215	212	118	103	118	127	343	224	121	100	343	177	24	4239
12	396	305	295	549	230	213	214	164	122	174	293	****	196	****	201	169	149	177	172	142	142	130	128	114	114	549	213	22	4675
13	147	151	122	237	149	220	555	171	313	188	280	210	228	181	169	155	152	173	117	113	118	128	124	108	108	555	188	24	4509
14	119	101	78	86	139	134	148	324	****	147	141	195	207	178	184	172	136	137	132	108	208	114	133	125	78	324	150	23	3446
15	123	128	113	94	108	166	158	99	139	136	159	147	164	170	157	155	145	208	214	190	179	384	228	****	94	384	164	23	3764
16	251	197	392	144	146	301	230	159	****	252	293	317	1811	322	174	121	127	136	121	134	90	136	98	115	90	1322	236	23	5437
17	106	54	69	108	85	132	170	1811	597	444	****	763	3861	357	200	552	213	194	175	447	****	944	150	164	54	1597	386	22	8491
18	267	510	220	287	159	182	159	125	183	194	178	204	235	248	228	246	220	146	114	183	93	261	142	91	91	510	203	24	4875
19	159	139	425	129	134	138	132	177	135	160	157	169	156	180	208	228	186	154	92	73	305	196	146	134	73	425	171	24	4110
20	137	123	132	179	124	102	116	153	208	216	241	271	242	296	302	314	465	155	102	1401	172	163	124	198	102	1172	236	24	5675
21	88	67	255	93	137	136	174	133	228	183	208	167	229	285	295	321	219	166	1186	138	120	783	240	88	67	1186	247	24	5939
22	132	79	108	100	102	90	51	100	240	181	226	216	175	200	301	225	199	175	467	479	98	98	****	113	51	479	181	23	4155
23	81	93	118	140	277	632	231	81	201	284	204	188	215	193	294	326	557	925	183	187	325	125	180	492	81	925	272	24	6532
24	146	185	106	71	166	93	130	144	152	158	131	168	164	235	168	147	179	145	162	136	142	129	123	117	71	235	146	24	3497
25	122	111	124	160	239	271	207	234	421	185	181	149	191	217	183	167	166	126	145	126	123	142	128	158	111	421	177	24	4256
26	143	140	****	147	210	130	122	421	423	183	199	196	212	232	196	151	148	153	126	136	146	118	119	123	118	423	181	23	4174
27	135	154	122	373	345	133	415	273	480	229	189	254	158	216	181	171	136	133	125	134	121	122	121	129	121	480	202	24	4849
28	139	116	110	115	88	86	197	176	245	139	168	168	179	141	191	157	126	136	128	131	112	161	131	130	86	245	144	24	3450
29	137	134	139	129	112	109	181	149	190	172	188	221	193	168	154	154	150	139	136	128	123	109	105	122	105	221	148	24	3542
MIN	81	54	69	71	85	86	51	81	122	127	131	147	125	137	152	121	114	118	92	73	90	97	98	88	51				
MAX	396	510	425	549	499	1640	555	421	1597	444	293	763	3861	357	302	552	557	925	1186	762	1172	944	242	492		1640			
AVE	149	141	155	156	172	220	187	169	291	195	193	231	197	286	196	202	189	177	183	175	192	210	143	139			189		
HOUR	29	29	28	29	29	29	28	29	26	28	26	26	28	28	29	29	29	29	29	29	27	29	28	28				678	
TOTAL	4307	4078	4350	4522	5001	6369	5238	4894	7554	5454	5011	6005	5525	8019	5675	5860	5482	5130	5314	5067	5184	6091	4011	3886					128027

Table 1-9 (2) Example of Air Turbulence Measurement Result (σ_E)

********** MONTHLY REPORT ********** PAGE - 2

1988YEAR 2 MONTH ITEM (10) SIG E ST. (1) (MS1) ONEB STATION (0.1°)

HOUR DAY	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	66	59	57	64	57	60	34	32	186	175	74	83	93	109	71	80	79	72	63	54	55	54	59	52	32	186	74	24	1786
2	50	56	54	32	12	0	0	30	80	140	186	284	190	277	196	132	73	96	71	68	25	27	10	44	0	284	89	24	2133
3	66	69	38	76	81	37	27	19	66	76	90	****	123	219	159	143	155	68	24	23	********		26	44	19	219	78	21	1629
4	48	35	12	26	16	22	17	**********		189	169	174	166	228	277	244	258	234	243	287	77	53	49	50	12	287	131	22	2874
5	54	34	37	44	44	41	55	62	80	81	87	96	83	88	114	130	108	105	61	57	93	77	65	44	34	130	73	24	1740
6	38	26	16	27	17	13	30	24	32	45	47	81	93	80	99	88	81	73	77	72	93	59	117	231	13	231	65	24	1559
7	143	62	71	29	44	97	61	43	43	67	83	79	72	81	99	109	83	54	25	37	59	54	90	72	25	143	68	24	1637
8	107	122	147	97	88	49	55	49	133	236	269	284	295	119	90	74	81	97	132	131	129	82	84	45	45	295	125	24	2995
9	52	59	55	26	32	22	21	43	101	161	205	174	108	92	97	101	112	103	63	51	32	18	27	50	18	205	75	24	1805
10	59	36	19	22	50	107	51	52	70	123	213	198	180	264	245	372	83	51	40	15	15	24	17	21	15	372	97	24	2327
11	11	14	22	20	32	35	75	153	71	55	68	118	203	189	195	190	40	193	57	141	62	63	85	60	11	203	90	24	2152
12	15	29	51	32	23	36	33	30	399	353	94	317	227	156	264	210	137	144	101	136	185	115	79	73	15	399	135	24	3239
13	99	58	29	52	48	29	15	26	64	104	75	137	135	136	150	76	54	82	245	227	103	193	211	138	15	245	104	24	2486
14	152	118	71	77	39	26	25	23	51	143	140	110	138	184	158	179	106	75	75	72	73	84	152	139	23	184	100	24	2410
15	148	136	75	69	112	237	63	63	169	168	163	176	120	101	90	93	109	109	152	74	30	31	22	19	19	237	105	24	2529
16	10	23	20	56	69	59	44	97	61	202	178	427	152	95	93	76	68	59	43	40	35	25	24	25	10	477	83	24	1989
17	26	25	19	26	14	20	15	32	58	71	73	64	77	264	203	69	99	45	34	11	8	9	20	21	8	264	54	24	1303
18	25	23	12	20	38	36	50	72	135	202	359	119	294	326	133	141	163	87	26	39	78	52	73	14	12	359	105	24	2517
19	30	26	23	14	39	30	32	69	120	149	168	231	211	198	168	119	129	87	41	50	84	142	117	116	16	231	100	24	2395
20	142	58	142	179	48	36	24	126	94	59	111	166	337	528	382	397	210	92	53	29	22	69	139	114	22	528	148	24	3557
21	114	35	78	33	45	23	32	55	80	111	126	123	122	132	161	182	215	102	43	68	77	57	21	34	21	215	86	24	2069
22	84	61	29	43	67	45	47	57	49	48	56	72	85	84	84	91	73	42	25	28	76	44	20	35	20	91	56	24	1345
23	40	52	31	43	42	15	27	36	53	101	138	143	121	120	104	102	69	52	94	77	45	53	44	30	15	143	68	24	1632
24	98	212	218	49	33	56	81	94	136	118	158	183	215	256	203	167	117	85	72	66	98	95	95	92	33	256	125	24	2997
25	76	63	76	80	28	14	25	55	102	114	158	180	190	191	194	174	175	172	149	185	149	120	95	48	14	194	117	24	2813
26	71	78	41	28	59	74	78	96	303	150	143	374	270	173	174	129	122	154	133	161	240	253	138	125	28	374	149	24	3567
27	170	133	31	14	18	30	41	45	159	235	308	131	133	140	125	155	218	293	166	130	119	121	118	107	14	308	131	24	3140
28	67	80	81	36	17	12	22	32	69	82	79	80	75	83	89	102	106	101	76	65	75	83	102	91	12	106	70	24	1685
29	90	152	204	283	130	91	45	79	92	86	98	81	97	97	71	65	61	49	44	56	40	39	37	51	37	283	89	24	2138
MIN	10	14	12	14	12	0	0	19	32	45	47	64	72	80	71	65	40	42	24	11	8	9	10	14	0				
MAX	170	212	218	283	130	237	61	153	399	353	359	427	337	528	382	397	258	293	245	287	240	253	211	231		528			
AVE	74	67	61	55	46	46	38	57	108	133	142	169	158	173	155	144	117	103	84	84	78	75	74	68			96		
HOUR	29	29	29	29	29	29	29	28	28	29	29	28	29	29	29	29	29	29	29	29	28	28	29	29				691	
TOTAL	2151	1934	1759	1599	1362	1332	1105	1594	3034	3844	4116	4735	4585	5010	4688	4190	3384	2976	2426	2450	2177	2096	2136	1985					66448

(3) Study result of σ_A and σ_E

Table 1-10 shows values of σ_A and σ_E investigated with respect to such parameters as wind velocity range, solar radiation and net radiation flux. It is seen from the graph that both σ_A and σ_E decrease with increasing wind velocity or increase proportionally to solar radiation intensity when the wind velocity maintains constant. On the other hand, Table 1-11 shows values of σ_A and σ_E consolidated in accordance with the same categories of air stability as mentioned in Table 1-6. From Table 1-11, one can notice that both σ_A and σ_E increase as the atmosphere becomes unstable or decrease as stability of the atmosphere improves.

Table 1-10 (1) Average Standard Deviation of Horizontal Wind Direction (σ_A) at Each Wind Velocity Rank, Solar Radiation Rank and Net Radiation Flux Rank

South Wet (deg)

Wind velocity (m/s)	Solar radiation (W/m²)				Net radiation (W/m²)		Average
	T≧580	580 >T ≧290	290 >T ≧151	151 >T ≧ 0	Q≧-34	-34 >Q	
0.0 ~ 0.4	– (0)	– (0)	– (0)	– (0)	– (0)	– (0)	– (0)
0.5 ~ 0.9	– (0)	42.6 (1)	– (0)	76.0 (2)	46.6 (5)	49.8 (5)	52.1 (13)
1.0 ~ 1.9	44.2 (5)	40.5 (30)	32.5 (44)	34.1 (56)	31.2 (312)	28.2 (290)	30.8 (737)
2.0 ~ 2.9	31.2 (74)	31.1 (130)	22.5 (89)	25.4 (101)	21.7 (359)	16.1 (423)	21.7(1176)
3.0 ~ 4.9	22.5 (259)	22.4 (288)	20.8 (129)	20.4 (142)	22.8 (180)	15.9 (152)	21.2(1150)
5.0 ~	17.3 (17)	16.5 (32)	15.0 (18)	16.7 (15)	18.1 (11)	23.6 (1)	16.6 (94)
Average	24.4 (355)	25.5 (481)	22.8 (280)	24.6 (316)	25.4 (867)	20.3 (871)	23.6(3170)

North Dry (deg)

Wind velocity (m/s)	Solar radiation (W/m²)				Net radiation (W/m²)		Average
	T≧580	580 >T ≧290	290 >T ≧151	151 >T ≧ 0	Q≧-34	-34 >Q	
0.0 ~ 0.4	– (0)	– (0)	– (0)	– (0)	– (0)	– (0)	– (0)
0.5 ~ 0.9	– (0)	– (0)	47.6 (1)	21.8 (2)	26.8 (6)	43.5 (9)	35.7 (18)
1.0 ~ 1.9	67.3 (8)	34.4 (12)	24.7 (12)	26.6 (24)	34.0 (19)	22.8 (143)	26.5 (223)
2.0 ~ 2.9	32.3 (49)	29.2 (89)	25.4 (54)	21.0 (89)	17.1 (68)	14.9 (570)	18.6 (919)
3.0 ~ 4.9	24.6 (169)	21.4 (181)	19.3 (57)	18.8 (85)	15.6 (27)	14.1 (263)	19.0 (782)
5.0 ~	18.5 (53)	17.7 (34)	15.5 (7)	15.5 (4)	16.0 (7)	15.0 (10)	17.5 (115)
Average	26.0 (279)	23.7 (316)	22.3 (131)	20.6 (204)	19.7 (127)	16.1(1000)	19.7(2057)

South Dry (deg)

Wind velocity (m/s)	Solar radiation (W/m²)				Net radiation (W/m²)		Average
	T≧580	580 >T ≧290	290 >T ≧151	151 >T ≧ 0	Q≧-34	-34 >Q	
0.0 ~ 0.4	30.6 (2)	31.4 (1)	– (0)	– (0)	– (0)	50.5 (2)	38.7 (5)
0.5 ~ 0.9	23.2 (6)	20.6 (8)	27.9 (5)	16.7 (4)	13.3 (2)	26.1 (37)	24.2 (62)
1.0 ~ 1.9	22.3 (43)	27.3 (76)	27.9 (38)	23.2 (48)	23.9 (44)	21.0 (259)	23.0 (508)
2.0 ~ 2.9	27.1 (49)	24.0 (65)	27.4 (37)	19.7 (45)	22.6 (58)	14.5 (218)	19.6 (472)
3.0 ~ 4.9	19.2 (182)	17.8 (116)	16.0 (44)	14.6 (54)	19.5 (29)	14.1 (425)	16.0 (850)
5.0 ~	15.6 (40)	15.0 (27)	14.8 (3)	13.8 (11)	13.6 (1)	13.5 (26)	14.7 (108)
Average	20.5 (322)	21.5 (293)	23.3 (127)	18.6 (162)	22.1 (134)	16.5 (957)	18.9(2005)

Annual (deg)

Wind velocity (m/s)	Solar radiation (W/m²)				Net radiation (W/m²)		Average
	T≧580	580 >T ≧290	290 >T ≧151	151 >T ≧ 0	Q≧-34	-34 >Q	
0.0 ~ 0.4	30.6 (2)	31.4 (1)	– (0)	– (0)	– (0)	50.5 (2)	38.7 (5)
0.5 ~ 0.9	23.2 (6)	23.1 (9)	31.2 (6)	33.2 (8)	32.3 (13)	31.5 (51)	30.3 (93)
1.0 ~ 1.9	30.7 (56)	31.4 (118)	29.6 (94)	28.6 (128)	30.5 (375)	24.4 (697)	27.4(1468)
2.0 ~ 2.9	30.3 (172)	28.9 (284)	24.4 (180)	22.6 (235)	21.2 (485)	15.2(1211)	20.2(2567)
3.0 ~ 4.9	22.1 (610)	21.2 (585)	19.5 (230)	18.8 (281)	21.6 (236)	14.4 (840)	19.0(2782)
5.0 ~	17.3 (110)	16.5 (93)	15.1 (28)	15.5 (30)	17.1 (19)	14.2 (37)	16.3 (317)
Average	23.6 (956)	23.9(1090)	22.8 (538)	22.0 (682)	24.4(1128)	17.5(2838)	21.2(7232)

Table 1-10 (2) Average Standard Deviation of Vertical Wind Direction (σ_E) at Each Wind Velocity Rank, Solar Radiation Rank and Net Radiation Flux Rank

South Wet (deg)

Wind velocity (m/s)	Solar radiation (W/m²) T≧580	580 >T ≧290	290 >T ≧151	151 >T ≧ 0	Net radiation (W/m²) Q≧-34	-34 >Q	Average
0.0 - 0.4	— (0)	— (0)	— (0)	— (0)	— (0)	— (0)	— (0)
0.5 - 0.9	— (0)	19.2 (1)	19.2 (3)	11.6 (3)	8.1 (7)	7.9 (7)	10.6 (21)
1.0 - 1.9	16.5 (12)	14.1 (52)	10.5 (57)	8.3 (69)	5.9 (348)	5.5 (297)	6.9 (835)
2.0 - 2.9	12.0 (80)	10.4 (142)	8.6 (92)	7.5 (107)	6.8 (372)	6.3 (422)	7.6(1215)
3.0 - 4.9	9.4 (257)	8.6 (288)	8.0 (130)	7.4 (144)	7.6 (184)	7.1 (152)	8.2(1155)
5.0 -	8.3 (18)	7.8 (32)	7.5 (18)	7.6 (15)	7.8 (11)	8.3 (1)	7.8 (95)
Average	10.2 (367)	9.6 (515)	8.8 (300)	7.7 (338)	6.6 (922)	6.2 (879)	7.7(3321)

North Dry (deg)

Wind velocity (m/s)	Solar radiation (W/m²) T≧580	580 >T ≧290	290 >T ≧151	151 >T ≧ 0	Net radiation (W/m²) Q≧-34	-34 >Q	Average
0.0 - 0.4	— (0)	— (0)	— (0)	— (0)	— (0)	— (0)	— (0)
0.5 - 0.9	35.2 (1)	35.7 (2)	28.4 (2)	15.9 (3)	5.6 (6)	6.2 (12)	12.3 (26)
1.0 - 1.9	20.0 (11)	15.7 (15)	11.2 (14)	7.2 (25)	6.1 (19)	4.9 (147)	7.1 (231)
2.0 - 2.9	12.9 (55)	11.1 (94)	9.4 (53)	7.7 (85)	7.0 (64)	6.0 (559)	7.4 (910)
3.0 - 4.9	9.8 (163)	9.1 (177)	8.3 (56)	7.7 (84)	7.8 (27)	7.1 (262)	8.3 (769)
5.0 -	8.1 (49)	7.9 (32)	7.6 (7)	7.7 (4)	8.0 (7)	7.5 (10)	7.9 (109)
Average	10.6 (279)	10.0 (320)	9.3 (132)	7.8 (201)	7.0 (123)	6.2 (990)	7.8(2045)

South Dry (deg)

Wind velocity (m/s)	Solar radiation (W/m²) T≧580	580 >T ≧290	290 >T ≧151	151 >T ≧ 0	Net radiation (W/m²) Q≧-34	-34 >Q	Average
0.0 - 0.4	50.3 (2)	39.7 (1)	— (0)	— (0)	— (0)	13.4 (2)	33.4 (5)
0.5 - 0.9	32.2 (6)	29.8 (10)	24.0 (5)	23.7 (4)	10.6 (3)	12.1 (37)	18.2 (65)
1.0 - 1.9	18.4 (47)	16.3 (89)	12.7 (39)	9.2 (49)	6.9 (46)	7.1 (262)	10.2 (532)
2.0 - 2.9	12.3 (51)	10.2 (66)	8.9 (37)	7.9 (47)	7.0 (60)	6.0 (220)	7.8 (481)
3.0 - 4.9	9.1 (184)	8.3 (117)	7.9 (45)	7.3 (54)	5.8 (30)	6.9 (425)	7.6 (855)
5.0 -	8.0 (40)	7.6 (27)	7.5 (3)	7.4 (11)	4.4 (1)	7.8 (26)	7.7 (108)
Average	11.5 (330)	11.7 (310)	10.2 (129)	8.4 (165)	6.8 (140)	7.0 (972)	8.7(2045)

Annual (deg)

Wind velocity (m/s)	Solar radiation (W/m²) T≧580	580 >T ≧290	290 >T ≧151	151 >T ≧ 0	Net radiation (W/m²) Q≧-34	-34 >Q	Average
0.0 - 0.4	50.3 (2)	39.7 (1)	— (0)	— (0)	— (0)	13.4 (2)	33.4 (5)
0.5 - 0.9	32.6 (7)	29.9 (13)	23.4 (10)	17.7 (10)	7.6 (16)	10.3 (56)	15.4 (112)
1.0 - 1.9	18.3 (70)	15.5 (156)	11.4 (110)	8.4 (143)	6.0 (413)	6.0 (706)	8.0(1598)
2.0 - 2.9	12.4 (186)	10.6 (302)	8.9 (182)	7.6 (239)	6.8 (496)	6.1(1201)	7.6(2606)
3.0 - 4.9	9.4 (604)	8.7 (582)	8.1 (231)	7.5 (282)	7.4 (241)	7.0 (839)	8.1(2779)
5.0 -	8.1 (107)	7.8 (91)	7.6 (28)	7.5 (30)	7.7 (19)	7.7 (37)	7.8 (312)
Average	10.7 (976)	10.3(1145)	9.2 (561)	7.9 (704)	6.7(1185)	6.4(2841)	8.0(7412)

Table 1-11 (1) Average Standard Deviation of Horizontal Wind Direction (σ_A) by Atmospheric Stability

(deg)

Stability		South Wet	North Dry	South Dry	AVE
Calm	CA	— (0)	— (0)	30.6 (2)	30.6 (2)
	CB	— (0)	— (0)	31.4 (1)	31.4 (1)
	CC (Day)	— (0)	— (0)	— (0)	— (0)
	CC (Night)	— (0)	— (0)	— (0)	— (0)
	CD	— (0)	— (0)	50.5 (2)	50.5 (2)
Windy	A	— (0)	— (0)	23.2 (6)	23.2 (6)
	B	27.4 (499)	28.5 (328)	22.7 (428)	26.1(1255)
	C	22.7 (567)	21.4 (357)	19.9 (275)	21.6(1199)
	D (Day)	23.4 (366)	20.1 (245)	18.0 (192)	21.1 (803)
	D (Night)	22.5 (192)	15.5 (44)	16.6 (56)	20.3 (292)
	E	24.4 (828)	16.0 (356)	15.8 (529)	20.0(1713)
	F	21.2 (718)	16.8 (727)	18.6 (514)	18.9(1959)
AVE		23.6(3170)	19.7(2057)	18.9(2005)	21.2(7232)

Note) Standard deviation (number of hours)

Table 1-11 (2) Average Standard Deviation of Vertical Wind Direction (σ_E) by Atmospheric Stability

(deg)

Stability		South Wet	North Dry	South Dry	AVE
Calm	CA	— (0)	— (0)	50.3 (2)	50.3 (2)
	CB	— (0)	— (0)	39.7 (1)	39.7 (1)
	CC (Day)	— (0)	— (0)	— (0)	— (0)
	CC (Night)	— (0)	— (0)	— (0)	— (0)
	CD	— (0)	— (0)	13.4 (2)	13.4 (2)
Windy	A	— (0)	35.2 (1)	32.2 (6)	32.6 (7)
	B	10.7 (547)	11.5 (342)	12.6 (452)	11.6(1341)
	C	8.6 (585)	8.9 (349)	8.9 (278)	8.8(1212)
	D (Day)	7.7 (388)	7.8 (240)	8.3 (195)	7.9 (823)
	D (Night)	7.6 (196)	7.7 (44)	6.7 (57)	7.5 (297)
	E	6.5 (879)	7.0 (351)	6.9 (534)	6.7(1764)
	F	6.0 (726)	5.8 (718)	7.0 (519)	6.2(1963)
AVE		7.7(3321)	7.8(2045)	8.7(2046)	8.0(7412)

Note) Standard deviation (number of hours)

1.2 Analysis of Ambient Pollutant Concentration (SO_2, NO_2, NO_x and SPM)

1.2.1 Monthly and Diurnal Variations of Concentration

Variations of SO_2 concentration are shown in Fig. 1-15, variations of NO_2 concentration in Fig. 1-16, variations of NO_x in Fig. 1-17 and variations of SPM in Fig. 1-18, respectively.

With respect to SO_2, high concentrations are seen in both monthly and hourly variations at MS2 and MS3. High concentrations are particularly seen in January through April at MS3, and in November through December at MS2. When hourly SO_2 concentration is reviewed, high values are seen from night through morning (around 19:00 to 09:00 hours) at every monitoring station, and peaks are at around 08:00 hour and 21:00 to 22:00 hours, and low concentrations are recorded in daytime.

As for monthly radiations of NO_2 and NO_x concentrations, high concentrations are seen at MS1 and MS4 along the trunk highways. Especially, high concentrations were recorded in August through October at MS1 and in November through December at MS4. No significant trends are seen in monthly variations of NO_2 and NO_x concentration at other monitoring stations. When diurnal variations of NO_2 and NO_x are reviewed, there are 2 peaks at every station, one in 07:00–08:00 and the other in 19:00–21:00.

With respect to SPM, significant differences in concentration cannot be seen between stations. As for monthly variations, high concentrations are recorded in October through March, which correspond to the dry season, and SPM concentrations are low at every station in May through August, which correspond to the wet season. In reviewing hourly variations, there can be seen a trend for 2 peaks, in the same manner as the cases of SO_2, NO_2 and NO_x. Seasonal, daytime and nighttime ambient pollutant concentration are shown in Table 1-12.

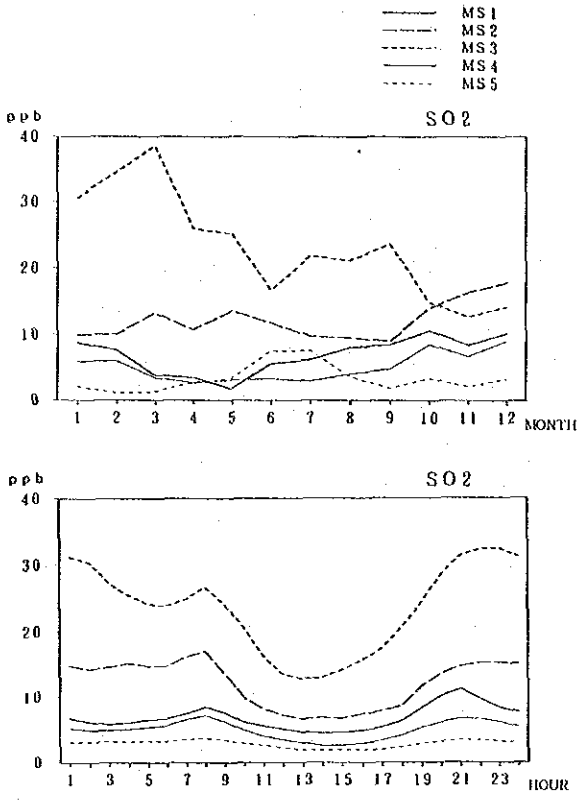


Fig. 1-15 Monthly and Diurnal Variations of SO_2 Concentration

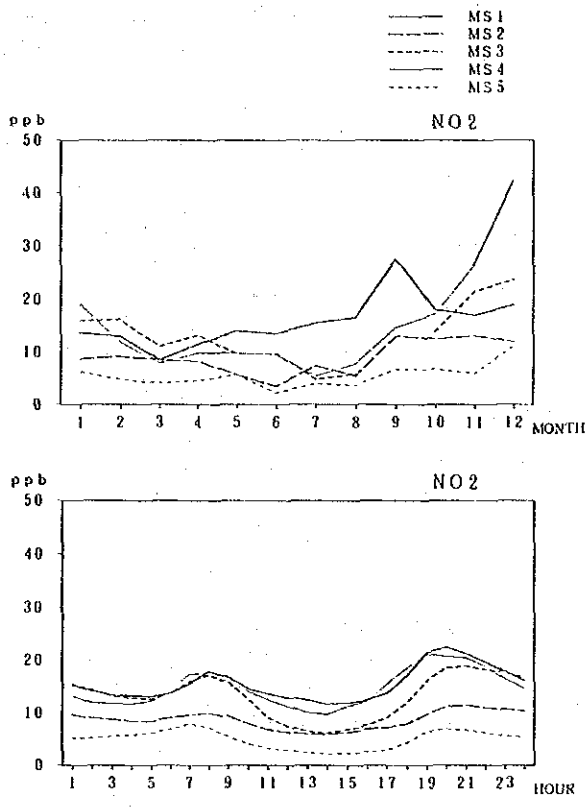


Fig. 1-16 Monthly and Diurnal Variations of NO_2 Concentration

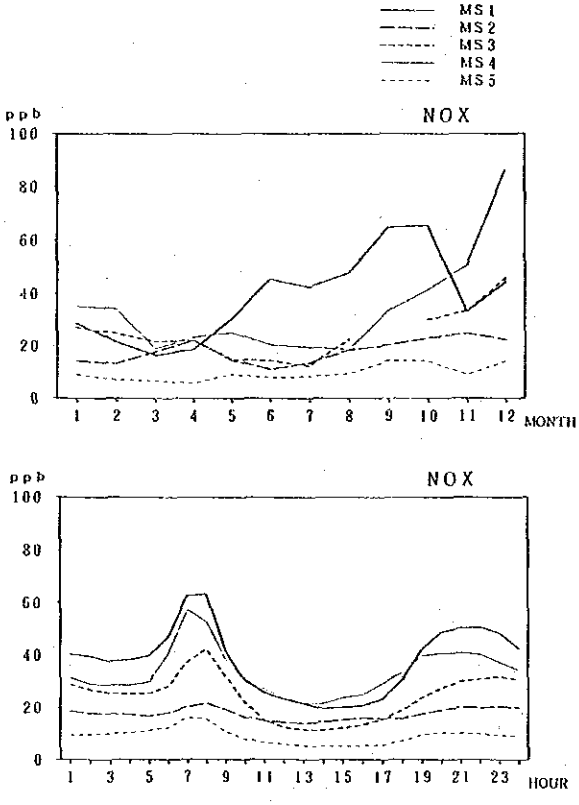


Fig. 1-17 Monthly and Diurnal Variations of NO_x Concentration

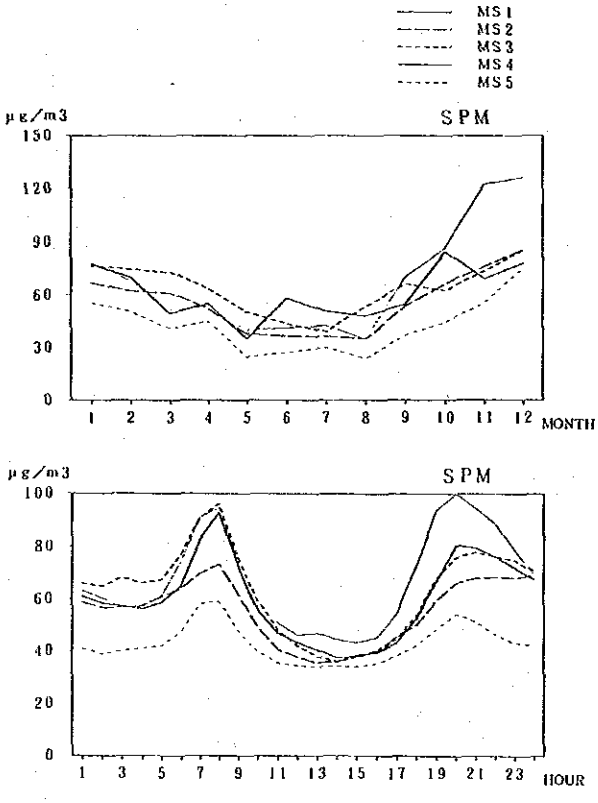


Fig. 1-18 Monthly and Diurnal Variations of SPM Concentration

Table 1-12 Average Concentration of Air Pollutants Classified Seasonal and Day/Night

Item	Station	Southerly Wet			Northerly Dry			Southerly Dry			Annual		
		Day	Night	Ave.	Day	Night	Ave.	Day	Night	Ave.	Day	Night	Ave.
SO_2 (ppb)	MS 1	6.4	7.1	6.8	5.9	11.8	9.1	4.6	5.3	4.9	5.8	7.8	6.9
	MS 2	9.3	12.9	11.3	8.5	19.7	14.7	9.7	12.8	11.4	9.2	14.6	12.2
	MS 3	17.1	23.5	20.6	15.9	22.6	19.6	20.9	43.3	33.1	17.7	28.3	23.5
	MS 4	3.6	5.1	4.4	5.3	8.7	7.1	3.8	4.1	4.0	4.0	5.7	5.0
	MS 5	3.5	4.4	4.0	1.8	3.0	2.5	1.6	1.7	1.7	2.4	3.2	2.9
NO_2 (ppb)	MS 1	17.8	17.0	17.4	10.9	21.1	16.5	10.0	11.7	11.0	14.1	16.7	15.6
	MS 2	7.3	8.1	7.7	7.2	14.3	11.1	7.6	9.5	8.6	7.3	9.8	8.7
	MS 3	6.9	9.7	8.4	14.6	24.8	20.2	10.4	16.1	13.5	10.1	15.7	13.2
	MS 4	10.3	11.1	10.7	27.1	34.7	31.2	9.2	10.0	9.7	13.5	15.7	14.7
	MS 5	3.4	5.7	4.7	4.1	8.3	6.4	3.5	5.2	4.4	3.6	6.1	5.0
NOx (ppb)	MS 1	39.7	56.4	48.8	20.3	47.7	35.3	17.2	19.9	18.7	29.2	45.1	37.9
	MS 2	16.2	16.7	16.5	15.0	24.4	20.1	17.0	18.0	17.6	16.2	18.7	17.6
	MS 3	14.3	20.0	17.4	25.5	44.4	35.8	19.1	26.0	22.8	18.8	28.5	24.1
	MS 4	24.4	28.6	26.7	49.8	71.7	61.7	25.5	25.1	25.3	29.9	36.7	33.6
	MS 5	8.3	12.0	10.3	6.8	11.5	9.4	5.5	7.1	6.3	7.2	10.5	9.0
SPM ($\mu g/m^3$)	MS 1	48.0	59.7	54.3	54.1	92.9	75.3	55.0	60.5	58.0	51.2	67.9	60.3
	MS 2	40.3	46.8	43.8	51.0	95.7	76.0	54.5	62.5	58.9	46.4	63.3	55.6
	MS 3	44.9	58.3	52.2	60.0	93.8	78.4	58.5	80.0	70.2	52.1	72.6	63.3
	MS 4	45.2	58.8	52.6	83.3	129.2	108.1	55.6	59.3	57.6	57.3	76.2	67.6
	MS 5	30.1	32.5	31.4	54.3	68.7	62.2	42.4	47.8	45.3	39.5	45.8	42.9

1.2.2 Resemblance among Monitoring Stations by Cluster Analysis and Principal Component Analysis

(1) Cluster analysis

This analysis is applied to a number of measurements that represent a plural number of group units and classifies such units based on mutual resemblance. The method is often called as Numerical Classification or Numerical Taxonomy and in this study measurement data and group unit correspond to pollutant concentrations and station respectively. The analytical method has been developed as advancement of computer technology and has versatile application fields such as medical science, biology and economics. The method was found effective for sorting of diseases based on diagnostic and medical data or in biological study for classification of bacteria by knowing their geometrical and behavioral data. The economics addresses its application to characterization of enterprises based on financial data.

Among many proposed options of cluster analysis, application to this study is one that depends on correlation coefficients of atmospheric pollutant concentrations as measure to represent similarity between monitoring stations. The clustering distance is calculated by group average method.

The clustering of group units (stations) starts such that the clustering distance first calculated directs which group units to be combined first (between near-most two) and then distance calculation is repeated for a new cluster system and second stage clustering takes place again about two units having the shortest distance. The repetive calculations and clusterings proceed until the all

group units are combined in one.

The correlation coefficients among stations were calculated with respect to monthly average concentrations of SO_2, NO_x and SPM and are shown in Table 1-13. Those coefficient data were used for cluster analysis, the result of which is as shown by a hierarchical structure or dendrogram in Fig. 1-19.

Fig. 1-19 shows the clustering of MS1 and MS4 about SO_2, that of MS4 and MS5 about NO_2, and that of MS1 and MS5 about NO_x as indicated by similarity value being larger than 0.8 in each case. Other clustering was not observed among stations but as for SPM the similarity value exceeded 0.8 about all combinations among stations. This may be probably due to the fact that the secondary particulate borne by the air and broadly existing across the area deprived stations of regional characteristics.

Table 1-13 Correlation Coefficients among Stations with respect to Atmospheric Pollutant Concentrations

(SO_2)

	MS 1	MS 2	MS 3	MS 4	MS 5
MS1) ONEB STATION					
MS2) POWER PLANT	-0.82				
MS3) MIN.DEP.OFFICE	0.37	0.01			
MS4) S.P.PRO.OFFICE	0.95	-0.68	0.39		
MS5) H.& I.ESTATE	0.60	0.31	-0.94	0.59	

(NO_x)

	MS 1	MS 2	MS 3	MS 4	MS 5
MS1) ONEB STATION					
MS2) POWER PLANT	-0.62				
MS3) MIN.DEP.OFFICE	-0.22	-0.11			
MS4) S.P.PRO.OFFICE	0.52	-0.68	0.60		
MS5) H.& I.ESTATE	0.93	-0.72	-0.18	0.43	

(NO_2)

	MS 1	MS 2	MS 3	MS 4	MS 5
MS1) ONEB STATION					
MS2) POWER PLANT	-0.00				
MS3) MIN.DEP.OFFICE	-0.44	0.80			
MS4) S.P.PRO.OFFICE	-0.34	0.30	0.70		
MS5) H.& I.ESTATE	-0.38	-0.30	0.24	0.82	

(SPM)

	MS 1	MS 2	MS 3	MS 4	MS 5
MS1) ONEB STATION					
MS2) POWER PLANT	0.87				
MS3) MIN.DEP.OFFICE	0.86	1.00			
MS4) S.P.PRO.OFFICE	0.99	0.86	0.84		
MS5) H.& I.ESTATE	0.97	0.92	0.91	0.94	