THE REPORT ON ENVIRONMENTAL EFFECTS OF COAL FIRING POWER STATIONS AND INTEGRATED STEEL MILL IN THE REPUBLIC OF SINGAPORE VOLUME II – AIR QUALITY

JULY 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Republic of Singapore, the Government of Japan decided to conduct a study on the Environmental Effects of the Planned Coal-Firing Power Stations and Integrated Steel Mill and entrusted the study to the Japan International Cooperation Agency (JICA).

The JICA has carried out a field survey on water quality from February to March, 1981 and submitted a report on the study to the Government of Singapore in February, 1982.

Futhermore, the JICA sent to Singapore an air quality survey team 5 times during the period between June, 1981, and July, 1982, and conducted a field survey in collaboration with the Jurong Town Corporation and the officials concerned of the Government of Singapore.

After the team returned to Japan, data analyses and simulation were conducted and the present report has been prepared.

I hope that this report will serve for environmental assessment and environmental protection measures in Singapore.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Singapore for their close cooperation extended to the team.

Tokyo, July, 1983

Keisuke Arita
President
Japan International Cooperation Agency

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SUMMARY & RESULTS

(I) Summary of Study

The Government of the Republic of Singapore has requested the Government of Japan to conduct the environmental study on the effects of coal firing power stations and integrated steel mill which will be sited in Pulau Seraya and Tekong by 1990.

In response to the request, the preliminary survey team has been dispatched to Singapore in December 1980 and the scope of work including survey items, survey schedule and so on has been discussed and entered into agreement between two parties.

Japanese survey team for water quality has carried out the field survey, and numerical simulation on COD (Chemical Oxygen Demand) and thermal effluent during February to December 1981 and in February 1982 the report on water quality has been submitted.

As for the air quality, Japanese survey team stayed in Singapore for 30 days during June 15th to July 14th 1981 for (1) establishing 7 monitoring stations in the survey area, (2) installation and adjustment of instruments and (3) training on handling and maintenance of instruments.

During the above period, Japanese team has conducted the study on vertical distribution of wind direction and velocity for two days and at 2 points.

Through-year monitoring of SO_2 ambient concentration, wind direction & velocity, solar & net radiation and temperature has been carried out during July 15th 1981 to July 14th 1982 under the maintenance control by Singapore side. During the period, calibration and adjustment of instruments have been performed by Japanese team for 4 times, and the data on present emission sources have been collected.

The data obtained through the field survey and collected from the competent Authorities have been processed and analyzed, and SO_2 diffusion simulation has been carried out during August to December 1982. The results of these study have been compiled into the report.

The flow chart of environmental study on air quality is shown in Fig. (I)-1 and the outline of field survey are shown in Table (I)-1. Table (I)-2 shows total schedule of field survey.

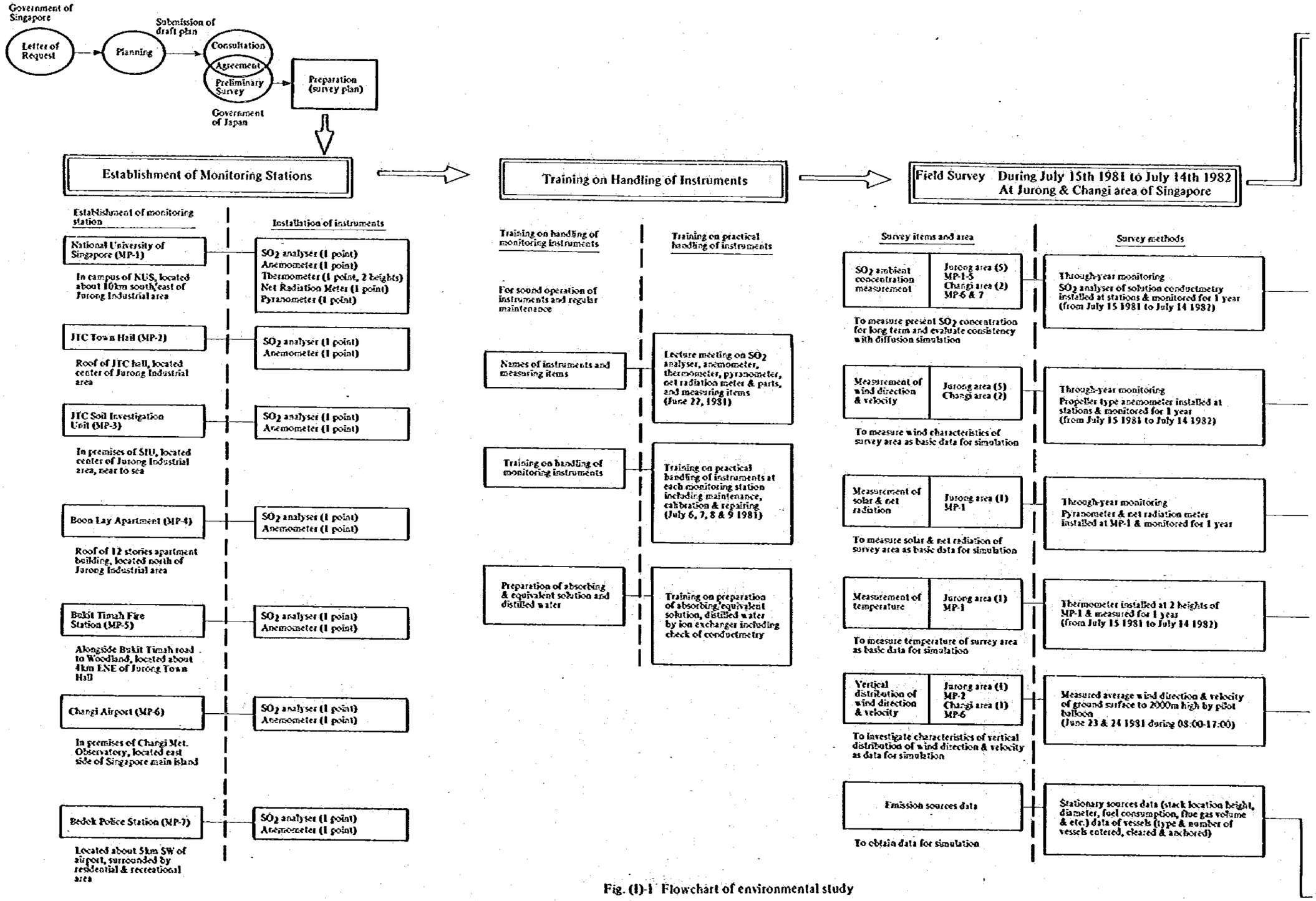


Fig. (I)-1 Flowchart of environmental study

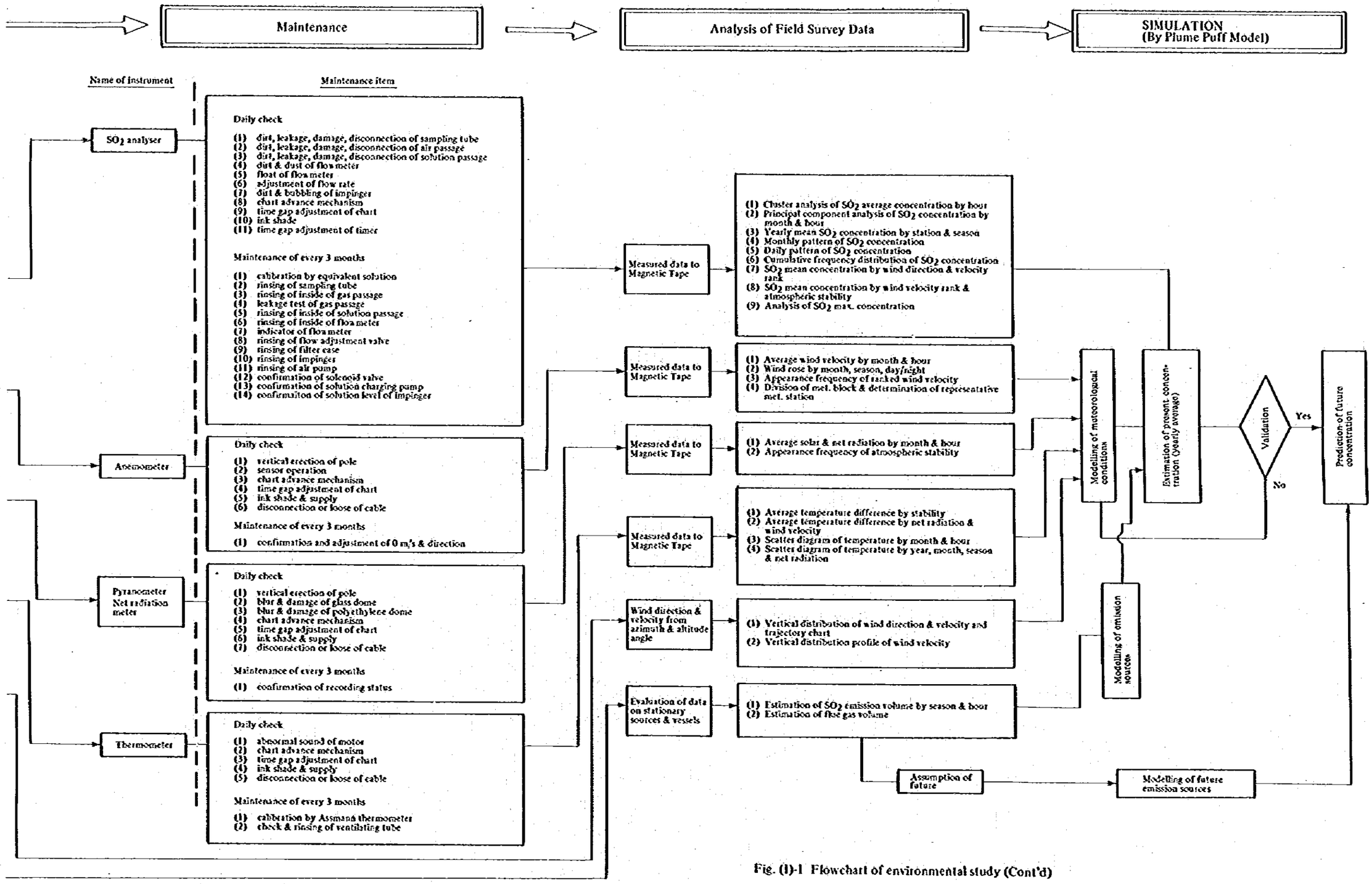


Fig. (I)-1 Flowchart of environmental study (Cont'd)

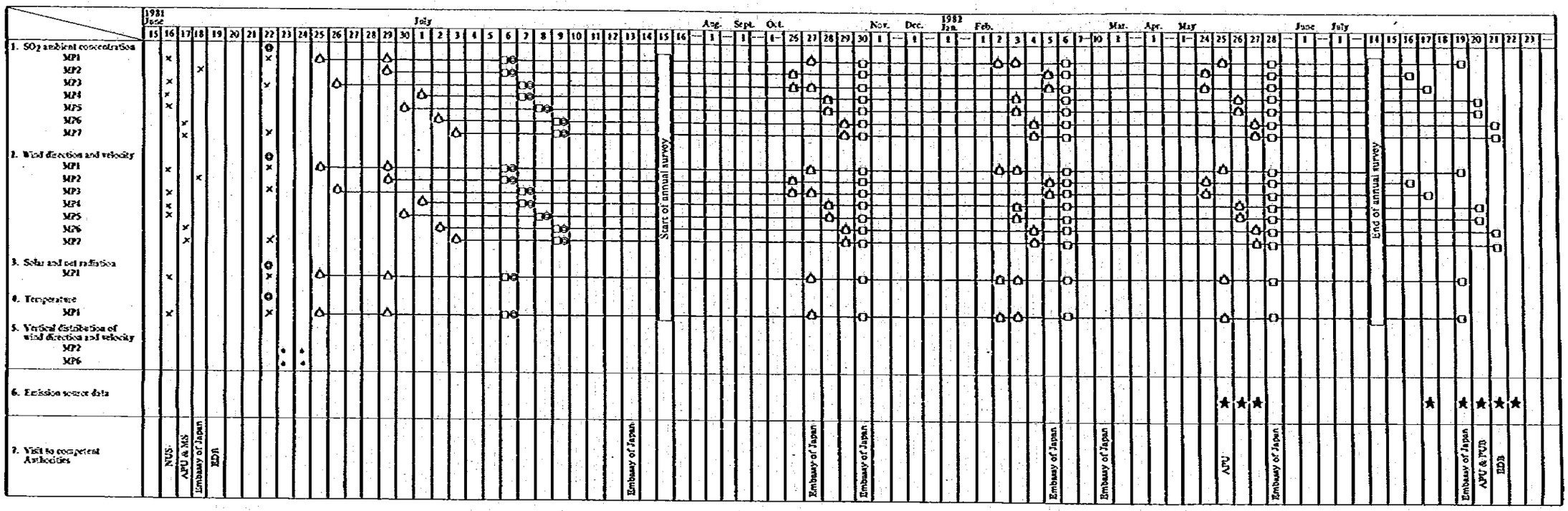
Table (I)-1 Outline of field survey

Survey item	Survey point	Monitoring height	Survey period	Survey method	Training on instrument handling
1. SO_2 ambient concentration	Jurong area National University of Singapore (MP-1) JTC Hall (MP-2) JTC SIU (MP-3) Boon Lay Apartment (MP-4) Bukit Timah Fire Station (MP-5) Changi area Changi Airport (MP-6) Bedok Police Station (MP-7)	2m from ground 20.5m from ground 2m from ground 45m from ground 4m from ground 2m from ground 2.5m from ground	July 15th 1981 to July 14th 1982	SO_2 analyzer of solution conductmetry installed and measured one hour value continuously.	Training on instrument handling, measurement principles, preparation of absorbing & equivalent solution and distilled water
2. Wind direction and velocity	Jurong area NUS (MP-1) JTC Hall (MP-2) JTC SIU (MP-3) Boon Lay Apt (MP-4) Bukit Timah (MP-5) Changi area Airport (MP-6) Bedok (MP-7)	10m from ground 29m from ground 10m from ground 51m from ground 10m from ground 6m from ground 13m from ground	July 15th 1981 to July 14th 1982	Propeller type anemometers installed at stations and measured running mean of 10 minutes value continuously	Training on instruments handling, measurement principle, calibration & adjustment methods
3. Solar & net radiation	Jurong area NUS (MP-1)	1.5m from ground	July 15th 1981 to July 14th 1982	Pyranometer & net radiation meter installed and measured instantaneous & one hour value continuously	Training on instruments handling, measurement principle, calibration & adjustment methods
4. Temperature	Jurong area NUS (MP-1)	1.5m & 10m from ground	July 15th 1981 to July 14th 1982	Thermometer installed at MP-1 and measured instantaneous value continuously	Training on instrument handling, measurement principle, adjustment methods
5. Vertical distribution of wind direction and velocity	Jurong area JTC Hall (MP-2) Changi area Airport (MP-6)	up to 2,000m from ground, each 100m layer	June 23 & 24 1981	Pilot balloon having elevating capacity of 100m/40s released and measured altitude & azimuth angle by Theodolite	Training on instrument handling, measurement purpose
6. Collection of emission source data	61 factories		May 23-29 1982 July 15-24 1982	Data collected by questionnaire on stack location, number, SO_2 & flue gas volume etc.	

Establishment of monitoring stations

(1) National University of Singapore (MP-1)
A prefabricated hut built next to Dr. Pakium's meteorological laboratory in NUS campus
(2) JTC Town Hall (MP-2)
A room on roof of JTC hall (about 20m high)
(3) JTC Soil Investigation Unit (MP-3)
A prefabricated hut built in field about 50m apart from SIU building
(4) Boon Lay Apartment (MP-4)
Roof of apartment building, about 41m high, landing space used for station
(5) Bukit Timah Fire Station (MP-5)
A corner of fire station's garage used for station
(6) Changi Airport (MP-6)
A reserved room of airport met. observatory used for station
(7) Bedok Police Station (MP-7)
A prefabricated hut built next to police station

Table (I)-2 Time schedule of field survey



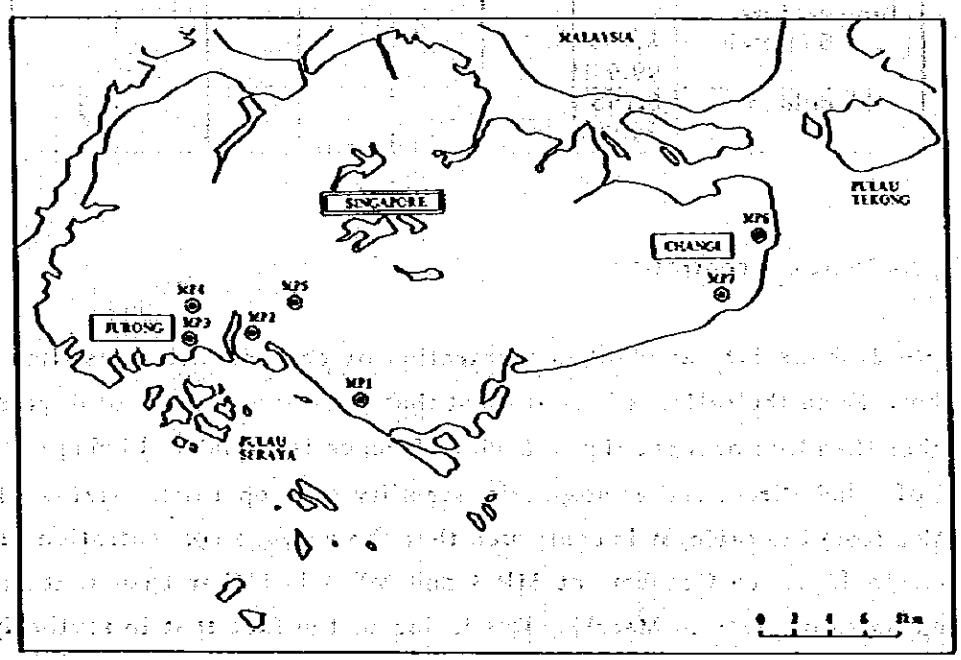
NUS: National University of Singapore
APU: Anti Pollution Unit
EDB: Economic Development Board
MS : Meteorological Service
PUB: Public Utility Board

◎ : Training on instrument handling
× : Establishment of monitoring station
○ : Installation of instrument
△ : Adjustment of instrument
□ : Inspection of instrument
— : Automatic continuous measurement
• : Study by pilot balloon
★ : Emission sources data

(II) Summary on Results of Field Survey

For the comprehensive environmental study, the prediction of future concentration of pollutants has to cover the effects of the proposed sources and also the effects of the present existing sources.

The present conditions, therefore, have to be studied in the first place and 7 monitoring stations have been established as shown in Fig. (II)-1, for monitoring SO_2 ambient concentration, and meteorological conditions (wind direction/velocity, solar & net radiation, temperature) for one year by automatic continuous monitoring instruments. Besides the above, the vertical distribution of wind direction and velocity has been studied although the term was short.



MP-1: National University of Singapore (NUS)
MP-2: JTC Town Hall
MP-3: JTC Soil Investigation Unit (SIU)
MP-4: Boon Lay Apartment
MP-5: Bukit Timah Fire Station
MP-6: Changi Airport
MP-7: Bedok Police Station

Fig. (II)-1 Location of monitoring stations

The effective measurement hours (excluding loss time for calibration, maintenance, troubles & so on) of each station classified by measuring items are shown in Table (II)-1.

At all stations, the effective measurement hours are exceeding the standard of Japan (over 6,000 hours).

Table (II)-1 Effective measurement hours of each station

Survey item	MP-1	MP-2	MP-3	MP-4	MP-5	MP-6	MP-7
SO_2 ambient concentration	8,145 93.0%	8,329 95.1%	8,411 96.0%	7,526 85.9%	8,137 92.9%	8,404 95.9%	8,151 93.0%
Wind direction and velocity	8,568 97.8%	8,316 94.9%	7,332 83.7%	8,628 98.5%	8,340 95.2%	8,544 97.5%	8,484 96.8%
Solar radiation	8,514 97.2%	—	—	—	—	—	—
Net radiation	8,667 98.9%	—	—	—	—	—	—
Temperature 1.5 m high	8,753 99.9%	—	—	—	—	—	—
10 m high	8,755 99.9%	—	—	—	—	—	—

(II)-1 SO_2 Ambient Concentration

Table (II)-2 shows SO_2 ambient concentration of each station, classified by season and day/night. From the table, it is confirmed that the concentration of daytime is about 2 times higher than that of night time. Such difference is considered being caused by the difference of wind direction, atmospheric stability and operation status of emission sources. Also from the table, it is confirmed that the average concentration of southerly monsoon season (April to October) at MP-3 and MP-4 is higher than that of northerly monsoon season (November to March). This is due to the fact that in southerly monsoon season, the appearance frequency of S wind is dominant and the effects from the emission sources located in the south direction are directly contributed.

Table (II)-2 Average SO_2 concentration of each station classified by season & day/night

Unit ppb

Station	Southerly monsoon			Northerly monsoon			Yearly average		
	Day time	Night time	Through day	Day time	Night time	Through day	Day time	Night time	Through day
(1) N.U.S.	17.5	9.4	13.1	20.7	11.7	15.8	18.8	10.4	14.2
(2) JTC HALL	18.0	11.1	14.3	18.4	12.1	15.0	18.2	11.5	14.6
(3) S.I.U.	39.3	18.5	28.0	28.4	19.8	23.7	34.8	19.0	26.2
(4) BOON LAY APARTMENT	34.1	12.8	22.3	17.8	12.9	15.0	27.8	12.8	19.4
(5) BUKIT TIMAH FIRE STATION	26.9	10.3	17.9	23.6	11.8	17.2	25.5	10.9	17.6
(6) CHANGI AIRPORT	7.7	6.0	6.8	8.7	4.9	6.6	8.1	5.5	6.7
(7) BEDOK POLICE STATION	11.3	7.6	9.3	9.6	5.2	7.2	10.6	6.6	8.4

Fig. (II)-2 shows an areal distribution of yearly average SO_2 concentration. From the figure, the ambient concentration is higher in Jurong industrial area and its surrounding area, and lower in Changi and its surrounding area.

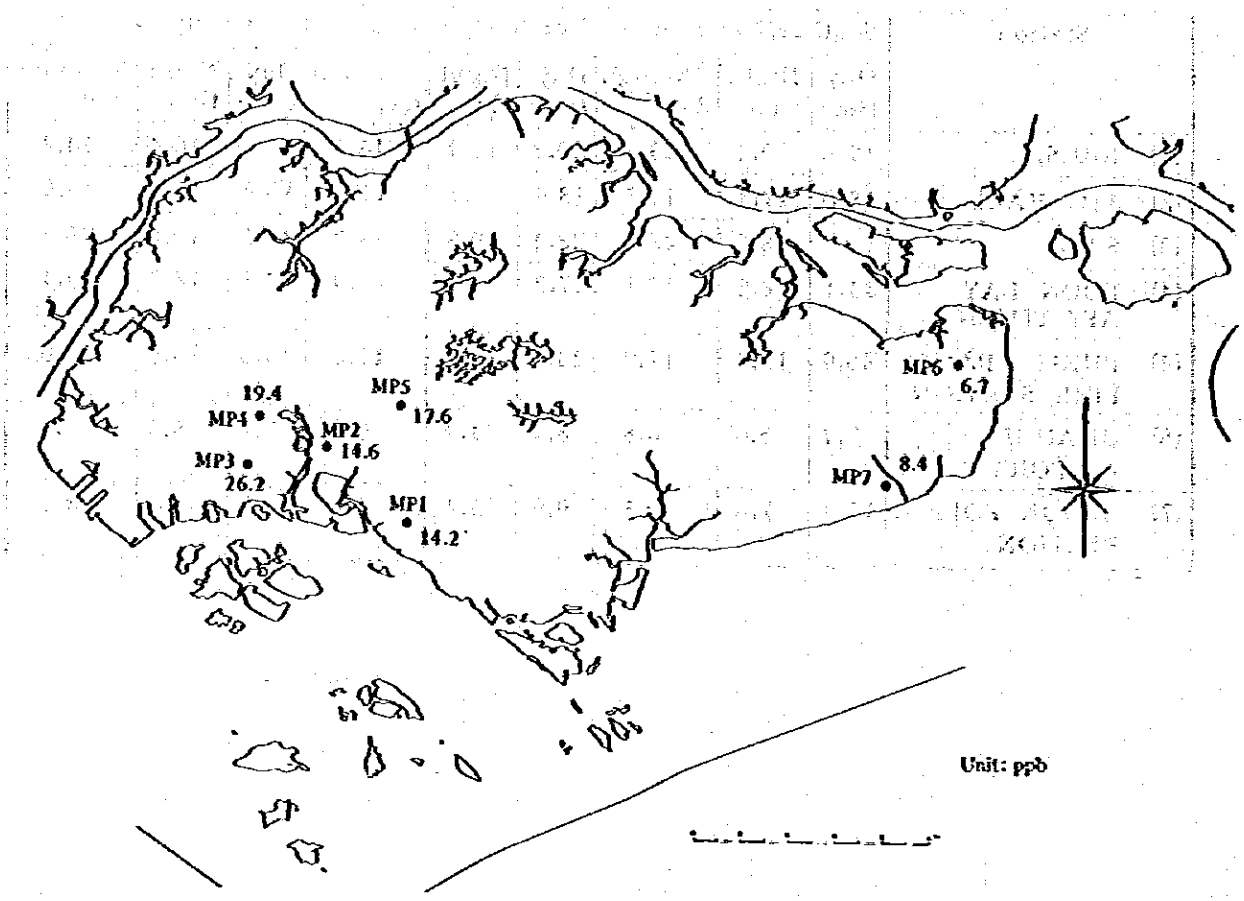
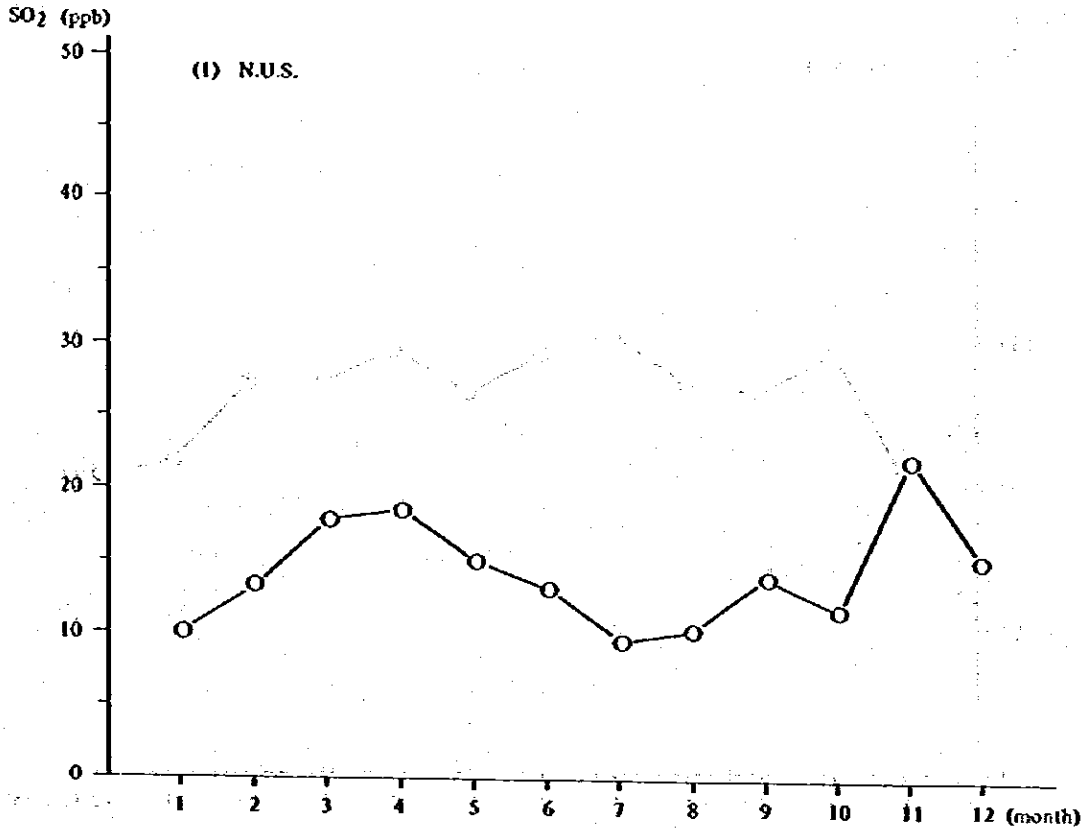


Fig. (II)-2 Areal distribution of SO_2 ambient concentration (yearly average)

Fig. (II)-3 shows time series monthly average concentration of each station. From the figure, it is found that at stations except MP-3 and MP-4, the period of March to May and September to January are indicating two peaks. In case of MP-3 and MP-4, during the period of February to October, the concentration is high and during the period of November to January, the concentration is lower compared with the former period. The difference between MP-3 and MP-4 and the remaining stations are caused by the fact that MP-3 and MP-4 are located in downwind direction of major emission sources when the wind direction is SE-S. In case of other stations, they are located in downwind of major emission sources when the wind direction is SSW-WSW, which is not the dominant wind directions.



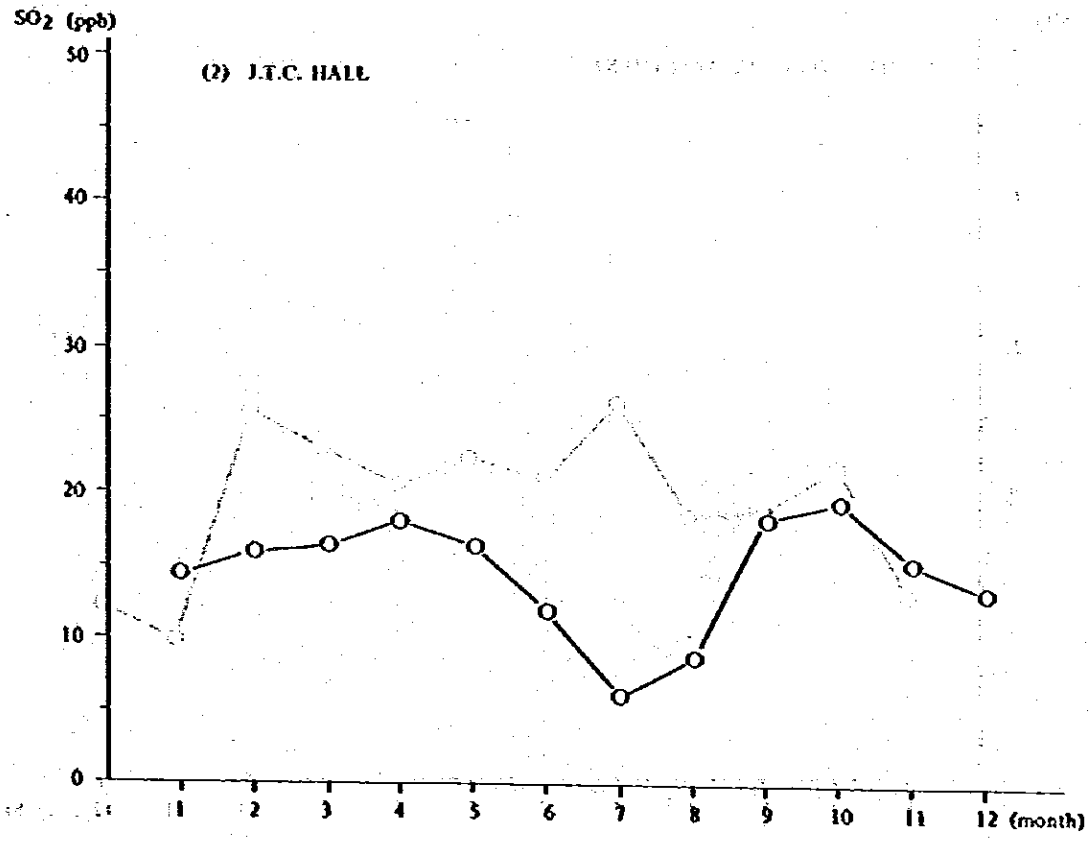
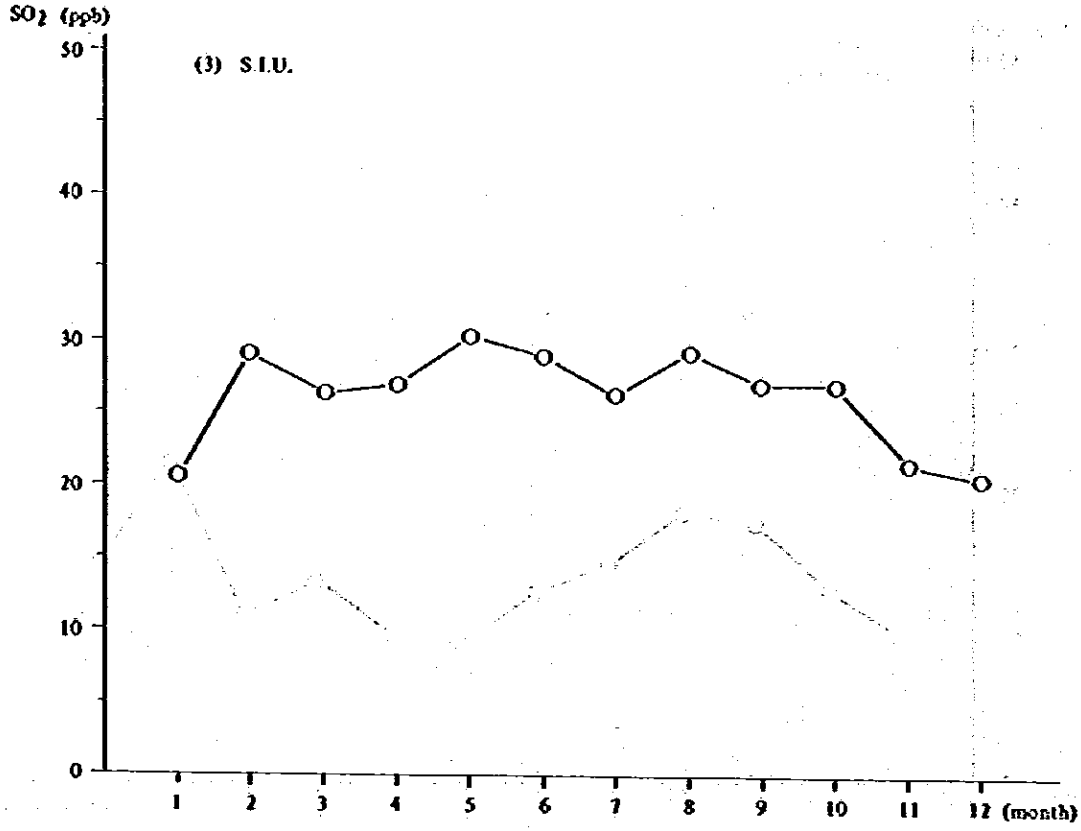


Fig. (II)-3-(1) Time series monthly SO_2 average concentration



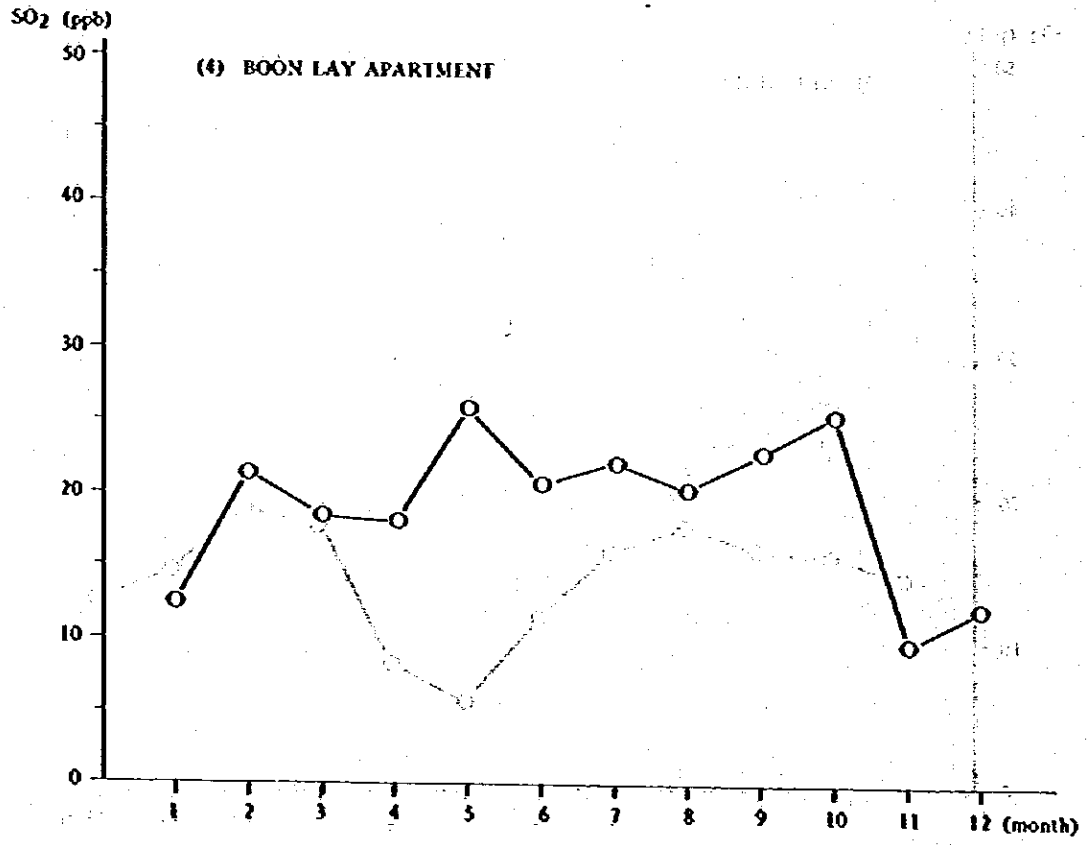


Fig. (II)-3-(2) Time series monthly SO_2 average concentration

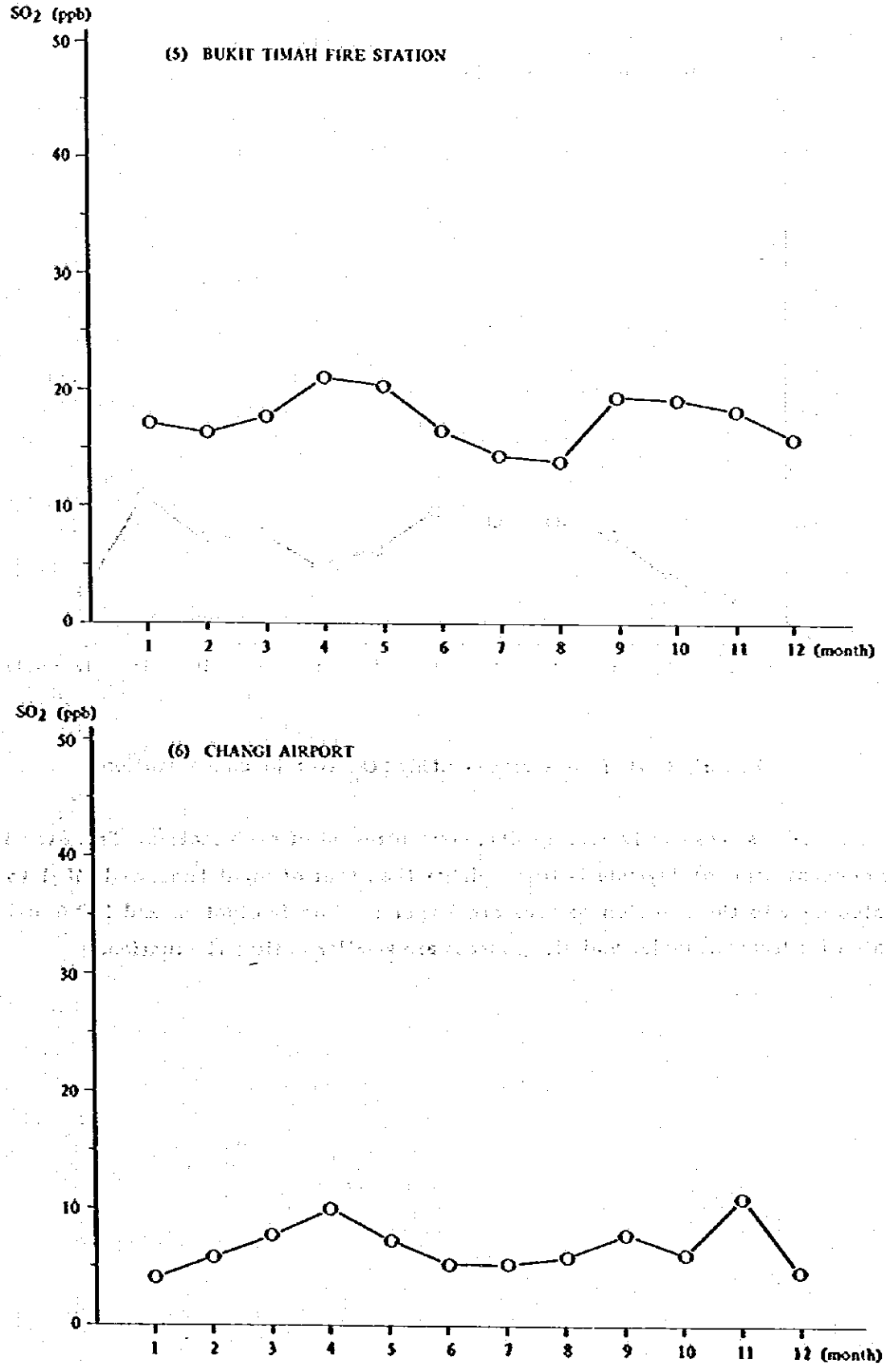


Fig. (II)-3-(3) Time series monthly SO_2 average concentration

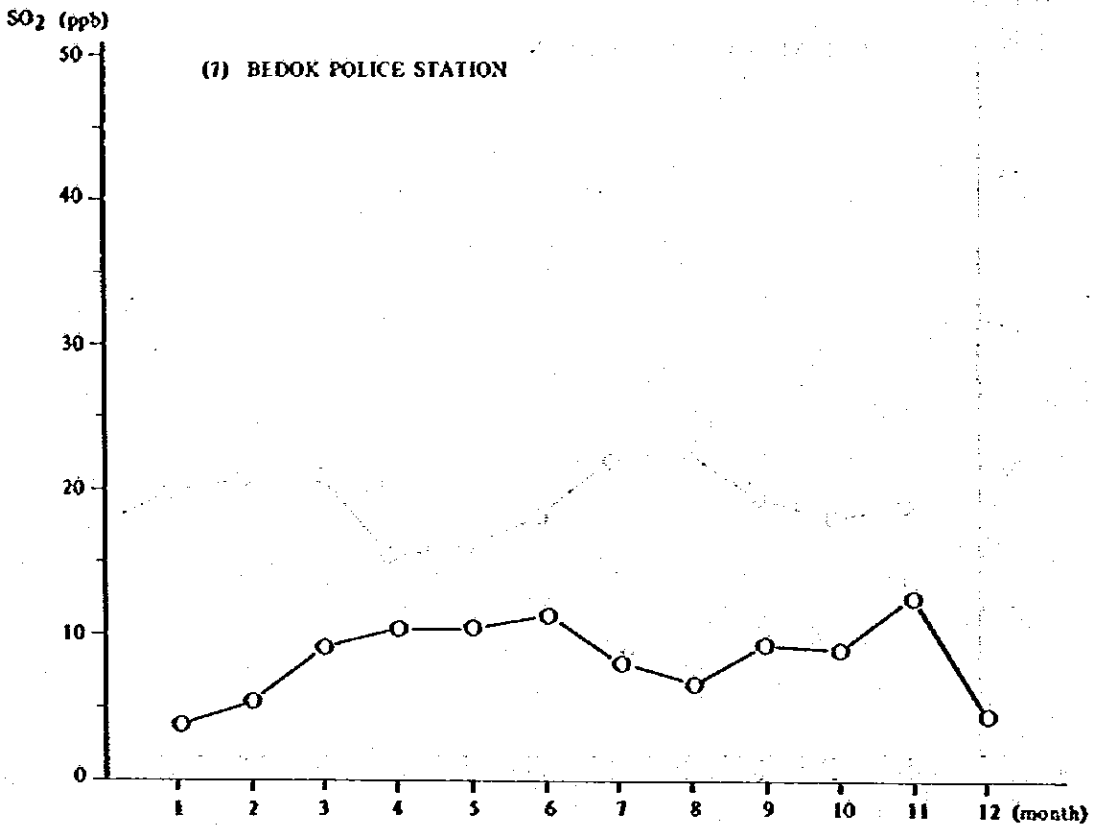


Fig. (II)-3-(4) Time series monthly SO_2 average concentration

Fig. (II)-4 shows hourly average SO_2 concentration of each station. From the figure, the concentration of daytime is found higher than that of night time, and MP-1 to MP-5 located near to the emission sources are larger in time fluctuation and MP-6 and MP-7 located far from the major emission sources are smaller in time fluctuation.

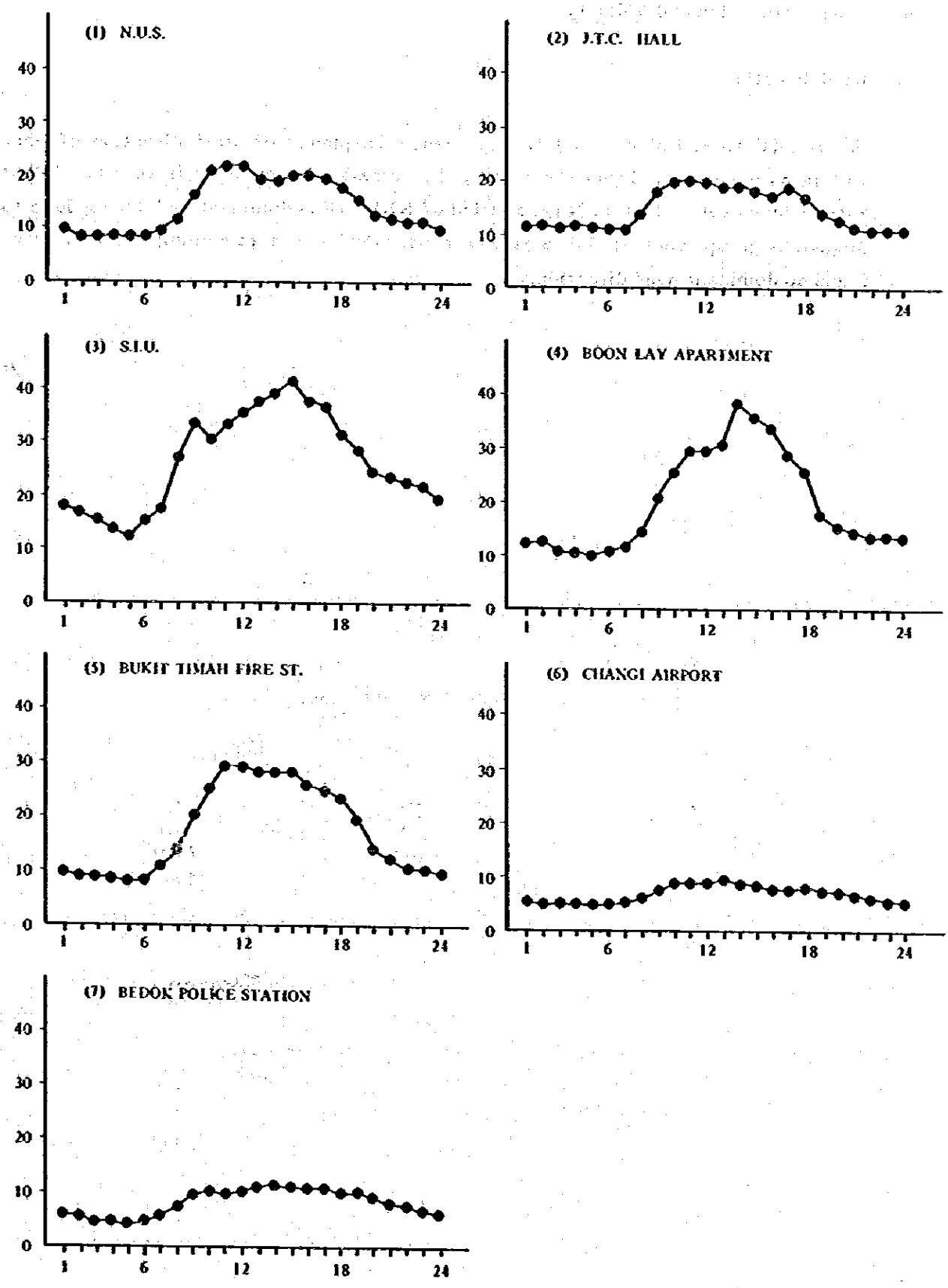
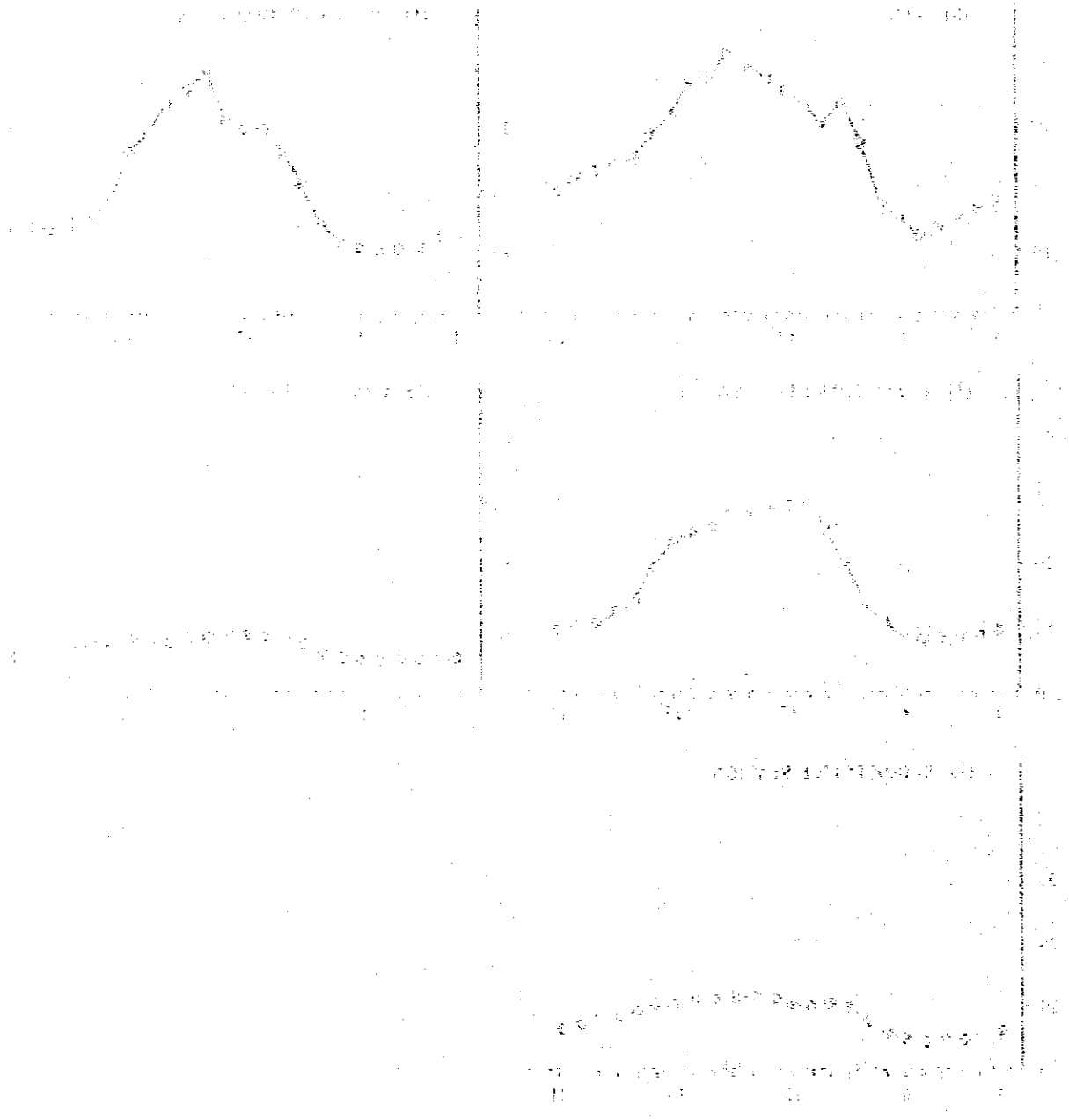


Fig. (II)-4 Hourly average SO_2 concentration

(II)-2 Wind Direction and Velocity

(1) Wind direction

Fig. II-5-(1) to -(7) show monthly appearance frequency of wind direction of each station as wind rose. From the figure, the remarkable tendency is confirmed that during December to March, N group wind of NNW-NE is dominant and during June to August, S group wind of SSE-S is dominant. During the remaining months, there found no dominant wind direction.



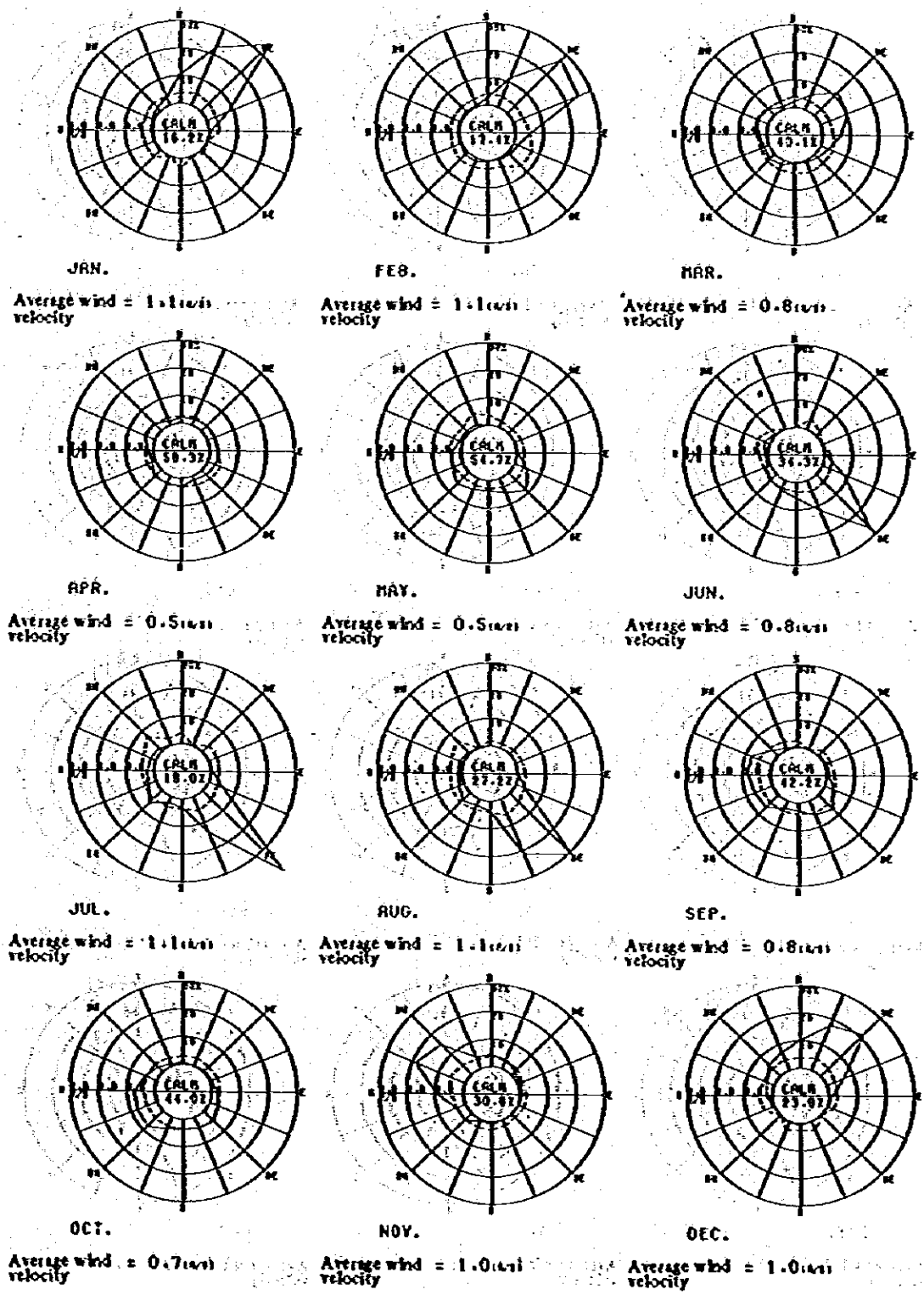


Fig. (II)-5-(1) Monthly wind rose at MP-1

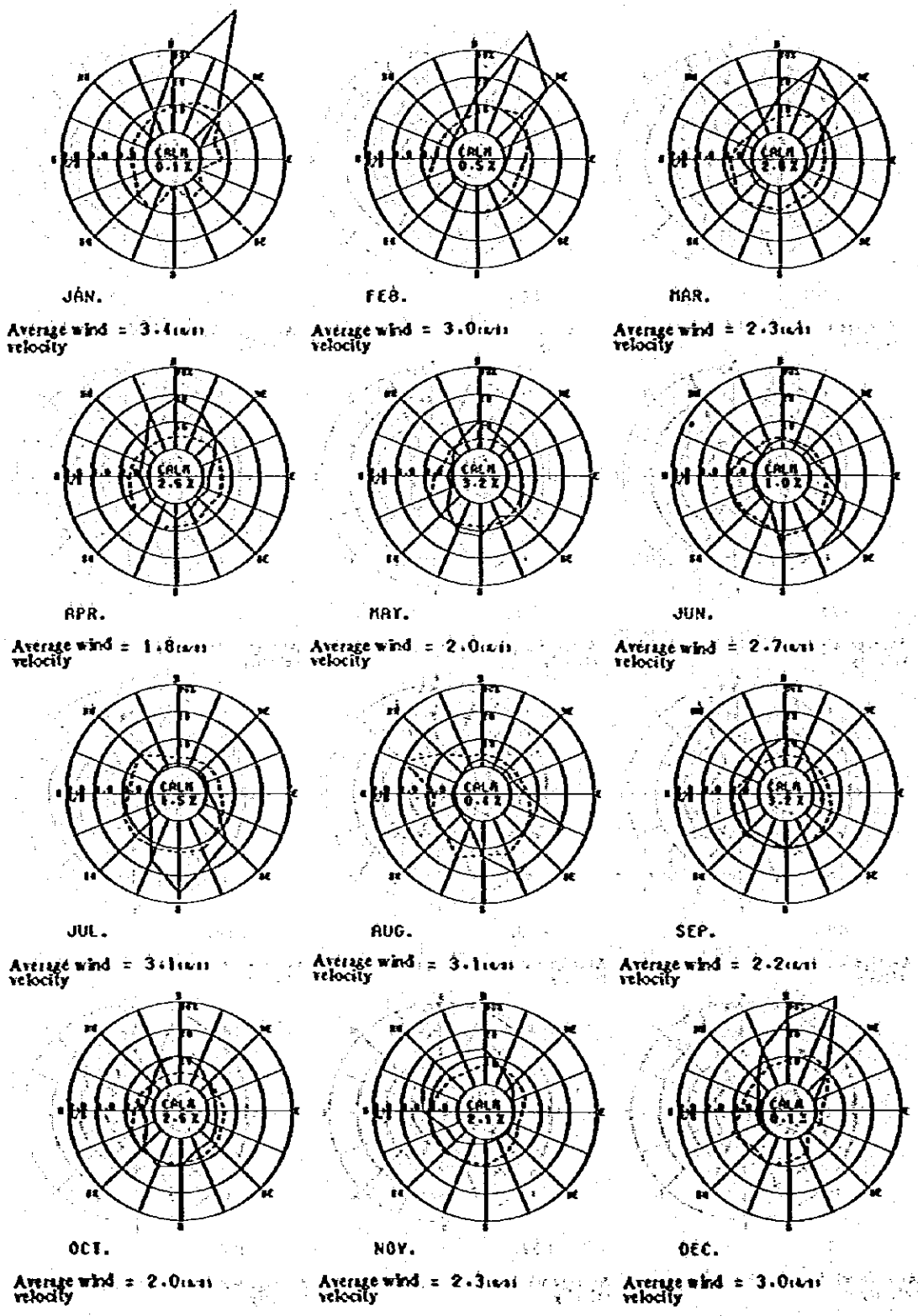


Fig. (II)-5-(2) Monthly wind rose at MP-2

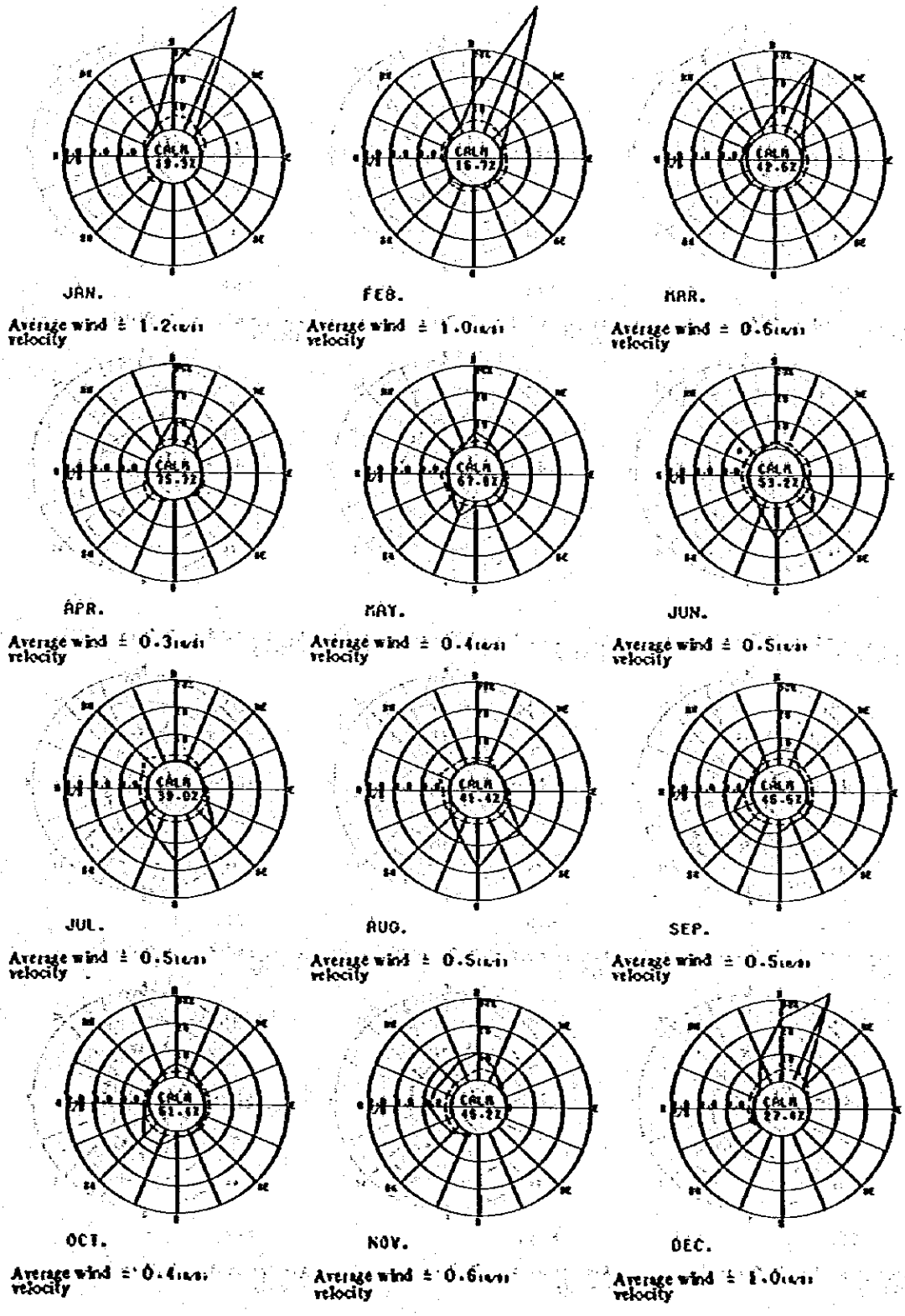


Fig. (II)-5-(3) Monthly wind rose at MP-3

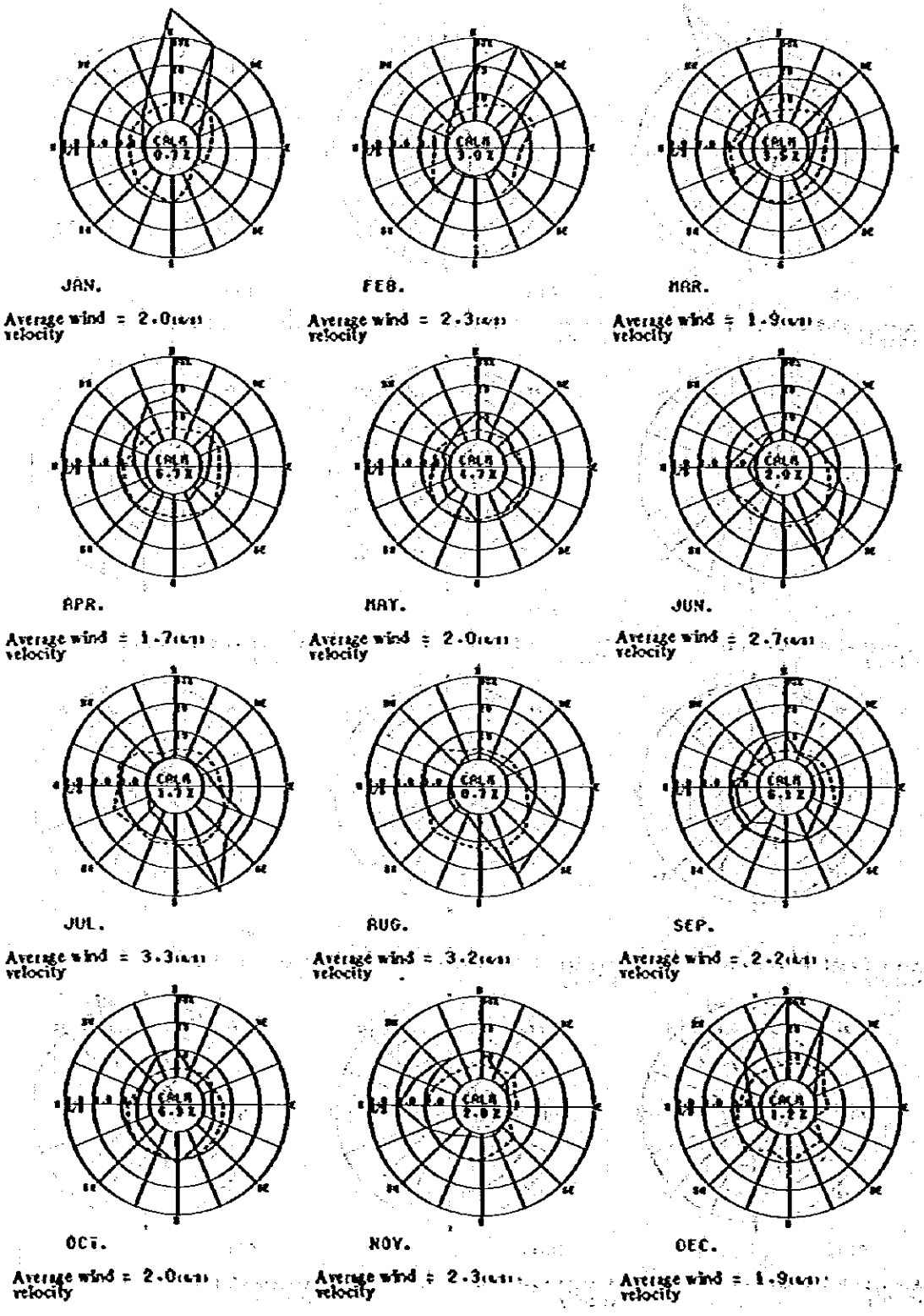


Fig. (II)-5-(4) Monthly wind rose at MP-4

5 BUKIT TIMAH FIRE ST.

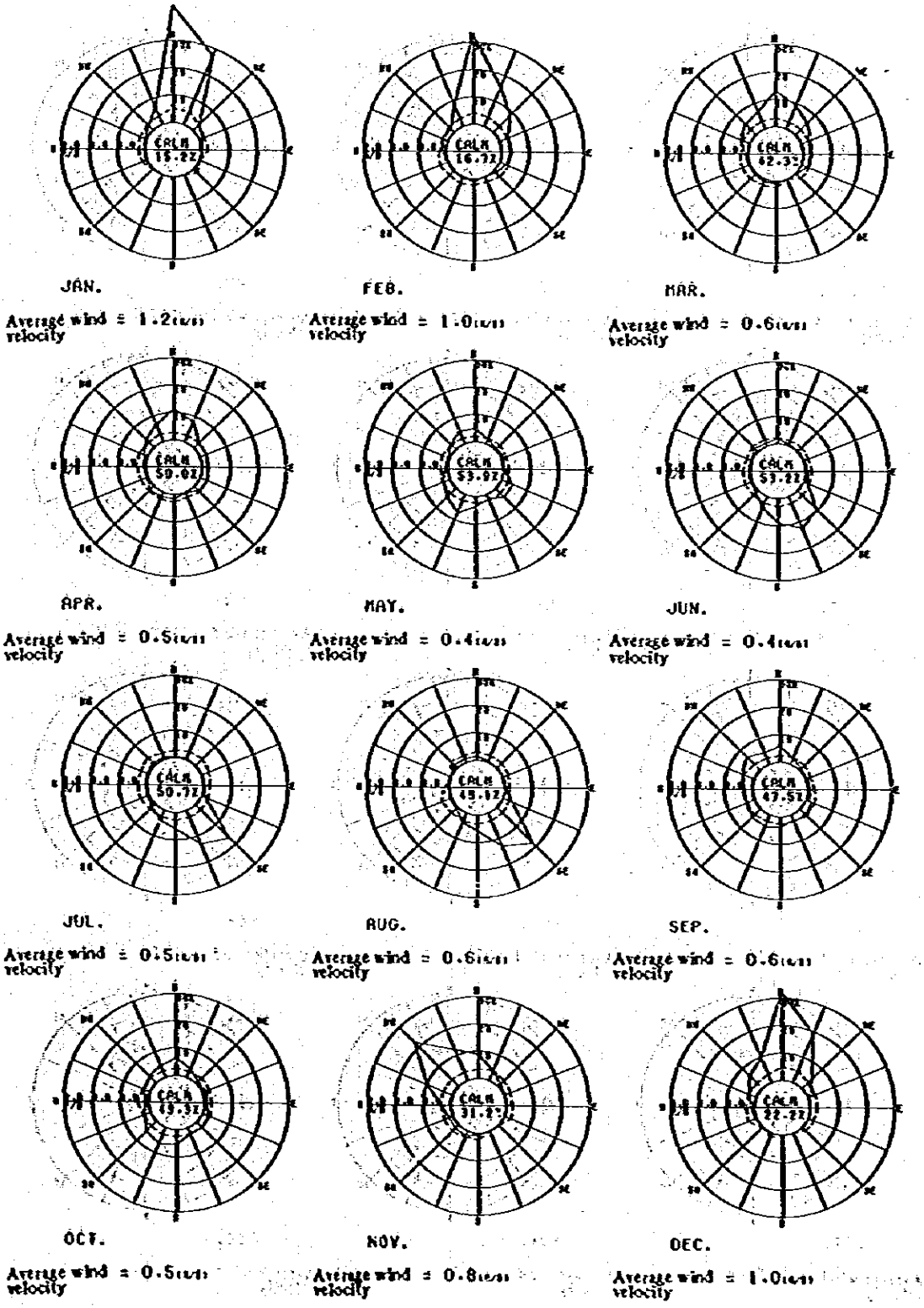
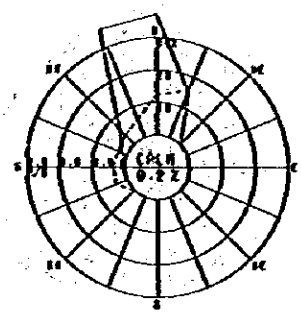
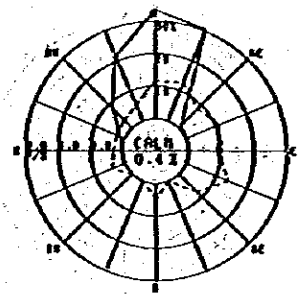


Fig. (II)-5-(5) Monthly wind rose at MP-5



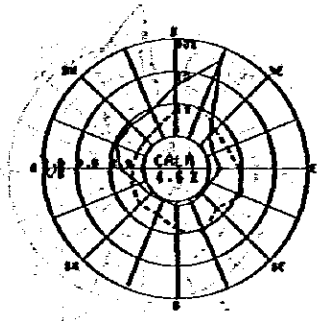
JAN.

Average wind velocity = 2.9m/s



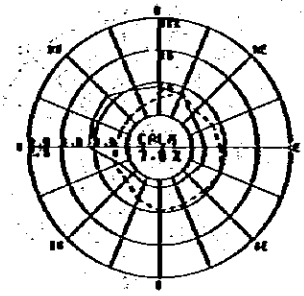
FEB.

Average wind velocity = 2.9m/s



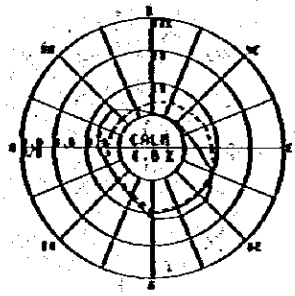
MAR.

Average wind velocity = 2.0m/s



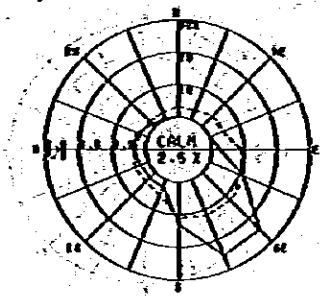
APR.

Average wind velocity = 1.5m/s



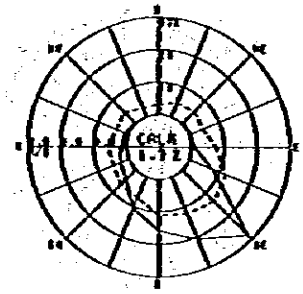
MAY.

Average wind velocity = 2.0m/s



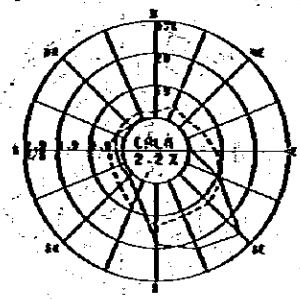
JUN.

Average wind velocity = 3.0m/s



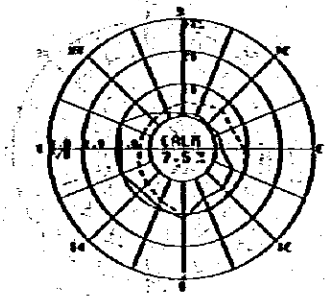
JUL.

Average wind velocity = 3.3m/s



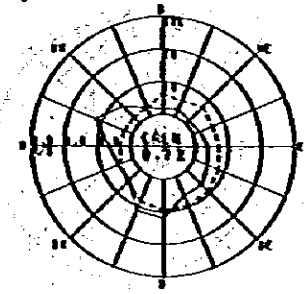
AUG.

Average wind velocity = 3.3m/s



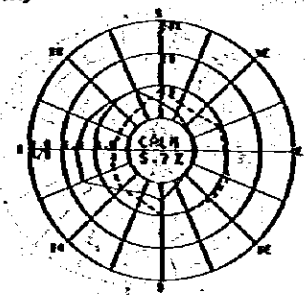
SEP.

Average wind velocity = 1.8m/s



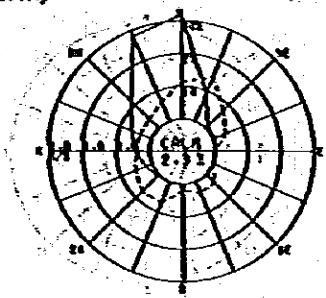
OCT.

Average wind velocity = 1.7m/s



NOV.

Average wind velocity = 1.5m/s



DEC.

Average wind velocity = 2.4m/s

Fig. (II)-5-(6) Monthly wind rose at MP-6

7 BEOOK POLICE STATION

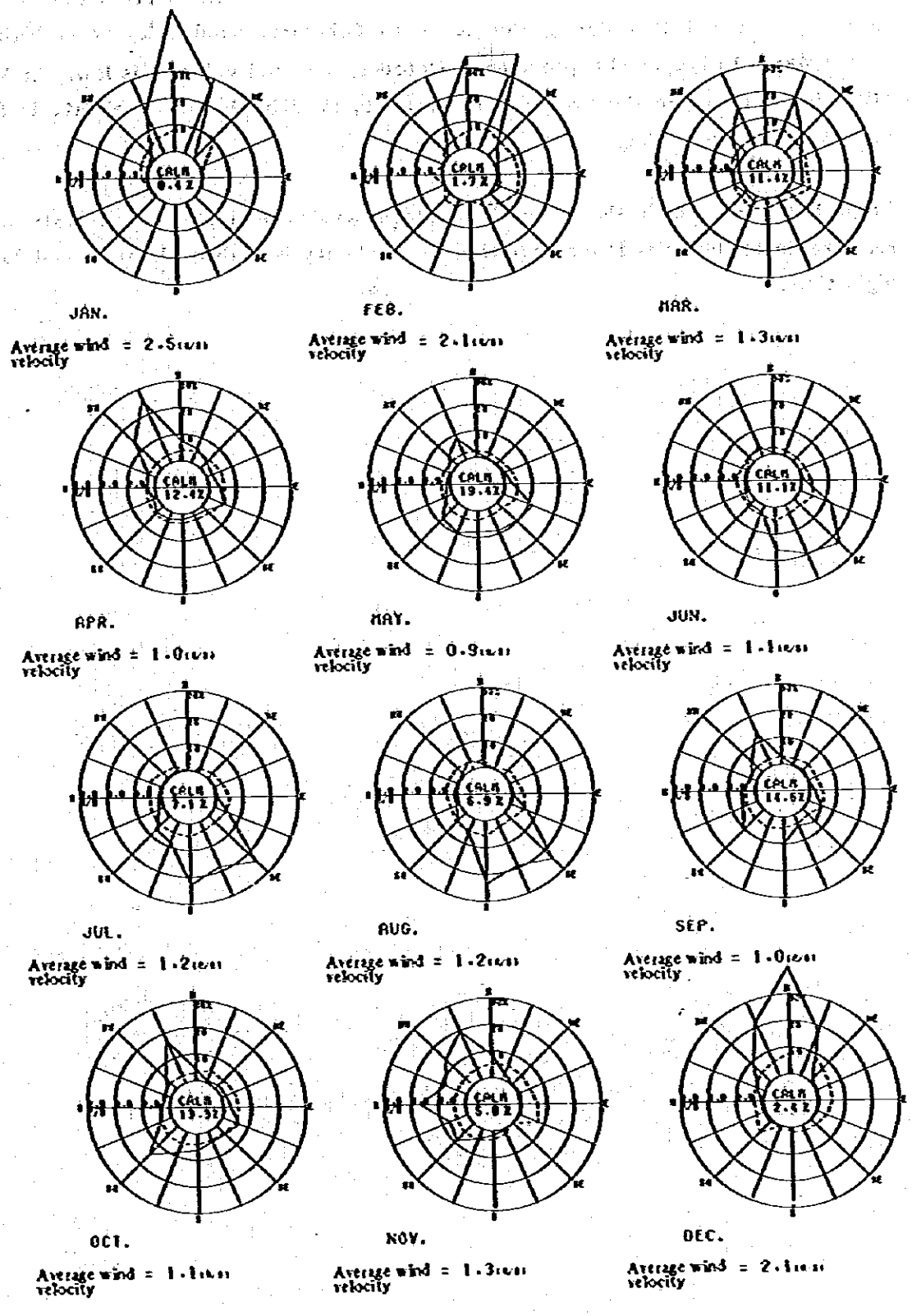


Fig. (II)-5-(7) Monthly wind rose at MP-7

(2) Wind velocity

Fig. (II)-6 shows monthly average wind velocity of each station. From the figure, a tendency is found that during December to February, wind velocity is high and during March to May, and September to October, the wind velocity is low. At MP-2, MP-4 & MP-6, where the average wind velocity is high, the wind velocity is found high even in July and August.

From Fig. (II)-7 which shows hourly average wind velocity of each station, the remarkable tendency is found that the wind velocity is high in daytime and low in night time.

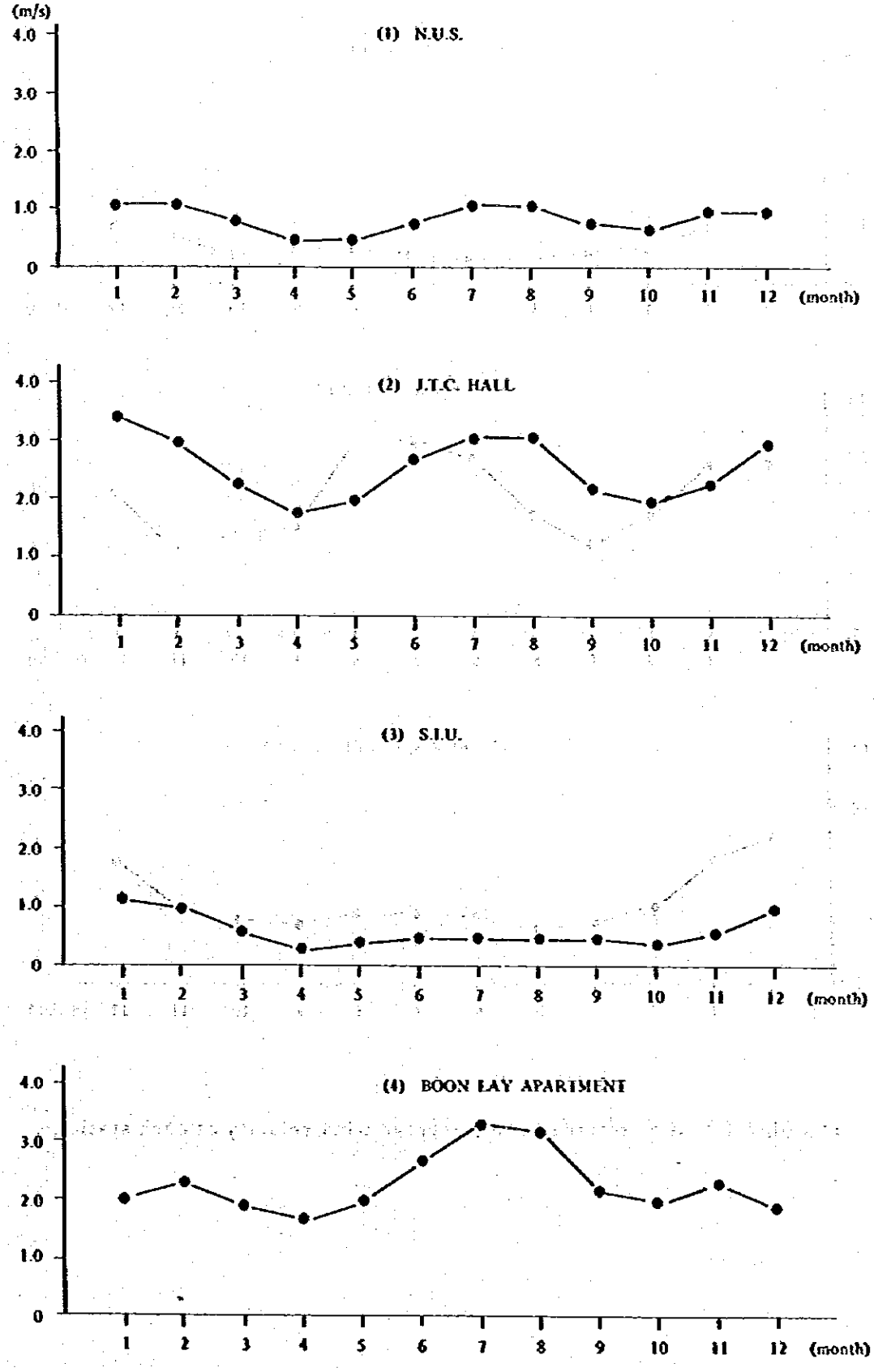


Fig. (II)-6-(1) Time series monthly average wind velocity of each station

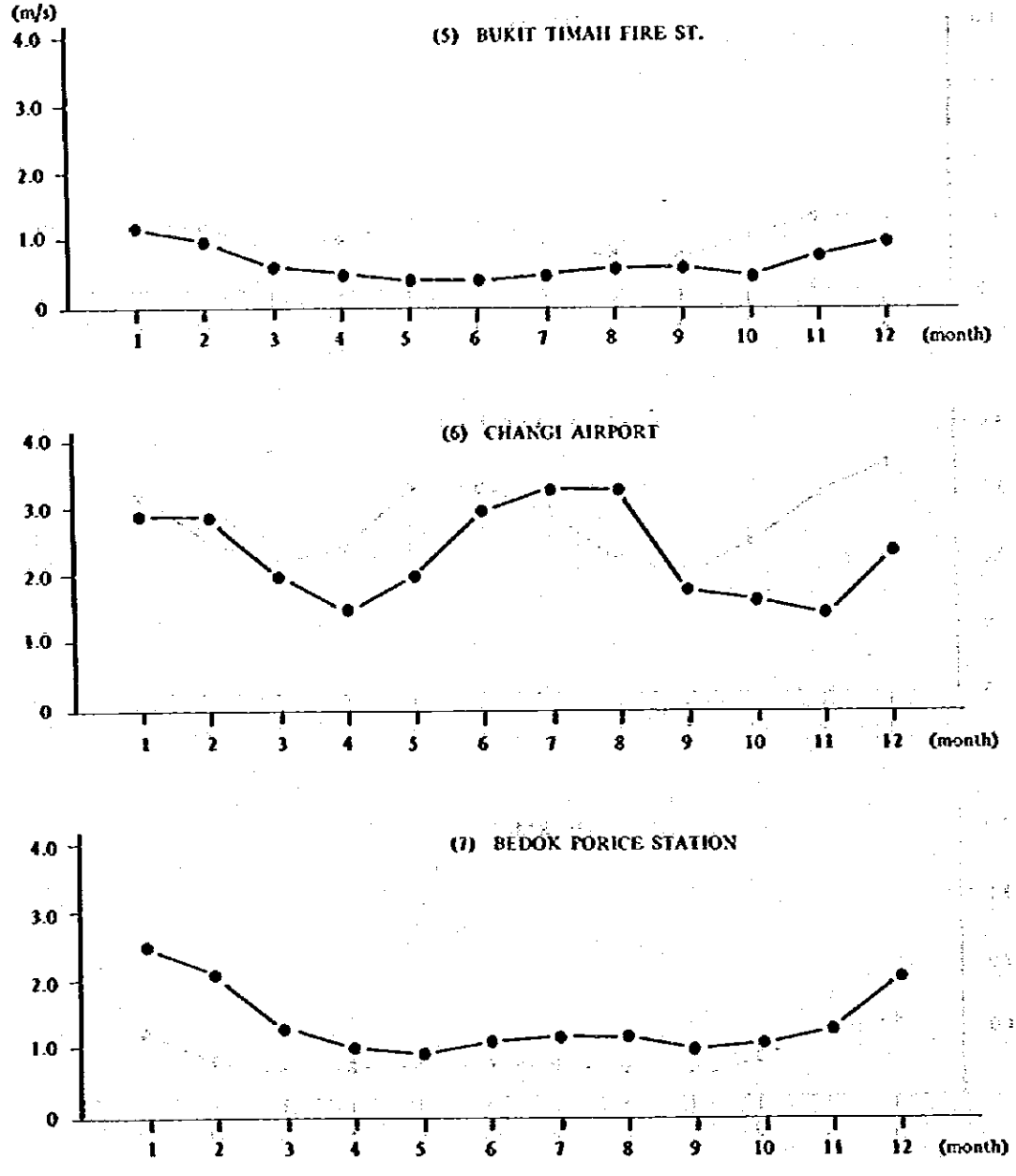


Fig. (II)-6-(2) Time series monthly average wind velocity of each station

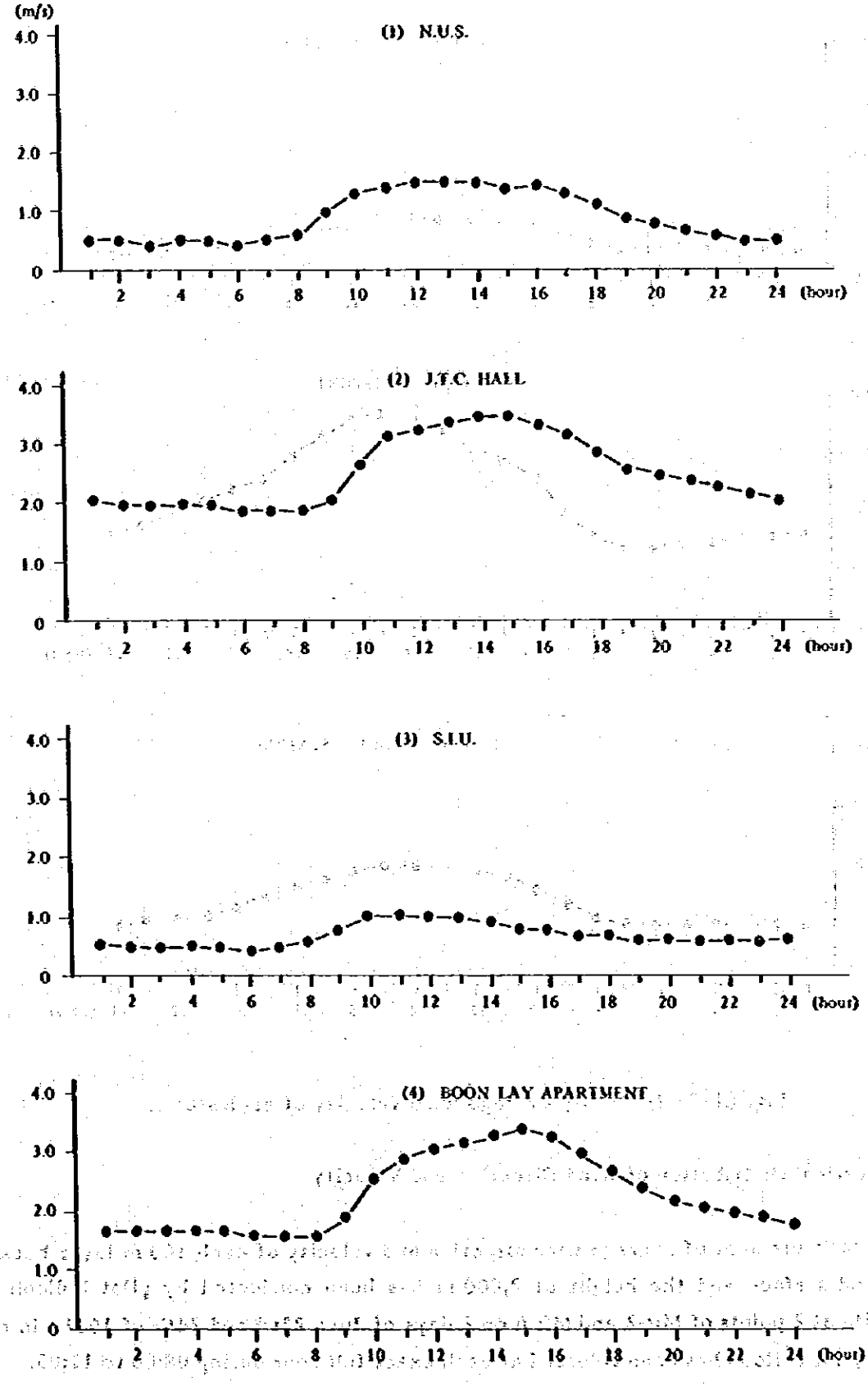


Fig. (II)-7-(1) Hourly average wind velocity of each station

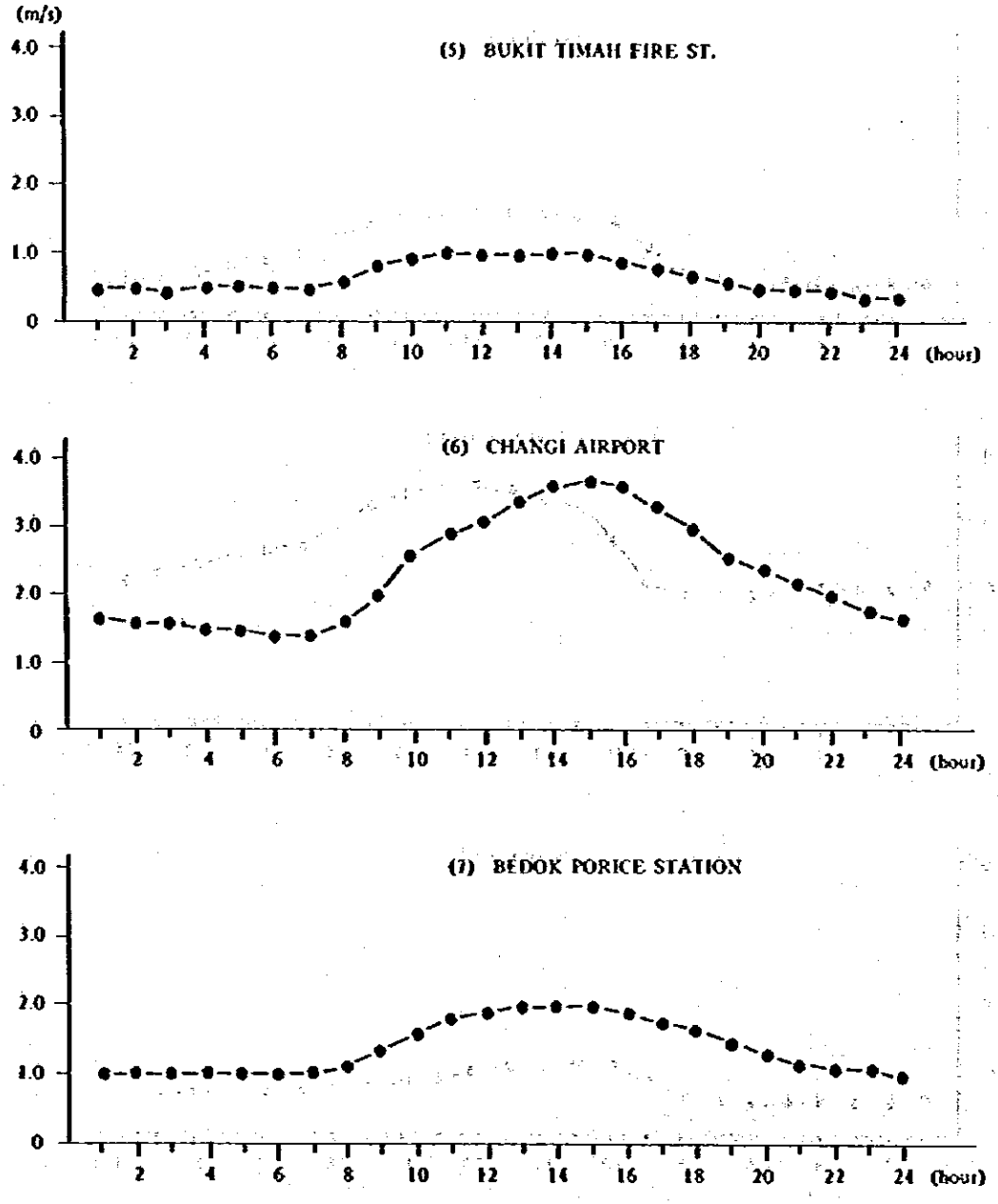


Fig. (II)-7-(2) Hourly average wind velocity of each station

(II)-3 Vertical Distribution of Wind Direction and Velocity

The measurement of average wind direction and velocity of each 100 m layer between the ground surface and the height of 2,000 m has been conducted by pilot balloon and Theodolite at 2 points of MP-2 and MP-6 on 2 days of June 23rd and 24th of 1981. In each day, the pilot balloon has been released at each exact full hour during 08:00 to 17:00.

Fig. (II)-8-(1) to -(4) is isopleth diagram on which the wind direction and velocity are plotted. The vertical axis represents height and horizontal axis represents time in the diagram.

From the figure, the clear difference of wind direction is found between ground surface and upper layers. As for the wind velocity, the general tendency (wind velocity increases with height) is not found and the difference of wind velocity between ground surface and upper layers is also not found.

Judging from the fact that the above study has been performed only for 2 days, the above tendency is considered not representing general tendency of Singapore in terms of vertical distribution of wind direction and velocity.

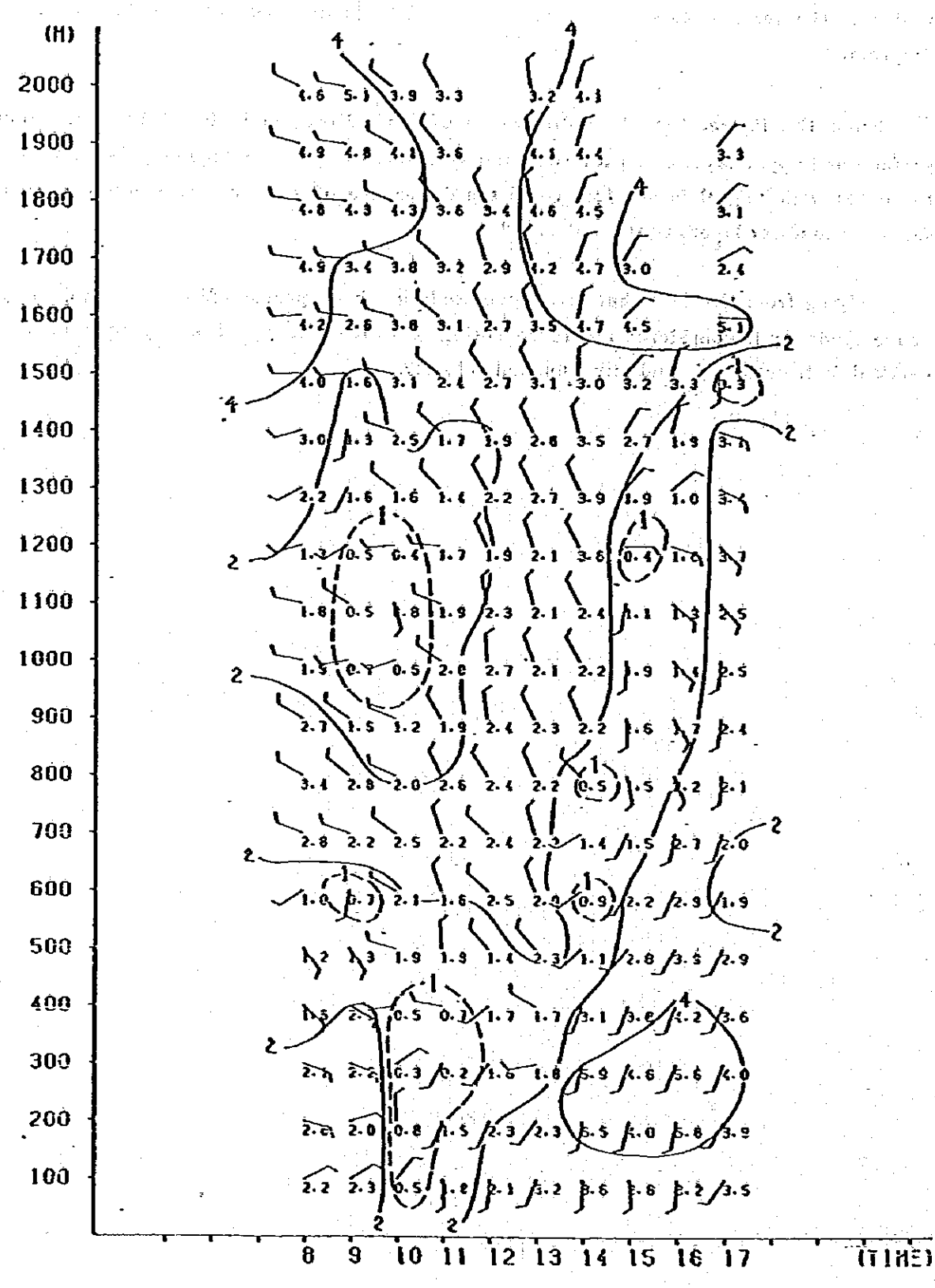


Fig. (10-8-(1) Isopleth diagram of wind direction and velocity (June 23rd, 1981 at MP-2)

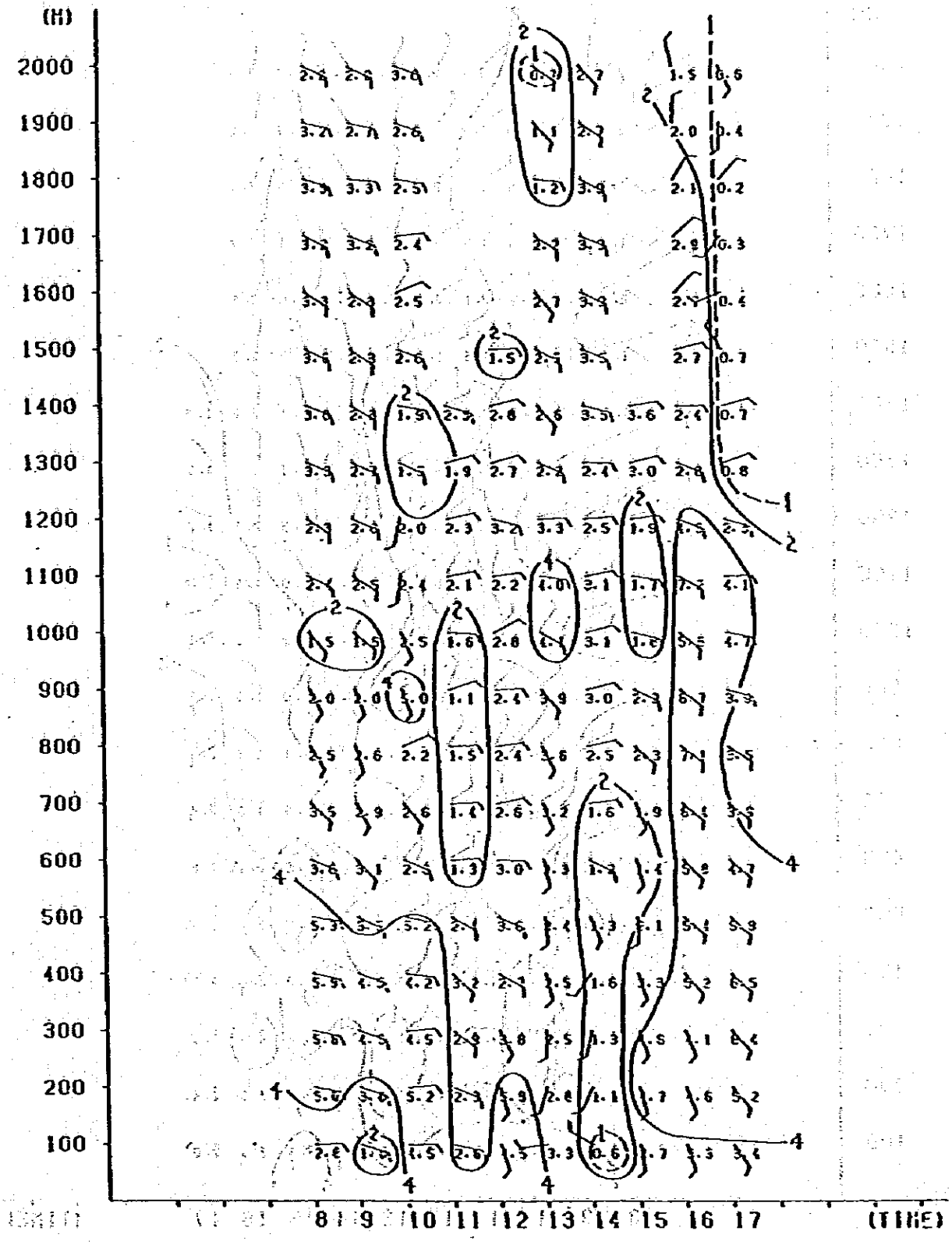


Fig. (II)-8-(2) Isopleth diagram of wind direction and velocity (June 24th, 1981 at MP-2)

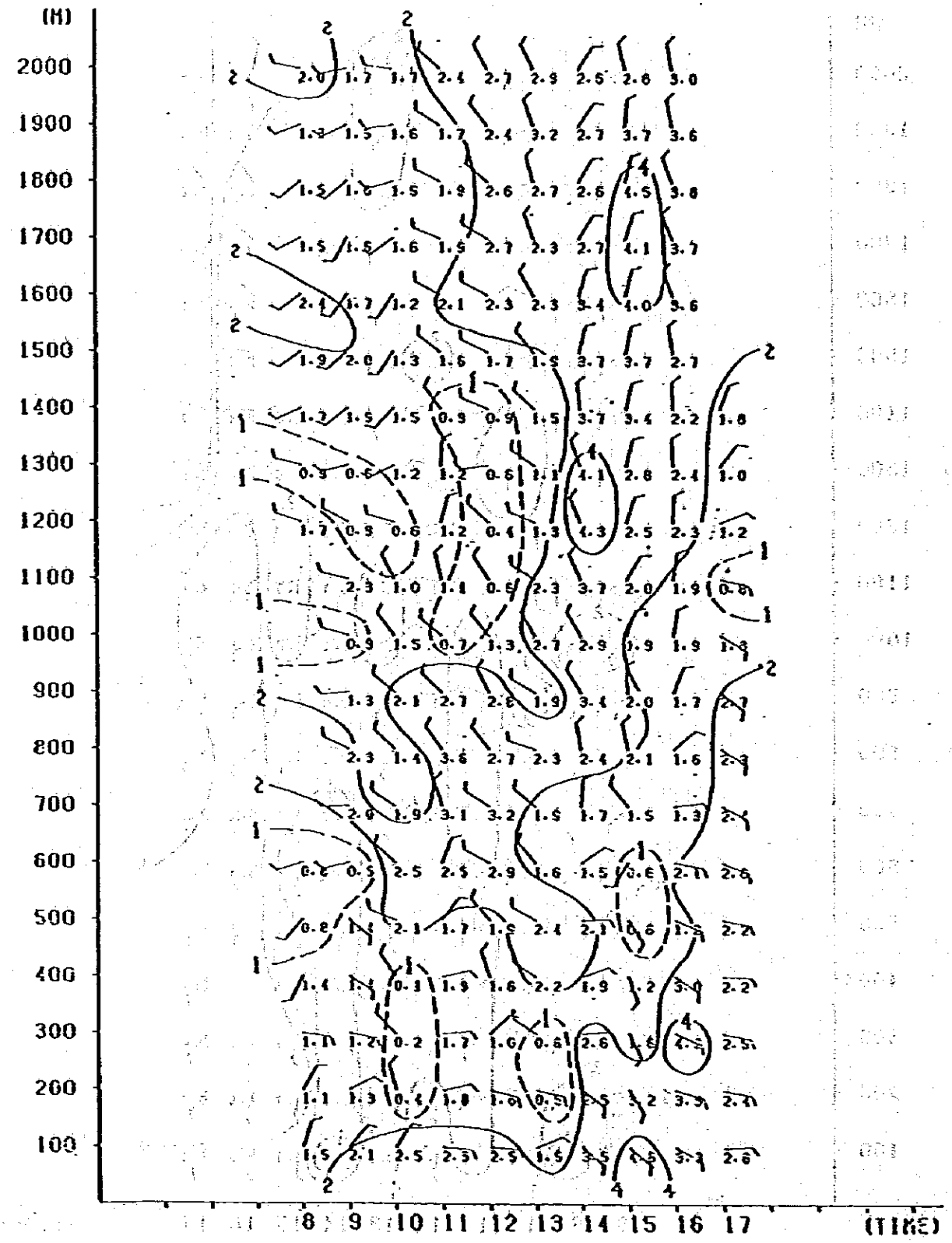


Fig. (II-8-(3) Isopleth diagram of wind direction and velocity (June 23rd, 1981 at MP-6)

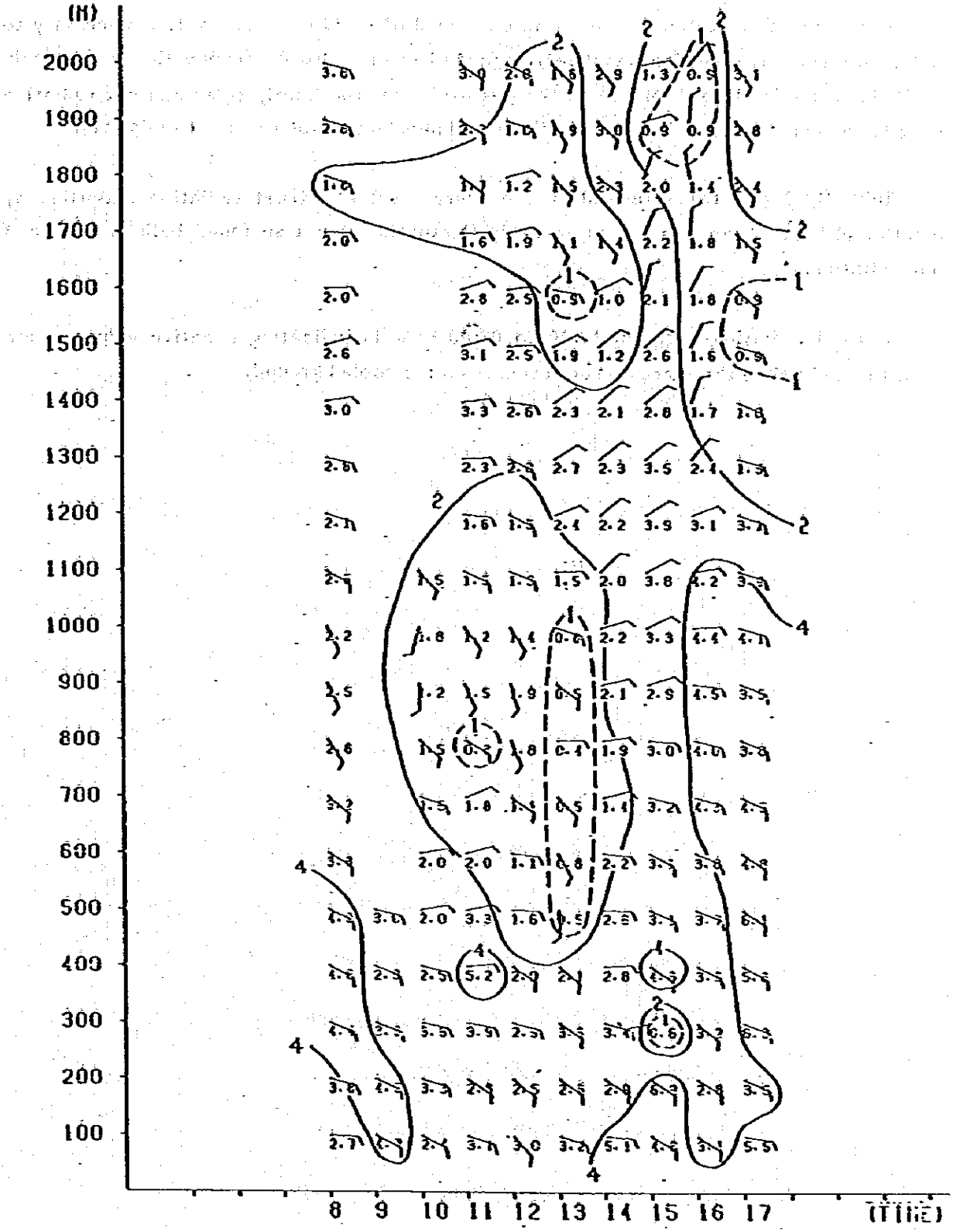


Fig. (II)-8-(4) Isopleth diagram of wind direction and velocity (June 24th, 1981 at MP-6)

(II)-4 Solar and Net Radiation

For calculation of concentration in downwind of emission sources, it is necessary to determine the gas diffusion quantitatively. And in order to determine the atmospheric stability which is closely related to the gas diffusion, the hourly solar and net radiation have been measured (stability is classified by wind velocity, solar and net radiation).

Table (II)-3 and Table (II)-4 show the average solar and net radiation classified by month and hour. From the tables, monthly fluctuation is not so found both in solar and net radiation.

The net radiation between 19:00 to 07:00 hour is indicating negative values which means in night time there are no reflection from the cooled ground.

Table (II)-3 Monthly and hourly average solar radiation

Site No.	1 Site name	N.U.S.			Item No. 3	Item name	Solar radiation		Yard-stick	(CAL/CM2/H)			
Time	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	Annual average
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.4	0.0	0.0	0.0	0.2	0.6	1.3	1.5	1.3	1.6	0.6
8	2.0	2.1	5.2	5.5	3.8	3.4	5.1	9.9	11.4	15.1	10.1	11.7	7.1
9	13.7	16.1	19.5	20.1	17.5	15.4	17.2	25.1	23.4	29.2	22.2	27.0	20.5
10	28.6	36.0	33.7	35.5	29.1	30.8	30.3	39.0	36.1	45.9	37.0	37.1	34.8
11	41.8	52.6	46.5	46.5	40.8	41.8	45.2	52.4	47.0	53.9	48.0	50.5	47.2
12	52.3	61.3	53.4	51.1	47.6	50.4	55.5	68.8	55.4	62.2	53.2	49.6	55.0
13	53.7	65.8	54.6	50.7	53.0	58.9	60.9	72.4	61.4	59.7	50.5	47.1	57.5
14	52.5	62.5	54.2	46.6	54.5	61.9	59.3	61.8	54.4	52.7	48.3	37.9	54.0
15	46.7	55.0	46.1	36.2	46.6	56.8	49.8	54.6	46.9	41.4	42.2	33.1	46.4
16	34.8	42.4	33.9	25.9	34.0	45.7	41.0	44.7	33.8	30.1	32.8	23.3	35.2
17	22.5	33.3	23.5	18.9	23.5	30.4	27.5	29.9	18.7	17.2	19.8	15.2	23.4
18	12.3	18.4	13.1	9.1	12.8	17.6	13.4	12.2	6.4	7.1	7.0	6.5	11.4
19	3.2	5.4	3.2	2.0	3.4	5.5	3.1	1.0	0.2	0.1	0.1	0.0	2.3
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Daily average	15.2	18.7	16.0	14.5	15.1	17.4	17.0	19.7	16.5	17.0	15.6	14.2	16.4

Table (II)-4 Monthly and hourly average net radiation

Site No.	1	Site name	N.U.S.			Item No.	13	Item name	Net radiation flux		Yard-stick	(CAL/CM2/H)		

Time	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	Annual average
1	-4.6	-4.8	-3.6	-3.1	-3.2	-3.8	-4.0	-4.6	-3.6	-3.3	-3.2	-3.3	-3.8
2	-4.5	-4.8	-3.6	-3.1	-3.2	-3.7	-3.9	-4.3	-3.4	-3.1	-3.2	-3.4	-3.7
3	-4.4	-4.8	-3.5	-3.0	-3.0	-3.6	-3.9	-4.0	-3.3	-3.1	-3.2	-3.3	-3.6
4	-4.4	-4.7	-3.4	-2.7	-2.8	-3.3	-3.8	-3.7	-3.0	-2.7	-3.1	-3.2	-3.4
5	-4.2	-4.5	-3.2	-2.5	-2.8	-3.0	-3.8	-3.5	-2.7	-2.8	-2.9	-3.3	-3.3
6	-4.1	-4.4	-3.1	-2.3	-2.7	-2.9	-3.5	-3.4	-2.6	-2.8	-2.9	-3.4	-3.2
7	-4.1	-4.1	-3.0	-2.1	-2.6	-2.8	-3.2	-2.3	-1.2	-1.3	-1.8	-2.1	-2.5
8	-2.3	-2.4	0.3	1.7	0.2	-0.2	0.4	3.4	5.0	7.0	4.5	4.6	1.9
9	5.1	6.6	9.1	10.2	8.4	7.2	8.5	12.9	13.5	15.7	12.8	14.6	10.4
10	15.0	19.8	18.7	19.9	16.1	17.0	17.2	21.7	22.2	26.6	22.2	20.6	19.7
11	23.5	30.7	27.4	27.1	24.2	24.0	26.7	30.0	28.4	32.0	29.3	29.2	27.7
12	30.0	35.9	31.6	30.0	28.7	29.5	32.7	39.9	32.9	36.8	32.5	29.7	32.5
13	31.4	39.0	32.4	29.7	32.0	34.8	35.8	42.1	35.9	35.3	30.4	27.8	33.8
14	30.7	37.2	32.4	27.3	33.1	36.6	34.7	35.5	31.7	30.0	27.7	22.2	31.6
15	27.1	32.5	27.1	20.7	28.2	33.2	29.1	30.4	26.7	23.9	22.9	18.3	26.7
16	19.4	24.8	19.0	14.2	19.4	26.5	23.5	23.5	18.2	16.0	16.7	12.2	19.4
17	11.9	18.7	12.7	9.4	12.6	17.1	14.7	14.2	8.5	8.1	8.8	6.2	11.9
18	5.2	9.0	5.6	3.4	5.2	6.8	4.5	2.7	0.3	0.8	0.9	0.2	3.7
19	-1.0	-0.1	-1.0	-1.5	-1.4	-0.6	-1.9	-4.1	-3.8	-3.6	-3.5	-3.1	-2.1
20	-3.7	-4.1	-3.3	-3.2	-3.7	-4.0	-4.2	-5.0	-3.9	-3.7	-3.6	-3.4	-3.8
21	-4.3	-4.6	-3.8	-3.3	-3.6	-4.2	-4.2	-4.9	-4.0	-3.9	-3.6	-3.5	-4.0
22	-4.4	-4.8	-3.8	-3.4	-3.6	-4.1	-4.2	-4.8	-3.9	-3.7	-3.3	-3.5	-4.0
23	-4.4	-5.0	-3.8	-3.3	-3.5	-4.0	-4.0	-4.8	-3.9	3.7	-3.3	-3.5	-3.9
24	-4.4	-5.0	-3.7	-3.1	-3.5	-4.0	-4.0	-4.8	-3.7	-3.6	-3.1	-3.4	-3.8
Daily average	6.0	8.1	7.1	6.5	6.9	8.0	7.5	8.4	7.5	7.8	7.0	5.9	7.2

Fig. (II)-9 shows daily pattern of solar and net radiation, and from the figure, the maximum is found at 13:00 hour both in solar and net radiation.

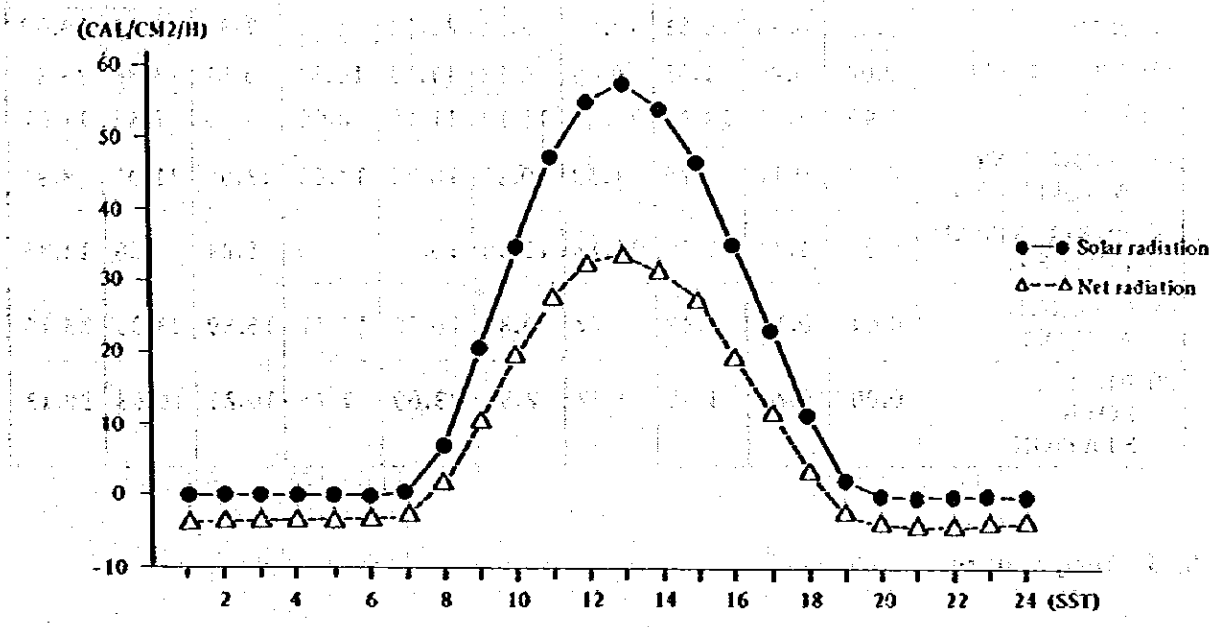


Fig. (II)-9 Daily pattern of solar and net radiation

Table (II)-5 shows appearance frequency of atmospheric stability which is closely related to the gas diffusion, based on the data of hourly average solar and net radiation. In the table, CA-CD represent stability at calm (0-0.3 m/s), A to D represent stable condition (D is most stable) and A to F represent stable under windy condition (F is most stable).

In the cases of MP-2 and MP-6 which are representing Jurong and Changi area respectively, the appearance of stable condition of atmospheric stability (E-F) are most frequent in both stations and unstable condition (A-B) is not appeared frequently.

Table (II)-5 Appearance frequency of atmospheric stability

Station	CA	CB	CC	CD	A	B	C	D	E	F
(1) N.U.S	0.25	0.64	15.61	17.57	3.74	24.94	4.05	7.32	7.79	18.09
(2) J.T.C HALL	0.02	0.20	1.03	0.45	0.82	17.13	14.84	15.81	23.88	25.82
(3) S.I.U	0.99	2.76	18.88	18.46	15.10	11.16	2.09	5.55	7.34	17.67
(4) BOON LAY APARTMENT	0.02	0.17	1.79	1.30	0.98	18.25	14.01	13.58	21.01	28.89
(5) BUKIT TIMAH FIRE ST.	0.97	1.74	17.09	21.12	11.56	16.26	2.36	6.24	8.28	14.38
(6) CHANGI AIRPORT	0.01	0.10	2.28	1.77	0.87	16.50	14.37	15.89	23.06	25.15
(7) BEDOK POLICE STATION	0.06	0.24	3.91	4.77	2.55	23.69	7.76	10.21	16.68	30.13

(II)-5 Temperature

The vertical distribution of temperature is related to the atmospheric stability and also closely concerned with gas diffusion behaviour. In order to study the vertical distribution of temperature, the measurement of temperature has been carried out at MP-1, installing thermometers at 2 heights of 1.5 m and 10 m.

Fig. (II)-10 shows time series monthly average temperature and from the figure, the temperature at 10 m of each month is found about 0.3 to 0.4°C higher than that of 1.5 m.

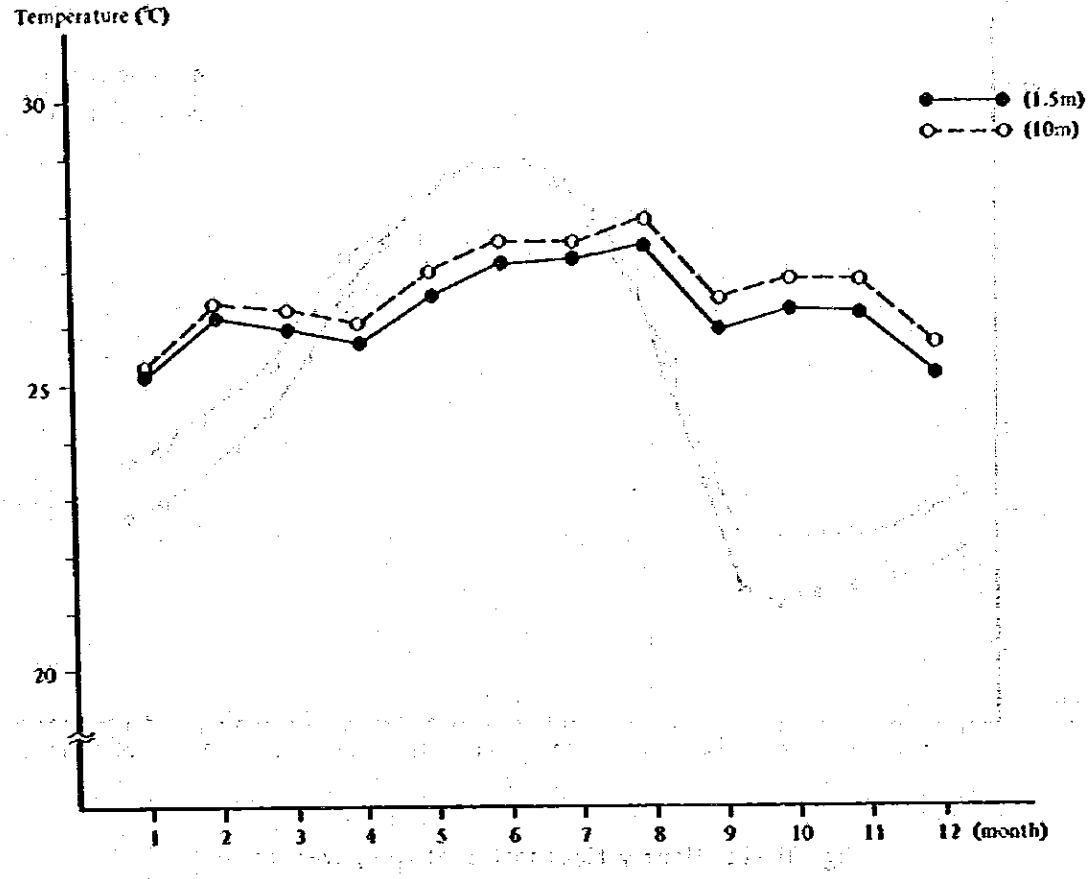


Fig. (II)-10 Time series monthly average temperature

Fig. (II)-11 shows hourly average temperature and from the figure, it is confirmed that (1) difference between 1.5 m and 10 m in daytime is not found and (2) the temperature of 10 m in night time is higher by 0.5 to 0.6°C than that of 1.5 m, which is due to the reflection from the ground warmed in daytime.

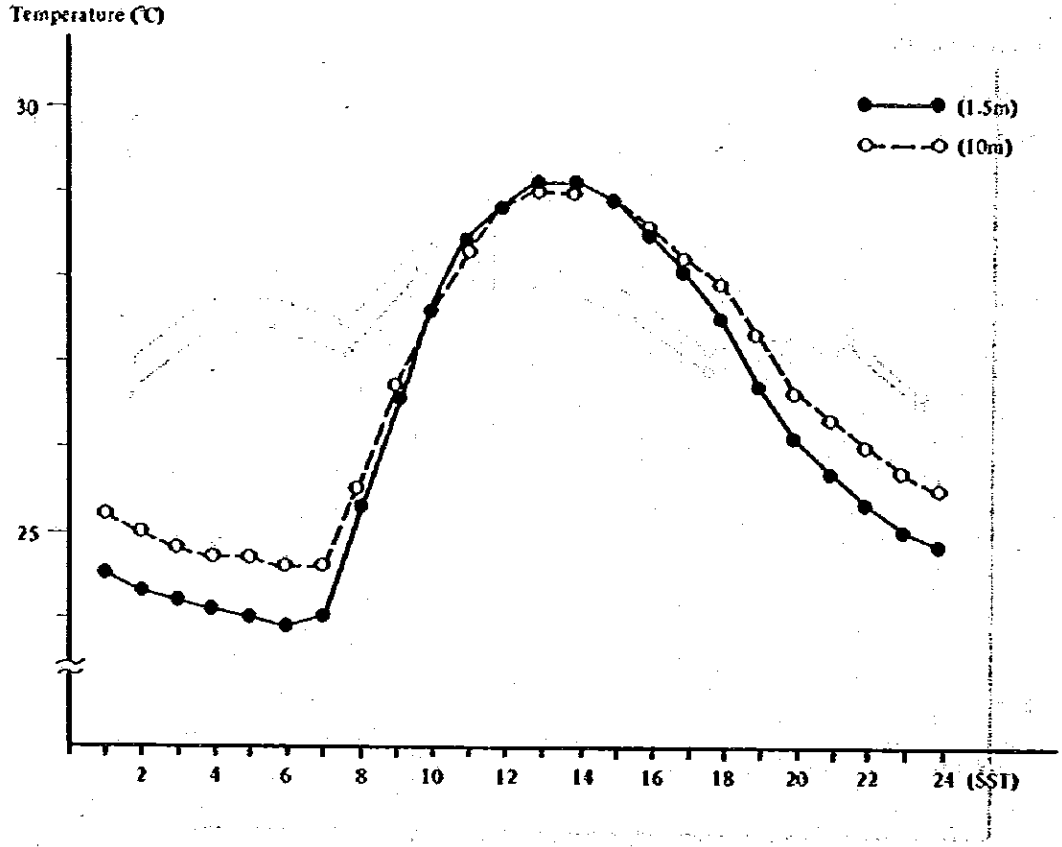


Fig. (II)-11 Hourly fluctuation of temperature

Table (II)-6 shows the average temperature classified by season and day/night, and from the table, the yearly average temperature of 10 m is about 0.3°C higher than that of 1.5 m.

Table (II)-6 Average temperature classified by season and day/night

Unit (°C)

Height	Southerly Monsoon			Northerly Monsoon			Yearly Average		
	Day time	Night	Through day	Day time	Night	Through day	Day time	Night	Through day
1.5 m	28.3	25.2	26.6	27.5	24.3	25.8	28.0	24.8	26.3
10 m	28.4	25.9	27.0	27.6	24.8	26.1	28.0	25.5	26.6

(III) Summary of Results of SO_2 Ambient Concentration Simulation

SO_2 ambient concentration simulation has to be performed based on the data to cover the total emission sources including the present existing emission sources and the future proposed emission sources. Therefore, the diffusion simulation for the present existing sources has to be performed in the first stage and after confirming the consistency between the estimated and measured values, the total simulation will be carried out by the parameters thus validated with the factors for the future sources.

In this study, the emission factors (SO_2 emission volume & etc.) of the present existing sources have been collected by questionnaire and other means. As for the volume from the vessels, the estimation has been made from the data supplied by Port of Singapore Authority through JTC.

As for the future factors of the stationary sources,

(1) the emission factors for coal firing power stations and integrated steel mill have been discussed between JTC and Japanese team and mentioned in Minutes of Meetings.
(2) the factors for the present existing factories have been obtained by applying the growing rate estimated by EDB.
(3) the factors for the developing plan of the existing power plant have been supplied by PUB as shown in Table (III)-1.
(4) the factors for the vessels have been obtained by applying the growing rate supplied by EDB although the number of tanker remained same with the present. Also the correction has been made, taking the necessary tanker and bulk carrier for the new proposed factories into calculation.

Table (III)-1 Outline of proposed facilities

Name of facility	Proposed date of commissioning	Outline
Seneko Power Station Phase III	June 1983	250MW x 1 (oil firing)
	December 1983	250MW x 1 (oil firing)
Seraya Power Station	1987	250MW x 2 (oil firing)
	1988	250MW x 1 (oil firing)
	1990	250MW x 3 (coal firing)
Tekong Power Station	1990	350MW x 2 (coal firing)
Tekong integrated Steel Mill	1990	Grate Kiln
	1990	Reheating Furnace
Sumitomo Petrochemical	1983	Boiler x 2 (oil firing)

SOx emission volume from the stationary sources thus estimated is shown in Table (III)-2. From the table, the present volume (1981) is estimated as 226,362 ton/year and future is 480,019 ton/year which corresponds about 2.1 times of the present. Taking the emission volume from the classified industry, electric power industry and petroleum hold 98.0% of the present and 78% of the future, which means these two industries hold the majority of the total emission volume.

Table (III)-2 SO_2 emission volume from stationary sources classified by type of industry

Type of industry	Present (1981)					Future (1990)					
	Number of factory	Number of stacks	Number of facility	SO_2 volume (t/y) & %		Number of factory	Number of stacks	Number of facility	SO_2 volume (t/y) & %		Additional SO_2 volume
Electric Power Ind.	3	6	17	174,509.5	77.1	5	10	27	327,330.1	68.2	152,820.6
Petroleum	4	47	68	47,236.6	20.9	4	47	68	47,143.2	9.8	
Petrochemical	1	1	2	25.9	0.01	2	2	4	4,443.3	0.9	4204.8
Chemicals	8	13	15	436.0	0.2	8	13	15	1,327.3	0.3	
Pharmaceuticals	3	3	4	37.2	0.02	8	3	4	211.7	0.04	
Rubber	4	4	5	102.1	0.05	4	4	5	157.5	0.03	
Non-Metalic	3	4	4	638.8	0.3	3	4	4	1,087.6	0.2	
Food	1	1	2	1,029.1	0.5	1	1	2	2,563.5	0.5	
Textiles	3	4	7	154.6	0.1	3	4	7	236.7	0.04	
Miscellaneous	3	7	8	502.8	0.2	3	7	8	983.0	0.2	
Machine Tools	1	1	2	18.9	0.01	1	1	2	80.8	0.02	
Iron & Steel	1	5	5	1,529.4	0.7	2	7	7	93,941.5	19.6	90,102.9
Fabricated Metal	6	14	14	100.9	0.04	6	14	14	293.7	0.06	
Consumer/Industrial Electrical Ind.	1	6	7	40.7	0.02	1	6	7	218.8	0.05	
Others	19	15	15	0.0	0.00	19	15	15	0.0	0.00	
TOTAL	61	131	175	226,362.5	100.0	70	138	189	480,018.7	100.0	247,128.3

Remarks : Future emission volume include proposed factories.

The estimated emission volume of SO_2 from the vessels are shown in Table (III)-3. The present volume (1981) is 3,917 ton/year and the future (1990) is 5,705 ton/year which corresponds about 1.5 times of the present.

Table (III)-3 SO_2 emission volume from vessels

Type of Vessel	Present (1981)		Future (1990)	
	Emission volume (t/y)	%	Emission volume (t/y)	%
Coaster & Freighter	743.5	19.0	1,936.8	33.9
Container	213.3	5.4	555.6	9.7
Tanker	2,861.5	73.1	2,908.7	51.0
Bulk Carrier	97.0	2.5	299.5	5.2
Others	1.8	0.1	4.7	0.1
Total	3,917.1	100.0	5,705.3	100.0

The simulation model is employed from several models which have the respective characteristics according to the objective, topographic conditions of the survey area and other factors.

The objective of this study is to estimate the present and future pollution status of the Republic of Singapore in terms of SO_2 and it is necessary to determine contributing concentration from the various emission sources by analyzing the present and future pollution behaviour and it is also necessary to predict the future concentration of SO_2 in the total area which has the dimension of 60 km in east and west, and 30 km in north and south. In this study, judging comprehensively from the above, Guassian plume puff model has been employed.

Table (III)-4 shows yearly average estimated SO_2 concentration at each monitoring station. Yearly average SO_2 concentration of 1981 is in the range of 6.7 to 26.2 ppb by measured value and 6.7 to 23.2 ppb by calculated value. The contribution rate of the stationary sources is reaching to 79-93% and the rate of vessels is 7-21%.

In 1990, from the table, emission volume of SO_2 is estimated to increase and the maximum increased concentration, 15.4 is found at MP-3 and minimum increased concentration, 2.8 ppb is found at MP-6.

The contribution rate of stationary sources and vessels in 1981 and 1990 is found almost same.

Table (III)-4 Results of estimation of SO_2 ambient concentration of each station (yearly average)

Station	Year	Measured value (ppb)	Estimated value (ppb)	Stationary sources (ppb)	Contribution rate (%)	Vessel (ppb)	Contribution rate (%)	Background (ppb)	Contribution rate (%)
MP-1) N.U.S	1981	14.2	15.9	10.10	64	1.46	9	4.3	27
	1990	-	21.6	13.66	63	2.23	10	5.7	26
MP-2) J.T.C. HALL	1981	14.6	16.7	11.21	67	1.14	7	4.3	26
	1990	-	24.7	17.30	70	1.74	7	5.7	23
MP-3) S.LU	1981	26.2	23.2	17.26	74	1.61	7	4.3	19
	1990	-	39.9	31.85	80	2.38	6	5.7	14
MP-4) BOON LAY APARTMENT	1981	19.4	21.4	15.88	74	1.18	6	4.3	20
	1990	-	33.9	26.50	78	1.73	5	5.7	17
MP-5) BUKIT TIMAH FIRE STATION	1981	17.6	14.9	9.70	65	0.94	6	4.3	29
	1990	-	20.7	13.61	66	1.42	7	5.7	27
MP-6) CHANGI AIRPORT	1981	6.7	6.7	1.97	29	0.43	6	4.3	64
	1990	-	9.5	3.18	33	0.66	7	5.7	60
MP-7) BEDOK POLICE STATION	1981	8.4	8.1	2.99	37	0.79	10	4.3	53
	1990	-	11.5	4.58	40	1.26	11	5.7	49

Fig. (III)-1 and Fig. (III)-2 show SO_2 ambient concentration of total survey area and. from the figures the increase of concentration in 1990 is predicted.

Table (III)-5 shows number of meshes classified by SO_2 concentration rank and from the table, number of meshes exceeding 30ppb in 1981 is 18 but in 1990 it is predicted to increase to 168.

Table (III)-5 Number of meshes classified by estimated SO_2 concentration

Concentration rank (ppb)	1981	1990
below 10 ppb	467	103
over 10 below 15	368	397
over 15 below 20	196	280
over 20 below 30	161	262
over 30	18	168
Total	1,210	1,210

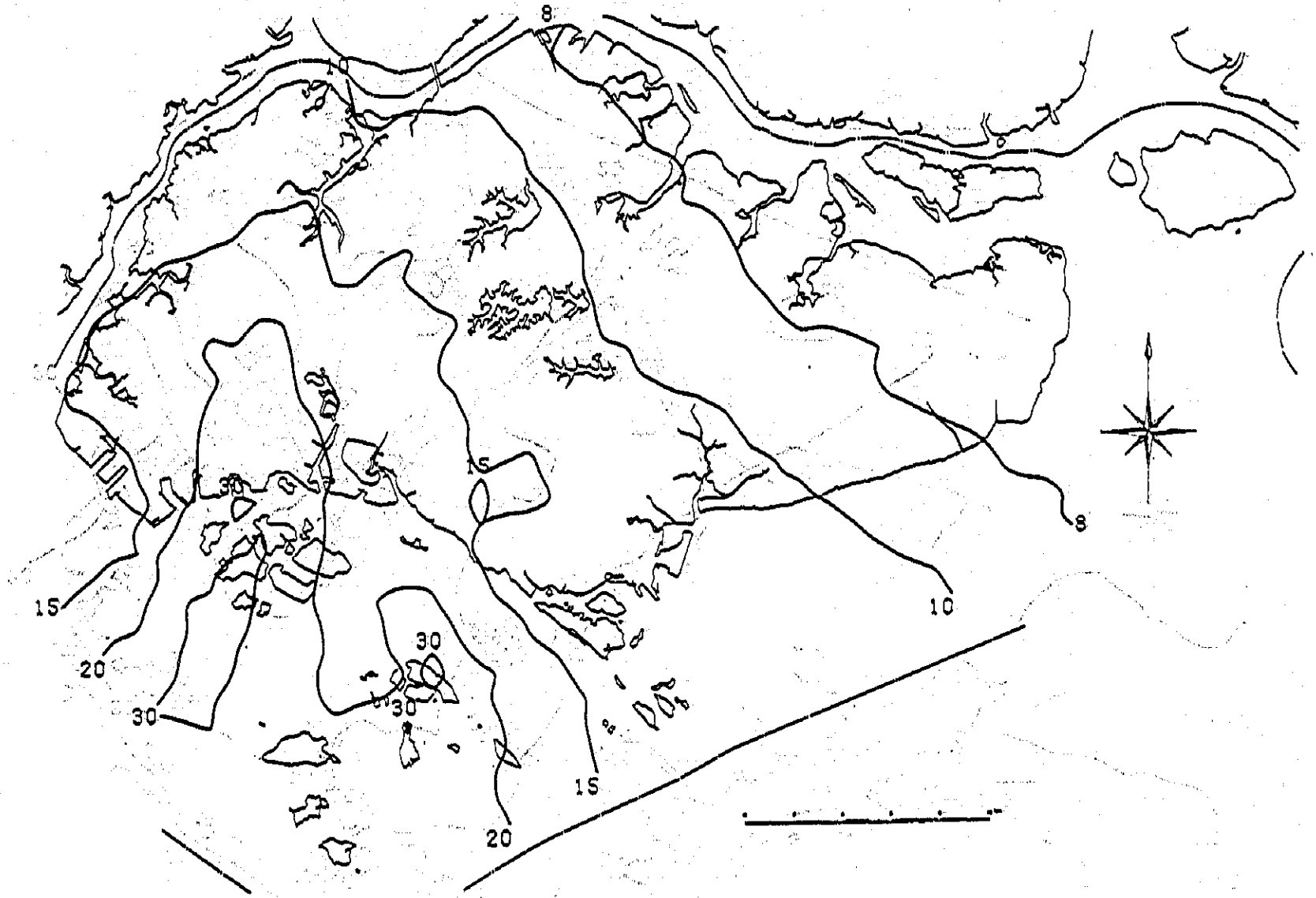


Fig. (III)-1 Contour map of estimated SO_2 ambient concentration (yearly average in 1981)

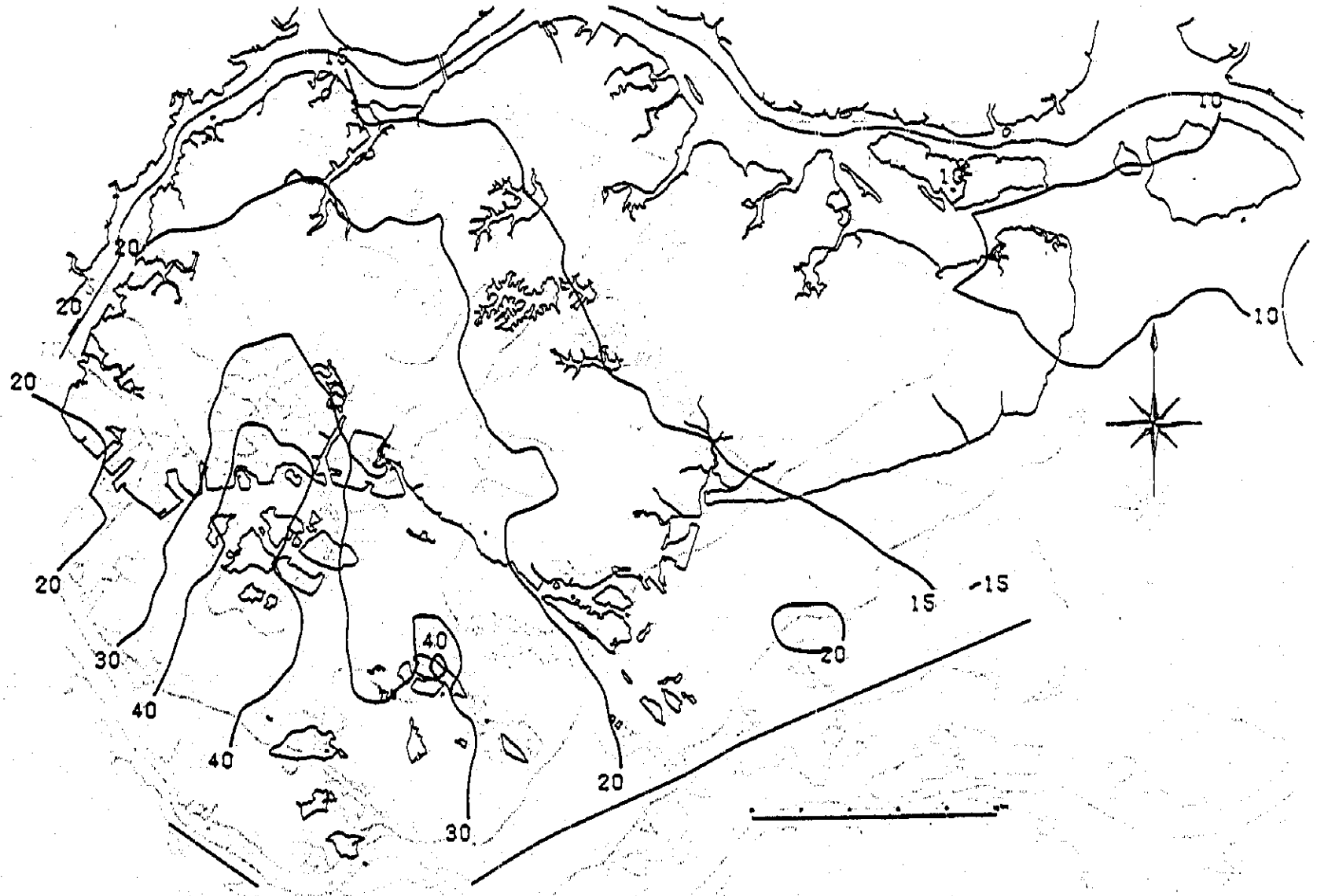


Fig. (III)-2 Contour map of estimated SO_2 ambient concentration (yearly average in 1990)

PART I INTRODUCTION

CHAPTER 1 BACKGROUND AND OUTLINE OF THE STUDY

I-1-1 Background of the Study

The Government of Japan has been proposed by the Government of Republic of Singapore to extend its technical cooperation to the study on the effects of coal firing power stations and integrated steel mill which will be sited in the newly developed areas at the official meeting held in August 1979 in Singapore between the Government of the Republic of Singapore and Annual Consultation Mission of the Government of Japan. And later, it was officially requested by the Government of the Republic of Singapore.

In response to the above request, the Government of Japan has decided to conduct a preliminary survey on the study of environmental effects of the above mentioned plants and Japan International Cooperation Agency (hereinafter referred to as "JICA") has been commissioned to carry out such survey.

JICA has sent a preliminary survey team of 7 persons, headed by Mr. I. Kikushima, deputy director of Environmental Protection Bureau, Ministry of International Trade and Industry (MITI) to Singapore for 13 days in December 1980. The preliminary survey team has made the necessary surveys and has entered into agreement with JURONG TOWN CORPORATION who has been designated as the counterpart of the project, under SCOPE OF WORK (SW) and Minutes of Meetings, in which the followings have been confirmed.

(1) Total schedule of the study on the environmental effects
(2) Specifications of field survey
(3) Specifications of simulation
(4) Contribution of Singapore side

Based on Scope of Work and Minutes of Meetings, JICA has conducted the environmental study on water quality during February to December 1981, on which the report has been submitted in February 1982.

Following to the study on water quality, JICA has carried out the field survey on air quality and simulation for sulpure di-oxide (SO_2) during June 1981 to March 1983.

I-1-2 Objective of the Study

The objectives of the study are (1) to conduct the field survey on air quality including SO_2 ambient concentration and meteorological conditions, and (2) based on the data of field survey and emission sources, to carry out the simulation to predict the environmental effects of coal firing power stations and integrated steel mill which will be commissioned by 1990.

CHAPTER 2 SPECIFICATIONS OF THE STUDY

For the environmental study, it is necessary to obtain the accurate data on the present ambient concentrations of the pollutants together with the meteorological conditions, monitored for a long term. In this study, the monitoring of SO_2 ambient concentration and meteorological conditions (wind direction, velocity and so on) has been carried out for one year (365 days). The monitoring has been conducted by automatic continuous measuring instruments, and for the maintenance of the instruments, daily check has been performed by Singapore side and calibration of the instruments has been conducted by Japanese team. The necessary training for the maintenance methods has been provided by Japanese team to the staffs of JURONG TOWN CORPORATION prior to the commencement of monitoring. For the calibration of the instruments, it has been agreed to conduct once every 3 months which made total 4 times in a year.

The data obtained through the one year monitoring have been sent to Japan for analysis and together with other data collected from emission sources and so on, SO_2 diffusion simulation has been carried out to predict the environmental effects of coal firing power stations and integrated steel mill which are proposed to be sited in Pulau Seraya and Tekong.

I-2-1 Survey Area

The survey area in this study covers the total area of the Republic of Singapore, extending 60 km from east to west, and 30 km from north to south, as shown in Fig. I-2-1.

The monitoring stations have been established 5 in Jurong area where will be affected by coal firing power station of Pulau Seraya and 2 in Changi area where will be affected by coal firing power station and integrated steel mill of Pulau Tekong. The location of monitoring stations are shown in Fig. I-2-1 and Table I-2-1.

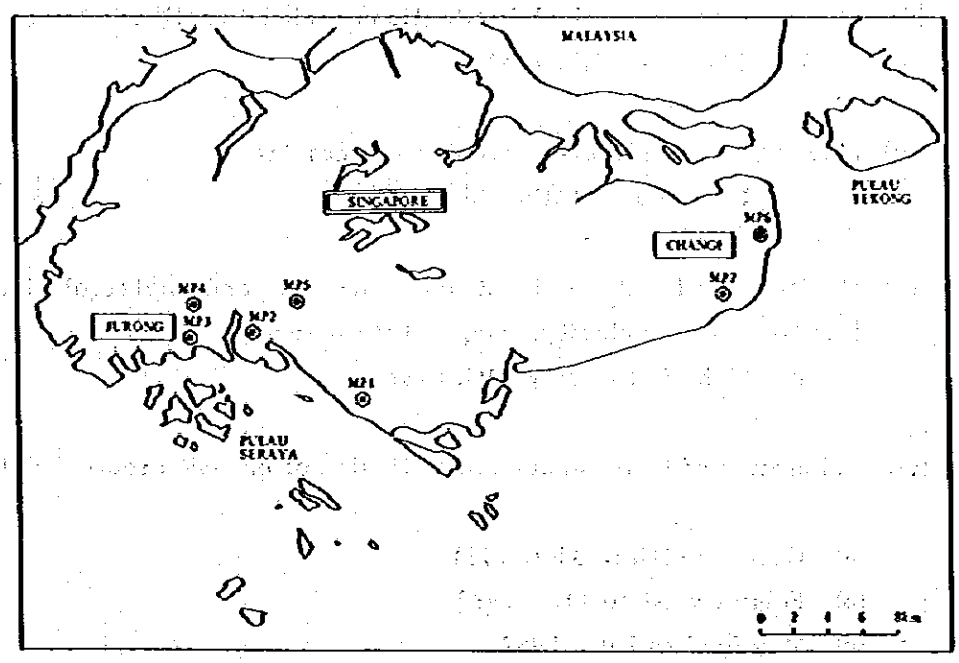


Fig. I-2-1 Survey area and location of monitoring stations

Table I-2-1 Location of monitoring stations

Jurong area	Changi area
MP-1 National University of Singapore	MP-6 Changi Airport
MP-2 JTC Town Hall	MP-7 Bedok Police Station
MP-3 JTC Soil Investigation Unit	
MP-4 Boon Lay Apartment	
MP-5 Bukit Timah Fire Station	

I-2-2 Survey Schedule

The survey schedule is as follows:

(1) Field survey during June 15th 1981 to July 14th 1982

(i) Installation of instruments and calibration

June 15th to June 22nd 1981 --- installation

June 25th to July 5th 1981 --- calibration

(ii) Training on handling and maintenance of the instruments

July 6th to July 9th 1981

(iii) Measurement of vertical distribution of wind direction and velocity
June 23rd and 24th, 1981

(iv) Meeting on collection of emission sources data
July 10th to July 14th, 1981

(v) Monitoring of SO_2 ambient concentration and meteorological conditions (wind direction, velocity, temperature & so on)
July 15th 1981 to July 14th 1982

(vi) Calibration of instruments and collection of emission sources data

(a) October 25th to 31st, 1981
(b) February 1st to 11th, 1982
(c) May 23rd to 29th, 1982
(d) July 15th to 24th, 1982

(2) Analysis of data and simulation
April to December, 1982

I-2-3 Survey Items and Survey Methods

I-2-3-1 Field survey

In order to survey the present SO_2 ambient concentration and meteorological conditions, the following field survey has been conducted.

Further, it must be noted that the field survey has been carried out under the close cooperation of JURONG TOWN CORPORATION and assistance of ANTI POLLUTION UNIT (APU), National University of Singapore (NUS), ECONOMIC DEVELOPMENT BOARD (EDB) and other related Authorities of the Republic of Singapore.

(1) Measurement of SO_2 ambient concentration

The automatic and continuous SO_2 analyzers of solution conductmetry type have been installed in 7 monitoring stations (MP-1 to MP-7) and SO_2 hourly ambient concentration has been measured for one year.

(2) Monitoring of surface wind direction and velocity

The propeller type automatic and continuous anemometers have been installed in each monitoring station and measured 10 minutes running mean values of wind direction and velocity for one year.

(3) Monitoring of solar and net radiation

The solar and net radiation meter have been installed at MP-1, and instantaneous and one hour mean values of solar and net radiation have been measured for one year.

(4) Measurement of temperature

The nickel resistance type thermometers have been installed at the height of 1.5 m and 10.0 m of MP-1 and the instantaneous values of temperature have been measured for one year.

(5) Monitoring of vertical distribution of wind direction and velocity

The vertical distribution of wind direction and velocity has been monitored by releasing pilot balloons and by using Theodolite at 2 points, MP-2 and MP-6. The monitoring has extended up to the height of 2,000 m and the average wind direction and velocity of each 100 m have been measured at exact full hour during 08:00 to 17:00 for 2 days (June 23rd and 24th, 1981).

1-2-3-2 Analysis of field survey data

The data obtained through the field survey have been analyzed as follows:

(1) Data analysis of SO_2 ambient concentration

(i) Cluster analysis of SO_2 average concentration classified by hour

(ii) Principal component analysis of SO_2 concentration classified by month and hour

(iii) SO_2 average concentration for each monitoring station classified by season and year

(iv) Monthly deviation pattern of SO_2 concentration for each monitoring station

(v) Daily deviation pattern of SO_2 concentration for each monitoring station

(vi) Cumulated frequency distribution of SO_2 concentration for each monitoring station

(vii) SO_2 average concentration for each monitoring station classified by wind direction and velocity

(viii) SO_2 average concentration for each monitoring station classified by wind velocity and atmospheric stability

(ix) Analysis of maximum SO_2 concentration for each monitoring station

(2) Analysis of meteorological data

(i) Average wind velocity for each monitoring station classified by month and hour

(ii) Wind rose for each monitoring station classified by year, month, season, day & night, wind velocity

(iii) Wind velocity appearance frequency for each monitoring station classified by wind velocity

(iv) Designation of representative station for meteorological conditions

(a) Vector correlation coefficient between each monitoring station
(b) Cluster analysis based on vector correlation coefficient
(c) Principal component analysis based on vector correlation coefficient

(v) Vertical distribution of wind direction and velocity by pilot balloon and trajectory chart

(vi) Vertical distribution profile of wind velocity

(vii) Average solar and net radiation classified by month and hour

(viii) Appearance frequency of atmospheric stability

(ix) Average temperature difference by atmospheric stability

(x) Net radiation and average temperature difference by windy & calm conditions

(xi) Scatter diagram of temperature classified by month and hour

(xii) Scatter diagram of net radiation and temperature classified by year, month, and season

I-2-3-3 Collection of emission sources data and assumption of future emission

The emission sources data are used as input data for SO_2 diffusion simulation.

The sources data have been collected by JURONG TOWN CORPORATION circulating and collecting the questionnaire from the factories and plants located in Singapore at present (1981) under the guidance of Japanese team.

As for the future (1990) emission data, the arrangement has been made as follows:

(1) The estimated emission data of coal firing power stations and integrated steel mill which will be sited in Pulau Seraya and Tekong confirmed in the Minutes of Meetings.

(2) The information has been provided by PUB (Public Utility Board) with the data for developing plan of existing power stations during 1982 to 1989.

(3) The estimation of future emission for the remaining industries has been performed by applying EDB's information on the future prospects of each industry of the Republic of Singapore.

I-2-3-4 Simulation of SO_2 diffusion

SO_2 yearly average concentration has been calculated by Gaussian plume puff model based on the analyzed data of the field survey and emission sources data, as shown in Fig. I-2-2.

The simulation has been carried out for the following points.

(1) Monitoring stations, MP-1 to MP-7 (present and future)
(2) Center point of each mesh (1k x 1k) covering total area of the Republic of Singapore (present and future)

In addition to the above calculation, contribution rate at the above mentioned points has been calculated by industries, stacks and ships (present and future).

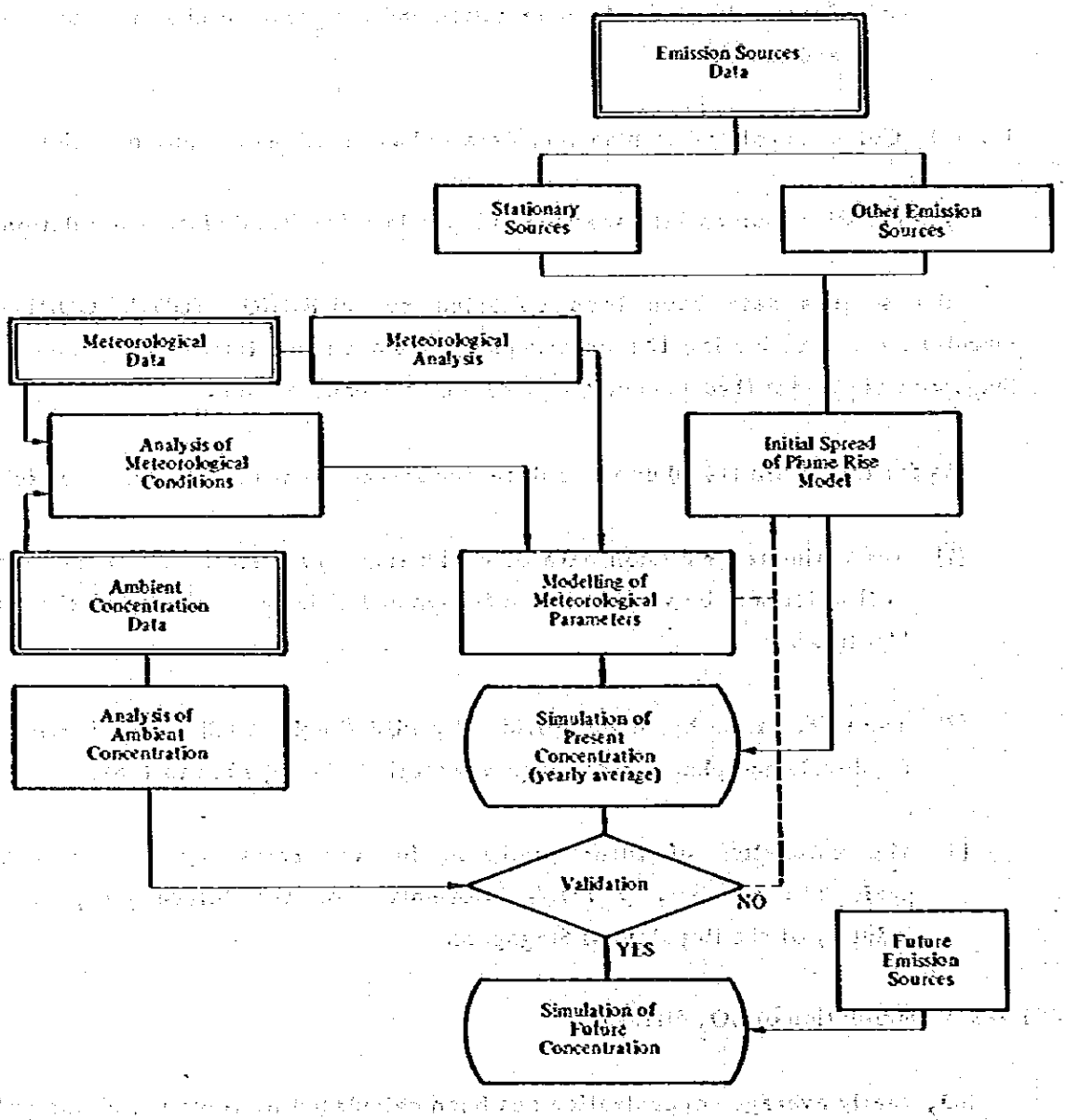


Fig. I-2-2 Flow chart for SO_2 simulation process

I-2-4 Formation of Survey Team

Table I-2-2 shows the members of survey team who engaged in the field survey.

Table I-2-2 Members of survey team (*)

Name	Business	Period
(1) Installation and calibration of the instruments		
K. Kobayashi	Team leader	June 15th to July 14th, 1981
K. Inagaki	Coordinator	- ditto -
T. Kusaka	Monitoring	- ditto -
K. Nakahashi	- ditto -	- ditto -
T. Noguchi	- ditto -	- ditto -
M. Fujikawa	- ditto -	- ditto -
(2) The 1st calibration		
N. Ono	Team leader Calibration	October 25th to 31st, 1981
T. Noguchi	Calibration	- ditto -
(3) The 2nd calibration		
K. Kobayashi	Team leader Calibration	February 1st to 11th, 1982
K. Inagaki	Instructor for training on handling of instruments	- ditto -
T. Noguchi	Calibration	- ditto -
(4) The 3rd calibration		
K. Inagaki	Team leader Emission sources data collection	May 23rd to 29th 1982
T. Kusaka	Calibration	- ditto -
T. Noguchi	- ditto -	- ditto -
(5) The 4th calibration, collection of emission sources data and withdrawal of instruments		
K. Inagaki	Team leader Emission sources data collection	July 15th to 24th, 1982
N. Ono	Calibration and withdrawal	- ditto -
T. Noguchi	- ditto -	- ditto -

* The members of the survey team belong to Industrial Pollution Control Association of Japan (IPCAJ).

I-2-5 Schedule of the Study

The total schedule of the environmental study is as follows:

(1)	Field survey	June 15th 1981 to July 24th 1982
	(i) Installation and calibration of instruments, training on handling and maintenance	June 15th 1981 to July 14th 1981
	(ii) Monitoring	July 15th 1981 to July 14th 1982
	(iii) The 1st calibration	October 25th to 31st, 1981
	(iv) The 2nd calibration	February 1st to 11th, 1982
	(v) The 3rd calibration and collection of emission sources data	May 23rd to 29th, 1982
	(vi) The 4th calibration, collection of emission sources data, and withdrawal of instruments	July 15th to 24th, 1982
(2)	Processing of the field survey data	April to August, 1982
(3)	Processing and modelling of emission sources data	April to August, 1982
(4)	Analysis of field survey data	August to September, 1982
(5)	Simulation for the present	October to December, 1982
(6)	Simulation for the future	December 1982

The daily progress of the field survey is shown in Table I-2-3 to Table I-2-7.

Table I-2-3 Daily progress for preparatory works, including installation and calibration of instruments

Date	Contents of works
June 15th (Mon) 1981	Survey team arrived in Singapore by JL-715
16th (Tue)	Meeting with JTC officers. Confirmation of transported instruments. Preliminary survey of monitoring points, MP-1, MP-3, MP-4 and MP-5. Meeting with Prof. Dr. Pakium of SIU.
17th (Wed)	Official visits to APU and Meteorological Service. Meeting with Dr. Huang Hsing Hua of NUS on SO_2 monitoring. Preliminary survey of monitoring points, MP-6 and MP-7.
18th (Thu)	Official visit to Embassy of Japan. Meeting with JTC officers on the outline of the environmental study on air quality. Preliminary survey of the monitoring point, MP-2. Preparatory work, checking the materials for prefabricated huts. Confirmation of distiller function.
19th (Fri)	Official visit to EDB. Checking of transported instruments.
20th (Sat)	Checking of transported instruments
21st (Sun)	Holiday
22nd (Mon)	Meeting with JTC officers on installation of instruments at 7 monitoring stations
23rd (Tue)	Monitoring of vertical distribution of wind direction and velocity by releasing pilot balloons at MP-2 and MP-6.
24th (Wed)	- ditto -
25th (Thu)	Installation of instruments at MP-1
26th (Fri)	Installation of instruments at MP-3
27th (Sat)	Processing of data obtained on June 23rd and 24th by releasing pilot balloon
28th (Sun)	Holiday
29th (Mon)	Installation of instruments at MP-2 and adjustment of installed instruments at MP-1
30th (Tue)	Installation of instruments at MP-5

Table I-2-3 Daily progress for preparatory works, including installation and calibration of instruments (Cont'd)

Date	Contents of works
July 1st (Wed) 1981	Installation of instruments at MP-4
2nd (Thu)	Installation of instruments at MP-6
3rd (Fri)	Installation of instruments at MP-7
4th (Sat)	Same as June 27th
5th (Sun)	Holiday
6th (Mon)	Adjustment of installed instruments at MP-1 and MP-2. Training of JTC officers on maintenance of instruments.
7th (Tue)	Adjustment of installed instruments at MP-3 and MP-4. Training of JTC officers on maintenance of instruments.
8th (Wed)	Adjustment of installed instruments at MP-5. Training of JTC officers on maintenance of instruments.
9th (Thu)	Adjustment of installed instruments at MP-6 and MP-7. Training of JTC officers on maintenance of instruments.
10th (Fri)	Meeting with JTC officers on emission sources data
11th (Sat)	- ditto -
12th (Sun)	Holiday
13th (Mon)	Comprehensive meeting with JTC officers. Official visit to Embassy of Japan.
14th (Tue)	Survey team left Singapore by SQ-012

Table I-2-4 Daily progress for the 1st calibration of instruments

Date	Contents of works
October 25th (Sun) 1981	Calibration team arrived in Singapore by JL-715
26th (Mon)	Calibration of instruments at MP-2 and MP-3
27th (Tue)	Calibration of instruments at MP-1 and MP-3. Official visit to Embassy of Japan. Meeting with JTC officers.
28th (Wed)	Calibration of instruments at MP-4 and MP-5
29th (Thu)	Calibration of instruments at MP-6 and MP-7
30th (Fri)	Patrol around monitoring stations. Official visit to Embassy of Japan.
31st (Sat)	Team left Singapore by SQ-012

Table I-2-5 Daily progress for the 2nd calibration of instruments

Date	Contents of works
February 1st (Mon) 1982	Calibration team arrived in Singapore by JL-715
2nd (Tue)	Calibration of instruments at MP-1
3rd (Wed)	Calibration of instruments at MP-1, MP-4 and MP-5. A team member arrived in Singapore for report meeting on water quality.
4th (Thu)	Calibration of instruments at MP-6 and MP-7
5th (Fri)	Meeting at Embassy of Japan. Calibration of instruments at MP-2 and MP-3.
6th (Sat)	Patrol around monitoring stations
7th (Sun)	Holiday
8th (Mon)	Training on maintenance, calibration and repairing of instruments (SO_2 analyzer, anemometer, pyranometer, net radiation meter, and thermometer) for JTC and APU officers
9th (Tue)	- ditto -
10th (Wed)	- ditto - Official visit to Embassy of Japan
11th (Thu)	Team left Singapore by SQ-012

Table I-2-6 Daily progress for the 3rd calibration of instruments and collection of emission sources data

Date	Contents of works
May 23rd (Sun) 1982	Team arrived in Singapore by JL-715
24th (Mon)	Meeting with JTC officers. Calibration of instruments at MP-2 and MP-3.
25th (Tue)	Meeting at APU, calibration of instruments at MP-1, and visits to 6 factories for collection of emission sources data
26th (Wed)	Meeting with JTC officers on emission sources data, and calibration of instruments at MP-4 and MP-5
27th (Thu)	Calibration of instruments at MP-6 and MP-7, and visits to 15 factories for collection of emission sources data
28th (Fri)	Comprehensive meeting with JTC officers. Meeting at Embassy of Japan. Patrol around 7 monitoring stations
29th (Sat)	Team left Singapore by SQ-012

Table I-2-7 Daily progress for calibration of instruments, collection of emission sources data and withdrawal of instruments

Date	Contents of works
July 15th (Thu) 1982	Team arrived in Singapore by JL-715
16th (Fri)	Meeting with JTC officers. Calibration of instruments at MP-2.
17th (Sat)	Collection of emission sources data. Calibration of instruments at MP-3
18th (Sun)	Holiday
19th (Mon)	Collection of emission sources data. Calibration of instruments at MP-1. Official visit to Embassy of Japan.
20th (Tue)	Collection of emission sources data. Calibration of instruments at MP-4 and MP-5. Meetings at APU and PUB.
21st (Wed)	Collection of emission sources data. Calibration of instruments at MP-6 and MP-7. Meeting at EDB.
22nd (Thu)	Final checking of collected emission sources data
23rd (Fri)	Withdrawal of instruments (partially). Final meeting with JTC officers.
24th (Sat)	Team left Singapore by SQ-012