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CANADA

DEPARTMENT OF TRANSPORT
METEOROLOGICAL BRANCH

THE ANALYSIS OF NATIONAL AIR POLLUTION PROGRAM DATA

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CANADA - DEPARTMENT OF TRANSPORT - METEOROLOGICAL BRANCH

THE ANALYSIS OF NATIONAL AIR POLLUTION PROGRAMME DATA

by

J. H. Emslie

1. INTRODUCTION

Air pollution is, initially, an industrial problem which may, eventually, involve the health of the community at large. Consequently, in Canada, interested parties are industry, the Federal Occupational Health Division, Provincial Health Departments and City Engineering or Health Departments. Each is involved in some phase of measurement, control, analysis or regulation. Each may work independently of the other, using varying techniques or regulations which fit a particular requirement.

Once pollution is emitted into the air, its transport, spread and concentration is governed by meteorological factors; hence, the Meteorological Branch of the Department of Transport is asked to provide meteorological information and advice.

In 1962, the Meteorological Branch, because of its network of stations making continuous measurements of related meteorological data, and its extensive I.B.M. punched card processing facility, was authorized to act as a central repository for Canadian air pollution data.

A certain amount of standardization in air pollution instrumentation and measurement procedure might be expected through conformity with such literature, as the Air Pollution Handbook(1) and the International Journal of Air and Water Pollution(2). However, the various Health or Engineering Departments across the country worked independently on the documentation and study of the data, depending upon their program, budget, and size of staff.

While there was no compunction for the agencies measuring pollution to submit their data to the Meteorological Branch, most realized that complete analysis of the large amounts of data produced by a comprehensive sampling program defied economical manual methods. As a result, all major cities in Canada, with the exception of a few, such as Toronto, Halifax and Quebec City, forward their pollution measurements, generally through Provincial Health Departments to the Federal Occupation Health Division and thence onward to the Air Pollution and Turbulence Unit of the Meteorological Branch.

2. STANDARD DOCUMENTATION

If an approved agency should wish to have its data processed by the Meteorological Branch, it must forward the data on source documents designed and provided by the Meteorological Branch.

The design of the source document, and its companion punched card, must incorporate sufficient latitude to cover the possible range of pollution measurements for the wide variety in air quality present from coast to coast. It must be adaptable to cover differing sampling programs, from one instrument site per city to perhaps fifteen or more, and from the measurement of one pollutant to four or five.

Figure 1 is the National Air Pollution Programme form in use. Each measurement must be recorded in a specific column on the document, in a specified number of digits, in order that it may be manually transferred to the punched card, rapidly and efficiently, with no chance of error or ambiguity I.B.M. punched card 14-A, Figure 2, corresponds, column by column, to the source document.

Each document holds a complete day's record of up to five pollutant measurements from one to five sampling stations, as well as appropriate meteorological data. Agencies operating more than five stations may use consecutively numbered documents. One card 14-A is required for each hour of data on the source document. Thus, twenty-four cards must be punched manually by machine operators of the Data Processing Unit of the Meteorological Branch for each day's record from each participating agency across Canada. It is obvious that data must be entered on the document legibly and in the prescribed form.

3. TABULATIONS

Modern machine methods permit great latitude in statistical analysis of data once the information is on punched cards, (Cudbird, 1961[3]). Many meteorological variables may be correlated with a pollution measurement, so that, initially, the decision must be made which meteorological factors are related to the dispersal of pollution, and into what ranges of values the meteorological and pollution measurements should be subdivided.

It is recognized that the ability of the atmosphere to disperse airborne material depends upon the three-dimensional motions of the atmosphere. Since these motions, over the geographical volume containing the pollutant train, are physically, impossible to measure, a best approximation is obtained by considering a representative wind flow and, where possible, the vertical temperature stratification.

Thus the air pollution measurements obtained from a city sampling program are correlated, in the punched card tabulations, with the continuous wind record from the meteorological office at the adjacent airport. Where it is felt that the airport wind flow is not representative of that within the sampling area, additional wind equipment has been established. Since wind flow is normally variable in both direction and speed over short time intervals, no meaningful result would be obtained by relating a long term pollution measurement to hourly wind values. Hence only those pollution measurements are tabulated by the Meteorological Branch whose sampling times are of the same order as that for the meteorological variables, and the analysis of such data as monthly dustfall, total particulate and instantaneous peak values, of say, sulphur dioxide must be carried out by some other agency.

The format of the tabulation in use by the Metoerological Branch to correlate pollution measurements to the meteorological parameters controlling dispersion, relates measurement occurrences of specified classes of the pollutant, viz. light, moderate and heavy, to the eight cardinal wind directions under three wind speed ranges. The data are initally sub-divided into four six-hourly periods of the day roughly corresponding to night, day and sunrise-sunset transition, and finally, the totalizations are completed on a three-monthly, seasonal basis. Where the vertical temperature structure of the sampling area is available through an instrumented meteorological or television transmission tower, the tabulation is further subdivided into occurrences during the presence of isothermal or small inversion conditions, and occurrences under large inversions.

4. THE POLLUTANTS

As stated in Section 3, a statistical correlation of pollution measurements against wind and stability data will bear meaningful results if their measuring times are of the same order. Pollutants which lend themselves to this type of tabulation are sulphur dioxide, smoke (COH/1000 feet), ozone, oxides of nitrogen and carbon and hydrogen sulphide, to mention a few. To date, the Meteorological Branch prepare routine tabulations on only sulphur dioxide and smoke data, though several of the other pollutants are recorded on punched cards.

5. SULPHUR DIOXIDE TABULATION

The hourly sulphur dioxide measurements have been divided into class ranges which give a reasonable number of occurrences in each class, considering the relatively low concentration of sulphur dioxide pollution in Canada, while still retaining some semblance to the generally accepted classification based on the effect of the pollutant on plant and animal life.

Three classes - 0 to 0.03, 0.04 - 0.09, and greater than or equal to 0.10 p.p.m termed as light, moderate and heavy respectively, are used, though experimental evidence by Thomas[(4)] and the Manufacturing Chemists' Association[(5)] indicates that the minimum concentration for damage to even the most sensitive plants may be well above 0.10 P.P.M.

Figure 3 is a sample tabulation of sulphur dioxide measurements taken at the War Service Records Building in downtown Ottawa. The hourly occurrences of the specified classes of measurements are tabled by wind direction, wind speed and time period as indicated in Section 3. This tabulation, Routine A, includes all measurement occurrences during the three month period. Routine B tables only those occurrences during inversion or isothermal conditions as measured by the meteorological tower in Ottawa(6), and Routine C, only those occurrences during inversions of greater than 5°F between the 20 and 200 foot levels of the tower. (Routine B and C are not included here).

The period of record of Figure 3 is the winter season, December, 1961 to February, 1962. From the body of the table, as an example, one finds that there were 41 occurrences of an hourly sulphur dioxide measurement in the concentration range 0.04 to 0.09 P.P.M. which occurred during the hours 06 - 11 E.S.T., with east winds of speed greater than or equal to 10 m.p.h.

The tabulation, then, contains all of the measurement occurrences for the season, correlated with wind direction, speed and time period in a form from which the Air Pollution Control Officer may develop many varieties of graphs, diagrams, tables and figures, depending upon his requirement.

6. SMOKE TABULATION

Two-hour aerosol deposits, as collected by the Hemeom Sampler, expressed in COH units per 1000 linear feet of air drawn through the filter paper, have been divided into three class ranges in the tabulation, viz. 0.0 - 0.9, 1.0 - 1.9 and ≥ 2.0 COH units per 1000 feet. This classification corresponds to that developed in a 1956 study in the State of New Jersey(7) and now in common use in North America.

The rate of deposit on the filter paper is not linear with time once the accumulation is such that the light transmittance of the spot is reduced by 50%. Two-hourly COH values can not, therefore, be compared with three-hourly values.

Figure 4, Tabulation 143, is a sample smoke tabulation for Vancouver, Station A, covering the winter season, December, 1961 - February, 1962. The wind and time period classifications are identical to those of the sulphur dioxide tabulation. Note, for example, there were twenty-two occurrences of two-hourly aerosol deposits producing COH values in the range 1.0 - 1.9 during the 00:00 - 0.5:00 L.S.T. period under an east wind of 5 - 9 m.p.h.

Once again, Routines B and C, occurrences under inversion and large inversion conditions respectively, are produced for locations where vertical temperature gradient data are available.

7. THE TABULATION ANALYSIS

A preliminary analysis model has been developed which exhibits much of the information in the tabulation, in a form which may be applied to all measurement locations and all pollutants.

The model, the Pollution Wind Rose, presents the percentage directional wind flow distribution for the particular station and season, and relates to it the percentage directional distribution of light and heavy pollution as carried by that wind flow. By noting those directions where the percentage distribution of the pollutant exceeds or is less than the wind flow distribution, excesses and deficits, i.e. polluted and clean wind flow directions, are readily apparent, and may be related by the Pollution Control Officer to possible sources or source areas, and by the Town Planner to preferable residential and industrial zoning areas. For stations with Routine B tabulations, the Pollution Wind Rose may be prepared relating wind flow and pollution ranges under inversion or under lapse conditions.

Figure 5 A, B, C, displays the development of the model, using the information in the sample sulphur dioxide tabulation, Fig. 3 (Ottawa, Dec. 1951 - Feb. 1962). Fig. 5A is the conventional wind rose; the percentage directional distribution of wind flow for the period in question. Fig. 5B shows the percentage distribution of light and heavy pollution by wind direction. Since only simultaneous measurements of wind and pollution are included in the tabulation, the two figures, when superimposed (Fig. 5C), exhibit the actual quality of the airflow for the period. Using information contained in Routines A and B of this tabulation, occurrences of wind flow and simultaneous pollution under lapse and under inversion conditions, during the three month period, are presented in Figs. 6 and 7.

A considerable difference in wind flow is noted, with a marked channeling of wind flow in the east-west directions under lapse conditions (Fig. 6), while under inversion conditions, flow from the southwest quadrant prevailed over 50% of the time (Fig. 7). Under lapse conditions, air flow from the west was excessively clean, while flow from the east was excessively polluted. In both temperature stratifications, measurements showed an excess of sulphur dioxide pollution under northeast circulation, with 12% of heavy pollution occurring with that wind direction under inversion conditions even though the northeast flow occurred only 6% of the time. Under lapse conditions, that winter, 28% of the heavy pollution occurred with the northeast flow though that wind direction was present only 9% of the time. It is indicated that the Pollution Control Officer should give close scrutiny to sulphur dioxide pollution sources northeast of the Ottawa measurement station. Calm conditions were much more frequent under inversion conditions (15.6%), and it is noted that 24.4% of heavy pollution was measured during these calm periods.

Since positioning of the station analyses on a topographical outline of a city may more clearly show pollution - topographic - residential - industrial relationships, outlines of each city in Canada with multiple pollution measurement stations have been prepared.

Figure 8, as an example, is the outline of the City of Vancouver with the Pollution Wind Rose analyses of COH data for the winter season Dec. 1961 - Feb. 1962, superimposed. For this particular period, when winds prevailed from the east, only Station C, close to the waterfront complex of Vancouver, received an excess of heavy COH from that direction. East winds were relatively clean at Station E, while the less frequent west and northwest winds carried in that station's major portion of heavy COH from the direction of the industrial heart of Vancouver. Station D, well removed from industry, experienced no occurrences of heavy COH during the entire winter period.

The topographic analysis may be prepared using vertical temperature criteria, where that information is available (ref. Figs. 6 and 7) thus providing a further refinement of the meteorological influence on city pollution dispersion.

8. OTHER ANALYSES

The Pollution Wind Rose analysis depicts percentage occurrences by wind direction. It is only one of many analyses which may evolve from the tabulation but is recommended since it combines much of the data in the tabulation, may be produced rapidly, and is equally adaptable to all single and multiple sampling stations in Canada.

Actual occurrences may be totalled from the tabulation as may occurrences during particular time periods or individual wind speed ranges. A table such as Fig. 9 may be helpful in extracting from the tabulation significant meteorological - pollution correlations and may be prepared with a minimum of effort. Data in the example are extracted from the sample Tabulation 142, Fig. 3. Routine completion of the table will exhibit diurnal and seasonal trends of the selected classification of pollution.

It should be remembered that a comparison of actual occurrences must take into account the possibility of differing total numbers of observations, due, for example, to instrument trouble, if the comparison is not to be misleading.

Individual Air Pollution Control Officers may well require other analyses to suit their own special requirements. These likely may be prepared from the data in the tabulations. If not, manual analysis of the original data (Fig. 1), or preparation of a special tabulation by the Meteorological Branch may be required.

9. THE SAMPLING STATION LOCATION

An appreciation of the representativeness of the sampling location is paramount in study of the tabulation analysis. Presence of a nearby point source will result in a pollution peak with wind flow from that direction. The tabulation analysis merely documents the peak; it is up to the agency official to decide whether the peak is operationally significant. If channeling of wind flow by ground contours or buildings occurs, the directional distribution of pollution from sources in the immediate vicinity will not be in agreement with the flow over the area in general, which will mask point source orientation.

Should the station be located, for example, in a park, the ambient pollution may be diluted as indicated in studies in London Park by Wainwright and Wilson[8], and Montreal by Summers[9]; hence, the measured pollution level would not be representative of the area as a whole. A sampling site in an isolated hollow would likewise, rarely be representative, since cold air drainage could establish an inversion lid on the hollow, thus preventing the penetration of ambient pollution to the sampler.

Finally, a knowledge of source variability, which cannot be separated out in the machine analysis of meteorological effects, must be applied by the Pollution Control Officer, if his consideration of diurnal and seasonal meteorological factors, as documented in the tabulation analyses, are to assume the correct order of magnitude.

APPROVED,

J. R. H. Noble,
Acting Director.

REFERENCES

(1) Magill, P. L., F. R. H. Holden and C. Auckley, 1956: Air Pollution Handbook, New York, McGraw-Hill Book Co.

(2) International Journal of Air and Water Pollution, Pergamon Press London.

(3) Cudbird, B. S. V., 1961: Modern Techniques in Canadian Climatic Data Processing. Canada, Department of Transport, Meteorological Branch, CIR-3558, CLI-28.

(4) Thomas, M. D., 1951: Gas Damage to Plants, Annual Review Plant Physiology, 2: 293: 322.

(5) Manufacturing Chemists' Association, Air Pollution Abatement Manual.

(6) Munn, R. E., J. H. Emslie, and H. J. Wilson, 1963: A Preliminary Analysis of the Inversion Climatology of Southern Ontario. Canada, Department of Transport, Meteorological Branch, Technical Circular Series. CIR-3834, TEC-466.

(7) New Jersey State Department of Health, 1958: State-wide Air Pollution Survey - Smoke Index.

(8) Wainwright, C. W. K. and M. J. G. Wilson, 1962: Atmospheric Pollution In A London Park. Int. J. Air, Water Pollution, Pergamon Press, Vol. 6, 337 - 347.

(9) Summers, P. W., 1961: Smoke Concentrations in Montreal Related to Local Meteorological Factors, U. S. Public Health Service Symposium, Air Over Cities, A62-5, 89 - 113.

NATIONAL AIR POLLUTION PROGRAMME (MUNICIPAL)

STATION ______________________________(cols. 1-7) TYPE OF PROGRAM ______________________(cols. 16-17)

DATE & TIME	CARD NUMBER	TEMPERATURE DIFFERENCE (°F) T_2-T_1	Wind at Surface		HOURLY PRECIPITATION	STATION A					STATION B					STATION C					STATION D					STATION E					REMARKS
LOCAL STANDARD TIME YYMMDDHH			Direction (16 pts.)	Speed MPH		SO_2 PPHM	COH per 1000 ft.	H_2S PPHM			SO_2 PPHM	COH per 1000 ft.	H_2S PPHM			SO_2 PPHM	COH per 1000 ft.	H_2S PPHM			SO_2 PPHM	COH per 1000 ft.	H_2S PPHM			SO_2 PPHM	COH per 1000 ft.	H_2S PPHM			
Cols. 8 - 15	18	19-21	22-25		26-28	29-30	31-32	33-34	35-36	37-38	39-40	41-42	43-44	45-46	47-48	49-50	51-52	53-54	55-56	57-58	59-60	61-62	63-64	65-66	67-68	69-70	71-72	73-74	75-76	77-78	
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STATION LOCATIONS

A________________ D________________

B________________ E________________

C________________

NOTES: 1) COH values are recorded midway through 2-hour sampling period. e.g. A COH value for period 06-08 LST is recorded at 07 LST.

2) Hourly SO_2 values are the average for the half hour preceding and the half hour following a given hour. e.g. An SO_2 value for 07 LST is the average concentration for the period 0630-0730 LST.

62-9731

Figure 1

The National Air Pollution Programme Form

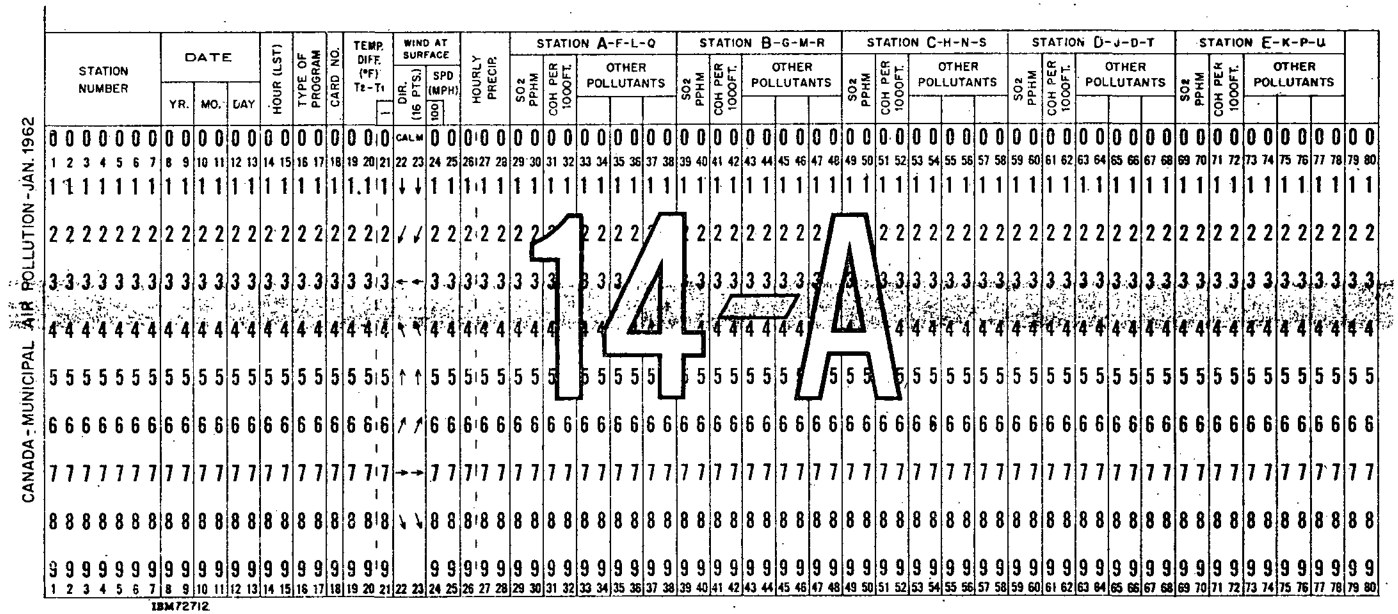

Figure 2
The National Air Pollution I.B.M. Punched Card

REPORT: PERIOD OF RECORD: DEC. 1961 - FEB. 1962 OTTAWA AP STN A. ROUTINE A TAB. # 142 SHEET NO.

	SO_2 00.0 - 0.03								
	N	NE	E	SE	S	SW	W	NW	CALM
0-4 MILES NO INVERSION TEST									
TOTALS	2	1	6	5	17	13	6	7	18
00-05 L.S.T.	)		2		6	3			3
06-11	2				3	1	2	3	2
12-17			2	5	6	3	3	4	5
18-23		1	2		2	6	1		8
5 - 9 MILES NO INVERSION TEST									
TOTALS	9	5	23	6	8	12	58	19	
00-05 L.S.T.	5	2	6	1	3	1	11	6	
06-11	2		2	1		5	9	3	
12-17	1		8	3	2	4	16	4	
18-23	1	3	7	1	3	2	22	6	
≥ 10 MILES NO INVERSION TEST									
TOTALS	23	2	33	2	22	61	180	48	
00-05 L.S.T.	5	1	7		1	23	32	15	
06-11	3		13	1	7	17	40	9	
12-17	6	1	10	1	9	12	68	9	
18-23	9		3		5	9	40	15	

	SO_2 0.04 - 0.09								
	N	NE	E	SE	S	SW	W	NW	CALM
0-4 MILES NO INVERSION TEST									
TOTALS	4	4	13	5	5	14	11	4	24
00-05 L.S.T.	1	1	1		2	7	6		6
06-11		1	1		1	6	2	1	3
12-17	2	1	6	3	2	1	2	3	4
18-23	1	1	5	2			1		11
5 - 9 MILES NO INVERSION TEST									
TOTALS	8	16	39	7	17	11	27	12	
00-05 L.S.T.	6	3	4	3	7	3	10	4	
06-11	1	4	7		2	2	5	2	
12-17		8	15	2	3	1	5		
18-23	1	1	13	2	5	5	7	6	
≥ 10 MILES NO INVERSION TEST									
TOTALS	8	21	149	1	1	12	42	19	
00-05 L.S.T.	2	7	39			5	8	4	
06-11	1	6	41	1		1	18	9	
12-17	2	4	31				8	4	
18-23	3	4	38		1	6	8	2	

	SO_2 ≥ 0.10										
	N	NE	E	SE	S	SW	W	NW	CALM	TOTALS	
0-4 MILES NO INVERSION TEST											
TOTALS	6	5	9	5	5	3	1		31	224	0
00-05 L.S.T.	2	1	2		1	1			12	57	0
06-11	3	3	4	1	1	1	1		5	47	0
12-17	1			2		1			5	61	0
18-23		1	3	2	3				9	59	0
5 - 9 MILES NO INVERSION TEST											
TOTALS	15	33	25	1	4	12	4	5		376	0
00-05 L.S.T.	5	14	4		1	2	1			102	0
06-11	7	11	9		2	4	3	4		85	0
12-17		2	3		1					78	0
18-23	3	6	9	1		6		1		111	0
≥ 10 MILES NO INVERSION TEST											
TOTALS	9	23	48			7	3	10		724	0
00-05 L.S.T.	5	8	14			3		4		183	0
06-11	3	9	15				1	2		197	0
12-17		1	6							172	0
18-23	1	5	13			4	2	4		172	0

Figure 3
Sample Sulpher Dioxide Pollution Tabulation

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REPORT: PERIOD OF RECORD: DEC. 1961 - FEB. 1962 INCL. VANCOUVER AP. STN. A. ROUTINE A ONLY TAB. # 143 SHEET NO.

	COH 00-09									COH 10-19									COH ≥ 20									
	N	NE	E	SE	S	SW	W	NW	CALM	N	NE	E	SE	S	SW	W	NW	CALM	N	NE	E	SE	S	SW	W	NW	CALM	TOTALS
0-4 MILES NO INVERSION TEST																												
TOTALS	5	13	34	8	4	9	10	6	16	6	6	44	6	3	5	12	11	25	4	7	24	7	1	4	5	9	24	308
00-05 L.S.T.	2	5	14	5		3	1	1	5	1	2	11		2	3	2	1	7		2	6	1				2	5	81
06-11	3	2	10	1	1	1	2	1	8	3	1	11	3		2		3	4	1		9	3		1	1	3	7	81
12-17		2	7	1	1	4	6		3		2	10	1	1		6	3	5		3	1	1	1	1	2	1	2	64
18-23		4	3	1	2	1	1	4		2	1	12	2			4	4	9	3	2	8	2		2	2	3	10	82
5-9 MILES NO INVERSION TEST																												
TOTALS	3	29	120	14	8	9	20	13		1	18	64	2		4	7	8		2	13	28	2			4	7		376
00-05 L.S.T.	2	11	40	3	3		3				3	22			1		1			2	6					2		99
06-11		7	42	2	1	1	2	3		1	4	18					1		1	2	8				1	1		95
12-17		3	20	5	3	6	13	9			4	8	2		2	6	2			1	2	1			2	2		91
18-23	1	8	18	4	1	2	2	1			7	16			1	1	4		1	8	12	1			1	2		91
≥10 MILES NO INVERSION TEST																												
TOTALS		57	81	23	20	21	52	9		1	10	23	1	5	2	18	4				2		1			5		335
00-05 L.S.T.		13	25	6	2	4	13	3				4				4					1							75
06-11		12	21	8	2	3	8				3	9	1	1		2	2						1			5		78
12-17		17	16	4	10	7	19	2		1	5	5		4	2	6	2											100
18-23		15	19	5	6	7	12	4			2	5				6					1							82

Figure 4
Sample Smoke Pollution Tabulation

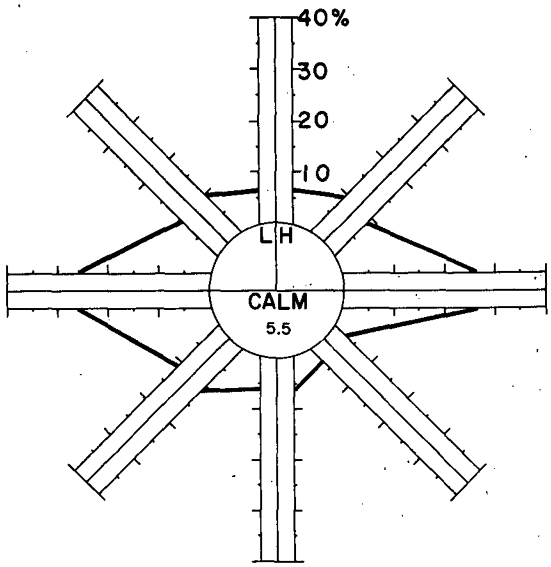


Figure 5A
The Pollution Wind Rose

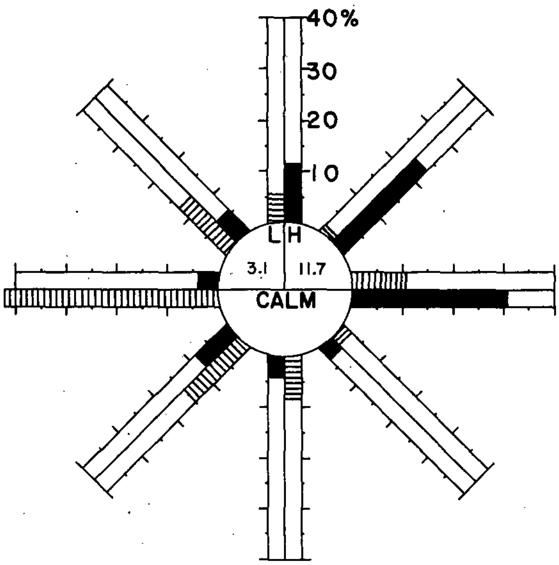


Figure 5B
The Pollution Wind Rose

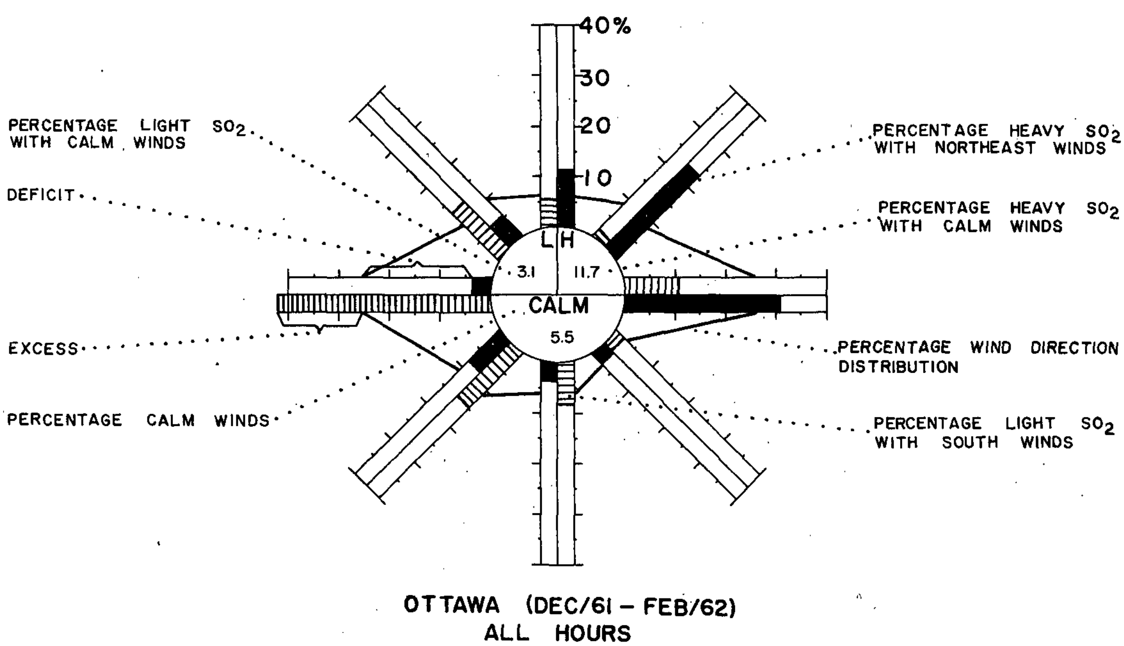
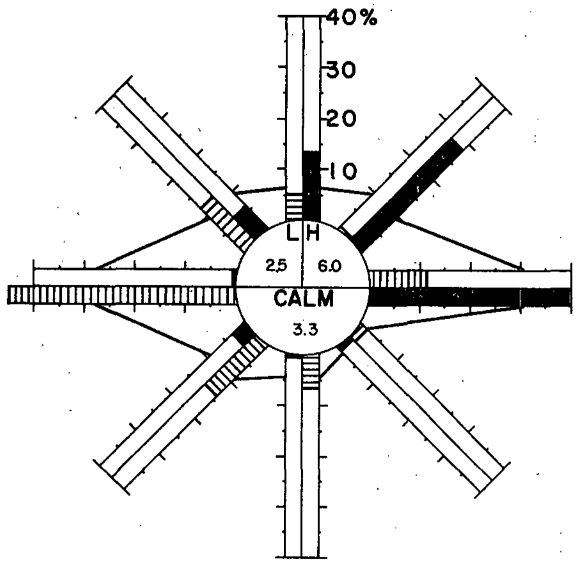
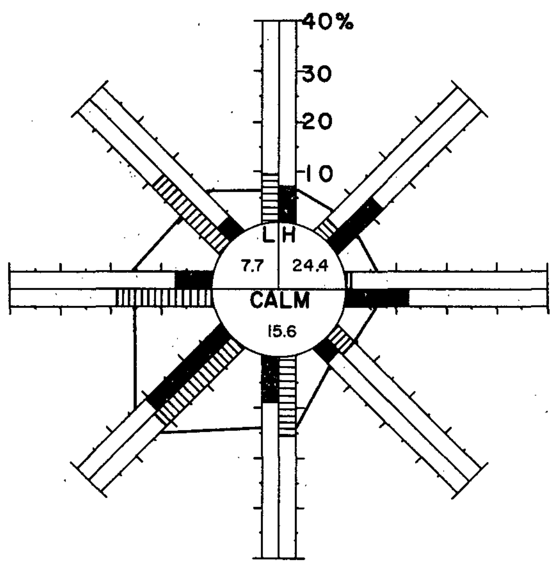


Figure 5C
The Pollution Wind Rose



OTTAWA (DEC/61 – FEB/62)
LAPSE HOURS

Figure 6
Pollution Wind Rose (Lapse Hours)



OTTAWA (DEC/61 – FEB/62)
INVERSION HOURS

Figure 7
Pollution Wind Rose (Inversion Hours)

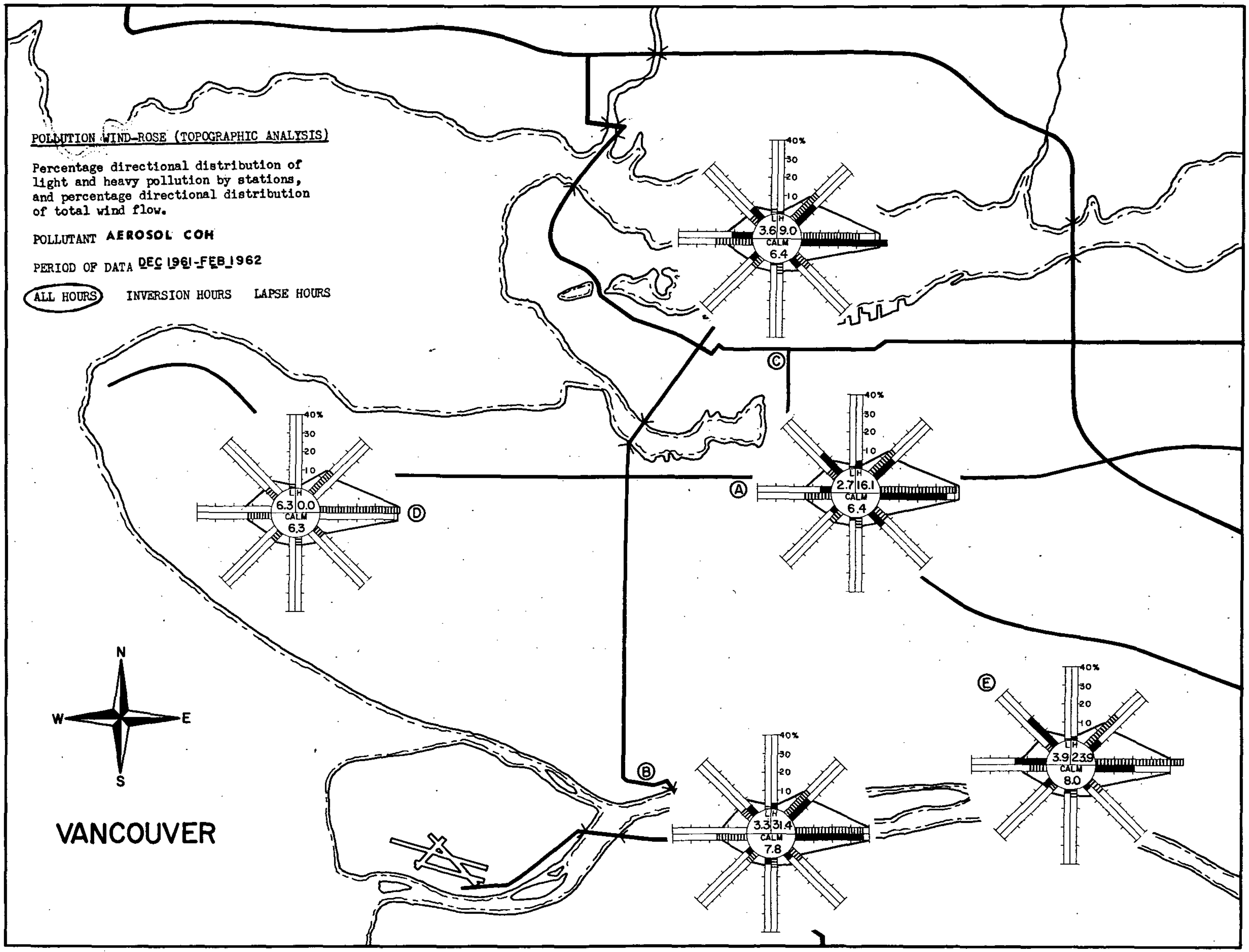


Figure 8
Pollution Wind Rose Topographic Analysis

Occurrences Of Sulphur Dioxide Pollution(0.10 PPM) By Windspeed And Time Class

Time Period (L:S.T.)	00 - 05			06 - 11			12 - 17			18 - 23			Total
Wind Speed (M.P.H.)	0-4	5-9	10	0-4	5-9	10	0-4	5-9	10	0-4	5-9	10	
Dec.61 - Feb.62	19	27	34	19	40	30	9	6	7	18	26	29	264
Mar.62 - May 62					etc.								

Figure 9
Pollution Occurrences

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Canada
Department of Transport - Meteorological Branch

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7 pp. 9 refs. 9 figs.

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