AIR QUALITY AT AN ELECTRIC-ARC STEEL MANUFACTURING PLANT

by

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CHAPTER I

INTRODUCTION

A generally accepted definition of air pollution states that air pollution is any material emitted into the atmosphere by other than natural sources that creates a condition which is detrimental to human health or welfare. This would include any element or compound that adversely affects animals, plants, property, or aesthetic surroundings either directly or indirectly. There are many pollutants present in the atmosphere, but only a few are considered feasibly measurable and controllable by current methods. These pollutants are particulate matter, sulfur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (H/C), and photochemical oxidants such as ozone (O_3). The Unites States Environmental Protection Agency (EPA) has set forth ambient air standards to limit the concentrations of each of these pollutants that may exist in the atmosphere. These standards are based on criteria developed from medical studies conducted in areas of relatively high pollution levels and on controlled scientific experiments using animals, plants, and materials that may be adversely affected by pollutants in the atmosphere.

Since it would be very difficult to obtain continuous measurements of the concentrations of pollutants at all points in the atmosphere, the EPA has established reference methods for each pollutant which specify sampling frequencies and procedures. These reference methods are incorporated into the Code of Federal Regulations and subsequently

published in the United States Federal Register[1]. This standardization of procedure provides industry, government agencies, and others with feasible means to determine the approximate levels of pollution in order to compare them with the appropriate standards. Based on these comparisons, pollution sources can be identified and control measures can be enacted to achieve compliance with the standards for each pollutant. Individual states have the responsibility and authority to enforce these standards or more stringent ones.

The iron and steel industry contributes certain types of pollutants to the atmosphere. It has been found that, without some means of control, manufacturing plants in the iron and steel industry can cause atmospheric pollutant concentrations to exceed the allowable limits specified in the ambient air standards.

There are two principal types of steel manufacturing facilities, integrated and secondary. Integrated plants produce iron from ore, then convert the iron to steel in a separate operation. Secondary steelworks smelt no ore, but produce steel by remelting scrap steel and repeating the refining steps. Most steel in the United States today is produced in integrated steel plants. These integrated plants are outnumbered, however, by smaller secondary steelworks with melting furnaces and small rolling mills. Steel manufacturing plants normally use one of three major processes which are characterized by different types of melting furnaces. These are open-hearth furnaces, basic oxygen furnaces, and electric-arc furnaces. The present study was conducted on the premises of an electric-arc, secondary steel manufacturing plant.

Electric-arc furnaces employed in the steel making process are cylindrical, refractory lined vats with a dish bottom and a flat dome roof as shown in Figure 1. The electric-arc furnace is used to produce steel with a wide range of compositions because of the flexibility of operation provided by accurate control of temperature and time of reaction for producing the desired alloy composition. Low grade scrap can be charged and refined to meet necessary structural standards because of close control provided by the furnace. A typical furnace charge is presented in Table I.

Since the furnaces are generally kept extremely hot, except when they are allowed to cool for relining, dust and fumes from the scrap charging operation escape into the atmosphere. The heat for melting and heating the charge is supplied through three externally supported carbon electrodes that are automatically raised and lowered through holes in the furnace roof. Intense heat is produced by the current arcing between the electrodes and the metal charge. This action coupled with resistance heating brought about by current flow through the charge results in melting and super-heating of the charge. The melt temperature reaches 3000 F. Particulate emissions during melting are composed of volatile matter from the scrap charge including grease, oil, and oxides of metals with high vapor pressures. This process is illustrated in the flow diagram in Figure 2.

Meltdown of the charge occurs under oxidizing conditions in order to effect removal of phosphates and to achieve a good carbon boil after complete meltdown. The oxygen for the oxidizing reactions

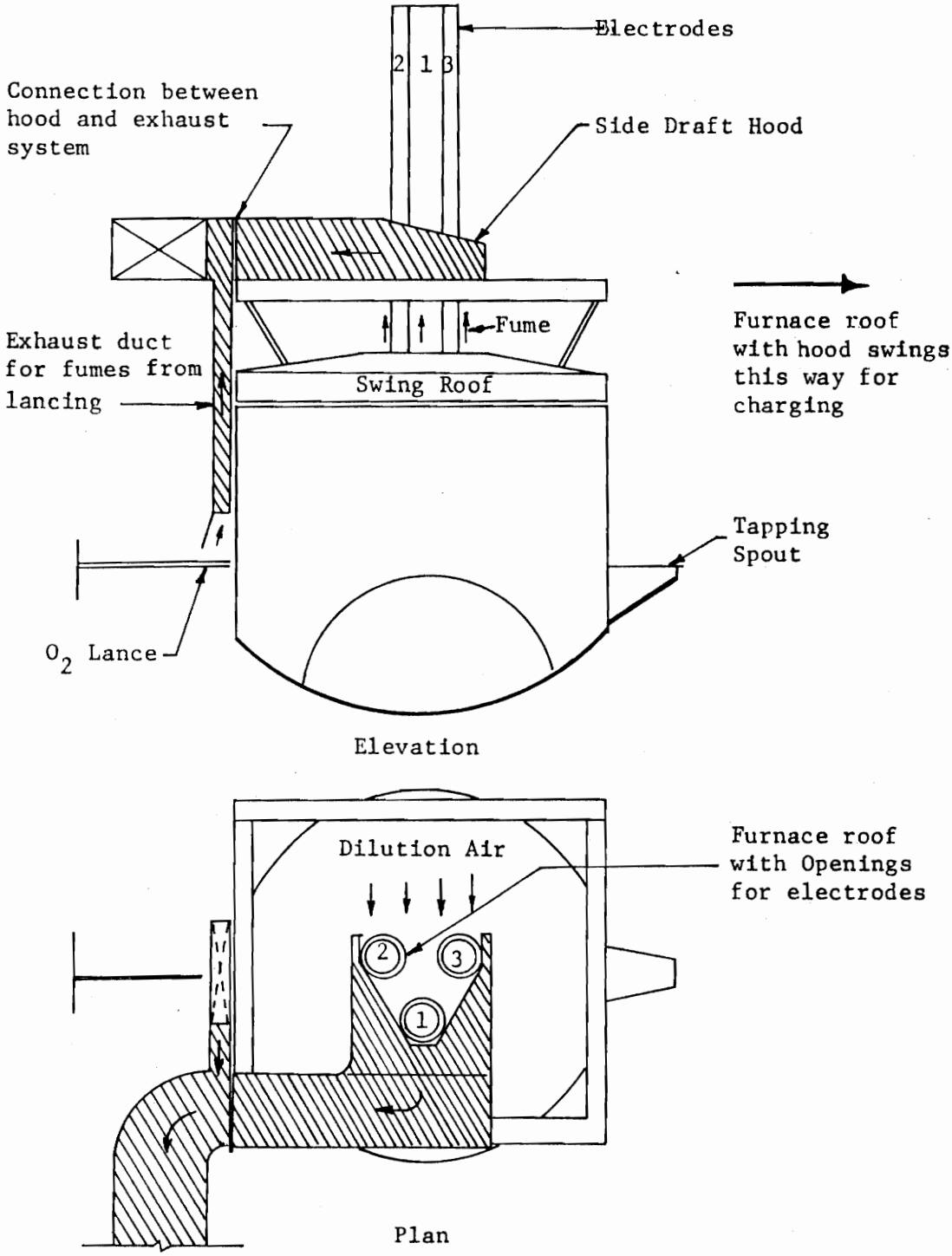


Figure 1. Electric Arc Furnace Equipped with Side Draft Hood.

Table I

TYPICAL CHARGE FOR AN ELECTRIC-ARC FURNACE[2]

Material	Weight (percent)
Fluxes, carbon and ore	5
Turnings and borings	7
Home Scrap	20
No. 2 baled scrap	25
Miscellaneous Scrap (auto, etc.)	43

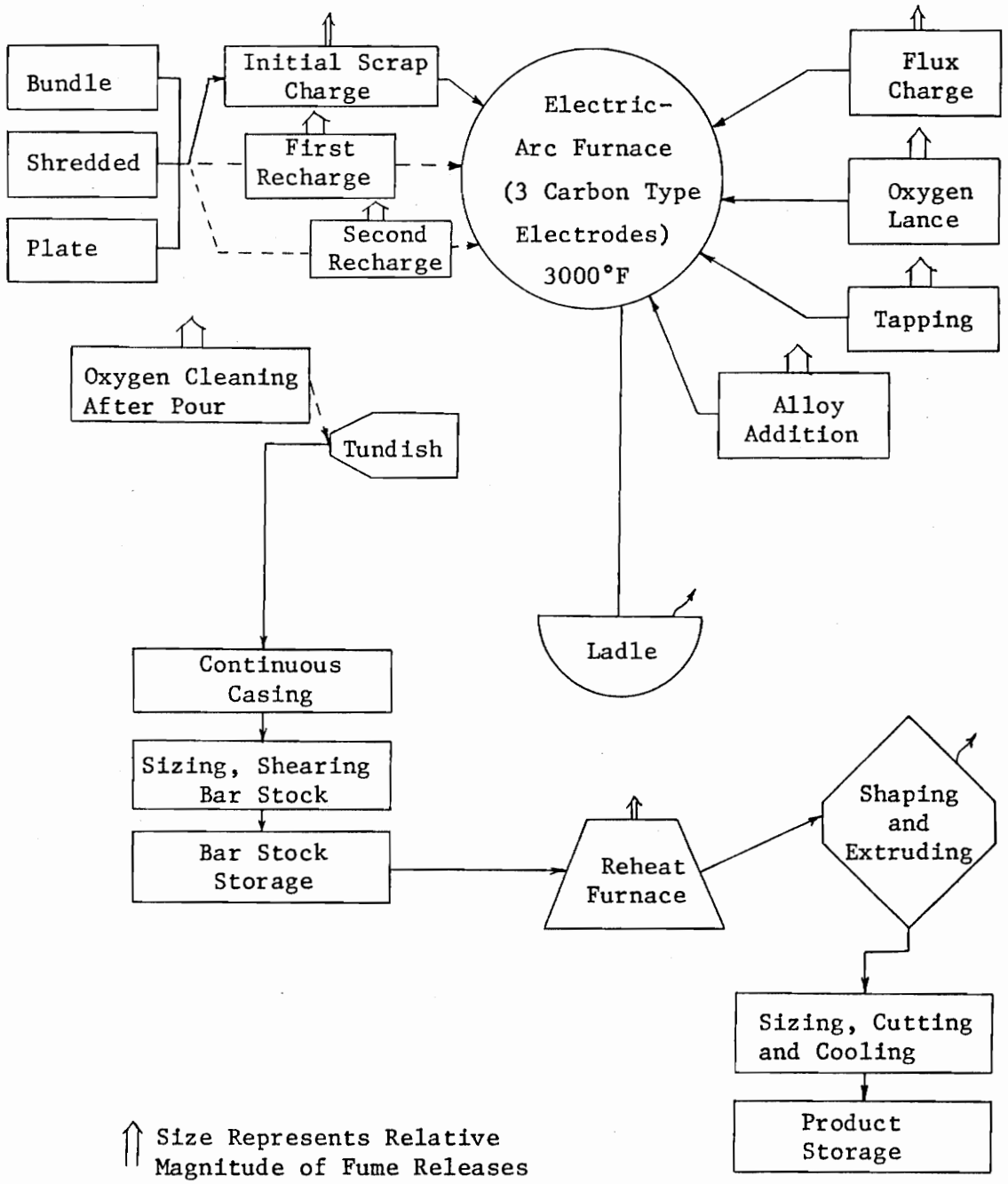


Figure 2. Flow Diagram of Secondary Steel Manufacturing Process.

occurring before and during the carbon boil is obtained from (1) the oxygen lance injected into the bath after meltdown, (2) oxygen from the furnace atmosphere, (3) decomposition of the lime in the charge, (4) oxides of alloying elements used in the charge, and (5) iron ore or mill scale used in the charge or added after meltdown.

The oxygen lance used is very important because of the rapidity with which the carbon boil may be initiated and oxidizable components removed from the melt. The temperature of the bath is also increased during the lancing, promoting carbon removal, and increasing the fluidity of the bath. The reaction of the oxygen with carbon in the melt forms CO gas that gives rise to the carbon boil benefitting the purge of hydrogen and nitrogen. Also the oxygen combines with silicon, manganese, and zinc in the melt and produces furnace atmospheres containing CO, some free O_2, CO_2, and hydrogen.

After the initial scrap load has been melted down, considerable additional scrap is added as a recharge. Usually there are two recharges per melt; each time the furnace is recharged there are considerable dust and fume emissions. When the meltdown is finished, the oxygen lance is used for the carbon boil which causes another period of dust and fume emission. Subsequent tapping of the inlet for sampling melt conditions, alloy addition, slag removal, and pouring of the molten steel into the ladle for transport to the casting operation are other periods of emission. The ladle is usually moved by crane to a casting machine. Casting is a lower temperature process than the meltdown and emissionsare negligible with the

exception of cleaning the tundish nozzle with oxygen lancing at which time considerable fumes are emitted.

The oxygen cleaning of casting machines is performed to remove solidified metal from the tundish nozzles at the end of the cast and is similar to the deseaming process in which flaws are removed from billets by an oxygen flame. Quantities of sub-micron iron oxide fumes are generated and subsequently entrained in low temperature air. The evolution rate of the fumes is dependent on the composition of the cast material and the quantity of oxygen used.

The casting operation produces continuous bar stock which is fed down to the process line where it is gaged and sheared. The cut bar stock is fed down the line by roller transport and is removed by fork lifts to a temporary storage area where it is allowed to cool. Then the bar stock is transported to a reheat furnace and reheated to 1000 F. by combustion of natural gas or oil. The main pollutant from this step is generally sulfur dioxide. The red hot bar stock is then extruded by a high pressure hydraulic ram to form structural reinforcing rods or is worked by other means to form other similar products. Hand working of the bar stock involves the use of a water spray that is evolved to steam emission. The final product is removed to a storage area where it remains until shipment to the consumer.

Electric furnaces without emission controls emit an average of 11 pounds of fume for each ton of steel produced. The size distribution and chemical composition of the fume are shown in Table II.

The majority of emissions occur when the cold scrap comes in contact with the hot electrodes or the molten steel which is already

Table II

TYPICAL EMISSIONS WITH SIZE DISTRIBUTION OF DUST AND FUME FROM ELECTRIC-ARC FURNACES[3]

Material	Weight (percent)
Zinc Oxide	37
Iron Oxide	25
Lime	6
Manganese Oxide	4
Alumina	3
Sulfur Trioxide	3
Silica	2
Magnesium Oxide	2
Copper Oxide	0.2
Phosphorus Pentoxide	0.2

Diameter (u)	Weight (percent)
0 - 5	72.0
5 - 10	10.5
10 - 20	2.7
20 - 40	4.7
> 40	10.1

in the furnace and when the molten steel is poured from the furnace into the ladle. Most plants have taken measures to control the emissions by installing fabric filters, electrostatic precipitators, or wet scrubbers. Before the emissions can be collected, they must first be captured through some suitable hooding arrangement at the furnace[4]. Many of the hooding arrangements used are not effective during such evolutions as charging, oxygen lancing, and tapping.

The plant observed in this study produces an average of 600 tons per day of merchant steel in the form of angle irons, reinforcement rods, and steel ingots. The raw materials used are similar to those in Table I, except that scrap containing zinc has been practically eliminated. This results in emissions containing about 60 percent iron oxide by weight.

The plant operates a 5000 kva, a 7500 kva, and a 13,000 kva furnace and two casting machines. The emission from the 5000 kva furnace are evacuated by direct shell eduction and the emissions from the furnaces are captured by the side-draft method. This system consists of a large duct that extends from the side of the furnace to the area where the electrodes enter the furnace through the roof. A side-draft arrangement is shown on the furnace in Figure 1. High-velocity indraft air is generated to capture the emissions released around the electrodes. Once captured, the emissions travel through a large duct to a fabric filter baghouse for collection. The side-draft method has no capability to capture emissions generated during the charging and tapping phase because the system must be disengaged

when the furnace roof is removed.

There are no controls on the two casting machines or on the oil fired reheat furnace. A partial plant layout is presented in Figure 3 with equipment description in Table III.

The melt shop shown in Figure 3 is a large steel building covered with corrugated steel panels. The building has a row of open windows along one side and is open at both ends. Emissions released from the furnaces, not captured by the hooding arrangement, are allowed to escape through the openings in the building. These metallurgical fumes are characteristically finer in particle size, higher in opacity, and otherwise more complex than other process emissions such as those from power generation. Dust and dirt from scrap is compounded with the fumes from the oxidizing reaction that converts iron to steel. The electric-arc process, accelerated with injected oxygen, can generate a plume of red iron-oxide dust visible for many miles.

Since the most obvious emissions are in the form of particulates, it was decided to sample the ambient air in the vicinity of the plant and make comparisons with the current standards for suspended particulates. These standards, set forth by the EPA, are classified as primary standards and secondary standards. Primary standards are based on human health criteria and secondary standards on effect on inert material and life other than human. The national primary ambient air quality standards for particulate matter, measured by the EPA reference method for suspended particulates, are (1) the concentration of particulates in the ambient air shall not exceed 75

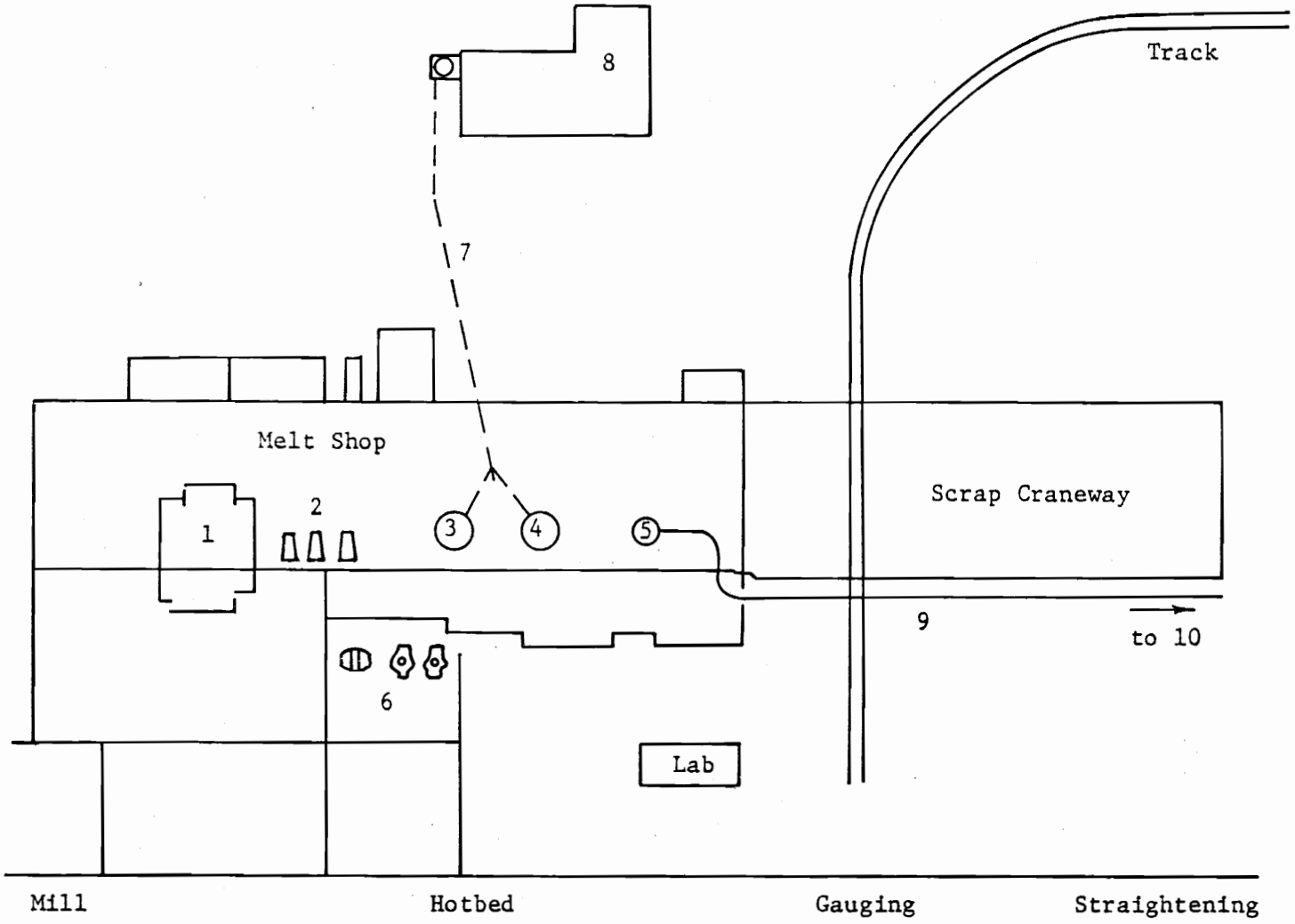


Figure 3. Partial Plant Layout of Facility under study. [Legend on next page]

Table III

LEGEND SHOWING EQUIPMENT DESCRIPTION

Number	Description
1	Danieli Casting Machine: Three strand type (3-1/2 x 3-1/2 to 6" x 6")
2	Reheat Furnace: 2 zone, 25 ton per hour capacity; 13' x 45' hearth producing 60 x 10^6 Btu/hr.
3	Electric Furnace: No. 3, 18 ton capacity, 11' diameter; 13,500 kva.
4	Electric Furnace: No. 2, 18 ton capacity, 11' diameter; 7,000 kva.
5	Electric Furnace: No. 1, 9' diameter; 5,000 kva.
6	Babcock and Wilcox Casting Machine: two strand (3" x 3" to 6" x 6")
7	Ductwork to Baghouse Filter: 7' dia. about 210' long.
8	Large Baghouse collector (serving 18 ton furnaces); Carborundum Co. type consisting of 2 rectangular sections in parallel containing 3800 bags (each 5" diameter x 14' long) using mechanical shaker cleaning and forced draft collection via centrifugal fan driven by 600 Hp motor (170,000 cfm).
9	Ductwork to baghouse filters: 3' diameter x about 430' long.
10	Small baghouse collector (serving small furnace): American Air Filter Company type consisting of 2 cylindrical sections about 10' in diameter and connected in parallel with by-pass and exhaust stack; each section uses 42 bags 1' diameter x 31' long of silicon impreginated dacron type and employs reverse air flow cleaning. Collection is by forced draft centrifugal fan (36,000 cfm capacity) driven by 200 Hp motor.

micrograms per cubic meter - annual geometric mean and (2) the concentration of particulates in the ambient air shall not exceed 260 micrograms per cubic meter, maxium 24-hour concentration more than once per year. The national secondary ambient air quality standards for particulate matter, as measured by the EPA reference method, specifies a maximum annual geometric mean of 60 micrograms per cubic meter and a maximum 24-hour concentration of 150, not to be exceeded more than once per year. At the time of this study, the national secondary standards had not yet been implemented and, therefore, comparisons are made only with the primary standard.

The reference method for the sampling of suspended particulates in the atmosphere requires the use of the HI-VOLUME sampler. In this method, air is drawn into a covered housing and through a filter by means of a high-flow-rate blower at a rate (40 to 60 cubic feet per minute) that allows suspended particles having diameters of less than 100 microns to pass to the filter surface. Particles larger than 100 microns tend to settle rapidly and, therefore, are found only short distances from the source. A schematic representation of the High-Volume sampler is shown in Figure 4.

By placing a number of these HI-VOLUME samplers at strategic locations in the vicinity of the plant and sampling at regular intervals, an indication of the plant's effect on the surrounding air quality may be found. Since the direction and speed of the wind blowing during a sampling period would have considerable effect on the concentrations of suspended particulates at different locations,

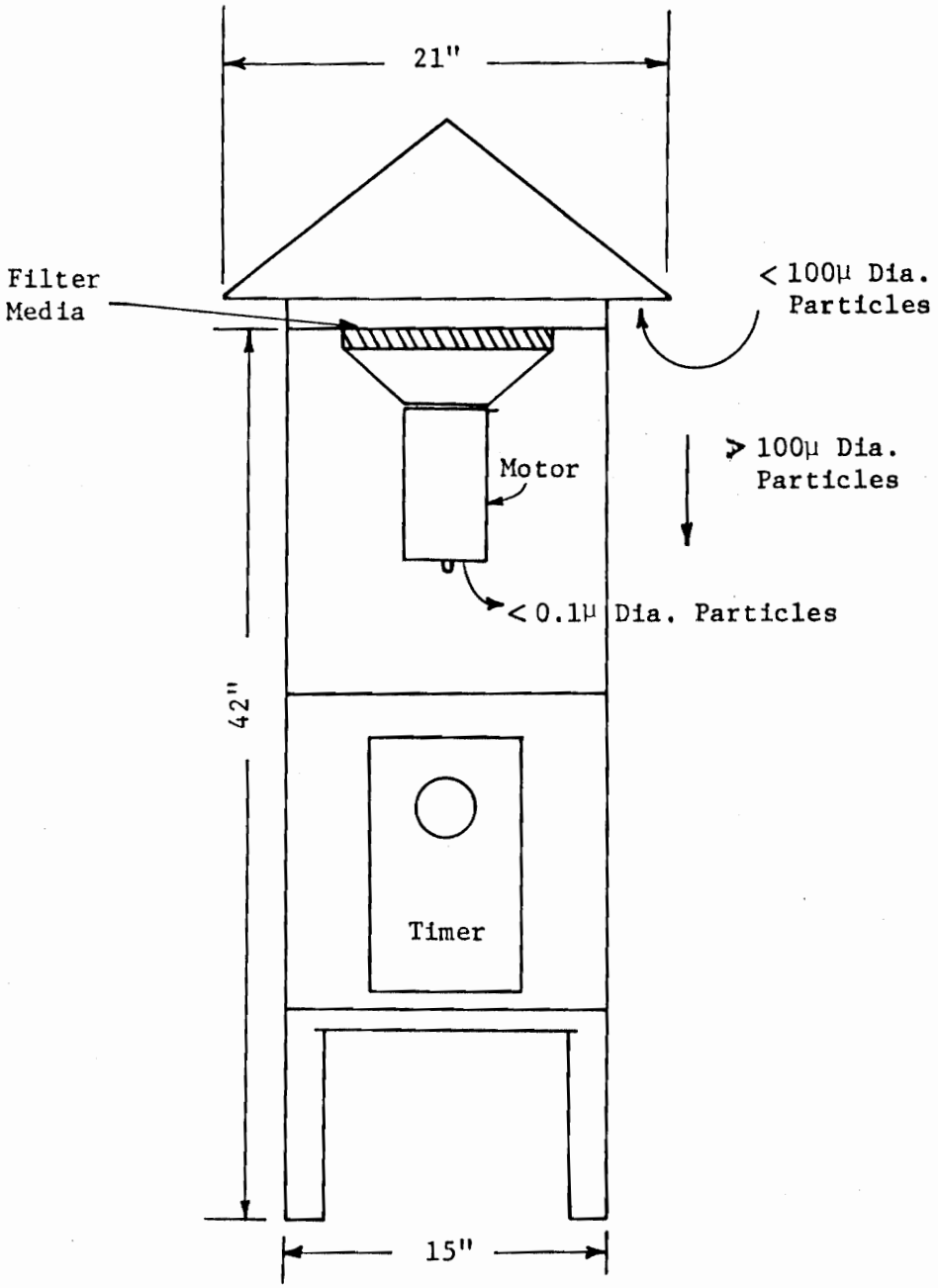


Figure 4. Schematic Representation of High Volume Sampler.

a means of measuring the wind variations was needed.

The objectives of the study were to (1) determine the quality of the ambient air in the vicinity of the steel manufacturing facility, (2) find a correlation between the suspended particulate concentrations for each sampling day and the wind direction and speed obtained at the facility, (3) find a correlation of the particulate concentrations obtained at each sampler with wind direction and atmospheric stability conditions using meteorological data obtained from the local weather bureau, (4) determine the geometric mean for the samples collected at each sampling location for comparison with the national standard, (5) determine a background level, and (6) show a relationship between mean particulate concentration and distance from the source of emissions and using average wind speed, and average stability class, determine an approximate rate of emission from the plant for comparison with the local standard.

CHAPTER II

LITERATURE SURVEY

One method of sampling ambient air quality for suspended particulates is that of measuring particle concentrations and correlating those concentrations with the daily prevailing winds. For example, Susman, et al.[5] used high volume samplers to measure the concentrations of beryllium at different distances and directions from a beryllium plant. Wind data from a U. S. Weather Station 4.5 miles (7.2 kilometers) away were used after checking their accuracy with a meteorological field station placed near the plant. The daily prevailing winds were correlated with the beryllium concentrations collected on the samplers and were presented as concentration roses. The results showed a definite relationship between the concentrations at the different locations and prevailing wind directions. Holtaway[6] set up sampling stations at the four points of the compass around the periphery of a foundry. Samples were collected using the high volume method and electrostatic precipitators. A strong correlation was obtained between the two, so the use of the high volume sampler was discontinued. No local wind measuring device was used and samples were taken only when the wind appeared to be steady from one direction. Concentrations of particulates were found to be higher at those locations downwind of the foundry. Stewart and Matheson[7] correlated high volume sampling in a city with wind direction using the prevailing wind for each sampling. The winds were separated into those

blowing from the north sector of the city and those blowing from the south sector. Isopleths of concentrations were plotted using all available samples, samples on those days with a north wind, and samples on those days with a south wind. A significant conclusion of this study was that prevailing winds could not be used if the wind varied during the sampling period. The method of sampling and wind data reduction used in the present study was developed in order to overcome the disadvantages of using the prevailing winds as in the previous studies.

Methods of selective sampling and continuous wind recording to discern background levels from the ambient concentrations were used by Alcocer, et al.[8] and Burt and Gueho[9]. Alcocer placed a high volume sampler in a location near a cement manufacturing plant where complaints about the dust from the plant had been registered. A second sampler was placed directly opposite the first on the other side of the plant. An automatic wind direction control system was installed at the source. As long as the wind blew from one sampler, across the source, to the other sampler, the samplers were allowed to operate. If the wind shifted, the control system would shut off both samplers. This method isolated the sampling process to show plant produced particulates plus background particulates on the downwind sampler and only background particulates on the upwind sampler. Burt and Gueho[9] used six high volume samplers along the property line of a hot mix asphalt plant. A mechanical weather station with recorder was also used. The results revealed that the plant area was too irregular to

get a true indication of the wind and that sampling stations should include a sampler elevated from the others to detect the presence of plume looping, fumigation, or aerodynamic downwash. A conclusion was that, by most laws, the levels of concentrations are not necessarily the results of the upwind sampler subtracted from the downwind sampler, but the average quality of air within a specific area. These procedures for sampling and wind correlation were modified in the present study to conform to the operations of the steel manufacturing plant and the sampling equipment available.

CHAPTER III

ANALYTICAL PROCEDURES AND TECHNIQUES

A. High Volume Sampling Method

1. Particular Physical Procedures

Suspended particulate samples were collected and processed by the High Volume Sampler Reference Method in accordance with Environmental Protection Agency procedures stated in the Federal Register. General Metal Works[10] Model GMWL-2000 samplers in aluminum cabinets with automatic timers were used. Samplers were calibrated with the recommended orifice calibration procedure. The filters used were Type A, Glass Fiber, manufactured by Gelman Instrument Company.[11] They were inspected, stamped with an identification number, and then desicated for a minimum of 24 hours at less than 55 percent relative humidity.[12] The filters were then tared with a balance and placed in envelopes appropriately marked with the identification numbers until ready for use. All timers were set to operate the samplers from midnight to midnight to Sundays, Tuesdays, and Thursdays. This allowed the filters to be changed on normal working days. The collected samples were placed in the dessicator for at least 24 hours to insure that no significant amounts of moisture would be present during the final weighing. The samples were then weighed and the resulting particulate weights were used with the true air flows through the samplers to calculate the particulate concentrations.

2. Accuracy

The weights of the clean and used filters were determined to the nearest one-tenth of a milligram, and airflow rates were determined to the nearest one-tenth cubic foot per minute. This degree of measurement was possible with the balance and flow calibration curves that were used. Since the flow meters were accurate only to the nearest cubic foot per minute, the concentrations were rounded off to the nearest microgram per cubic meter.

The rubber gaskets used in the filter holders were replaced when the edges of the sample began to show a seepage. The samplers were calibrated each time the brushes were replaced. The correction factor for temperature and pressure was not applied because the temperature and pressure at the place of calibration and the location of sampling were not significantly different.[1]

B. Wind Monitoring

1. Method

To obtain wind direction and speed on the premises of the steel manufacturing plant, a wind vane and anemometer were used in conjunction with an appropriate power supply translator and chart recorder. Continuous chart records of wind speed and direction were determined by a R. M. Young Company[13] Gill Microvane, 3-Cup anemometer. This high sensitivity windvane overcomes the limitations of standard windvanes which exhibit an averaging effect because of their inability to follow momentary wind gusts. During fluctuating wind conditions, many standard windvanes tend to indicate much wider angles than the true

wind fluctuation because of the relatively high moment of inertia of the vane. The microvane and anemometer were attached to a steel pole and mounted about twenty feet above the buildings to minimize wind interference from plant structures and also to attempt to approach normal effective stack height.

2. Analysis

The charts from the recorder continuously indicated the instantaneous direction and speed of the wind. The directions were those from which the wind blew and were grouped in directions based on the nearest of the 16 points of the compass (N, NNE, NE, etc.). The wind direction channel of the recorder was aligned with the wind vane by turning the wind vane to each of the four compass points and marking the pen position on the chart. The remaining 12 points were then determined by interpolation. Speeds were recorded to the nearest mile per hour. The wind speed channel of the recorder was calibrated from 0 to 50 miles per hour by connecting the anemometer shaft to an electric motor with a shaft speed that corresponded to 50 mph at the anemometer.

To approximate the average wind direction and speed, the chart paper was examined for relatively constant trends in direction and speed with durations of at least 15 minutes. Straight lines were then drawn through the centroids of these areas (Figure 5). These lines were considered to be the average value for the duration of the trend. The average directions and speeds were obtained by placing the key developed during calibration on the chart paper and reading the values

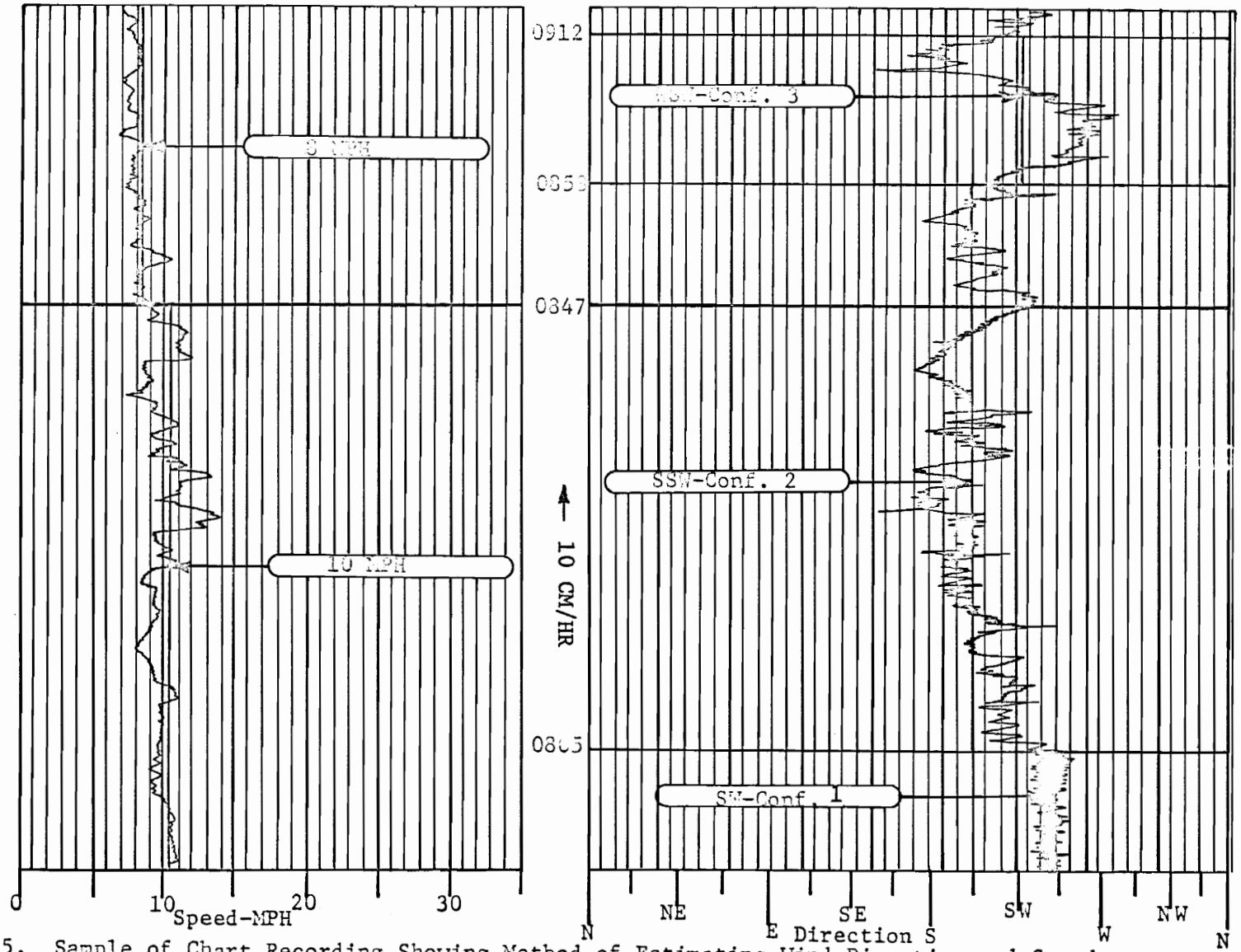


Figure 5. Sample of Chart Recording Showing Method of Estimating Wind Direction and Speed.

nearest the straight lines. The times spent at each mean direction and speed were calculated by measuring the distances along the chart paper and dividing them by the chart speed. If no directional trend could be observed from the display of instantaneous wind directions or if the indicated wind varied by more than 10 points from the constructed mean, the wind was considered too erratic to measure and was classified as variable for the duration of these conditions.

The speeds at particular directions were weighted by the time spent at each of those speeds and directions. These products were considered to be the magnitude of the wind vectors and were used with the wind directions to solve for the resultant wind vectors. The sampling time was then divided out of the resultant vector to produce the resultant wind speed.

3. Accuracy

The prevailing wind direction for a given number of hours was considered to be accurate to the nearest compass point (22.5 degrees). To place instantaneous direction and speed readings of different deviations into degrees of credibility, confidence factors were established as follows:

1. Actual wind displayed varies less than one compass point from value measured.
2. Actual wind displayed varies less than two compass points from value measured.
3. Actual wind displayed varies less than four compass points from value measured.

4. Actual wind displayed varies more than four compass points from value measured.

Since the winds measured at the steel plant were, with few exceptions, very erratic, these confidence factors were not considered when calculating resultant wind. Confidence factors were not used with wind speed measurements.

C. Overall Sampling Scheme

Initially, six high volume samplers were placed in locations as shown in Figure 6. The object of this placement was to encircle the premises of the plant. A comparison of the loadings of upwind samplers with those of downwind samplers to determine the presence of a significant concentration of particulates from a source outside the steel plant's premises was planned. In order to conform to the perimeter of the plant property, samplers B, C, and D of Figure 6 had to be placed along an unpaved road. The dust caused by plant traffic proved to be overwhelming and these three sampling stations were discontinued. The other three samplers were located on hills within the plant premises that positioned the samplers on the same level with the top of the melting building.

The wind vane and anemometer were mounted as close as possible to what was considered the major source of emissions. This was done in order to measure the wind that would have a direct effect on the dispersion of furnace emissions.

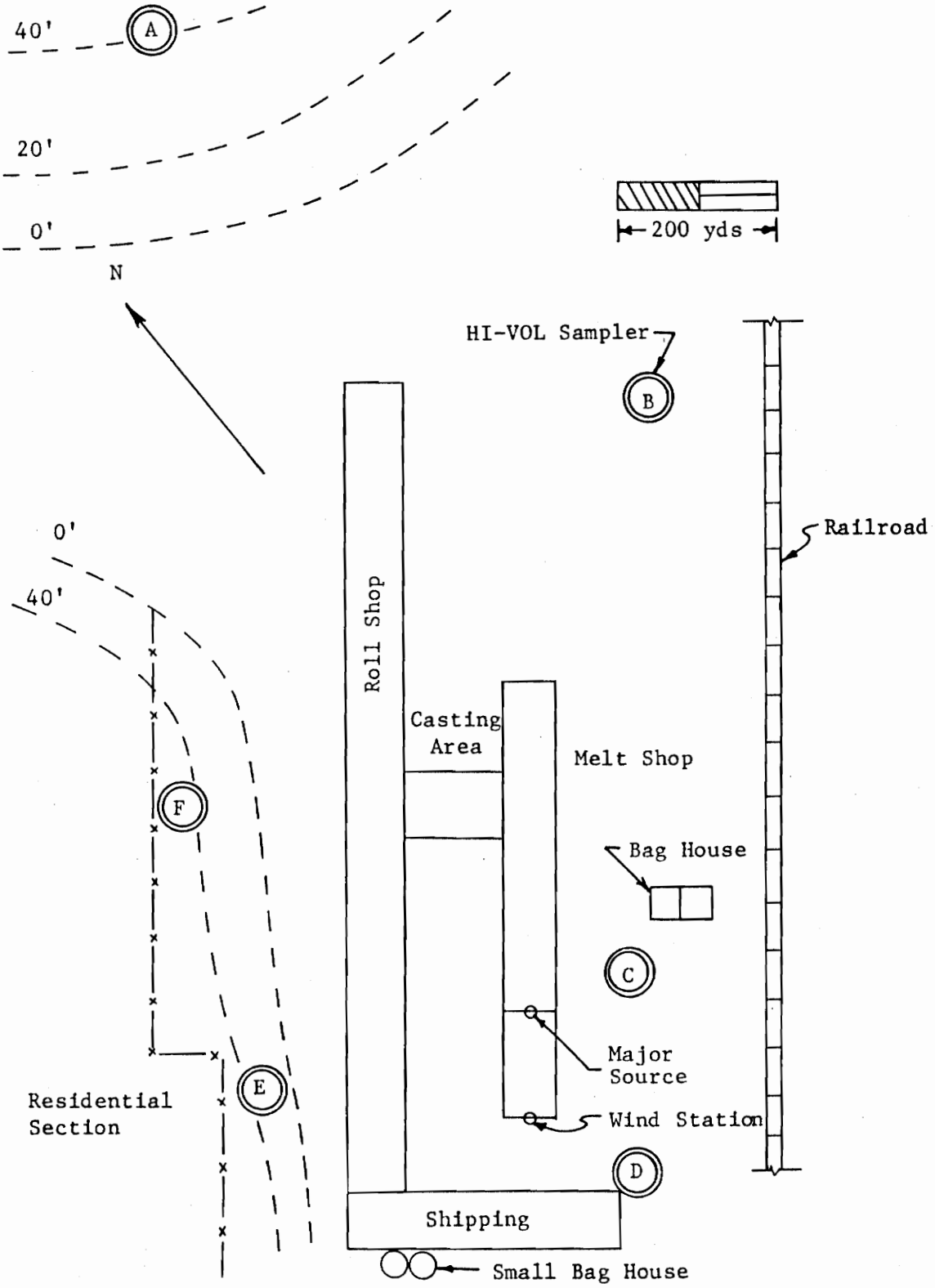


Figure 6. Plan of Facility Showing Inital Location of Samplers.

CHAPTER IV

RESULTS

The sampling program at the steel plant was conducted for the six months from April, 1974 through September, 1974. Ambient air samples were obtained on 75 days out of the six month period. On 70 of those days the plant was in full operation. On May 27, July 4, August 6, August 8, and August 11, the plant was closed for holidays and vacation periods. A local air pollution control agency sampler was located to the northwest about 1000 yards from the melt shop in a residential area with paved streets. The agency adjusted its sampling schedule to conform with the Sunday-Tuesday-Thursday sampling schedule at the plant. The data obtained from the agency sampler were available to augment the data obtained from the plant samplers.

A. Correlation of Plant Wind Data with Sampler Loadings

In order to correlate sampler loadings with wind direction, the horizons around samplers A, E, and F of Figure 7 were divided into two sectors each. One sector included all of the directions from the vicinity of the plant and the other sector included only those directions that should have been free of direct influence from the plant. The correlation of particulate loadings for each sampling day with the wind measured at the plant is presented for each month in Tables 1 through 18 in Appendix A. The absences of values in these tables were caused by equipment failures.

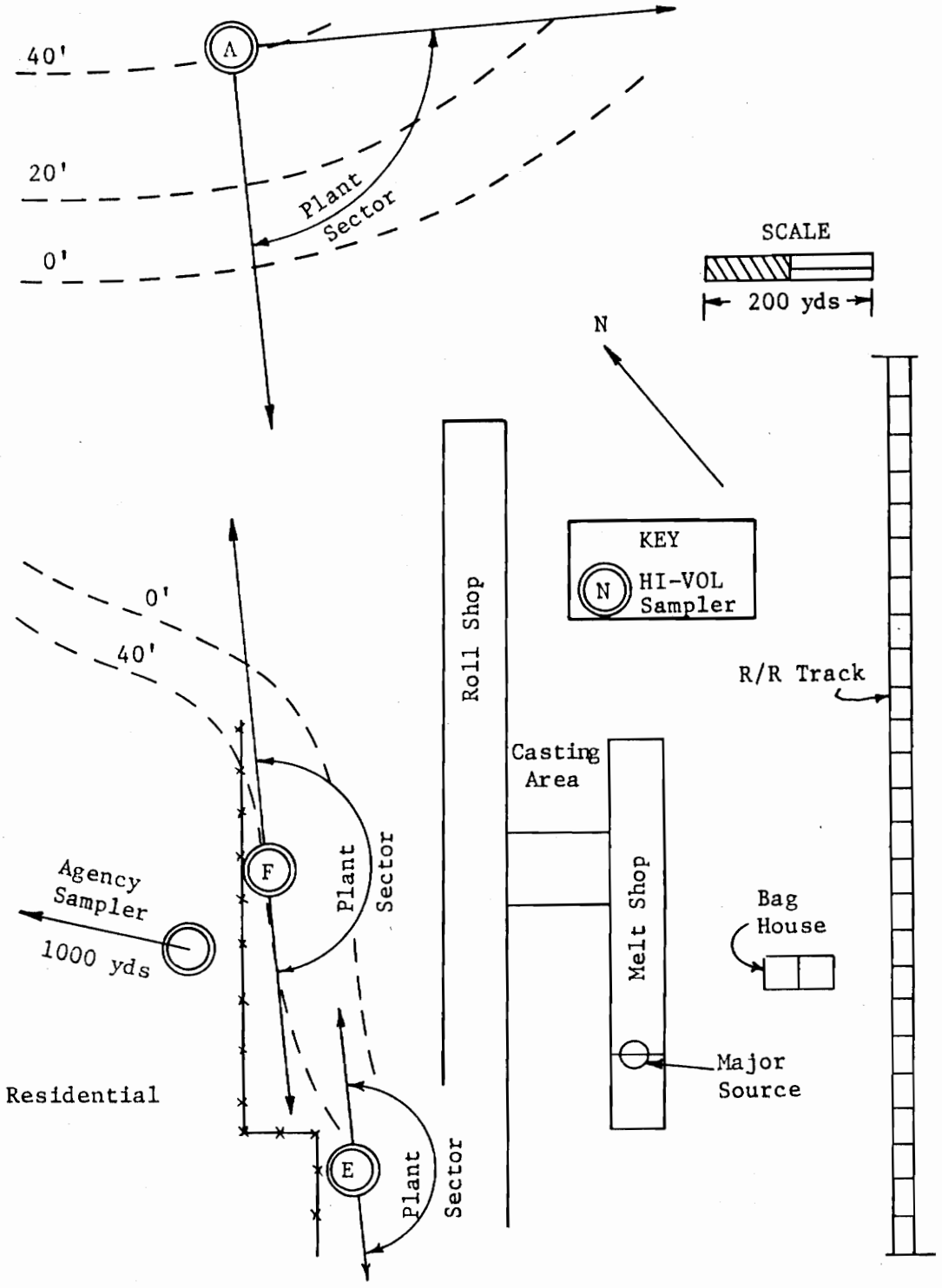


Figure 7. Plant Plan Showing Wind Sectors at Each Sampler used for Correlation with Particulate Loadings.

1. April Results

Table IV is a summary of the wind correlation data collected during the month of April. The days on which no wind data were collected are not included in the table.

A correlation between wind characteristics and average particulate concentrations can be obtained from Table IV by evaluating resultant wind speed from the plant and non-plant sectors, the percentage of the sampling period that the winds were from each sector, and the average particulate concentration collected for that sampling period. The percentage of variable winds are considered to be evenly distributed around the compass.

For example, on April 4, the average particulate concentration collected was 127 $\mu g/m^3$. The wind blew from the plant sector to Sampler A 26 percent of the period with a resultant speed of 2 m.p.h. and to Samplers E and F 51 percent of the period with a resultant speed of 2 m.p.h. On April 9, the average particulate concentration was 24 $\mu g/m^3$. The wind blew from the non-plant sector to all samplers 83 percent of the period with a resultant speed of 18 m.p.h.

From these two examples, it can be postulated that a low speed wind from the plant area can result in a very high particulate concentration at the sampler and that a high speed wind from other than the plant area can result in a very low concentration. By evaluating the table as a whole, it can be seen that, for the most part, wind speeds over 12 m.p.h. usually result in lower particulate concentrations.

TABLE IV

APRIL WIND AND PARTICULATE CORRELATION

		APRIL								
Sampler	Wind Sector	2	4	9	18	23	25	28	30	Units *
A	P	0/0	2/26	0/0	0/0	0/0	20/5	11/15	0/0	mph/%
	N	1/77	8/51	18/83	9/100	21/100	13/95	10/100	12/100	mph/%
E/F	P	0/0	2/51	0/0	0/0	0/0	7/22	8/20	0/0	
	N	1/77	11/26	18/83	9/100	21/100	16/78	11/80	12/100	mph/%
AEF	Var-ible	23	23	17	0	0	0	0	0	%
$\overline{AEF}$	Conc.	163	127	24	71	51	48	166	110	$\mu g/m^2$

*Resultant wind speed and percentage of sampling period at each sampler for winds that blew from the plant sector (P) and the non-plant sector (N), displayed with the average of all samples collected at the plant on a given day.

2. May Results

The data collected during the month of May are summarized in Table V. This table was constructed in the same fashion as Table IV.

By examining the high average concentrations in Table V of 138, 151, 135, and 117 $\mu g/m^3$ collected on May 2, 9, 14, and 16 respectively, it can be seen that for the three samplers, the resultant wind was from the plant sector 48 to 77 percent of the time with speeds ranging from 7 to 11 m.p.h. This observation supports the April results. May 27, with its low average concentration of 41 $\mu g/m^3$, was a day of complete plant shutdown.

3. Results for June, July, and August

At the end of May the wind vane/anemometer device had to be removed because of plant operations. The device was relocated within the same area on June 16. After relocation of the device, it became very difficult to find a correlation between sampler loadings and wind direction. The wind vane and anemometer were accessible only by crane or bucket lift and therefore could not be aligned with the chart recorder whenever desired. In August the wind vane slipped in its casing causing the fin to rub the tops of the anemometer cups. A crane was made available and the device was taken down for repairs at the end of August. The wind vane was repaired and aligned with the chart recorder. During calibration of the chart recorder, it was found that the servo drive motors were faulty, the replacement of which caused a delay until September 12. At that time the system was placed in operation.

TABLE V

MAY WIND AND PARTICULATE CORRELATION

Sampler	Wind Sector	MAY 2	5	7	9	14	16	27	Units*
A	P	7/52	10/38	0/0	10/50	11/48	10/49	4/14	mph/%
	N	5/40	8/41	10/63	8/27	4/30	7/43	4/86	mph/%
E/F	P	8/71	10/69	0/0	7/77	11/48	10/49	7/76	mph/%
	N	3/21	2/10	10/63	0/0	4/30	7/43	7/24	mph/%
AEF	Var-ible	8	21	37	23	22	8	0	%
$\overline{AEF}$	Conc.	138	87	48	151	135	117	41	$\mu g/m^3$

*Resultant wind speed and percentage of sampling period at each sampler for winds that blew from the plant sector (P) and the non-plant sector (N), displayed with the average of all samples collected at the plant on a given day.

4. September Results

For September (TableVI), a strong correlation of particulate loadings with wind data was available. On September 19 and 24, the winds blew from the plant sector to all samplers during 36 percent and 39 percent of the sampling periods, resulting in plant averages of 110 and 113 $\mu g/m^3$, respectively, which are the largest values of the month.

B. Correlation of Plant Wind Data and Airport Wind Data

Since there were many days of wind monitoring equipment failures and unreliable wind data, it was decided to investigate the relationship between wind data obtained at the plant site and wind data obtained by the National Weather Service at the local airport. "Local Climatological Data" summaries for each month were obtained from the U. S. Department of Commerce, National Oceanic and Atmospheric Administration. These reports were based on weather data taken at the municipal airport located about four miles from the plant. The airport was within 100 feet elevation of the plant and there were no major obstructions in between.

At the National Weather Service Office, wind readings are taken eight times each day. The resultant wind for each day is the vector sum of wind directions and speeds divided by the number of observations. These resultant wind directions were rounded off to the nearest compass point and assigned values of 1 through 16. The wind speeds were rounded off to the nearest mile per hour. Values of 1 through 16 were assigned to the wind direction obtained from the plant wind data.

TABLE VI

SEPTEMBER WIND AND PARTICULATE CORRELATION

		SEPTEMBER								
Sampler	Wind Sector	12	15	17	19	22	24	26	29	Units*
A	P	10/2	5/15	7/16	12/36	5/19	12/39	0/0	7/28	mph/%
	N	6/98	5/78	6/84	6/64	5/81	5/61	7/100	16/72	mph/%
E/F	P	10/2	5/15	7/16	12/36	5/19	12/39	0/0	7/28	mph/%
	N	6/98	5/78	6/84	6/64	5/81	5/61	7/100	16/72	mph/%
AEF	Var-ible	0	7	0	0	0	0	0	0	%
$\overline{AEF}$	Conc.	71	48	85	110	38	113	73	57	$\mu g/m^3$

*Resultant wind speed and percentage of sampling period at each sampler for winds that blew from the plant sector (P) and the non-plant sector (N), displayed with the average of all sampler collected at the plant on a given day.

These data are correlated in Appendix B.

The correlation results showed that the average of the differences between resultant plant wind direction and resultant airport wind direction for each day in April and May are approximately one compass point. For September it is approximately two compass points. Comparing these values with the corresponding values for June (4 points), July (5 points), and August (6 points), it can be stated that the plant wind data did correlate favorably with the airport wind data during April, May, and September, when the wind vane and chart recorder at the plant were properly aligned and calibrated. Based on these findings it was accepted that the wind observed at the airport gave a close indication of wind conditions at the plant.

C. Determination of Stability Classes

Data taken from the "Local Climatological Data" summaries were entered into the STAR (Stability Rose) computer program to determine the frequency distribution of Pasquil's[14] stability classes for the days that air samples were collected. The inputs to the STAR program are latitude and longitude of the area, time zone, date, ground wind speed and direction, cloud cover, and ceiling for each of the eight observations taken in a day. The program computes the declination and altitude of the sun and, in conjunction with weather phenomena, estimates the atmospheric stability class for each observation. These classes are a function of solar radiation.

Pasquil's stability classes range from A through F with A-B being unstable conditions, C-D neutral, and E-F stable. Under stable

conditions, foreign matter infused into the atmosphere would be rapidly diluted and dispersed while under stable conditions the material would tend to remain concentrated and close to its height of emission.

The most stable conditions are normally found late at night and early morning when the earth's surface has had time to cool causing its temperature to fall below that of the warm surrounding air. Under these conditions a parcel of air cannot rise adiabatically. This causes an accumulation of the air and its contents near the earth's surface, thus limiting diffusion.

Unstable conditions are most likely found in mid-afternoon. This is when the earth's surface is at its warmest and is warmer than the surrounding air mass. At these times, a parcel of air will repeatedly rise until it cools and fall until it warms, thus enhancing diffusion of the air and any foreign matter suspended in the air.

The results of the STAR program revealed that 38.7 percent of the observations fell in stability class D, 19.3 percent in class F, 16.7 percent in class C, 12.5 percent in class E, and 11.1 percent in class B, and only 1.7 percent in class A. By slightly modifying the program, a stability class for each observation and an average for each day was obtained. These results showed that 79.7 percent of the sampling days had an average stability class of D, 17.6 percent had an average of E, and 2.7 percent had an average of C. These daily averages are compared with the pollution roses developed in Section D of this chapter.

D. Correlation of Sampler Loadings with Airport Weather Data

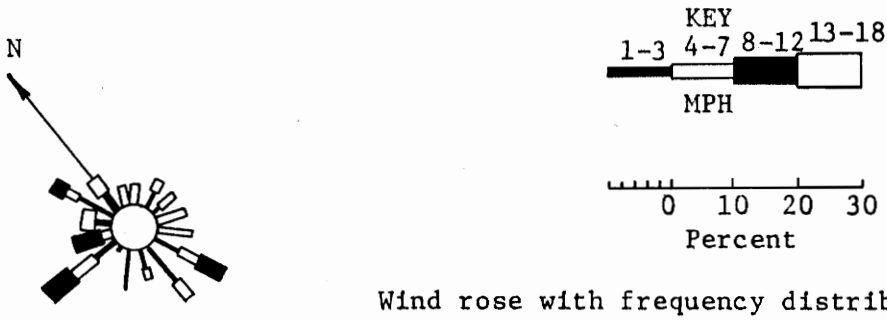
1. Plant Samplers

Since uninterrupted wind data were available from the National Weather Service, the relationship of particulate loadings at the plant to the airport wind data was determined. Wind/pollution roses were constructed as shown in Figures 8, 9, and 10. Figure 8 compares a wind rose for the entire period with wind/pollution roses for days of high and low particulate concentrations at Sampler A. The prevailing winds are from the west, south-southeast, south, and north-northwest. Figure 9 shows the frequency distribution of winds that occurred when particulate loadings were equal to or greater than 75 $\mu g/m^3$ at each sampler. Figure 10 shows the frequency distribution of winds that occurred at each sampler when particulate loadings were below 75 $\mu g/m^3$. The object of these presentations is to locate sources of heavy loadings and areas of light loadings.

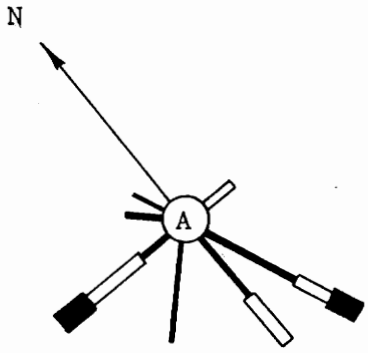
Also included in Figures 9 and 10 are the frequency of occurrence of the different atmospheric stability classes. These are shown adjacent to each rose.

Figure 9 shows a pronounced relationship between the days of loadings equal to or greater than 75 $\mu g/m^3$ with the direction of the winds. The sectors of the roses containing vectors with the greatest frequency distribution clearly point toward the areas of plant activity. The wind distribution vectors in Figure 10 are concentrated in sectors away from plant influence.

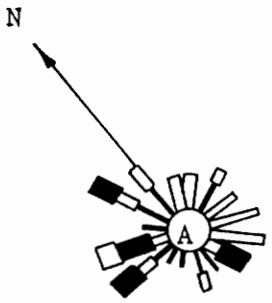
By studying the stability class distributions for each sampler of both figures, it is seen that the occurrence of E stability on the



Wind rose with frequency distribution and prevailing winds in the area during the sampling program.



Wind/pollution rose with frequency distribution of winds on the days that the particulate concentration was greater than 75 $\mu g/m^3$ at Location A.



Wind/pollution rose with frequency distribution of winds on the days that the particulate concentration was less than 75 $\mu g/m^3$ at Location A.

Figure 8. Comparison of Area Wind Rose with Wind/Pollution Roses for Days of High and Low Concentrations at Sampling Location A.

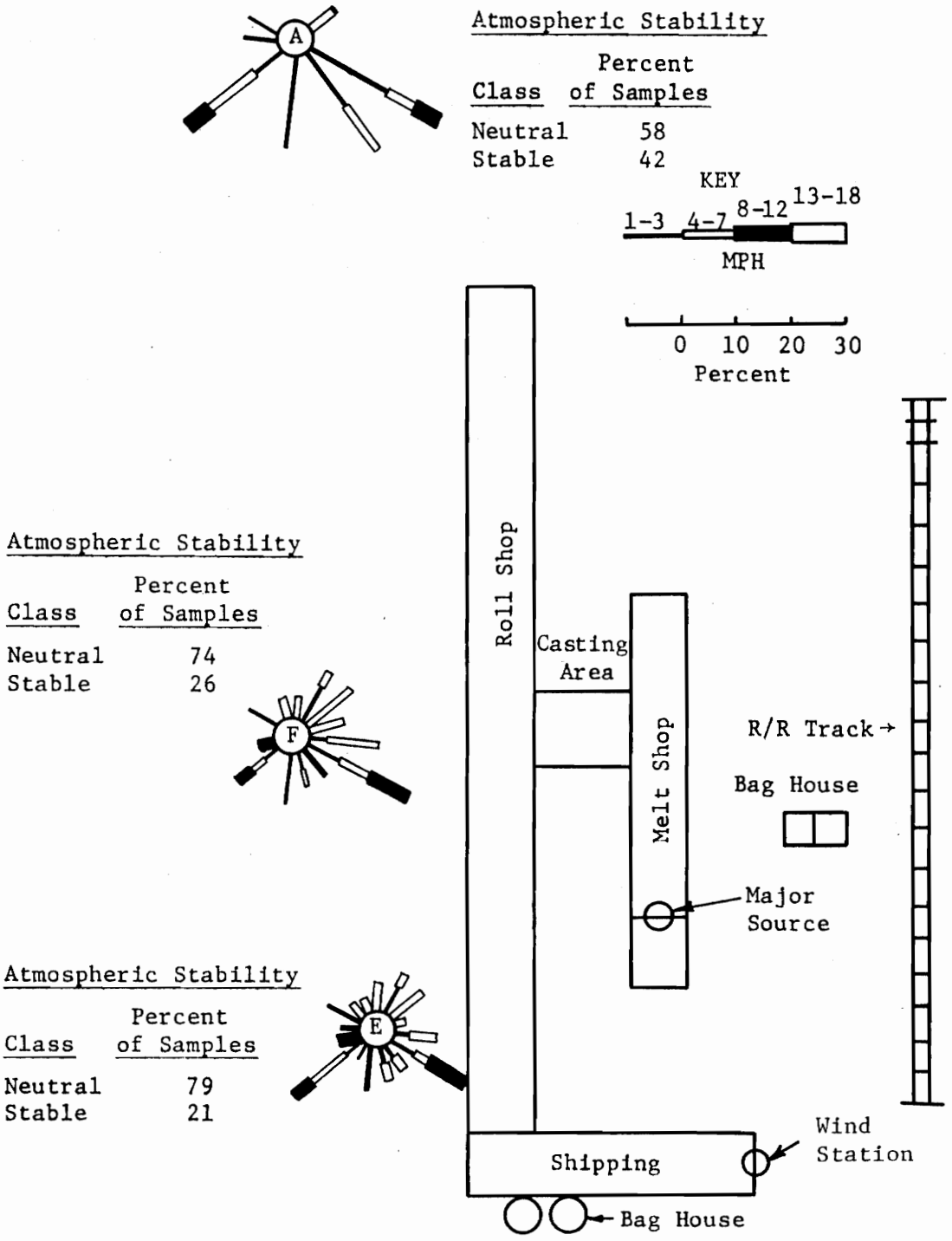


Figure 9. Frequency Distribution of Winds when Particulate Loadings were Greater than 75 $\mu g/m^3$ at Each Plant Sampler.

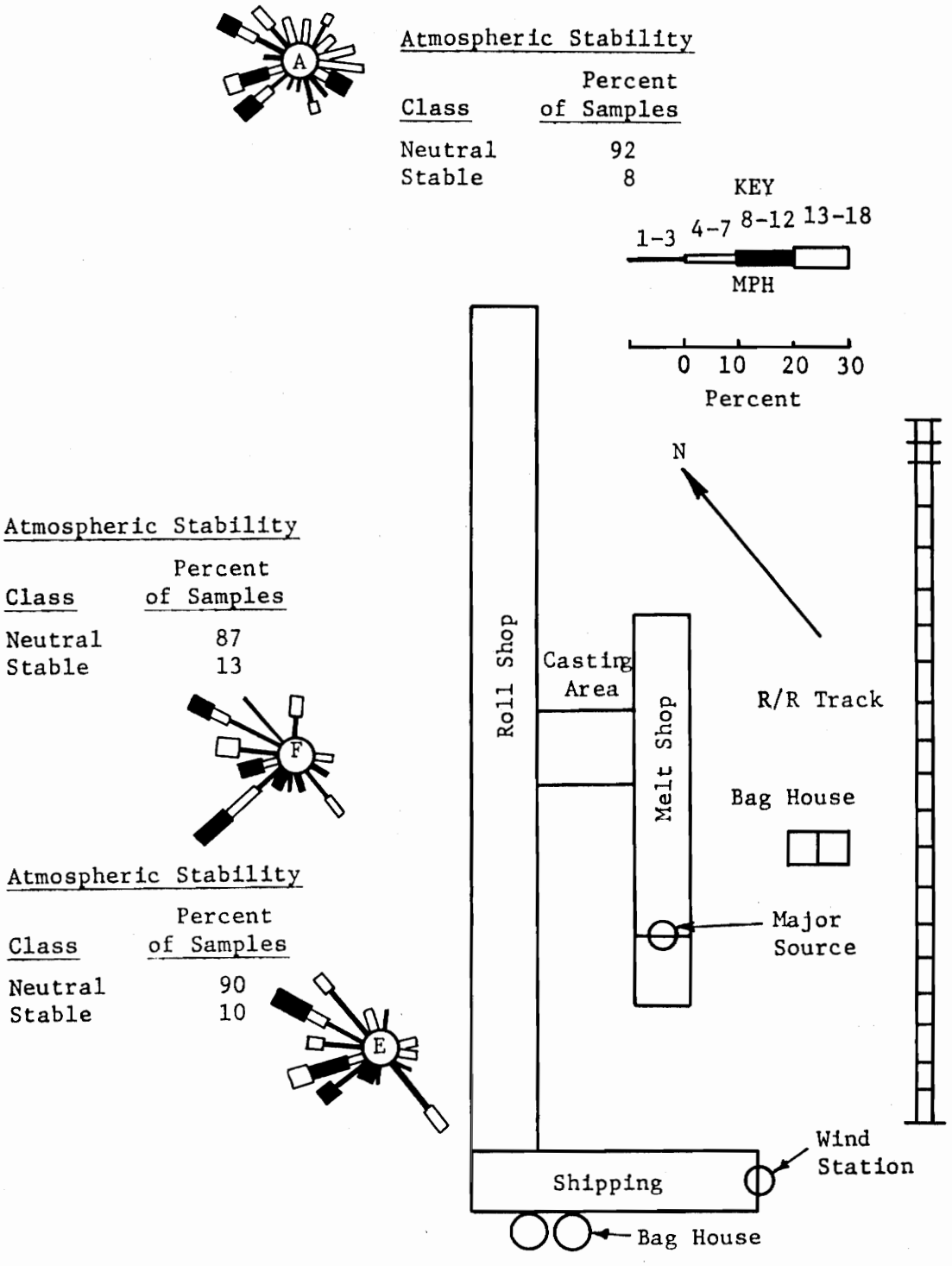


Figure 10. Frequency Distribution of Winds when Particulate Loadings were Less Than 75 $\mu g/m^3$ at each plant sampler.

days of high loadings range from 21 percent to 42 percent while on the days of loadings below 75 $\mu g/m^3$, they range from 8 percent to 13 percent. These results indicate that the stable conditions occurred at ground level.

2. Air Pollution Control Agency Sampler and Background Level

As previously mentioned, the local air pollution control agency's high-volume sampler was located approximately 1000 yards to the northwest of the plant. Since this is within the same general area of the plant, it appeared to be the best choice for determination of an area background level for suspended particulates, because it was far enough from the plant not to be affected by re-entrained dust. It was determined that only winds from the E, ESE, S, SSE, and SE would show plant influence at this sampler location.

A geometric mean was calculated for particulate loadings obtained from the agency sampler using only those days during the six month period which had winds that would not show plant influence. Airport wind data were used and the geometric mean calculated was 48 $\mu g/m^3$. On the five days of plant shutdown, the values obtained from this sampler were 49, 43, 60, and 56 $\mu g/m^3$ with a geometric mean of 52 $\mu g/m^3$.

E. Probability Distribution of Values at Each Sampler

Log-probability distributions of all samples collected at each sampler (including the local agency sampler) are presented in Figure 11. These distributions are dependent on the yearly wind pattern for that location.

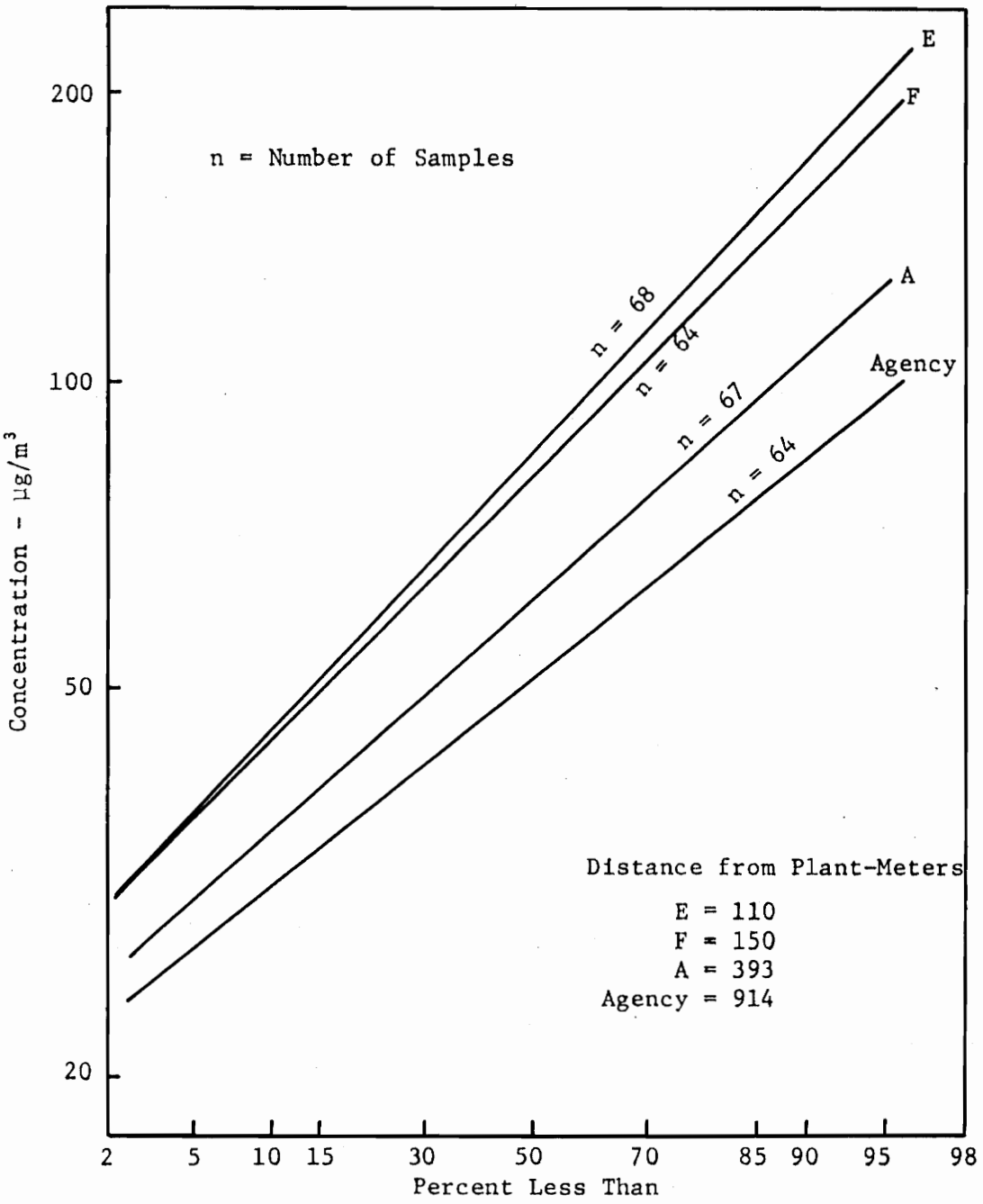


Figure 11. Log-Probability Distribution of Samples Collected at Each Sampler

The geometric mean (μ_g) is located on each curve at the 50 percent mark and the geometric deviation (σ_g) is equal to the concentration at the 84.13 percent mark divided by the geometric mean or the geometric mean divided by the concentration at the 15.87 percent mark. The geometric mean and deviation can be found mathematically by using the following equations:

$$\mu_g = \sqrt[n]{\prod_{i=1}^{n} C_i} \text{ or, } \exp\left(\frac{\Sigma \ln C_i}{n}\right) \quad (1)$$

$$\sigma_g = \exp\left(\frac{1}{n-1} \cdot \left[\Sigma(mC_i)^2 - \frac{(\Sigma \ln C_i)^2}{n}\right]\right) \quad (2)$$

where, n = the number of samples and

C = concentration of particulate matter ($\mu g/m^3$).

Compared to an arithmetic mean, the geometric mean gives a more meaningful indication of the central location of a set of observations. It is helpful in finding the central tendency of data whose different values tend to cluster around a certain level. The geometric mean gives equal weight to changes of equal relative importance. For example, if an index is doubled in value, this change is weighted equally to a change which halves the value of this index. Because of the nature of the calculations, no value can be equal to zero.

The geometric deviation gives an indication of the consistency of the values; that is, to what extent they vary above and below the mean.

The curves in Figure 11 are presented in the order of each sampler's distance from the source of emissions under study. By studying these figures, it can be seen that the geometric means and

the geometric deviations decrease with distance from the source. A more detailed study of this relationship is conducted in Chapter V.

F. Precision of High Volume Method

During the month of September, an additional sampler was placed at sampling location E in Figure 6 in order to check the precision of of the method. These data are shown on line 8 of Table A.17 in Appendix A. The averages of these two values were used for the loadings at location E for each day. Using the original sampler as a bases, the particulate loadings collected on six out of eleven days were within 3 percent of each other. The average deviation was 4.36 percent with a high of 14 percent and a low of zero. The median value was 3 percent.

Since Environmental Protection Agency procedures state that the repeatability of the high volume sampling method is within 3 percent under laboratory conditions, using the same sampler, these results indicate that the quality control of the sampling program was well within the expected limits.

CHAPTER V

DISCUSSION OF RESULTS AND CONCLUSIONS

In examining the plant wind data for April, May, and September in Tables IV, V, and VI, a definite correlation between wind characteristics and suspended particulate concentrations can be seen. The wind data obtained at the plant for the months of June, July, and August were determined to be unreliable because of problems with the equipment, and therefore, were not used in this analysis.

By geometrically averaging the loadings obtained on those days in April, May, and September that, according to plant wind data, had no winds blowing from the plant sector, a geometric mean of 58 $\mu g/m^3$ was found for the plant samplers. In comparing this average with the background value of 48 $\mu g/m^3$ found at the agency sampler in section D-2 of Chapter IV, it is believed that the difference was caused by the particulates released from the continuing construction program at the plant and re-entrained dust generated from the grounds and roadways by turbulence.

After a study of Figures 9 and 10, it can clearly be seen that on days of high sampler loadings (Figure 9) the winds were from the SSE. Obviously, winds from the S, SE, or ESE would have had the same effect on Samplers E and F, and winds from the S and SSW would have had a similar effect on Sampler A. Also, high frequencies of west winds were recorded on days of high particulate loadings. At the airport, the resultant wind directions for three out of the six months was from

the West. This would tend to cause a large distribution of west winds at the pollution roses which are displaying daily resultant winds.

It can be observed from the contour lines of Figure 7, that the hill in the area of Samplers E and F could channel a west wind into a SSW direction. During parts of the summer, the dirt road adjacent to Sampler E was being used by heavy trucks and throughout the six month sampling period there was work in progress at the power sub-station to the west of Sampler A. These potential sources, combined with the channeling effect of the hill mentioned above, appear to have caused the heavy loadings on days of west winds.

Figure 10 shows that on days of light particulate loadings for each sampler, the majority of the winds were from the N, NNW, NW, and WNW directions. A comparison of Figure 9 with Figure 10 reveals the sources of heavy loadings and the areas of light loadings. The majority of the samples obtained from sampler A were less than 75 $\mu g/m^3$ while the majorities obtained from samplers E and F were over 75 $\mu g/m^3$. On days of high particulate loadings, a greater portion of the resultant winds had speeds of under 8 mph than did those resultant winds on days of light loadings. There were no resultant winds with speeds over 12 mph on days of heavy loadings.

The consideration of daily stability classes with the pollution roses show that relatively stable atmospheric conditions with slow winds result in higher concentrations of pollution at a particular receptor location over an extended sampling period. A short sampling period with unstable conditions and moderate winds could show a relatively

high concentration at a particular receptor as a result of plume looping, which is caused by the constant vertical movement of the air. This phenomenon would not likely occur on a continuing basis and was not the case in this study.

The results of the log-probability distributions of Figure 11 are summarized in Table VII. The geometric deviations are essentially the slopes of each curve. Their values show that the sampler with the greatest mean concentration experienced more radical fluctuations in particulate concentrations, while the sampler with the smallest mean experienced the least fluctuations. (It is interesting to note that, in this case, there is a linear relationship between these geometric means and their respective deviations.) Since the samples with the smallest mean and smallest deviation were collected at the greatest distance from the source, it can be concluded that the varying effect of emissions from the source was diminished with distance from the source.

By comparing the six month geometric mean for the Agency sampler (52 $\mu g/m^3$) with the means calculated for the same sampler during days of favorable winds (48 $\mu g/m^3$) and during days of plant shutdown (52 $\mu g/m^3$), it appears that the emissions from the plant had little long range effect on the ambient air quality at this sampling location.

By plotting the average concentration for each sampler as a function of the sampler's distance from the source on log-log paper, a linear relationship can be seen. This relationship can be expressed mathematically with the following equation:

TABLE VII

SUMMARY OF THE RESULTS OF THE LOG-PROBABILITY DISTRIBUTIONS COMPARED WITH DISTANCE FROM THE SOURCE

Sampler	E	F	A	Agency
Distance from Source (yds)	120	165	430	1000
Geometric Mean ($\mu g/m^3$)	86	82	62	52
Geometric Deviation	1.66	1.63	1.54	1.48

$$y = 278.6x^{-0.248}, \quad 100 < x < 1000 \qquad (3)$$

where y = concentration - $\mu g/m^3$ and

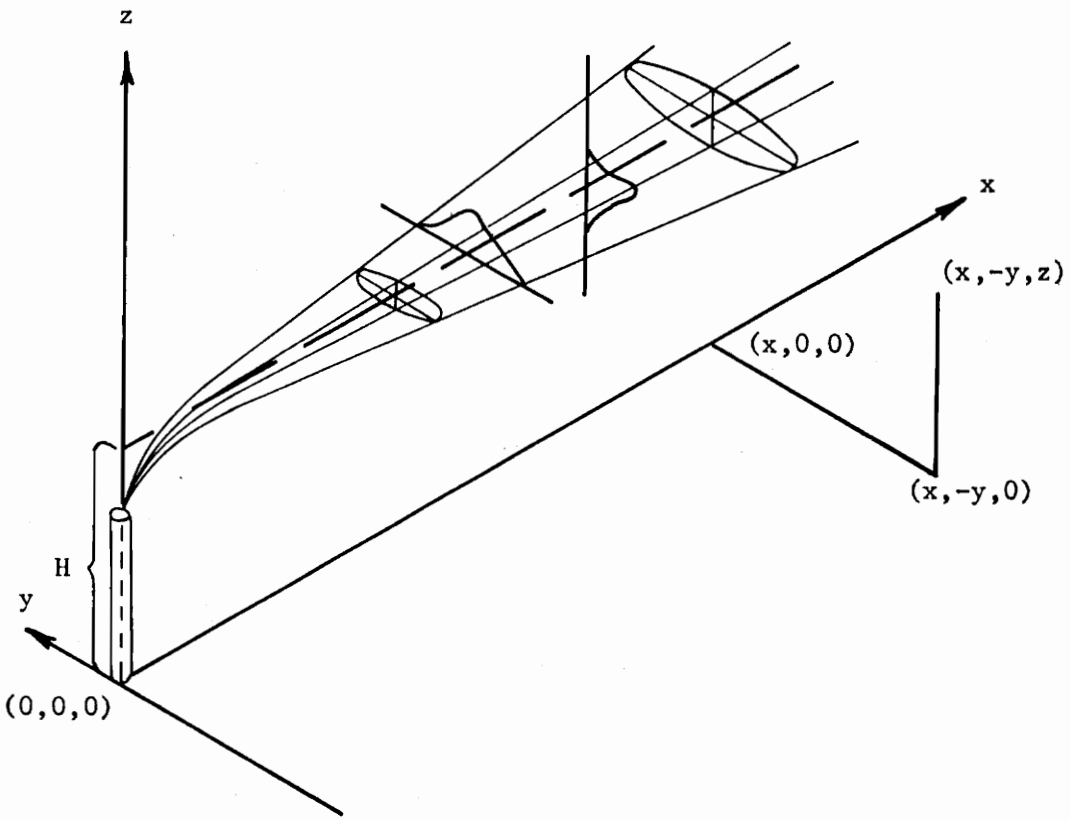
x = distance from source - meters.

This indicates that, within certain limits, the average concentrations vary exponentially with distance from the source. This follows, to some extent, the results of the work done by Pasquill[14], modified by Gifford[15]. This work uses the Gaussian plume spread equation to predict the concentration of a pollutant at a specified distance downwind from a source of emission. The Gaussian plume spread equation is illustrated in Figure 12.

The standard deviations, σ_y and σ_z, for this equation were determined experimentally using a continuous source of emissions, constant stability and wind conditions, flat terrain, and a plume duration of 10 to 15 minutes. When the measurements of σ_y and σ_z were plotted on log-log paper as a function of distance downwind of the source, a linear relationship was found. This indicates that the pollution concentration decreased exponentially with the distance downwind of the source. By using these curves in conjunction with the equation in Figure 12, estimation of downwind concentrations can be calculated.

To calculate an estimated emission rate from the 6 month average concentrations at receptors various distances and directions from the source under study, it was assumed that

(1) the terrain from the source to all of the receptor points was flat,



$$\chi_{(x,y,z;H)} = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp^{-1/2(\frac{y}{\sigma_y})^2} \left[\exp^{-1/2(\frac{z-H}{\sigma_z})^2} + \exp^{-1/2(\frac{z+H}{\sigma_z})^2} \right]$$

χ = concentration at a point downwind (g/m^3)
Q = source emission rate (g/sec)
u = average wind speed (m/sec)
H = effective emission height (m)
σ_y, σ_z = standard deviations of plume concentration distribution in the horizontal and vertical, respectively (m)
x,y,z = distances from the origin in the downwind direction, horizontal, and vertical, respectively (m)

Figure 12. Gaussian Plume Spread Equation with Illustration (16).

(2) the receptor points were located at ground level and were located on the center line of one direction from the source,

(3) the concentration of particulates were distributed normally about the vertical and horizontal axes, and

(4) the averaging effect over the extended sampling period is similar to instantaneous readings taken during a typical short plume life.

Since the receptor points were at ground level and because the receptors were assumed to be along the center line of an average wind direction, the plume dispersion equation can be reduced to the following form:

$$\chi = \frac{Q}{\pi \sigma_y \sigma_x u} \exp^{-1/2(\frac{H}{\sigma_z})^2} \qquad (4)$$

The effective emission height (H) was calculated to be 198 meters using the Briggs[17] plume rise equations with the Air Pollution Engineering Manual[3] method for determining velocity of emissions. Since the furnaces are three meters tall and the roof of the melt shop is 15 meters from the ground, the apparent effective emission height was reduced to 186 meters. This is because the top of the melt shop was considered to be at ground level. The apparent effective emissions height would be reduced considerably by the fact that when the emissions escape from the furnace, they are deflected laterally by the top of the melt shop and then rise from the ends and openings of

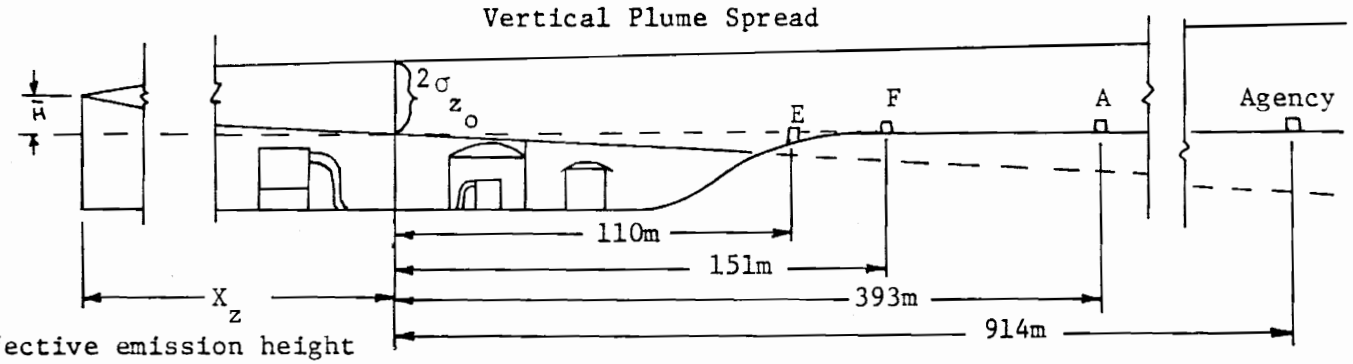
the building. The melt shop and its relationship to the surrounding terrain is shown in Figure 13.

In view of the numerous sources of emissions at various locations and effective heights in the central area of the plant, an area source with an average effective emission height was considered to most closely fit the actual emission pattern. All major sources of emissions were found to be within a circle of 500 meters diameter and, by numerous trial and error attempts, an average effective emission height of 31 meters was found. This effective emission height is considered to be a reasonable estimate because of the many secondary sources of emissions in the area of the melt shop and the damping effect that the melt shop roof would have on the calculated effective emission height of 186 meters. These emissions characteristics are shown in Figure 13.

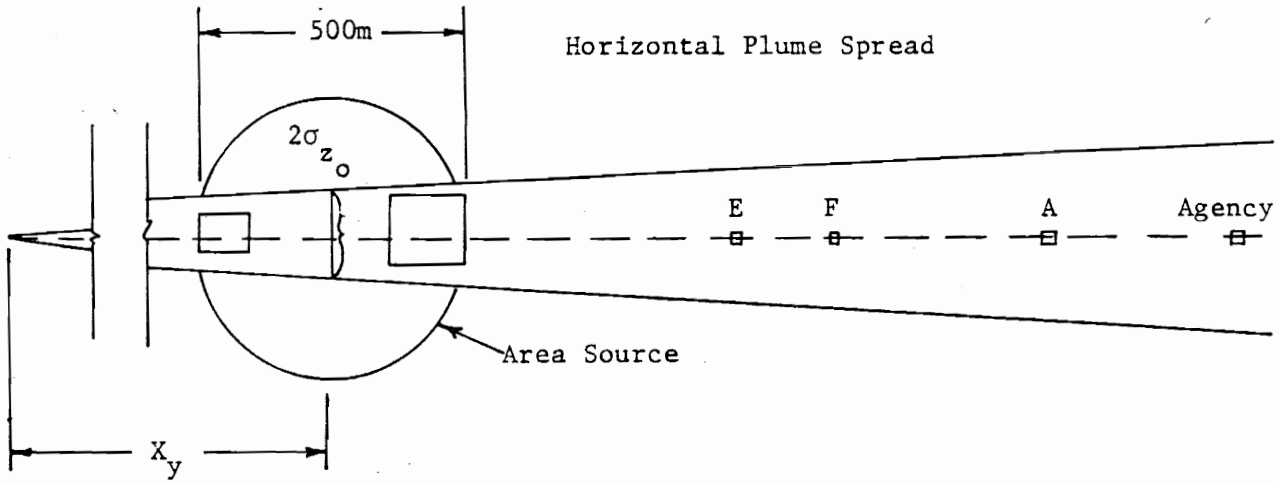
Equation (4) was then expressed as follows:

$$Q = \frac{\chi \pi \sigma_y \sigma_z u}{\exp -1/2 \left(\frac{H}{\sigma_z}\right)^2} \qquad (5)$$

Using the STAR computer program, the average wind speed was calculated as 3.13 meters per second and the average stability class was determined to by Class D. By finding σ_y and σ_z from the curves developed by Gifford and solving Equation (5) using each average concentration, an average emission rate (Q) of 3 grams/second or 24 pounds/hour was found for the plant. The local standard based on production rate is 42 pounds/hour or 5.29 grams/second.



$\bar{H}$ = average effective emission height
X_z = virtual distance = 2900M
σ_{z_o} = standard deviation of the initial vertical distribution of sources



X_y = virtual distance = 485M
σ_{y_o} = standard deviation of the initial horizontal distribution of sources = $\frac{\text{Diameter}}{4.3}$

Figure 13. Vertical and Horizontal Plume Spread over Source and Sampling Points.

To show a comparison, Equation (4) was solved using the maximum allowable emission rate (Q) of 5.29 grams/second. The resultant average concentrations calculated for Samplers E, F, A, and Agency were 174, 162, 117, and 70 $\mu g/m^3$, respectively compared to the actual of 86, 82, 62, and 52 $\mu g/m^3$. This indicates that, even though some of the assumptions made in order to calculate an emission rate were probably not valid, the plant emission rate would still remain below the allowable maximum.

The Air Pollution Engineering Manual[3] claims that approximately 70 percent of the emissions from direct-arc electric furnaces are particles of 5 microns and below. According to Williamson[18], most of the particles in this size range would not be removed by "washout" from rainfall. It was expected that the particulate loadings would be inversely proportional to the rainfall for each month because of the wetting down of the plant grounds and clogging of the filters in the samplers by high humidity. Apparently, the road dust generated at the plant had properties which decreased its ability to remain suspended. Attempts to show a relationship of rainfall with the particulate concentrations were unsuccessful. It is also noted that the temperature variations during the six month sampling period were not of such significance to expect a trend in the sampler loadings resulting from different plume rise rates.

Conclusions made from this study are:

1. A postulation that selected winds blowing across a source of particulate emissions will cause predictable levels of suspended particulate material in the atmosphere of specific areas cannot be

substantiated with only a few observations. A general trend can be noted throughout the course of an extended sampling period. By using the wind-pollution roses, this trend was realized in spite of interferences from such irregularities as topography and intermittent construction near the samplers.

2. The averages of all the samples collected decreased exponentially with their distance from the major sources of emissions. Using equation (3), a reliable estimate of the air quality at a location within the given limits can be obtained.

In order to estimate an emission rate for the facility, one of the assumptions was that the concentration of suspended particulates was distributed normally about the vertical and horizontal. These bell-shaped distributions are illustrated graphically in Figure 11. This was probably the most critical assumption. Because of the irregular topography, the angular disposition of the samplers, and the necessary averaging of wind speed and stability class, the distribution about both the vertical and horizontal were most likely other than normal.

It should be noted at this point that the estimated value of plant emissions of 24 pounds/hour was calculated using the actual mean value of concentrations collected at the various samplers. This gave the emission source under study full credit for pollution found at these locations. Since a background level has been established for the area, it appears that the plant was not responsible for all the particulates collected. This fact tends to support the theory that the plant was indeed operating under the allowable emission rate.

3. Since a background level of approximately 50 $\mu g/m^3$ was obtained from the study, the responsibility of particulate loadings in excess of this value could be placed with any of several sources. The steel plant itself, the adjacent railroad yard, vehicles on paved and unpaved roads, soil erosion, and even home heating could cause suspended particulate loadings in excess of 50 $\mu g/m^3$, especially when aggravated by periods of wind stagnation and thermal inversion.

CHAPTER VI

REFERENCES CITED

1. Federal Register, 36: (84) 8186 (April 30, 1971)

2. Coulter, R. S., "Smoke, Dust, and Fumes Closely Controlled in Electric Furnaces". Iron Age, 173, 107 (January 1954)

3. U. S. Environmental Protection Agency, "Air Pollution Engineering Manual", Second Edition, AP-40, (May 1963)

4. Celenza, G. J. "Air Pollution Problems Faced by the Iron and Steel Industry". Plant Engineering, 60, (April 1970)

5. Sussman, V. H., Lieben, J., and Cleland, J. G., "An Air Pollution Study of a Community Surrounding a Berryllium Plant". American Industrial Hygiene Association Journal, 20, 504 (December 1959)

6. Holtaway, J. S., "Determination of Background Levels and Health Hazards in Plant Environmental Air Contamination" Industrial Medicine and Surgery, 33, 230 (April 1964)

7. Stewart, I. M. and Matheson, D. H., "Methods of Relating High Volume Sampler Particulate Loadings to Wind Direction". Atmospheric Environment, 2, 181 (1968)

8. Alcocer, A. E., Potter, L. B., Feldstein, M., and Moore, H., "The Collection and Analysis of Inorganic Dust Downwind of Source Effluents". Journal of the Air Pollution Control Association, 19, 236 (April 1969)

9. Burt, W. T., III, and Gueho, B. J., "Air Pollution from Hot Mix Plants". Louisiana Department of Highways, Research and Development Section, Research Report No. 50 (October 1970)

10. General Metal Works, Inc., 8368 Bridgetown Road, Cleves, Ohio 45002

11. Gelman Instrument Company, Ann Arbor, Michigan

12. Tierny, G. P. and Conner, W. D., "Hygroscopic Effects on Weight Determinations of Particulates Collected on Glass-Fiber Filters". American Industrial Hygiene Association Journal, 28, 363 (August 1967)

13. R. M. Young Company, 2801 Aero-Park Drive, Traverse City, Michigan 49684

14. Pasquil, F., "The Estimation of the Dispersion of Windborne Material". Meteorology Magazine, 90, 1063, 33 (1961)

15. Gifford, F. A., "Uses of Routine Meteorological Observations for Estimating Atmospheric Dispersion". Nuclear Safety, 2, 4, 47 (1961)

16. Turner, D. B., "Workbook of Atmospheric Dispersion Estimates". U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (1970)

17. Briggs, G. A., "Some Recent Analyses of Plume Rise Observation". Proceedings of the Second International Clean Air Congress, edited by H. M. Englund and W. T. Beery, Academic Press, New York, 1029 (1971)

18. Williamson, S. J., Fundamentals of Air Pollution. Addison-Wesley Publishing Company, Reading, Massachusetts (1973)

APPENDIX A

DAILY WIND AND PARTICULATE DATA,

April - September

Explanation of Confidence Factor:

1. Actual wind displayed varies less than one compass point from value measured.

2. Actual wind displayed varies less than two compass points from value measured.

3. Actual wind displayed varies less than four compass points from value measured.

4. Actual wind displayed varies more than four compass points from value measured.

TABLE A.1

SAMPLER A

Date:	APRIL	2	4	7	9	11	14	16	18	21	23	25	28	30	GM
1	Resultant wind from plant sector (dir/mph)	0	SSW 2	-	0	-	-	-	0	0	0	S 20	SSW 11	0	
2	Percent of sampling period	0	26	-	0	-	-	-	0	0	0	5	15	0	
3	Resultant wind not from plant sector (dir/mph)	WNW 1	SW 8	-	NW 18	-	-	-	NW 9	0	NW 21	NNW 13	W 10	NW 12	
4	Percent of sampling period	77	51	-	83	-	-	-	100	0	100	95	85	100	
5	Hours of variable wind	5.6	5.6	-	4.0	-	-	-	0	24	0	0	0	0	
6	Percent of sampling period	23	23	-	17	-	-	-	0	100	0	0	0	0	
7	Wind data confidence factor	3	1	-	1	-	-	-	1	4	1	1	1	1	
8	Particulate matter collected ($\mu g/m^3$)	58	51	81	23	95	62	-	68	138	50	42	140	100	66
8A	Particulate matter from local agency sampler	-	34	41	18	71	47	45	54	126	51	68	113	110	57
9	Average of all plant samplers	63	127	73	24	121	68	71	71	173	51	48	166	110	
10	Percent over or under plant ave. 8/9	92	32	111	96	79	91	-	96	80	98	88	84	91	

TABLE A.2

SAMPLER A

Date:	APRIL	2	4	7	9	11	14	16	18	21	23	25	28	30	GM
1	Resultant wind from plant sector (dir/mph)	0	ESE / 2	-	0	-	-	-	0	-	0	NNE / 7	SSW / 8	0	
2	Percent of sampling period	0	51	-	0	-	-	-	0	-	0	22	20	0	
3	Resultant wind not from plant sector (dir/mph)	WNW / 1	SW / 11	-	NW / 18	-	-	-	NW / 9	-	NW / 21	NW / 16	W / 11	NW / 12	
4	Percent of sampling period	77	26	-	83	-	-	-	100	-	100	78	80	100	
5	Hours of variable wind	5.6	5.6	-	4.0	-	-	-	0	24	0	0	0	0	
6	Percent of sampling period	23	23	-	17	-	-	-	0	100	0	0	0	0	
7	Wind data confidence factor	3	1	-	1	-	-	-	1	4	1	1	1	1	
8	Particulate matter collected ($\mu g/m^3$)	72	161	72	26	138	78	-	73	208	52	54	177	115	88
8A	Particulate matter from local agency sampler	-	34	41	18	71	47	45	54	126	51	68	113	110	57
9	Average of all plant samplers	63	127	73	24	121	68	71	71	173	51	48	166	110	
10	Percent over or under plant ave. 8/9	114	127	99	108	114	115	-	103	120	102	113	107	105	

TABLE A.3

SAMPLER F

Date:	APRIL	2	4	7	9	11	14	16	18	21	23	25	28	30	GM
1	Resultant wind from plant sector (dir/mph)	0	ESE 2	-	0	-	-	-	0	-	0	NNE 7	SSW 8	0	
2	Percent of sampling period	0	51	-	0	-	-	-	0	-	0	22	20	0	
3	Resultant wind not from plant sector (dir/mph)	WNW 1	SW 11	-	NW 18	-	-	-	NW 9	-	NW 21	NW 16	W 11	NW 12	
4	Percent of sampling period	77	26	-	83	-	-	-	100	-	100	78	80	100	
5	Hours of variable wind	5.6	5.6	-	4.0	-	-	-	0	24	0	0	0	0	
6	Percent of sampling period	23	23	-	17	-	-	-	0	100	0	0	0	0	
7	Wind data confidence factor	3	1	-	-	-	-	-	1	4	1	1	1	1	
8	Particulate matter collected ($\mu g/m^3$)	58	180	66	24	129	63	-	-	-	-	-	181	115	85
8A	Particulate matter from local agency sampler	-	34	41	18	71	47	45	54	126	51	68	113	110	57
9	Average of all plant samplers	63	127	73	24	121	68	71	71	173	51	48	166	110	
10	Percent over or under plant ave. 8/9	92	142	90	100	107	93	-	-	-	-	-	109	105	

TABLE A.4

SAMPLER A

Date	MAY	2	5	7	9	12	14	16	19	21-23	27	29	23	30	GM
1	Resultant wind from plant sector (dir/mph)	SE 7	SE 10	0	SSE 10	-	SSW 11	SSE 10	-	0	SE 4	-			
2	Percent of sampling period	52	38	0	50	-	48	49	-	0	14	-			
3	Resultant wind not from plant sector (dir/mph)	ESE 5	ESE 8	N 10	E 8	-	W 4	WNW 7	-	NNE 5	ENE 4	-			
4	Percent of sampling period	40	41	63	27	-	30	43	-	92	86	-			
5	Hours of variable wind	1.9	5.1	8.8	5.5	-	5.4	2.1	-	2.7	0	-			
6	Percent of sampling period	8	21	37	23	-	22	8	-	8	0	-			
7	Wind data confidence factor	2	3	3	3	-	2	4	-	4	3	-			
8	Particulate matter collected ($\mu g/m^3$)	31	34	41	62	58	115	102	54	65	40	106			58
8*	Particulate matter from local agency sampler	94	61	39	40	37	72	67	100	70	49	-	34	51	56
9	Average of all plant samplers	138	87	48	151	129	135	117	113	97	41	93			
10	Percent over or under plant ave. 8/9	22	39	85	41	45	85	87	48	67	98	114			

TABLE A.5

SAMPLER E

Date:	MAY	2	5	7	9	12	14	16	19	21-23	27	29	23	30	GM
1	Resultant wind from plant sector (dir/mph)	SE 8	SE 10	0	SE 7	-	SSW 11	SSE 10	-	NE 6	ENE 7	-			
2	Percent of sampling period	71	69	0	77	-	48	49	-	11	76	-			
3	Resultant wind not from plant sector (dir/mph)	WSW 3	W 2	N 10	0	-	W 4	WNW 7	-	NNE 5	WSW 7	-			
4	Percent of sampling period	21	10	63	0	-	30	43	-	81	24	-			
5	Hours of variable wind	1.9	5.1	8.8	5.5	-	5.4	2.1	-	2.7	0	-			
6	Percent of sampling period	8	21	37	23	-	22	8	-	8	0	-			
7	Wind data confidence factor	2	3	3	3	-	2	4	-	4	3	-			
8	Particulate matter collected ($\mu g/m^3$)	209	142	51	173	81	150	129	175	132	55	90			115
8A	Particulate matter from local agency sampler	94	61	39	40	37	72	67	100	70	49	-	34	51	56
9	Average of all plant samplers	138	87	48	151	129	135	117	113	97	41	93			
10	Percent over or under plant ave. 8/9	151	163	106	115	63	111	110	155	136	134	97			

TABLE A.6

SAMPLER F

Date:	MAY	2	5	7	9	12	14	16	19	21-23	27	29	23	30	GM
1	Resultant wind from plant sector (dir/mph)	SE 8	SE 10	0	SE 7	-	SSW 11	SSE 10	-	NE 6	ENE 7	-			
2	Percent of sampling period	71	69	0	77	-	48	49	-	11	76	-			
3	Resultant wind not from plant sector (dir/mph)	WSW 3	W 2	N 10	0	-	W 4	WNW 7	-	NNE 5	WSW 7	-			
4	Percent of sampling period	21	10	63	0	-	30	43	-	81	24	-			
5	Hours of variable wind	1.9	5.1	8.8	5.5	-	5.4	2.1	-	2.7	0	-			
6	Percent of sampling period	8	21	37	23	-	22	8	-	8	0	-			
7	Wind data confidence factor	2	3	3	3	-	2	4	-	4	3	-			
8	Particulate matter collected ($\mu g/m^3$)	174	85	53	219	248	139	119	111	93	28	83			105
8A	Particulate matter from local agency sampler	94	61	39	40	37	72	67	100	70	49	-	34	51	56
9	Average of all plant samplers	138	87	48	151	129	135	117	113	97	41	93			
10	Percent over or under plant ave. 8/9	126	98	110	145	192	103	102	98	96	68	89			

TABLE A.7

SAMPLER A

Date	JUNE	2	4	6	9	11	13	16	18	20	23	25	27	30	GM
1	Resultant wind from plant sector (dir/mph)	-	-	-	-	-	-	-	SSW 5	SSW 4	0	SSW 5	0	S 4	
2	Percent of sampling period	-	-	-	-	-	-	-							
3	Resultant wind not from plant sector (dir/mph)	-	-	-	-	-	-	-	NW 7	NNE 4	SW 3	N 4	WSW 5	WNW 4	
4	Percent of sampling period	-	-	-	-	-	-	-	66	48	100	31	94	85	
5	Hours of variable wind	-	-	-	-	-	-	-	0	1.29	0	0	1.5	0	
6	Percent of sampling period	-	-	-	-	-	-	-	0	5	0	0	6	0	
7	Wind data confidence factor	-	-	-	-	-	-	-	4	4	2	2	1	3	
8	Particulate matter collected ($\mu g/m^3$)	23	75	46	45	43	77	34	43	63	35	40	55	-	46
8A	Particulate matter from local agency sampler	21	57	76	-	51	50	47	31	65	30	34	73	55	46
9	Average of all plant samplers	37	47	106	56	49	88	56	61	76	39	48	101	55	
10	Percent over or under plant ave. 8/9	62	160	43	80	88	88	61	71	83	90	83	55	-	

TABLE A.8

SAMPLER E

Date:	JUNE	2	4	6	9	11	13	16	18	20	23	25	27	30	GM
1	Resultant wind from plant sector (dir/mph)	-	-	-	-	-	-	-	SSW 5	SSW 4	0	SSW 5	0	S 4	
2	Percent of sampling period	-	-	-	-	-	-	-	34	47	0	69	0	15	
3	Resultant wind not from plant sector (dir/mph)	-	-	-	-	-	-	-	NW 7	NNE 4	SW 3	N 4	WSW 5	WNW 4	
4	Percent of sampling period	-	-	-	-	-	-	-	66	48	100	31	94	85	
5	Hours of variable wind	-	-	-	-	-	-	-	0	1.29	0	0	1.5	0	
6	Percent of sampling period	-	-	-	-	-	-	-	0	5	0	0	6	0	
7	Wind data confidence factor	-	-	-	-	-	-	-	4	4	2	2	1	3	
8	Particulate matter collected ($\mu g/m^3$)	55	24	-	-	55	102	65	71	95	43	60	151	49	63
8A	Particulate matter from local agency sampler	21	57	76	-	51	50	47	31	65	30	34	73	55	46
9	Average of all plant samplers	37	47	106	56	49	88	56	61	76	39	48	101	55	
10	Percent over or under plant ave. 8/9	149	51	-	-	112	116	116	116	125	110	125	150	89	

TABLE A.9

SAMPLER F

Date:	JUNE	2	4	6	9	11	13	16	18	20	23	25	27	30	GM
1	Resultant wind from plant sector (dir/mph)	-	-	-	-	-	-	-	SSW 5	SSW 4	0	SSW 5	0	S 4	
2	Percent of sampling period	-	-	-	-	-	-	-	34	47	0	69	0	15	
3	Resultant wind not from plant sector (dir/mph)	-	-	-	-	-	-	-	NW 7	NNE 4	SW 3	N 4	WSW 5	WNW 4	
4	Percent of sampling period	-	-	-	-	-	-	-	66	48	100	31	94	85	
5	Hours of variable wind	-	-	-	-	-	-	-	0	1.29	0	0	1.5	0	
6	Percent of sampling period	-	-	-	-	-	-	-	0	5	0	0	6	0	
7	Wind data confidence factor	-	-	-	-	-	-	-	4	4	2	2	1	3	
8	Particulate matter collected ($\mu g/m^3$)	33	41	165	66	-	85	69	70	71	40	45	97	61	64
8A	Particulate matter from local agency sampler	21	57	76	-	51	50	47	31	65	30	34	73	55	46
9	Average of all plant samplers	37	47	106	56	49	88	56	61	76	39	48	101	55	
10	Percent over or under plant ave. 8/9	89	87	156	118	-	97	123	115	93	103	94	96	111	

TABLE A.10

SAMPLER A

Date:	JULY	2	4	7	9	11	14	16	18	21	23	25	28	30	31	GM
1	Resultant wind from plant sector (dir/mph)	SSW/2	NW/1	0	SSW/2	SSW/2	SSW/2	SSW/2	-	0	0	0	SE/4	-		
2	Percent of Sampling period	9	100	0	27	66	29	89	-	0	0	0	34			
3	Resultant wind not from plant sector (dir/mph)	WNW/4	0	WSW/2	NW/2	NW/2	W/2	NNW/2	-	W/7	W/4	WSW/7	WSW/3	-		
4	Percent of sampling period	89	0	100	73	34	71	11	-	100	100	100	66	-		
5	Hours of variable wind	0.5	0	0	0	0	0	0	-	0	0	0	0	-		
6	Percent of sampling period	2	0	0	0	0	0	0	-	0	0	0	0	-		
7	Wind data confidence factor	3	3	2	3	3	3	3	-	2	1	2	1	-		
8	Particulate matter collected ($\mu g/m^3$)	-	36	37	82	100	-	72	486	70	88	60	-	32		73
8A	Particulate matter from local agency sampler	66	43	34	63	64	59	57	91	64	66	72	37	-	43	56
9	Average of all plant samplers	-	73	49	94	94	63	75	264	102	104	-	49	46		
10	% over or under plant ave. 8/9	-	49	75	87	106	-	96	184	69	85	-	-	70		

TABLE A.11

SAMPLER E

Date:	JULY	2	4	7	9	11	14	16	18	21	23	25	28	30	31	GM
1	Resultant wind from plant sector (dir/mph)	SSW/2	ENE/3	0	SSW/2	SSW/2	SSW/2	SSW/2	-	0	0	0	SE/4	-		
2	Percent of sampling period	9	27	0	27	66	29	89	-	0	0	0	34	-		
3	Resultant wind not from plant sector (dir/mph)	WNW/4	W/2	WSW/2	NW/2	NW/2	W/2	NNW/2	-	W/7	W/4	WSW/7	WSW/3	-		
4	Percent of sampling period	89	73	100	73	34	71	11	-	100	100	100	66	-		
5	Hours of variable wind	0.5	0	0	0	0	0	0	-	0	0	0	0	-		
6	Percent of sampling period	2	0	0	0	0	0	0	-	0	0	0	0	-		
7	Wind data confidence factor	3	3	2	3	3	3	3	-	2	1	2	1	-		
8	Particulate matter collected ($\mu g/m^3$)	91	99	50	104	77	84	77	156	113	116	-	44	54		83
8A	Particulate matter from local agency sampler	66	43	34	63	64	59	57	91	64	66	72	37	-	43	56
9	Average of all plant samplers	-	73	49	94	94	63	75	264	102	104	-	49	46		
10	% over or under plant ave. 8/9	-	136	102	111	82	133	103	59	111	112	-	90	117		

TABLE A.12

SAMPLER F

Date:	JULY	2	4	7	9	11	14	16	18	21	23	25	28	30	31	GM
1	Resultant wind from plant sector (dir/mph)	SSW/2	ENE/3	0	SSW/2	SSW/2	SSW/2	SSW/2	-	0	0	0	SE/4	-		
2	Percent of Sampling period	9	27	0	27	66	29	89	-	0	0	0	34	-		
3	Resultant wind not from plant sector (dir/mph)	WNW/4	W/2	WSW/2	NW/2	NW/2	W/2	NNW/2	-	W/7	W/4	WSW/7	WSW/3	-		
4	Percent of sampling period	89	73	100	73	34	71	11	-	100	100	100	66	-		
5	Hours of variable wind	0.5	0	0	0	0	0	0	-	0	0	0	0	-		
6	Percent of sampling period	2	0	0	0	0	0	0	-	0	0	0	0	-		
7	Wind data confidence factor	3	3	2	3	3	3	3	-	2	1	2	1	-		
8	Particulate matter collected ($\mu g/m^3$)	-	83	60	95	105	41	-	149	124	109	-	54	52		81
8A	Particulate matter from local agency sampler	66	43	34	63	64	59	57	91	64	66	72	37	-	43	56
9	Average of all plant samplers	-	73	49	94	94	63	75	264	102	104	-	49	46		
10	% over or under plant ave. 8/9	-	114	122	101	112	65	-	56	122	105	-	110	113		

TABLE A.13

SAMPLER A

Date:	AUGUST	1	4	6	8	11	13	15	18	20	22	25	27	29	21	GM
1	Resultant wind from plant sector (dir/mph)	SE/5	SSE/8	-	0	-	0	0	SSW/5	SSE/5	-	-	-	-		
2	Percent of sampling period	17	21	-	0	-	0	0	5	7	-	-	-	-		
3	Resultant wind not from plant sector (dir/mph)	W/7	WSW/6	-	W/3	-	W/6	WSW/2	W/3	W/3	-	-	-	-		
4	Percent of sampling period	83	79	-	100	-	75	100	71	85	-	-	-	-		
5	Hours of variable wind	0	0	-	0	-	6.0	0	5.8	1.8	-	-	-	-		
6	Percent of sampling period	0	0	-	0	-	25	0	24	8	-	-	-	-		
7	Wind data confidence factor	2	2	-	3	-	4	4	4	4	-	-	-	-		
8	Particulate matter collected ($\mu g/m^3$)	97	29	67	35	37	70	70	50	64	61	68	114	80		60
8A	Particulate matter from local agency sampler	84	29	60	-	56	51	-	41	-	-	49	74	36	72	53
9	Average of all plant samplers	114	56	81	45	79	86	94	45	115	95	77	121	159		
10	% over or under plant ave. 8/9	85	52	83	78	47	81	74	111	56	64	88	94	50		

TABLE A.13

SAMPLER A

Date:	AUGUST	1	4	6	8	11	13	15	18	20	22	25	27	29	21	GM
1	Resultant wind from plant sector (dir/mph)	SE/5	SSE/8	-	0	-	0	0	SSW/5	SSE/5	-	-	-	-		
2	Percent of sampling period	17	21	-	0	-	0	0	5	7	-	-	-	-		
3	Resultant wind not from plant sector (dir/mph)	W/7	WSW/6	-	W/3	-	W/6	WSW/2	W/3	W/3	-	-	-	-		
4	Percent of sampling period	83	79	-	100	-	75	100	71	85	-	-	-	-		
5	Hours of variable wind	0	0	-	0	-	6.0	0	5.8	1.8	-	-	-	-		
6	Percent of sampling period	0	0	-	0	-	25	0	24	8	-	-	-	-		
7	Wind data confidence factor	2	2	-	3	-	4	4	4	4	-	-	-	-		
8	Particulate matter collected ($\mu g/m^3$)	97	29	67	35	37	70	70	50	64	61	68	114	80		60
8A	Particulate matter from local agency sampler	84	29	60	-	56	51	-	41	-	-	49	74	36	72	53
9	Average of all plant samplers	114	56	81	45	79	86	94	45	115	95	77	121	159		
10	% over or under plant ave. 8/9	85	52	83	78	47	81	74	111	56	64	88	94	50		

TABLE A.14

SAMPLER E

Date:	AUGUST	1	4	6	8	11	13	15	18	20	22	25	27	29	21	GM
1	Resultant wind from plant sector (dir/mph)	SE/5	SSE/8	-	0	-	0	0	SSW/5	E/4	-	-	-	-		
2	Percent of sampling period	17	21	-	0	-	0	0	5	19	-	-	-	-		
3	Resultant wind not from plant sector (dir/mph)	W/7	WSW/6	-	W/3	-	W/6	WSW/2	W/3	W/5	-	-	-	-		
4	Percent of sampling period	83	79	-	100	-	75	100	71	73	-	-	-	-		
5	Hours of variable wind	0	0	-	0	-	6.0	0	5.8	1.8	-	-	-	-		
6	Percent of sampling period	0	0	-	0	-	25	0	24	8	-	-	-	-		
7	Wind data confidence factor	2	2	-	3	-	4	4	4	4	-	-	-	-		
8	Particulate matter collected ($\mu g/m^3$)	124	53	91	44	126	112	94	20	165	155	-	-	330		95
8A	Particulate matter from local agency sampler	84	29	60	-	56	51	-	41	-	-	49	74	36	72	53
9	Average of all plant samplers	114	56	81	45	79	86	94	45	115	95	77	121	159		
10	% over or under plant ave. 8/9	109	95	112	98	159	130	100	44	143	163	-	-	208		

TABLE A.15

SAMPLER F

Date:	AUGUST	1	4	6	8	11	13	15	18	20	22	25	27	29	21	GM
1	Resultant wind from plant sector (dir/mph)	SE/5	SSE/8	-	0	-	0	0	SSW/5	E/4	-	-	-	-		
2	Percent of Sampling period	17	21	-	0	-	0	0	5	19	-	-	-	-		
3	Resultant wind not from plant sector (dir/mph)	W/7	WSW/6	-	W/3	-	W/6	WSW/2	W/3	W/5	-	-	-	-		
4	Percent of sampling period	83	79	-	100	-	75	100	71	73	-	-	-	-		
5	Hours of variable wind	0	0	-	0	-	6.0	0	5.8	1.8	-	-	-	-		
6	Percent of sampling period	0	0	-	0	-	25	0	24	8	-	-	-	-		
7	Wind data confidence factor	2	2	-	3	-	4	4	4	4	-	-	-	-		
8	Particulate matter collected ($\mu g/m^3$)	122	86	86	55	75	76	118	64	117	69	85	128	66		85
8A	Particulate matter from local agency sampler	84	29	60	-	56	51	-	41	-	-	49	74	36	72	53
9	Average of all plant samplers	114	56	81	45	79	86	94	45	115	95	77	121	159		
10	% over or under plant ave. 8/9	107	154	106	122	95	88	126	142	102	73	110	106	42		

TABLE A.16

SAMPLER A

Date:	SEPTEMBER	1	3	5	8	10	12	15	17	19	22	24	26	29		GM
1	Resultant wind from plant sector (dir/mph)	-	-	-	-	-	SE/10	S/5	SSW/7	S/12	SSE/5	SSE/12	0	S/7		
2	Percent of sampling period	-	-	-	-	-	2	15	16	36	19	39	0	28		
3	Resultant wind not from plant sector (dir/mph)	-	-	-	-	-	NW/6	WNW/5	WNW/6	NNW/6	N/5	W/5	WNW/7	NNW/16		
4	Percent of sampling period	-	-	-	-	-	98	78	84	64	81	61	100	72		
5	Hours of variable wind	-	-	-	-	-	0	1.7	0	0	0	0	0	0		
6	Percent of sampling period	-	-	-	-	-	0	7	0	0	0	0	0	0		
7	Wind data confidence factor	-	-	-	-	-	4	3	3	2	4	2	4	3		
8	Particulate matter collected ($\mu g/m^3$)	49	72	57	36	37	72	42	69	90	-	-	84	47		57
8A	Particulate matter from local agency sampler	-	-	45	22	31	-	-	37	-	-	71	39	14	39	34
9	Average of all plant samplers	52	82	78	38	54	71	48	85	110	38	113	73	57		
10	% over or under plant ave. 8/9	94	88	73	95	69	101	88	81	82	-	-	115	82		

TABLE A.17

SAMPLER E

Date: SEPTEMBER	1	3	5	8	10	12	15	17	19	22	24	26	29	13	
1 Resultant wind from plant sector (dir/mph)	-	-	-	-	-	SE/10	S/5	SSW/7	S/12	SSE/5	SSE/12	0	S/7		
2 Percent of sampling period	-	-	-	-	-	2	15	16	36	19	39	0	28		
3 Resultant wind not from plant sector (dir/mph)	-	-	-	-	-	NW/6	WNW/5	WNW/6	NNW/6	N/5	W/5	WNW/7	NNW/16		
4 Percent of sampling period	-	-	-	-	-	98	78	84	64	81	61	100	72		
5 Hours of variable wind	-	-	-	-	-	0	1.7	0	0	0	0	0	0		
6 Percent of sampling period	-	-	-	-	-	0	7	0	0	0	0	0	0		
7 Wind data confidence factor	-	-	-	-	-	4	3	3	2	4	2	4	3		
8 Particulate matter-E1	55	87	92	39	55	60	47	88	114	43	145	69	53		
collected ($\mu g/m^3$) -E2	17	210	79	39	59	61	47	97	118	41	140	68	54		
8A Particulate matter from (Ave. of E)	55	87	86	39	57	61	47	93	116	42	143	69	53		
Local agency sampler	-	-	45	22	31	-	-	37	-	-	71	39	14	39	33
9 Average of all plant samplers	52	82	78	38	54	71	48	85	110	38	113	73	57		
10 % over or under plant ave. 8/9	106	106	110	103	106	86	98	109	105	111	127	95	93		

TABLE A.18

SAMPLER F

Date:	SEPTEMBER	1	3	5	8	10	12	15	17	19	22	24	26	27		
1	Resultant wind from plant sector (dir/mph)	-	-	-	-	-	SE/10	S/5	SSW/7	S/12	SSE/5	SSE/12	0	S/7		
2	Percent of sampling period	-	-	-	-	-	2	15	16	36	19	39	0	28		
3	Resultant wind not from plant sector (dir/mph)	-	-	-	-	-	NW/6	WNW/5	WNW/6	NNW/6	N/5	W/5	WNW/7	NNW/16		
4	Percent of sampling period	-	-	-	-	-	98	78	84	64	81	61	100	72		
5	Hours of variable wind	-	-	-	-	-	0	1.7	0	0	0	0	0	0		
6	Percent of sampling period	-	-	-	-	-	0	7	0	0	0	0	0	0		
7	Wind data confidence factor	-	-	-	-	-	4	3	3	2	4	2	4	3		
8	Particulate matter collected ($\mu g/m^3$)	53	83	91	38	69	64	-	-	103	36	96	72	49		
8A	Particulate matter from local agency sampler	-	-	45	22	31	-	-	37	-	-	71	39	14	39	33
9	Average of all plant samplers	52	82	78	38	54	71	48	85	110	38	113	73	57		
10	% over or under plant ave. 8/9	102	105	117	100	128	90	-	-	94	95	85	99	86		

APPENDIX B

Correlation of wind data recorded at the plant with wind data recorded at the local airport for the months of April through September 1974.

Key for Directions

1 (17) - N	9 - S
2 - NNE	10 - SSW
3 - NE	11 - SW
4 - ENE	12 - WSW
5 - E	13 - W
6 - ESE	14 - WNW
7 - SE	15 - NW
8 - SSE	16 - NNW

Speeds Are Expressed to the

Nearest Mile per Hour

Mean direction, difference $\bar{D}$, and mean speed, difference $\bar{S}$ were calculated using the following equation:

$$\bar{D} \text{ or } \bar{S}_p = \frac{\Sigma x_i}{n}$$

Standard deviation of differences in directions and speeds were calculated using the following equation:

$$S = \left[\frac{\Sigma(x_i - \bar{x})^2}{n-1}\right]^{1/2}$$

TABLE B.1

APRIL RESULTANT WINDS

Date	Plant Wind			Airport Wind		
	Dir	--	Spd	Dir	--	Spd
2	14	-	10	13	-	10
4	9	-	6	8	-	11
7	-		-	9	-	7
9	15	-	18	15	-	16
11	-		-	8	-	5
14	-		-	13	-	5
16	-		-	15	-	12
18	15	-	9	14	-	8
21	-		-	9	-	5
23	15	-	21	14	-	13
25	16	-	11	17	-	5
28	13	-	9	11	-	3
30	15	-	12	13	-	11

Differences in direction: $\bar{D} = 1.125$, $S = 0.64$

Differences in speed: $\bar{S}_p = 3.625$, $S = 2.99$

MAY RESULTANT WINDS

Date	Plant Wind				Airport Wind			
	Dir	-	Spd		Dir	-	Spd	
2	7	-	6		8	-	5	
5	7	-	9		5	-	6	
7	17	-	10		16	-	8	
9	7	-	8		7	-	7	
12	-		-		14	-	8	
14	10	-	7		8	-	8	
16	9	-	4		8	-	2	
19	-		-		7	-	4	
27	18	-	4		16	-	3	
29	-		-		13	-	7	

Differences in direction: $\bar{D} = 1.286$, $S = 0.755$

Differences in speed: $\bar{S}_p = 1.571$, $S = 0.788$

JUNE RESULTANT WINDS

Date	Plant Wind			Airport Wind		
	Dir	-	Spd	Dir	-	Spd
2	-		-	2	-	5
4	-		-	8	-	3
6	-		-	7	-	7
9	-		-	10	-	3
11	-		-	16	-	11
13	-		-	11	-	2
16	-		-	9	-	2
18	11	-	4	13	-	3
20	12	-	1	13	-	10
23	11	-	3	16	-	3
25	18	-	2	16	-	6
27	12	-	5	4	-	5
30	4	-	3	12	-	8

Differences in direction: $\bar{D} = 4.34$, $S = 3.13$

Differences in speeds; $\bar{S}_p = 3.17$, $S = 3.55$

JULY RESULTANT WINDS

Date	Plant Wind			Airport Wind		
	Dir	-	Spd	Dir	-	Spd
2	14	-	4	15	-	3
4	15	-	1	10	-	6
7	12	-	2	17	-	1
9	14	-	2	16	-	2
11	11	-	1	13	-	1
14	12	-	2	16	-	2
16	10	-	2	17	-	5
18	-		-	11	-	2
21	13	-	7	6	-	5
23	13	-	4	8	-	3
25	12	-	7	6	-	4
28	10	-	2	3	-	3
30	-		-	14	-	5

Differences in direction: $\bar{D} = 4.64$, $S = 2.16$

Differences in speeds: $\bar{S}_p = 1.55$, $S = 1.57$

AUGUST RESULTANT WINDS

Date	Plant Wind			Airport Wind		
	Dir	-	Spd	Dir	-	Spd
1	13	-	5	5	-	4
4	12	-	5	6	-	4
6	-		-	3	-	5
8	13	-	3	7	-	5
11	-		-	8	-	8
13	13	-	6	2	-	4
15	12	-	2	4	-	2
18	13	-	4	1	-	2
20	13	-	3	5	-	5
22	-		-	3	-	4
25	-		-	16	-	3
27	-		-	9	-	1
29	-		-	13	-	4

Differences in direction: $\bar{D} = 6.40$, $S = 1.63$

Differences in speed: $\bar{S}_p = 1.40$, $S = 0.79$

SEPTEMBER RESULTANT WINDS

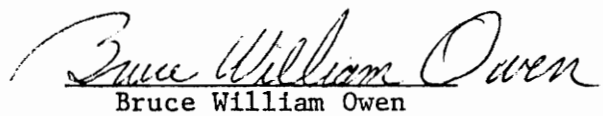
Date	Plant Wind			Airport Wind		
	Dir	-	Spd	Dir	-	Spd
1	-		-	15	-	2
3	-		-	10	-	2
5	-		-	4	-	3
8	-		-	9	-	3
10	-		-	13	-	3
12	15	-	6	11	-	2
15	14	-	3	9	-	1
17	13	-	5	12	-	1
19	12	-	2	9	-	2
22	17	-	3	17	-	3
24	10	-	4	7	-	2
26	14	-	7	15	-	2
29	16	-	10	14	-	10

Differences in direction: $\bar{D} = 2.37$, $S = 1.68$

Differences in speed: $\bar{S}_p = 2.12$, $S = 2.3$

VITA

The author received the Bachelor of Science degree in Civil Engineering from Virginia Polytechnic Institute in June 1962 and served as an officer in the United States Navy until November 1970. He then entered the United States Civil Service as a General Engineer for the Veterans Administration Hospital, Salem, Virginia. He is presently working toward a Master of Science degree in Sanitary Engineering.



Bruce William Owen

AIR QUALITY AT AN ELECTRIC-ARC STEEL MANUFACTURING PLANT

by

Bruce William Owen

(ABSTRACT)

An extended air sampling program was conducted at an electric-arc secondary steel manufacturing facility using the HI-VOLUME Sampler reference method for suspended particulates. A wind recording device was installed at the facility to provide a continuous record of wind data for correlation with the particulate concentrations collected. Weather data obtained from the National Weather Service were also used.

A relationship between wind direction and speed with the levels of particulate matter collected was found indicating areas of significant pollution sources. Wind-pollution roses were constructed showing the frequency distribution of the wind during periods when particulate concentrations were above and below the national ambient air standards. These roses were compared with the atmospheric stability classes for each of those periods.

Log-probability plots were constructed for each sampling point and an exponential relationship was found between mean concentrations at each sampler and each sampler's distance from the source. Using this relationship, an estimated emission rate for the facility was calculated. A background level for the area in the vicinity of the

of the facility was found.

Some conclusions were that the mean level of concentration decreased exponentially with distance from the source and that the estimated emission rate for the facility was below the maximum allowable by the State Air Pollution Control Board.

It was also concluded that, in long term sampling, wind characteristics showed a positive relationship with particulate concentrations. The most significant conclusion was that the emission activity at the steel facility had minimal effect on a sampler located 1,000 yards away.