3.3.2 Factory and enterprise

Table 3.3.2-1 and Fig 3.3.2-1 show the sector-wise number of the industrial units and workers in GTA districts in 1994. The manufacturing industries in GTA account for 40% of the energy consumption and 25% of the number of workshops both in the manufacturing sector of total Iran, causing a great deal of environmental pollution as well as heavy congestion of the city. Hence, tighter environmental control by the manufacturing industries in addition to control of mobile sources is a most urgent task to be faced by MOT.

The manufacturing sector in this report is classified based on the following international code of ISIC (International Standards of Industrial Classification).

- 31 Food Products
- 32 Textile Products
- 33 Wood Products
- 34 Paper Products
- 35 Industrial Chemicals
- 36 Nonmetal Products
- 37 Iron & Steel
- 38 Machinery Products
- 39 Other Industries

(1) Problems of the manufacturing sectors in GTA

Among the industries classified above, the following industries have been considered unsuitable in residential areas by MOT:

- 31 Butchery and meat processing
- 32 Tannery and processing
- 33 Wood chemical processing
- 35 Chemical manufacturing
- 36 Brick manufacturing and processing
- 37 Metal melting and foundry
- 38 Chemicals handling machinery

(2) Countermeasure for the problem

In order to plan and implement countermeasures, AQCC was established in 1993, and ORSUITO in 1990 as MOT's affiliate organizations dedicated to environmental control. The major step taken by MOT was to relocate polluting industries to the suburbs of GTA by providing them with the alternative sites (industrial estates).

There are 4 industrial estates under the control of MOT and 8 under MOI in the outskirts of GTA, as shown in Fig 3.2.4-1, site preparation of which is now under progress and where, in the near future, some of the relocated workshops will start operation.

Table 3.3.2-1 : Sectorwise number of industrial units and workers in GT

Industrial Code Sector	Workshop Size (No of Workers) Small 1-10	Medium 11-50	Medium 51-100	Large 100<	Total Number Unit	Total Number Worker
31 Food	6,703	182	21	20	6,926	42,399
32 Rextile	24,195	527	21	36	24,779	99,400
33 Wood	4,063	49	0	2	4,114	9,920
34 Paper	2,229	171	13	23	2,436	17,899
35 Chemicals	2,623	247	33	48	2,951	42,311
36 Nonmetal	1,454	218	19	29	1,720	24,748
37 Iron	887	60	3	13	963	11,121
38 Machinery	18,307	683	72	105	19,167	120,490
39 Others	7,795	126	6	7	7,934	23,512
(Total)	68,256	2,263	188	283	70,990	391,800

(Source) AQCC

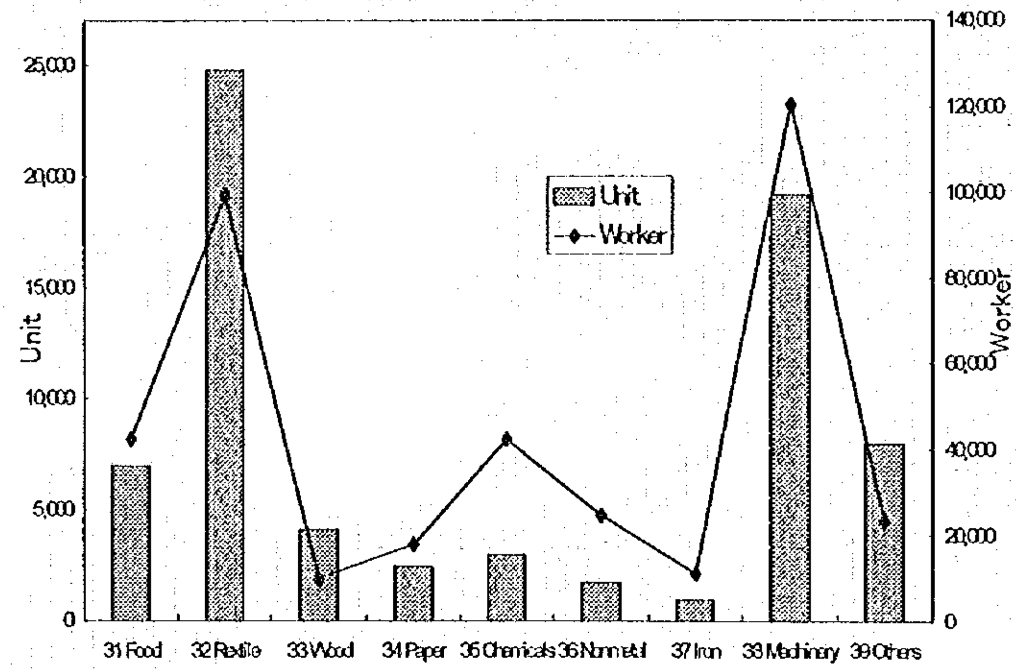


Fig 3.3.2-1 : Total number of industrial units and workers in GTA

(3) Organization for environmental management

There are two (2) organizations under MOT which are in charge of the environmental management for stationary emission sources in GTA as follows.

1) ORSUITO

This organization carries out technical inspections of industries and commercial enterprises causing pollution and nuisance, and set forth the necessary rulings in order to prevent pollution in GTA. There is a branch office in each district of GTA where 2-3 personnel are assigned for local inspection activities. Such inspection activities have been conducted, in general, based on the claims made by local inhabitants for environmental hazardous matters, and rulings are not always based on the measurement and analytical works on the environmental conditions, since there are almost no such type of equipment in the office of ORSUITO. Table 3.3.2-2 shows the number of rulings set forth by June 20, 1996.

Table 3.3.2-2 : Number or Rulings by ORSUITO

	Type of activity	Rulings	%
1	Agriculture	645	3.2
3	Industry	9,537	47.4
4	Electricity, Gas and Water	18	0.1
5	Construction	242	1.2
6	Wholesales, Retails, Restaurant and Hotel	3,172	15.8
7	Transport, Warehouse and Communication	343	1.7
8	Financial Service, Insurance, Real Estate and Trade	20	0.1
9	General, Social and Personal Service	6,154	30.6
	(Total)	20,131	100.0

(Source) ORSUITO

2) AQCC

This organization is engaged in working out pollution control procedures in GTA in view of mobile emission sources as well as stationary emission sources. AQCC provides MOT with air quality conditions in GTA measured by their monitoring stations, compiles data inventory of air pollution and conducts public relations through mass media besides preparation of a master plan for air pollution control.

3.3.3 Residential and commercial sector

Table 3.3.3 -1 shows the number of households and commercial units in GTA districts in 1994, which account for 33% in the total energy consumption in GTA following the first ranked manufacturing sector. The population and households in GTA account for 12% and 16% respectively of those in the country, generating about 14% of SOx and 11% of NOx in GTA, being a large emission source of air pollutants, although an emission amount per unit is small. Fig 3.3.1-1 indicates that the commercial units are densely located in the district 12 where the largest bazaar in Iran is located.

Table 3.3.3-1 Number of household & commercial units in GTA districts

District	Population	Household	Commercial	Area(km^2)
1	264,301	65,789	5,246	77.5
2	369,729	92,703	6,942	50.2
3	228,401	60,952	6,752	32.0
4	574,685	129,771	17,737	56.8
5	398,064	89,503	6,817	51.9
6	252,840	67,479	16,667	19.9
7	284,299	76,955	15,043	14.8
8	371,947	92,189	10,781	12.4
9	249,451	55,635	7,675	18.8
10	315,717	77,638	11,885	7.2
11	243,481	63,417	20,061	11.1
12	263,210	65,970	60,314	15.1
13	197,740	48,468	7,450	14.5
14	407,400	96,621	13,349	20.7
15	578,511	124,597	21,898	41.4
16	324,938	73,585	12,242	18.2
17	348,912	76,224	12,216	7.2
18	345,787	67,698	13,687	8.9
19	255,479	48,802	9,022	3.6
20	325,487	73,022	11,224	33.4
	6,600,379	1,547,018	287,008	515.6

(Source) Map of Tehran

(1) Problems of household & commercial sector in GTA

Fuel replacement with natural gas has been accelerated in this sector by the government, substantially helping reduce SOx emission in GTA. However, a large amount of HC emission in this sector has been considered serious in view of photo-chemical reactions in the atmosphere. HC is emissioned through evaporation and/or leakage rather than fuel combustion by the following sources:

1) Commercial shops	2) Depots	3) Household
- Petrol stations	- Ray depot	- Fittings/valves of pipelines
- Printing shops	- Kan depot	
- Dry cleaning shops	- Ghoochak depot	- Fugitive gas before ignition
- Painting shops	- Nazi Abad depot	
- Electric metal plating		

(2) Countermeasure for the problem

No definite countermeasures have been put into practice in this sector, although emission volume of HC in this sector shares around 44% of the total stationary sources.

Since measures for preventing emission of HC are well-known actions such as careful operation and maintenance activities for fugitive gas from pipelines, and installation of an HC gas recovery system at commercial work shops and refinery & depots, MOT is expected to take immediate action on these matters. For reference, typical examples of HC recovery process are illustrated as follows.

Fig 3.3.3-2 : Condensation process

Fig 3.3.3-3 : Absorption process (John Zink)

Fig 3.3.3-4 : Co-generation process

Fig 3.3.3-5 : Souver process

Fig 3.3.3-6 : Reverse Braiton process

Fig 3.3.3-1 : Number of household & commercial units in GTA districts

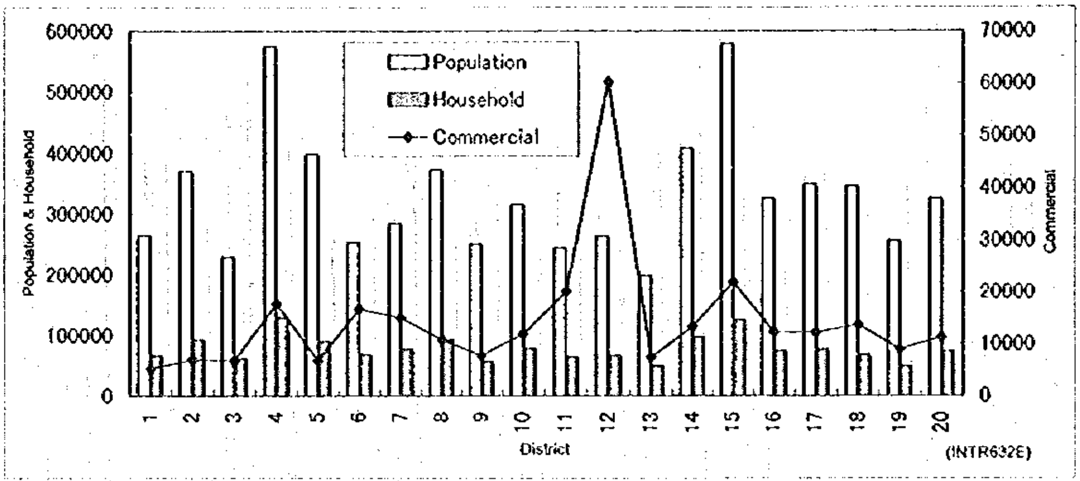


Fig 3.3.3-2 : Condensation process

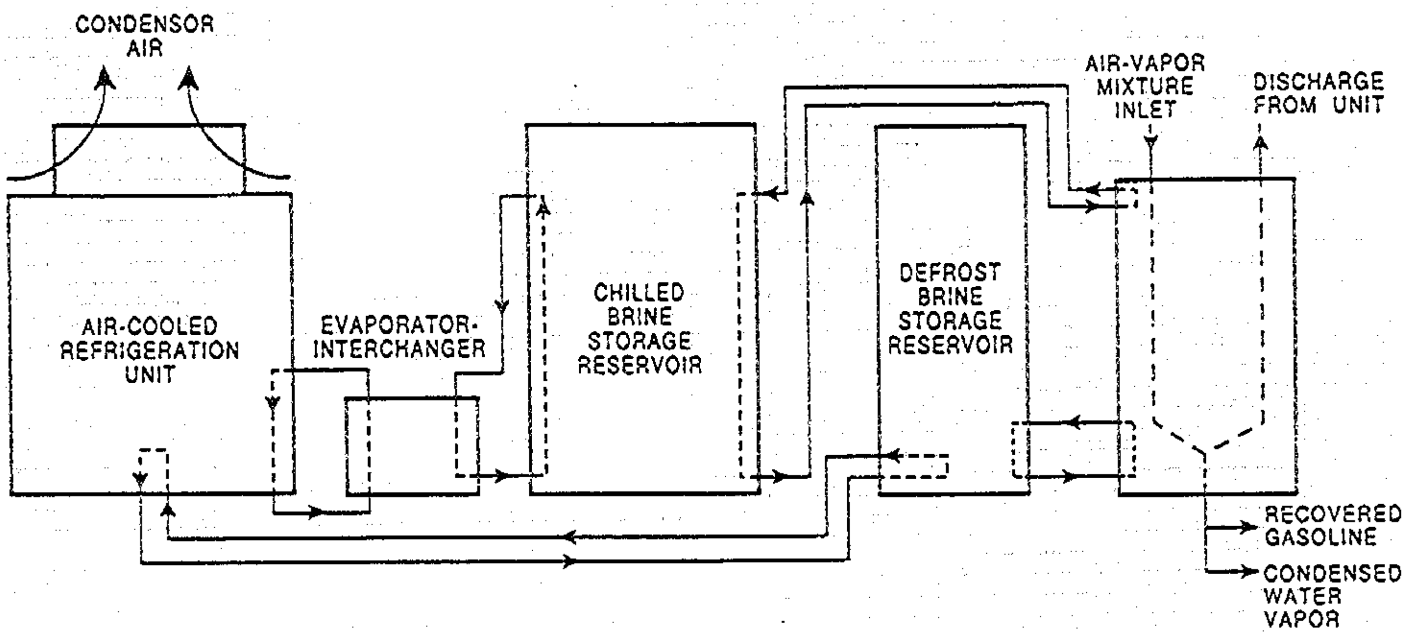


Fig 3.3.3-3 : Absorption process (John Zink)

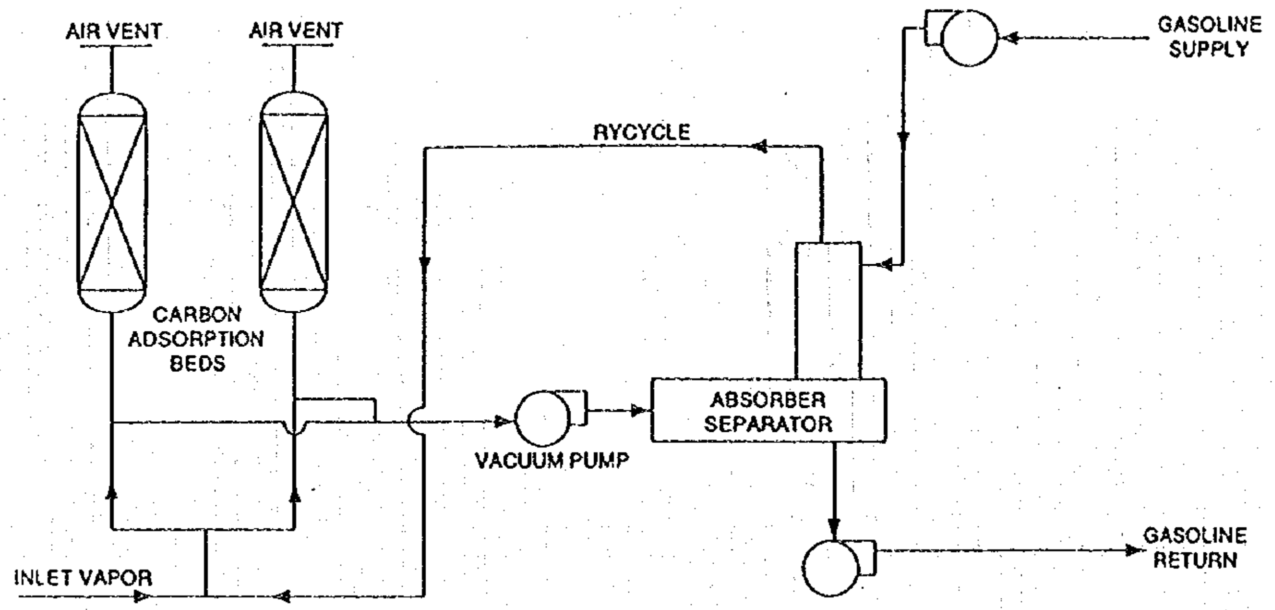


Fig 3.3.3-4 : Co-generation process

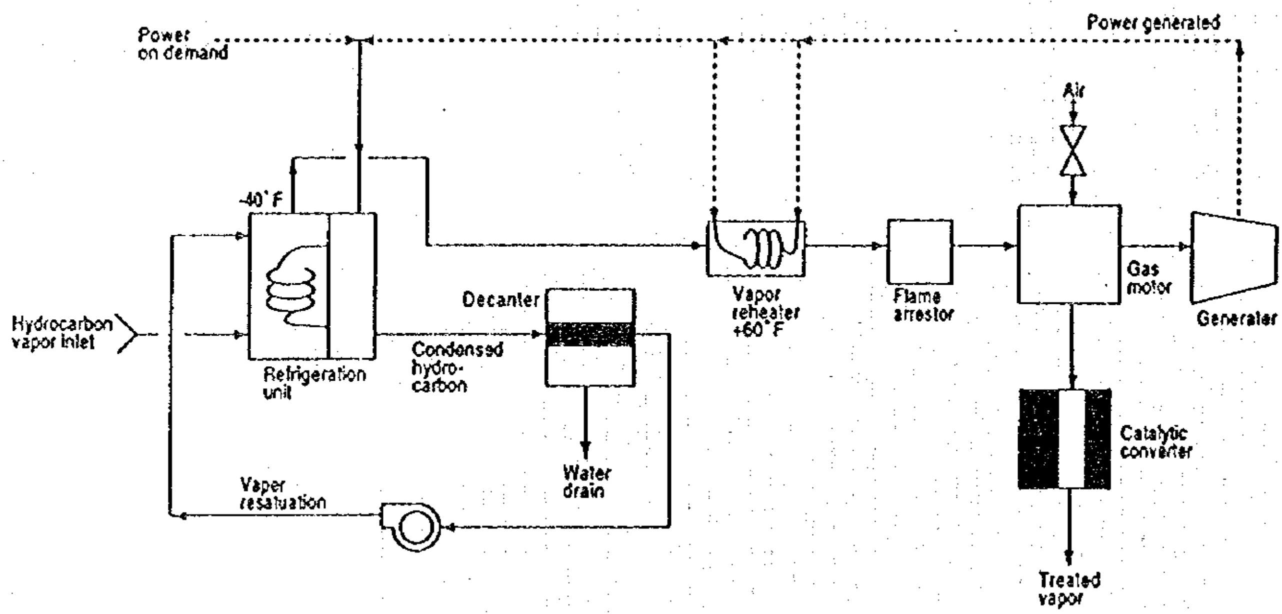


Fig 3.3.3-5 : Souver process

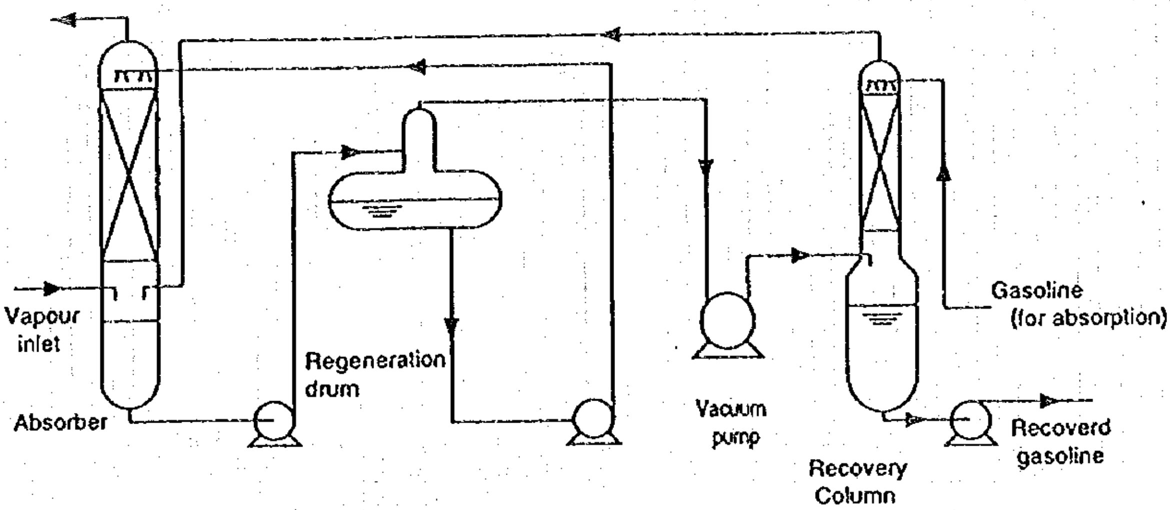
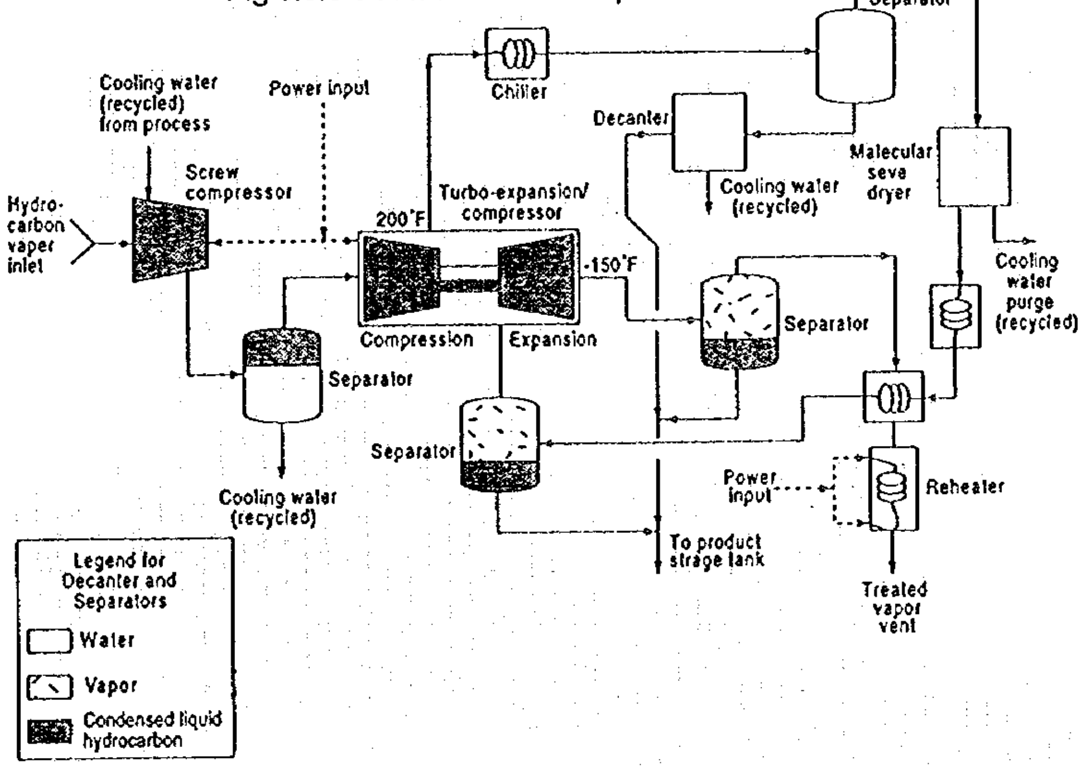


Fig 3.3.3-6 : Reverse Braiton process



3.4 Method and analysis of measurement

3.4.1 Outline of observation and measurement

Observation and measurements were held twice, the first one in September and October, and the second one in March.

The schedule is shown in table 3.4.1-1.Table 3.4.1-2 indicates the out line of each item.

Table 3.4.1-1 The schedule of observation and measurement

Item	First measurement (October)	Second measurement (February, March)
Meteorological observation	○	○
Ambient Air Quality	○	○
Automotive Source	○	—
Stationary Source	○	○

Table 3.4.1-2(1) List of observation / measurement procedure and instrument

Measurement Procedure	Instrument
1. Meteorological Observation	
1.1 Surface Meteorology	
(1) Surface wind	
Wind direction, speed and turbulence at 10m above surface will be measured by the ultra sonic anemometer. The data is necessary for determination of the parameter that is used for the prediction model of air pollutant diffusion. Point : AGHDACIYE AREA (1 point) Period :For 1 year Schedule : Hourly continuos observation	1. Ultra sonic anemometer 2. Data logger (with connecting cable) 3. Observation pole(10m aluminum pole, flange, branch wire, base) 4. setting up tools5. Recording paper
(2) Solar radiation	
Solar radiation will be measured by the pyranometer. The data is necessary for classification of the atmospheric stability that is used for the prediction model of air pollutant diffusion. Point, period and schedule are the same as surface wind observation.	1. Pyranometer(with cable) 2. observation pole (2m aluminum pole,flange,branch wire,base) 3. recorder for 6 item 4. recording paper
(3) Radiation balance	
Radiation balance will be measured by the net radiometer. The data is necessary for classification of atmospheric stability. Point, period and schedule are the same as surface wind observation.	1. Net Radiometer (with cable) 2. Flange (Pole is common use with pyranometer) 3. Recorder for 6 items (Recorder is common use with Pyranometer) 4. Polyethylene dome
1.2 Upper Layer Meteorology	
(1) Raball observation	
Wind direction and speed between the surface to 2000m height will be observed by tracking of the released sonde using the theodolite to know the characteristics of the wind field in the considering area of air pollutant diffusion. Point : AGHDACIYE AREA (1 point) Period : For 7 days Schedule : For 7 days, Twice a day (at 8 and 13 o clock)	1. Theodolite (with data cable) 2. Electric cable 3. Data logger (attached printer, with connecting cable) 4. IC card 5. Recording paper
(2) Low-level sonde observation	
Temperature, humidity and pressure between the surface and 2000m height will be measured by the radio sonde to know the characteristics of depth of the mixing layer in which the air pollutant diffuse. Point, period and schedule are the same as raball observation.	1. Receiver (Common use with captive sonde obs.) 2. Portable antenna 3. Data processor (with printer) 4. Sonde sensor checker 5. Non break down electric supply 6. Assmann aspiration psychrometer 7. Aneroid barograph 8. Electric cable 9. AVR (with 2kV step down trans) (1,5,6,7,8,9; Common use with captive sonde obs.) 10. Low-level sonde (100 pieces) 11. Water poured battery with miniature electric bulb

Table 3.4.1-2(2) List of observation / measurement procedure and instrument

	12. Recording paper (for printer) 13. Hose with buoyancy adjust weight (10m long, for filling balloon with He gas)
(3) Captive sonde observation	
Temperature, humidity and pressure between the surface and 700 height will be measured by the captive balloon to know the characteristics of the inversion height that controls diffusion of the air pollutant. Point : AGHDACIYE AREA (1 point) Period : For 7 days Schedule : For 7 days, 8 times a day (At 3,6,9,12,15,18,21 and 24 o clock)	1. Captive sonde system(Captive balloon, Captive sonde, Winch) 2. A set of sonde receiver(Receiver, Portable antenna) 3. Digitizer 4. Data processor 5. Non down electric supply 6. Acumen aspiration psychrometer 7. Aneroid barograph 8. Electric cable 9. AVR 10. Flash light 11. Dry batteries 12. Recording paper 13. Hose (10m long, for filling balloon with He gas)
2. Ambient Air Quality	
2.1 Simplified Measurements	
(1) Nox ($NO + NO_2$)	
Diffusion of the gaseous molecules Point : 31points Period :8 days(Rehearsal 1 day + measurement 7 days) Sampling time : 24 continuous passive sampling. Analysis: Spectrophotometric analysis.	1. Simultaneous sampling 2. Shelter 3. Filter for NO2 4. Filter for Nox 5. Analytical Implement
(2) SO2	
Diffusion of the gaseous molecules.(same as NOx) Point : 31points Period :6 days(measurement 6 days) Sampling time : 72 continuous passive sampling. Analysis: Chromatography analysis.(in Japan)	1. Simultaneous sampling 2. Shelter 3. Filter for SO2 4. Analytical Implement
(3) CO	
Air bag sampling with minisamplers and Salan bag. Point : Surface points:13points Vertical points: 5points Period : 4 days(Rehearsal 1 day + measurement 3 days) Samplingtime : 5:00-21:00(16 hours continuous sampling, 1 sampling in each hour) Analysis: NDIR detector analysis.	1. Mini-sampler 2. Timer Control Unit 3. Pump Unit 4. Air Bag 5. Alkaline Dry Cell 6. Tygon Tube 7. Filter 8. Tape Measure 9. CO Monitor
(4) HC	
Air bag sampling with indirect sampling system and Tedolar bag. Point : 5 points Period : 4 days(Rehearsal 1 day + measurement 3 days) Sampling time : 5 minute sampling for each hour from 5:00 to 20:00). Analysis: FID detector analysis. Item:THC,NMHC,CH_4	1. Indirect Sampling Set 2. Tedlar bag 3. Digital Flow Meter 4. Gas Leak Detector 5. HC Monitor
(5) VOC	

Table 3.4.1-2(3) List of observation / measurement procedure and instrument

Absorption sampling using Tenax GC absorbent. Point : Several points in MOT. Period : 1 days Sampling time : About 10 minutes . Analysis : Gas chromatography with thermal description injector.(in Japan)	1. Bake Out Equipment for Sampling Tube 2. Personal Mini Pump 3. Tenax GC Tube 4. High Purity N2 Gas 5. Pressure regulator
2.2 CMB Measurement	
Collection of SPM on the filters by filtration of the ambient air with use of Low volume Air sampler. Point : MOT government office building ground floor. Period : 7 days continuous sampling. Analysis: Radio activation analysis. Atomic absorption spectrometry analysis Fluorescent X-ray analysis Ion chromatography.(in Japan)	1. Low-volume Air Sampler 2. Teflon packing 3. Silicon packing 4. Pump blade 5. Pump element 6. Bypass filter 7. Electric Power Cable 8. Desiccatoe 9. Filter 10. Petri dish
3. Automotive Source	
3.1 Traffic Volume Survey	
(1) Traffic volume survey	
Traffic Volumes is recorded with video cameras installed at the survey locations and later played back, during which the traffic volume is measured by vehicle type. Survey locations : 20 location Survey time: 24 hours Type of vehicles: 7categories Survey date: Working day and holiday	1. Color Video Camera 2. Lens 3. Camera Housing 4. Video Coaxial Cable Connector 5. Video tape recorder 6. Color Monitor 7. Connecting Cable 8. Tape 9. Manual Counter 10. Stop Watch
3.2 Chassis Dynamo Test	
(1) Chassis dynamo test	
3.3 Field Driving Test	
(1) Traversing speed survey	
The survey was carried out by driving selected routs with vehicles installed speed meters and analysers. Routs: 19 routs	1. Non-contact Velocity Meter 2. Rotating Meter for Gasoline engine 3. Rotating Meter for Diesel engine 4. Pressure Gauge 5. Data Analyzing System 6. Thermometer 7. IC Memory Card 8. Analyzer 9. Calibration Gas 10. AC/DC Converter 11. Recorder 12. Calibration Unit
4. Stationary Source	
4.1 Flue Gas Measurements	
(1) Flow rate of gas	
Insert the measuring apparatus into the measuring hole	1. Pitot tube

Table 3.4.1-2(4) List of observation / measurement procedure and instrument

and set it as to fit the measuring point. Measurement of gas temperature, velocity and pressure. Factory name : Brick factory Power plant Tehran refinery Cement factory	2. Rubber bag 3. Thermocouple 4. Thermo pile 5. Compensating wire 6. Manometer
(2) Concentration of gas composition (CO_2, O_2, CO, H_2O)	
Use the tube made of glass or metal. To prevent the penetration of dust, full its tip with glass fiber or others. Insert it in duct through a measuring hole to lead the flue gas into the absorption tube. Factory name : Brick factory Power plant Tehran refinery Cement factory	1. Gas Detector 2. Moisture absorption tube 3. Suction pipe with heater 4. Orsat Analyzer 5. Distribution tube 6. Rubber bag
(3) Concentration of Nox, Sox	
Use the tube made of glass or metal. To prevent the penetration of dust, full its tip with glass fiber or others. Insert it in duct through a measuring hole to lead the flue gas into the analyzer. Factory name : Brick factory Power plant Tehran refinery Cement factory	1. MODEL VIA-510 (For NOX) Method NDIR, 2. MODEL VIA-510 (For SOX),Method ND IR 3. MODEL ES-510 (Sampler For O2,SOX) 220V 4. MODEL ES-510 (Sampler For O2,SOX) 220V 5. Recorder 6. Standard Gas 7. Pressure Regulator
(4) Concentration of dust	
Traverse the measuring points by using one dust collector to take a dust sample in the same sucking time at each point. Factory name : Brick factory Power plant Tehran refinery Cement factory	1. Sampling apparatus for dust 2. Printer paper and inkribon 3. Flange 4. Filter paper 5. Desiccatoc 6. Stop watch 7. Silica wool

3.4.2 Method of measurement and analysis

(1) Meteorological observation

The surface and upper meteorological observation was made by the JICA study team in autumn (October 8 - 15, 1996) and in winter (February 22 - March 1, 1997). The purpose of surface observation is to know the wind field and atmospheric turbulence and stability, which are governing pollutant diffusion in the surface boundary layer. The items of the surface observation are wind direction, wind speed, standard deviations of wind direction and speed, solar radiation in the daytime and radiation balance in the night-time. On the other hand, upper air is observed for the purpose of knowing the characteristics of the inversion and mixing layer, of which appearance and intensity affect the surface pollutant concentration, because they control the vertical transportation of the pollutants. Profiles of temperature, relative humidity, wind direction and speed were derived a by low level sonde and captive sonde. Details of these observation are as follows:

1) Surface meteorological observation

① Observation site

The Meteorological Bureau at Aghdasiyeh located 15km NE from the center of Tehran City was selected as the site of surface meteorological observation. Its altitude is 1548m above sea level and about 300m higher than that of the center of the city. There is the Elburz mountains to the north behind the observation site and its slope gradually descending to the south.

② Items and methods of observation

Items and methods of observation are summarized in Table 3.4.2-1. Solar radiation means here the total energy of the direct solar radiation and the diffuse sky radiation, while radiation balance indicates the balance (difference) between incomings and outgoings of radiation energy. If the balance is negative, it is equivalent to radiative cooling. The intensity of solar radiation controls activities of the thermal convection in the daytime, and the net radiation determines radiative cooling on the surface in the night-time. Therefore, both of them are the definitely important factors for determining atmospheric stability in the surface boundary layer.

Table 3.4.2-1 Items and methods of surface meteorological observation

Item	Instrument	Height of sensor	Reading
Wind direction Wind speed Standard deviation	Model DA-200 2-component ultra sonic anemometer	10m	Every 10 minutes
Solar radiation	Model MS43F Pyranometer	3m	The value is the average of the data for 10 minutes before reading time
Radiation balance	Model MF11 Net Radiometer	1.5m	

③ Observation period

The routine observation was started on October 4 in 1996 by the JICA study team and operated by them until March 2 in 1997. Thereafter, the job of operation and maintenance of the observation equipment was handed over to the Iranian side and observation has been made continuously. Analysis of the surface meteorology in this report was based on the data before March 1.

2) Upper layer meteorological observation

① Observation site

The upper layer meteorological observation was made at the same site with the surface meteorological observation

② Items and methods of observation

The items and methods of observation are summarized in Table 3.4.2-2.

Table 3.4.2-2 Items and methods of upper layer meteorological observation

Item	Method	Instrument	Observation schedule	Observation height
Wind direction Wind speed	Raball	Theodolite (Model : KDT-3)	For 7 days Twice a day (8:00,13:00)	Every 50m Up to 2000m
Wind direction Wind speed Temperature	Captive sonde	Sonde system (Model : CBS-T-14) Gas : helium	For 7 days Every 3 hours	Every 50 m Up to 700m
Temperature	Low level sonde	Sonde system (Model : JWA-94W) Balloon : rubber(100g) Gas : helium Ascent speed : 200m/min	Same as raball Observation	

③ Observation period

Observation was carried out in autumn and winter for the period of full seven days as shown below.

Autumn : from 12:00 on October 8 to 9:00 on October 15 in 1996

Winter : from 15:00 on February 22 to 13:00 on March 1 in 1997

④ Observation achievement

Achievement lists of observation runs in autumn and winter are shown in Table 3.4.2-3. In these field surveys, it was determined that each observation altitude to be reached by a captive sonde and low level sonde should be 700m and 2000m, respectively. Figures in the table denote the altitude where the sonde reached actually. After the sonde reached the target altitude, the captive sonde was pulled down while keeping observation. On the other hand, as for the low level sonde, signal receiving was discontinued as soon as it got to the altitude. In such cases where the observation was completed, the target altitudes are shown in the table. And " - " denotes that the observation was canceled or ended unsuccessfully.

Table 3.4.2-3 Achievement list of captive sonde and low level sonde observations

upper : temperature
lower : wind unit : m

October 8 - 15, 1996

	Captive Sonde								Low-level Sonde Raball	
Date	3:00	6:00	9:00	12:00	15:00	18:00	21:00	24:00	8:00	13:00
Oct.8				700 700	700 700	700* 700*	700 700	700 700		2000 2000
Oct.9	700 700	600 600	700 700	700 700	700 700	700 700	700 700	700 700	2000 2000	2000 2000
Oct.10	700 700	700 700	700 700	700 700	- -	700 700	700 700	700 700	2000 2000	2000 2000
Oct.11	- -	700 700	700 700	400 400	50 50	700 700	700 700	- -	- -	2000 2000
Oct.12	- -	600 600	700 700	250 250	- -	100 100	400 400	700 700	2000 2000	2000 2000
Oct.13	600 600	- -	700 700	700 700	600 600	700 700	700 700	700 700	2000 2000	2000 2000
Oct.14	- -	500 500	500 500	100 100	- -	50 50	700 700	650 650	2000 2000	2000 2000
Oct.15	400 400	700 700	700 700						2000 2000	

* : Surface data is missing.

upper : temperature
lower : wind unit : m

February 22 - March 1, 1997

	Captive Sonde								Low-level Sonde Raball	
Date	3:00	6:00	9:00	12:00	15:00	18:00	21:00	24:00	8:00	13:00
Feb.22					100 100	50 50	- -	50 50		
Feb.23	100 100	100 100	700 700	- -	- -	250 250	700 700	700 700	2000 2000	2000 2000
Feb.24	700 700	700 700	700 700	50 50	700 700	700 700	700 700	700 700	2000 surface	2000 700
Feb.25	700 700	700 700	700 700	50 50	450 450	700 700	700 700	450	2000 1300	2000 2000
Feb.26	700 700	100 100	700 700	500 500	700 700	150 150	100 100	100 100	2000 2000*	2000 2000
Feb.27	600 600	700 700	250 250	- -	- -	200 200	100 100	700 700	2000 2000	2000 2000
Feb.28	500 500	300 300	600 600	650 650	- -	700 700	700 700	700 700	2000 1400	2000 2000
Mar.1	700 700	700 700	700 700	700 700					2000 2000	2000 2000

* Data at 50 - 550m are missing.

- Raball observation and low level sonde observation

The total of 14 runs were supposed to be carried out in each season. The measurement from the surface to 2000m altitude should be accomplished at every run.

Autumn : 13 out of 14 runs were accomplished completely, except the run at 8:00 on October 11.

Winter : All of 14 runs for temperature were completed successfully. On the other hand, 13 runs of wind observation were accomplished, but the run at 8:00 on February 24 was unsuccessful.

- Captive sonde observation

The total of 56 runs were supposed to be carried out in each season. The measurement from the surface to 700 m altitude should be accomplished at every run. In order to avoid the accident, several runs under the conditions of wind stronger than 6 m/s or rain were canceled.

Autumn : Thirty-four runs were accomplished completely, and 41 runs could obtain data from the surface to the level higher than 500m. On the other hand, 9 runs could not reach 50m because of strong wind or rain. The wind tended to be stronger in the afternoon, so that 4 out of 7 runs scheduled at every 15:00 could not reach 50m.

Winter : Twenty-seven runs were accomplished completely, and 32 runs could obtain data from the surface to the level higher than 500m. On the other hand, 6 runs could not reach 50m because of strong wind or rain as in the case of the run in autumn. Similar to the runs in autumn, 3 out of 7 runs scheduled at 15:00 every day could not reach 50m.

3) Method of analysis

The atmospheric condition is an important factor controlling the pollutant diffusion and advection. Generally, urban air pollution is considered to be a localized phenomenon which is characterized by not only artificial circumstances but also natural environment such as flora, topography, and weather. Because of such a locality of the background of the air pollution, it is significant to know the local climate in the area concerned for each season in order to know accurately the characteristics of the local air pollution. For this purpose, it is necessary to know the general weather conditions in the specific period based on the statistics of the observation data as well as climatological characteristics based on the analysis using the data accumulated for a long term.

① Analysis of surface meteorology

The items of the statistics for the analysis of surface meteorology using the data obtained by the JICA study team are shown in the following table (Table 3.4.2-4). The statistics were made to know the characteristics of the atmospheric behavior which was essential to the pollutant diffusion and advection in the boundary layer. The period for statistics (daytime, night-time and whole day) was determined in the light of the diurnal variation of the wind and atmospheric stability.

Table 3.4.2-4 Items of statistics for surface meteorology

Meteorological element	Items for statistics	Period for statistics
Wind direction Wind speed	The most frequent wind direction	Whole period
	Frequency of the wind direction by classified wind speed	Day/night/whole day
Wind speed	Average wind speed	Whole period
	Average wind speed for each wind direction	Day/night/whole day
Atmospheric stability	Frequency of atmospheric stability	Whole period

* The division of daytime and night-time is determined based on the time of sunrise and sunset.

daytime : 7:00 - 17:00 night-time : 18:00 - 6:00

② Analysis of upper layer meteorology

The items of the statistics for the analysis of the upper layer meteorology using the captive sonde data are shown in the following table. The data were compiled for every 50m from surface to 700m. The statistics were made to know the vertical atmospheric structure and its diurnal variation which are typical in the region and season concerned. Especially, our interest was in the inversion layer and thermal mixing layer which control the vertical advection of the pollutants and are relevant to fumigation. Therefore, they were thought to have considerable influence on the surface concentration. The period for statistics (hourly, daytime, night-time and whole day) was determined in the light of the diurnal variation of the wind and atmospheric stability as well as surface meteorology.

Table 3.4.2-5 Items of the statistics for upper layer meteorology

Items for statistics	Period for statistics
Frequency of wind direction at each altitude	Day/night/whole day
Profile of average wind speed	Day/night/whole day/hourly
Frequency of classified wind speed	Day/night/whole day
Profile of average temperature	Day/night/whole day/hourly
Profile of average temperature gradient	Day/night/whole day/hourly
Frequency of classified temperature gradient	Day/night/whole day

* The division of daytime and night-time is determined based on the time of sunrise and sunset.

daytime : 7:00 - 17:00 night-time : 18:00 - 6:00

(2) Simplified and Additional measurements of air pollutants

The simplified measurements of NOx (NO_2 and NO) and SO_2, and the additional measurements of CO and HC were carried out in two seasons, i.e. autumn (October '96; the first measurement) and winter (February - March '97; the second measurement), with the simultaneous meteorological observations.

The ambient air quality of MOT is now monitored by some organizations mentioned in 4.2.1. Most of these air-monitoring stations are located at the cross-section of main roads or near the road. At these stations, it is supposed that the measured data are affected by the direct emission from vehicles. Therefore, simplified measurements and additional measurements were planned and conducted for the purpose of grasping the representative concentration of pollutants which were not affected by vehicles directly and of complementing the existing monitoring data. Especially, CO is considered as pollutant to be given priority in the investigation because of its high concentration observed in the past monitoring activities in the MOT. The sampling points and sampling time were selected on the assumption that CO concentration data should be utilized as input data and the materials for verification of the simulation model.

The time schedules of the simplified and additional measurements are shown in Table 3.4.2-6(1) for autumn and in Table 3.4.2-6(2) for winter. Table (a) shows the date when sampling and measurements were carried out and table (b) shows the sampling time and frequency during the period.

The explanation of each sampling point is shown in Table 3.4.2-7, and the latitude and longitude of them are summarized in Table 3.4.2-8. And their locations are plotted in the map (Fig. 3.4.2-1). Basically, the same sampling points were used for both measurement periods.

The VOC concentration was planned for measurement mainly during winter. During the autumn period, more than 20 samples at roadsides and in residential areas were collected as a test run.

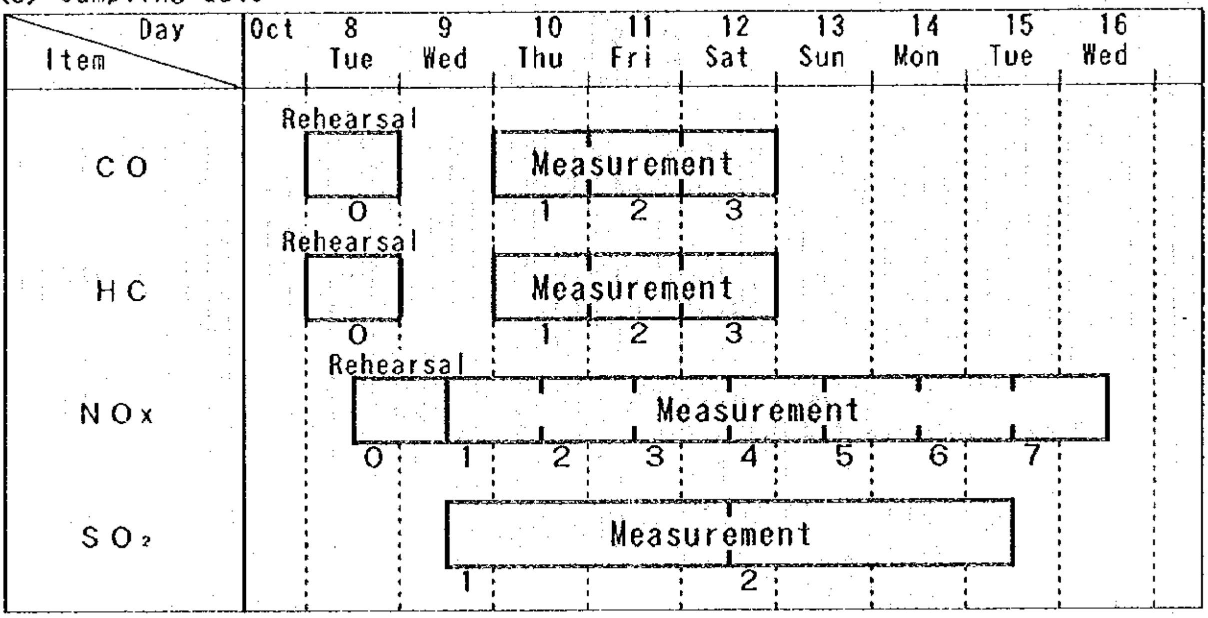
Each target pollutant and its measurement methodology are explained below:

In addition, CO, HC, NOx and SO_2 were measured in spring (May – June '97; the third measurement) in the same way with those in autumn and winter. The time schedules of the spring measurement are shown in Appendix 3.4.2-F.

Table 3.4.2-6(1) Schedule of simplified / additional measurements

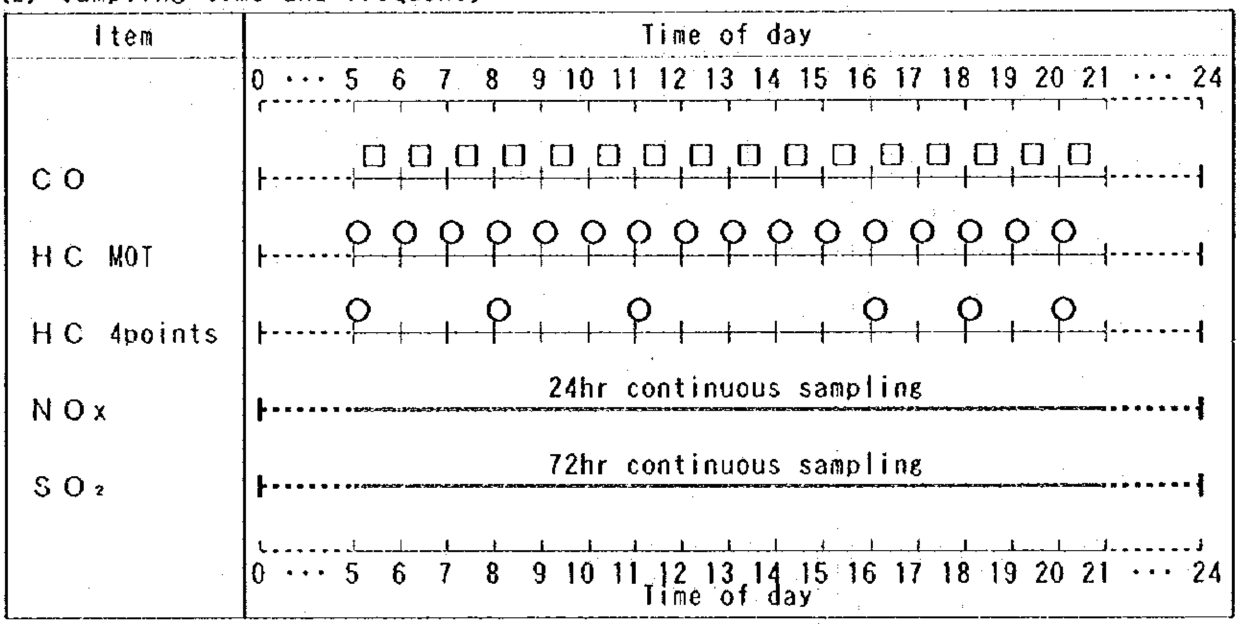
Autumn (Oct. '96)

(a) Sampling date



<Note> The number of each bar means Run No.

(b) Sampling time and frequency



<Notes> □ ; 1 hour Sampling

○ ; 5 minute Sampling

HC MOT ; HC taken at MOT government office building

Table 3.4.2-6(2) Schedule of simplified / additional measurements

Winter (Feb.-Mar. '97)

(a) Sampling date

Item \ Month / Day	Feb 21 Fri	Feb 22 Sat	Feb 23 Sun	Feb 24 Mon	Feb 25 Tue	Feb 26 Wed	Feb 27 Thu	Feb 28 Fri	Mar 1 Sat	Mar 2 Sun	Mar 3 Mon	Mar 4 Tue	Mar 5 Wed	Mar 6 Thu	Mar 7 Fri	Mar 8 Sat	Mar 9 Sun
CO		1		2		3		4									
HC		1		2		3		4									
NOx	0	1	2	3	4	5	6	7									
SO_2	1				2												
VOC																1	2

<Note> [Run No.] : Measurement

(b) Sampling time and frequency

Item	0 ···	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21 ··· 24
CO		□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	
HC MOT		◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	
HC 4points		◎			◎			◎					◎		◎		◎	
NOx	24hr continuous sampling																	
SO_2	96hr continuous sampling																	
VOC MOT,AQCC			◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	
VOC 4points			◎		◎			◎					◎		◎		◎	

Time of day

<Notes>
□ ; 1 hour Sampling
◎ ; 10 minute Sampling
HC MOT ; HC taken at MOT government office building
VOC MOT,AQCC ; VOC taken at MOT building and AQCC

Table 3.4.2-7 Measurement Points of CO, HC, NOx, SO_2 and VOC

Point No.	Explanation, Name of facilities	Measurement : O				
		CO	HC	NOx	SO_2	VOC
1	Public hall of the 13th-ward	O		O	O	
2	504 Hospital of Army	O		O	O	
3	Public hall of the 4th-ward	O	O	O	O	O
4	Public hall of Area 3, the 11th-ward	O		O	O	
5	Public hall of Area 6, the 2nd-ward	O		O	O	
6	Public hall of the 5th-ward	O	O	O	O	O
7	Teheran Railway station	O		O	O	
8	Public hall of the 18th-ward	O	O	O	O	O
9	Basij Sepah Center	O		O	O	
10	Facilities of Taxi organization of MOT	O	O	O	O	O
11	Public hall of the 15th-ward	O		O	O	
12	Facilities of MOT related brick and cement	O		O	O	
131	MOT government office building ground floor	O				
132	ditto, 2nd floor (10m)	O	O*1	O*2	O*2	O*1
133	ditto, 4th floor (20m)	O				
134	ditto, 7th floor (30m)	O				
135	ditto, roof (40m)	O				
136	ditto, roof (50m)	O				
14	AQCC building			O	O	O*1
15	AQCC mobile station			O	O	
16	Electrical bus station			O	O	
17	Facilities of the 16th-ward			O	O	
18	Synoheh clinic			O	O	
19	Water and wastewater organization			O	O	
20	Abbas-abad agriculture and animal husbandry area			O	O	
21	Public hall of 1st-Area, the 15th-ward			O	O	
22	Ekbatan town			O	O	
23	17 Shahrivar park			O	O	
24	TTTO building			O	O	
25	Fire fighting station of the 9th-ward			O	O	
26	Golf lands and Tennis club			O	O	
27	Mrs. Moghadam dentistry			O	O	
28	Meteorological station, Aghdasiyeh			O	O	
29	Shahid Abbaspoor University			O	O	
30	PARS Electric Factory			O	O	
31	Apartment of an AQCC staff			O	O	

<Notes> *1 : Each hour sampling *2 : 1st floor VOC : Winter measurement

Table 3.4.2-8 Latitude and longitude of sampling point

Point No.	Latitude		Longitude	
	deg(°N)	min	deg(°E)	min
1	35	41.408	51	26.705
2	35	43.877	51	27.229
3	35	44.576	51	29.508
4	35	42.027	51	22.803
5	35	42.563	51	21.557
6	35	43.971	51	18.902
7	35	39.568	51	23.933
8	35	38.992	51	20.901
9	35	35.930	51	18.508
10	35	39.488	51	27.032
11	35	38.402	51	28.852
12	35	36.952	51	30.311
13*1	35	40.871	51	24.918
14	35	44.000	51	26.295
15	35	41.568	51	29.524
16	35	43.475	51	31.426
17	35	38.308	51	25.311
18	35	37.354	51	23.835
19	35	35.475	51	26.344
20	35	35.260	51	21.359
21	35	40.442	51	21.475
22	35	42.335	51	18.852
23	35	40.228	51	18.934
24	35	43.582	51	23.754
25	35	46.751	51	20.246
26	35	46.697	51	23.689
27	35	48.550	51	27.050
28	35	48.054	51	29.181
29	35	45.220	51	33.361
30	35	42.643	51	12.918
31	35	43.086	51	26.279

<NOTE> *1 : 131 - 136

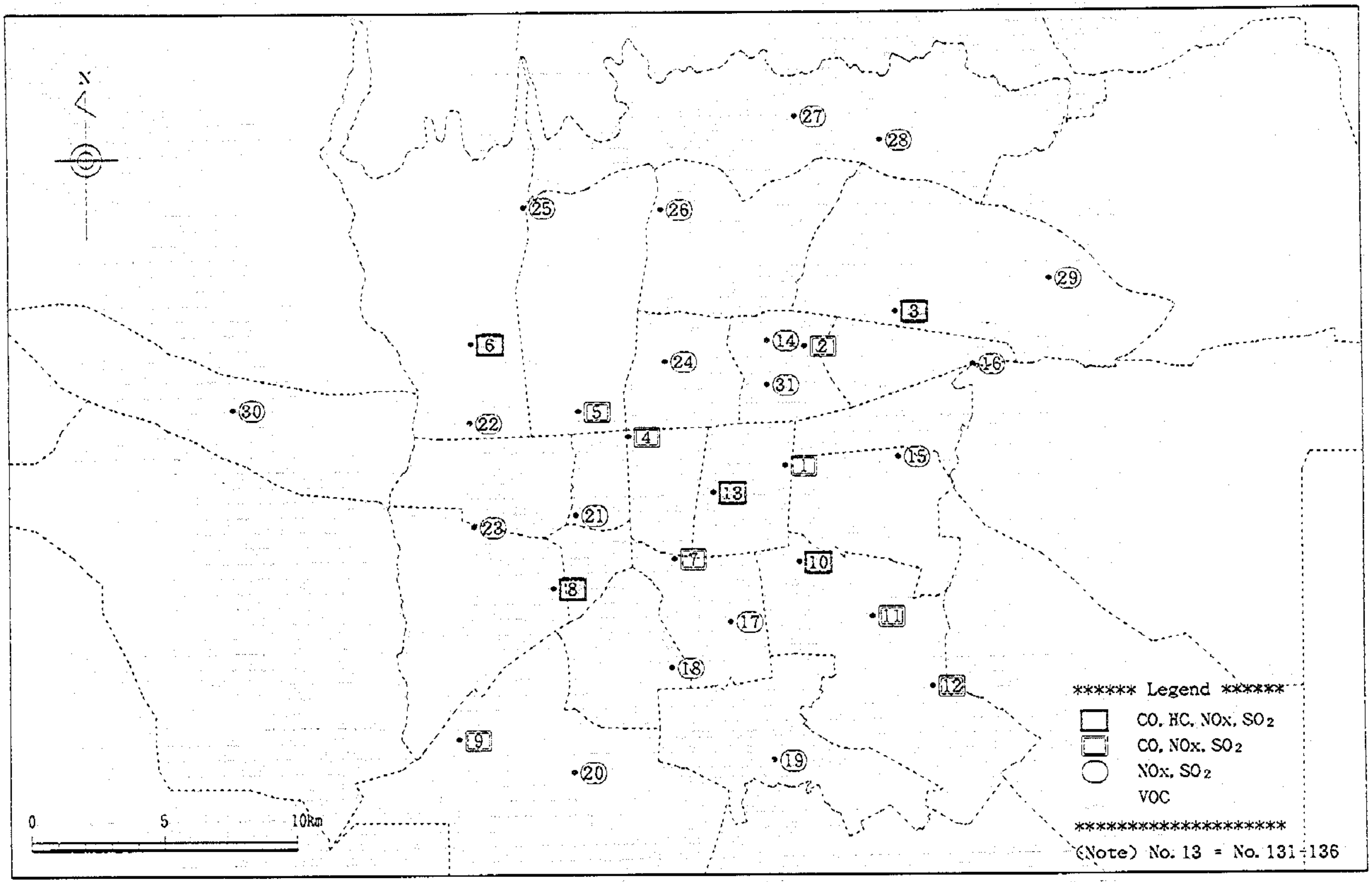


Fig. 3.4.2-1 Location of sampling points of Simplified/Additional measurements

1) CO

① Information of sampling points are shown in Table 3.4.2-7, Table 3.4.2-8 and Fig. 3.4.2-1.

a. Surface measurement points : Total 13 points.

- MOT government office building (1 point, No. 131)

- 3 points in each direction, i.e. NE, NW, SW and SE viewed from the position of No. 131 at the center of GTA (12 points, No. 1 - 12)

b. Vertical measurement points : Total 5 points.

- MOT government office building (10, 20, 30, 40 and 50m height, No. 132 - 136).

② The sampling period and time are shown in Table 3.4.2-6.

a. The number of days : Total 4 days for each measurement

- Autumn measurement : Rehearsal 1 day + 3 consecutive days

- Winter measurement : 4 times every other day

At the winter measurement, sampling is made every other day taking care of physical conditions of staff.

b. Sampling Time : 5:00 - 21:00 (16 hour continuous sampling, 1 sample in each hour)

③ Sampling method : Air bag sampling with JWA-93 Mini samplers and Salan bags

- The schematic diagram and pictures of CO sampling are shown in Appendix 3.4.2-A.

- Capacity of Salan bag = 10 L

- The flow rate of each sampler is calibrated and adjusted to about 170 mL/min (= 10 L/h) before measurement to collect the sample air enough for the following analysis.

- Salan bag is selected for CO sampling because the gas permeability of Salan, i.e. polyvinylidene chloride, is very low.

- Before use, each air bag is pre-cleaned and checked whether it has any leak, with the following process: to fill up the bags with high purity N_2 gas, leave them for the night, and release the gas from the bags on the next day.

④ Analysis method : NDIR detector analyses using APMA-350E type CO monitors (at AQCC).

- CO monitors are calibrated for each analysis day using a Zero air cylinder and CO standard cylinder which includes about 9 ppm of CO in high purity N_2 gas.

- (The way of analysis) The air bag is connected to the CO monitor directly using Teflon and silicon tubes. Then the CO concentration value on the display is recorded on the analysis note just 3 minutes after the bag is connected. The waiting time of 3 minutes is selected based on the result of the previous test showing that it took about 2 minutes for the monitor to show the nearly constant value. Analysis of CO is carried out within two or three days from each sampling day.

2) HC

① Information of five sampling points for HC is shown in Table 3.4.2-7, Table 3.4.2-8 and Fig. 3.4.2-1.

- MOT government office building (1 point, No. 132)

- 1 point in each direction of NE, NW, SW and SE viewed from the position of No. 132 at the center of GTA (4 points, No. 3, 6, 8 and 10).

② The sampling period and time are shown in Table 3.4.2-6.

a. The number of days : Total 4 days for each measurement (same as CO)

- Autumn measurement : Rehearsal 1 day + 3 consecutive days

- Winter measurement : 4 times every other day

b. Sampling Time :

- MOT building (5 minute sampling in autumn and 10 minute sampling in winter, at every hour from 5:00 to 20:00 ; 16 samples / day)

- Other 4 points (5 minute sampling in autumn and 10 minute sampling in winter, at 05, 08, 11, 16, 18 and 20h ; 6 samples / day)

(Note) Sampling times of the 4 other points were chosen in the light of the diurnal variations of typical traffic volume and concentration of pollutants in Tehran, i.e. early morning (05h), the morning traffic peak (08h), day time (11,16h) and the evening traffic peak (18,20h).

For the winter measurement, sampling duration was lengthened to 10 minutes from 5 minutes of the autumn measurement for better representativity of the sample.

③ Sampling method : Air bag sampling with an indirect sampling system and Tedolar bag

- The schematic diagram and pictures of HC sampling are shown in Appendix 3.4.2-B.

- Capacity of Tedolar bag = 20 L

- A Tedolar bag is selected for HC sampling because Tedolar is characterized by its low adsorption of gas.

- Before use, each air bag is pre-cleaned and checked to detect any leak in the same way with the Salan bag.

④ Analysis method : FID detector analyses using the APHA-350E type HC monitors (at AQCC).

- Item : CH_4 (Methane)

  NMHC (Non-methane hydrocarbon)

  THC (Total hydrocarbon)

- HC monitors were calibrated for each analysis day in the similar way to CO.

- (The way of analysis) The air bag is connected to an HC monitor directly using Teflon and silicon tubes. Then HC values on the display are recorded on the analysis note for each of 3 items of HC just 3 minutes after the bag is connected. The waiting time of 3 minutes is also determined by the previous test. Analysis of HC must be finished within the day or at latest before the next morning, because of the possibilities for the HC concentration to change its reactivity and permeability of a Tedolar bag.

3) NOx and SO_2

① Information of total 31 sampling points for NOx and SO_2 is shown in Table 3.4.2-7, Table 3.4.2-8 and Fig. 3.4.2-1.

② The sampling period and time are shown in Table 3.4.2-6.

- The number of days :

  NOx - Total 8 days (for both seasons, Rehearsal 1 day + Measurement 7 days)

  SO_2 - Autumn : Total 6 days (Measurement 6 days)

  - Winter : Total 8 days (Measurement 8 days)

- Sampling Time :

  NOx - 24 hour continuous passive sampling (in both seasons)

  SO_2 - Autumn : 72 hour continuous passive sampling

  - Winter : 96 hour continuous passive sampling

According to the manufacturing company of the sampler mentioned later, the standard exposure periods of the samplers are 24 hours (=1 day) for NOx and 168 hours (=7 days) for SO_2, respectively. Based on the preliminary analysis of the ambient air monitoring data, showing the SO_2 concentration was higher than that of Japan, 24 hour sampling for NOx and 72 hour sampling for SO_2 were adopted. But the sampling time of SO_2 was lengthened to 96 hours (=4 days) for the winter measurement from 72 hours (=3 days) for the autumn measurement because the results of the autumn measurement were considered to be underestimated. The Start / End time for each sample, that is, the timing of replacing sampled filters with new ones is fixed in early afternoon in view of the previous result of the monitoring stations showing that the diurnal variation of NOx and SO_2 concentration sink in the daytime.

③ Sampling methods

- Passive sampling by diffusion of the gaseous pollutants using an Ogawa Passive Sampler shown in Appendix 3.4.2-C.
- Item for NOx

  NO_2 : Measured by the result from the NO_2 filter

  NO : Difference between the values of the NOx and NO_2 filters

④ Analysis methods

NO_2 and NOx samples were analyzed by using a spectrophotometer at the Chemical Engineering Department of Sharif University in Tehran, while SO_2 samples were carried to Japan and analyzed there.

NO_2 and NOx : Extracted with water and analyzed with a spectrophotometer.

SO_2 : Extracted with water and analyzed with an ion chromatography.

The analysis methods are also outlined in Appendix 3.4.2-C.

It must be noticed that NO data for both seasons are not available because the oxidation reagent reduced its ability of oxidation affected by high temperature during the transportation in the case of the autumn measurement, and because the blank value of NOx filter prepared for the winter measurement was extremely high according to the analysis of Sharif University. Consequently, only the concentration of NO_2 is listed in this report.

4) VOC

① Sampling for the autumn measurement

For the autumn measurement, 26 samples of VOC were collected at several points in MOT mentioned below.

a. Point : Intersection : Fatemi

Gas station : gasoline and LPG stations

Residential area: AQCC and the apartment of AQCC staff

Roadside and on the road

b. Date : Oct. 29 '96 (1 day)

c. Number of samples : 26.

② Sampling for the winter measurement

a. Sampling points of VOC are 6 in total, of which 5 points are common with HC and AQCC (No. 14).

Information of them is shown in Table 3.4.2-7, Table 3.4.2-8 and Fig. 3.4.2-1:

- MOT government office building (No. 132)

- 1 point in each direction of NE, NW, SW and SE viewed from the position of No. 132 at the center of GTA (4 points, No. 3, 6, 8 and 10).

- AQCC (No. 14)

b. The sampling period and time are shown in Table 3.4.2-6.

- The number of days : Total 2 days

VOC was sampled in accordance with different schedules from those for other items on two days just before the departure of the JICA study team, because the VOC sampling tube would not keep its purity for long time due contamination caused by surrounding air. Therefore the analysis had to be made in a week after pre-cleaning.

- Sampling Time :

MOT building and AQCC (10 minute sampling at each hour from 6:00 to 20:00 ; 15 samples / day)

4 other points (10 minute sampling at 06, 08, 11, 16, 18 and 20h ; 6 samples / day)

c. Sampling of HC.

In addition to VOC, HC sampling was carried out at the MOT office building and

AQCC on the same schedule with that for VOC for comparison.

③ Sampling methods

- Adsorption sampling using a Tenax GC tube and SIBATA mini sampler.

The schematic diagram and pictures of VOC sampling are shown in Appendix 3.4.2-D.

- Sampling time : 10 minutes

- Sampling air volume : about 1 L

The flow rate of each sampler was adjusted to about 100 mL/min. The sampler has an LCD digital counter which displays the counts of revolution of the pump, i.e. one count for one revolution of the pump. Then the sampler was calibrated by measuring the air volume per one count. Figures displayed on the LCD counter at the start and end of the sampling were written on the field note. The difference of them (= net counts) denotes the air volume which was pulled through the Tenax GC tube.

Before measurement, Tenax GC tubes were pre-cleaned by heating at 180 - 200℃ for about 30 minutes and flushing inside of the tubes with high purity N_2 gas. The tubes were pre-cleaned on the day before each sampling day.

④ Analysis method

VOC samples were carried to Japan and were analyzed immediately with special analysis devices.

- Analysis method : Gas chromatography with a thermal desorption injector.

The schematic diagram of the VOC analyzing system is shown in Appendix 3.4.2-D.

Item of the analysis : Benzene
Toluene
Ethylbenzene
m,p-Xylene
o-Xylene

(3) SPM sampling for Chemical Mass Balance (CMB) Measurement

Samplings of SPM (Suspended Particulate Matter, ≦10μm) were carried out at the MOT government office building in two seasons with two sets of a low-volume air sampler.

① Sampling point : Backside of the MOT government office building, on the ground level (almost the same with No. 131)

Note : Because of an emergency electric power supplier uses a diesel engine, the sampling place was moved to 20m east of the first sampling point for the second sampling of the autumn measurement and subsequent sampling.

② Sampling period and time:

The number of days : Autumn = total 21 days (Oct. 3 - Oct. 24 '96)
Winter = total 27 days (Feb. 5 - Mar. 4 '97)

Sampling time : Autumn = 7 day continuous sampling (Oct. 3-10, Oct. 10-17, Oct. 17-24)
Winter = 14 day (Feb. 5 - Feb. 19) and 13 day (Feb. 19 - Mar. 4) continuous sampling

The sampling time of the winter measurement was lengthened because the concentrations of some pollutants analyzed in Tehran at the autumn measurement showed "ND", i.e. less than the detection limit. Sampling of the second winter measurement was terminated on the 13th day because the 14th day was a national holiday of Iran.

The Start / End time for each sample, that is, timing of replacing sampled filters with new ones is fixed at noon in view of the variation in traffic volume and SPM concentration.

③ Sampling method :

Collection of SPM on the filters through filtration of ambient air with use of a low-volume air sampler. Two kinds of filters were used for this sampling; a quartz filter and cellulose nitrate filter.

④Analytical items and methods :

After measurement of weight, every filter sample was divided into halves, a half which was analyzed at the Chemical Engineering Department of Sharif University, and the other half which was carried to Japan and analyzed there. The analytical items and equipment are as follows;

Concentration of SPM

- Gravimetric method (weighing method)

Principal elements and metals: Al, Mn, V, K, Na, Fe, Sc, Zn, Pb, S, etc.

- Radio activation analysis (Japan)
- Atomic absorption spectrometry analysis (Iran)
- Fluorescent X-ray analysis (Iran, Japan)

Ions : NO_3^-,SO_4^{2-},Cl^-,NH_4^+

- Ion chromatography (Japan)
- Spectrophotometric analysis (Iran)

Carbons : C-org(Organic carbon), C-ele(Elemental carbon)

- Thermal carbon analyzer (Japan)

Specifications and explanation of each analyzer are shown in Appendix 3.4.2-E.

(4) Stationary emission source

Analytical measurements for exhaust gas emission were conducted in both summer and winter for energy-intensive factories in GTA as well as for home appliances such as small boilers for room heating and cooking utensils. Methods of measurement and analysis for stationary emission sources are described under 1) in this section, and the name and type of facilities and measured results are described under 2).

Furthermore, in order to make sure sulfur contents of fuels used in GTA, fuel analysis is conducted in Japan for five (5) samples, all of the outcome of which meet the specification of NIOC described under 3).

1) Method of measurement and analysis for stationary emission sources

JIS (Japan Industrial Standard) is applied to measurement and analysis. In the field measurement, portable instrument analyzers are selected because of easy handling and inspecting activities. As for a measuring method, popularly used and authorized methods by WHO, EPA, etc. are selected as shown below.

	Item	Method
1	Water	Weighing by U-tube
2	Oxygen	Orsat method
3	Flow rate	Pitot tube method
4	Dust	Filter with computer-aided equal velocity suction system
5	SOx	Non-dispersion type infrared gas analyzer
6	NOx	Non-dispersion type infrared gas analyzer
7	CO	Detector tube

(a) Gas temperature

The flue gas temperature is measured with a thermocouple, which is inserted into an exhaust gas duct, and indication is read when it becomes stable.

(b) Moisture content

A U tube is packed with granular CaCl2 and let fixed volume of exhaust gas flow through the tube, and moisture is absorbed, then water content is calculated on the basis of the weight difference of the tube as follows.

$$Xw = \frac{22.4*ma*100/18}{Vm*273/(273+\theta m)*(Pa+Pv)/760+22.4*ma/18}$$

Xw : water content(%), ma : absorbed water (g)

Vm : exhaust gas volume(l), Pa : atmospheric pressure (mmHg)

Pv : gas meter pressure(mmHg)

(c) Component in flue gas

Exhaust gas in the duct is taken into a rubber sack and analyzed with an Orzat analyzer. An Orzat analyzer is to absorb CO_2, O_2, CO with a respective liquid absorbent shown below, and each gas composition is calculated by reduction of gas volume. In the case of low concentration of component, a detector tube is used in place of an Orzat analyzer.

Absorbent :

CO_2: Potassium hydroxide

O_2 : Pyrogallol and potassium hydroxide

CO : A detector tube is used

(d) Velocity

Velocity is calculated on the basis of exhaust gas pressure to be measured by a pitot tube of Western type as follows:

$$\gamma_0 = ((100-Xw)(CO_2*44+O_2*32+CO*28+N_2*28)/100+Xw*18)/(22.4*100)$$

$$\gamma = \gamma_0*273/(273+\theta s)*(Pa+Ps/13.6)/760$$

$$V = C*\sqrt{\frac{19.6\ h}{\gamma}}$$

Ps : static pressure of exhaust gas(mmHg) C : coefficient of Pitoh tube

V : velocity(m/s) θs : exhaust gas temp (C)

(e) Dust concentration

A sampling probe is inserted into a duct and exhaust gas is extracted with the same velocity of exhaust gas, and dust is collected by a paper filter attached to a probe, then the filter is dried and difference of weight is measured.

$$C = \frac{md}{V_N}$$

C : dust concentration (g/Nm3)

V_N: exhaust gas extraction volume (Nm3)

(f) SOx and NOx concentration

Molecular particles absorb a particular range of spectrum by excitation when exposed to infrared radiation. By means of this phenomena, the concentration of special gas component can be measured. Zero-span calibration is always necessary for analyzing equipment for each measurement.

2) Measuring results

Analytical measurements for exhaust gas emission are conducted at 22 points in total as shown in Table 3.4.2-9, and analyzed data are shown in Table 3.4.2-10.

3) Fuel analysis

Fuel analysis to verify sulfur contents in the fuels used in GTA is conducted as shown in Table 3.4.2-11, evidencing that all of the fuels meet the specification of NIOC.

Table 3.4.2-9 : Name of facilities visited for measurement

1. First field survey : 1996/09/22-1996/10/09

Sector	Name	facility	Date	Address	District
Brick factory	Sofalijadid		1996/9/22	Ismaicl abad-savehringway sofal Jadid Co.	
Power plant	Besat		1996/9/24	Besat highway-against terminal	16
Refinery	Tehran	12H-101	1996/9/28	Qom road	DB 20
		2H151	1996/9/29		
		2H-181	1996/10/1		
		Steam boiler	1996/10/2		
Cement factory	Moshirieh	No.7	1996/10/5		15
	Tehran	No.5	1996/10/6	Khavaran road	15
		No.4	1996/10/8		
		No.6	1996/10/9		

2. Second field survey : 1997/02/18-1997/03/02

Sector	Name	facility	Date	Address	District
Household	Room heater by gasoil		1997/2/18		
	Room heater bykerosene		1997/2/18		
	Fire place		1997/2/19		
	Room heater by NG		1997/2/19		
	Boiler house		1997/1/20		
	stove by NG		1997/2/22		
	Stove by LPG		1997/2/22		
Cement factory	Moshirieh	No.7	1997/3/6		15
	Tehran	No.4	1997/3/25	Khavaran road	15
		No.6	1997/3/26		
Refinery	Tehran	2H-101	1997/3/1	Qom road	DB 20
		Steam boiler	1997/3/2		

Table 3.4.2-10(1) : Analized data sheet for first field survey

Item	Unit	Sofal Jadid	Besat	Tehran Refinery			
		(Brick)	(power plant)	2H-101	2H-151	2H-181	Boiler
Date	-	96.09.22	96.09.24	96.09.28	96.09.29	96.10.01	96.10.02
Fuel	-	Natural Gas	Natural Gas	Gas & Oil	Gas & Oil	Gas & Oil	Heavy Oil
Fuel Consumption	-	225 m3/h	11040 m3/h	284 MMBtu/h	160 MMBtu/h	42.8 MMBtu/h	25160 lb/h
Excess Air Ratio		12.8	2.32	1.52	1.32	1.55	1.24
Outlet Temp	Centigrade	97	-	429	-	446	426
Moisture	%	7.4	-	12.3	12.2	10.4	11.1
Composition CO2	%	1.5	5	6.5	9.5	8	12
O2	%	19.4	12.5	7.8	5.5	7.9	4.3
CO	ppm	60	N.D	20	5	30	N.D
SOx	ppm	2	2	575	396	572	> 1000
NOx	ppm	22	66	136	129	145	208
SPM	g/m3	> 0.005	-	0.026	-	0.021	0.023
Emission Factor CO	g/Gj	113	0	27	-	49	0
SOx	g/Gj	8.6	2.5	1747	-	2150	-
NOx	g/Gj	68	60	297	-	392	98
SPM	g/Gj	0	-	28	-	28	5.3

Item	Unit	Tehran Cement			
		No 4	No 5	No 6	No.7
Date	-	96.10.05	96.10.06	96.10.08	96.10.09
Fuel	-	Natural Gas	Natural Gas	Natural Gas	Natural Gas
Fuel Consumption	-	6930 m3/h	2440 m3/h	14670 m3/h	8000 m3/h
Excess Air Ratio		2.19	1.97	2.03	3.25
Outlet Temp	Centigrade	148	188	128	115
Moisture	%	17.1	9.5	12.4	10.2
Composition CO2	%	10.6	10	11	6.1
O2	%	11.3	10.4	12.6	14.6
CO	ppm	4000	N.D	10	30
SOx	ppm	5	N.D	N.D	N.D
NOx	ppm	274	192	319	300
SPM	g/m3	0.49	0.009	0.51	0.026
Emission Factor CO	g/Gj	2370	0	9.1	33
SOx	g/Gj	9.4	0	0	0
NOx	g/Gj	368	140	471	538
SPM	g/Gj	321	5.3	372	23

Table 3.4.2-10(2) : Analized data sheet for second field survey

Item	Unit	Room heater				Cooking burner	
		Gas Oil	Kerosene	Fire Place	Heater(NG)	NG	LPG
Date	-	97.02.18	97.02.18	97.02.19	97.02.19	97.02.22	97.02.22
Fuel	-	Gas Oil	Kerosene	Natural Gas	Natural Gas	Natural Gas	LPG
Fuel Consumption	-	0.353 Kg/h	0.229 Kg/h	1.27 m3/h	0.6 m3/h	0.25 m3/h	0.18 Kg/h
Excess Air Ratio							
Outlet Temp	Centigrade	-	-	-	-	-	-
Moisture	%	-	-	-	-	-	-
Composition CO2	%	4.4	2.8	0.64	2.2	0.64	0.22
O2	%	14.2	15.8	19.8	16.7	20.5	20.6
CO	ppm	105	360	53	25	N.D	N.D
SOx	ppm	137	27.3	1.3	0	2.1	0.1
NOx	ppm	14.6	6.5	6.4	21.3	3.2	2
SPM	g/m3	-	-	-	-	-	-
Emission Factor CO	g/Gj	106	595	234	32.2	0	0
SOx	g/Gj	316	103	13.1	0	21.2	3.9
NOx	g/Gj	24.2	17.6	46.5	45	23.3	61.8
SPM	g/Gj	-	-	-	-	-	-

Item	Unit	Boiler	Tehran Cement			Tehran refinery	
		Water heater	No.4	No.6	No.7	2H-101	Boiler
Date	-	97.02.20	97.02.25	97.02.26	97.03.06	97.03.01	97.03.02
Fuel	-	Natural Gas	Natural Gas	NG + HO	Natural Gas	FG + FO	Fuel Oil
Fuel Consumption	-	6.3 m3/h	6000 m3/h	(7.6Km3+7KL)/h	6000 m3/h	(2116m3+5.13t)/h	13200 Kg/h
Excess Air Ratio			2.17	2.31	2.19	1.73	1.14
Outlet Temp	Centigrade	-	145	156	126	429	460
Moisture	%	-	12.8	11	14.9	9.8	12.2
Composition CO2	%	2.1	16	11.4	14.5	6.8	12.4
O2	%	15.8	10.6	11.6	10.8	9.4	2.8
CO	ppm	7550	2200	N.D	38	N.D	750
SOx	ppm	-	4	N.D	N.D	521	778
NOx	ppm	5.9	307	258	252	111	186
SPM	g/m3	-	0.32	0.37	0.14	0.028	-
Emission Factor CO	g/Gj	10200	1850	0	30.3	0	884
SOx	g/Gj	-	7.7	0	0	4870	2100
NOx	g/Gj	12.5	425	407	331	746	360
SPM	g/Gj	-	212	284	89.4	91.6	-

Table 3.4.2-11(1) : Measuring method for fuel analysis

	Component	Fuel	Method
1	Pb content	Gasoline	JIS k 2255-B (Atomic absorption)
2	Sulfur content	Gasoline	Coulometric titration
		Kerosene	Coulometric titration
		Gas oil	JIS K 2541 (Excitation)
		Heavy oil (Sample 1)	JIS K 2541 (Excitation)
		Heavy oil (Sample 2)	JIS K 2541 (Excitation)

Table 3.4.2-11(2) : Analytical result of sulfur content in fuel oil

	Fuel	Sulfur content		Pb content	
		Spec of NIOC	Sample	Spec of NIOC	Sample
1	Gasoline	<0.1w%	860ppm	<0.56g/liter	0.22g/liter
2	kerosene	<0.2w%	0.2w%		
3	Gas oil	<1.0w%	0.8w%		
4	Heavy oil (Sasmle 1)	<3.0w%	2.71w%		
5	Heavy oil (Sasmle 2)	<3.0w%	2.72w%		

Chapter 4

Clarification of pollution mechanism and characteristics

4. Clarification of pollution mechanism and characteristics

4.1 Meteorological condition in Tehran

The analysis of the meteorological background related to air pollution in Tehran was made based on the field survey data obtained by the JICA study team and existing data belonging to IRIMO. The field survey data consist of the surface meteorological data for five months from October, 1996 to February, 1997, and the two sets of the upper layer meteorological data obtained for the periods of October 8 - 15, 1996 and February 22 - March 1, 1997. And the IRIMO data for one year from January to December in 1994 are used for the analysis and comparison. For reference, almost all of these observation data and statistics are compiled in the data book and supporting report, respectively.

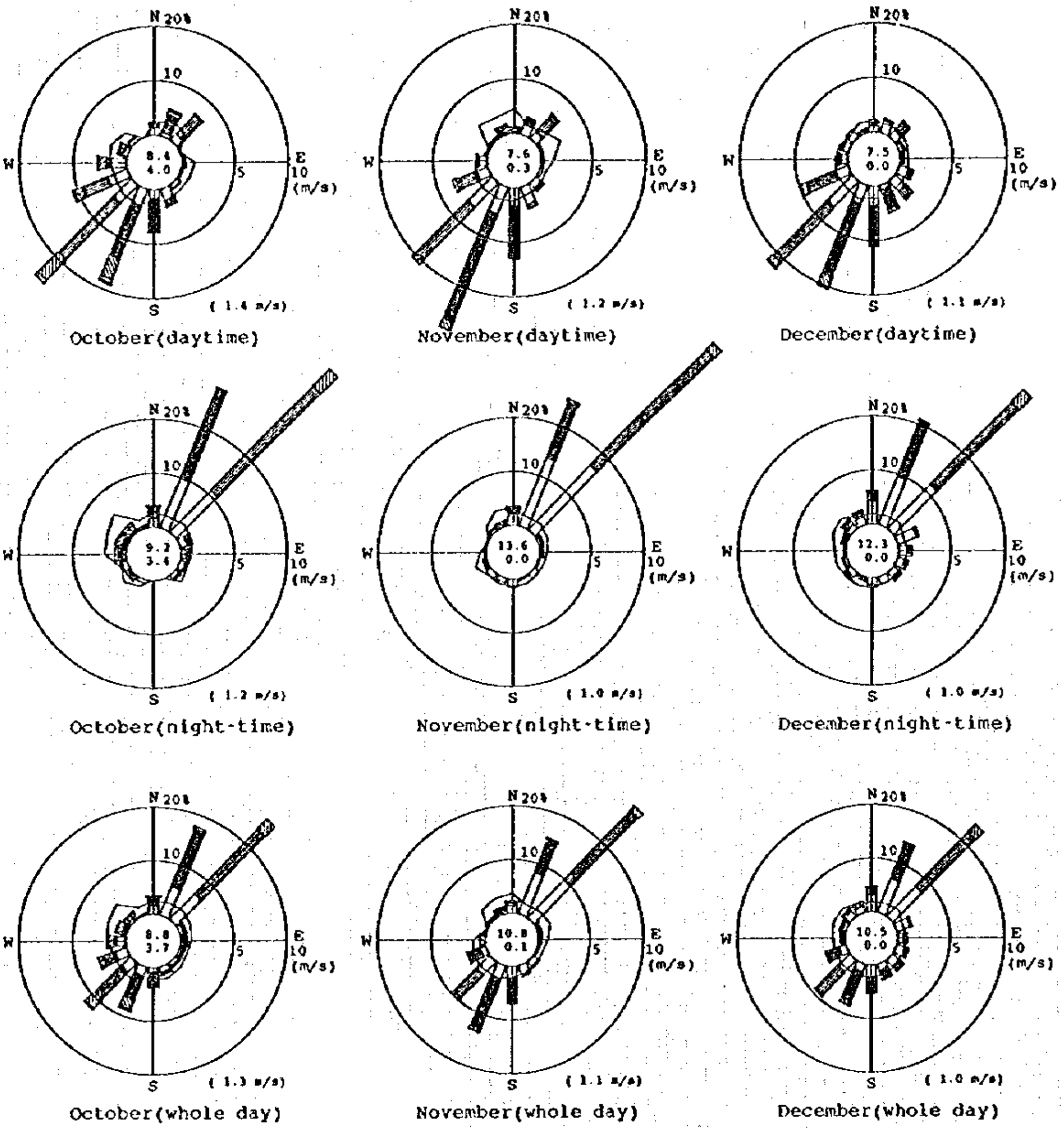
4.1.1 Surface meteorological condition

(1) Statistics based on the data obtained during the field survey

1) Frequency of wind direction

The monthly statistics of wind direction for five months from October, 1996 to February, 1997 at Aghdasiyeh are shown in Fig.4.1.1-1. The wind rose for the total observation period is also shown. As there is no particular difference among the monthly the wind roses, the wind system around the site remains unchanged through the period. The most prevailing wind in the daytime is SSW or SW, and the total frequency of S~WSW accounts for 50 - 60 %; on the other hand, in the night-time, NE is the most prevailing and NNE and NE account for 50 - 60%.

Aghdasiyeh, the observation site, is located on the slope gradually descending to southwest, and Elburz mountains are on the north behind the site. The above mentioned diurnal change of wind direction, namely the wind alternation of day and night, reflects the characteristics of "mountain and valley wind", which is the thermally induced local wind system in the mountainous region. Coincidence of the directions of prevailing wind and slope inclination supports this speculation. The SSW or SW wind is considered to be a kind of valley wind ascending along the slope during the daytime, due to the buoyancy of the



Observation point ; Aghdasiyeh
Observation period ; October, 1996 - February, 1997

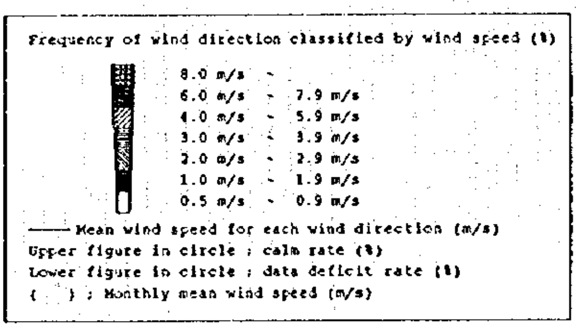
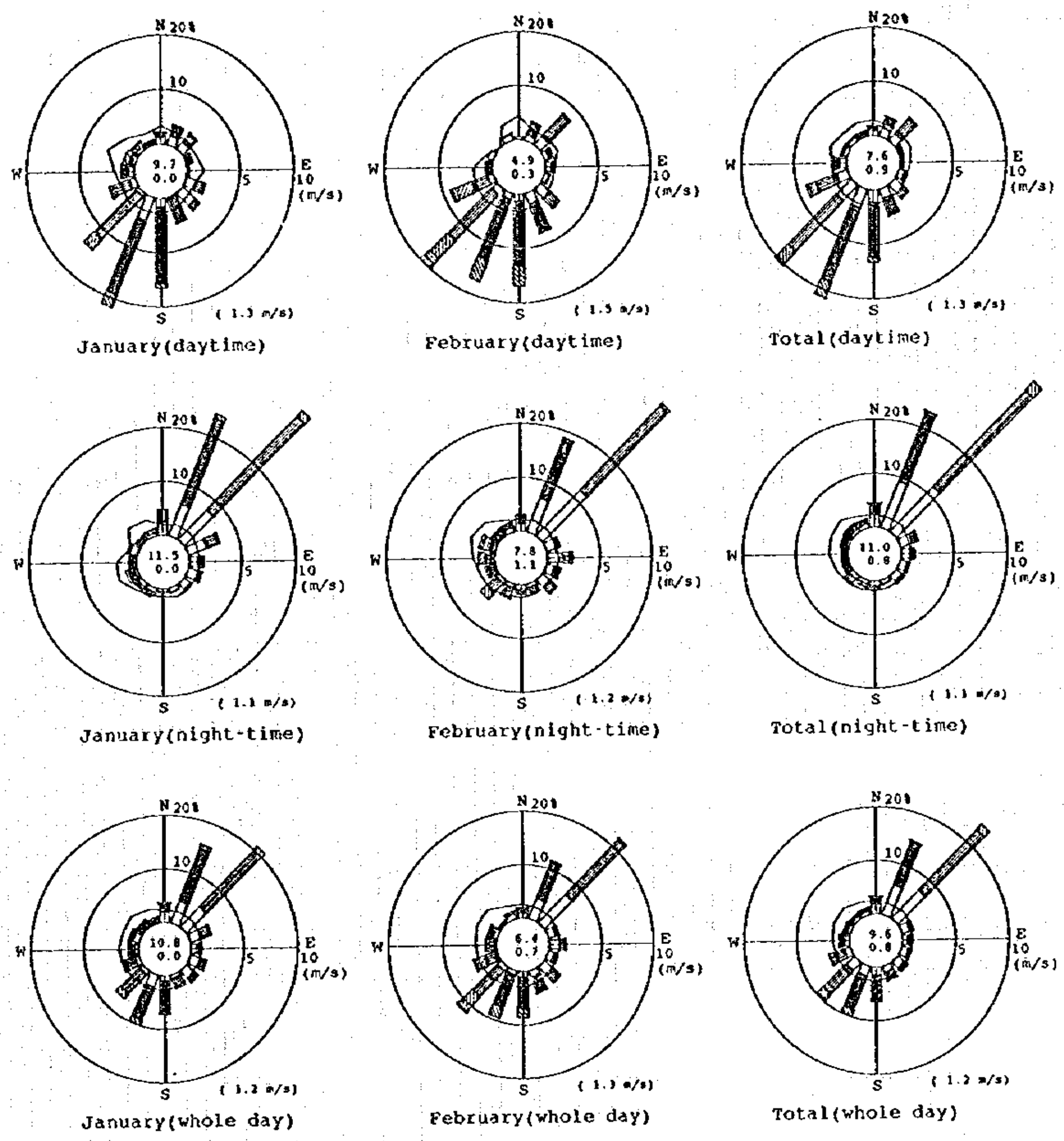


Fig.4.1.1-1(1) Wind rose for monthly frequency of wind direction classified by wind speed, and monthly mean wind speed at each wind direction.



Observation point ; Aghdasiyeh
Observation period ; October, 1996 - February, 1997

Frequency of wind direction classified by wind speed (%)

8.0 m/s ~
6.0 m/s ~ 7.9 m/s
4.0 m/s ~ 5.9 m/s
3.0 m/s ~ 3.9 m/s
2.0 m/s ~ 2.9 m/s
1.0 m/s ~ 1.9 m/s
0.5 m/s ~ 0.9 m/s

—— Mean wind speed for each wind direction (m/s)
Upper figure in circle ; calm rate (%)
Lower figure in circle ; data deficit rate (%)
( ) ; Monthly mean wind speed (m/s)

Fig.4.1.1-1(2) Wind rose for monthly frequency of wind direction classified by wind speed, and monthly mean wind speed at each wind direction.

heated air near the ground surface. On the contrary, the mechanism and the circulation are reversed at night. Surface cooling induces the cold air drainage down the slope. NE is regarded to be a mountain wind.

2) Mean wind speed and frequency of classified wind speed for each wind direction

The monthly mean wind speed is given in the lower right corner of each wind rose. The mean wind speed during the night-time (1.0～1.2 m/s) is somewhat weaker than that during the daytime (1.1～1.5 m/s). The calm frequency at night is 7～14%, 5～10 percentage points more than in the day. As for the frequency of classified wind speed for each wind direction, the wind of 1.0～1.9 m/s is the most dominant and the next is that of 0.5 ～0.9 m/s. Consequently, most of the surface wind around the site are less than 2.0 m/s not only in the night but also in the daytime. It is the distinctive feature of this area that calm or breezy condition at surface is dominant all day through.

3) Atmospheric stability

Fig.4.1.1-2 shows the monthly and total frequency of the classified atmospheric stability based on the data from October, 1996 to February, 1997. Atmospheric stability is derived from the table of "Pasquill's atmospheric stability classification" (Table 4.1.1-1) which gives us the stability class according to the data of wind speed, solar radiation (daytime) and radiation balance (night-time). The monthly histogram for the frequency of stability class suggests the existence of active convection in the daytime and strong inversion in the night-time. In the daytime, the strongly unstable classes ("A", "A-B", "B") and the neutral class "D" account for 24 - 27 % and 11 - 17%, respectively, but other classes can hardly be seen. On the other hand, in the night-time, the strongly stable class ("G") amounts to 47 - 54 %, while each class of "D", "E" and "F" accounts for only less than 7%. The strongly stable class and strongly unstable class occupy the majority because the gradient wind was weak and fine weather was lasting and precipitation was exceptionally little. It is supposed that such condition tends to persist at least in autumn and winter, because any particular seasonal variation cannot be seen in the monthly histograms.

Table 4.1.1-1 Pasquill's atmospheric stability classification

Wind Speed (U; m/s)	Solar radiation (T) kW/m²				Radiation balance (Q) kW/m²		
	T≧0.60	0.60>T ≧0.30	0.30>T ≧0.15	0.15>T	Q≧-0.020	-0.020>Q ≧-0.040	-0.040>Q
U<2	A	A - B	B	D	D	G	G
2≦U<3	A - B	B	C	D	D	E	F
3≦U<4	B	B - C	C	D	D	D	E
4≦U<6	C	C - D	D	D	D	D	D
6≦U	C	D	D	D	D	D	D

notes;

① Regarding the direction of radiation energy transportation, upward is "minus" and downward is "plus".

② The values of solar radiation and radiation balance are the average of data for 10 minutes before the observation time.

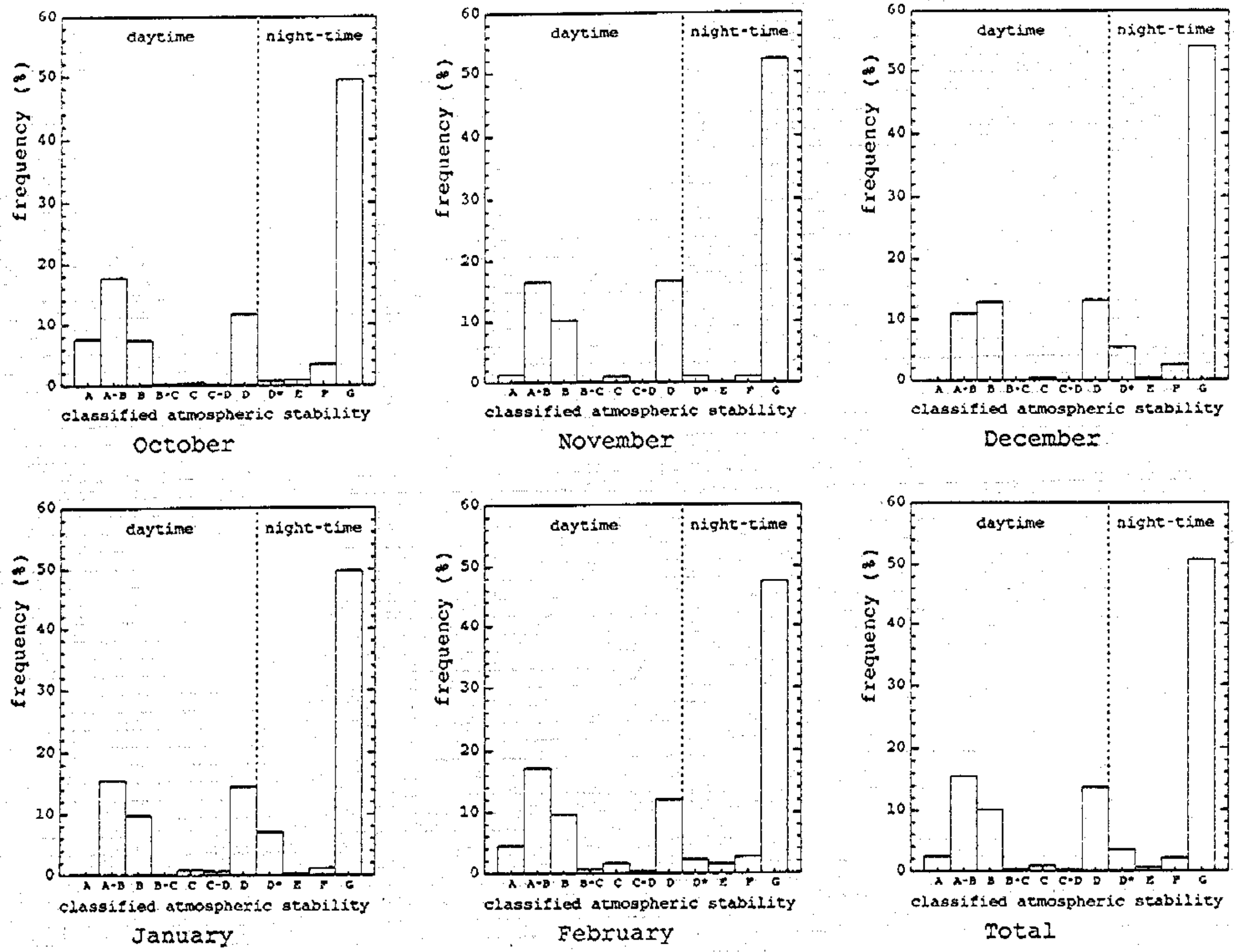
③ The values of solar radiation and radiation balance are applied for evaluation of atmospheric stability in the daytime and night-time, respectively.

④ The units of solar radiation and radiation balance are unified at kW/m².

⑤ Classification of wind speed is based on the Pasquill's method (Japanese type).

⑥ Each class stands for the level of atmospheric stability as follows:

A : unstable (strong)
B : unstable (medium)
C : unstable (weak)
D : neutral
E : stable (weak)
F : stable (medium)
G : stable (strong)
A - B : middle of A and B
B - C : middle of B and C
C - D : middle of C and D



Observation point ; Aghdasiyeh
Observation period ; October, 1996 - February, 1997

Fig.4.1.1-2 Frequency of the classified atmospheric stability.

(2) Statistics of wind direction and wind speed at surface based on the existing data

Fig.4.1.1-3 shows the frequency of wind direction and mean wind speed for each wind direction based on the surface data at the following four IRIMO stations in 1994.

- Mehrabad Airport : hourly
- Dooshan Tappeh : 3 hourly
- Aghdasiyeh (Shomale Tehran) : 3 hourly
- Geophysics : 3 hourly (only one measurement during night-time)

Seasonal and diurnal divisions in those figures are as follows :

- seasonal : spring (March to May) , summer (June to August),
  autumn (September to November), winter (December to February)
- diurnal : daytime (7-18h), night-time (19-6h)

At the Mehrabad Airport, westerly wind prevails in most periods. Its dominance is clearer in the night-time or winter, while easterly and southerly are observed sometimes in the daytime of summer. The calm frequency shows high values (around 70%) in the night-time of autumn and winter, and low values (around 20%) in the daytime of spring and summer. The mean wind speed also shows a higher value for westerly.

At Dooshan Tappeh and Aghdasiyeh (Shomale Tehran), in any season through the year, calm occupies at least 70% and especially in the night-time more than 90%. On the other hand, Geophysics is distinguished from other stations by its low calm occurrence. This difference probably comes from the location of this station on the top of a small hill. In addition to this, it would be due to its observation schedule which has only one measurement in the night-time when the wind tends to calm down. The other conspicuous feature of this station is that wind direction changes quite clearly to the opposite direction between day and night.

Fig.4.1.1-4 is based on the SYNOP data in 1993 for the surrounding area of GTA. Names and locations of these stations are shown in Table 4.1.1-2 and Fig.4.1.1-5. There is no figure for 1-Geop and 21-Firo due to lack of some data. Roughly speaking, stations

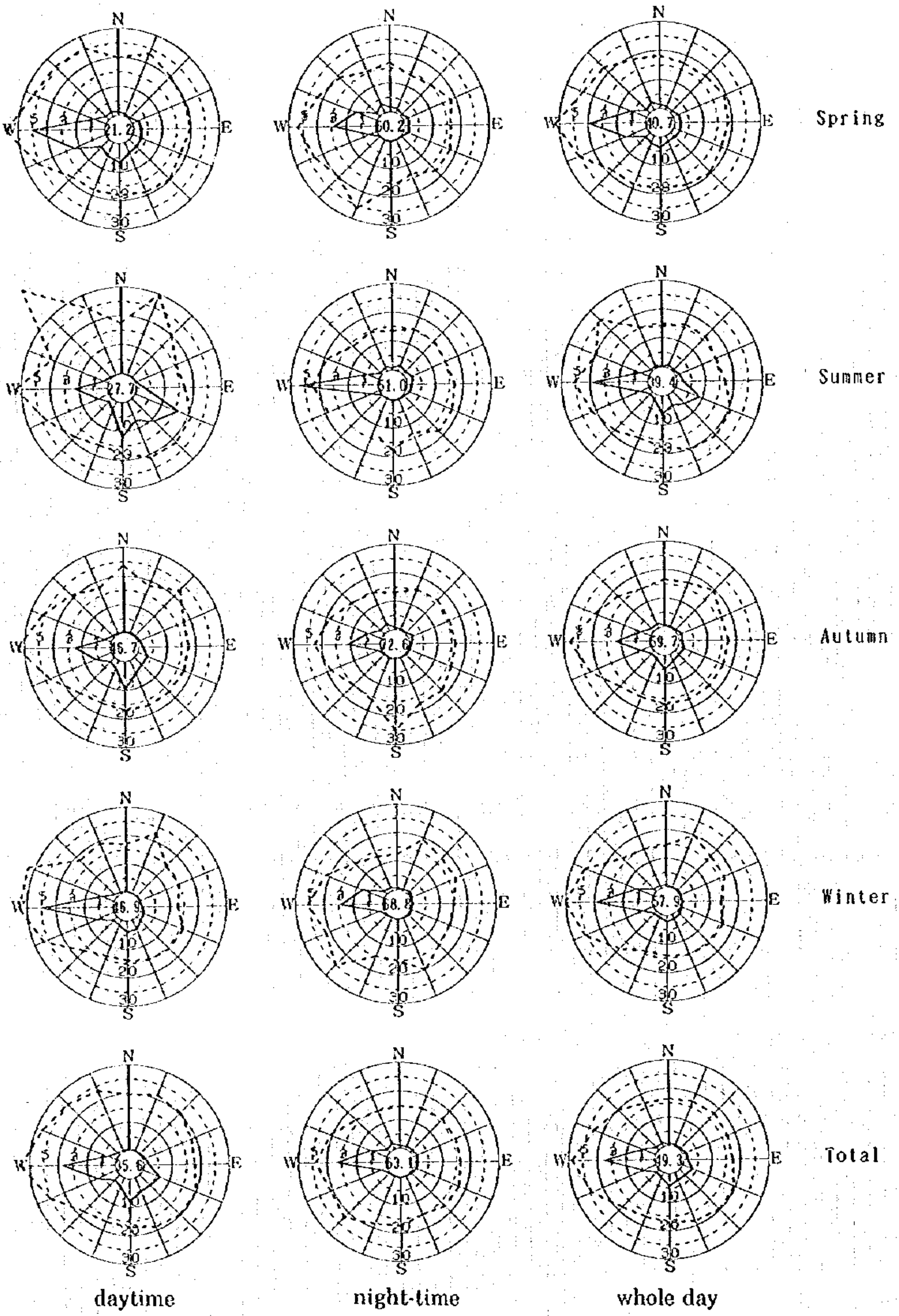
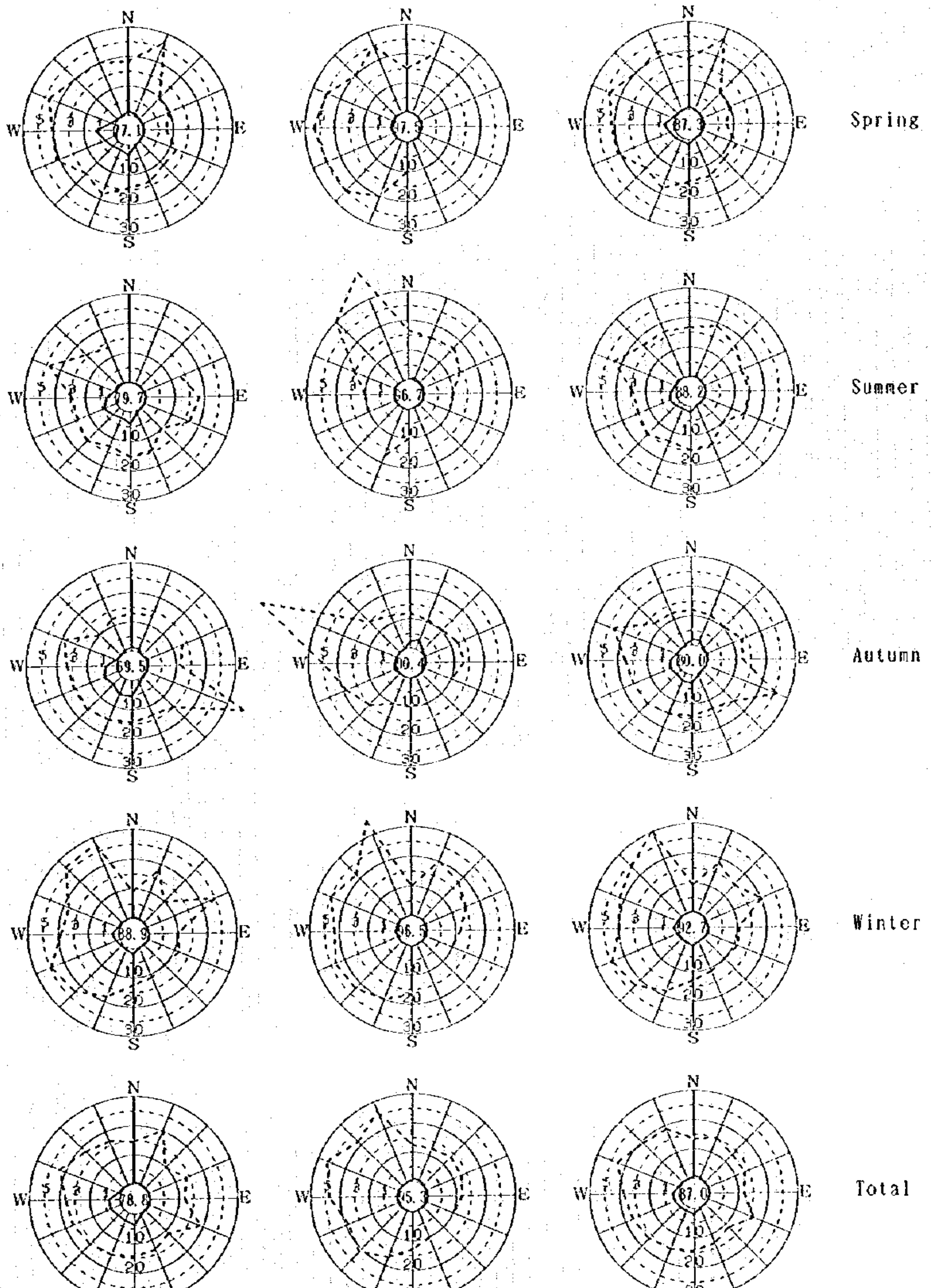


Fig.4.1.1-3(1) Wind rose and mean wind speed at surface based on the data of Mehrabad Airport in 1994.

SOLID : frequency (%)
DASHED : mean w.sp. (m/s)
CENTER : calm (%)



SOLID : frequency (%)
DASHED : mean w.sp. (m/s)
CENTER : calm (%)

Fig.4.1.1-3(2) Wind rose and mean wind speed at surface based on the data of Dooshan Tappeh in 1994.

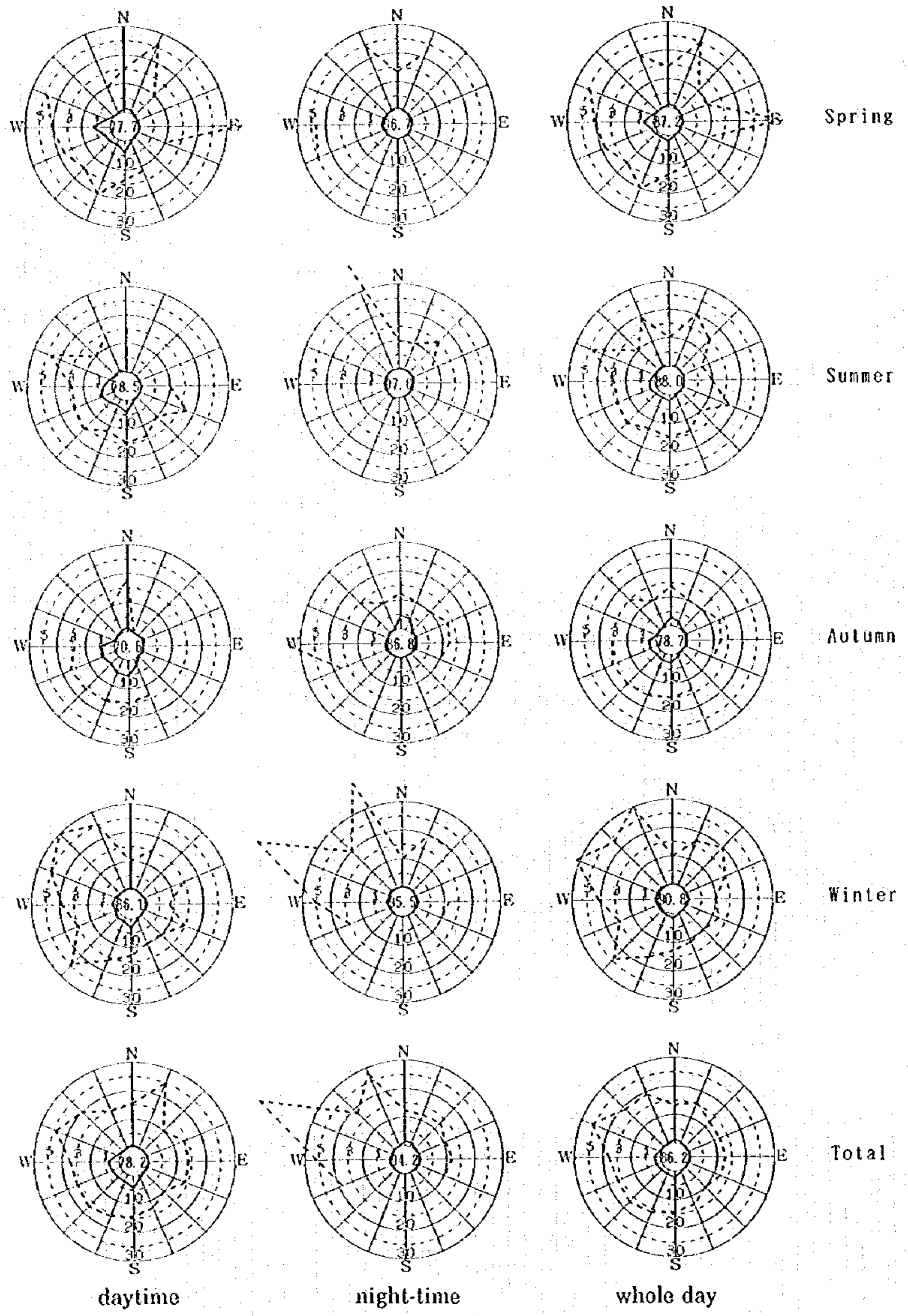


Fig.4.1.1-3(3) Wind rose and mean wind speed at surface based on the data of Aghdasiyeh(Shomale Tehran) in 1994.

SOLID : frequency (%)
DASHED : mean w. sp. (m/s)
CENTER : calm (%)

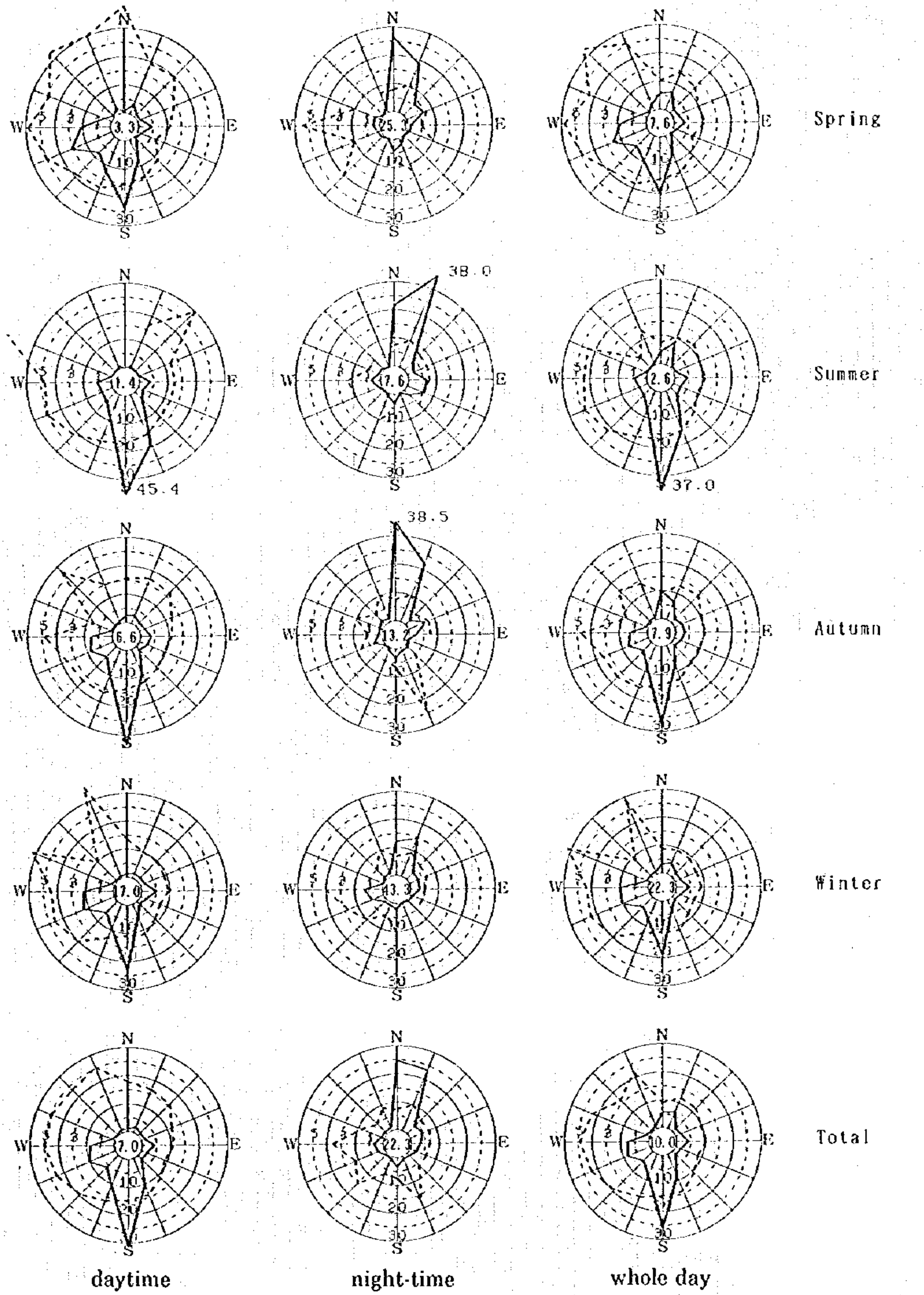


Fig.4.1.1-3(4) Wind rose and mean wind speed at surface based on the data of Geophysics in 1994.

located in the west of GTA (No.5, 11, 17) show the dominance of northwesterly while east side stations (No.20) show the dominance of southwesterly, pointing to the influence of large scale topography on the wind field.

(3) Comparison between the data derived by JICA study team and the existing data belonging to IRIMO

The surface meteorological data at Aghdasiyeh collected by the JICA study team and by IRIMO are compared for the period of October, 1996 - February, 1997. The differences in the statistics due to observation methods are examined.

1) Frequency of wind direction and mean wind speed for each wind direction

Statistics of the wind direction and wind speed at Aghdasiyeh obtained by the JICA team and IRIMO are shown for comparison. The wind rose, the correlation of wind direction, comparison of mean wind speed for each wind direction, and the correlation of wind speed are shown in Fig.4.1.1-6 - Fig.4.1.1-9.

It should be taken into account that the IRIMO data discussed here were obtained by the automatic anemometer operated in a quite different way from the SYNOP stations. Furthermore, "calm" is defined as the condition of wind speed that is less than 1m/s at the SYNOP stations, because they had been established for the purpose of disaster prevention; on the other hand, it denotes the condition that is less than 0.4m/s for the data discussed here. In consequence, the wind roses at Aghdasiyeh obtained respectively by the SYNOP station and with an automatic anemometer (see Fig.4.1.1-3(3) and Fig.4.1.1-6) are considerably different from each other, especially concerning the calm rate.

According to the wind rose based on these data, S~WSW in the daytime and NNE and NE in the night-time are the most prevailing winds in this period common to all. However, the anti-clockwise shift of the prevailing wind direction of the IRIMO data is recognized in reference to the JICA data.

The mean wind speed for each wind direction of the IRIMO data is larger than that of the JICA team for almost all the wind directions, and the greatest difference between them reaches about 0.7m/s. The correlation coefficient is 0.694, the regression coefficient is 0.831

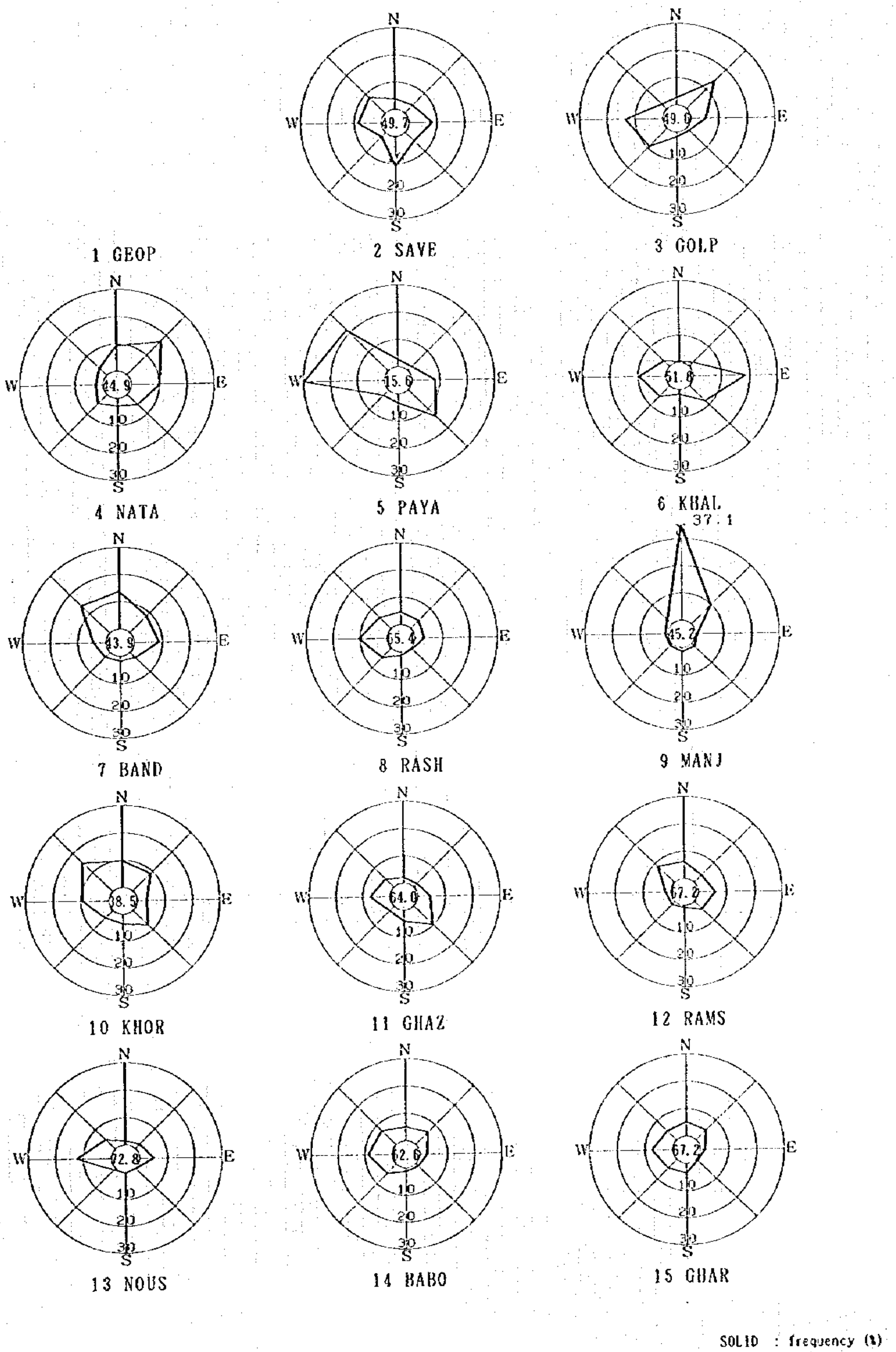
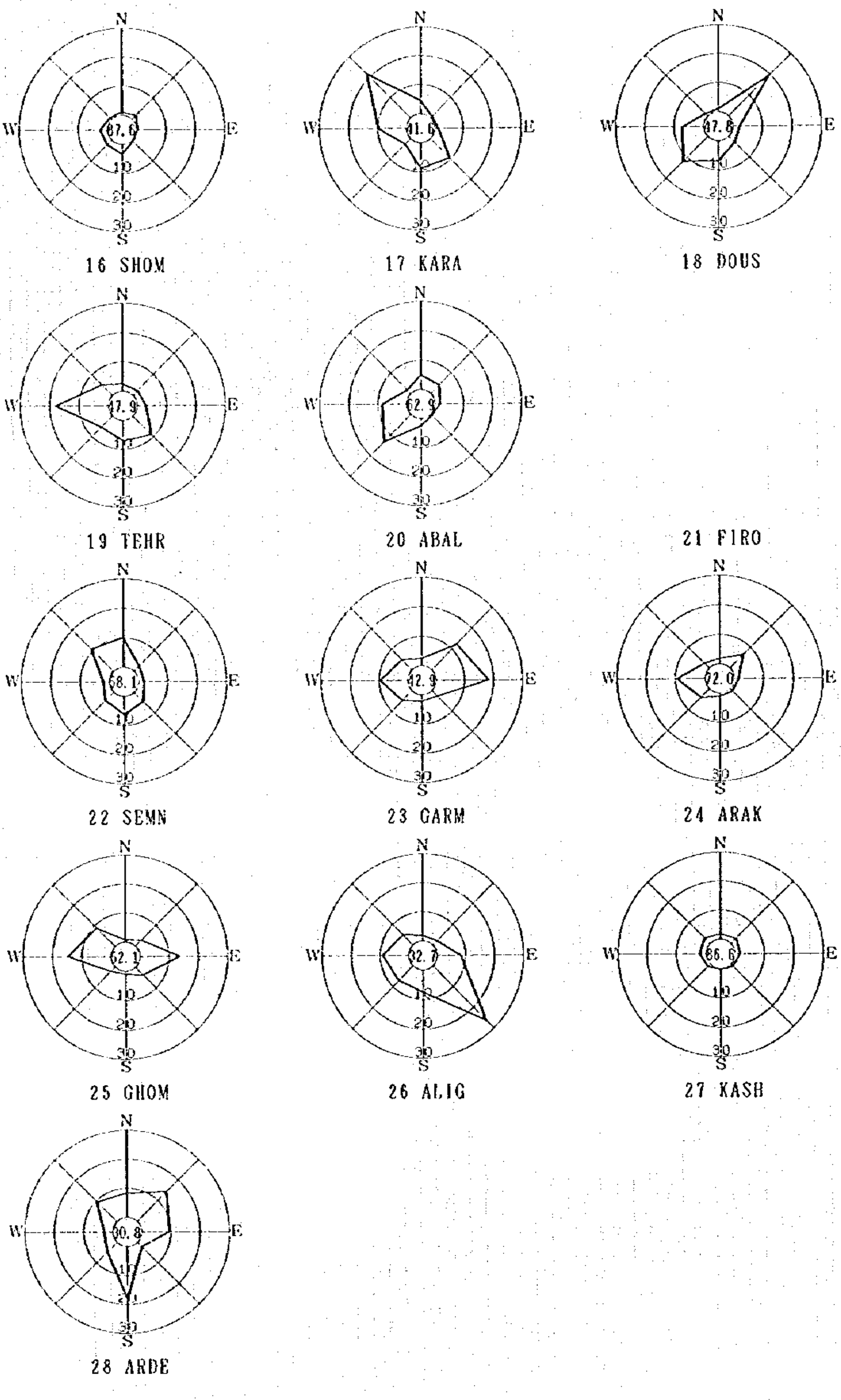


Fig.4.1.1-4(1) Wind rose at SYNOP stations in 1993.



SOLID : frequency (%)

Fig.4.1.1-4(2) Wind rose at SYNOP stations in 1993.

CENTER : calm (%)

Table 4.1.1-2 List of SYNOP stations

1	STATION	GEOPHYSICS TEHRAN	LATITUDE	35	44	N	LONGITUDE	51	23	E	ELEVATION 1418.6	MET.
2	STATION	SAYEH	LATITUDE	35	3	N	LONGITUDE	50	20	E	ELEVATION 1167.0	MET.
3	STATION	GOLPAIGAN	LATITUDE	33	28	N	LONGITUDE	50	17	E	ELEVATION 1870.0	MET.
4	STATION	NATANZ	LATITUDE	33	32	N	LONGITUDE	51	54	E	ELEVATION 1684.9	MET.
5	STATION	PAYAM	LATITUDE	35	47	N	LONGITUDE	50	50	E	ELEVATION 1260.5	MET.
6	STATION	KHALKHAL	LATITUDE	37	38	N	LONGITUDE	49	2	E	ELEVATION 1796.0	MET.
7	STATION	BANDAR ANZALI	LATITUDE	37	28	N	LONGITUDE	49	28	E	ELEVATION -26.2	MET.
8	STATION	RASHT	LATITUDE	37	15	N	LONGITUDE	49	36	E	ELEVATION -6.9	MET.
9	STATION	MANJIL	LATITUDE	36	44	N	LONGITUDE	49	24	E	ELEVATION 333.0	MET.
10	STATION	KHORAMDAREH	LATITUDE	36	11	N	LONGITUDE	49	11	E	ELEVATION 1575.0	MET.
11	STATION	GHAZVIN	LATITUDE	36	15	N	LONGITUDE	50	0	E	ELEVATION 1278.3	MET.
12	STATION	RAMSAR	LATITUDE	36	54	N	LONGITUDE	50	40	E	ELEVATION -20.0	MET.
13	STATION	NOUSHAHR	LATITUDE	36	39	N	LONGITUDE	51	30	E	ELEVATION -20.9	MET.
14	STATION	BABOLSAR	LATITUDE	36	43	N	LONGITUDE	52	39	E	ELEVATION -21.0	MET.
15	STATION	GHARAKHIL GHAEMSHR	LATITUDE	36	27	N	LONGITUDE	52	53	E	ELEVATION 14.7	MET.
16.	STATION	SHOMALE TEHRAN	LATITUDE	35	47	N	LONGITUDE	51	37	E	ELEVATION 1548.2	MET.
17	STATION	KARAJ	LATITUDE	35	56	N	LONGITUDE	50	58	E	ELEVATION 1312.5	MET.
18	STATION	DOUSHAN TAPEH	LATITUDE	35	41	N	LONGITUDE	51	21	E	ELEVATION 1218.0	MET.
19	STATION	TEHRAN MEHRABAD	LATITUDE	35	42	N	LONGITUDE	51	21	E	ELEVATION 1191.0	MET.
20	STATION	ABALI	LATITUDE	35	45	N	LONGITUDE	51	53	E	ELEVATION 2465.2	MET.
21	STATION	FIROUZKOOH	LATITUDE	35	55	N	LONGITUDE	52	50	E	ELEVATION 1935.0	MET.
22	STATION	SEMNAN	LATITUDE	35	33	N	LONGITUDE	53	33	E	ELEVATION 1171.0	MET.
23	STATION	GARMSAR	LATITUDE	35	12	N	LONGITUDE	52	16	E	ELEVATION 825.2	MET.
24	STATION	ARAK	LATITUDE	34	6	N	LONGITUDE	49	46	E	ELEVATION 1708.0	MET.
25	STATION	GHOM	LATITUDE	34	42	N	LONGITUDE	50	51	E	ELEVATION 877.4	MET.
26	STATION	ALIGOODARZ	LATITUDE	33	24	N	LONGITUDE	49	41	E	ELEVATION 1972.0	MET.
27	STATION	KASHAN	LATITUDE	33	59	N	LONGITUDE	51	27	E	ELEVATION 982.3	MET.
28	STATION	ARDESTAN	LATITUDE	33	32	N	LONGITUDE	52	23	E	ELEVATION 1252.4	MET.

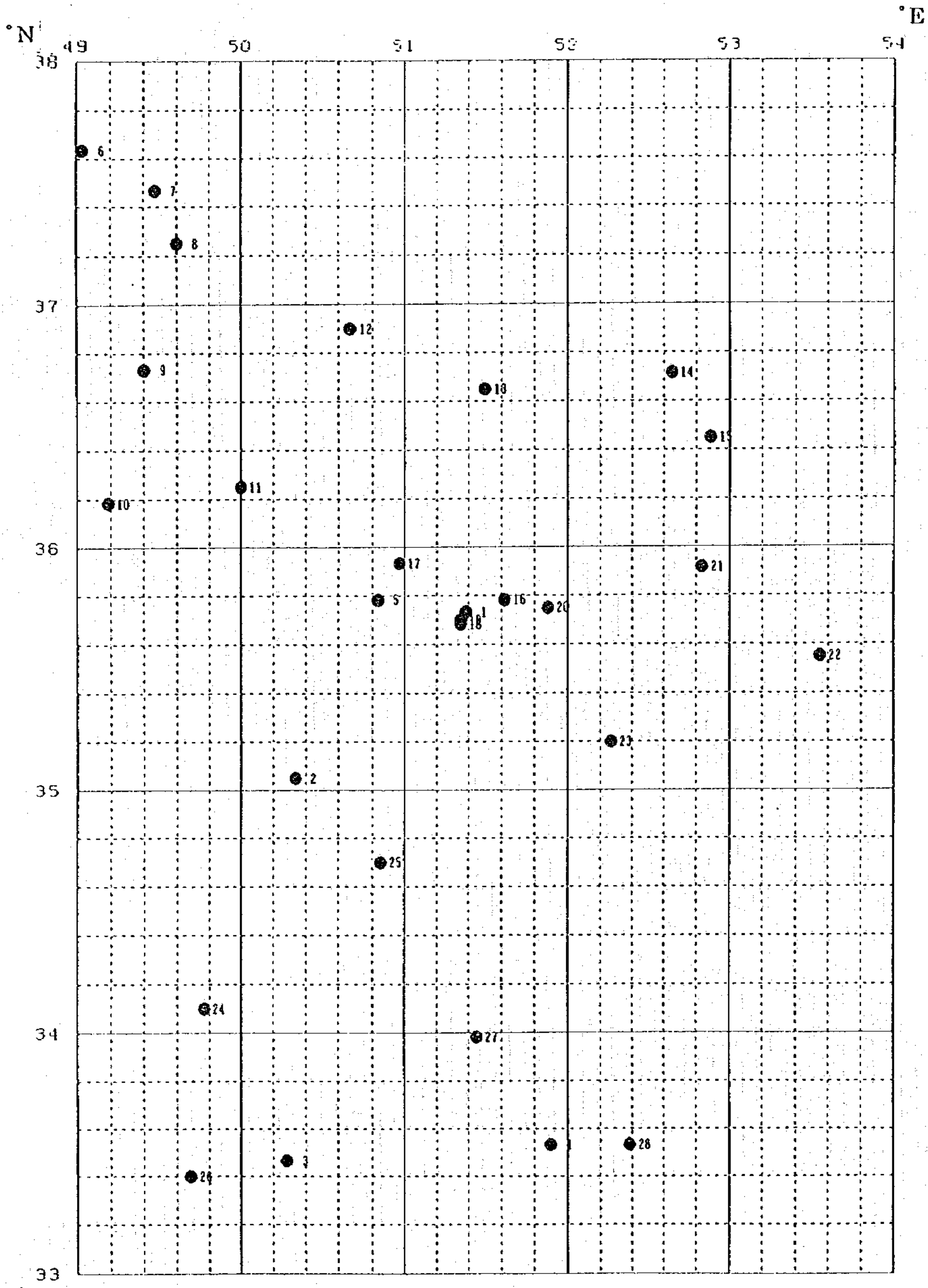
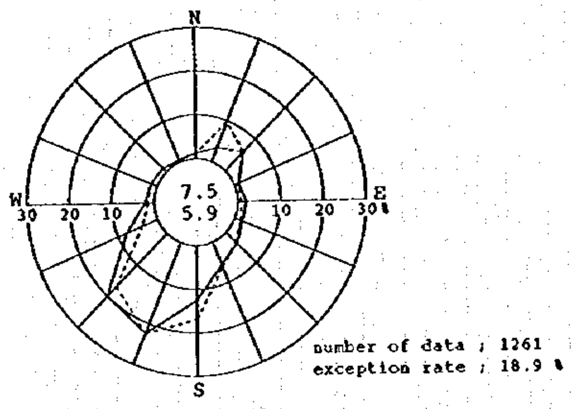
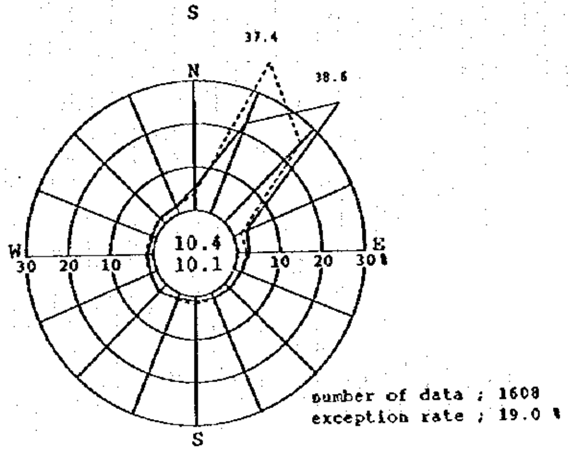


Fig.4.1.1-5 Locations of SYNOP stations.

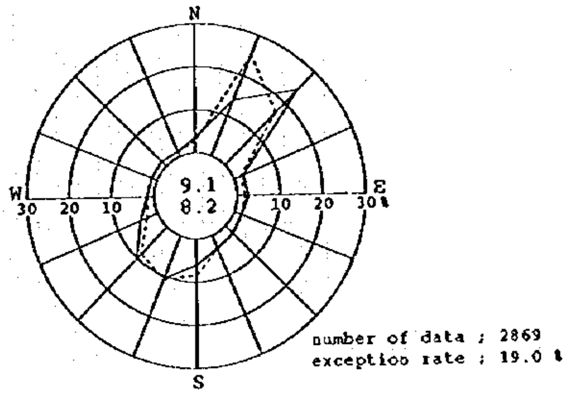
daytime



night-time



whole day



Observation point ; Aghdasiyeh

Observation period ; October, 1996 - February, 1997

note 1. The pair of data from which one is missed is excepted.

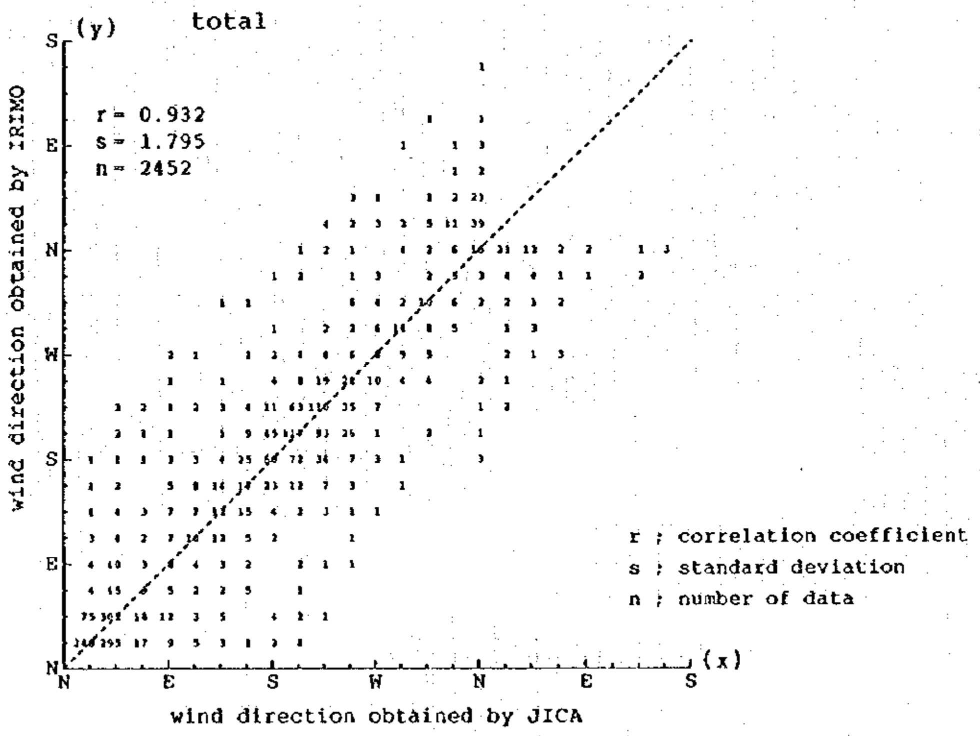
2. The figures in the inner circle denote the calm rate (%).

The Upper is for the data of JICA and the lower is for the data of IRIMO.

——— data of JICA

----- data of IRIMO

Fig.4.1.1-6 Comparison of wind rose based on the data obtained by JICA and IRIMO.

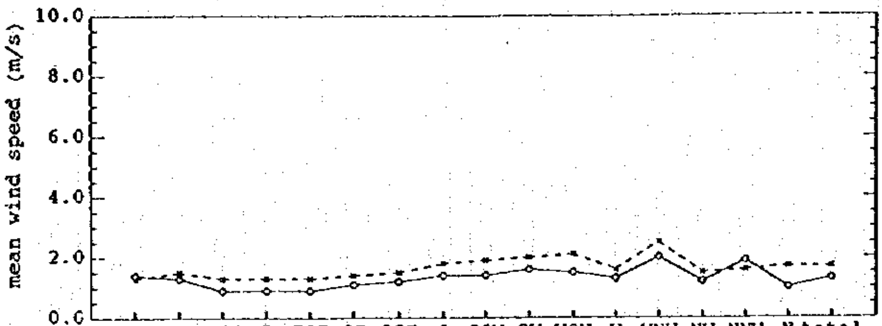


Observation point ; Aghdasiyeh

Observation period ; October, 1996 - February, 1997

Fig.4.1.1-7 Correlation of wind direction between the data of JICA and IRIMO.

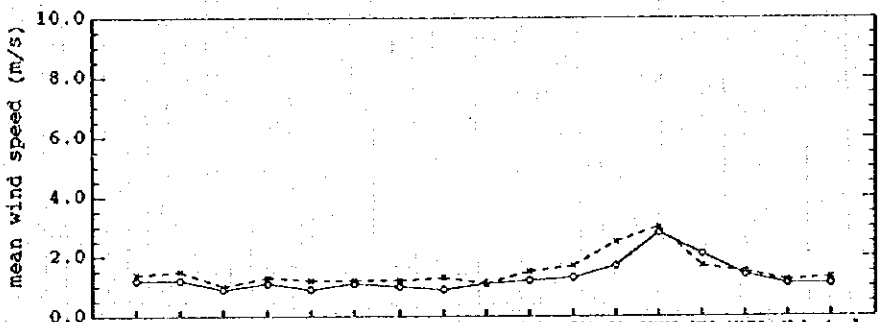
daytime



	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	total
JICA	42	77	12	24	23	46	70	157	282	252	98	27	20	13	7	17	1261
IRIMO	123	76	12	10	18	41	77	213	283	213	48	18	18	16	6	15	1261

number of data

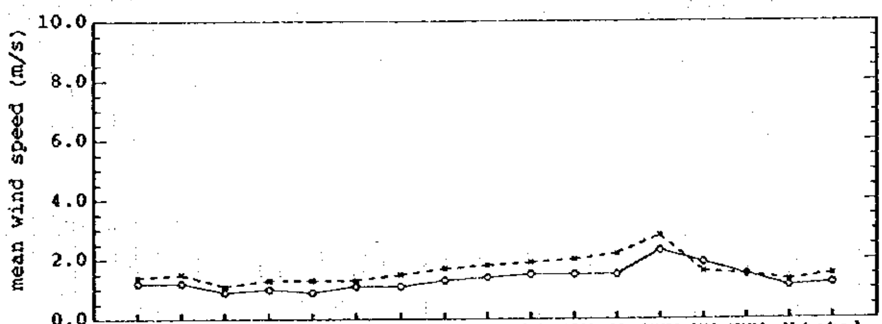
night-time



	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	total
JICA	360	620	52	47	26	29	21	18	18	41	25	22	16	30	30	86	1608
IRIMO	601	409	31	34	32	23	22	28	26	34	30	30	25	29	28	64	1608

number of data

whole day



	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	total
JICA	402	697	64	71	49	75	91	175	300	293	123	49	36	43	37	103	2869
IRIMO	724	485	43	44	50	64	99	241	309	247	78	48	43	45	34	79	2869

number of data

Observation point ; Aghdasiyeh

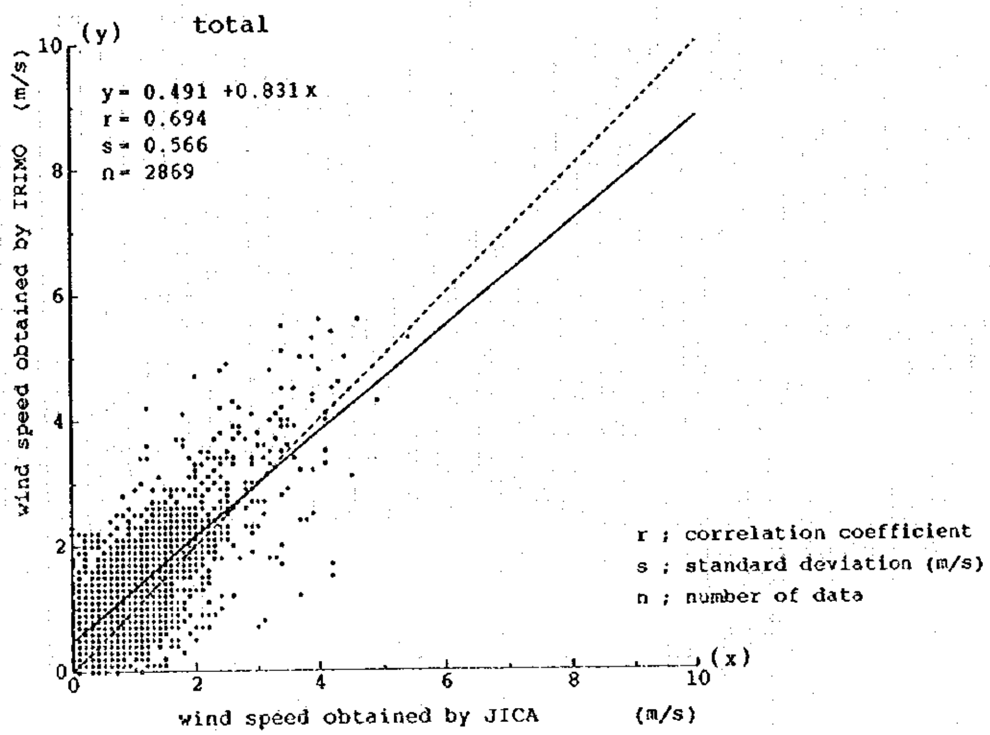
Observation period ; October, 1996 - February, 1997

note 1. The pair of data from which one is missed is excepted.

2. The mean wind speed for each wind direction is derived from the data excluding calm (less than 0.5m/s). However, the total average is based on all of the pairs of data.

o———o data of JICA ×-----× data of IRIMO

Fig.4.1.1-8 Comparison of average wind speed for each wind direction based on the data obtained by JICA and IRIMO.



Observation point ; Aghdasiyeh

Observation period ; October, 1996 - February, 1997

Fig.4.1.1-9 Correlation of wind speed between the data of JICA and IRIMO.

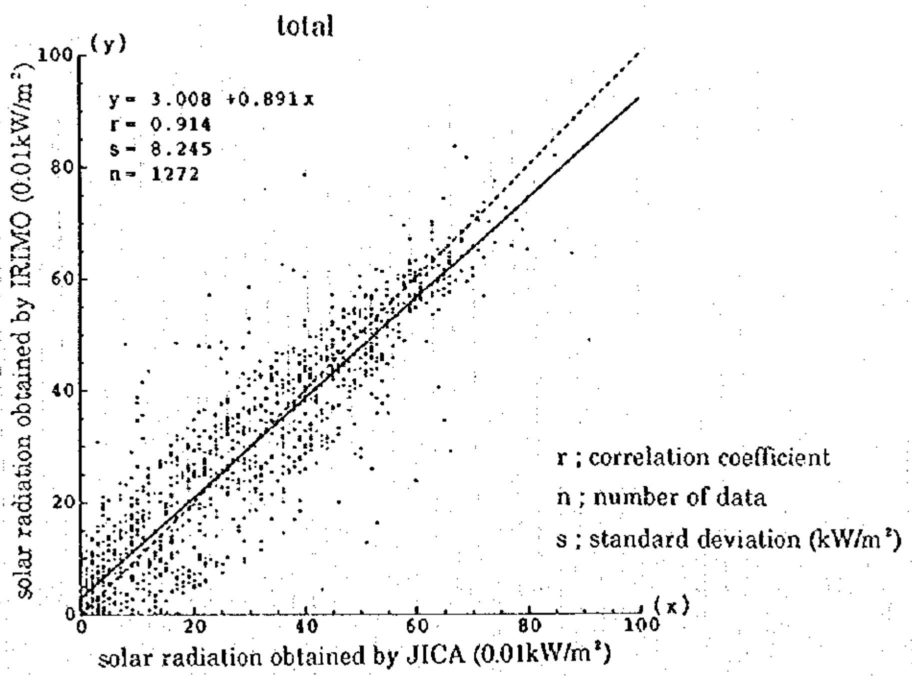
and the intercept on the Y-axis is 0.491. The data are scattered around the regression line but they exhibit somewhat large variability.

The above-mentioned differences in the wind direction and wind speed appear to be due to the difference in surroundings of the observation sites and the types of the instruments. The surroundings of the IRIMO station is open, while there are some trees and buildings around the JICA station. The instruments used at these stations are quite different in their measurement principles. The wind vane with a 3 cup anemometer is used at the IRIMO station and an ultrasonic anemometer is used at the JICA station. The 3 cup anemometer tends to collect data on the strong side. These are considered to be the reasons why the wind speed at the IRIMO station is always larger.

2) Solar radiation

The correlation between the solar radiation data obtained by JICA and IRIMO during the period from October, 1996 to February, 1997 is shown in Fig.4.1.1-10.

The dispersion diagram shows the feature close to one-to-one correspondence except some data which are far off the regression line. It indicates that the IRIMO and JICA data of solar radiation correlate well with each other. The correlation coefficient is 0.914, the regression coefficient is 0.891, and the intercept on the Y-axis is 3.008.



Observation point ; Aghdasiyeh

Observation period ; October, 1996 ~ February, 1997

Fig.4.1.1-10 Correlation of solar radiation between the data of JICA and IRIMO.

4.1.2 Upper layer meteorological condition

(1) Result of the field observation

The characteristics of profiles of wind and temperature based on the data obtained with a captive sonde and low level sonde during October 8 - 15 in 1996 and February 22 - March 1 in 1997 are summarized as follows. Description of temperature and wind profiles are made for only some selected cases. All of the profiles obtained with a captive sonde and low level sonde are shown in the supporting report. Concerning the analysis, attention should be paid to the statistics for each altitude showing some unnatural features, such as discontinuous changes in the profiles. This would be because the number of data is not sufficient for the statistics and some runs were given up or ended incompletely by strong wind above the surface boundary layer or rain.

1) Wind profiles

The profiles of wind direction and wind speed obtained with the captive sonde for the cases of selected 4 days are shown in Fig.4.1.2-1. The wind profiles from the surface to the 700m altitude show the common tendencies that southwesterlies start and then get stronger in the afternoon, while in most of the morning and night, westerlies or easterlies blow weakly sometimes accompanied by the transition layer of wind direction. And northeasterlies can be seen at night in the thin layer (< 100m) near the surface.

As mentioned before, the thick southwesterlies toward the northern mountains in the daytime and the shallow northeastelies from the mountains in the nighttime would be recognized as the thermally induced up slope wind and the down slope wind, respectively.

2) Temperature profiles

The profiles of temperature obtained with a captive sonde for the selected 5 days and the diagram of the temperature gradient averaged for each altitude based on all the available data in the observation period are shown in Fig.4.1.2-2 and Fig.4.1.2-3, respectively.

The surface boundary layer (from the surface to several ten meters) is characterized by the remarkable diurnal change of the temperature gradient, that is to say, super adiabatic in

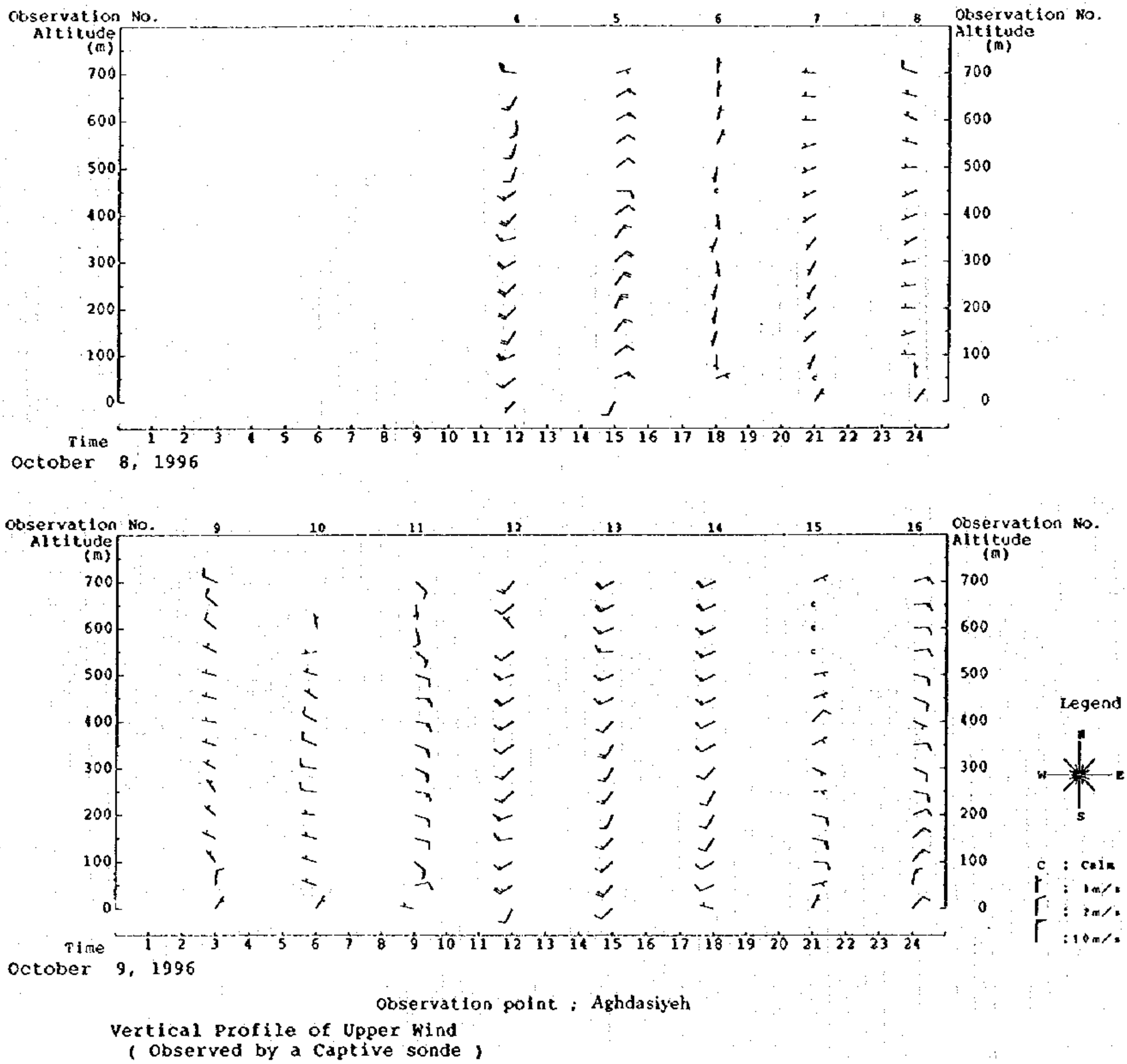


Fig.4.1.2-1(1) Vertical profiles of wind direction and wind speed observed by the captive sonde.

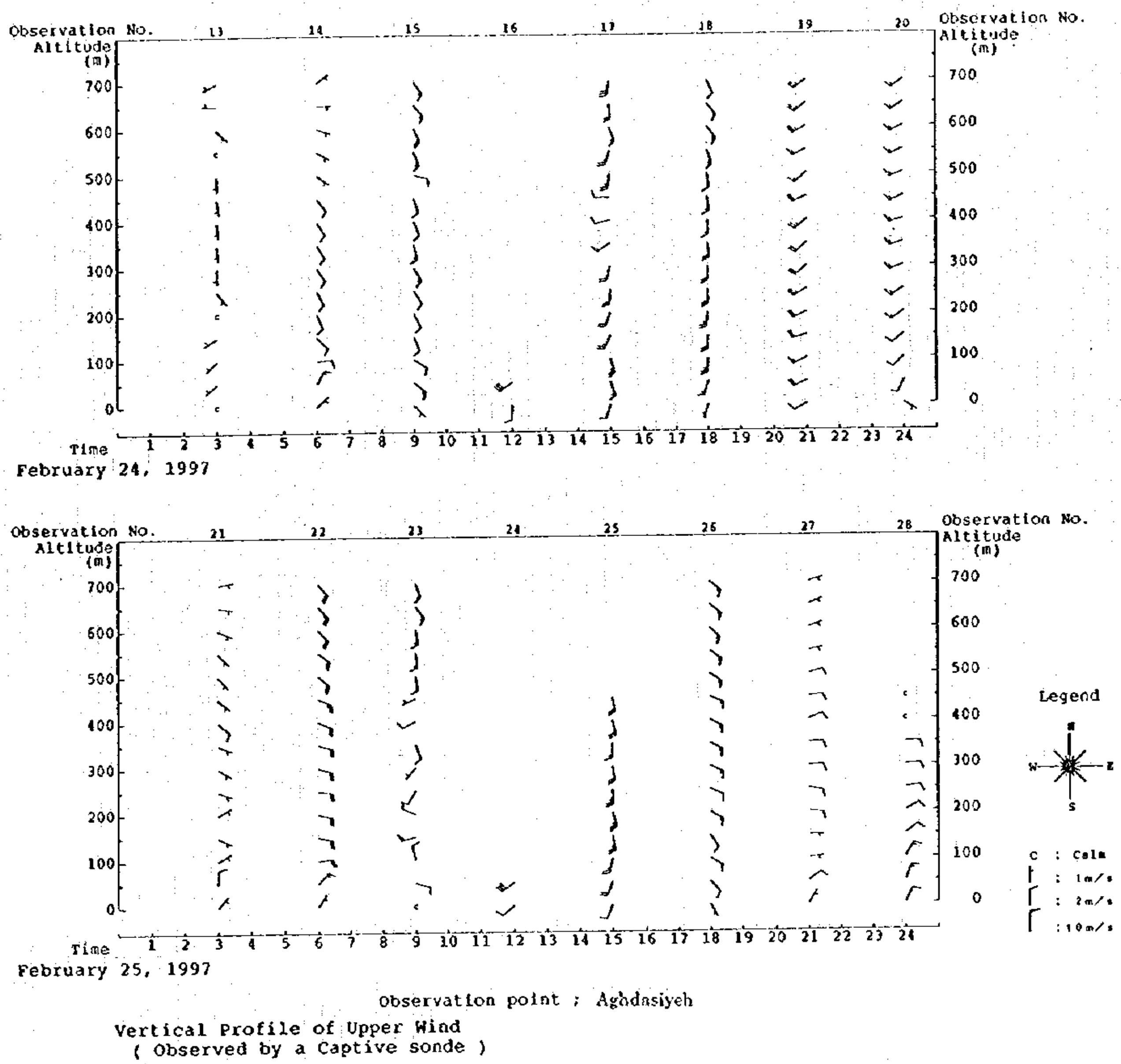


Fig.4.1.2-1(2) Vertical profiles of wind direction and wind speed observed by the captive sonde.

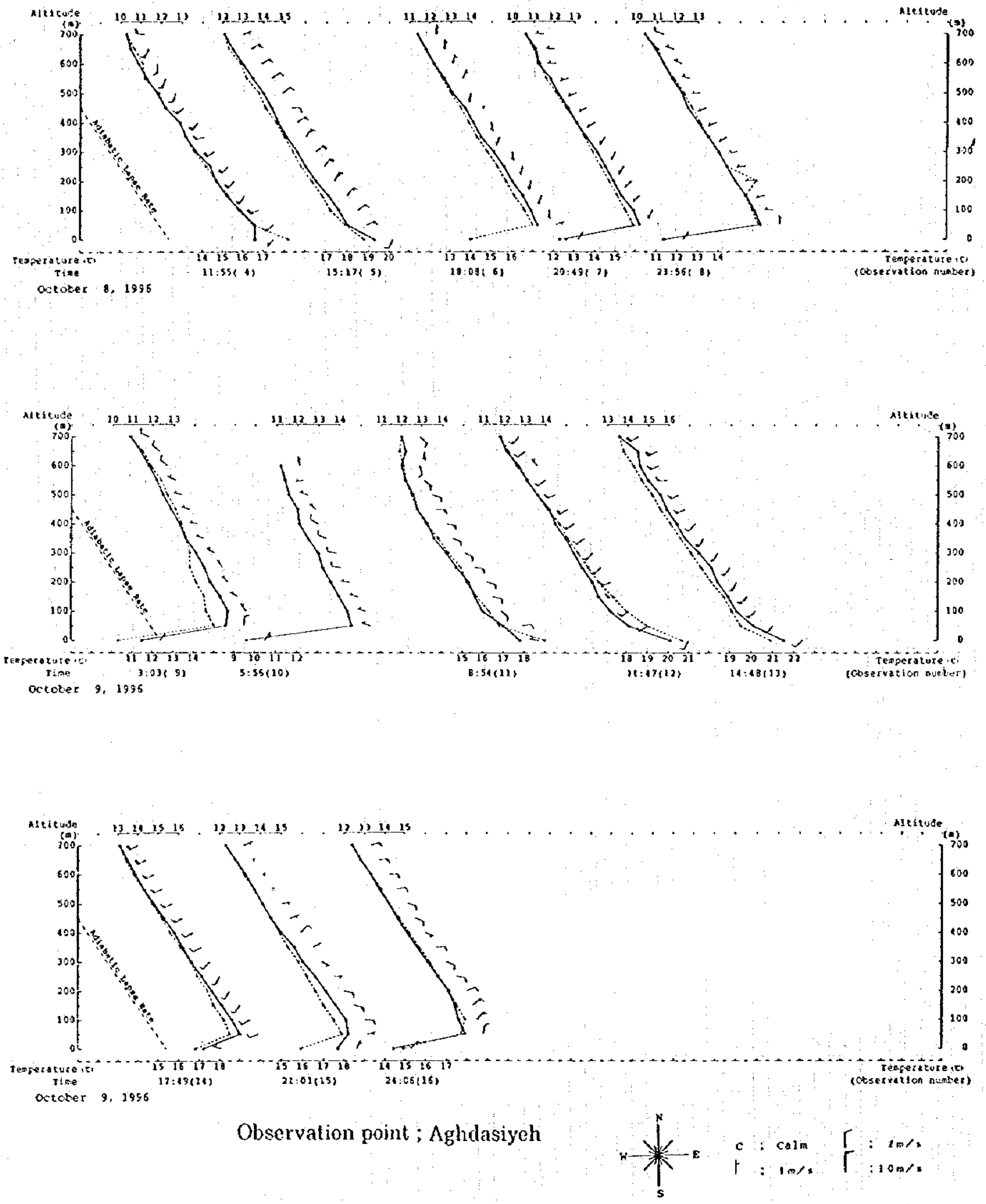
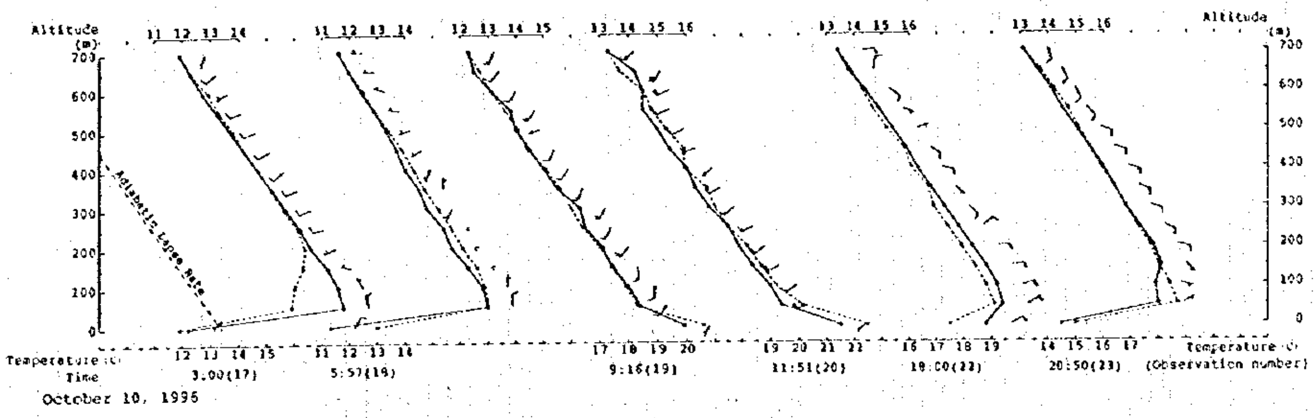
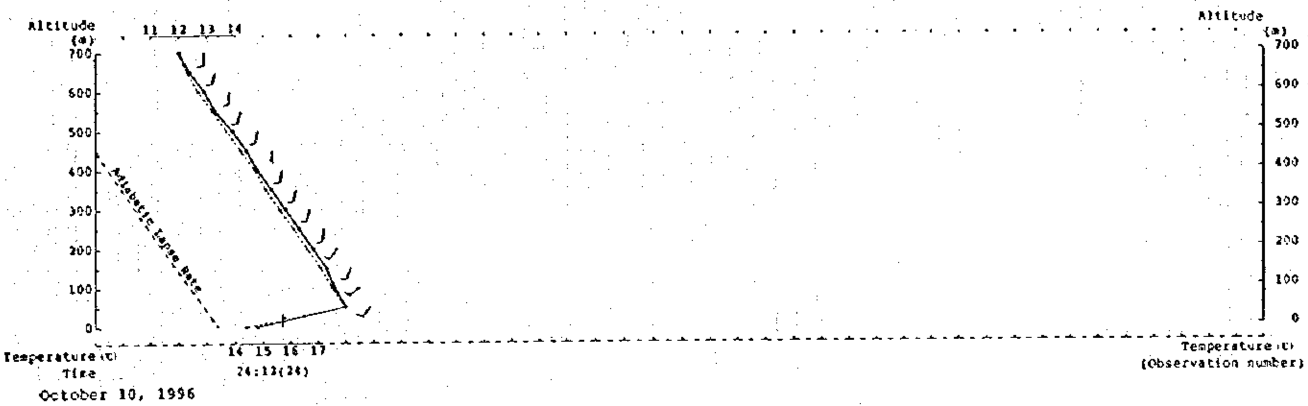


Fig.4.1.2-2(1) Vertical profiles of temperature observed by the captive sonde.





Observation point ; Aghdasiyeh

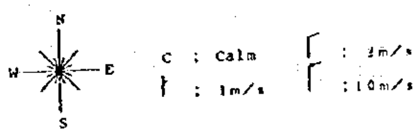


Fig.4.1.2-2(2) Vertical profiles of temperature observed by the captive sonde.

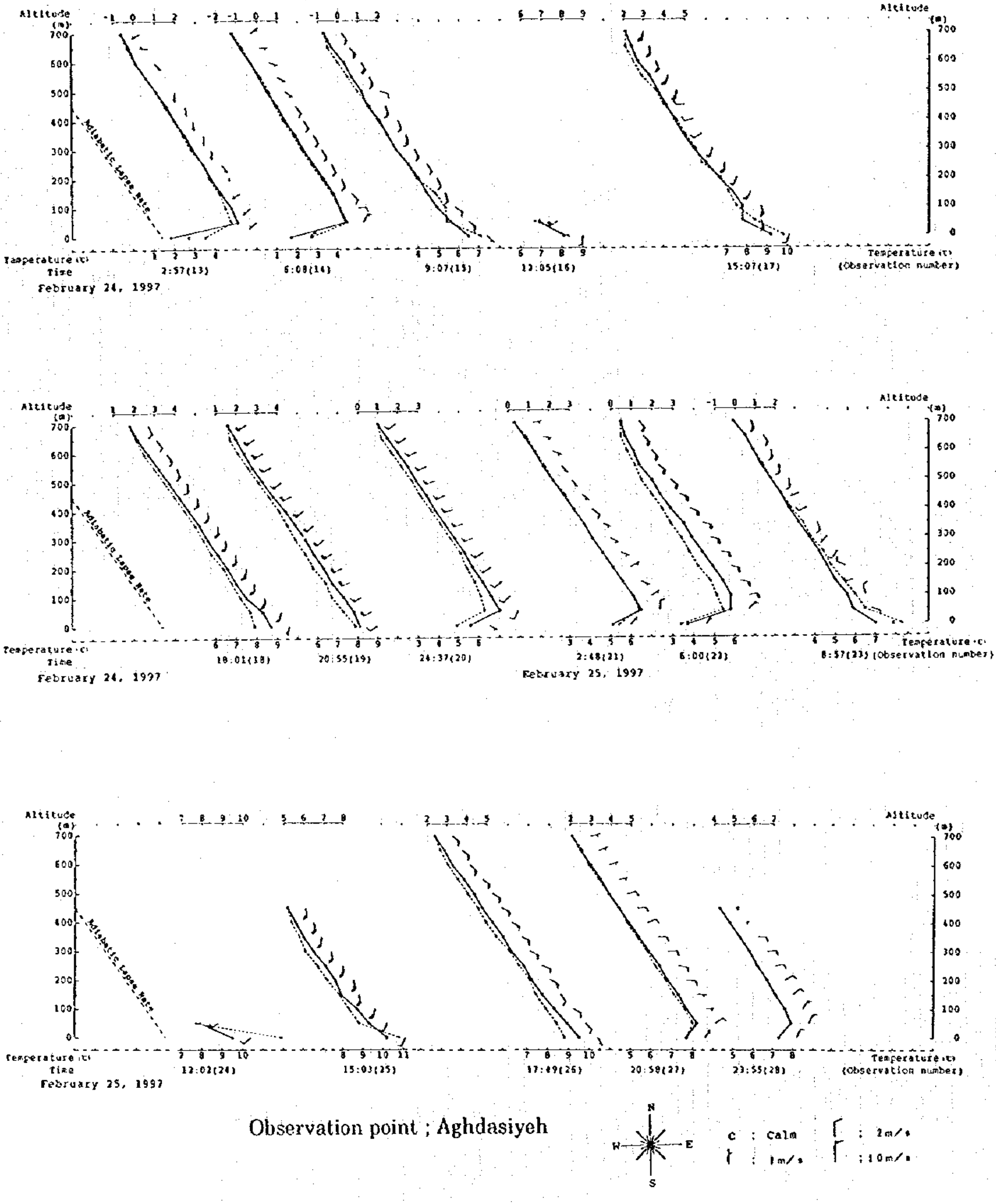
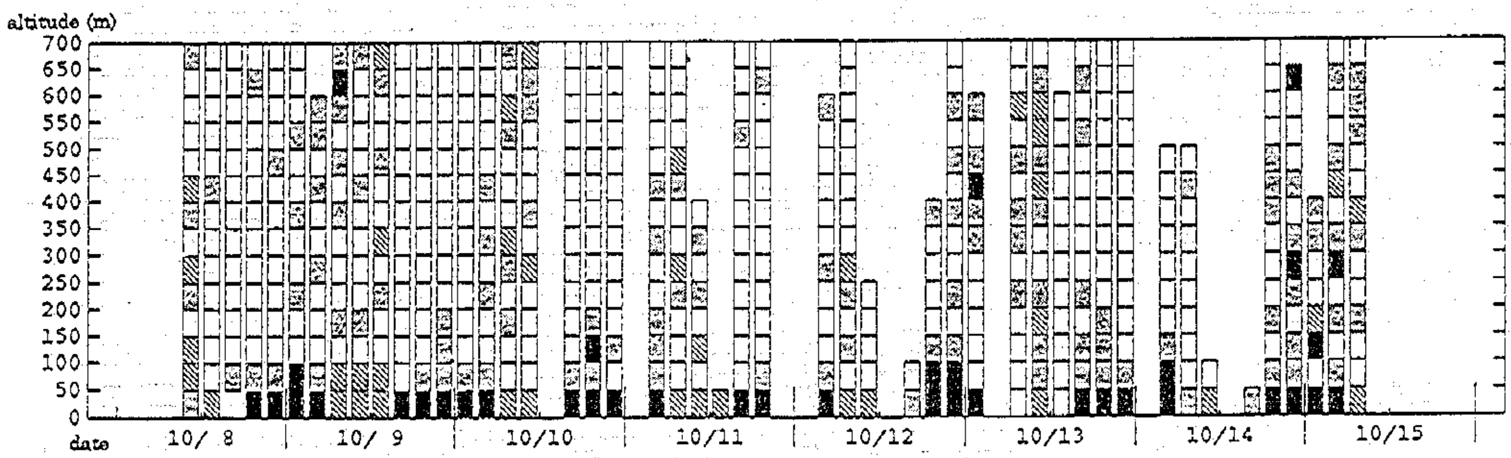
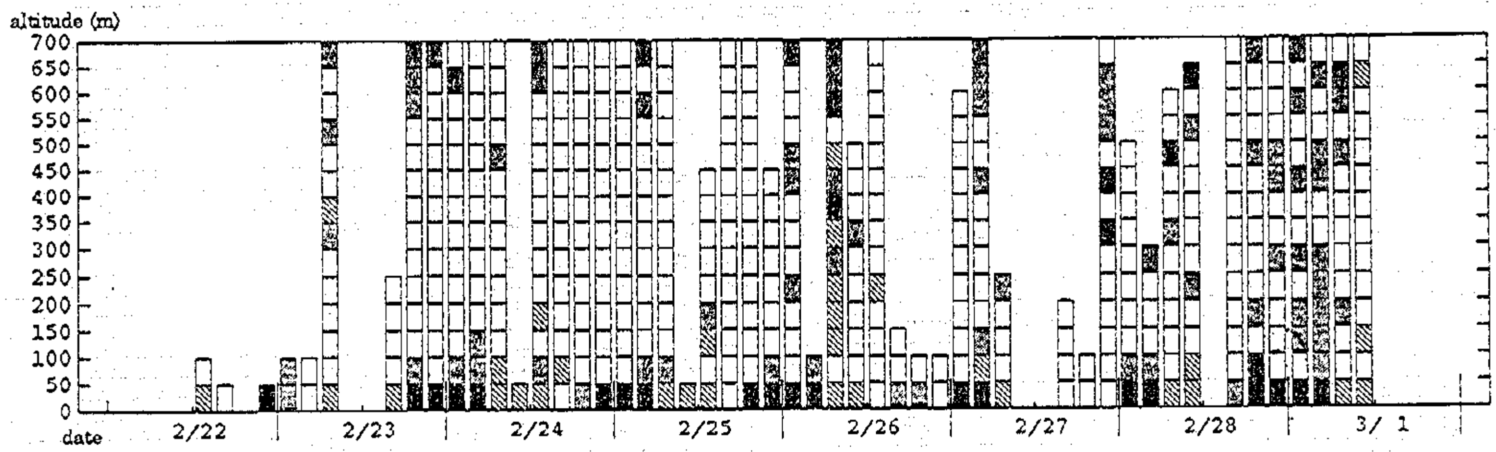


Fig.4.1.2-2(3) Vertical profiles of temperature observed by the captive sonde.



Observation point ; Aghdasiyeh
Observation period ; October 8, 1996 ~ October 15, 1996



Observation point ; Aghdasiyeh
Observation period ; February 22, 1997 ~ March 1, 1997

0.1 ~ ℃/100m (inversion)
-0.7 ~ 0.0 ℃/100m (stable)
-1.2 ~ -0.8 ℃/100m (neutral)
~ -1.3 ℃/100m (super adiabatic)

Fig.4.1.2-3 Time series of vertical gradient of temperature obtained by ascending captive sonde.

the daytime and inversion in the nighttime. The inversion layer is formed by surface radiative cooling and it corresponds to the northeasterlies. Therefore, it can be referred to as the cold air drainage. The temperature difference between the top and bottom of the inversion layer sometimes gets to more than 5℃. On the other hand, temperature in the upper atmosphere over the inversion layer decreases at the rate of 1.0℃/100m with height.

The selected examples of the vertical temperature profiles obtained with the low level sonde are shown in Fig.4.1.2-4. The observations were made only twice a day (8:00 and 13:00).

It seems that the profiles in mid-day (around 13:00) are characterized by the dependence of the vertical temperature gradient on the wind direction. When the southeasterlies or southwesterlies prevails up to 2000m as in the case of 14th October and 25th February, the temperature profiles are recognized neutral, because the temperature decreases with height at the adiabatic lapse rate (-1.0℃/100m). On the other hand, like the examples of October 8 and 9, there are some cases that inversion can be seen around the layer with a wind shear between the southwesterlies in the lower layer and the westerlies in the upper layer. The inversion layer appears around 1000 - 1500m. Beneath the inversion, the vertical temperature gradient is equal to the dry adiabatic lapse rate that suggests the air is well stirred by convection. Usually, it is termed as a "mixing layer". In the case that the mixing layer is capped by inversion, pollutant diffusion is confined in the mixing layer by the inversion which is strongly stable. The inversion layer plays a role of "lid", which prevents thermal convection from developing upward because of its stability.

As for the profiles in the morning (around 8:00) when the upper wind shear and temperature inversion appear, the layer below the inversion is more stable (around -0.5℃ /100m) and the wind is weaker. It suggests that the mixing layer is still in the early stage of development.

3) Wind rose at each altitude

Fig.4.1.2-5 shows the wind rose compiled for the whole day and day/night at every 50m from the surface to 700m based on the wind direction data obtained with a captive sonde. In the daytime, the prevailing wind direction is SSW～SW at the surface level, SW at 50m

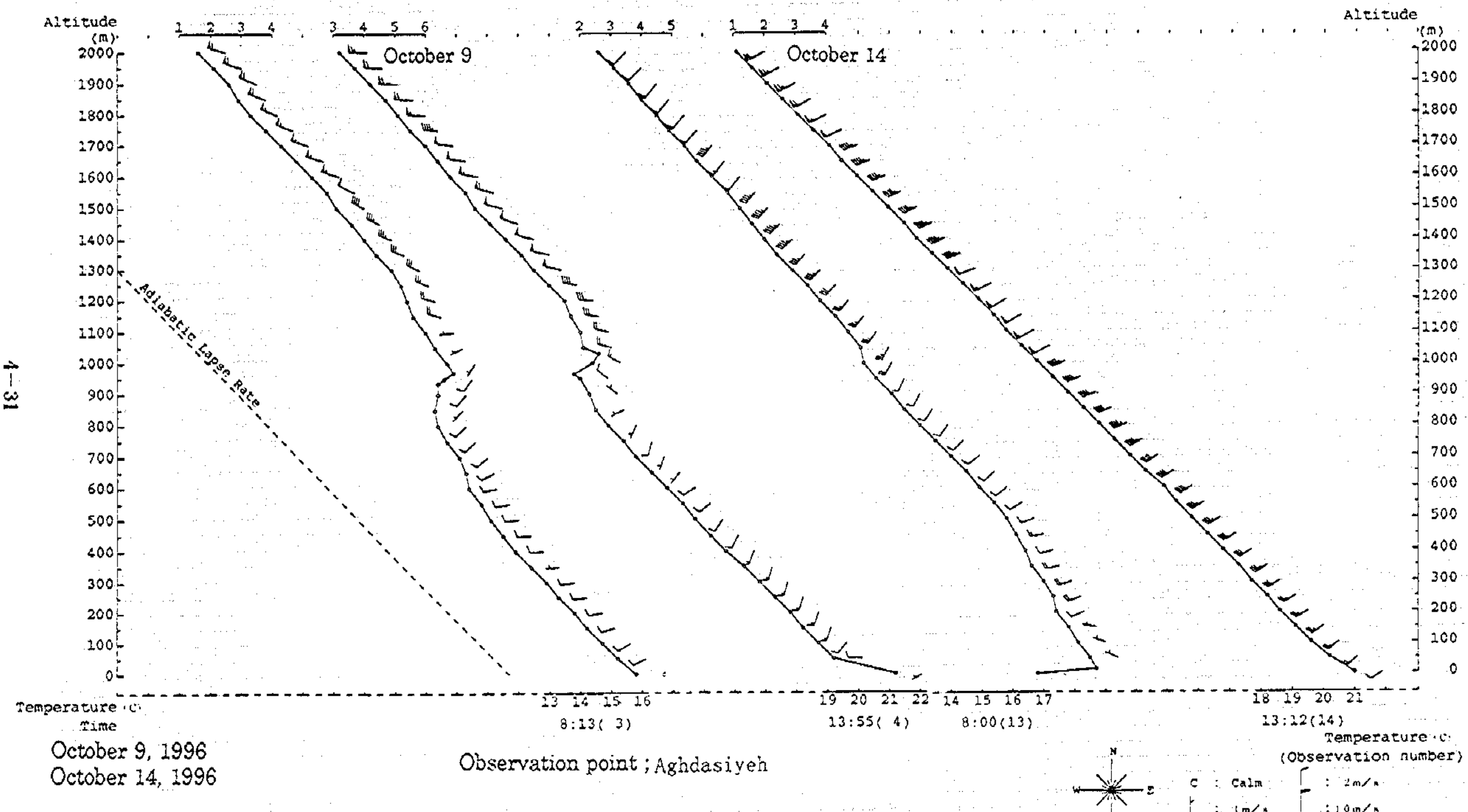


Fig.4.1.2-4(1) Vertical profiles of temperature observed by the low level sonde.

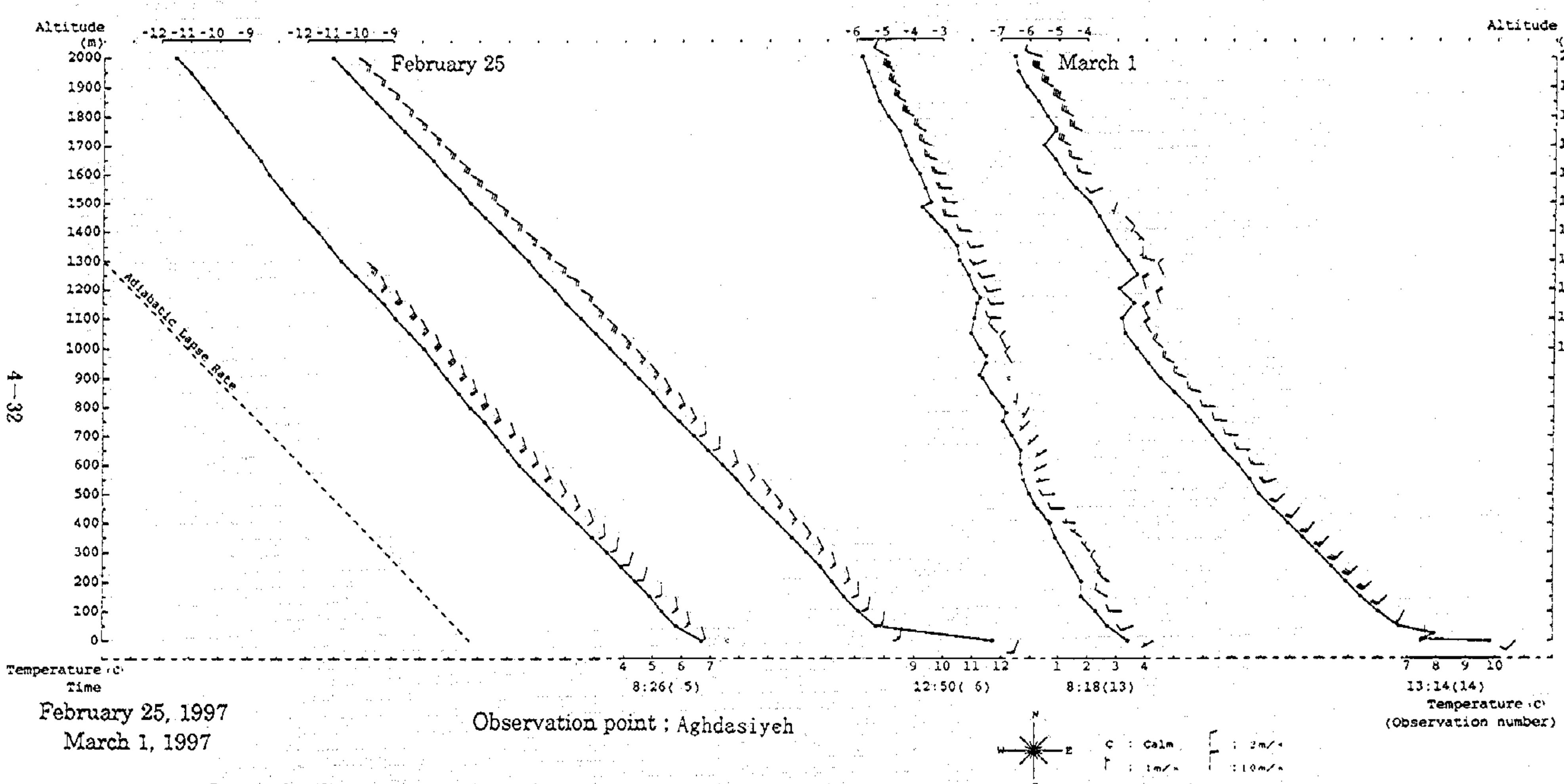
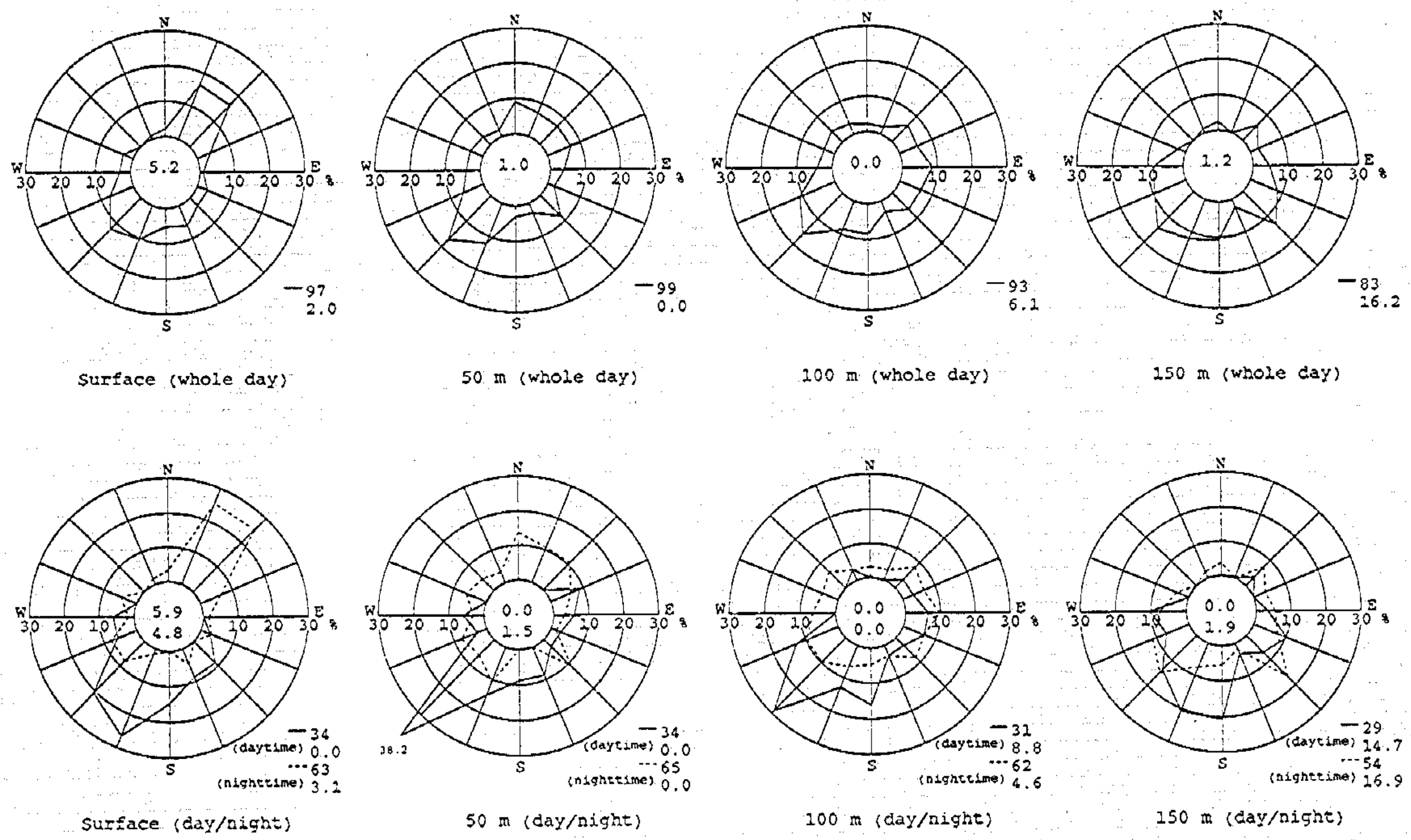


Fig.4.1.2-4(2) Vertical profiles of temperature observed by the low level sonde.



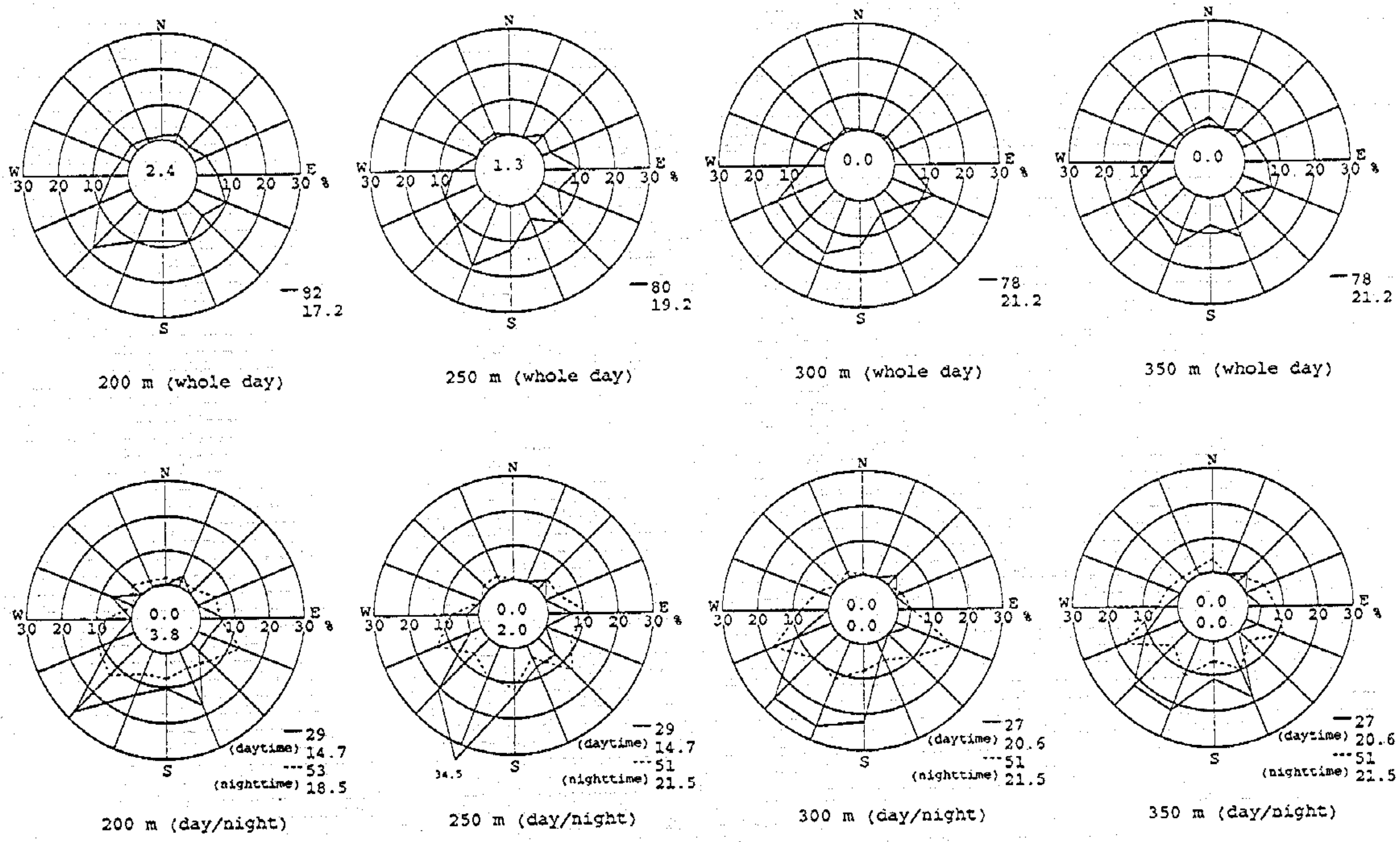
The figures indicated in the circle denote the calm rate (%). In the day/night wind rose, the upper one is for daytime and the lower one is for nighttime. The number of available data and the data deficit rate (%) are shown at the lower right corner of each wind rose.

Observation point ; Aghdasiyeh

Observation period ; October 8, 1996 ~ October 15, 1996

February 22, 1997 ~ March 1, 1997

Fig.4.1.2-5(1) Wind rose for each altitude.

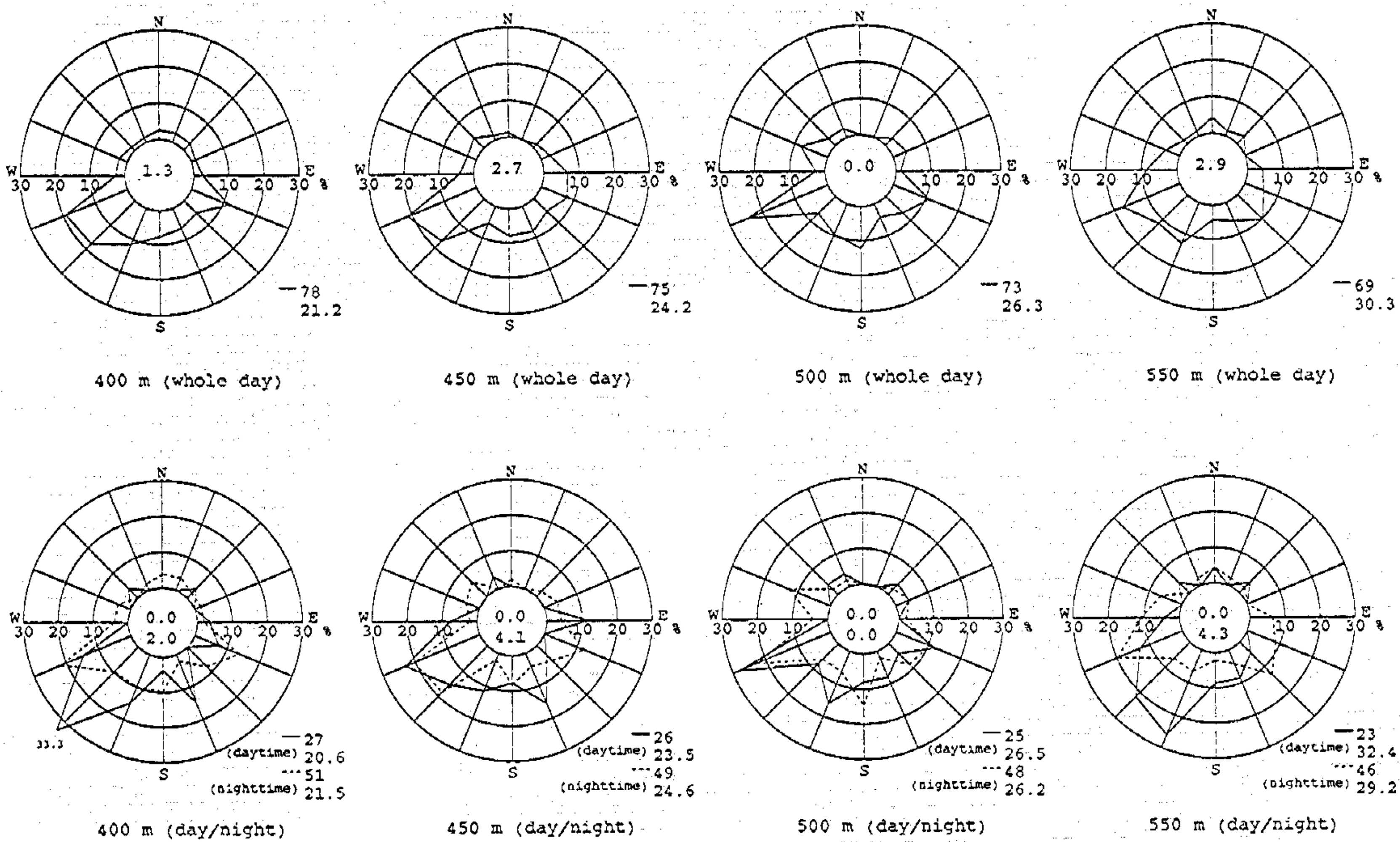


The figures indicated in the circle denote the calm rate (%). In the day/night wind rose, the upper one is for daytime and the lower one is for nighttime. The number of available data and the data deficit rate (%) are shown at the lower right corner of each wind rose.

Observation point ; Aghdasiyeh

Observation period ; October 8, 1996 ~ October 15, 1996
February 22, 1997 ~ March 1, 1997

Fig.4.1.2-5(2) Wind rose for each altitude.



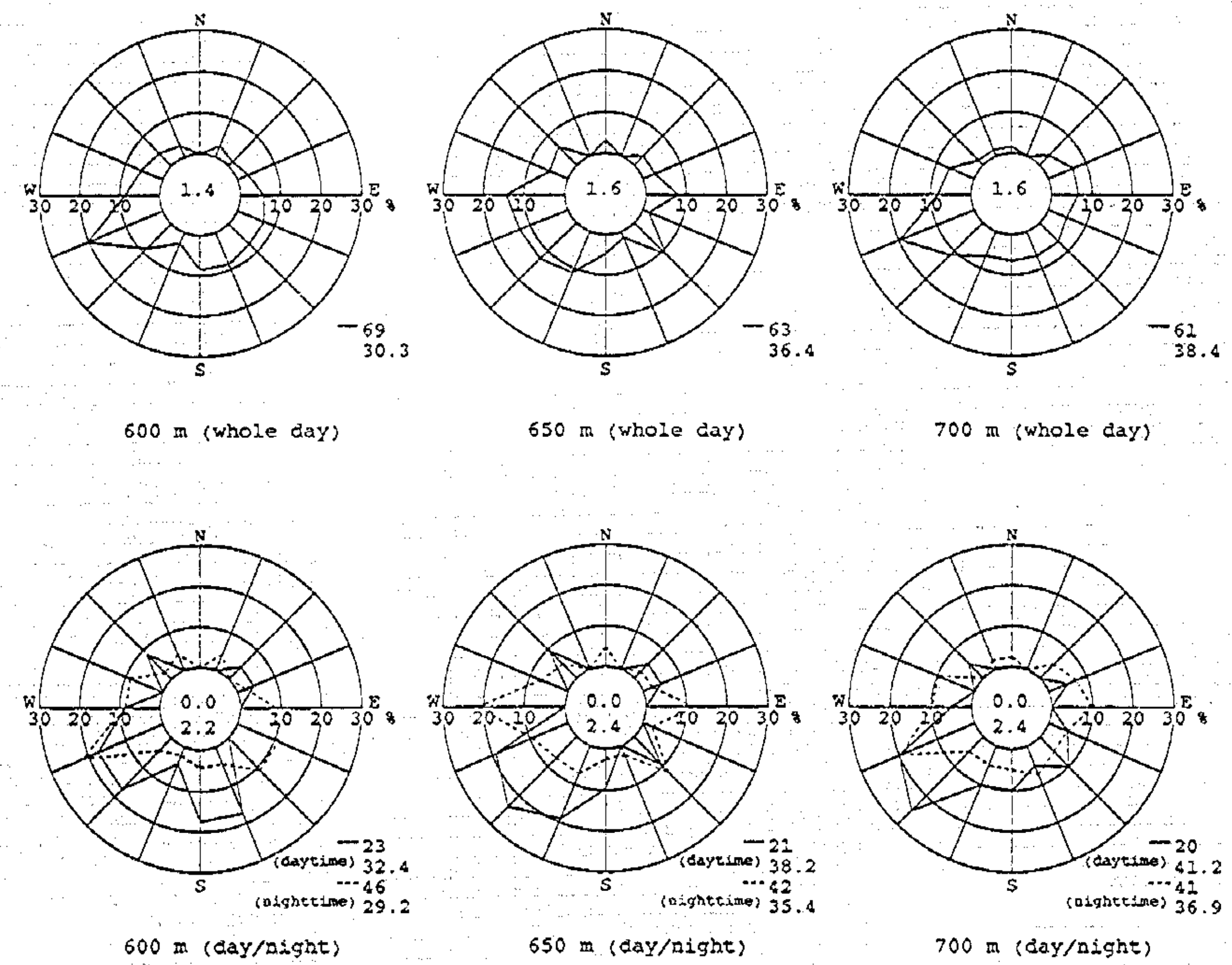
The figures indicated in the circle denote the calm rate (%). In the day/night wind rose, the upper one is for daytime and the lower one is for nighttime. The number of available data and the data deficit rate (%) are shown at the lower right corner of each wind rose.

Observation point ; Aghdasiyeh

Observation period ; October 8, 1996 ~ October 15, 1996

February 22, 1997 ~ March 1, 1997

Fig.4.1.2-5(3) Wind rose for each altitude.



The figures indicated in the circle denote the calm rate (%). In the day/night wind rose, the upper one is for daytime and the lower one is for nighttime. The number of available data and the data deficit rate (%) are shown at the lower right corner of each wind rose.

Fig.4.1.2-5(4) Wind rose for each altitude.

Observation point ; Aghdasiyeh

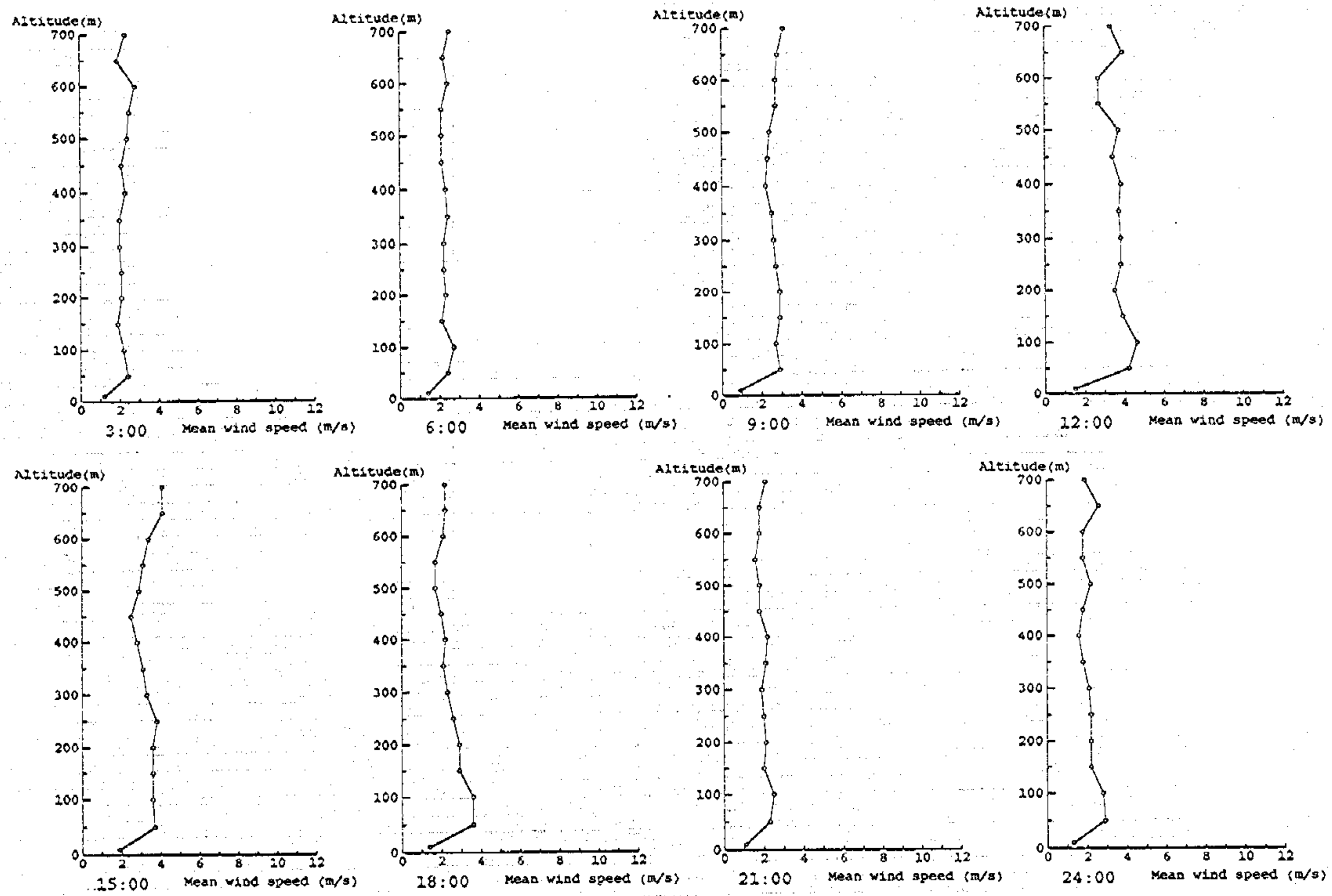
Observation period ; October 8, 1996 ~ October 15, 1996
February 22, 1997 ~ March 1, 1997

and 100m, SSW~SW at 150 - 400m, and SW~WSW at 450 - 700m. On the other hand, in the night-time, NNE~NE prevails at the surface level, and N - NE wind appears frequently at 50m. At 100 - 250m, there is no particular prevailing wind direction, but in the upper layer above 300m, WSW appears most frequently and a lot of ESE appear, too.

In this region, the geographical and topographical influences on the wind system are considerable. The difference in the wind rose between the night and day is recognizable even at 700m, and is the most distinctive in the lower atmosphere near the surface. The daytime SW wind blows uniformly from lower to upper air. On the other hand, the night wind is characterized by the thin NE layer near the surface (~50m). And in the upper air, changeable weak wind or parallel flow along the northern mountain range (E~W) is worthy of special mention.

4) Mean wind speed at each altitude

Vertical profiles of the mean wind speed obtained with a captive sonde are given in Fig. 4.1.2-6 for every 3 hours, the daytime, nighttime, and whole day. The magnitudes of wind speed averaged for the daytime and nighttime on the same level are compared with each other. At the surface level, there is no particular difference, 1.4m/s in the day and 1.3m/s at night. At the 50m or higher altitude, the daytime wind speed (2.7~3.5m/s) exceeds the night-time wind speed (1.9~2.8m/s) by around 1.0m/s. Diurnal change shows that the wind is strong at 12:00 and 15:00 (2.5~4.6m/s except at the surface level) and weak at 21:00 - 3:00 (1.5~2.9 m/s). The mean wind speed profiles for the daytime, nighttime, and whole day show the stratified structure. The wind is very weak near the surface, above which the wind speed increases rapidly up to 50m. And then, the wind speed is almost constant in the upper air above 50m, suggesting the air is well mixed by convection transporting the momentum vertically. This stratified structure of wind speed is well corresponding to the temperature profile characterized by the surface unstable/stable layer and the upper neutral layer. Incidentally, notably the peak wind speed observed at 50 - 100m owes to the cancel of the observation at the upper level over 100m because of the extremely strong wind.

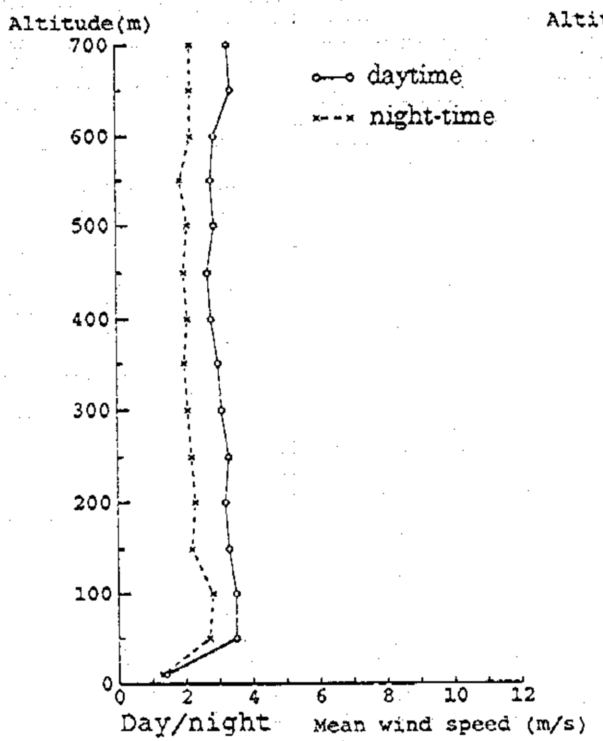


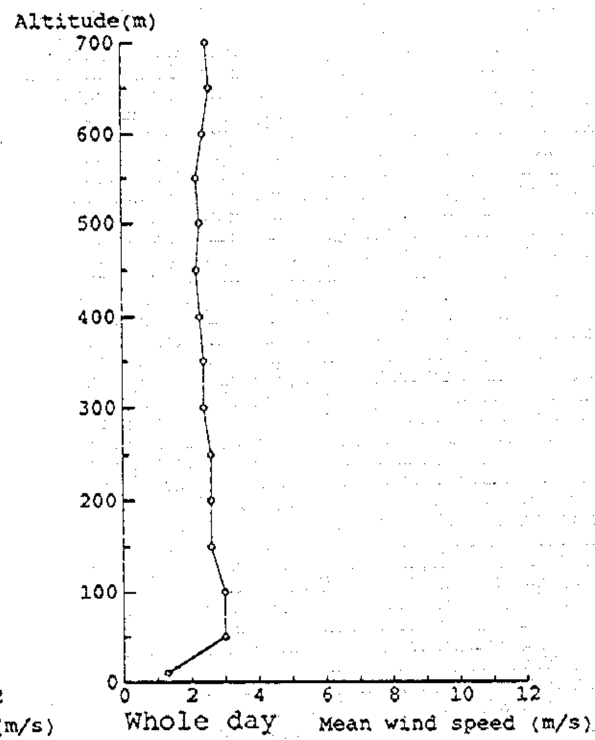
Observation point ; Aghdasiyeh

Observation period ; October 8, 1996 ~ October 15, 1996

February 22, 1997 ~ March 1, 1997

Fig.4.1.2-6(1) Vertical profile of mean wind speed obtained by captive sonde.





Observation point ; Aghdasiyeh

Observation period ; October 8, 1996 ~ October 15, 1996

February 22, 1997 ~ March 1, 1997

Fig.4.1.2-6(2) Vertical profile of mean wind speed obtained by captive sonde.

5) Frequency of classified wind speed

The frequency diagrams of the classified wind speed at every 50m based on the data obtained with a captive sonde are shown in Fig.4.1.2-7 respecting the daytime, nighttime and whole day. In the diagrams for the daytime and night-time, the common features are: (1) the surface boundary layer is distinguished by the majority of rather weaker wind classes, and (2) above that, the somewhat stronger classes are dominant and their percentages are almost constant irrespective of the altitude. As for the difference between the daytime and nighttime diagrams, the one for the daytime has the stronger classes than for the nighttime. For the whole day, the most dominant class at the surface level is 1.0~1.9 m/s, and the second most dominant is 0.5~0.9 m/s. At the 50m or higher altitude, 1.0~1.9 m/s is the most frequent class, and 2.5~2.9 m/s is the next, because the most frequent class in the day and night is 2.5~2.9 m/s and 1.0~1.9 m/s, respectively. The wind above this site even in the upper layer is seemingly always be weak. However, it may be because some observation runs in the afternoon were given up halfway due of the extremely strong wind in the layer higher than 100m.

6) Exponent of power-law for wind speed profile

Based on the data of wind speed (10 - 300m) obtained with a captive sonde, the power-law exponent is estimated by means of a linear regression on the logarithmic profile of wind speed assorted by day/night and atmospheric stability (Fig.4.1.2-8).

The profile of mean wind speed in the surface boundary layer is approximately reproduced by the power-law equation expressed below.

$$u(z_2)/u(z_1)=(z_2/z_1)^p \quad \text{----- (1)}$$

z : altitude(m)

$u(z_2)$, $u(z_1)$: mean wind speed at each altitude(m/s)

p : exponent

This equation is derived empirically; however, it can express the actual wind profile approximately. Therefore, it is practically used as the equation for estimating the upper

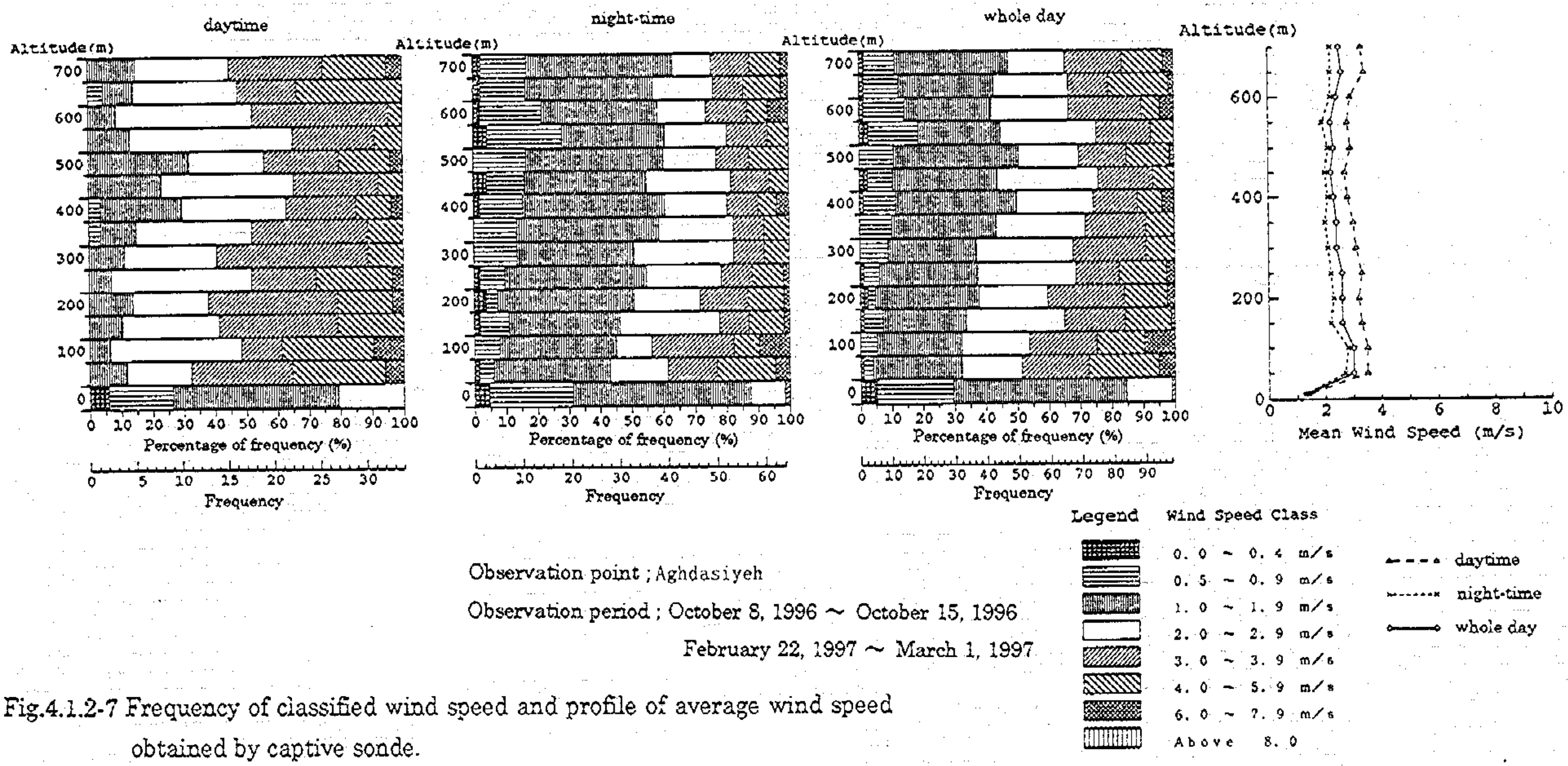
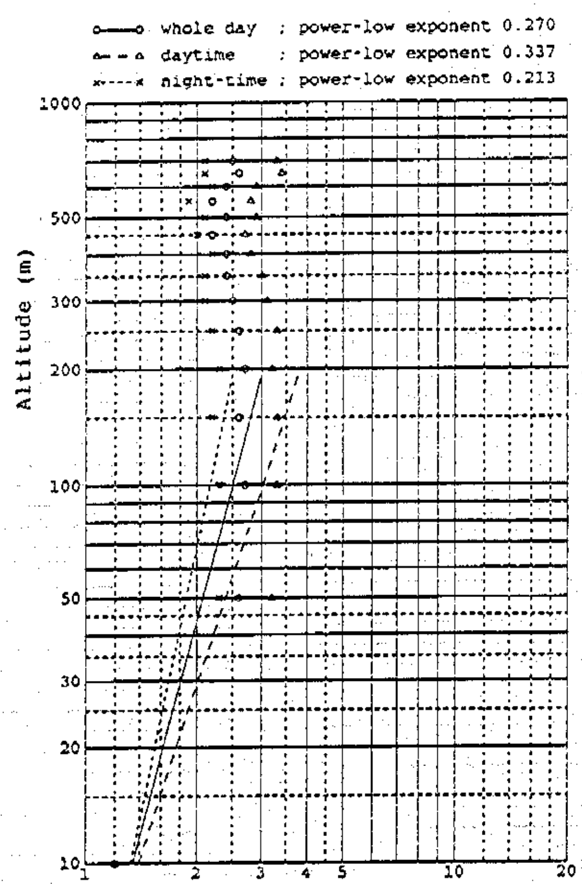
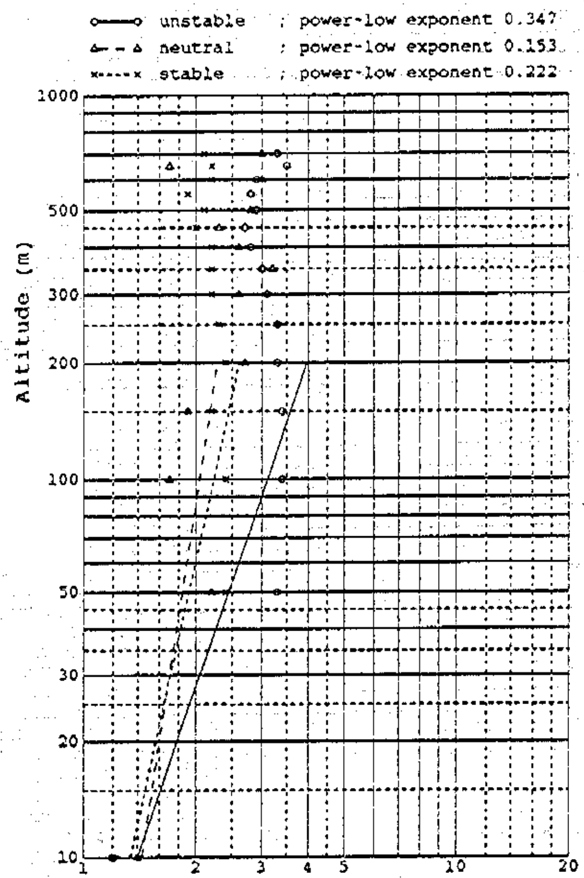


Fig.4.1.2-7 Frequency of classified wind speed and profile of average wind speed obtained by captive sonde.

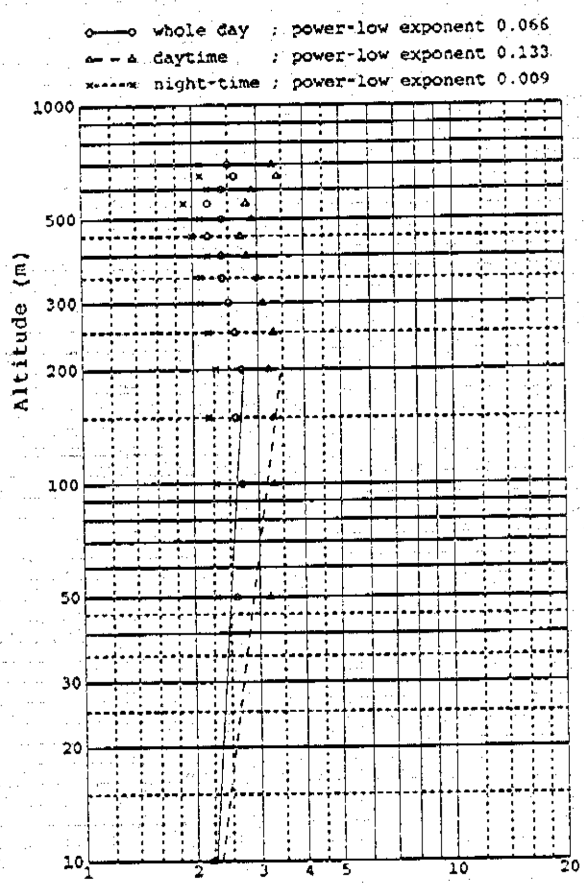




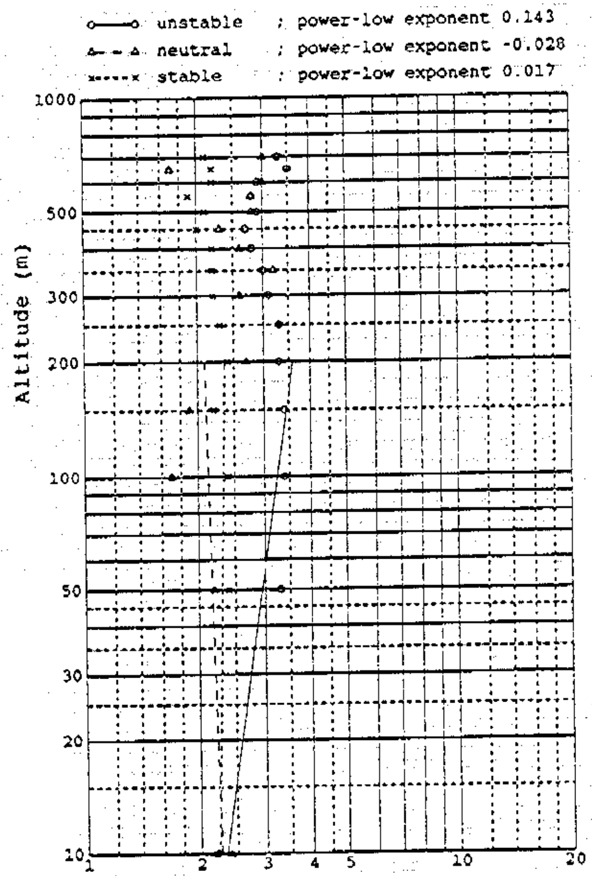
note 1. The difference in wind direction between the surface and upper air is not taken into consideration in this statistics.
2. The power-low exponent is determind based on the data from surface to 200m.

Observation point ; Aghdasiyeh
Observation period ; October 8 - October 15, 1996
February 22 - March 1, 1997

Fig.4.1.2-8(1) Power-low exponent based on the logarithmic profiles of average wind speed by day/night, whole day and by atmospheric stability.



Mean wind speed (m/s)
by day/night, whole day



Mean wind speed (m/s)
by atmospheric stability

note 1. The difference in wind direction between the surface and upper air is not taken into consideration in this statistics.
2. The power-low exponent is determind based on the data from surface to 200m.

Observation point ; Aghdasiyeh
Observation period ; October 8 - October 15, 1996
February 22 - March 1, 1997

Fig.4.1.2-8(2) Power-low exponent based on the logarithmic profiles of average wind speed by day/night, whole day and by atmospheric stability.

wind speed based on the data of surface wind.

The exponent of power-law for the wind speed profile is derived with a regression. The value varies depending on roughness of the ground surface and atmospheric stability as shown below (Table 4.1.2-1).

Table 4.1.2-1 Value of exponent of power-law (p) by land use

	Open grassland Coastal region	Rural district	Forest City
p	0.10 - 0.14	0.17 - 0.25	0.25 - 0.50

"Manual of atmospheric pollution survey", Japan Meteorological Agency (1968)

Table 4.1.2-2 Value of exponent of power-law (p) by Pasquill's atmospheric stability used in the CDM manual of EPA

	A	B	C	D	E	F,G
P	0.10	0.15	0.20	0.25	0.25	0.30

"NOx control manual" Japan Environment Agency

* EPA ; U.S. Environmental Protection Agency

* CDM ; Climatological Dispersion Model

The exponent of power-law (p) is estimated for several cases. Each value of 'p' for the whole day, daytime and nighttime is 0.201, 0.264 and 0.173, respectively. As for atmospheric stability, the 'p' value for "unstable", "neutral" and "stable" is 0.263, 0.198 and 0.190, respectively. Table 4.1.2-1 and Table 4.1.2-2 indicate the kind of standards of exponent in the several cases concerning surface roughness and atmospheric stability. It is hard to say the value for each stability corresponds to the EPA value shown in Table 4.1.2-2.

Fig.4.1.2-8(1) suggests that the power-law does not hold for the cases concerned, probably because of the extreme weak wind on the surface compared to the wind at 50m or higher, so that the data deviate from the regression line and do not fit with power-law.

In an attempt, to make the data fit better the regression line, the power-law equation is rewritten as below.

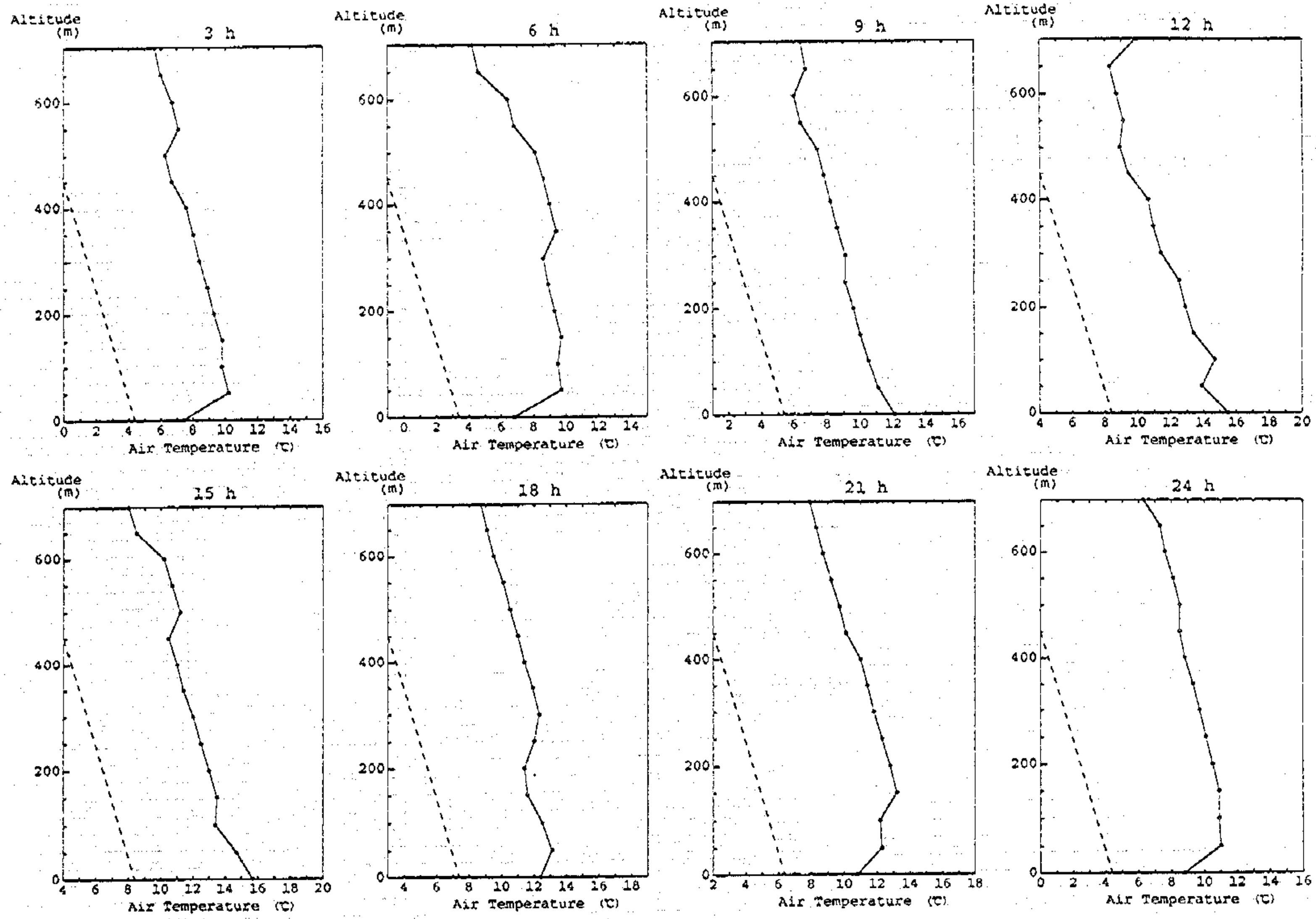
$$u(z_2)/\{u(z_1)+1.0\}=(z_2/z_1)^p \quad \cdots\cdots (2)$$

It is considered that the cause preventing the data from fitting the empirical equation derived in USA is the extreme calm condition near the surface at the site. To solve the problem, the surface wind speed in the equation (2) is inflated by 1.0 m/s. The result is shown in Fig.4.1.2-8(2), showing better fit than Fig.4.1.2-8(1). In the calculation of the power-law exponent, the data below 200m are used, because more data profiles are available than that below 300m. The exponent derived from the regression line for the whole day, daytime and nighttime is 0.066, 0.133, 0.009, respectively. From the point of view of atmospheric stability, the values for "unstable", "neutral", and "stable" is 0.143, -0.028 and 0.017, respectively. These exponents are small because the wind speed at 50m and higher is almost constant and 1.0 m/s is added to the surface wind speed. As a matter of course, it is hardly possible that they coincide with the values in the Table 4.1.2-1 and Table 4.1.2-2 used in Japan and USA. It is recommended to accumulate the wind profile data sufficient for an another empirical equation which is appropriate for wind profile in Tehran and enables reliable estimation of upper wind based on the surface data.

7) Profiles of average air temperature and average air temperature gradient

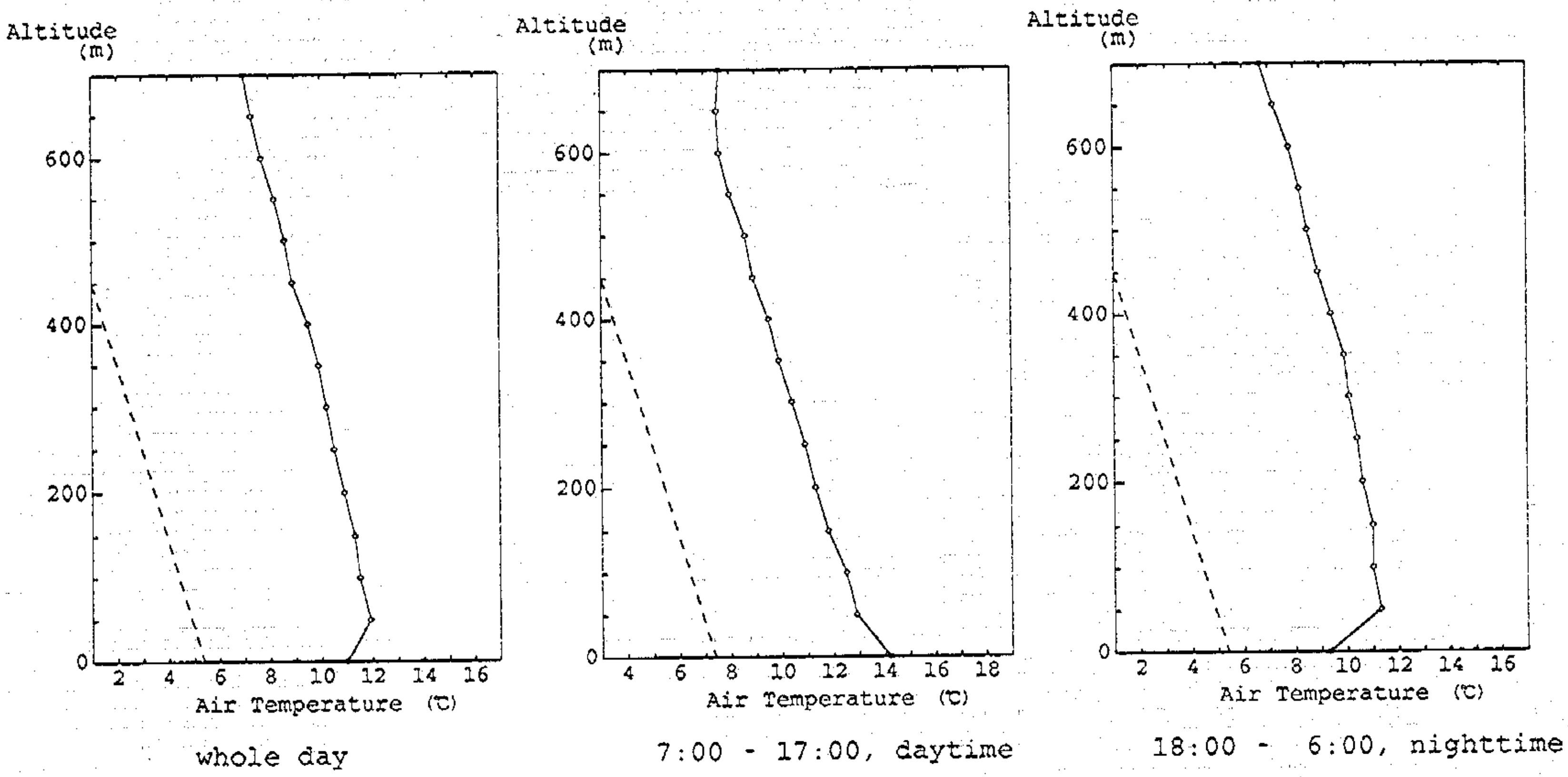
Profiles of the average air temperature and average air temperature gradient at every 50m obtained with a captive sonde for the daytime, nighttime and whole day are shown in Fig.4.1.2-9 and Fig.4.1.2-10, respectively. There is no particular difference in the profiles of temperature gradient between the daytime and nighttime except near the surface. The daytime profiles are characterized by the super adiabatic layer near the surface, and in the upper layer higher than 100m, the temperature decreases with height at the rate of -0.7～-1.0 ℃/100m. On the other hand, the remarkable surface inversion caused by radiative cooling characterize the nighttime profile. The inversion is very shallow and the layer above that is somewhat stable compared to the profile in daytime; the gradient is -0.6～-0.9 ℃/100m.

The profile of average temperature at each time is irregular, perhaps due to the difference in the number of observed data according to the altitude, because some runs could



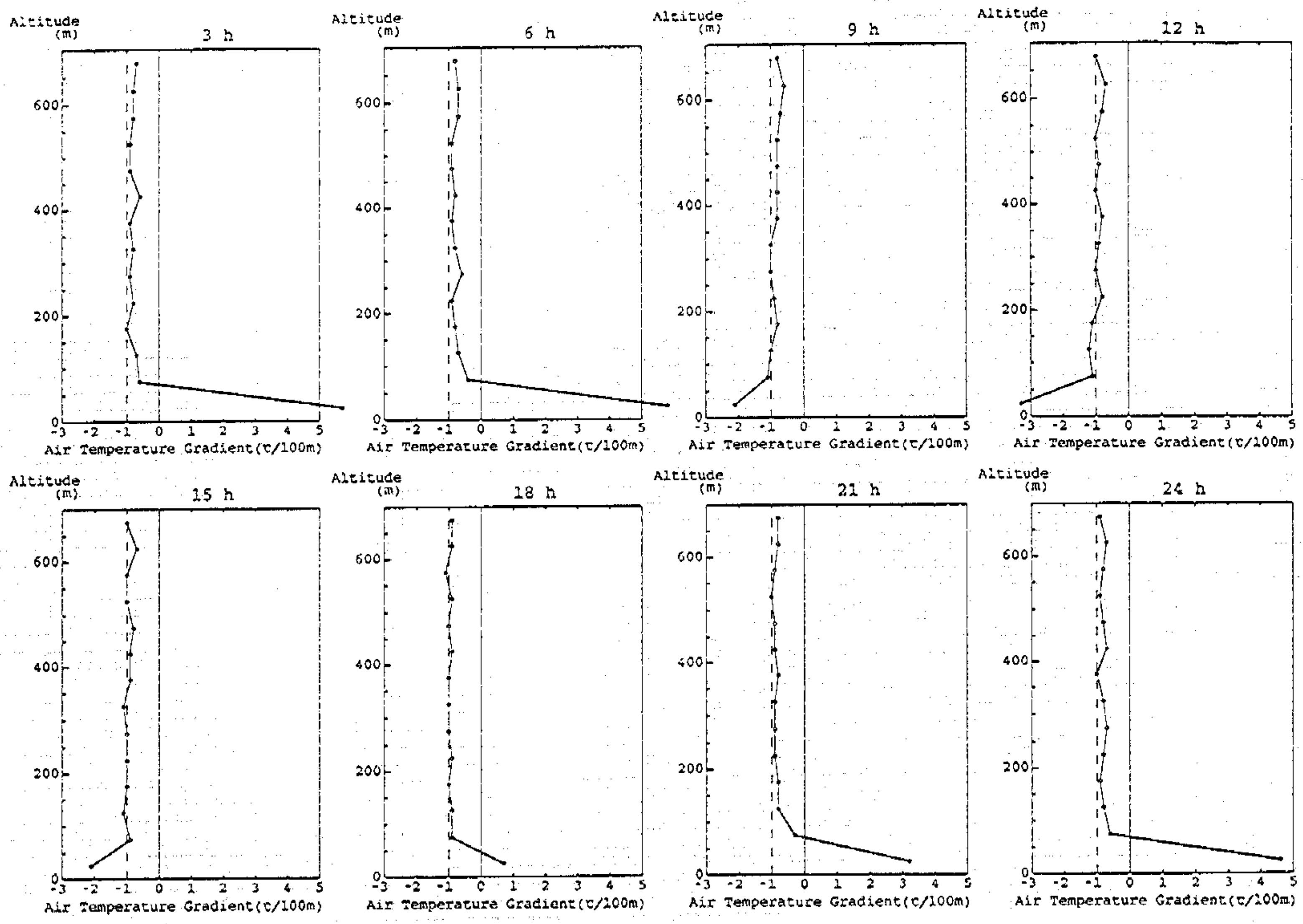
Observation point ; Aghdasiyeh
Period ; October 8, 1996 - March 1, 1997
Instrument ; Captive sonde

Fig.4.1.2-9(1) Profiles of mean air temperature obtained with captive sonde.



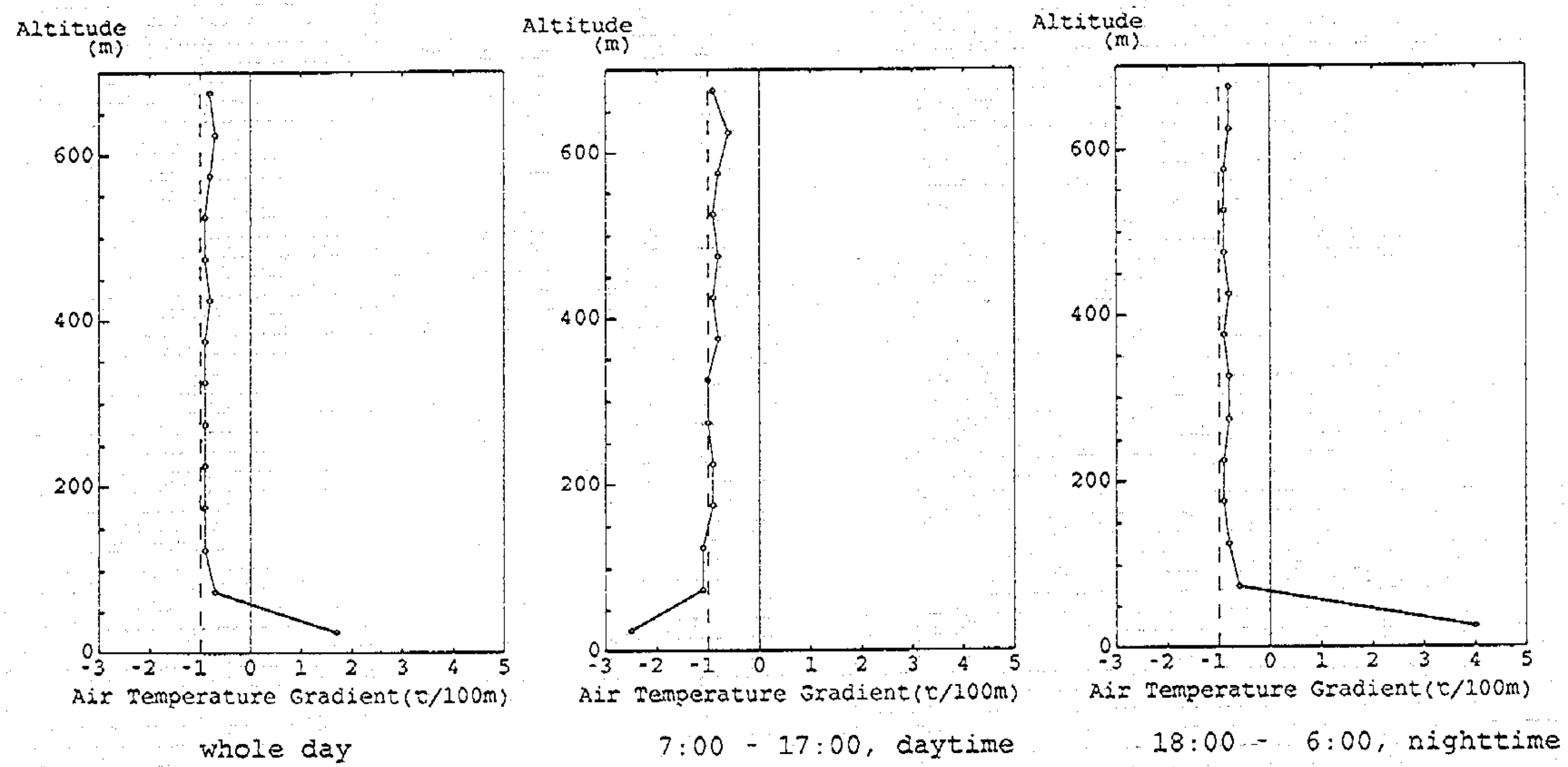
Observation point ; Aghdasiyeh
Period ; October 8, 1996 - March 1, 1997
Instrument ; Captive sonde

Fig.4.1.2-9(2) Profiles of mean air temperature obtained with captive sonde.



Observation point ; Aghdasiyeh
Period ; October 8, 1996 - March 1, 1997
Instrument ; Captive sonde

Fig.4.1.2-10(1) Profiles of mean air temperature gradient obtained with captive sonde.



Observation point ; Aghdasiyeh
Period ; October 8, 1996 - March 1, 1997
Instrument ; Captive sonde

Fig.4.1.2-10(2) Profiles of mean air temperature gradient obtained with captive sonde.

not be completed.

8) Frequency of the classified vertical temperature gradient

Fig.4.1.2-11 shows the frequency of the classified vertical temperature gradient at every 50m obtained with a captive sonde for the daytime, nighttime and whole day. Concerning the daytime diagram, the super-adiabatic class (less than -1.8℃/100m) accounts for about 80% in the lowest layer (surface to 50m). In the upper air above the unstable layer, the neutral class (-0.8~-1.2℃/100m) occupies 50 - 80%, and inversion can be seen 4 - 15% above 350m. On the other hand, the night-time diagram is in marked contrast to the daytime in the lowest layer; that is, the inversion class (greater than 1.8℃/100m) accounts for about 60%. In the second lowest layer (50 - 100m), each class of -0.3~-0.7℃/100m and -0.8~-1.2℃/100m occupies around 40%, and the inversion class about 8%. In the upper layer above them, the neutral class (-0.8~-1.2℃/100m) is dominant (70 - 80%) and inversion appearance is no more than 4%.

(2) The statistics of the upper wind based on the existing data

Fig.4.1.2-12 shows the annual and seasonal wind roses at the surface level, 850hPa and 700hPa based on the upper air observation data at the Mehrabad International Airport through the year of 1994.

The most frequent wind direction in the year is W at the surface level, 850hPa and 700hPa. Especially, at the surface level, W is overwhelming. On the other hand, WNW, E, ESE at 850hPa and WNW, SE, SSE at 700hPa appear frequently in addition to W. The annual mean wind speed is 2.7m/s at the surface level, 4.6m/s at 850hPa and 6.8m/s at 700hPa. Calm appearance is 43.9% at the surface level, but less than 4% at both levels of 850hPa and 700hPa.

At the surface level, W is the most frequent wind direction in all seasons. The seasonally prevailing wind at 850hPa is W in spring and autumn, WNW in winter, while at 700hPa, W and WNW are dominant in all seasons except summer. Wind in summer at both levels of 850 and 700hPa is considerably different from the other seasons. The summer prevailing wind is ESE at 850hPa and SE - SSE at 700hPa, and appearance of W and WNW are not frequent. The seasonal mean wind speed is around 3m/s at the surface level, 4 - 5m/s at 850hPa and 6 - 9m/s at 700hPa.