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Second Progress Report

METEOROLOGICAL INSTALLATION AND ANALYSIS

E. Wendell Hewson
Professor of Meteorology

Gerald C. Gill
Associate Research Engineer

Eugene W. Bierly
Graduate Research Assistant

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ABSTRACT

The principles of operation of the Thomas autometer which is used for measuring the concentration of SO_2 are described in detail along with the specific problems associated with the autometer on Silver Hill. Wind direction and wind speed are analyzed to show the predominant river-valley effect on the wind-direction distribution. Either the 1957 seasons were not typical or a seven-year record is not enough to obtain a stable frequency distribution for wind speeds and wind directions. The gust-count data are analyzed, showing the importance of topography and the effect of local modification of the lower layer on the gust count. It is pointed out that gust counts vary as the square of the wind speed throughout the year. The importance of precipitation and its reaction with SO_2 are pointed out. Topography plays an important role in the distribution of precipitation received at the plant site. The effects of SO_2 on vegetation and human beings are noted. It is shown that there is a source of SO_2 to the south of the plant site. The SO_2 behaves in its diurnal pattern as a typical atmospheric pollutant. It is concluded that the river-valley and topographic effects are predominant, that the added instrumentation on the stack will aid in the physical analysis of the effects observed at the site, and that there is a measurable SO_2 background existing in the Silver Hill area today.

INTRODUCTION

This report brings under one cover the data which have been gathered at the New Albany plant site for the 1957 seasons. The year is taken to commence on 1 December 1956 and to end on 30 November 1957 since we consider December, January, and February the winter season; March, April, and May the spring; June, July, and August the summer; and September, October, and November the fall. All the data have been analyzed according to season so any seasonal effects might be observed. In addition to the seasonal divisions, an annual summary has been included in sections for which data for a complete year have been collected.

The wind-direction, wind-speed, and turbulence sections have been analyzed as in the first progress report except that the turbulence-section analysis has been divided into the seasonal divisions rather than being presented as one unit.

A section on precipitation has been included in this report because of the importance of rainfall in washing aerosols from the atmosphere and because of the chemical reaction of SO_2 and water. Although rainfall is not measured at the plant site, the assumption has been made that the rainfall at Standiford Field is equal to that at the plant site. Proceeding on this assumption, the rainfall distribution has been analyzed for all four seasons.

The Thomas autometer used in recording the concentration of SO_2 did not begin working properly until late May, 1957, so only the summer and fall seasons are included in the section on SO_2 analysis of this report. A section has been devoted to a description of the autometer as an addition to the experimental installation.

ADDITIONS TO THE EXPERIMENTAL INSTALLATION

Several plants that emit sulfur dioxide to the atmosphere are located on the outskirts of Louisville, to the southwest of the city. With southerly winds and poor diffusion conditions, this SO_2 could reach Silver Hill in sufficient concentrations to be noticed by the residents. To have a reliable record of what concentrations of SO_2, if any, were occurring on Silver Hill prior to the operation of the new power plant, the Public Service Company of Indiana decided in the spring of 1955 to install a permanent SO_2 recorder. They would thus have a record of the day-to-day concentrations of SO_2 on Silver Hill for almost a three-year period prior to the operation of the power plant.

The latest type of Thomas autometer, Leeds and Northrup No. 64251-A1, was purchased and installed on top of Silver Hill near the SE end of the ridge. The autometer was started on 1 November 1955, and has been running almost continuously ever since. Several problems were encountered with the new instrument so that during the first eighteen months of operation there were extended periods of faulty functioning. Since 22 May 1957, reliable records of SO_2 concentrations have been obtained.

1. DESCRIPTION OF SO_2 RECORDER

The chemical reaction underlying the construction of the Thomas autometer is:

$$SO_2\uparrow + H_2O_2 \longrightarrow H_2SO_4 \quad .$$

The air to be tested for SO_2 is bubbled through a slightly acidified solution of hydrogen peroxide and distilled water. If any SO_2 is present in the air, it reacts with the hydrogen peroxide to form sulfuric acid. There is a corresponding increase in the electrical conductivity of the solution, with the resulting increase in acidity. A pair of platinized electrodes is suspended near the base of the absorption chamber and connected to a recording Wheatstone bridge which measures continuously the solution's conductivity. With proper calibration of the instrument, the values of the conductivity of the solution are converted directly into readings of sulfur dioxide concentrations as parts of sulfur dioxide per million parts of air by volume (ppm).

In the earlier models of the Thomas autometer,[1] the air was bubbled through 100 cc of hydrogen peroxide solution for a 20-minute period and then switched to an alternate freshly prepared cell for the succeeding 20-minute period. The conductivity of the cell which was being aspirated was recorded. The air leaving the vacuum pump passed through a wet-test gas meter before being expelled to the outside. The passage of each cubic foot of air was recorded by a separate pen near the edge of the chart roll. Air flow rate was maintained at about 20 cu ft/hr. The Leeds and Northrup bridge recorded changes in resistance from 125 to 100,000 ohms. For the rate of air flow and the volumes of solution employed, this range permitted the measurement of sulfur dioxide concentrations from about 0.01 ppm to about 7.0 ppm.

In this system changes in concentration could be detected by changes in the slope of the conductivity curve for the 20-minute period, but no accurate quantitative value of short-period concentrations of SO_2 was possible. Recorded values of SO_2 concentrations could easily be in error by ± 8% or more owing to diurnal temperature changes of the absorbing solutions. For example, a 1°C change in solution temperature would change the conductivity of the solution approximately 2%.

In the new autometer purchased for Silver Hill, the above weaknesses had been largely overcome by a new design.[2,3] Figure 1 shows the interior of the

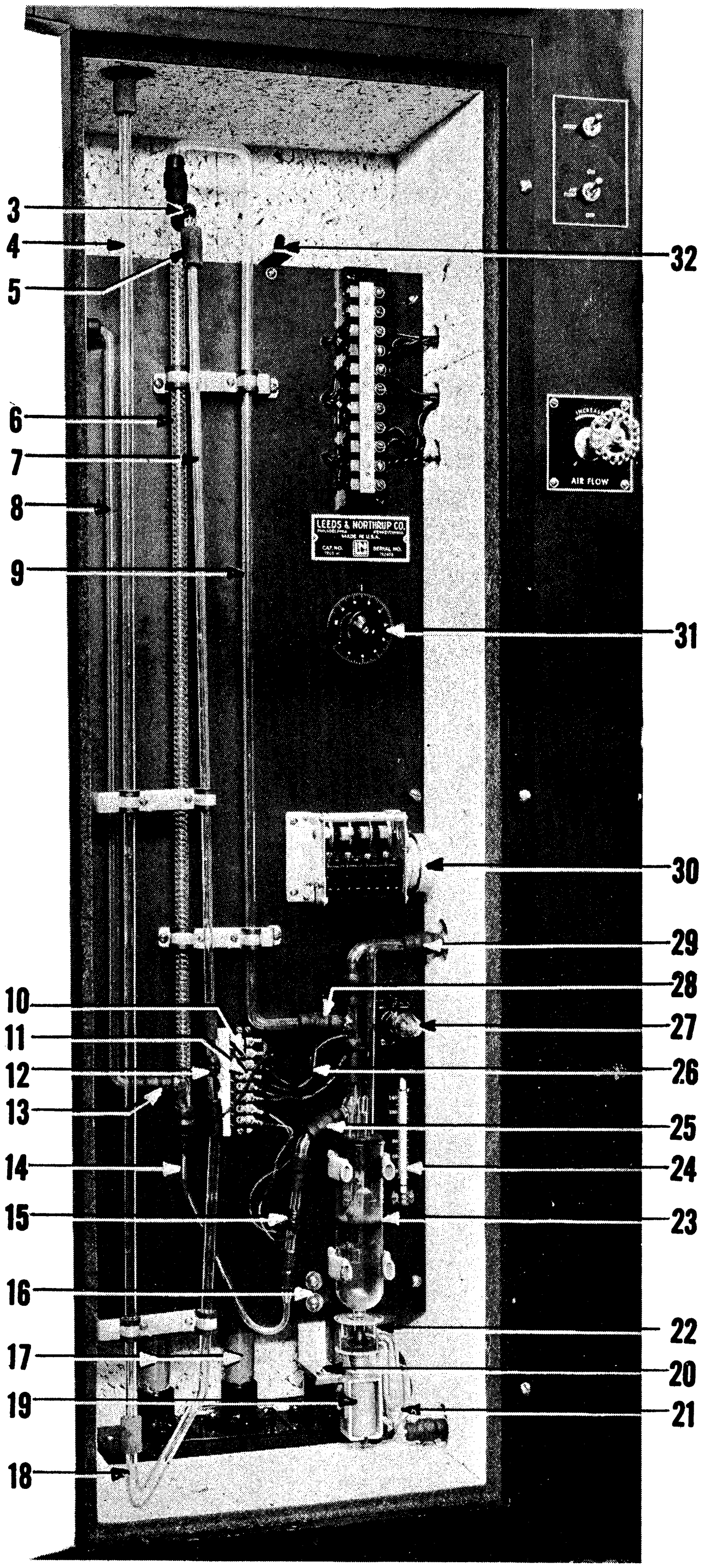


Fig. 1. Interior of cell cabinet of SO_2 recorders.

cell cabinet. The principal changes in the design and the reasons for them are as follows:

(1) The cell cabinet is electrically heated and maintained at a constant temperature of 120° ± 2°F, winter and summer. The purpose of this temperature control is to reduce the diurnal and longer-period temperature fluctuations and the corresponding large errors in concentration measurements.

(2) A new absorbing cell, identified as 6 in Fig. 1, has been used in which the absorbing solution flows in a thin film down a spiral tube while the air being sampled passes up the tube in intimate contact with the solution. The conductivity of the exposed absorbing solution is measured by the instantaneous cell, 15 in Fig. 1. With this arrangement the average SO_2 concentration in the air, accurate to within 10%, is recorded two minutes later on the recorder. With a solution flow rate of 3.3 ml per minute, about 1 drop per second, it takes 27 minutes for the integrating cell to fill and trip a relay, which automatically switches the conductivity measuring circuit from the instantaneous cell to the integrating cell where the average SO_2 concentration for the previous 27 minutes is measured. One and one-half minutes later the timer, 30 in Fig. 1, switches the conductivity measuring circuit to the conductivity cell, 12 in Fig. 1, where the conductivity of the incoming blank solution is measured. After 1-1/2 minutes on this cell, the timer returns the conductivity measuring circuit to the instantaneous cell, and the cycle is repeated. Thus during each 30-minute cycle the instantaneous cell is operating approximately 27 minutes. With this recorder the minute-to-minute fluctuations in SO_2 concentration are accurately recorded, as well as the half-hourly mean values.

During the period of faulty operation at Silver Hill, much of the trouble was due to air bubbles forming in the solution lines and either slowing down the rate of flow of solution or stopping it entirely. The formation of the bubbles resulted from the release of dissolved air when the solution temperature was raised from room temperature to the 120°F cabinet temperature. Giever reported on the identical problem, and others associated with it, in 1952.[4] The remedial measures taken in the spring of 1957 were almost identical with the ones he used in 1952.

The general specifications given by Leeds and Northrup for their instrument follow.

Reagent:	5×10^{-5}N H_2SO_4 2×10^{-3}M H_2O_2 2×10^{-3} g/l Dowicide B
Sample flow:	20 cu ft/hr
Reagent flow:	3.3 ml/min (about 1 drop per sec)
Power supply:	115 volt, 60 cycle; 1350 watts starting, 450 watts running

Accuracy:	±0.1 ppm when operated and tested as specified
Stability:	readings are reproducible to 0.1 ppm of SO_2
Sensitivity:	better than 0.05 ppm of SO_2
Range:	0 to 5 ppm of SO_2
Response:	90% of final reading (for stepwise change) is reached within 2 min

From a careful analysis of the record, it is considered that the claims of Leeds and Northrup are justified. There is usually a small diurnal shift of the recorder reading due to the diurnal temperature changes of the incoming air. This change can usually be easily separated from a change caused by the presence of SO_2. If the temperature of the incoming air and of the solution were both regulated to 120° ± 2°F, it appears likely that there would be little or no ambiguity in recognizing concentrations as low as 0.01 ppm. In practice the concentrations of SO_2 are read to the nearest 0.01 ppm, with values below 0.03 ppm being recorded as a trace.

ANALYSIS OF WIND-DIRECTION AND WIND-SPEED DATA

Winds have been observed at a height of 104 ft at the plant site near New Albany, Indiana, since 12 October 1956, a period of nearly 14 months. The U.S. Weather Bureau has observed winds at a height of 71 ft at Standiford Field, Louisville, Kentucky, since September, 1950. Although the instruments are only 8 miles apart, the separate and distinct topographic influences mentioned in the first progress report produce widely differing wind regimes at the two locations.

The general plan of analysis presented in the first progress report was as follows. The winds for a given season at Standiford Field were compared with the average obtained from the five-year period, 1951-1955, at Standiford Field for the corresponding season. If the season under consideration appeared typical at Standiford Field, then the wind distribution at the New Albany plant site was also considered typical of that season. In addition, the winds at Standiford Field were compared with those at the plant site for each individual season. To make an adequate comparison, the eight-point compass bias in the observations at Standiford Field had to be removed.

This plan has been partially followed in the present report although more statistical techniques have been used to determine whether the present seasons are typical or not. We now know that it is useless to try to compare wind regimes from Standiford Field with those at New Albany because of the pronounced topographical differences. Figures 2-6 present the biased Standiford Field data along with the New Albany data. Figures 2 and 3 differ from those of the first report because the similar figures in that report had the bias removed from the Standiford Field winds. The present report contains the biased Standiford Field data.

The data to be analyzed are presented in Tables I-XX. Tables IV, VIII XII, XVI, and XX contain both the biased and unbiased frequencies for Standiford Field. These tables have been presented primarily to maintain continuity.

1. WIND DIRECTION

Conventional wind roses were constructed for all four seasons and the annual summary, Figs. 2-6, to allow seasonal comparisons to be made of the wind-direction distributions at New Albany and Standiford Field.

After nearly 14 months of observing the wind at the New Albany plant site, the feature of the strong bimodal distribution still remains dominant. The bimodal distribution is caused by the wind orienting itself in a NNE-SSW line which coincides with the direction of the Ohio River valley at that point. This dominant feature has been evident in each of the seasons examined to approximately the same extent. A major departure was noted, however, in the fall season of 1957, as Fig. 5 shows. This departure may be attributed to the persistence of a synoptic pattern which caused the occurrence of fewer southerly winds.

At Standiford Field no such strong bimodal pattern was observed. The first progress report mentioned the tendency toward a NNW-SSE bimodal distribution corresponding to the orientation of the broad flat valley in which Standiford Field lies. A fairly strong SSE mode is still observed during the summer and fall of 1957, but a pronounced decrease is evident in the NNW mode, as indicated in Figs. 4 and 5. Instead there is a large number of N and NE winds, which, if the bias were removed (see Tables XII and XVI) would indicate a strong NNE mode. Such a shift from NNW to NNE would suggest that the broad valley in which Standiford Field is located does not exert the dominant influence on wind direction that the Ohio River valley does at the New Albany plant site.

2. WIND SPEED

The data obtained during the summer and fall of 1957 further substantiate the conclusion drawn in the first progress report that winds at New Albany, in general, average 75% of those at Standiford Field. This conclusion still must be accepted as valid at this time. The installation of wind-speed measuring equipment near the top of the stack will indicate whether this condition exists at the top of the stack where the valley influences may not be as great.

Again the percentage of calms is significantly greater at New Albany than at Standiford Field. Some of these calms may be due to our data-reduction procedures which state that, if there is no prevailing wind direction for 30 min or more during an hour period when the wind speed is 2 or 3 mph, that hour is recorded as calm. The Weather Bureau would record such conditions as light and variable but we have no provision for such a category. Even so, it is felt that the New Albany plant site is subjected to long periods of calm weather, especially in the early morning hours due to inversions formed in the valley. Such reasoning gives credence to the observations as recorded by the New Albany aerovane.

During the summer of 1957, winds from all directions at the plant site were lighter than the corresponding winds at Standiford Field. The fall showed higher values from the S and SE than the corresponding values at Standiford Field. This result is due to the longer sweep of relatively flat terrain S and E of the plant site.

The wind speeds at New Albany in the SW to W sector are generally lighter in relation to the corresponding winds at Standiford Field than winds from other sectors. The fact that winds from the SW to W sector must pass over rough terrain before reaching the plant site probably accounts for this difference.

3. GENERAL REMARKS

A statistical test, Chi-square, was used to measure the degree to which the four seasons, December, 1956, through November, 1957, were representative of the five-year normal. The values of Chi-square obtained for all the seasons could be expected to occur with a frequency of less than 1 in 1000 if the present seasons were truly normal. A result such as this leads to one of two conclusions. Either the seasons of 1956-1957 were not normal or the five-year period itself does not represent a stable frequency distribution.

Considering the latter alternative, an attempt was made to lengthen the period of record. Unfortunately, prior to January, 1948, wind observations were not made at Standiford Field, while before September, 1949, hourly wind observations were taken with respect to an eight-point compass. Owing to these restrictions only two more years of data, December, 1949, through December, 1950, and January, 1956, through November, 1956, could be added to the already existing five years of record. The period of record for establishing a normal frequency distribution then consisted of seven years of data.

Again a Chi-square test was applied to compare the 1956-1957 seasons with the new seven-year standard. Although reductions in the size of the Chi-square values were obtained for three of the four seasons, the values still indicated that the 1956-1957 seasons were not typical of the seven-year period. This result then suggests that more than seven years of wind data may be necessary to obtain a stable frequency distribution and hence an accurate picture of the normal wind regime at Standiford Field.

That conclusion, together with the inherent bias in the Standiford Field data, plus the distinct topographic differences between Standiford Field and New Albany, indicate that the Standiford Field wind data will have limited use in the future. As the length of record of on-site data increases and as wind frequency distributions at the top of the stack become available, the emphasis will be placed upon careful analysis of wind data at the plant site.

TABLE I

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Louisville, Kentucky (Standiford Field)
(Wind instrument at height of 71 ft)

(Winter Seasons; 1951-1955 incl.)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	0.6	4.7	1.8			6.5	7.1	772	10.1
NNE	0.2	2.1	0.8			2.9	3.0	327	10.4
NE	0.8	4.1	0.8			4.9	5.7	621	8.7
ENE	0.2	1.1	0.1			1.2	1.4	153	8.2
E	0.5	1.7	0.1			1.8	2.4	258	6.6
ESE	0.2	1.1	0.1			1.2	1.3	142	7.6
SE	1.6	7.5	0.4			7.9	9.5	1024	7.4
SSE	0.7	5.6	1.4			7.0	7.6	827	9.4
S	0.8	7.6	5.1	0.2	0.1	13.0	13.8	1472	11.9
SSW	0.3	3.4	3.6	0.2		7.2	7.5	816	13.3
SW	0.5	5.1	3.4	0.1		8.6	9.1	985	11.9
WSW	0.1	2.6	1.3	0.1		4.0	4.1	446	11.5
W	0.2	3.2	1.4	0.1		4.7	4.9	531	10.9
WNW	0.1	3.4	2.6	0.1		6.1	6.1	661	12.5
NW	0.4	6.3	4.0			10.3	10.8	1163	11.7
NNW	0.1	2.3	1.6			3.9	4.0	432	12.2
Calm	1.7						1.7	184	0.0
Totals	9.0	61.8	28.5	0.8	0.1	91.2	100.0	10814	10.6

TABLE II

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Louisville, Kentucky (Standiford Field)
(Wind instrument at height of 71 ft)

1 December 1956 - 28 February 1957
(Winter)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	1.2	6.3	3.7			10.0	11.2	242	10.0
NNE	0.4	2.3	1.9			4.2	4.6	99	10.3
NE	1.7	6.2	1.4			7.6	9.3	201	7.9
ENE	0.3	1.5	0.3			1.8	2.2	47	7.7
E	0.9	1.7	0.1			1.8	2.7	59	6.1
ESE	0.3	0.9				0.9	1.2	25	5.8
SE	2.0	7.1	0.7			7.8	9.8	212	6.8
SSE	0.4	2.7	0.6			3.3	3.8	81	8.2
S	0.6	3.5	3.9	0.2		7.6	8.1	176	11.5
SSW	0.1	1.9	3.6			5.5	5.6	122	13.5
SW	0.4	4.7	4.3			9.0	9.4	202	12.0
WSW	0.1	2.9	2.4			5.3	5.4	117	11.4
W	0.4	3.3	2.1			5.4	5.8	125	10.8
WNW	0.1	2.7	2.4			5.1	5.2	113	12.5
NW	0.8	4.7	4.5			9.2	10.1	219	11.8
NNW	0.1	2.2	2.3			4.5	4.7	101	12.5
Calm	0.9						0.9	19	0.0
Totals	10.7	54.6	34.2	0.2		89.0	100.0	2160	10.2

TABLE III

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Public Service Company of Indiana
New Albany, Indiana
(Aerovane at height of 104 ft)

1 December 1956 - 28 February 1957
(Winter)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	3.3	3.4	0.8			4.1	7.4	156	6.4
NNE	5.6	11.7	1.6			13.3	18.9	396	7.1
NE	1.5	3.3				3.3	4.9	102	6.1
ENE	0.3	0.7				0.7	1.0	21	6.3
E	0.3	0.4				0.4	0.7	15	5.2
ESE	0.7	1.0				1.0	1.7	35	5.6
SE	0.6	0.9				0.9	1.5	31	5.7
SSE	1.0	0.7				0.7	1.6	34	4.5
S	1.2	2.3	1.3			3.6	4.8	100	9.3
SSW	2.9	10.2	3.3			13.5	16.3	343	9.1
SW	1.2	6.0	0.6			6.6	7.8	164	7.9
WSW	1.0	3.8	0.1			3.9	5.0	104	7.0
W	1.6	3.4	0.3			3.7	5.3	111	6.7
WNW	1.5	2.8	0.5			3.3	4.8	100	7.3
NW	0.7	4.9	0.7			5.5	6.2	130	8.5
NNW	0.8	4.0	1.1			5.1	6.0	125	9.2
Calm	6.2						6.2	131	0.0
Totals	30.4	59.5	10.3			69.6	100.0	2098	7.1

TABLE IV

COMPARISON OF PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS, ALL SPEEDS, BIASED AND UNBIASED

Louisville, Kentucky (Standiford Field)

1 December 1956 - 28 February 1957
(Winter)

Direction	Biased Record		Unbiased Record	
	No. of Observations	Percentage of Total	No. of Observations	Percentage of Total
N	242	11.2	175	8.1
NNE	99	4.6	177	8.2
NE	201	9.3	140	6.5
ENE	47	2.2	76	3.5
E	59	2.7	39	1.8
ESE	25	1.2	48	2.2
SE	212	9.8	138	6.4
SSE	81	3.8	156	7.2
S	176	8.1	134	6.2
SSW	122	5.6	166	7.7
SW	202	9.4	171	7.9
WSW	117	5.4	140	6.5
W	125	5.8	106	4.9
WNW	113	5.2	145	6.7
NW	219	10.1	171	7.9
NNW	101	4.7	162	7.5
Calm	19	0.9	19	0.9
Totals	2160	100.0	2163	100.1

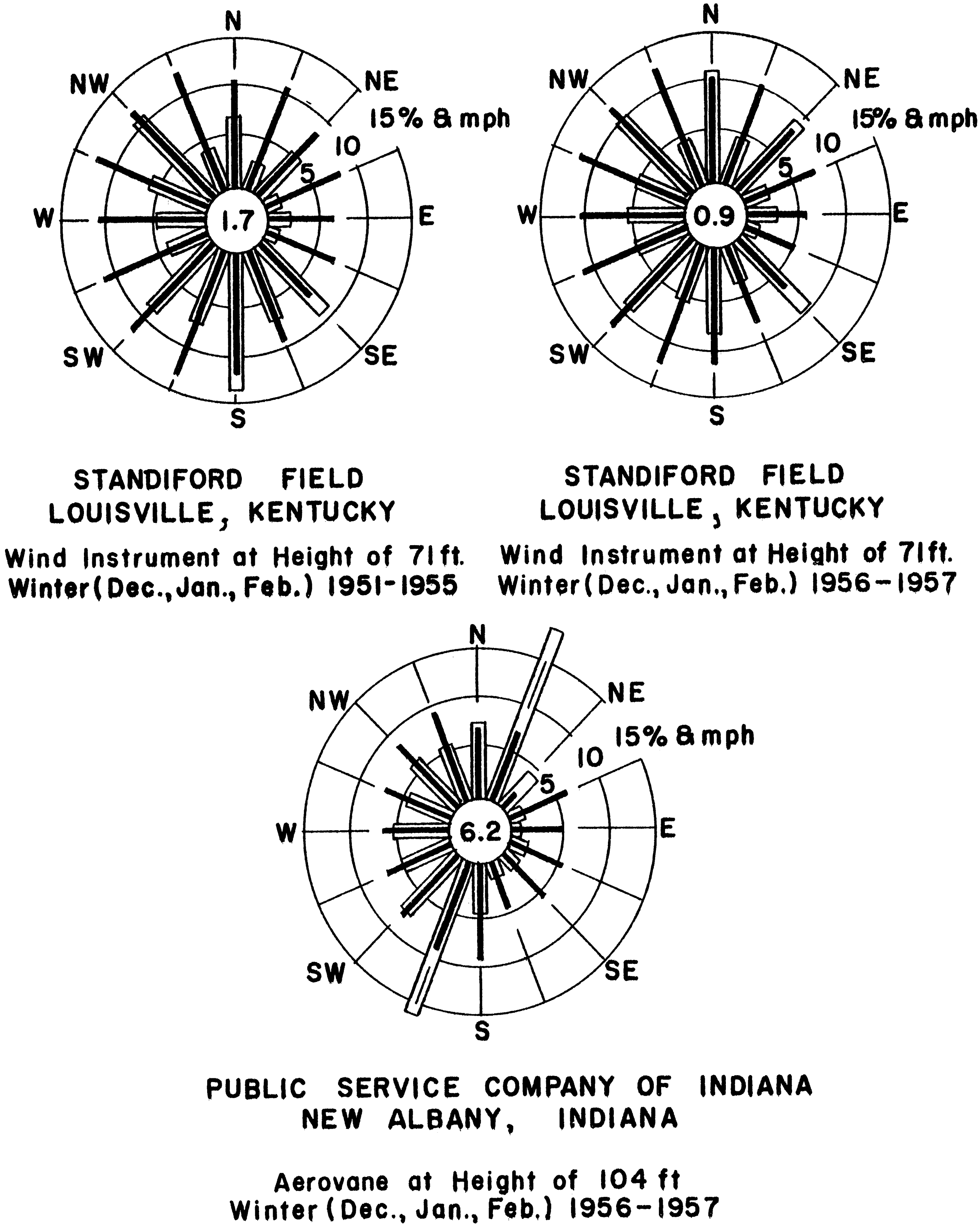


Fig. 2. Percentage frequency of occurrence of winds from 16 directions (rectangles) and corresponding wind speed in mph (heavy lines) at Standiford Field, 1951-1955; Standiford Field, 1956-1957; and New Albany plant site, 1956-1957: Winter. Percent of calms in center.

TABLE V

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Louisville, Kentucky (Standiford Field)
(Wind instrument at height of 71 ft)

(Spring Seasons; 1951-1955 incl.)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	0.8	6.0	2.1			8.1	8.9	986	10.0
NNE	0.3	2.4	0.3			2.7	3.0	335	8.6
NE	0.8	4.6	0.9			5.5	6.3	693	8.7
ENE	0.2	1.4	0.2			1.6	1.9	210	8.5
E	0.8	2.2	0.2			2.4	3.2	356	7.2
ESE	0.2	1.5	0.2			1.7	2.0	216	8.6
SE	2.0	7.1	0.7			7.9	9.8	1085	7.5
SSE	1.0	4.0	1.0		0.1	5.0	6.0	668	8.9
S	1.2	5.6	3.3	0.1		9.0	10.3	1135	10.9
SSW	0.3	2.3	3.1	0.3	0.1	5.8	6.1	670	14.1
SW	0.7	4.9	4.2	0.2	0.1	9.4	10.0	1110	12.5
WSW	0.1	2.7	1.9	0.1		4.7	4.7	524	12.6
W	0.3	3.4	1.6	0.1		5.1	5.3	589	11.0
WNW	0.2	3.4	2.8	0.1	0.1	6.4	6.5	719	12.7
NW	0.5	5.2	3.7	0.1		9.0	9.5	1052	11.9
NNW	0.2	2.1	1.2			3.3	3.6	395	11.2
Calm	2.8						2.8	308	0.0
Totals	12.4	58.8	27.4	1.0	0.4	87.6	100.0	11051	10.3

TABLE VI

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Louisville, Kentucky (Standiford Field)
(Wind instrument at height of 71 ft)

1 March 1957 - 31 May 1957
(Spring)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	0.4	3.9	1.6			5.5	5.9	131	10.0
NNE	0.2	2.1	1.5			3.6	3.8	83	10.9
NE	0.4	5.9	2.9			8.8	9.2	203	10.3
ENE	0.2	2.2	1.4			3.6	3.7	82	10.7
E	0.5	2.4	0.7			3.1	3.6	80	8.2
ESE	0.5	1.9	0.3			2.2	2.7	59	7.8
SE	1.8	9.7	1.6			11.3	13.2	291	8.1
SSE	0.6	4.6	1.7	0.1		6.4	7.0	155	9.7
S	0.7	4.3	2.4			6.7	7.5	165	10.0
SSW		2.6	2.3	0.1		5.0	5.1	112	13.8
SW	0.6	3.8	3.2			7.0	7.7	171	11.9
WSW	0.3	3.5	3.1	0.1		6.7	7.0	154	12.5
W	0.5	3.0	2.2			5.2	5.8	127	11.2
WNW	0.2	2.6	3.1			5.7	5.9	131	11.2
NW	0.4	3.4	3.4			6.8	7.2	160	11.4
NNW	0.2	2.2	1.7			3.9	4.1	90	11.4
Calm	0.6						0.6	14	0.0
Totals	8.1	58.1	33.1	0.3		91.5	100.0	2208	10.4

TABLE VII

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS
GROUPED ACCORDING TO WIND SPEEDS

Public Service Company of Indiana
New Albany, Indiana
(Aerovane at height of 104 ft)

1 March 1957 - 31 May 1957
(Spring)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	2.3	5.9	1.5			7.3	9.6	195	8.2
NNE	2.4	9.6	2.6			12.2	14.6	296	8.9
NE	1.1	4.0	0.6			4.6	5.7	115	8.0
ENE	0.2	1.5				1.5	1.8	36	7.2
E	0.4	0.2				0.2	0.6	13	4.3
ESE	0.3	1.0				1.0	1.3	27	6.7
SE	0.5	1.5				1.5	2.1	42	6.4
SSE	0.7	2.1	0.2			2.3	3.0	61	7.3
S	1.3	4.3	1.4			5.7	7.0	141	9.0
SSW	2.8	10.0	3.6			13.6	16.4	332	9.3
SW	1.7	3.3	0.9			4.2	5.9	120	7.9
WSW	0.8	4.2	1.2			5.4	6.3	127	9.2
W	1.1	3.1	0.2			3.3	4.4	89	7.1
WNW	0.5	3.3	0.2			3.5	4.0	82	7.9
NW	0.5	3.3	0.4			3.7	4.2	85	8.4
NNW	0.4	3.4	0.9			4.3	4.7	96	9.5
Calm	8.4						8.4	170	0.0
Totals	25.4	60.7	13.7			74.3	100.0	2027	7.8

TABLE VIII

COMPARISON OF PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS, ALL SPEEDS, BIASED AND UNBIASED

Louisville, Kentucky (Standiford Field)

1 March 1957 - 31 May 1957
(Spring)

Direction	Biased Record		Unbiased Record	
	No. of Observations	Percentage of Total	No. of Observations	Percentage of Total
N	131	5.9	104	4.7
NNE	83	3.8	124	5.6
NE	203	9.2	157	7.1
ENE	82	3.7	115	5.2
E	80	3.6	57	2.6
ESE	59	2.7	84	3.8
SE	291	13.2	219	9.9
SSE	155	7.0	232	10.5
S	165	7.5	137	6.2
SSW	112	5.1	126	5.7
SW	171	7.7	157	7.1
WSW	154	7.0	161	7.3
W	127	5.8	126	5.7
WNW	131	5.9	141	6.4
NW	160	7.2	141	6.4
NNW	90	4.1	113	5.1
Calm	14	0.6	14	0.6
Totals	2208	100.0	2208	99.9

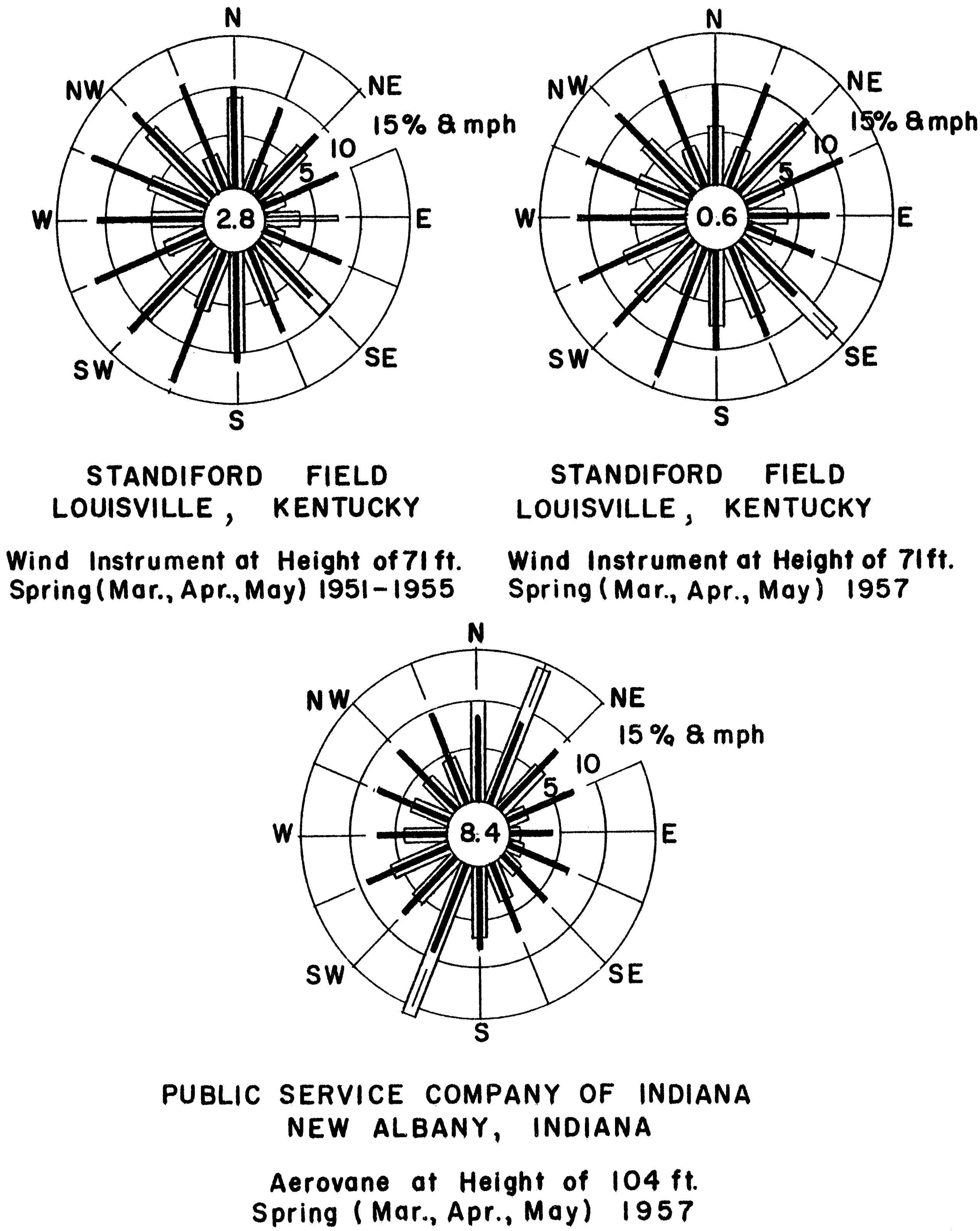


Fig. 3. Percentage frequency of occurrence of winds from 16 directions (rectangles) and corresponding wind speed in mph (heavy lines) at Standiford Field, 1951-1955; Standiford Field, 1957; and New Albany plant site, 1957: Spring. Percent of calms in center.

TABLE IX

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Louisville, Kentucky (Standiford Field)
(Wind instrument at height of 71 ft)

(Summer Seasons; 1951-1955 incl.)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	1.6	7.9	1.2			9.1	10.7	1179	8.3
NNE	0.5	3.6	0.6	0.0		4.2	4.7	529	8.7
NE	1.5	4.9	0.4		0.0	5.3	6.8	749	7.3
ENE	0.3	1.3	0.1			1.4	1.7	179	7.5
E	1.0	2.4	0.0			2.4	3.4	382	6.2
ESE	0.5	1.0				1.0	1.5	156	5.9
SE	3.0	6.7	0.2	0.0	0.0	6.9	9.9	1103	6.3
SSE	1.6	5.9	0.3			6.2	7.8	866	7.1
S	2.6	8.0	1.0			9.0	11.6	1280	7.5
SSW	0.4	3.8	1.2			5.0	5.4	599	9.7
SW	1.1	6.7	1.8	0.0		8.5	9.6	1060	9.2
WSW	0.2	2.6	0.8			3.4	3.6	412	9.9
W	0.7	2.9	0.4	0.0		3.3	4.0	443	7.9
WNW	0.4	2.0	0.4			2.4	2.8	309	8.8
NW	1.4	3.9	0.7			4.6	6.0	660	7.7
NNW	0.5	3.0	0.7	0.0		3.7	4.2	460	9.0
Calm	6.1						6.1	674	
Totals	23.4	66.6	9.8	0.0	0.0	76.4	99.8	11040	7.5

TABLE X

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Louisville, Kentucky (Standiford Field)
(Wind instrument at height of 71 ft)

1 June 1957 - 31 August 1957
(Summer)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	1.5	4.9	1.0			5.9	7.4	165	8.1
NNE	0.7	3.6	0.7			4.3	5.0	111	8.7
NE	1.3	8.5	1.2			9.7	11.0	241	8.4
ENE	0.1	1.2	0.2			1.4	1.5	33	8.9
E	0.7	1.9	0.1			2.0	2.7	59	6.6
ESE	0.3	0.9	0.0			0.9	1.2	26	6.9
SE	3.5	6.7	0.0			6.7	10.2	226	5.8
SSE	1.6	4.7	0.6			5.3	6.9	151	7.4
S	2.2	6.2	1.7			7.9	10.1	222	8.3
SSW	0.5	2.5	0.8			3.3	3.8	82	9.4
SW	1.5	5.8	2.4			8.2	9.7	216	9.6
WSW	0.4	4.8	1.8			6.6	7.0	153	10.3
W	0.6	3.4	0.5			3.9	4.5	100	8.3
WNW	0.2	2.2	0.5			2.7	2.9	64	9.3
NW	0.9	4.2	1.1			5.3	6.2	138	9.0
NNW	0.2	2.3	1.0			3.3	3.5	79	10.6
Calm	6.4						6.4	142	0.0
Totals	22.6	63.8	13.6			77.4	100.0	2208	8.0

TABLE XI

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS
GROUPED ACCORDING TO WIND SPEEDS

Public Service Company of Indiana
New Albany, Indiana
(Aerovane at height of 104 ft)

1 June 1957 - 31 August 1957
(Summer)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	3.7	7.2	0.4			7.6	11.3	213	6.3
NNE	4.3	14.9	0.4			15.3	19.6	367	6.8
NE	0.5	2.2				2.2	2.7	51	6.7
ENE	0.4	0.5				0.5	0.9	18	5.1
E	0.2	0.1				0.1	0.3	5	2.8
ESE	0.3	0.2				0.2	0.5	10	4.1
SE	0.5	0.4				0.4	0.9	17	4.6
SSE	0.9	0.9	0.1			1.0	1.9	34	5.2
S	2.8	4.0	0.6			4.6	7.4	137	6.4
SSW	4.3	10.0	1.6			11.6	15.9	297	7.3
SW	2.9	4.8	0.3			5.1	8.0	149	6.0
WSW	2.2	2.8				2.8	5.0	94	5.1
W	1.4	1.3				1.3	2.7	52	4.6
WNW	1.1	2.1	0.1			2.2	3.3	61	6.0
NW	0.7	2.8	0.1	0.1		3.0	3.7	69	7.4
NNW	1.0	3.1	0.3			3.4	4.4	81	7.3
Calm	11.4						11.4	212	0.0
Totals	38.6	57.3	3.9	0.1		61.3	99.9	1867	5.9

TABLE XII

COMPARISON OF PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS, ALL SPEEDS, BIASED AND UNBIASED

Louisville, Kentucky (Standiford Field)

1 June 1957 - 31 August 1957
(Summer)

Direction	Biased Record		Unbiased Record	
	No. of Observations	Percentage of Total	No. of Observations	Percentage of Total
N	165	7.4	127	5.8
NNE	111	5.0	204	9.2
NE	241	11.0	167	7.6
ENE	33	1.5	56	2.5
E	59	2.7	36	1.6
ESE	26	1.2	39	1.8
SE	226	10.2	162	7.3
SSE	151	6.9	247	11.2
S	222	10.1	170	7.7
SSW	82	3.8	122	5.5
SW	216	9.7	181	8.2
WSW	153	7.0	178	8.1
W	100	4.5	88	4.0
WNW	64	2.9	73	3.3
NW	138	6.2	106	4.8
NNW	79	3.5	110	5.0
Calm	142	6.4	142	6.4
Totals	2208	100.0	2208	100.0

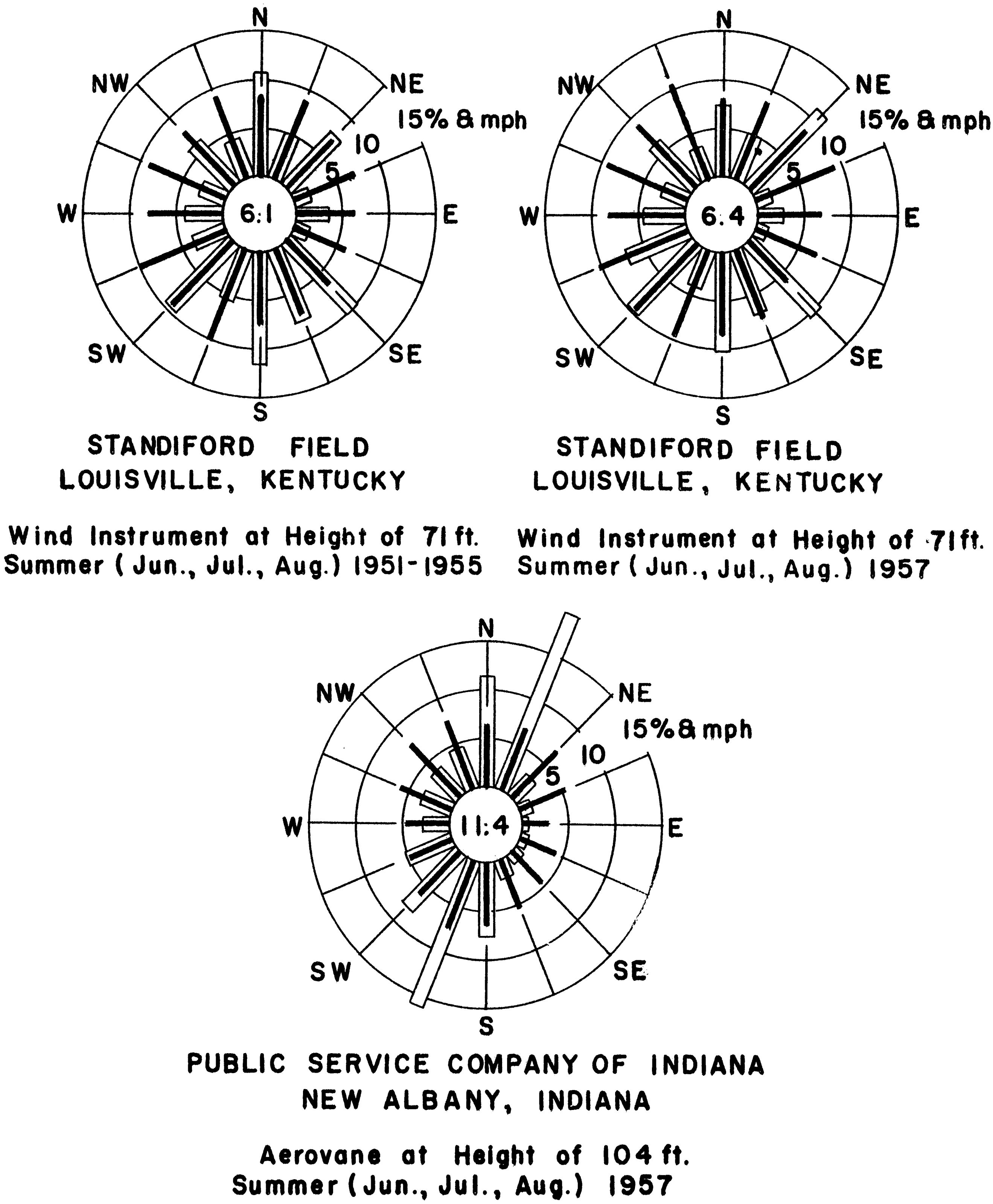


Fig. 4. Percentage frequency of occurrence of winds from 16 directions (rectangles) and corresponding wind speed in mph (heavy lines) at Standiford Field, 1951-1955; Standiford Field, 1957; and New Albany plant site, 1957: Summer. Percent of calms in center.

TABLE XIII

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Louisville, Kentucky (Standiford Field)
(Wind instrument at height of 71 ft)

(Fall Seasons; 1951-1955 incl.)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	1.3	7.1	1.2	0.0		8.3	9.6	1043	8.4
NNE	0.2	2.4	0.5			2.9	3.1	348	9.1
NE	1.2	3.6	0.6			4.2	5.4	585	7.7
ENE	0.2	0.9	0.1			1.0	1.2	133	7.6
E	0.9	1.2	0.1			1.3	2.2	235	5.6
ESE	0.4	0.8	0.0			0.8	1.2	129	6.0
SE	3.7	6.8	0.2			7.0	10.7	1178	6.0
SSE	1.6	5.0	0.7	0.0	0.0	5.7	7.3	804	7.7
S	2.4	7.3	3.0	0.1	0.0	10.4	12.8	1398	9.5
SSW	0.3	3.0	2.1	0.0		5.1	5.4	596	11.7
SW	0.9	5.1	2.7	0.1		7.9	8.8	959	10.6
WSW	0.2	2.4	1.0			3.4	3.6	392	10.4
W	0.7	3.1	1.0			4.1	4.8	515	9.2
WNW	0.4	3.0	1.2	0.0		4.2	4.6	506	10.4
NW	1.0	5.7	2.5	0.0	0.0	8.2	9.2	1004	10.2
NNW	0.3	2.5	1.2	0.1		3.8	4.1	443	10.9
Calm	6.0						6.0	652	
Totals	21.7	59.9	18.1	0.3	0.0	78.3	100.0	10920	8.6

TABLE XIV

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Louisville, Kentucky (Standiford Field)
(Wind instrument at height of 71 ft)

1 September 1957 - 30 November 1957
(Fall)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	1.3	9.0	2.7			11.7	13.0	283	9.5
NNE	0.3	2.4	1.1			3.5	3.8	82	10.5
NE	1.4	6.7	1.6			8.3	9.7	210	8.8
ENE	0.1	1.3	0.6			1.9	2.0	43	10.9
E	0.9	1.4	0.1			1.5	2.4	52	6.2
ESE	0.1	1.1				1.1	1.2	26	7.2
SE	3.2	6.1	0.8			6.9	10.1	221	6.8
SSE	1.1	4.1	2.0	0.0		6.1	7.2	159	10.1
S	1.4	5.1	2.7	0.0	0.0	7.8	9.2	205	10.4
SSW	0.1	1.7	1.2			2.9	3.0	66	11.8
SW	0.8	3.3	2.7			6.0	6.8	148	11.3
WSW	0.2	3.3	2.3		0.0	5.6	5.8	126	12.2
W	0.6	2.2	1.3	0.0		3.5	4.1	89	10.6
WNW	0.2	1.8	1.4	0.1		3.3	3.5	77	12.2
NW	1.1	4.1	2.5			6.6	7.7	169	10.5
NNW	0.2	2.9	2.1			5.0	5.2	113	12.0
Calm	5.3						5.3	115	0.0
Totals	18.3	56.5	25.1	0.1	0.0	81.7	100.0	2184	9.5

TABLE XV

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS
GROUPED ACCORDING TO WIND SPEEDS

Public Service Company of Indiana
New Albany, Indiana
(Aerovane at height of 104 ft)

1 September 1957 - 30 November 1957
(Fall)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	2.4	10.1	0.5			10.6	13.0	250	7.2
NNE	4.1	9.6	0.9			10.5	14.6	282	6.8
NE	1.0	2.6	0.3			2.9	3.9	75	7.2
ENE	0.5	0.8				0.8	1.3	26	5.5
E	0.2	0.4				0.4	0.6	12	5.8
ESE	1.0	0.7				0.7	1.7	33	4.3
SE	0.3	2.0	0.1			2.1	2.4	45	7.4
SSE	1.1	4.0	0.4			4.4	5.5	107	7.4
S	0.9	4.6	2.9			7.5	8.4	161	11.0
SSW	1.4	6.5	2.7			9.2	10.6	205	9.9
SW	1.2	5.1	1.6			6.7	7.9	153	9.0
WSW	0.8	3.6	0.4			4.0	4.8	92	7.7
W	0.5	3.0	0.4			3.4	3.9	76	8.2
WNW	0.9	3.1	0.2			3.3	4.2	80	7.1
NW	0.4	1.5	0.4			1.9	2.3	43	8.5
NNW	0.7	5.1	0.8			5.9	6.6	126	8.6
Calm	8.4						8.4	162	
Totals	25.8	62.7	11.6			74.3	100.1	1928	7.5

TABLE XVI

COMPARISON OF PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS, ALL SPEEDS, BIASED AND UNBIASED

Louisville, Kentucky (Standiford Field)

1 September 1957 - 30 November 1957
(Fall)

Direction	Biased Record		Unbiased Record	
	No. of Observations	Percentage of Total	No. of Observations	Percentage of Total
N	283	13.0	201	9.2
NNE	82	3.8	175	8.0
NE	210	9.7	140	6.4
ENE	43	2.0	69	3.2
E	52	2.4	33	1.5
ESE	26	1.2	35	1.6
SE	221	10.1	163	7.5
SSE	159	7.2	251	11.5
S	205	9.2	160	7.3
SSW	66	3.0	91	4.2
SW	148	6.8	128	5.9
WSW	126	5.8	133	6.1
W	89	4.1	82	3.8
WNW	77	3.5	84	3.8
NW	169	7.7	131	6.0
NNW	113	5.2	193	8.8
Calm	115	5.3	115	5.3
Totals	2184	100.0	2184	100.1

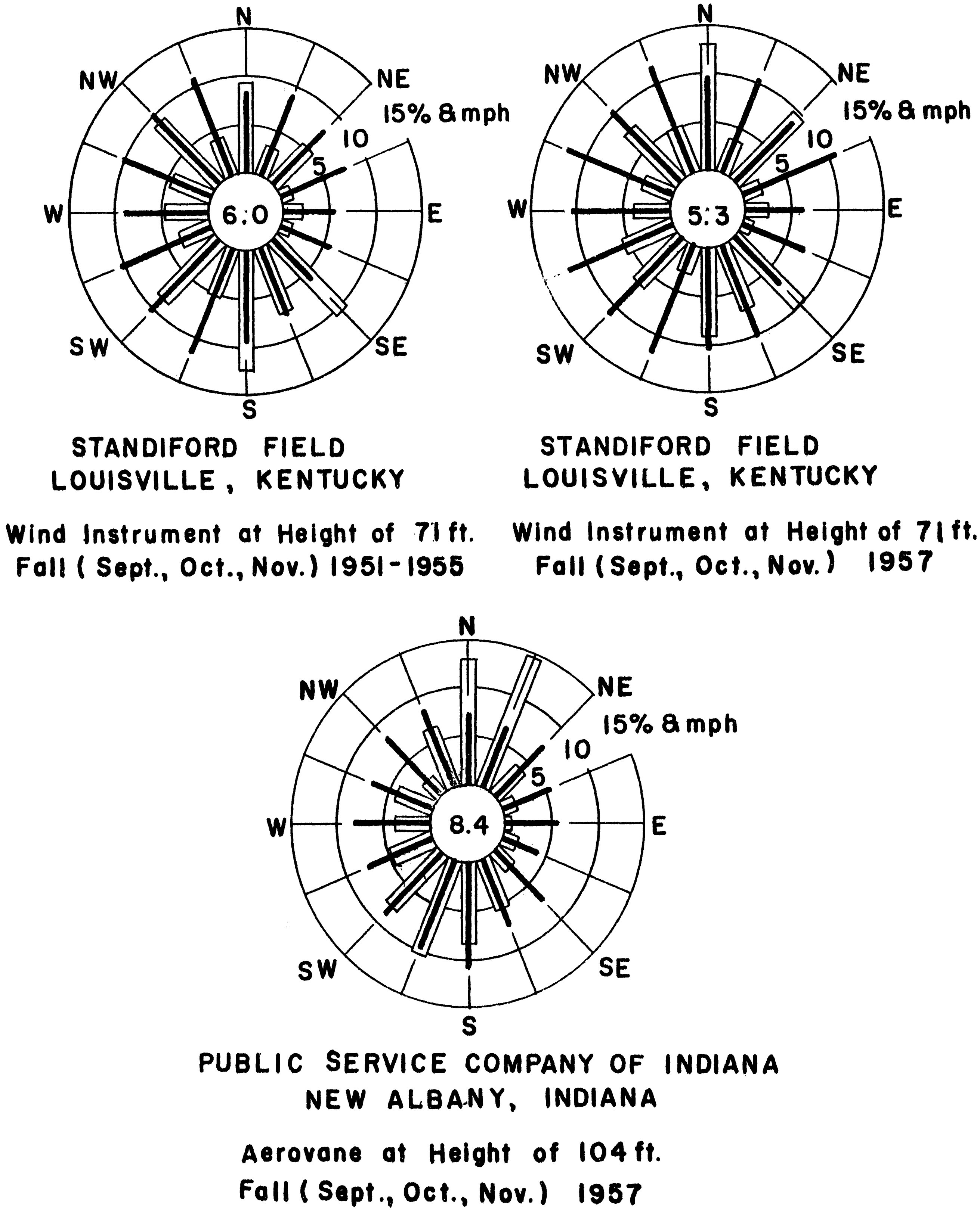


Fig. 5. Percentage frequency of occurrence of winds from 16 directions (rectangles) and corresponding wind speed in mph (heavy lines) at Standiford Field, 1951-1955; Standiford Field, 1957; and New Albany plant site, 1957: Fall. Percent calms in center.

TABLE XVII

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Louisville, Kentucky (Standiford Field)
(Wind instrument at height of 71 ft)

1 January 1951 - 31 December 1955
(Five-Year Summary)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	1.1	6.4	1.6	0.0		8.0	9.1	3980	9.1
NNE	0.3	2.6	0.6	0.0		3.2	3.5	1539	9.1
NE	1.1	4.3	0.7		0.0	5.0	6.1	2646	8.0
ENE	0.2	1.2	0.1			1.3	1.5	675	7.9
E	0.8	1.9	0.1			2.0	2.8	1231	6.5
ESE	0.3	1.1	0.1			1.2	1.5	643	7.2
SE	2.6	7.0	0.4	0.0	0.0	7.4	10.0	4390	6.7
SSE	1.2	5.1	0.9	0.0	0.0	6.0	7.2	3163	8.2
S	1.8	7.1	3.1	0.1	0.0	10.3	12.1	5288	9.9
SSW	0.3	3.2	2.5	0.1	0.0	5.8	6.1	2677	12.3
SW	0.8	5.5	3.0	0.1	0.0	8.6	9.4	4114	11.0
WSW	0.2	2.6	1.2	0.0	0.0	3.8	4.0	1774	11.2
W	0.5	3.2	1.1	0.0		4.3	4.8	2088	9.9
WNW	0.3	3.0	1.8	0.0	0.0	4.8	5.1	2194	11.5
NW	0.8	5.2	2.7	0.0	0.0	7.9	8.7	3874	10.7
NNW	0.3	2.5	1.2	0.0		3.7	4.0	1730	10.8
Calm	4.1						4.1	1818	
Total	16.7	61.9	21.1	0.3	0.0	83.3	100.0	43824	9.2

TABLE XVIII

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Louisville, Kentucky (Standiford Field)
(Wind instrument at height of 71 ft)

1 December 1956 - 30 November 1957
(Annual Summary)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	1.1	6.0	2.2			8.2	9.3	821	9.7
NNE	0.4	2.6	1.3			3.9	4.3	375	10.6
NE	1.2	6.8	1.8			8.6	9.8	855	9.1
ENE	0.2	1.6	0.6			2.2	2.4	205	10.3
E	0.7	1.8	0.3			2.1	2.8	250	7.3
ESE	0.3	1.2	0.1			1.3	1.6	136	7.4
SE	2.6	7.4	0.8	0.0		8.2	10.8	950	7.2
SSE	0.9	4.0	1.2	0.0		5.2	6.1	546	9.2
S	1.2	4.8	2.7	0.1	0.0	7.6	8.8	768	10.5
SSW	0.2	2.2	2.0	0.0		4.2	4.4	382	12.6
SW	0.8	4.4	3.1	0.0	0.0	7.5	8.3	737	11.3
WSW	0.3	3.6	2.4	0.0	0.0	6.0	6.3	550	11.9
W	0.5	3.0	1.5	0.0		4.5	5.0	441	10.5
WNW	0.2	2.3	1.8	0.0		4.1	4.3	385	12.4
NW	0.8	4.1	2.9	0.0	0.0	7.0	7.8	686	11.3
NNW	0.2	2.4	1.8	0.0		4.2	4.4	383	12.0
Calm	3.3	___	___	___	___	___	3.3	290	0.0
Totals	14.9	58.2	26.5	0.1	0.0	84.8	99.7	8760	9.9

TABLE XIX

PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Public Service Company of Indiana
New Albany, Indiana
(Aerovane at height of 104 ft)

1 December 1956 - 30 November 1957
(Annual Summary)

Direction	Speed, mph						Total Obs.		Mean Speed, mph
	0-3	4-12	13-24	25-31	32 and over	Total 4 and over	%	No.	
N	2.9	6.6	0.8			7.4	10.3	814	7.0
NNE	4.1	11.4	1.4			12.8	16.9	1341	7.3
NE	1.0	3.1	0.2			3.3	4.3	343	7.0
ENE	0.4	0.9				0.9	1.3	101	6.1
E	0.3	0.3				0.3	0.6	45	4.7
ESE	0.6	0.8				0.8	1.4	105	5.2
SE	0.5	1.2	0.0			1.2	1.7	135	6.2
SSE	0.9	1.9	0.2			2.1	3.0	236	6.6
S	1.5	3.8	1.5			5.3	6.8	539	8.9
SSW	2.8	9.2	2.9			12.1	14.9	1177	8.8
SW	1.8	4.8	0.8			5.6	7.4	586	7.7
WSW	1.2	3.6	0.4			4.0	5.2	417	7.3
W	1.2	2.7	0.2			2.9	4.1	328	6.8
WNW	1.0	2.8	0.3			3.1	4.1	323	7.1
NW	0.6	3.1	0.4	0.0		3.5	4.1	327	8.2
NNW	0.7	3.9	0.8			4.7	5.4	428	8.7
Calm	8.5	—	—	—		—	8.5	675	—
Totals	30.0	60.1	9.9	0.0		70.0	100.0	7920	7.1

TABLE XX

COMPARISON OF PERCENTAGE FREQUENCY OF OCCURRENCE OF WINDS IN VARIOUS DIRECTIONS, ALL SPEEDS, BIASED AND UNBIASED

Louisville, Kentucky (Standiford Field)

1 December 1956 - 30 November 1957
(Annual Summary)

Direction	Biased Record		Unbiased Record	
	No. of Observations	Percentage of Total	No. of Observations	Percentage of Total
N	821	9.4	607	6.9
NNE	375	4.3	689	7.9
NE	855	9.8	603	6.9
ENE	205	2.3	310	3.5
E	250	2.9	162	1.8
ESE	136	1.6	200	2.3
SE	950	10.8	680	7.8
SSE	546	6.2	900	10.3
S	768	8.8	604	6.9
SSW	382	4.4	508	5.8
SW	737	8.4	634	7.2
WSW	550	6.3	609	7.0
W	441	5.0	399	4.6
WNW	385	4.4	438	5.0
NW	686	7.8	547	6.2
NNW	383	4.4	580	6.6
Calm	290	3.3	290	3.3
Totals	8760	100.1	8760	100.0

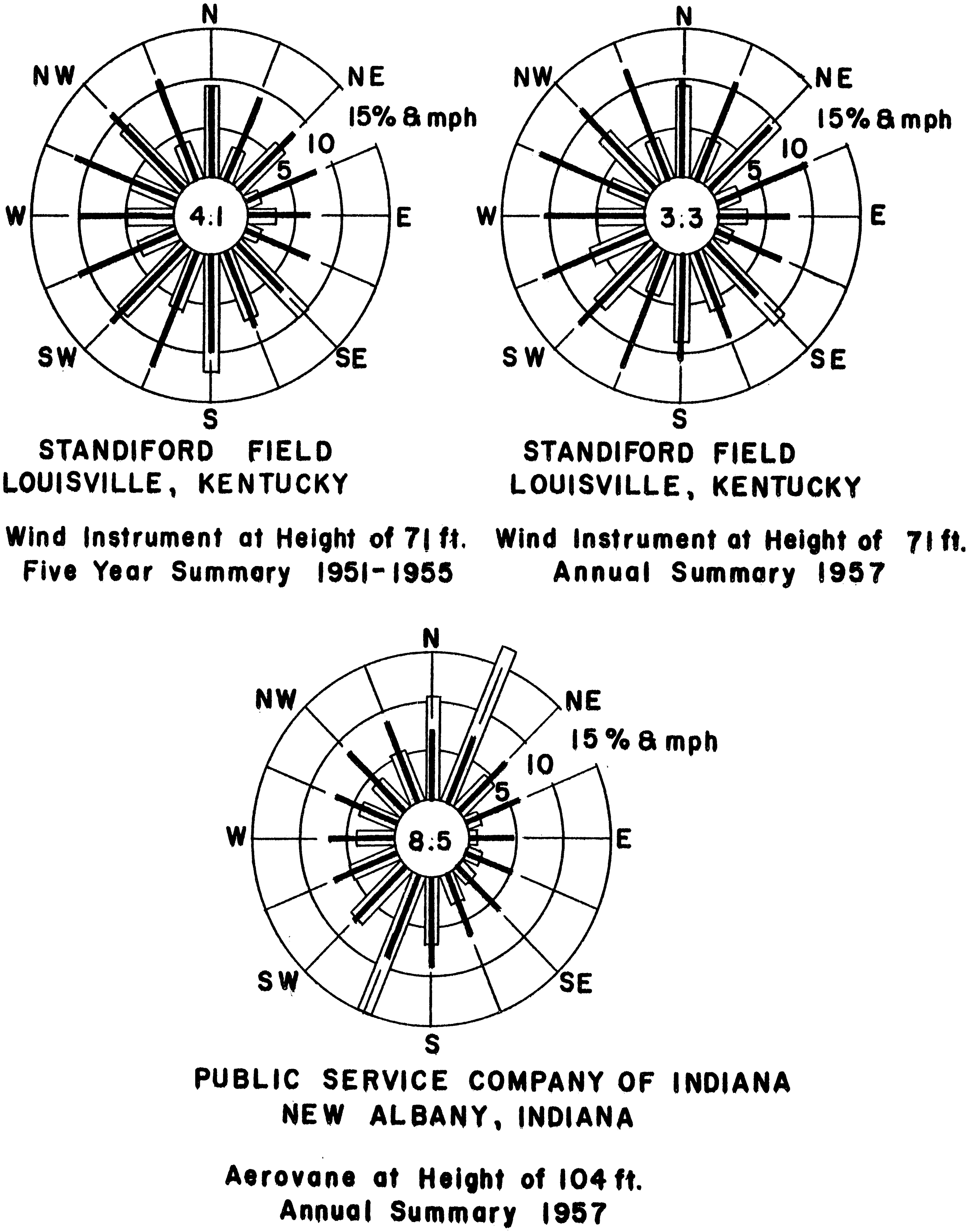


Fig. 6. Percentage frequency of occurrence of winds from 16 directions (rectangles) and corresponding wind speed in mph (heavy lines) at Standiford Field, 1951-1955; Standiford Field, 1957; and New Albany plant site, 1957: Annual Summary. Percent of calms in center.

ANALYSIS OF TURBULENCE DATA

Gust counts from the gust accelerometer were grouped together as a unit in the first progress report because there was little evidence of any seasonal variations. With the addition of the summer and fall seasons, it was felt that the individual seasons should be presented separately.

The speed of the wind and the roughness of the terrain are major factors in creating turbulence. Therefore, the seasonal gust-count data have been grouped according to wind direction and to wind speed (see Tables XXI-XXV and Figs. 7-11). The tables have an "average gust count" column and a "number of occurrences" column under each wind-speed category. The wind-speed categories are the same categories that are used in the wind-analysis section. The "average gust count" will bear some relation to the roughness of the terrain for a given wind direction while the number of occurrences will be strongly correlated with the frequency distribution of the wind from a given direction.

The figures are similar to the wind roses except that the rectangles indicate the magnitude of the average gust count while the numbers along the outside show the number of occurrences from a particular wind direction. The number in the center of the 0-3-mph graph is the number of occurrences of calm conditions. There is a separate graph for each of the first three wind-speed categories, 0-3 mph, 4-12 mph, and 13-24 mph. Such an arrangement necessitates a differenc scale for each wind-speed category. The difference of scales must be kept in mind when reading the graphs.

1. VARIATION OF TURBULENCE WITH WIND DIRECTION

The first progress report pointed out that the different wind trajectories around the plant site created various degrees of turbulence or variations in the gust count. Let us look at the four seasonal tables and see how they compare with the general comments stated under each wind direction from the first report. For reference to the topography see Fig. 12.

N.—During all seasons and at all wind speeds, we notice that the gust count for this wind direction is significatnly below the average value. This fact was noted previously and as pointed out before, it is difficult to explain adequately by physical reasoning. The cold northerly wind upon reaching the northern edge of Silver Hill either deviates around the hill, becoming a NNE wind at the tower, or goes up over the hill. Such an air mass is generally cold and relatively dense with little natural buoyancy effects, although due to passage over the ground which is warmer than the air, the air is unstable in the lower layers. The probabilities seem to be much better for the air to deviate around the hill because of the orientation of the northerly slope. By looking at Fig. 12, it can be seen that the northerly slope really is a NE-facing slope. Thus the path of least resistance is to move around the hill rather than up over it. Let us suppose that the air did rise over the hill. Either it descends immediately upon reaching the southern slope of Silver Hill and smooths out by the time it reaches the tower, which seems to be probable, or it remains aloft and above the gust accelerometer. The latter case would indicate an added amount of turbulence due to air being drawn into the stream from below, so we must reject this hypothesis since the observations show a relatively low count. The installation of the gust accelerometer on top of the stack 0.7 mile nearer to Silver Hill will help to illuminate this particular aspect of the turbulence pattern. Such analysis must wait for a future report. One other major factor should be mentioned concerning the northerly winds: that is, that in their passage over the terrain to the north of Silver Hill, there is not one obvious heat source within 10 miles such as a city which could modify the lower layers, thus creating instability and turbulence in the lower levels.

NNE.—The gust count from this direction is quite close to the average value in the first two wind categories, 0-3 and 4-12 mph, during all seasons except fall. These facts indicate some turbulence, but not an extreme amount. The trajectory of the air is relatively smooth as far as topography is concerned. What turbulence is registered at lower wind speeds may be attributed to two causes. The first and more important cause is that the air coming from the NNE crosses the City of New Albany, picking up heat and thereby making the lower layers unstable. The effect of heat sources on cold air masses is quite important. The second cause is produced by the convergence of the air stream as it deviates around Silver Hill. We noted before that probably a large portion of northerly winds curved around Silver Hill, thus becoming a NNE wind at the tower. As the air stream rounds the eastern edge of Silver Hill, it will meet other northerly air streams and a zone of convergence will be set up. A zone of convergence is very conducive to the formation of turbulence. Even though the turbulence originates in the vicinity of Silver Hill, it could still be measured at the tower because the decay area of such turbulence would cover a distance of several miles. At higher wind speeds, those above 12 mph, the gust count is above average, indicating that the above-mentioned effects have been magnified and coupled with an increase of wind speed which in itself is a cause of turbulence.

NE.—Generally speaking, in all seasons, the gust counts associated with a NE wind are significantly above the average value. At first, it was believed that the relatively warm river water was influencing the air by producing increased lapse rates, instability, and turbulence. The summer and fall seasons show even more turbulence relative to the average value than did the winter and spring seasons. The river is cooler than the land during the summer and early fall. This condition would cause stability in the lower layers and hence less turbulence. Therefore, we must reject the hypothesis of the river as the dominating influence. The only physical factor that could cause such a pronounced degree of turbulence is the rugged topography more than five miles upstream. Let us assume that the air becomes very turbulent upstream due to the rugged topography. As the air gets nearer to the plant site, the passage over towns and back and forth over the Ohio River produces successive heatings and coolings in the lower layers which maintain the turbulence rather than allowing it to decay. The temperature-lapse-rate and wind-speed and wind-direction equipment on the stack will be useful as tools in determining if there are any dynamic effects involved which are not obvious at the present time.

ENE.—The trajectory from the ENE has an average-to-moderate degree of turbulence which can only be attributed to turbulence produced upstream in the rough terrain area and maintained by temperature changes as it passes over the river and surrounding communities.

E.—There are not many easterly winds recorded at the New Albany plant site, but when such winds are recorded, there is one striking feature. With the exception of the summer season, the 0-3 mph-category is very turbulent relative to the average gust count encountered in that category, while in the 4-12-mph category, the gust count drops considerably. The summer season has only one occurrence in the 4-12-mph category, so that value cannot be used as being representative of the gust count in that category. The relatively high degree of turbulence associated with lower wind speeds may be explained as follows. The trajectory is directly over the City of Louisville. As a result of minor heating and cooling of the airstream, vertical motions are induced in the air mass. These vertical motions are registered as a relatively high gust count at the tower. When the wind speed increases, it damps out the small vertical motions, making the air stream smoother and less turbulent.

ESE, SE, and SSE.—These gust counts are among the lowest recorded since the trajectories are over relatively smooth territory for more than five miles before reaching the tower. The SSE airflow passes over some hills just south of Louisville (Fig. 12), so there is a possibility that there would be more turbulence from that direction than from the other two.

S.—Gust counts from this direction are significantly below average. The trajectory is long and flat, thereby keeping the gust count low. Southerly winds occur frequently during the year, 6.8% of the time. Both of the above-mentioned facts are relevant to the air-pollution problem at Silver Hill. As soon as the wind frequency distributions and speed distributions plus the gust count from the top of the stack are known, a more adequate assessment of the problem of pollution on Silver Hill will be possible. The first report mentioned the fact that high wind speeds were noted from the south. These winds occurred in the fall of 1956. A year more of data failed to produce any winds from the south of 25 mph or greater. This fact is of positive value in suggesting a lower possibility of any aerodynamic downwash taking place and polluting Silver Hill.

SSW.—This wind direction gives below-average gust counts again because of the long, flat trajectory up the river valley and river plain. Because SSW winds will carry effluent to the east of Silver Hill, the air-pollution problem will be minimized there. It might be well to mention, however, that winds from the SSW pass directly over New Albany. Winds from this direction occur 14.9% of the time during the year. Thus a problem that is minimized at Silver Hill may be increased at New Albany.

SW, WSW, W, WNW, and NW.—The winds from these directions are the most turbulent of all the winds that are recorded at the tower. The general pattern is that the SW winds have slightly above-average gust counts; the WSW winds have a little higher count; W winds have the highest counts; then the count begins to drop for WNW winds; and finally falls even lower for NW winds. It is obvious that the gust counts increase as the wind shifts into this sector and flows over the rough and hilly ground. The nearest hilly ground is to the west and hence the highest gust counts are recorded with west winds. Most of the area from the SW through the NW is quite hilly. These hills extend for five miles or so to the west, so there is a long stretch where turbulence is built up. As pointed out in the first report, such large gust counts and the accompanying turbulence lessen the potential pollution problem to the City of Louisville quite considerably. This is an important aspect to be remembered because the City of Louisville is quite aware of its air-pollution problem, not only in the city proper but also in the encompassing locale.

NNW.—Gust counts drop slightly when the wind is from this direction due probably to the small valley down which Middle Creek runs. Although this valley looks insignificant on a map, it is pronounced enough to make a smaller gust count show up at the tower. Turbulence is still great enough to make any pollution problem to Louisville very minor.

2. VARIATION OF TURBULENCE WITH WIND SPEED

In the first progress report it was shown that the gust count varied as the square of the wind speed. To substantiate such an observation, it was decided to separate the year's data into the four seasons and then draw graphs similar to the one in the first report. Figures 13-17 show the results of this work.

The graphs are drawn so that the average gust count for a given wind speed category is plotted versus the mid-point wind speed of that category. Thus the first three points on each graph, that is, the points for the 1.5-, 8-, and 18.5-mph speeds, may be considered accurate because they are the results of hundreds of observations. In Figs. 15 and 17, we see that there is a gust count plotted for the 28-mph speed. This point is based upon only one observation so it cannot be regarded as being representative. Therefore, to draw the line of best fit, only the first three points were considered usable.

After much examination and curve fitting, it seemed that the line of best fit in all cases was a straight line which passed through the first point, below the second, and above the third point. Actually, graphs were drawn on ordinary linear graph paper and semi-log graph paper to see if the relationship between the gust count and the wind speed might be represented in a more simple manner. The results were negative in all cases, so all the graphs were drawn on log-log type graph paper.

We might observe that, although none of the four seasonal graphs nor the annual graph has an equation exactly of the form $G = kV^2$, where G = gust count, k = constant, and V = wind speed, showing that the exponent of V is exactly 2, all the equations have exponents of V sufficiently close to the number 2 that we may say that the gust count does vary approximately as the square of the wind speed.

It now seems probable that the dynamic characteristics of the gust accelerometer may be responsible for this apparent linear relationship between the square of the wind speed and the gust count. The instrument was designed to measure gustiness by providing one electrical impulse for each 2-mph change in wind speed. To do this simply and efficiently, the instrument incorporates a spring mechanism that makes the angular deflection of the cup wheel proportional to the square root of the wind pressure, and therefore linearly proportional to the wind speed. This is explained in the first progress report, pages 7-10. To reduce oscillation of the cup-wheel shaft, electromagnetic damping was provided which created a restraining torque on the shaft that is linearly proportional to the angular speed of rotation of the shaft.

As was pointed out in the above reference, the best compromise on this damping was to have the cup wheel critically damped in the 10-20-mph range, which resulted in overdamping at wind speeds below 10 mph, and underdamping at wind speeds above 20 mph. It was realized that this damping would yield gust counts lower than the true at the low wind speeds and higher than true at wind speeds above 20 mph, but the actual correction factor is very difficult to determine. Other damping techniques were considered but none appeared to be more satisfactory without an almost complete redesign of the instrument. A mathematical analysis of the forces involved suggests that we might anticipate this instrument to have a correction factor inversely proportional to the indicated mean wind speed, thus making the true gust count a linear function of the mean wind speed instead of the square of the wind speed. Since we have only two gust accelerometers and both are at New Albany, further dynamic testing of the instruments must await return of one of these to The University of Michigan.

Although this correction factor is probably more serious than previously realized, we should not lose sight of the fact that this instrument does show marked differences in gustiness for different wind directions as shown in Figs. 7-11; that it shows marked differences in gustiness for winds of the same average speed and direction but occurring under different lapse rate conditions; and that the instrument will serve a very useful purpose until a more suitable instrument is developed.

In Figs. 13-17 we notice that the envelope surrounding each line is wider at the lower wind speeds and becomes more narrow at higher speeds. The envelope was drawn from a plot of the maximum and minimum values of gust count in each wind-speed category. As pointed out previously in the first report, this observation indicates that, as the wind speed increases, roughness of the underlying surface and the lapse rate play a relatively smaller role in causing turbulence.

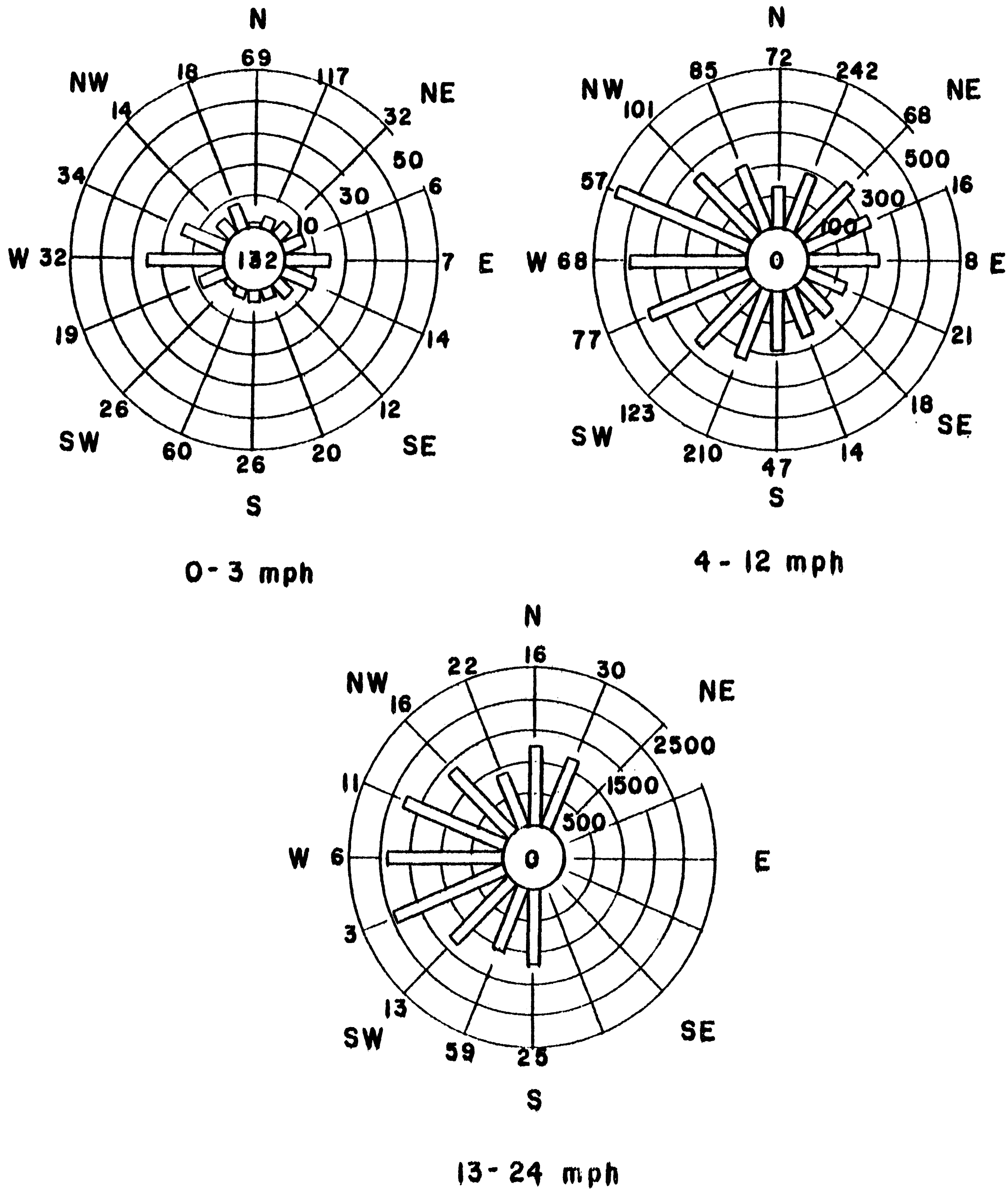
TABLE XXI

AVERAGE GUST COUNT PER HOUR

Public Service Company of Indiana
New Albany, Indiana

1 December 1956 - 28 February 1957
(Winter)

Direction	Speed, mph									
	0-3		4-12		13-24		25-31		32 +	
	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.
N	1	69	133	72	1230	16				
NNE	4	117	188	242	1185	30				
NE	5	32	237	68						
ENE	7	6	226	16						
E	15	7	236	8						
ESE	12	14	141	21						
SE	6	12	141	18						
SSE	3	20	149	14						
S	4	26	182	47	1158	25				
SSW	3	60	228	210	1019	59				
SW	2	26	262	123	1345	13				
WSW	9	19	349	77	1940	3				
W	25	32	384	68	1905	6				
WNW	15	34	474	57	1769	11				
NW	6	14	267	101	1401	16				
NNW	8	18	215	85	875	22				
Calm	0	132								
Avg.	5		243		1195					
Totals		638		1227		201				



PUBLIC SERVICE COMPANY OF INDIANA
NEW ALBANY, INDIANA

Winter (Dec., Jan., Feb.) 1956-1957

Fig. 7. Average gust count per hour by wind directions and wind-speed categories. New Albany plant site, 1956-1957: Winter.

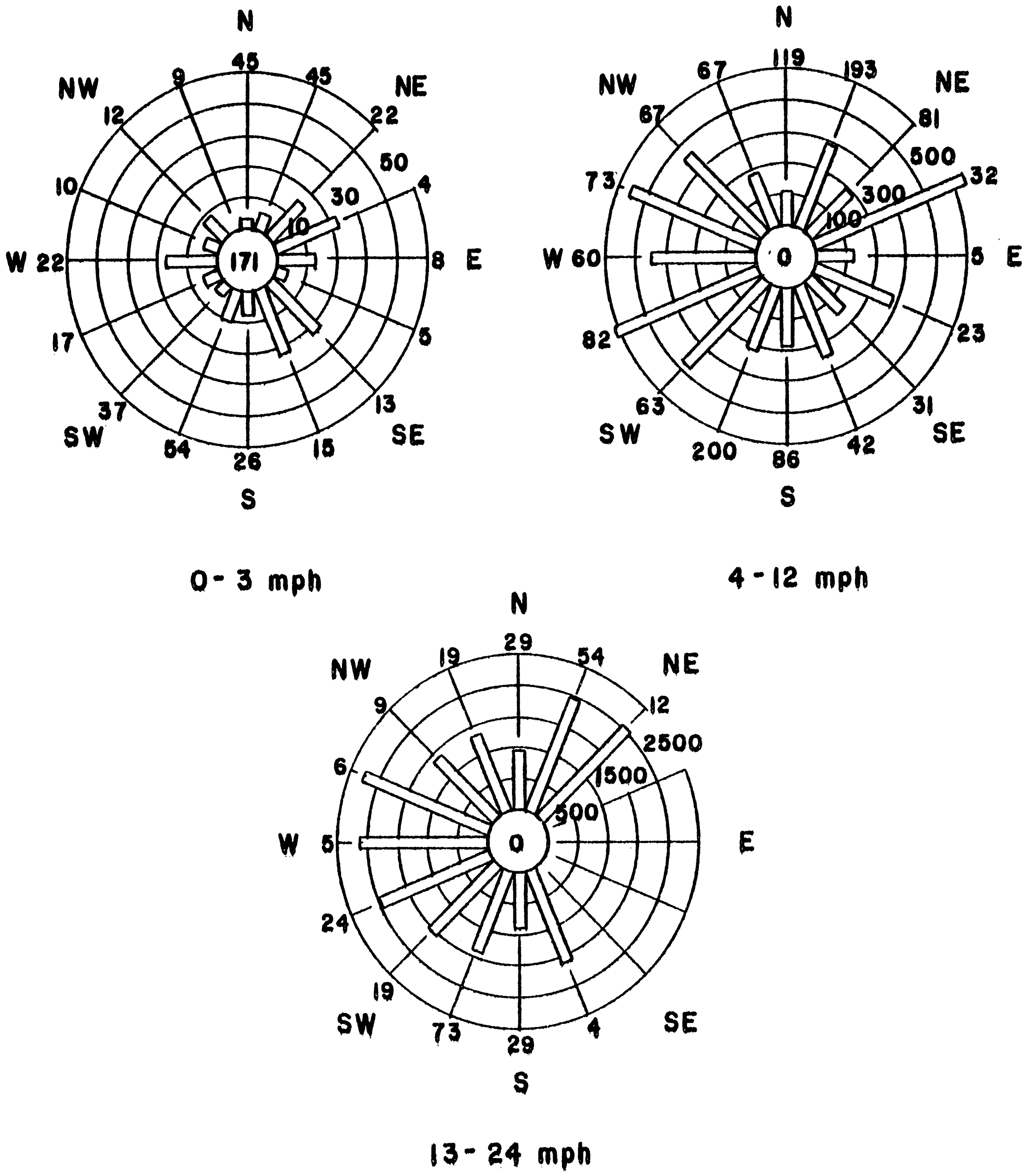
TABLE XXII

AVERAGE GUST COUNT PER HOUR

Public Service Company of Indiana
New Albany, Indiana

1 March 1957 - 31 May 1957
(Spring)

Direction	Speed, mph									
	0-3		4-12		13-24		25-31		32 +	
	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.
N	3	45	110	119	992	29				
NNE	6	45	284	193	1948	54				
NE	16	22	194	81	2078	12				
ENE	23	4	546	32						
E	13	8	128	5						
ESE	4	5	281	23						
SE	23	13	149	31						
SSE	22	15	246	42	1593	4				
S	8	26	184	86	904	29				
SSW	10	54	213	200	1369	73				
SW	4	37	377	63	1500	19				
WSW	5	17	512	82	1988	24				
W	17	22	346	60	2090	5				
WNW	5	10	458	73	2215	6				
NW	9	12	362	67	1381	9				
NNW	0	9	188	67	1326	19				
Calm	0	171								
Avg.	6		294		1516					
Totals		515		1224		283				



PUBLIC SERVICE COMPANY OF INDIANA
NEW ALBANY, INDIANA

Spring (Mar., Apr., May) 1957

Fig. 8. Average gust count per hour by wind directions and wind-speed categories. New Albany plant site, 1957: Spring.

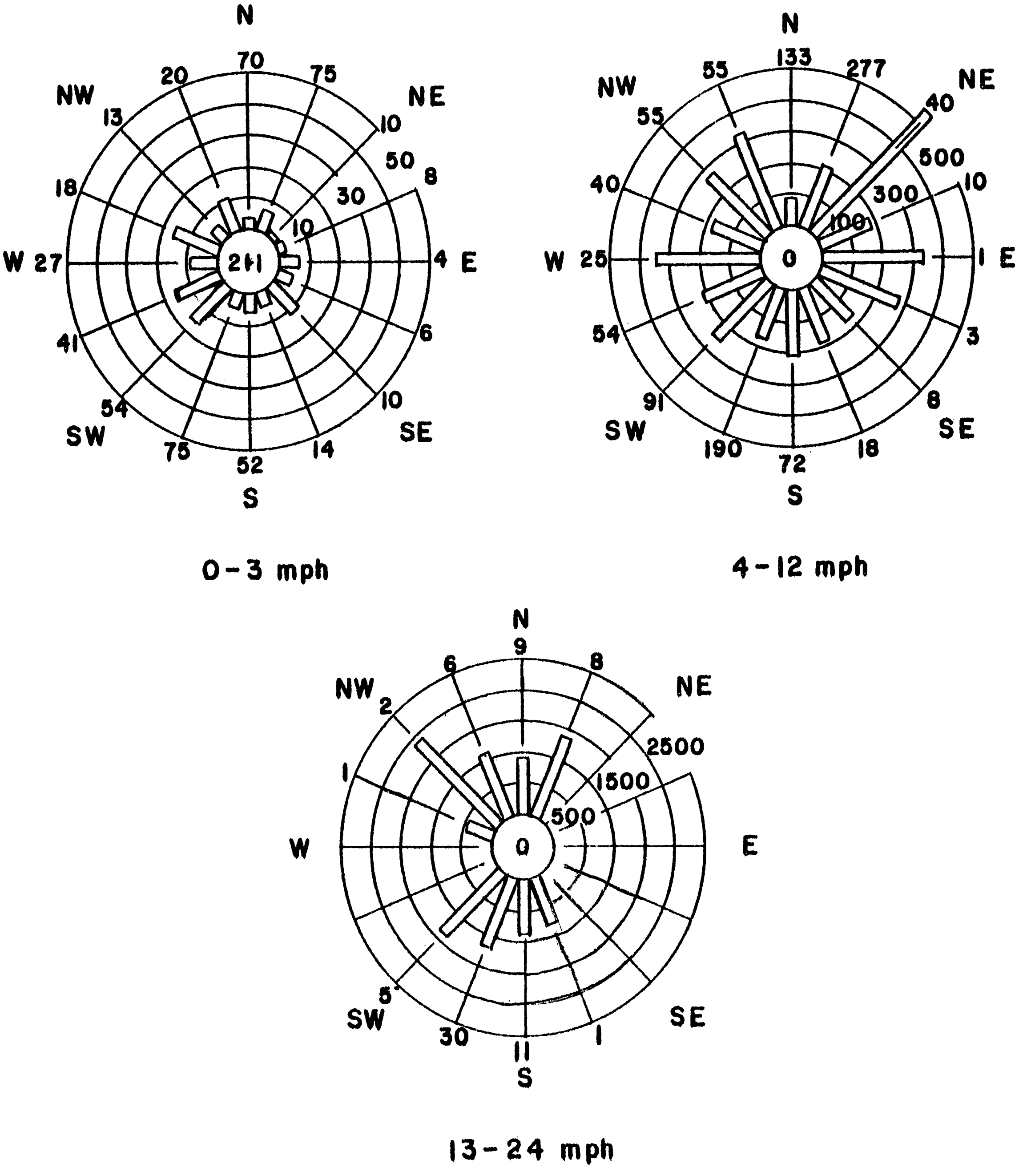
TABLE XXIII

AVERAGE GUST COUNT PER HOUR

Public Service Company of Indiana
New Albany, Indiana

1 June 1957 - 31 August 1957
(Summer)

Direction	Speed, mph									
	0-3		4-12		13-24		25-31		32 +	
	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.
N	3	70	92	133	912	9				
NNE	7	75	217	277	1333	8				
NE	1	10	542	40						
ENE	2	8	186	10						
E	7	4	340	1						
ESE	5	6	279	3						
SE	12	10	168	8						
SSE	5	14	189	18	800	1				
S	6	52	203	72	885	11				
SSW	5	75	174	190	1203	30				
SW	16	54	253	91	1370	5				
WSW	16	41	209	54						
W	9	27	343	25						
WNW	16	18	175	40	420	1				
NW	5	13	274	55	1880	2	5656	1		
NNW	11	20	329	55	1053	6				
Calm	0	211								
Avg.	6		217		1135		5656			
Totals		708		1072		73		1		



PUBLIC SERVICE COMPANY OF INDIANA
NEW ALBANY, INDIANA

Summer (Jun., Jul., Aug.) 1957

Fig. 9. Average gust count per hour by wind directions and wind-speed categories. New Albany plant site, 1957: Summer.

TABLE XXIV

AVERAGE GUST COUNT PER HOUR

Public Service Company of Indiana
New Albany, Indiana

1 September 1957 - 30 November 1957
(Fall)

Direction	Speed, mph									
	0-3		4-12		13-24		25-31		32 +	
	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.
N	1	43	115	194	562	14				
NNE	1	77	280	190	1107	16				
NE	7	20	390	50	1455	6				
ENE	7	9	439	17						
E	9	4	86	8						
ESE	3	16	120	17						
SE	9	7	225	36						
SSE	5	21	248	79	1323	6				
S	2	17	161	87	876	57				
SSW	2	27	131	125	937	51				
SW	3	24	339	100	1436	28				
WSW	8	16	488	70	1783	7				
W	15	10	568	57	1905	8				
WNW	8	17	384	58	1538	4				
NW	4	8	282	28	1368	7				
NNW	4	11	169	99	908	15				
Calm	0	161								
Avg.	3		256		1083					
Totals		488		1215		219				

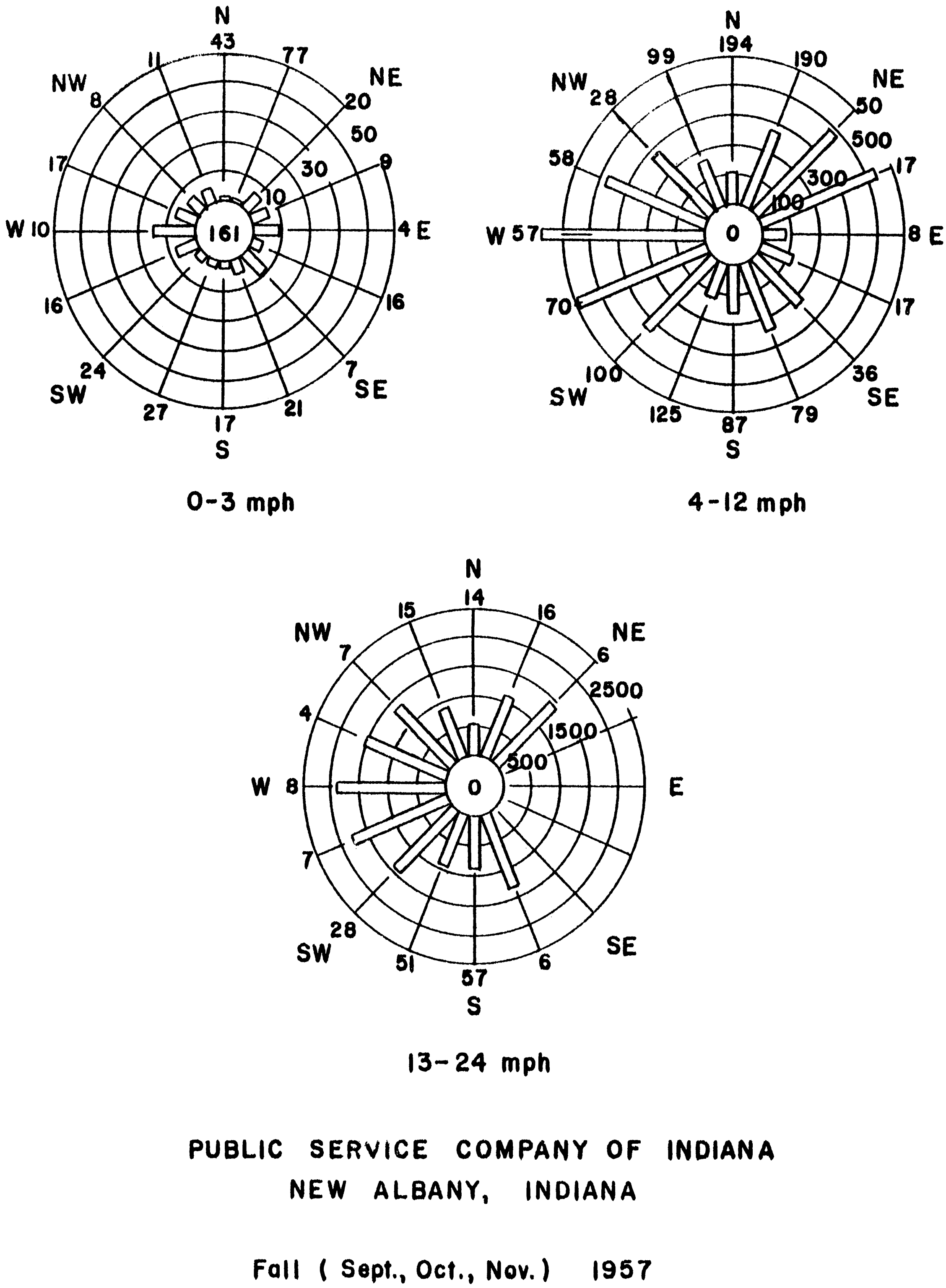


Fig. 10. Average gust count per hour by wind directions and wind-speed categories. New Albany plant site, 1957: Fall.

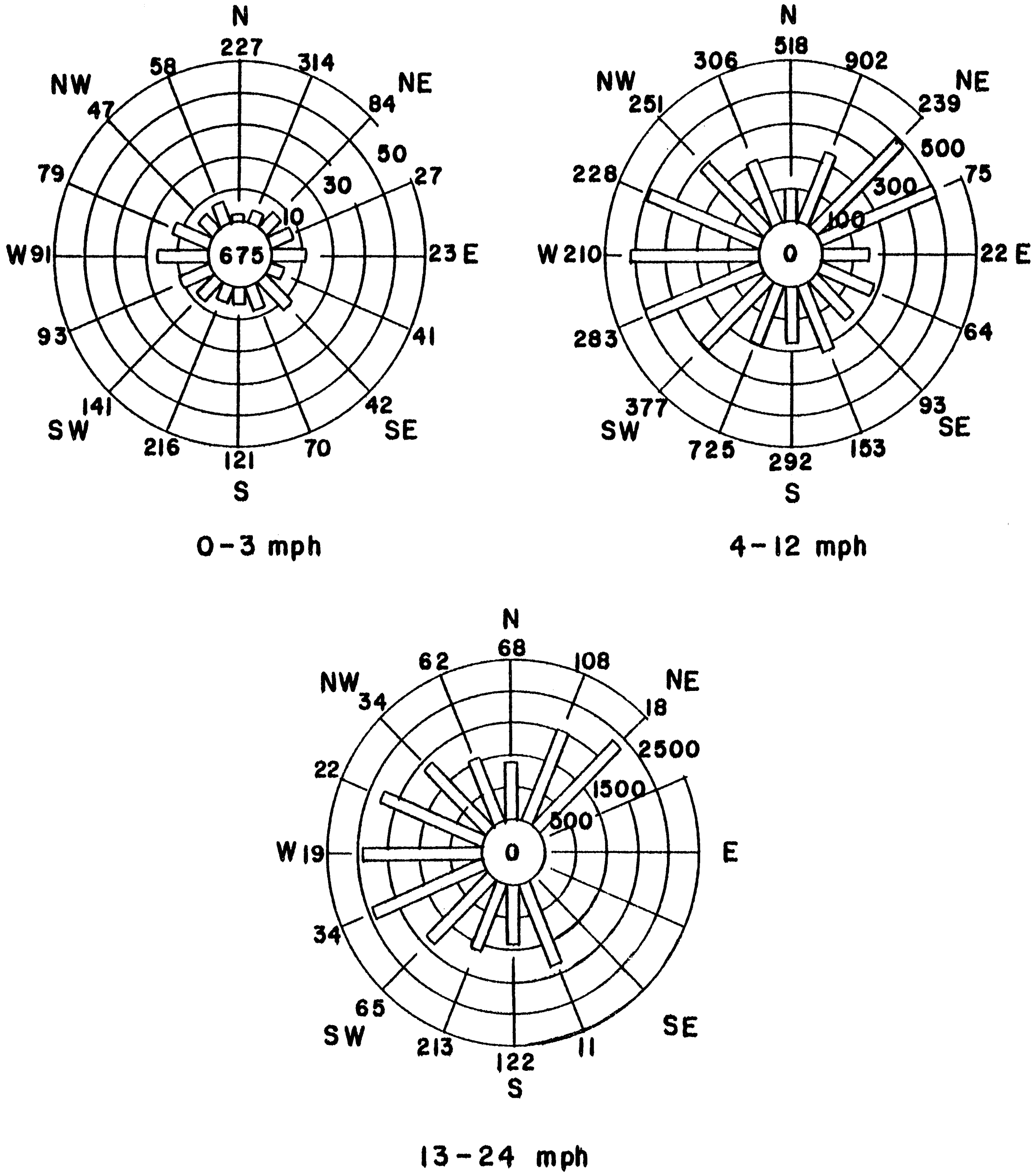
TABLE XXV

AVERAGE GUST COUNT PER HOUR

Public Service Company of Indiana
New Albany, Indiana

1 December 1956 - 30 November 1957
(Annual Summary)

Direction	Speed, mph									
	0-3		4-12		13-24		25-31		32 +	
	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.	Avg. G.C.	No. of occur.
N	2	227	110	518	949	68				
NNE	4	314	237	902	1566	108				
NE	7	84	396	239	1870	18				
ENE	8	27	405	75						
E	12	23	162	22						
ESE	5	41	192	64						
SE	13	42	179	93						
SSE	8	70	232	153	1373	11				
S	5	121	181	292	942	122				
SSW	5	216	193	725	1145	213				
SW	8	141	300	377	1431	65				
WSW	11	93	404	283	1941	34				
W	17	91	418	210	1954	19				
WNW	13	79	394	228	1787	22				
NW	6	47	296	251	1417	34	5650	1		
NNW	7	58	215	306	1038	62				
Calm	0	675								
Avg.	5		254		1275		5650			
Totals		2349		4738		776		1		



PUBLIC SERVICE COMPANY OF INDIANA

NEW ALBANY, INDIANA

Annual Summary 1957

Fig. 11. Average gust count per hour by wind directions and wind-speed categories. New Albany plant site, 1957: Annual Summary.

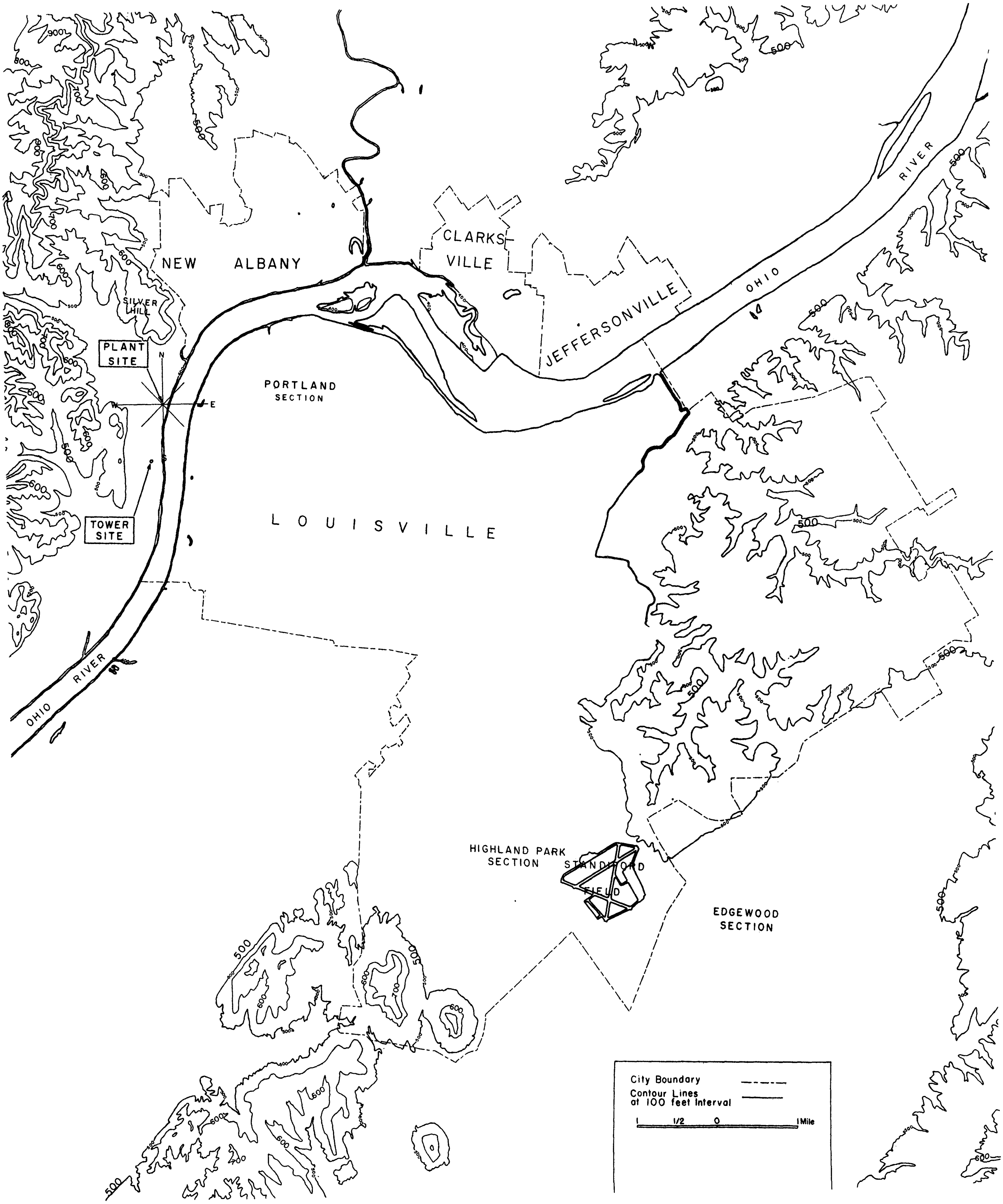


Fig. 12. Topographic map of site and surroundings.

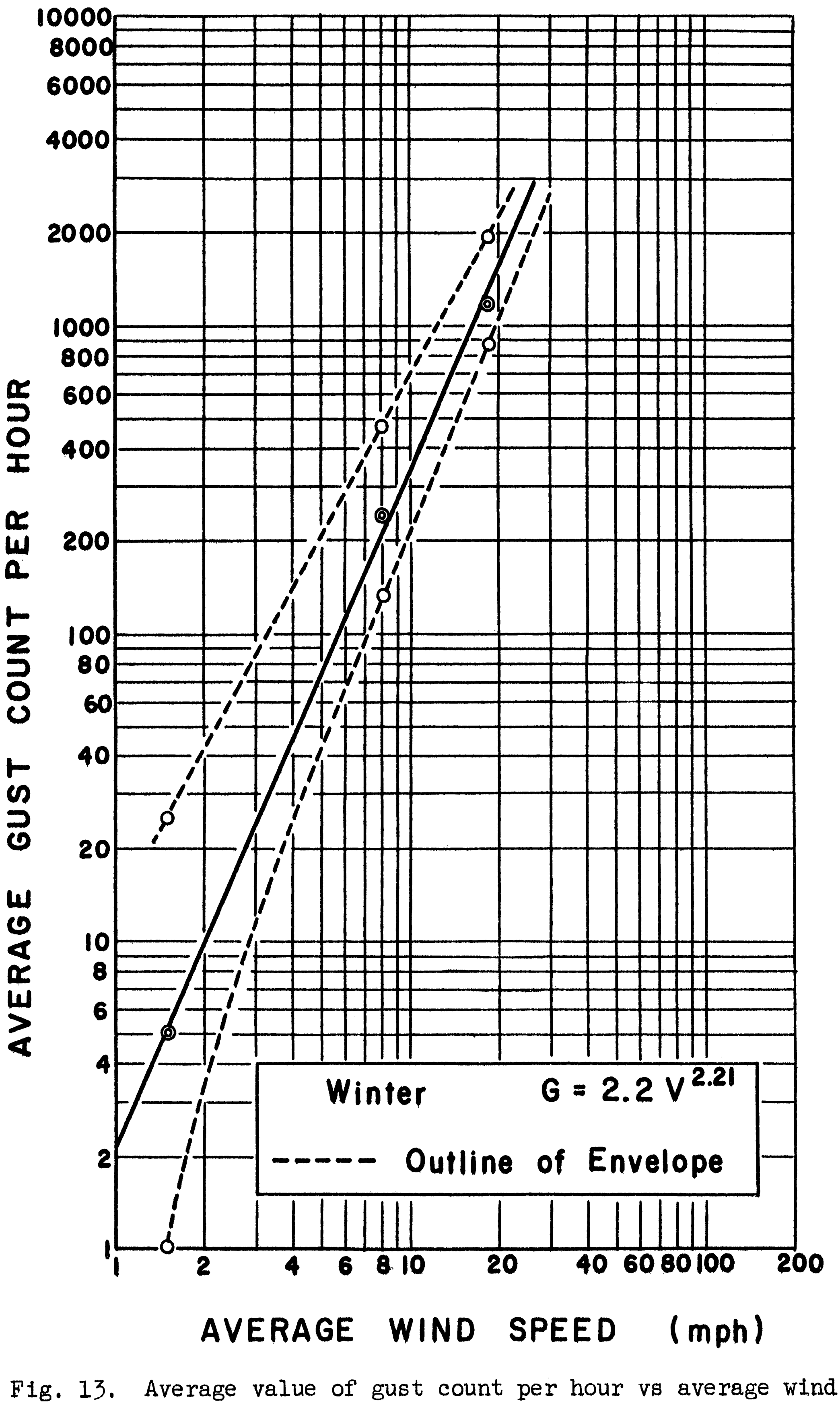


Fig. 13. Average value of gust count per hour vs average wind speed. New Albany plant site, 1956-1957: Winter.

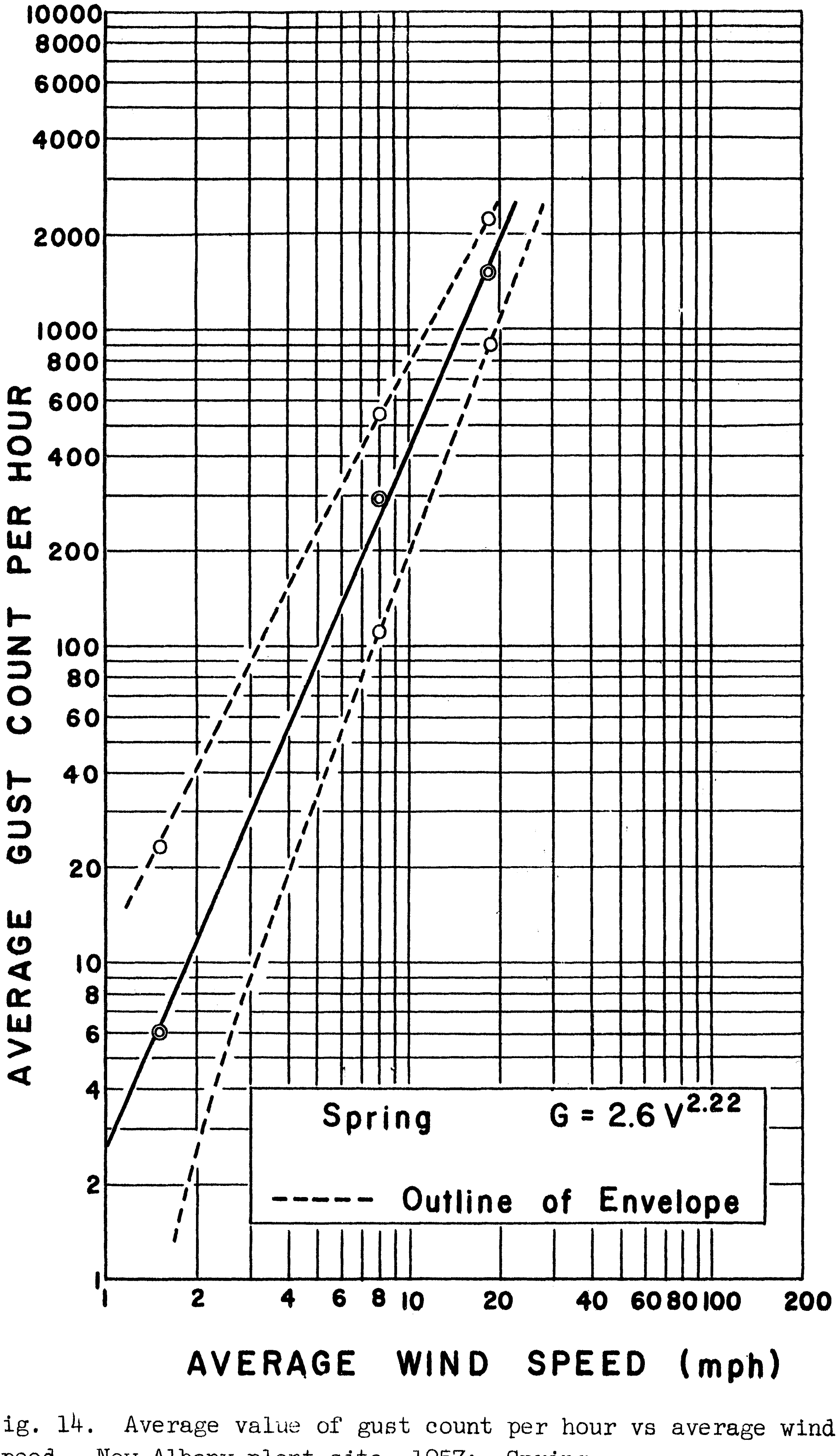


Fig. 14. Average value of gust count per hour vs average wind speed. New Albany plant site, 1957: Spring.

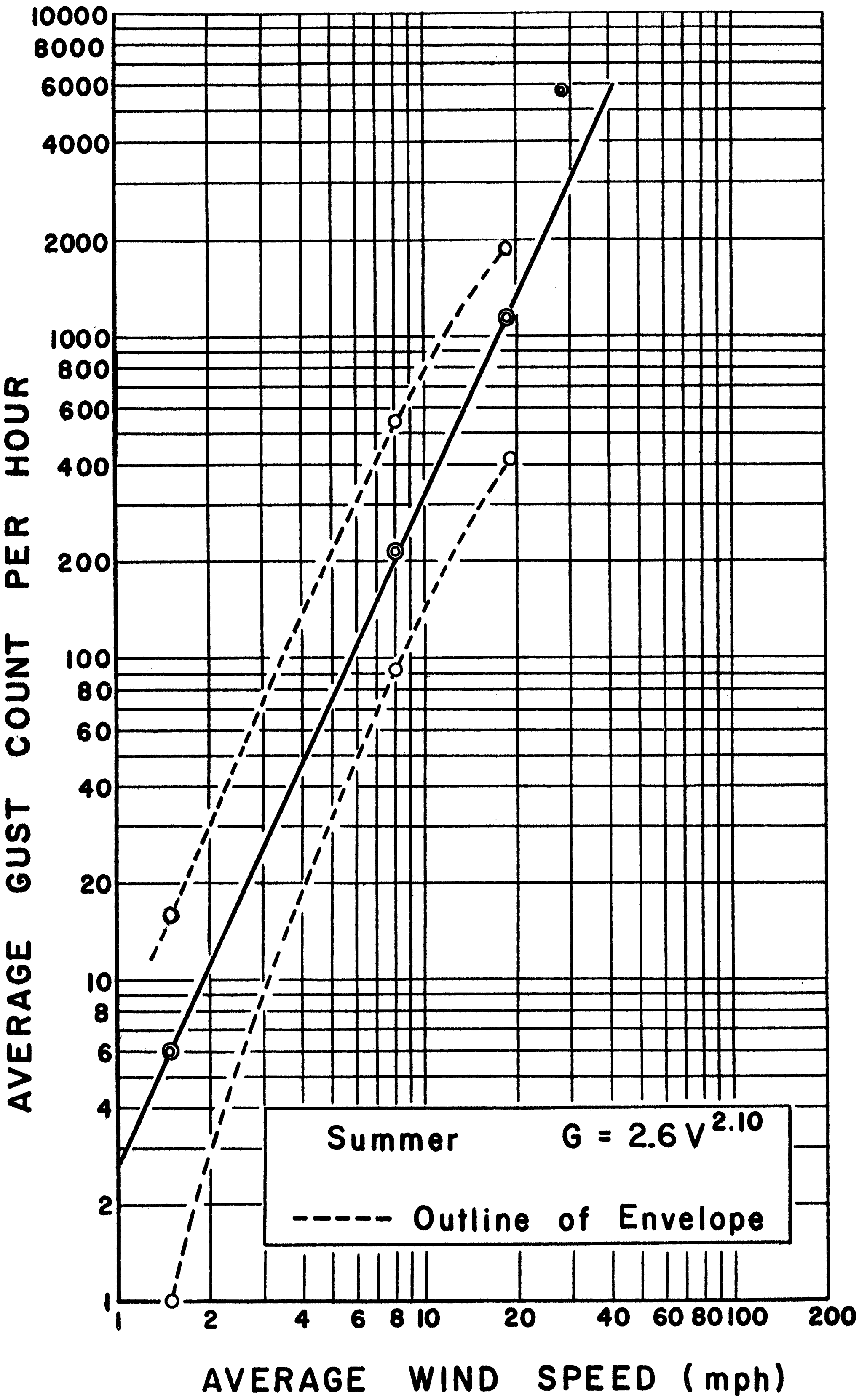


Fig. 15. Average value of gust count per hour vs average wind speed. New Albany plant site, 1957: Summer.

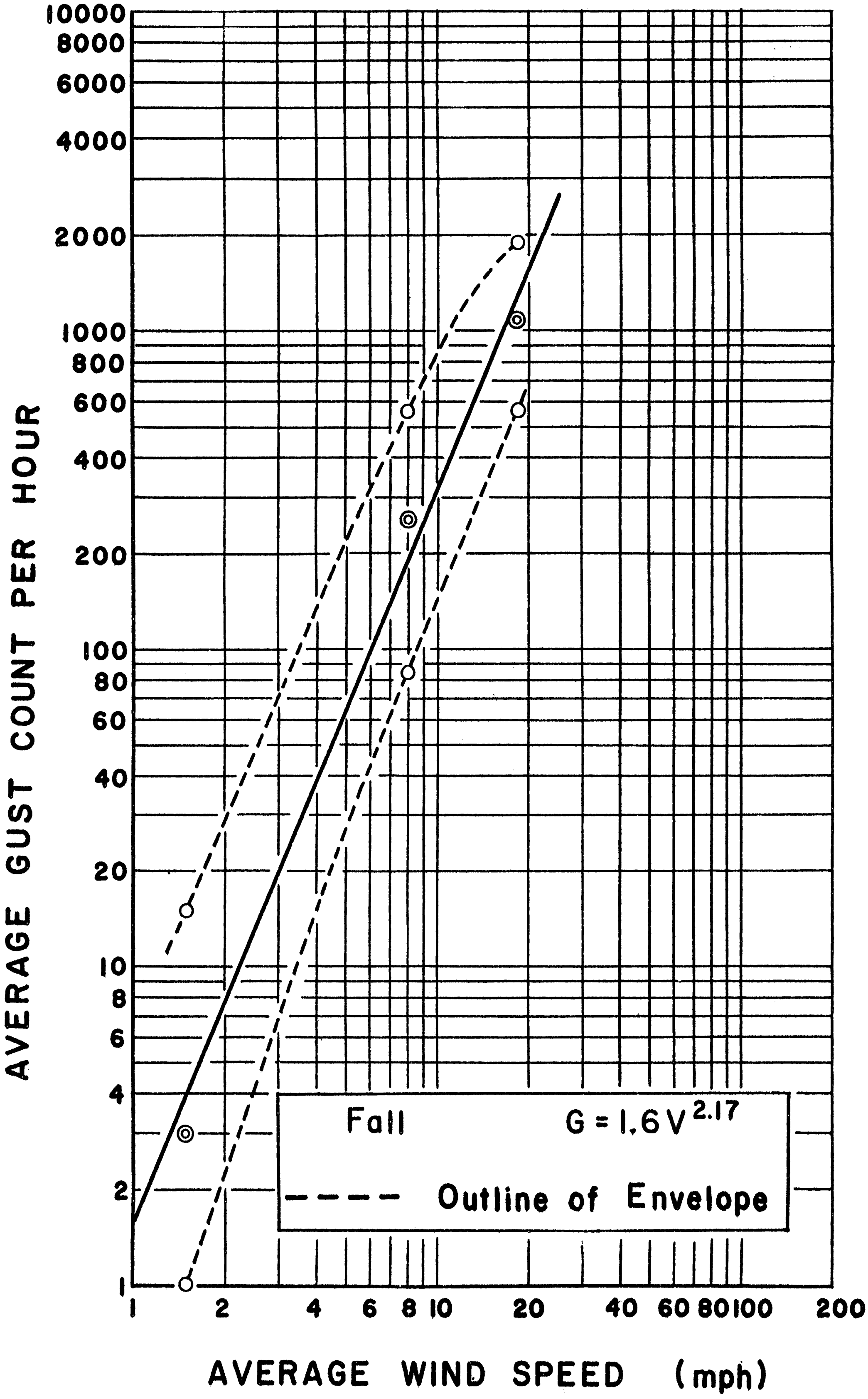


Fig. 16. Average value of gust count per hour vs average wind speed. New Albany plant site, 1957: Fall.

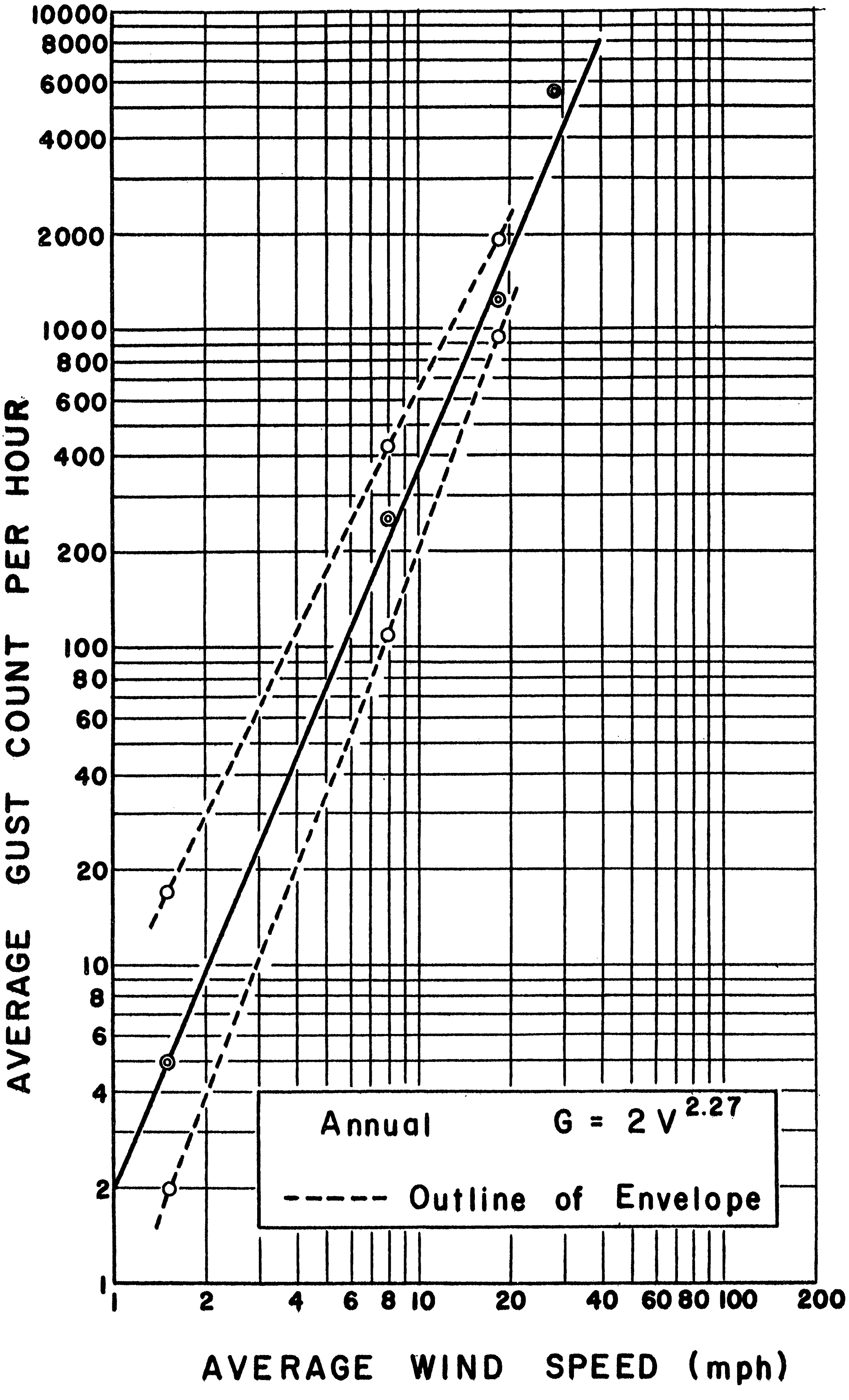


Fig. 17. Average value of gust count per hour vs average wind speed. New Albany plant site, 1957: Annual Summary.

ANALYSIS OF PRECIPITATION DATA

1. ROLE OF PRECIPITATION

The occurrence or nonoccurrence of precipitation can be very important in air-pollution problems. Precipitation has the ability to cleanse or scavenge the atmosphere of particulate and gaseous materials. If a rain shower should occur as soon as the effluent leaves a stack, it is possible that a large portion of the pollutant would be washed from the atmosphere, thus lessening the effects of the pollutant on some area downstream. Such a situation might increase the ground-level concentration in the immediate vicinity of the plant, which could be a serious local problem. On the other hand, an effluent may leave the stack, travel downstream for several miles diffusing into the atmosphere all the time, and then a rain shower may wash the effluent material out. Such a shower would probably not do any harm unless it occurred directly over a population center. For a thorough discussion on the theory of rain scavenging and its effects, see the work of Greenfield.[5]

Rainfall plays an even more important role when the gaseous effluent is SO_2 because SO_2 is quite soluble in water, 9.06 g/100 ml of H_2O at 26°C.[6] Therefore when it rains, not only is there rainout or washout of particles which have SO_2 adsorbed on them, but very dilute solutions of sulfurous acid, H_2SO_3, may also result. The equation for the formation of sulfurous acid is as follows:

$$H_2O + SO_2\uparrow \rightleftharpoons H_2SO_3 \quad .$$

This equation is favored toward the right or the formation of sulfurous acid by normal conditions of temperature and humidity. High temperatures cause the reaction to go to the left, releasing SO_2 as a gas. Sulfurous acid in itself may not be very harmful but unfortunately H_2SO_3 oxidized in the presence of air and light to sulfuric acid, H_2SO_4. The corrosive nature and effects of sulfuric acid are well known.

It was decided to include a section on the analysis of precipitation because of the importance of precipitation to air-pollution problems and, in particular, the SO_2 problem. Measurements of precipitation are not taken at the New Albany plant site, but continuous rainfall records are kept at Standiford Field. The assumption was made that, if it rained at Standiford Field, it probably rained at the plant site. Such an assumption has considerable validity during the fall, winter, and early spring when most of the precipitation comes from large-scale storms. The assumption is least valid in the summer when a large part of the precipitation is in the form of shower activity. It is a well-observed fact that showers may not extend over two stations which are eight miles apart. In this particular case where both stations are in the Ohio River valley, there is a better chance of showers occurring at both stations simultaneously than if the stations were out in the open plains country.

2. VARIATION OF PRECIPITATION WITH WIND DIRECTION AND WIND SPEED

Tables XXVI-XXX contain the data which show an association of precipitation at Standiford Field with winds at the plant site. Figures 18 and 19 show the same data with the rectangles representing the percentage frequency of occurrence of precipitation as a percentage of the total hours of precipitation. The heavy black lines show the average wind speed during precipitation. The number in the center is the percentage of time there is precipitation when the wind is recorded as calm.

During 1957 there was precipitation only 7.9% of the time, on the average. This shows that there is small likelihood of much influence of precipitation on the stack effluent. However, we must be prepared for extreme conditions since the extreme situations are the occurrences that may cause the most difficulties.

From Figs. 18 and 19 we see that precipitation is most often associated with either NNE or SSW sector winds. The exception to this generalization is during the fall when most of the precipitation is associated with SSE, S, or SSW winds. It seems, then, that the orientation of the Ohio River valley in this locality plays a direct role on the precipitation distribution. Other than the two or three above-mentioned directions that seem to have most of the precipitation associated with them, the remaining directions have fairly equal distribution of the precipitation. This uniform distribution is the result of the location of surrounding hills. The hills protect the valley so that most of the water content has fallen out on the windward side of the hills due to orographic lifting. The leeside is therefore drier. Such a case is exemplified at the plant site.

Whenever a wind direction at New Albany has a moderate amount of rainfall associated with it, the accompanying wind speed is always 7-10 mph. In a sense this is a favorable factor, for no one area would have too much pollutant washed on it with wind speeds of that order. Only if the wind speeds were low would there be a problem. Note the south winds associated with the precipitation. All the southerly wind speeds are 9 mph or greater. Therefore Silver Hill would not be affected to any great extent by rainout or washout since the amount of material washed out in any given period of time at one point would be small.

Because the areas of major interest in regard to air pollution are all close to the plant site, the occurrence of precipitation will in the long run bring more material to the ground in the nearby areas than they would normally receive without the precipitation. The moderate wind speeds associated with the precipitation will spread out the pollution over a larger area so this factor compensates for the washout and rainout effect.

TABLE XXVI

THE ASSOCIATION OF PRECIPITATION AT STANDIFORD FIELD WITH WINDS AT PUBLIC SERVICE COMPANY OF INDIANA, NEW ALBANY, INDIANA

1 December 1956 - 28 February 1957
(Winter)

Wind Direction	Average Wind Speed During Precipitation	No. of Observations	Hours of Precipitation as Percentage of	
			Total Hours of Precipitation	Total Hours of Wind Observations
N	5.9	29	13.7	1.4
NNE	6.1	45	21.3	2.1
NE	5.5	22	10.4	1.0
ENE	4.3	4	1.9	0.2
E	4.0	1	0.5	0.0
ESE	3.7	3	1.4	0.1
SE	3.3	3	1.4	0.1
SSE	5.5	4	1.9	0.2
S	11.2	8	3.8	0.4
SSW	9.9	25	11.8	1.2
SW	5.4	9	4.3	0.4
WSW	5.0	10	4.7	0.5
W	5.3	8	3.8	0.4
WNW	7.8	10	4.7	0.5
NW	6.5	11	5.2	0.5
NNW	9.9	6	2.8	0.3
Calm	0.0	13	6.2	0.6
Totals		211	99.8	9.9
Avg.	6.2			

TABLE XXVII

THE ASSOCIATION OF PRECIPITATION AT STANDIFORD FIELD WITH WINDS AT PUBLIC SERVICE COMPANY OF INDIANA, NEW ALBANY, INDIANA

1 March 1957 - 31 May 1957
(Spring)

Wind Direction	Average Wind Speed During Precipitation	No. of Observations	Hours of Precipitation as Percentage of	
			Total Hours of Precipitation	Total Hours of Wind Observations
N	10.4	23	14.3	1.1
NNE	8.4	30	18.6	1.5
NE	6.0	3	1.9	0.1
ENE	7.5	4	2.5	0.2
E	3.0	1	0.6	0.0
ESE	5.4	7	4.3	0.3
SE	5.3	4	2.5	0.2
SSE	7.8	4	2.5	0.2
S	9.3	11	6.8	0.5
SSW	9.3	27	16.8	1.3
SW	10.3	11	6.8	0.5
WSW	8.4	7	4.3	0.3
W	3.8	5	3.1	0.2
WNW	10.6	5	3.1	0.2
NW	10.0	3	1.9	0.1
NNW	13.2	9	5.6	0.4
Calm	0.0	7	4.3	0.3
Totals		161	99.9	7.4
Avg.	8.6			

TABLE XXVIII

THE ASSOCIATION OF PRECIPITATION AT STANDIFORD FIELD WITH WINDS AT PUBLIC SERVICE COMPANY OF INDIANA, NEW ALBANY, INDIANA

1 June 1957 - 31 August 1957
(Summer)

Wind Direction	Average Wind Speed During Precipitation	No. of Observations	Hours of Precipitation as Percentage of	
			Total Hours of Precipitation	Total Hours of Wind Observations
N	7.3	9	11.4	0.5
NNE	7.8	5	6.3	0.3
NE	7.5	2	2.5	0.1
ENE	4.5	2	2.5	0.1
E	1.0	1	1.3	0.1
ESE	---	0	---	---
SE	6.0	1	1.3	0.1
SSE	7.8	5	6.3	0.3
S	10.0	7	8.9	0.4
SSW	6.0	14	17.7	0.7
SW	4.4	7	8.9	0.4
WSW	8.0	4	5.1	0.2
W	8.3	3	3.8	0.2
WNW	4.8	5	6.3	0.3
NW	15.7	3	3.8	0.2
NNW	6.9	7	8.9	0.4
Calm	0.0	4	5.1	0.2
Totals		79	100.1	4.5
Avg.	6.8			

TABLE XXIX

THE ASSOCIATION OF PRECIPITATION AT STANDIFORD FIELD WITH WINDS AT PUBLIC SERVICE COMPANY OF INDIANA, NEW ALBANY, INDIANA

1 September 1957 - 30 November 1957
(Fall)

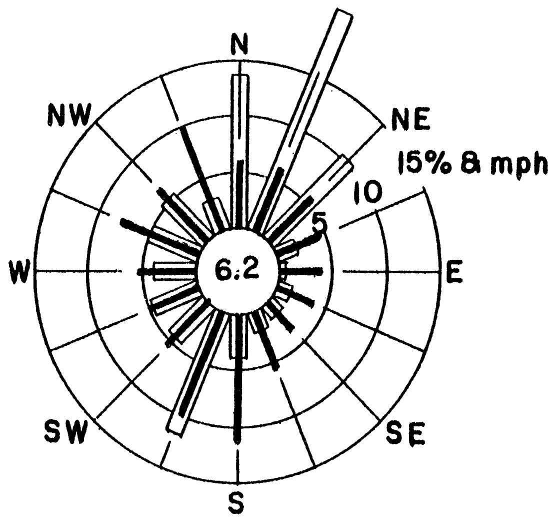
Wind Direction	Average Wind Speed During Precipitation	No. of Observations	Hours of Precipitation as Percentage of	
			Total Hours of Precipitation	Total Hours of Wind Observations
N	5.0	4	2.8	0.2
NNE	3.6	5	3.5	0.3
NE	4.0	1	0.7	0.1
ENE	---	0	---	---
E	5.0	1	0.7	0.1
ESE	4.4	8	5.7	0.4
SE	7.3	15	10.6	0.8
SSE	9.0	30	21.3	1.6
S	12.8	31	22.0	1.6
SSW	9.9	28	19.9	1.5
SW	8.5	6	4.3	0.3
WSW	11.5	4	2.8	0.2
W	12.5	2	1.4	0.1
WNW	9.0	1	0.7	0.1
NW	9.0	2	1.4	0.1
NNW	7.0	1	0.7	0.1
Calm	0.0	2	1.4	0.1
Totals		141	99.9	7.6
Avg.	9.2			

TABLE XXX

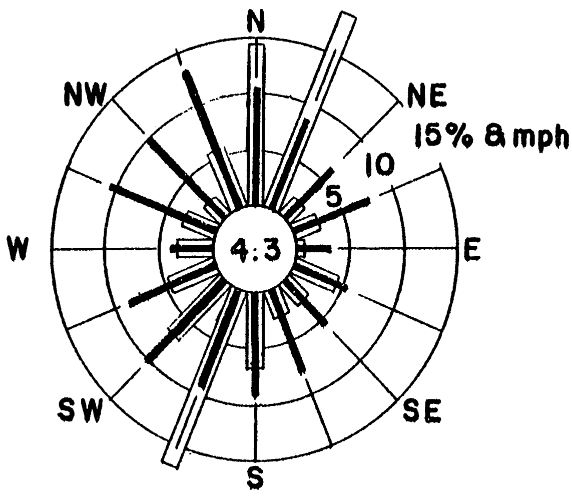
THE ASSOCIATION OF PRECIPITATION AT STANDIFORD FIELD WITH WINDS AT PUBLIC SERVICE COMPANY OF INDIANA, NEW ALBANY, INDIANA

1 December 1956 - 30 November 1957
(Annual Summary)

Wind Direction	Average Wind Speed During Precipitation	No. of Observations	Hours of Precipitation as Percentage of	
			Total Hours of Precipitation	Total Hours of Wind Observations
N	7.6	65	10.3	0.8
NNE	6.9	84	13.3	1.1
NE	5.6	28	4.4	0.4
ENE	5.6	10	1.6	0.1
E	3.3	4	0.6	0.1
ESE	4.7	18	2.9	0.2
SE	6.3	23	3.7	0.3
SSE	8.4	43	6.8	0.5
S	11.0	60	9.5	0.7
SSW	6.9	124	19.7	1.6
SW	7.4	33	5.2	0.4
WSW	6.4	29	4.6	0.4
W	5.8	19	3.0	0.2
WNW	7.8	21	3.3	0.3
NW	8.7	19	3.0	0.2
NNW	10.1	23	3.7	0.3
Calm	0.0	26	4.1	0.3
Totals		629	99.7	7.9
Avg.	7.2			

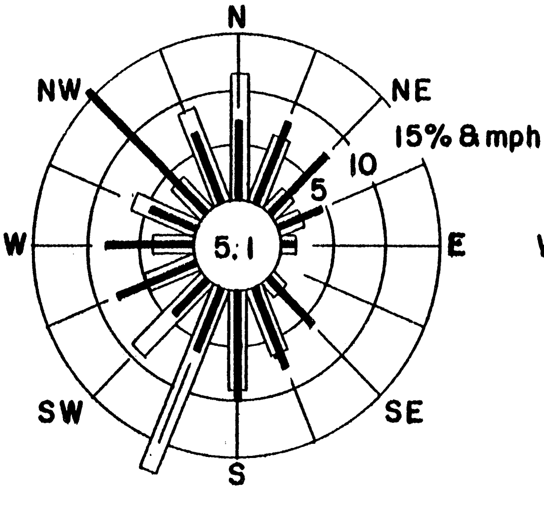


PUBLIC SERVICE COMPANY OF INDIANA
NEW ALBANY, INDIANA
Winter (Dec., Jan., Feb.) 1956-1957



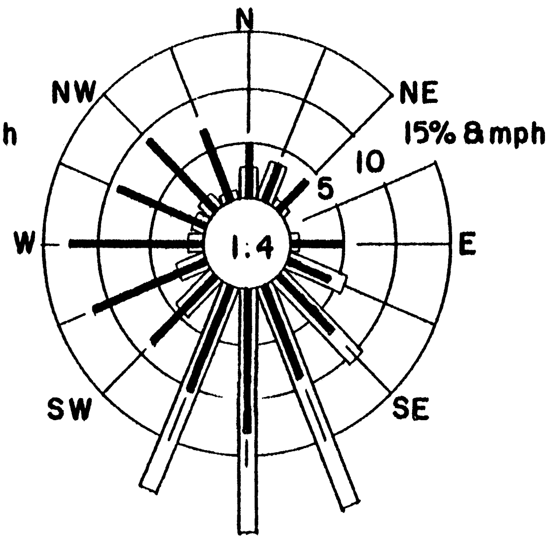
PUBLIC SERVICE COMPANY OF INDIANA
NEW ALBANY, INDIANA
Spring (Mar., Apr., May) 1957

Fig. 18. Percentage frequency of occurrence of winds from 16 directions (rectangles) at New Albany plant site and corresponding precipitation from Standiford Field, 1956-1957 (Winter); and 1957 (Spring). Average wind speed (heavy lines). Percent of calms in center.



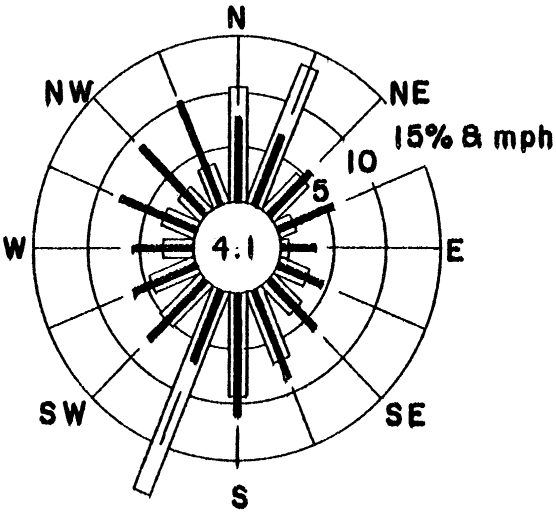
PUBLIC SERVICE COMPANY OF INDIANA
NEW ALBANY, INDIANA

Summer (Jun., Jul., Aug.) 1957



PUBLIC SERVICE COMPANY OF INDIANA
NEW ALBANY, INDIANA

Fall (Sept., Oct., Nov.) 1957



PUBLIC SERVICE COMPANY OF INDIANA
NEW ALBANY, INDIANA

Annual Summary 1957

Fig. 19. Percentage frequency of occurrence of winds from 16 directions (rectangles) at New Albany plant site and corresponding precipitation from Standiford Field, 1957 (Summer); 1957 (Fall); and 1957 (Annual Summary). Average wind speed (heavy lines). Percent of calms in center.

ANALYSIS OF SO_2 DATA

The Thomas autometer located on Silver Hill has been operating successfully since the latter part of May, 1957. The SO_2 background data have been analyzed by seasons since there are some obvious seasonal differences. Only the data from the summer and fall seasons are presented in this report. A statement of representative annual conditions must wait until reliable data for a longer period have been obtained.

The records from the autometer were abstracted at half-hourly intervals, using the convention that a trace of SO_2 was less than 0.03 ppm. A trace has been designated by "T" in the accompanying tables. Concentrations of SO_2 were read in parts per million (ppm), by volume. A reading of 5 ppm would mean that there were 5 parts of SO_2 per million parts of air on a volume basis. The conversion of ppm to weight per volume and vice versa is as follows:[7]

$$\text{1 ppm of } SO_2 \text{ (25°C and 760 mm)} = 0.0026 \text{ mg/l} .$$

$$\text{1 mg/l of } SO_2 \text{ (25°C and 760 mm)} = 382 \text{ ppm} .$$

Abstractions were made of average half-hourly concentration and also of the maximum half-hourly concentration. The maximum half-hourly value was defined as the highest concentration that appeared, no matter how short the time, during the half-hour period being considered. The values of average and maximum concentrations were associated with both wind direction and time of day.

1. GENERAL REMARKS ON SULFUR DIOXIDE

Even though SO_2 is a well-recognized pollutant of industrial atmospheres and one of the main constituents of stack gases from coal-burning power plants, there is still a great deal to be known and to be found out about the effects of the gas. The various tolerable concentration limits for SO_2 are not well defined. However, after a survey of the latest available literature, the following values of concentration limits will be used as standards during this study.

HUMAN BEINGS	
Maximum atmospheric concentration (allowable for an 8-hr period)	10 ppm[8]
Odor threshold	3.4 ppm[9]
Eye irritation	~ 20 ppm[10]
Maximum concentrations (for 1/2-1-hr exposure)	50-100 ppm[10]
Concentration immediately hazardous to life	400-500 ppm[10]

VEGETATION

Allowable exposure for 7 hr (General vegetation)	0.4 ppm[11]
Alfalfa for 1 hr	1.25 ppm[12]
Barley for 1 hr	1.25 ppm[12]
Oats for 1 hr	1.63 ppm[12]
Potatoes for 1 hr	3.75 ppm[12]
Corn for 1 hr	5.0 ppm[12]
Citrus for 1 hr	7.50-8.13 ppm[12]
Protracted fumigation lasting a period of weeks	0.08-0.11 ppm[13]

References to the above-mentioned literature will give a good general background on SO_2 and its effects on man and vegetation. There are still two important points which should be mentioned. Both of these points deal with low concentrations rather than large dosages, a condition which is most apt to exist in nature.

During prolonged exposures of plants to low concentrations of SO_2, it is not the concentration that is important but the amount of SO_2 that is absorbed by the plant's leaves. The amount of SO_2 absorbed is dependent upon relative humidity, time of day, and the age of the plant.[14,15] The primary factor which controls absorption in plants is the degree of opening of the stomata on the leaf.[16]

It has been observed that, when alfalfa is grown in a partly irrigated field or when the relative humidity is high, the plants become more sensitive to SO_2, indicating that the stomata are open and that the plant is absorbing more SO_2. The following table shows the sensitivity of alfalfa as a function of relative humidity.

RELATIVE SENSITIVITY OF ALFALFA TO INJURY BY SO_2 AT DIFFERENT ATMOSPHERIC RELATIVE HUMIDITIES[12]

Relative humidity	Relative sensitivity
%	%
100	100
80	89
60	77
50	69
40	54
30	31
20	18
10	13
0	10

The time of day has been found to be a rather important factor in absorption of SO_2 by plants. The plants have been observed to be less sensitive early in the morning to SO_2 owing to the fact that the stomata were nearly closed. As the day progresses, the plants become more and more sensitive to SO_2 as the stomata open. The maximum sensitivity was found to be at midmorning. During the afternoon, the sensitivity falls off until by night the sensitivity is at its lowest.

It appears that in general young plants are less sensitive to SO_2 than are older plants. Middle-aged leaves have been found to be most sensitive and older leaves less sensitive than the middle-aged ones.

In human beings, low prolonged concentrations may be very important. A small concentration of SO_2 will not necessarily harm the body when breathed in alone, but small concentrations of SO_2 coupled with an aerosol of sub-micron size may cause a great deal of damage to the human body.[17] The SO_2 is adsorbed on the aerosol, thereby actually increasing the amount of SO_2 that reaches the lungs, and the depth of penetration into the body. The striking features about this phenomenon are: (1) the aerosols must be below the size of one micron, but may be either inert or active in themselves; and (2) the concentrations of SO_2 must be less than 25 ppm.

2. VARIATION OF SO_2 WITH WIND DIRECTION AND WIND SPEED

The average half-hourly concentrations of SO_2 were tabulated with wind direction and wind speed (see Tables XXXI and XXXII). This analysis was performed to see if there were any one particular sector from which most of the recorded SO_2 might be coming. The general air pollution distribution in the Louisville area[18] is such as to suggest that the southerly quadrant might be the area from which SO_2 was being received. Both Tables XXXI and XXXII show an increase of concentration and an increase in number of occurrences with winds in the sector from SSE to SSW as compared with the other wind directions.

Table XXXII, for the fall season, shows some moderately high concentrations occurring quite often with winds in the sector from N through ENE. It must be noted that these occurrences are under light wind conditions. The usual chain of events preceding such an observation is as follows: (1) the wind direction for several hours previous to such an occurrence has been from the S or SSE; (2) a sudden change in wind direction from S or SSE to N to NNE occurs; (3) the wind speed is very low and within the next hour there is not enough mixing taking place to dilute the already present concentration of SO_2; (4) the net result is a wind from the north and a moderate concentration of SO_2 recorded by the autometer. The point to be emphasized is that even though the wind was recorded as a northerly wind, the SO_2 had in reality come from the south an hour or so before. In addition, there is some possibility that a plant up the river in the NNE or NE direction might be emitting SO_2 which is recorded at Silver Hill. It should be noted that, when the wind speed increases above 7 mph, there are no recorded occurrences of SO_2 from the NE sector.

The large number of calm conditions during the fall in which moderate SO_2 concentration is recorded may be accounted for by reasoning. The SO_2 has previously drifted from the S or SSE, so it is already present in the Silver Hill area, but for hours there may be no wind or turbulence to dilute the SO_2 concentration. Therefore it is recorded as a moderate concentration under calm conditions. This particular set of circumstances is apt to happen at the Silver Hill area quite often since the area is often subject to long periods of calm. If a large concentration of SO_2 should build up under light southerly wind conditions and then a long calm should prevail, some damage could be done to surrounding vegetation.

Both Tables XXXI and XXXII show that, as the wind speed increases, the only sector from which SO_2 comes is the southerly one. This is added evidence that downstream from Silver Hill in the sector from SSE to SSW there is a source of SO_2 which is strong enough to give measurable readings at the Silver Hill autometer.

Figures 20 and 21 show plotted values of relative concentration of SO_2 in ppm versus wind direction for the summer and fall of 1957. The average SO_2 concentrations are weighted, which means that the average concentration in a given wind-direction category is multiplied by the number of occurrences and then divided by the total number of occurrences in the season under consideration. This method takes into account not only the average concentration but also the number of occurrences. The division by the total number of observations is nothing more than a scaling or normalizing factor.

Both Figs. 20 and 21 show without a doubt that there is an SO_2 source somewhere to the south of Silver Hill. This is no small effect but a very, very pronounced one. The same effect is observed in both the summer and the fall with little change in direction with respect to the location of the peak concentration. In summer the peak concentration occurs with winds from the SSW direction with another high concentration with winds from the south. In the fall the peak is with winds from the southeast and the next two higher ones with winds from the south and the south-southwest.

Further analysis by wind direction for the two seasons of winter and spring will be done when complete data are available. However, there is little doubt that the distribution will remain essentially the same.

3. VARIATION OF SO_2 WITH TIME OF DAY

Most atmospheric pollutants exhibit a diurnal cycle in their concentrations as measured on the ground or at any stationary point. To investigate the diurnal cycle of SO_2 at the autometer site, the average concentration in parts per million was tabulated against the time of day at half-hour intervals. Tables XXXIII and XXXIV show the frequency of occurrence and the average concentration in ppm for each half-hour interval from 0030 to 2400 hours. Tables XXXV and XXXVI show the frequency of occurrence of the average maximum concentration for each half-hour interval. Figures 22-25 are visual representations of the same data. The values again have been weighted to draw the graphs.

In the diurnal cycle of a pollutant, the concentration begins to rise very slowly in the morning, reaches a peak about midmorning, then falls off more slowly than it climbed to a minimum in the late afternoon, rises slightly again to a possible secondary maximum in the early evening and finally falls to the lowest point in the early morning hours.

It is quite evident that a well-defined peak occurs prior to noon (Figs. 22 to 25). This peak indicates that the highest ground-level concentrations at Silver Hill are received prior to noon. This is known as the "fumigation" period. During the summer season, the peak occurred at 1100, and during the fall season, it occurred at 1130. Once the peak was reached, the concentration fell off to a rather low value which persisted until after midnight with some minor fluctuations.

The pattern at the autometer site on Silver Hill is not exactly typical, but it is very close to what would be expected normally.

The biggest difference between the theoretical and observational pattern arises in the lateness of the peak concentration or the fumigation period. The fumigation is caused by the breakup of the nocturnal inversion by the action of solar radiation heating the earth, which in turn heats the lower layers of the atmosphere. The heating causes vertical motions to begin. The pollutant that was lying above the inversion layer is mixed throughout the layer and brought down to the ground by the vertical air currents.

The reason for the delay in the fumigation at Silver Hill is due to the fact that the factories downstream are at least four miles from the autometer site. With the calm wind conditions that usually prevail at night and in the early morning associated with an inversion, not much SO_2 would collect above the inversion over the Silver Hill area. Instead, the SO_2 would remain in the vicinity of the industrial plants. By 0900 or 0930 in the morning, the inversion has begun to break up, but the wind speeds are still very low, only 2-3 mph. Because of the smooth trajectory from the southerly direction plus low wind speed, not much diffusion takes place. It is conceivable, therefore, that moderate to high concentrations of SO_2 do not reach Silver Hill for two hours or more after the inversion breakup over the industrial area.

4. COMMENTS AND RESULTS OF BACKGROUND STUDY OF SULFUR DIOXIDE

Sulfur dioxide does not occur every day at Silver Hill, but when it does occur, it is usually associated with winds from the southerly quadrant. The maximum concentrations are received around 1100. Not only is the amount of SO_2 that is received highest during this period prior to noon, but it is the most frequent time for an occurrence.

To give more positive evidence and a better picture, let us take one particular instance and explain it in detail. The instance will be the day of October 21, 1957. Table XXXVII presents the observational data and Fig. 26 portrays a surface map of the synoptic situation during the period. This day was chosen because the maximum concentration of 0.50 ppm recorded at 1130 was the highest concentration recorded to date at the autometer located on Silver Hill. The day began with calm winds which became very light north-northeasterly until 0500. Between 0400 and 0430 a trace of SO_2 was recorded on the autometer. This trace of SO_2 could have come from the railroad yards at New Albany. From 0500 until 0900 the wind was calm, although SO_2 was recorded continuously from 0600. When the wind did begin blowing, it was from the SSW, then S and SSE. The speed was quite low, only 2-4 mph. Notice, then, how the concentration of SO_2 rose to a peak around 1200.

In other words we had measurable SO_2 at Silver Hill early in the morning. As soon as the wind began blowing from the south, the concentration increased rapidly, leading one to suspect that the source was from the southerly quadrant. This example shows that the inversion breakup, over the industrial area, probably took place aroung 0900 or before, but because there was very little wind during the early morning, a small amount of SO_2 was concentrated above the inversion in the Silver Hill area. When the inversion broke, the light winds moved the SO_2 towards Silver Hill, causing high values of concentration to be recorded. After the noon peak, the concentration fell off, so by late afternoon there was no SO_2 being recorded at Silver Hill.

Whether or not an inversion existed during the morning of the 21st cannot be answered positively since no temperature profiles are available at the plant site. The observations from Standiford Field indicate clear skies and 8 miles visibility at 0000 in the morning. The visibility decreased to 6 miles and then to 7 miles an hour later. The sky was clear until 0600, after which a deck of high cirrus clouds began to move in above 20,000 ft. By 1600 the ceiling was recorded at 14,000 ft and the sky was overcast with cirrus clouds. These facts are very indicative of the conditions that would permit an inversion to be formed by 0000 and last until 0900. In fact, the high cirrus clouds would cut down on the incoming solar radiation, so the inversion breakup could easily have been delayed by another hour.

Figure 26 shows the synoptic situation at 0130 on the morning of 21 October 1957. The eastern half of the United States was dominated by a large high-pressure area centered over north-central West Virginia. There was little pressure gradient over the Louisville area so the winds would either have been calm or very light. The clockwise circulation around the high-pressure area was such that what little wind might have existed would have been from the southerly sector. A stagnant high-pressure system such as the one pictured in Fig. 26 is the classical type of synoptic situation that has produced the great fumigations of history such as Donora, Pennsylvania, and London, England. The eastern section of the United States is very susceptible to such a synoptic situation, especially during the fall of the year.

SO_2 has not been recorded continuously at Silver Hill but, rather, it occurs quite sporadically, depending mostly on the wind direction. In the summer season SO_2 was recorded only 3.8% of the time, while in the fall it occurred 6.6% of the time. We may conclude that, when the proper meteorological conditions prevail, the Silver Hill area does receive measurable concentrations of SO_2 from some source. Thus, a detectable SO_2 background is already present in the area.

TABLE XXXI

FREQUENCY OF OCCURRENCE AND AVERAGE CONCENTRATION OF SO_2 WITH VARIOUS WIND SPEEDS GROUPED ACCORDING TO DIRECTION

Public Service Company of Indiana
New Albany, Indiana

1 June 1957 - 31 August 1957
(Summer)

Direction	Speed, mph							
	0-3		4-12		13-24		25-31	
	Avg. conc.	No. of occur.	Avg. conc.	No. of occur.	Avg. conc.	No. of occur.	Avg. conc.	No. of occur.
N	.03	1						
NNE			T	1				
NE			T	1				
ENE								
E								
ESE	.22	1						
SE	.15	2	T	1				
SSE	.06	2	.05	1	.03	1		
S	.10	8	.08	18	.04	4		
SSW	.11	4	.10	25				
SW			.05	9				
WSW			.06	1				
W								
WNW								
NW			T	1				
NNW	T	1						
Calm								

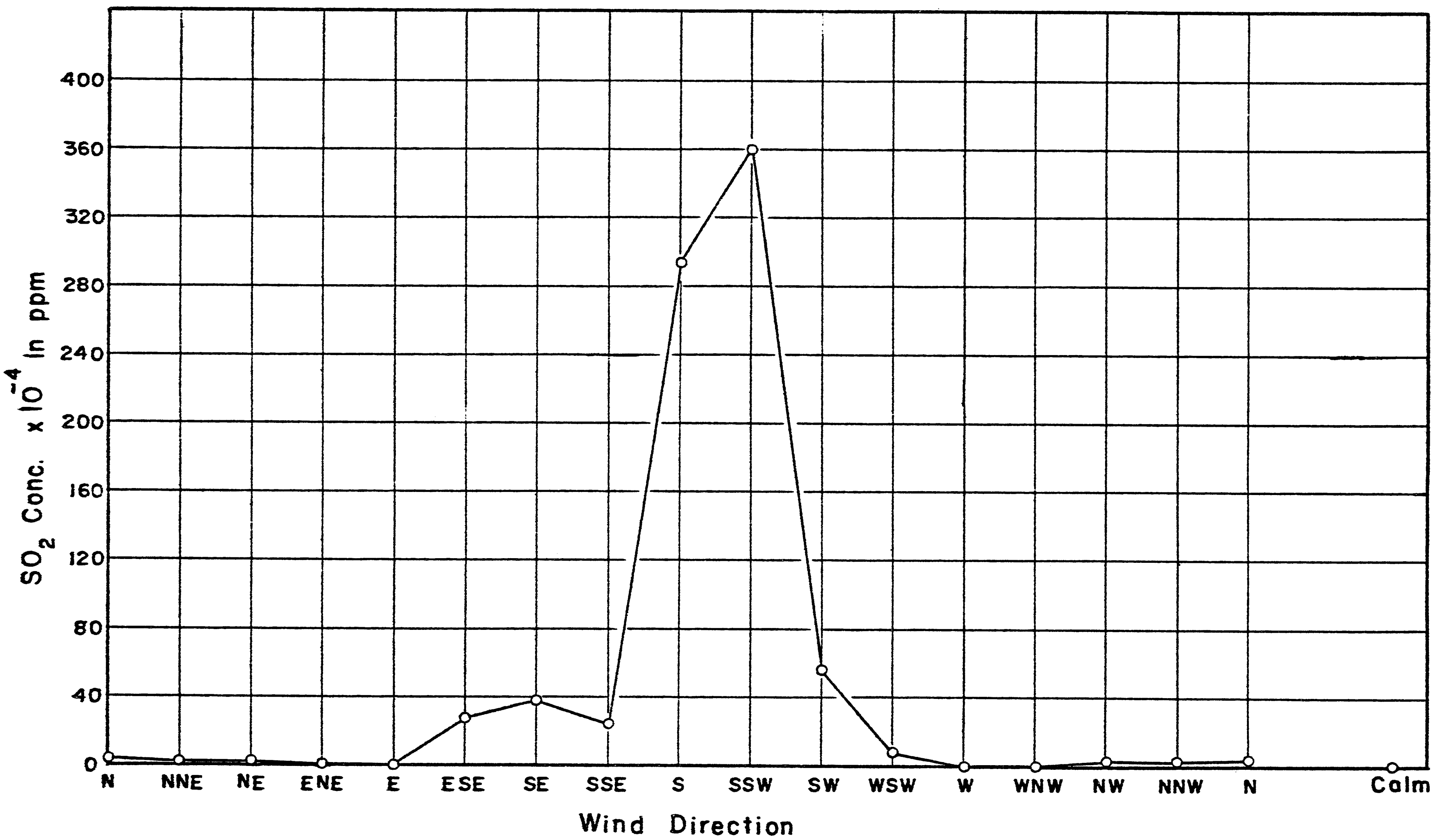


Fig. 20. Relative average concentration of $SO_2 \times 10^{-4}$ in ppm vs various wind directions from New Albany plant site: 1957, Summer.

TABLE XXXII

FREQUENCY OF OCCURRENCE AND AVERAGE CONCENTRATION OF SO_2 WITH VARIOUS WIND SPEEDS GROUPED ACCORDING TO DIRECTION

Public Service Company of Indiana
New Albany, Indiana

1 September 1957 - 30 November 1957
(Fall)

Direction	Speed, mph							
	0-3		4-12		13-24		25-31	
	Avg. conc.	No. of occur.	Avg. conc.	No. of occur.	Avg. conc.	No. of occur.	Avg. conc.	No. of occur.
N	.07	5						
NNE	.07	6	.06	4				
NE	.04	1						
ENE	.20	1						
E	.03	2						
ESE	.05	7	.04	2				
SE	.12	2	.03	7				
SSE	.23	10	.12	15				
S	.13	7	.10	18	.08	7		
SSW	.10	3	.05	4	.06	9		
SW	.03	1	T	1				
WSW	.03	1						
W								
WNW								
NW								
NNW	T	1						
Calm	.08	27						

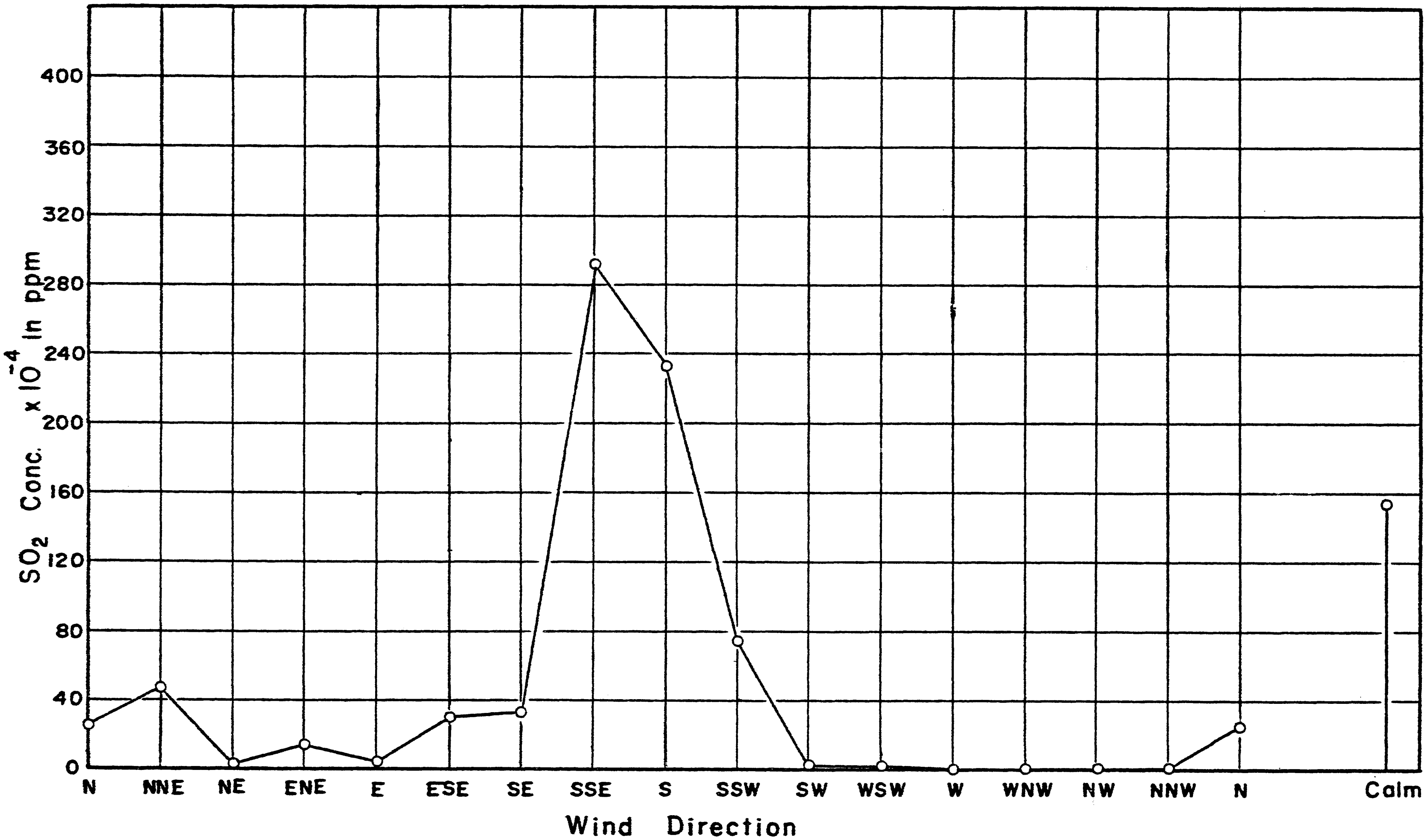


Fig. 21. Relative average concentration of $SO_2 \times 10^{-4}$ in ppm vs various wind directions from New Albany plant site: 1957, Fall.

TABLE XXXIII

FREQUENCY OF OCCURRENCE AND AVERAGE CONCENTRATION OF SO_2
FOR ALL WIND DIRECTIONS AND WIND SPEEDS GROUPED
ACCORDING TO TIME OF DAY

Public Service Company of Indiana
New Albany, Indiana

1 June 1957 - 31 August 1957
(Summer)

Time	Average Concentration (ppm)	Frequency of Occurrence	Time	Average Concentration (ppm)	Frequency of Occurrence
0030			1230	.04	9
0100			1300	.05	7
0130			1330	.04	8
0200			1400	.04	6
0230			1430	.04	6
0300			1500	.05	4
0330			1530	.06	3
0400			1600	.04	4
0430			1630	.04	3
0500			1700	T	4
0530			1730	T	6
0600			1800	T	2
0630			1830	T	2
0700			1900	T	4
0730			1930	.04	2
0800	T	2	2000	.03	2
0830	.04	5	2030	T	1
0900	.05	8	2100		
0930	.05	9	2130		
1000	.06	12	2200		
1030	.08	12	2230	T	1
1100	.07	14	2300	.07	1
1130	.06	15	2330	.07	1
1200	.07	9	2400	T	1

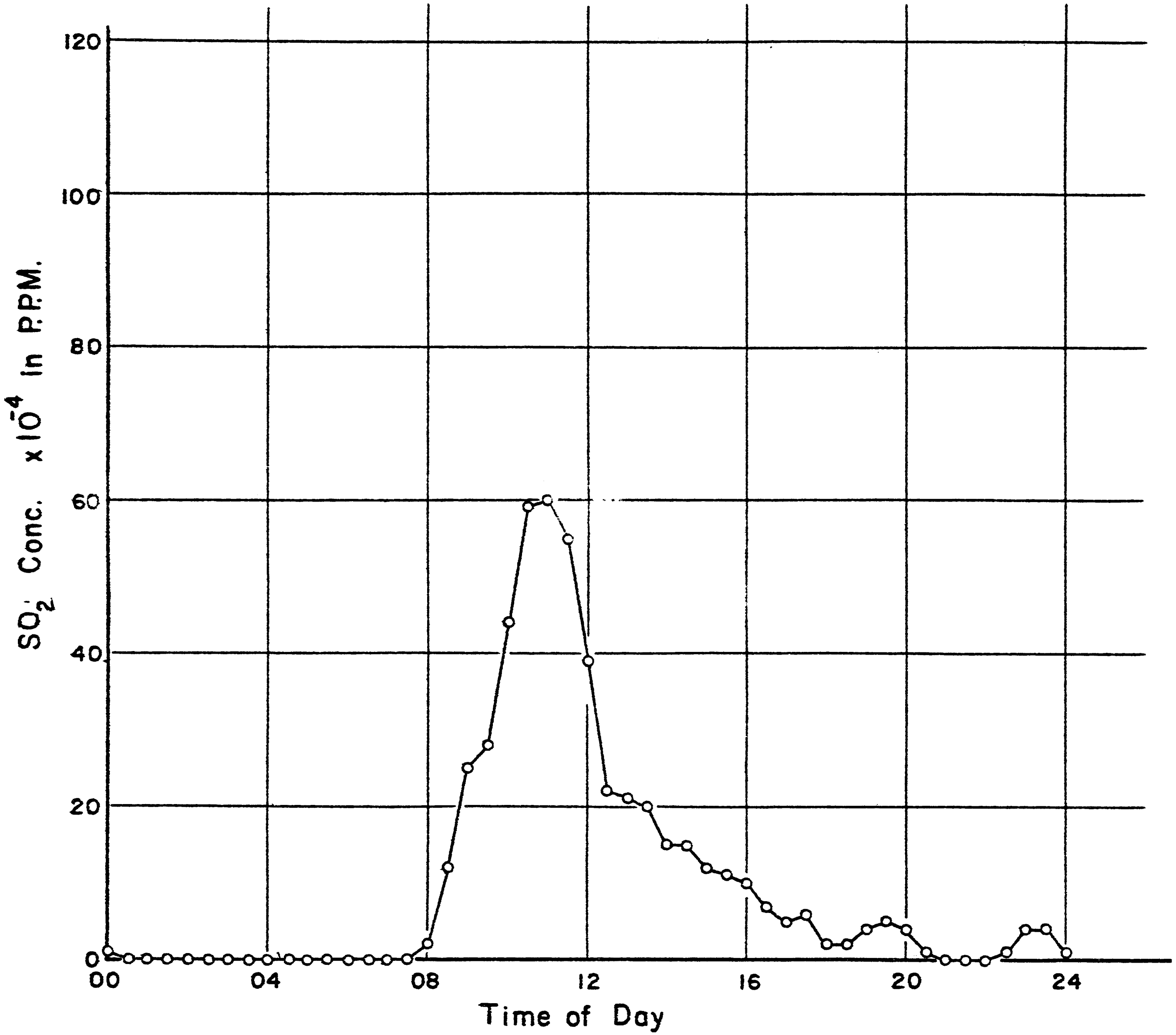


Fig. 22. Relative average concentration of $SO_2 \times 10^{-4}$ in ppm vs time of day: 1957, Summer.

TABLE XXXIV

FREQUENCY OF OCCURRENCE AND AVERAGE CONCENTRATION OF SO_2
FOR ALL WIND DIRECTIONS AND WIND SPEEDS GROUPED
ACCORDING TO TIME OF DAY

Public Service Company of Indiana
New Albany, Indiana

1 September 1957 - 30 November 1957
(Fall)

Time	Average Concentration (ppm)	Frequency of Occurrence	Time	Average Concentration (ppm)	Frequency of Occurrence
0030	.06	3	1230	.08	11
0100	.04	3	1300	.07	9
0130	.04	3	1330	.06	6
0200	.06	2	1400	.04	6
0230	.04	3	1430	.06	4
0300	.03	4	1500	.07	4
0330	.04	4	1530	.06	4
0400	T	6	1600	.04	6
0430	.04	4	1630	.04	8
0500	T	3	1700	.04	6
0530	.04	3	1730	.04	4
0600	T	3	1800	.06	2
0630	T	3	1830	.03	2
0700	T	3	1900	T	5
0730	.04	3	1930	T	3
0800	.04	3	2000	.03	4
0830	.03	7	2030	.04	4
0900	.06	11	2100	.06	2
0930	.07	11	2130	.08	2
1000	.06	12	2200	.05	3
1030	.06	14	2230	.05	4
1100	.06	16	2300	.05	5
1130	.09	15	2330	.04	4
1200	.09	13	2400	.04	3

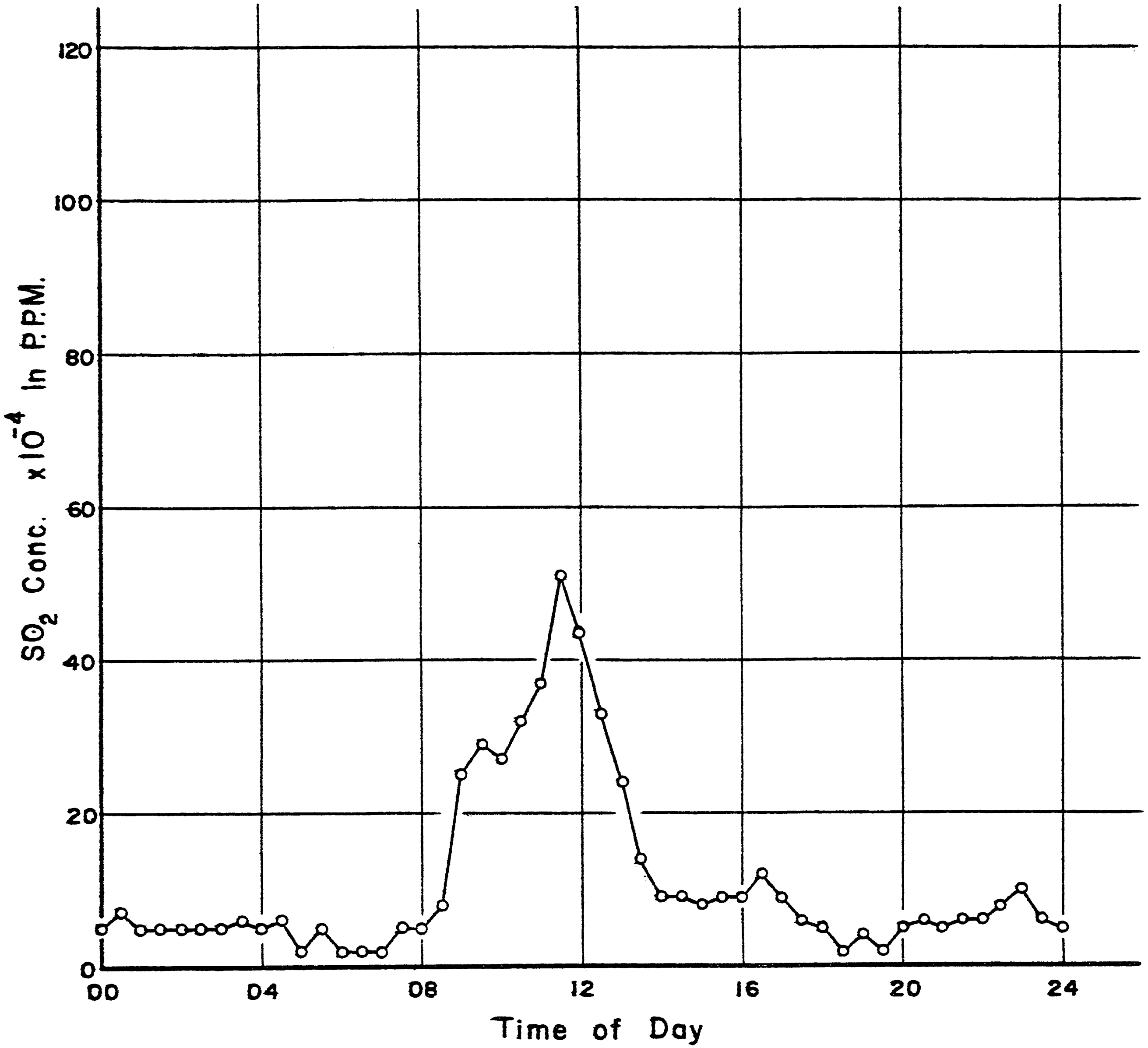


Fig. 23. Relative average concentration of SO_2 x 10^{-4} in ppm vs time of day: 1957, Fall.

TABLE XXXV

FREQUENCY OF OCCURRENCE AND AVERAGE MAXIMUM CONCENTRATION OF SO_2 FOR ALL WIND DIRECTIONS AND WIND SPEEDS GROUPED ACCORDING TO TIME OF DAY

Public Service Company of Indiana
New Albany, Indiana

1 June 1957 - 31 August 1957
(Summer)

Time	Average Maximum Concentration (ppm)	Frequency of Occurrence	Time	Average Maximum Concentration (ppm)	Frequency of Occurrence
0030			1230	.07	9
0100			1300	.07	7
0130			1330	.07	8
0200			1400	.05	6
0230			1430	.06	5
0300			1500	.06	5
0330			1530	.07	3
0400			1600	.06	3
0430			1630	.06	3
0500			1700	.05	4
0530			1730	.03	5
0600			1800	T	2
0630			1830	T	1
0700			1900	T	3
0730			1930	.05	2
0800	.04	2	2000	.04	2
0830	.06	5	2030	T	1
0900	.08	7	2100		
0930	.07	8	2130		
1000	.10	11	2200		
1030	.12	12	2230	.06	1
1100	.12	14	2300	.09	1
1130	.11	15	2330	.08	1
1200	.12	9	2400	.08	1

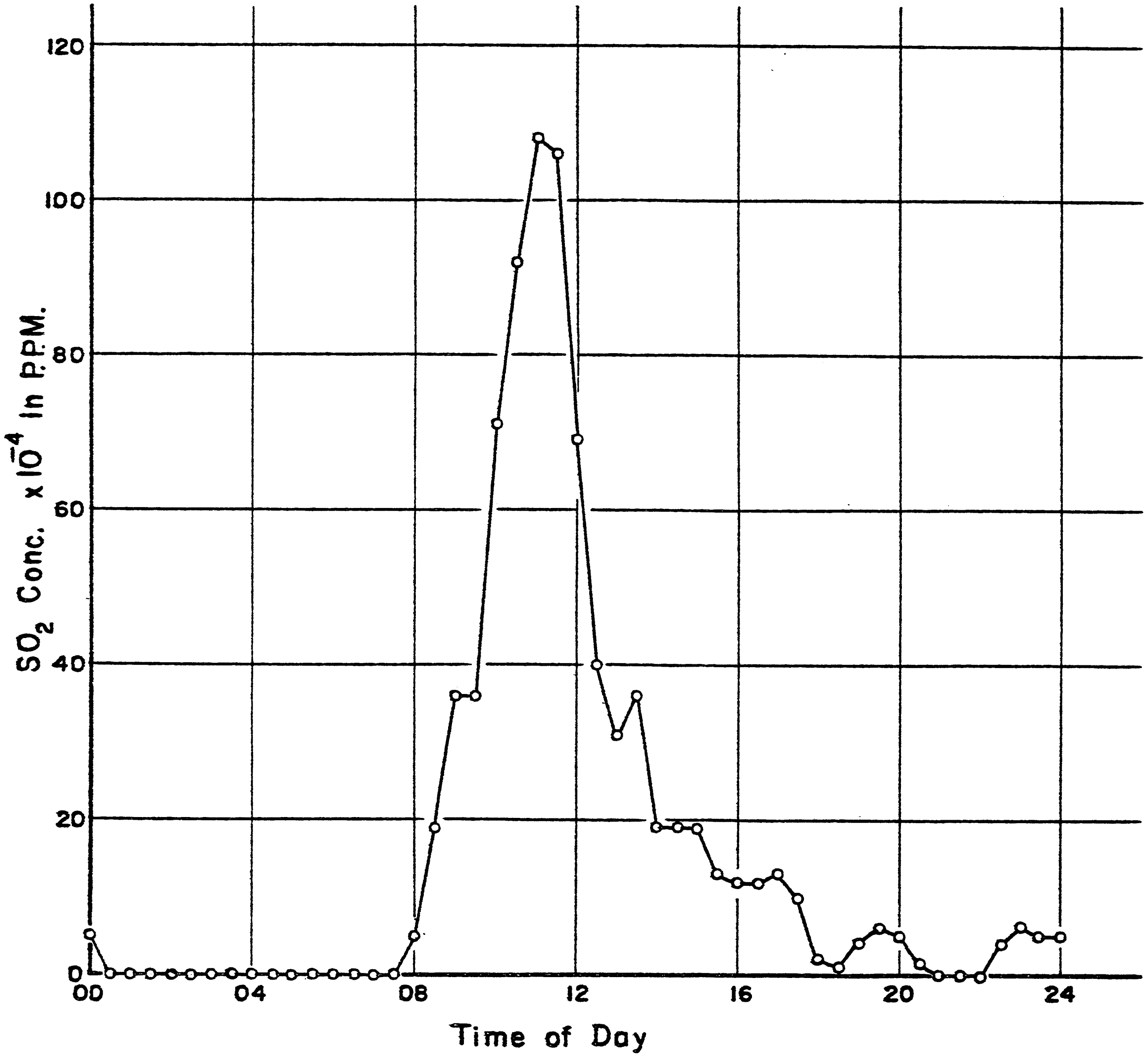


Fig. 24. Relative maximum concentration of $SO_2 \times 10^{-4}$ in ppm vs time of day: 1957, Summer.

TABLE XXXVI

FREQUENCY OF OCCURRENCE AND AVERAGE MAXIMUM CONCENTRATION OF SO_2 FOR ALL WIND DIRECTIONS AND WIND SPEEDS GROUPED ACCORDING TO TIME OF DAY

Public Service Company of Indiana
New Albany, Indiana

1 September 1957 - 30 November 1957
(Fall)

Time	Average Maximum Concentration (ppm)	Frequency of Occurrence	Time	Average Maximum Concentration (ppm)	Frequency of Occurrence
0030	.07	3	1230	.12	11
0100	.07	3	1300	.11	9
0130	.06	3	1330	.09	6
0200	.08	2	1400	.07	6
0230	.07	3	1430	.09	4
0300	.06	4	1500	.08	4
0330	.06	4	1530	.08	4
0400	.05	6	1600	.06	6
0430	.05	4	1630	.06	8
0500	T	3	1700	.04	6
0530	.07	3	1730	.06	4
0600	.05	3	1800	.07	2
0630	.05	3	1830	.03	2
0700	.04	3	1900	.04	5
0730	.06	3	1930	.05	4
0800	.06	3	2000	.05	5
0830	.06	7	2030	.07	4
0900	.08	11	2100	.08	2
0930	.10	10	2130	.09	2
1000	.07	12	2200	.06	3
1030	.08	14	2230	.07	4
1100	.09	16	2300	.06	5
1130	.13	15	2330	.06	4
1200	.13	13	2400	.06	3

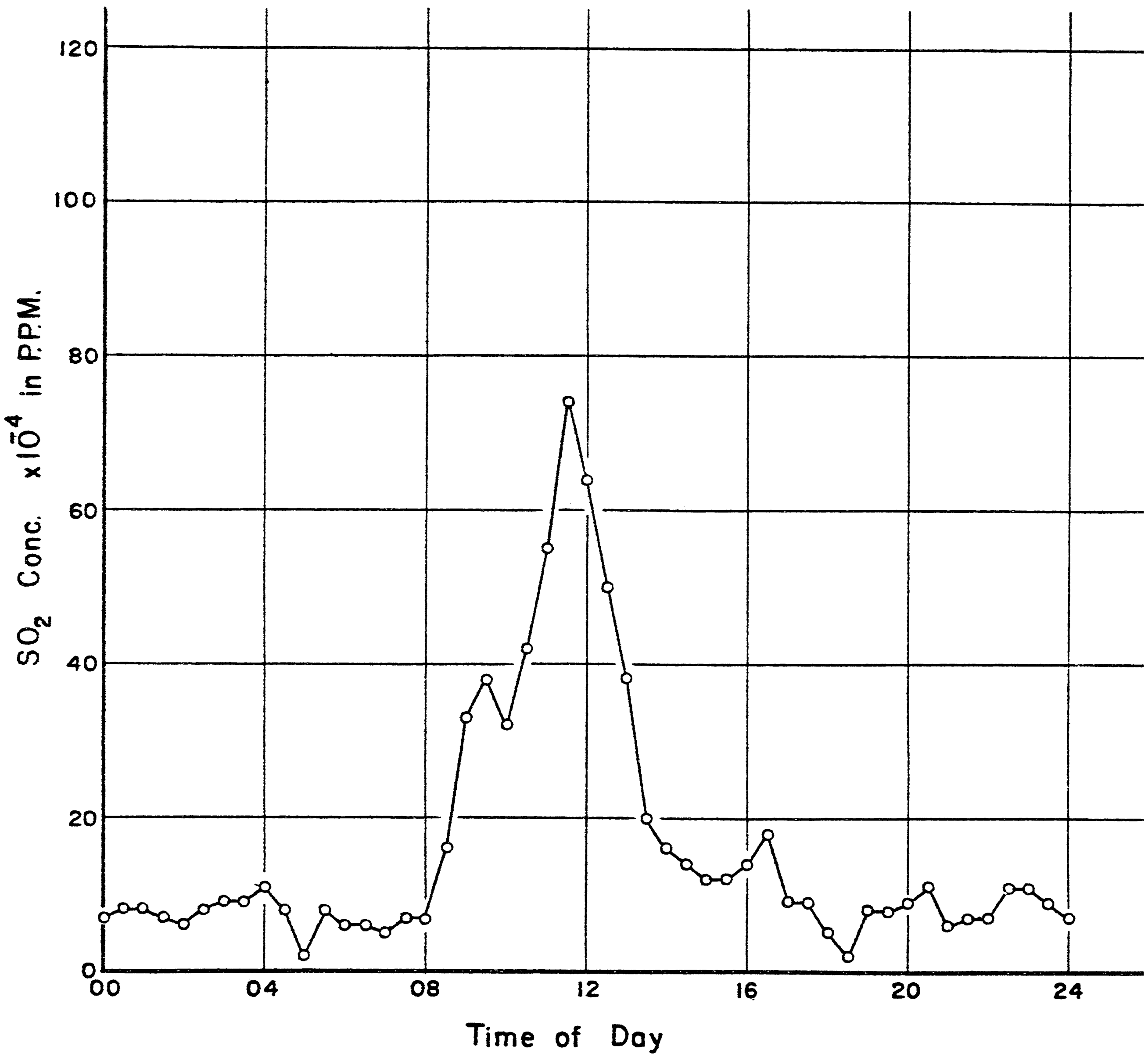


Fig. 25. Relative maximum concentration of SO_2 x 10^{-4} in ppm vs time of day: 1957, Fall.

TABLE XXXVII

OBSERVATIONAL DATA FROM 21 OCTOBER 1957
MEASURED AT NEW ALBANY PLANT SITE AND SILVER HILL

Time, hour ending at	Wind Direction	Wind Speed, mph	SO_2 Concentration, ppm	
			Average	Maximum
0030				
0100	Calm			
0130				
0200	NNE	2		
0230				
0300	NNE	2		
0330				
0400	NNE	1	T	.05
0430			T	T
0500	NNE	2		
0530				
0600	Calm		T	.05
0630			.04	.05
0700	Calm		.04	.05
0730			.06	.08
0800	Calm		.07	.10
0830			.05	.08
0900	Calm		.08	.11
0930			.09	.13
1000	SSW	3	.10	.12
1030			.10	.12
1100	S	4	.15	.22
1130			.38	.50
1200	SSE	2	.32	.42
1230			.38	.48
1300	SSE	2	.26	.35
1330			.12	.20
1400	SSE	3	.10	.14
1430			.11	.17
1500	S	8	.15	.17
1530			.10	.15
1600	SSE	3	.05	.10
1630			.07	.10
1700	SSE	7	T	T
1730				
1800	ESE	4		
1830				
1900	SE	3		
1930				
2000	SSE	2		
2030				
2100	S	2		
2130				
2200	ESE	2		
2230				
2300	SE	2		
2330				
2400	SSE	2		

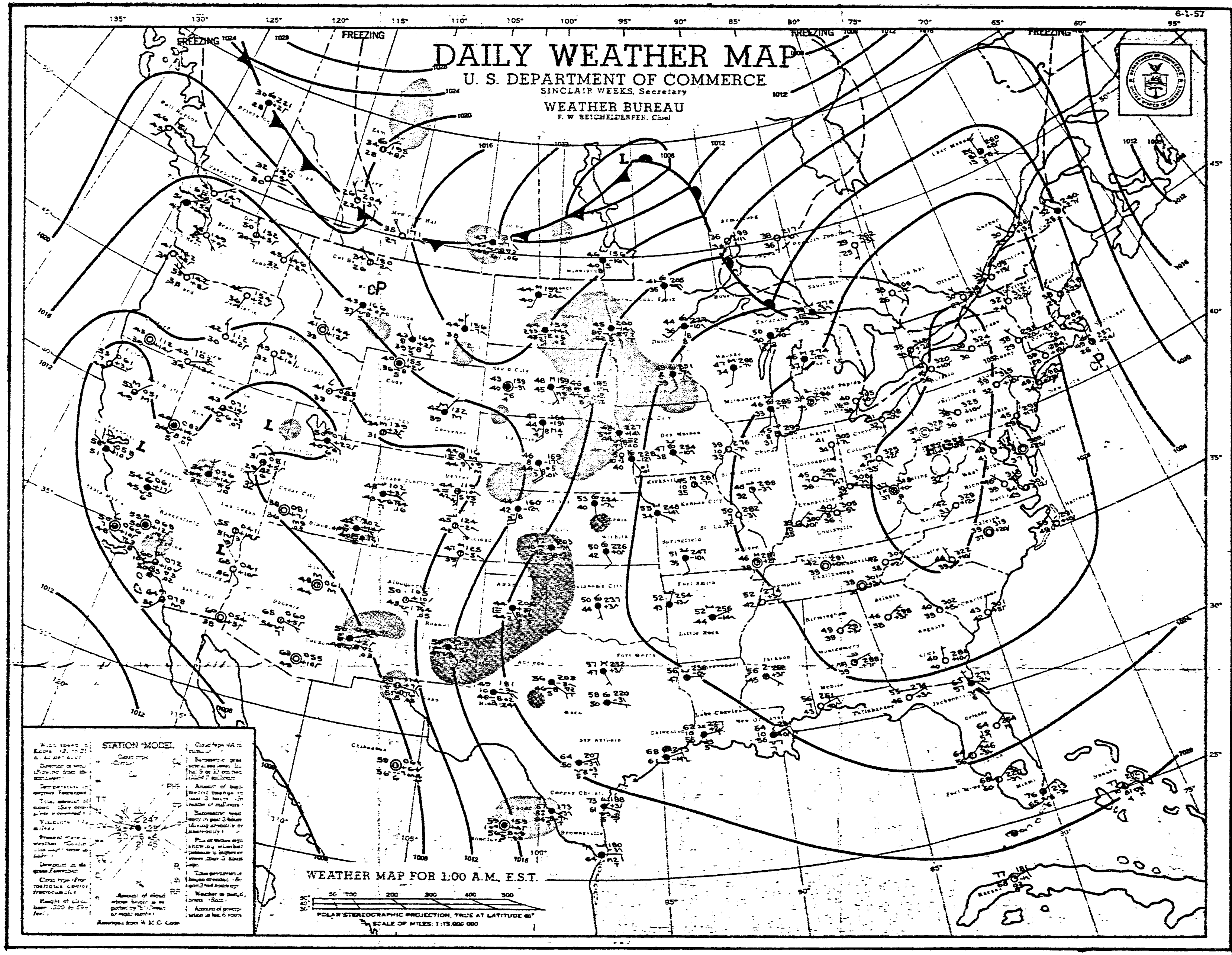


Fig. 26. Synoptic surface map, 0100 EST, 21 October 1957.

CONCLUSIONS

Upon the completion of the analysis of 13-1/2 months of data from the New Albany plant site, the following conclusions may be drawn and their value assessed relative to the air-pollution problem in the local area. NOTE: Many of these conclusions are based on the assumption that wind speeds, directions, and turbulence are highly correlated with those at heights where the stack effluents will flow. Projected wind measurements at these heights may lead to revisions of these conclusions.

1. WIND

a. The valley effect is the predominant factor in the wind direction distribution at 104 ft above the ground. The wind blows from the NNE 16.9% of the time during the year and from the SSW for 14.9% of the year. Thus the down-valley and up-valley winds are felt for one hour out of every three hours throughout the year. This valley effect is favorable with respect to the air-pollution problem at Silver Hill if it extends to the height of stack effluents because it lessens the number of southerly winds that occur in the area. An unfavorable aspect is that such a distribution may move more pollution toward the City of New Albany.

b. The plant site experiences a great number of calm wind conditions. In fact, for 8.5% of the year the wind is recorded as calm. Calm conditions prevail generally at night and during the early morning hours. Diffusion of stack gases takes place very slowly during calm conditions and moderate to high concentrations of pollutants tend to build up in local areas.

c. Wind speeds are noticeably lighter at the plant site than at other nearby weather stations such as Standiford Field for the same period of time. Fewer high winds will cause less aerodynamic downwash which might bring stack effluents to the ground. On the other hand, light winds cause poor diffusion in the atmosphere so that high concentrations of a pollutant may be found at one particular point.

d. The wind data from Standiford Field should not be used for computational or comparison purposes at the plant site because of basic differences in the wind regimes at the two observational points. This condition does not affect the air-pollution problem at the plant, but it does point out the need for recomputation of the number of hours of downwash to be expected at the plant site. Such a recomputation will be performed as soon as a year of data has been collected from the wind-measuring equipment located on top of the stack.

e. A seven-year wind record does not appear to be sufficient to establish a stable frequency distribution of wind speed and wind direction at a continental station such as Standiford Field; it indicates that perhaps 10 or 15 years of record might be needed at the site itself to establish stable distributions of wind speed and wind direction.

2. TURBULENCE

a. The surrounding topography of the area plays a very great part in the creation of mechanical turbulence for all wind trajectories from SW through NW to N. Turbulence tends to be a favorable characteristic in a potential air-pollution situation because the turbulence causes the pollutant to diffuse, and become mixed with other clean air in the atmosphere. Since any of the above-mentioned wind directions have trajectories across the plant site and then to highly populated areas, the creation of the turbulence is regarded as favorable in minimizing air pollution.

b. Heat sources such as the nearby cities seem to create some turbulence of a thermal nature. This turbulence occurs with winds from the NNE through E to the SE. Again the formation of any turbulence may be regarded as a favorable condition.

c. The gust count varies as the square of the wind speed. This conclusion is a first step in developing a set of criteria based upon weather parameters that will give an indication of the diffusion potential of the atmosphere for a specific period of time at the site. Thus a doubling of the wind speed produces a quadrupling of the gust count and a large increase in the diffusion capacity of the atmosphere.

d. The importance of the lapse rate or the vertical temperature gradient and the roughness of the surrounding terrain in the formation of turbulence becomes less as the wind speed increases. The magnitude of the effect of lapse rate on the production of turbulence has not been assessed as yet. The effect of the roughness must be quite large because the terrain is generally rugged. The relation of wind speed, lapse rate, and topography to the gust count will become more evident after the thermocouples have been mounted on the stack. However, all three of these factors interact in the production of turbulence at the plant site.

3. PRECIPITATION

a. Precipitation may cause an increase in concentration at a particular point due to rainout or washout. Such an event may be viewed as favorable or unfavorable depending upon where such rainout or washout might occur.

b. The distribution of rainfall according to wind direction is determined largely by the topography surrounding the plant site. Most of the precipitation, about 33%, occurs with NNE or SSW winds. Thus a large percentage of the rainout or washout will occur over unpopulated areas. The remaining wind directions have limited rainfall associated with them owing to the rain shadow caused by the surrounding hills. Thus the City of Louisville and the Silver Hill area would receive little washout or rainout from precipitation.

c. Wind speeds have been observed to be of moderate values, 7-10 mph, when precipitation occurs. Washout or rainout of a pollutant over any one particular area will be relatively less at such speeds than with lighter winds.

4. SULFUR DIOXIDE

a. Sulfur dioxide in small concentrations over long periods of time may be harmful to both plant and animal life. The adsorption of SO_2 gas upon aerosols poses an important health hazard to human beings. These factors must always be kept in mind whenever the air pollutant is sulfur dioxide.

b. One or more sources of SO_2 from an area south of the plant site are shown to exist. These result in the SO_2 background in the area being a measurable quantity. It is important to obtain the maximum amount of information about these background values and the associated meteorological conditions before the new plant goes into operation.

c. The maximum value of SO_2 concentrations are received at Silver Hill near noon, indicating a lag of about two hours in the normal time of the fumigation peak. Such a lag is desirable because the concentrations are quite dilute by the time they reach the Silver Hill area.

d. The times of maximum concentrations of SO_2 are periods in which there is a large high-pressure area over the east central portion of the United States. The pressure gradient is always weak, and what little wind there is blows predominantly from a southerly direction. Such synoptic conditions lead to high background air pollution at the plant site.

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