



Technical Report

THE CHEMISTRY, DISPERSION, AND
TRANSPORT OF AIR POLLUTANTS
EMITTED FROM FOSSIL FUEL
POWER PLANTS IN CALIFORNIA

Airborne Pollutant Measurement
and Analysis

MRI 75 FR-1382

Submitted to

California Air Resources Board
Sacramento, California

Contract No. ARB 3-929
Date 30 November 1975
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ACKNOWLEDGEMENTS

The cooperation of the various contributing groups (Caltech, Rockwell Air Monitoring Center, and Environmental Measurements, Inc.) has contributed significantly to the success of the field portions of the program. Sulfate analyses of the airborne filters were carried out by the Air Industrial Hygiene Laboratory. Mr. Gary Palo and Mr. Chuck Bennett from the ARB have served effectively in a coordinating role to provide a central focal point for organization of the program. Numerous personnel at MRI have contributed to the program. Notable among these is Mr. S. Muller who has supervised the extensive data reduction procedures.

NOTE

"The statements and conclusions in this report are those of the Contractor and not necessarily those of the State Air Resources Board. The mention of commercial products, their source or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products."

ABSTRACT

An extensive field program has been carried out to investigate the effects of large, fossil fuel plants on the air quality environment in California. Primary objectives of the program included an evaluation of the impact of the plants on surface SO_2 and NO_x concentrations and an assessment of the importance of SO_2 and NO_x reactions in the plume. A number of organizations cooperated in the field studies. These included Caltech, Rockwell Air Monitoring Center, Environmental Measurements, Inc., and Meteorology Research, Inc. The program consisted of SF_6 tracer releases from three different power plants and downwind sampling of SO_2 , SF_6 , and sulfates on the ground and in an instrumented aircraft. NO_x and other pollutants were also sampled in the aircraft.

The MRI portion of the studies consisted of airborne and meteorological measurements. Analyses of the data include an estimate of the impact of the plume on surface concentrations, details of the plume behavior and reaction estimates within the plume.

With only one major exception the plumes from the plant were confined to the low-level mixing layer and impacted at ground levels from 13 to 24 km downwind of the plant. On one day (September 10) at Moss Landing the plume penetrated above the mixing layer and did not significantly affect ground level concentrations. Peak hourly ground concentrations were found from the tracer studies to range between 0.009 and 0.082 ppm of equivalent SO_2 for a given power plant on the sampling days. An unusual feature of the Haynes-Alamitos studies was the consistency of the plume direction from the plants. On all test days the plume direction during the early afternoon hours (when mixing to the ground occurs most readily) was toward the northeast. Thus the area affected by the plumes from Haynes-Alamitos tends to be consistent and rather localized under typical seabreeze conditions.

The reaction of NO , NO_2 and O_3 in the plumes occurred rapidly and resulted in ozone deficits in the plumes. The conversion of SO_2 to sulfate occurred too slowly to be detected within the downwind distance of the identifiable plumes.

This report was submitted by MRI in fulfillment of Contract No. ARB 3-929 under sponsorship of the California Air Resources Board. Work was completed as of November 30, 1975.

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1. Conclusions

1. Observed plume heights generally ranged from 300 to 450 m msl. Environment test conditions at Haynes-Alamitos are considered to be typical of seabreeze flow conditions in the area. Somewhat lower values of plume rise could be expected under extreme stability conditions. At Moss Landing, strong temperature inversions characterized the test program. Observed plume rises consequently may be lower than would be considered typical.

2. On one day at Moss Landing the plume rise was sufficiently high (with attendant low level stability) that little tracer material was observed at the ground. On one day at Haynes a portion of the plume was apparently carried upward above the mixing layer. Otherwise the plumes remained in the low-level mixing layer and mixed to the ground as the result of surface heating effects downwind.

3. Plume direction at Moss Landing during the afternoon (when downward mixing can occur) was somewhat variable from easterly to southeasterly. At Haynes-Alamitos the plume direction during the early afternoon was consistently to the northeast. This put the peak ground impact of the Haynes-Alamitos plumes consistently at a distance of 15-20 km to the northeast of the plants.

4. On the basis of the observed SF_6 concentrations, peak equivalent SO_2 concentrations at ground level attributable to the total SO_2 output from a single plant ranged from 0.009 ppm to 0.082 ppm for the various sampling days.

5. Plumes were identifiable in the aircraft in the South Coast basin to a distance of 18 km for SO_2 and 8 km for NO_x . Limitations on plume identification at farther downwind distances were caused by background concentrations. This means that the plume can be considered as a single source for approximately these distances. Thereafter, the contribution of the plume can be treated as an effect on the total pollutant budget of the basin.

6. The reaction of NO and ozone in the plume results in a clearly defined O_3 deficit for a distance of at least 8 km from the plant. Thereafter, the effects of ambient hydrocarbons can be expected to play a more dominant role in the $\text{NO}_x - \text{O}_3$ chemistry of the plume.

7. The SO_2 to sulfate reaction occurred too slowly to be measured quantitatively during the experiments. Changes in sulfate concentration downwind appeared to reflect changes in background concentrations rather than reactions in the plume.

2. Recommendations and Comments

Results of the study lead to certain recommendations and comments concerning the impact of large power plants, particularly in the South Coast Basin.

1. The immediate coastal areas may not be the best environment for the large SO_2 sources from an environmental standpoint. Although the plumes are injected well into the mixing layer at the source, the plumes reach the ground downwind due to surface heating effects inland. Peak concentrations occur consistently from 10-20 km downwind and in a surprisingly uniform direction from the plants. At these downwind distances from the coast, population density tends to be very high. Numbers of people affected would be less for inland plant locations and the plumes might well be better dispersed. Plant requirements for water, for example, and associated problems are not being considered in these remarks.

2. The plumes in the South Coast Basin were rather easily contained within the mixing layer. This suggests that reasonably higher stack heights would not greatly improve the situation. On only a small fraction of the days will plumes penetrate above the mixing layer and be unable to affect ground concentrations. Additional stack heights of more than 100 m would probably be needed to affect this fraction significantly. Higher stack heights would also tend to decrease peak ground concentrations. Again, increases of 100 m or more would be needed to reduce the concentrations by 30% or more unless the top of the mixing layer were penetrated.

3. Estimates of the downwind ground impact of the plants do not indicate local violations of pollution standards if low sulfur content oil (approximately 0.45%) continues to be used. Instead, primary ground impact problems result from the high frequency of impact occurrence in a rather localized geographical area. If higher sulfur content oils come into use, standard violations in these areas might occur.

The principal SO_2 impacts under present conditions, therefore, are suggested to be the ultimate conversion to respirable sulfates and the ultimate effect of these aerosols on visibility. These impacts can be defined in terms of contributions to the total basin loadings rather than impacts in localized areas.

Control strategies directed at the total basin problems dictate that reductions of SO_2 of any magnitude would be beneficial. This concept, however, may conflict with the growing problems of natural gas supplies. The compromise position may be conversion to natural gas on an episodic basis (for time intervals as short as one day) in order to reduce SO_2 impact specifically during those periods when significant contributions to sulfates and visibility can be expected.

3. Program Discussion

3.1 Introduction

Increasing attention has been devoted recently to the effects of large, stationary sources on the air pollution environment in California. Primary questions have been raised in connection with large, fossil-fuel, power plants and their potential impact in air basins such as the South Coast. A major requirement for such information relates to the effectiveness of possible control strategies such as the use of alternate fuels.

A multi-organizational program was initiated by the Air Resources Board in 1974 to consider the effects of several fossil-fuel power plants on air quality in California. Objective of the program was to examine the chemistry, dispersion, and transport of pollutants from these plants. Operational variations consisting of the plant use of oil vs gas and differences in the background pollutant environment were incorporated into the program design. A key factor in assuring proper interpretation of the pollutant measurements was the release of a tracer gas, SF_6 , from each plant.

Areas of responsibility in the multi-organizational program included the following:

1. SF_6 release, sampling, and analysis - Caltech.
2. Ground observations of SO_2 and sulfates - Rockwell Air Monitoring Center.
3. Sulfate analyses - Air and Industrial Hygiene Laboratory.
4. Correlation spectrometer measurements of SO_2 - Environmental Measurements, Inc.
5. Airborne sampling and meteorological measurements - Meteorology Research, Inc.

The program consisted of nine days of sampling; three each at the Moss Landing (Pacific Gas and Electric Co.), Haynes (Los Angeles Water and Power), and Alamitos (Southern California Edison Co.) plants.

The present report discusses the MRI phases of the program. Program design, operational details, and data reduction are described. General descriptions of the meteorological environment on each day are included. Airborne plume data together with plume impact at ground level are also described.

3.2 Design of the Experiment

Basic components of the program consisted of the following:

1. SF₆ tracer release
2. SF₆ sampling (ground and airborne)
3. SO₂ concentrations (ground and airborne)
4. Sulfate sampling (ground and airborne)
5. Meteorological environment definition
6. Plant operating parameters.

A continuous release of SF₆ for a seven-hour period was made into the power plant stack during each experiment.¹ Hourly values of SF₆ were obtained at eighteen ground stations for the Moss Landing tests and at nineteen stations in the South Coast Basin. Simultaneous hourly SO₂ concentrations were measured at ten of these locations by the Rockwell Air Monitoring Center.² Sulfate samples were collected by sequential filters on the ground and by a filter system in the aircraft.

The MRI sampling aircraft (a Cessna 206) was equipped to measure a variety of meteorological and pollutant parameters. A list of the aircraft instrumentation is given in Table 3.1.

The aircraft was flown in two different sampling modes:

1. Vertical spirals - Soundings were made from the ground (or lowest practicable level) to an altitude of about 1500 m (msl). Principal objective was to define the vertical structure of the environment with particular emphasis on the depth of the mixing layer and the associated vertical mixing characteristics. Occasional spirals were made through the plume itself. A typical spiral sounding for Moss Landing is shown in Fig. 3.1.
2. Plume traverses - After identification of the plume, horizontal traverses were flown through the plume and perpendicular to the wind direction at plume height. SF₆ samples were obtained during the plume traverses by a syringe technique. These traverses were generally

TABLE 3.1. AIRCRAFT INSTRUMENTATION

1. MRI Integrating Nephelometer
2. Environment One Condensation Nuclei Monitor (Rich 100)
3. REM 612 Ozone Monitor
4. Monitor Labs 8440 NO-NO_x Monitor
5. Andros 7000 CO Monitor*
6. Theta Sensor LS-400 SO₂ Monitor
7. MRI Airborne Instrument Package
 - Temperature
 - Humidity
 - Turbulence
 - Altitude
 - Indicated Air Speed
8. Metrodata M/8 VOR Analog Converter (uses aircraft radio)
9. Metrodata 620 Data Logger (20 channels)

* Used occasionally.

AIRCRAFT - 286
 LOCATION - NE OF PLUMT
 GROUND ELEVATION - 80 1117
 CARTRIDGE NUMBER 895
 DATE 9/10/74
 FUELING TIME OF SPIRAL 14: 7:22
 NO/NO_x monitor temperature effects: O₃ = 1.2 ppm
 SO₂ = 0.05 ppm

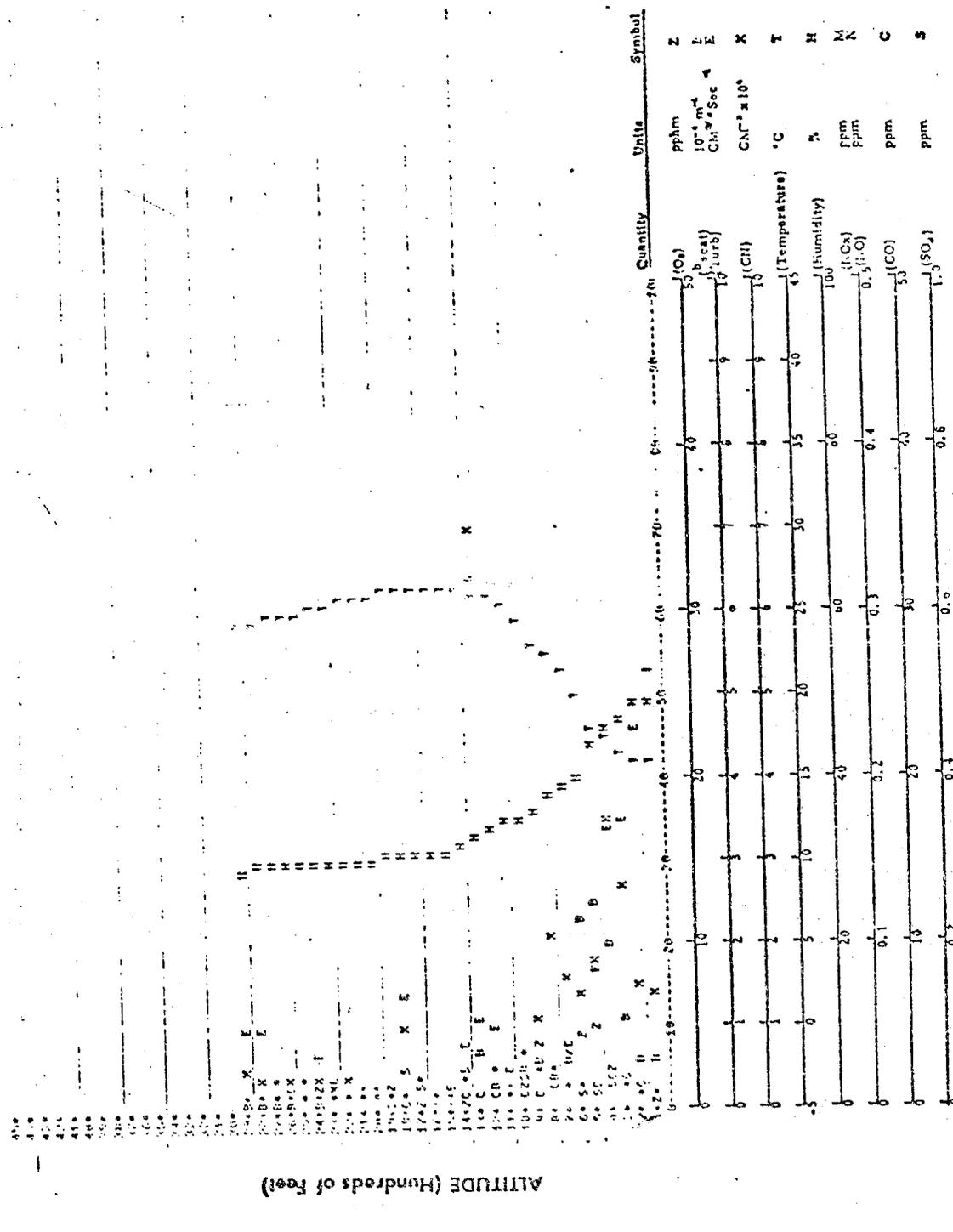


Fig. 3.1.
Moss Landing Sounding

made at 200-foot (61 m) height intervals down to an altitude below the base of the plume or as low as practicable in the area involved.

Pibal wind observations were made hourly during each test period except when low clouds prevented visual tracking of the balloon. In both test areas, one observation was made near the plant location with the other observation located about 20-25 km inland. This permitted an assessment of changes in mixing layers and parcel trajectories as the plume moved inland. Hourly values of surface winds were obtained from nearby locations, as available, in order to define surface wind trajectories.

3.3 Operational Phases of the Program

Dates of the sampling program are shown in Table 3.2. Flight times for each day are also included, together with comments on instrumentation problems and the number of SF₆ samples obtained in the aircraft.

Table 3.2 gives further details on the MRI portions of the field program. Periods of pibal operation each day are shown, together with the number of pibal observations carried out. Times of vertical soundings and times and locations of the horizontal cross-section patterns are also included in Table 3.2. Detailed data for each observational day can be found in a separate Data Volume.

TABLE 3.2. SAMPLING SUMMARIES

Location	Date	Time	Comments
Moss Landing	9/10/74	1101-1300 1350-1710	Inoperative NO, NO _x monitor replaced with CO monitor. Aircraft took 30 SF ₆ samples.
Moss Landing	9/11/74	1055-1211 1349-1453	Aircraft took 6 SF ₆ samples.
Moss Landing	9/12/74	1346-1712	Aircraft took 20 SF ₆ samples.
South Coast Air Basin (Haynes)	10/1/74	1343-1709	Aircraft took 20 SF ₆ samples.
South Coast Air Basin (Haynes)	10/11/74	1320-1718 1745-1852	Aircraft took 36 SF ₆ samples.
South Coast Air Basin (Haynes)	10/17/74	1447-1823	Aircraft took 19 SF ₆ samples.
South Coast Air Basin (Los Alamitos)	10/25/74	1250-1658 1728-1813	Aircraft took 39 SF ₆ samples.
South Coast Air Basin (Los Alamitos)	10/30/74	1214-1555 1623-1708	Aircraft took 38 SF ₆ samples.
South Coast Air Basin (Los Alamitos)	11/7/74	1237-1557 1626-1713	Inoperative NO, NO _x monitor replaced with CO monitor. Aircraft took 40 SF ₆ samples.

TABLE 3.2. (continued)
SAMPLING SUMMARIES

<u>Date</u>	<u>Location</u>	<u>Pibal Period</u>	<u>No. of Pibals</u>	<u>Times of Vertical Soundings</u>	<u>Times of Horizontal Cross Sections</u>	<u>Distance to Cross Section</u>
9/10/74	Moss Landing	1000-1700 PDT	13	1132 1251 1407 1655	1131-1242 PDT 1409-1433 1448-1531 1552-1634	0.8 KM 1.6 6.4 16.0
9/11/74	Moss Landing	0900-1500	11	1122 1415	1126-1150	1.6
9/12/74	Moss Landing	1200-1700	8	1432 1659	1445-1527 1530-1548 1608-1642	24.0 16.0 1.6
10/01/74	Haynes	1100-1600	12	1402 1529 1637 1656	1409-1421 1433-1513 1550-1614	0.8 4.8 32.0
10/11/74	Haynes	1100-1800	14	1418 1702 1718 1803 1830	1331-1405 1423-1443 1448-1524 1533-1614 1623-1646	0.8 4.8 9.6 19.2 32.0
10/17/74	Haynes	1300-1800	10	1537 1650 1713 1724 1758 1821	1455-1508 1512-1527 1542-1613 1622-1705 1733-1743	0.8 6.4 10.0 22.0 32.0

TABLE 3.2. (continued)
SAMPLING SUMMARIES

<u>Date</u>	<u>Location</u>	<u>Pibal Period</u>	<u>No. of Pibals</u>	<u>Times of Vertical Soundings</u>	<u>Times of Horizontal Cross Sections</u>	<u>Distance to Cross Section</u>
10/25/74	Los Alamitos	1100-1800 PDT	16	1316 1658 1750	1322-1403 PDT 1417-1442 1456-1642 1752-1812	0.8 KM 4.8 16.0 32.0
10/30/74	Los Alamitos	1000-1700 PST	16	1243 1554 1642	1250-1318 PST 1323-1421 1434-1539 1645-1705	0.8 4.8 16.0 32.0
11/07/74	Los Alamitos	1000-1700	16	1345 1557	1248-1324 1348-1430 1439-1712	0.8 4.8 16.0

4. Environmental Characteristics

4.1 Surface Streamline Patterns

Typical surface wind patterns for each plant location are given in Figs. 4.1 through 4.6. Characteristic winds at 0900 and 1500 PST are shown in the figures.

The wind flow patterns in each area are dominated by diurnal sea breeze effects. In the Moss Landing area a weak, disorganized flow exists at 0900. In the immediate coastal area a light, onshore wind is evident while winds in the inland areas reflect the land breeze flowing toward the northwest down the Salinas Valley. During the afternoon (Fig. 4.2) the sea breeze dominates the entire area in the form of steady, onshore winds from the northwest.

In the Southern California area the two streamline patterns for 0900 PST (Figs. 4.3 and 4.5) are similar in showing very light, onshore winds in the South Coast area near the plant sites (LOAL). Light offshore winds exist in the area north of Palos Verdes. Wind velocities are characteristically light throughout the basin.

During the afternoon the sea breeze flow becomes the dominant feature of the patterns in the South Coast area. Near the plant sites the onshore winds are characteristically from the southwest. The surface streamlines downwind of the plants show a divergent pattern with one branch turning to a more easterly direction and passing through Corona and Chino. The other branch of the flow turns toward the northwest along the foothills of the San Gabriel Mountains.

4.2 Meteorological Test Conditions

The meteorological and background pollution conditions for each test are summarized in the following sections. The mixing layer heights are estimated from the characteristics of the vertical aircraft soundings. Generally, the temperature and turbulence characteristics provide the best indications of the effective mixing layer. In all cases, however, the vertical profiles of the pollutant parameters were also examined in order to obtain a consistent pattern for the mixing layer depth.

A brief description of the overall weather conditions is included for each test. In addition an estimate of the wind speed at plume height is given together with the appropriate Pasquill stability category as defined by the temperature difference from the top of the stack to the top of the plume.

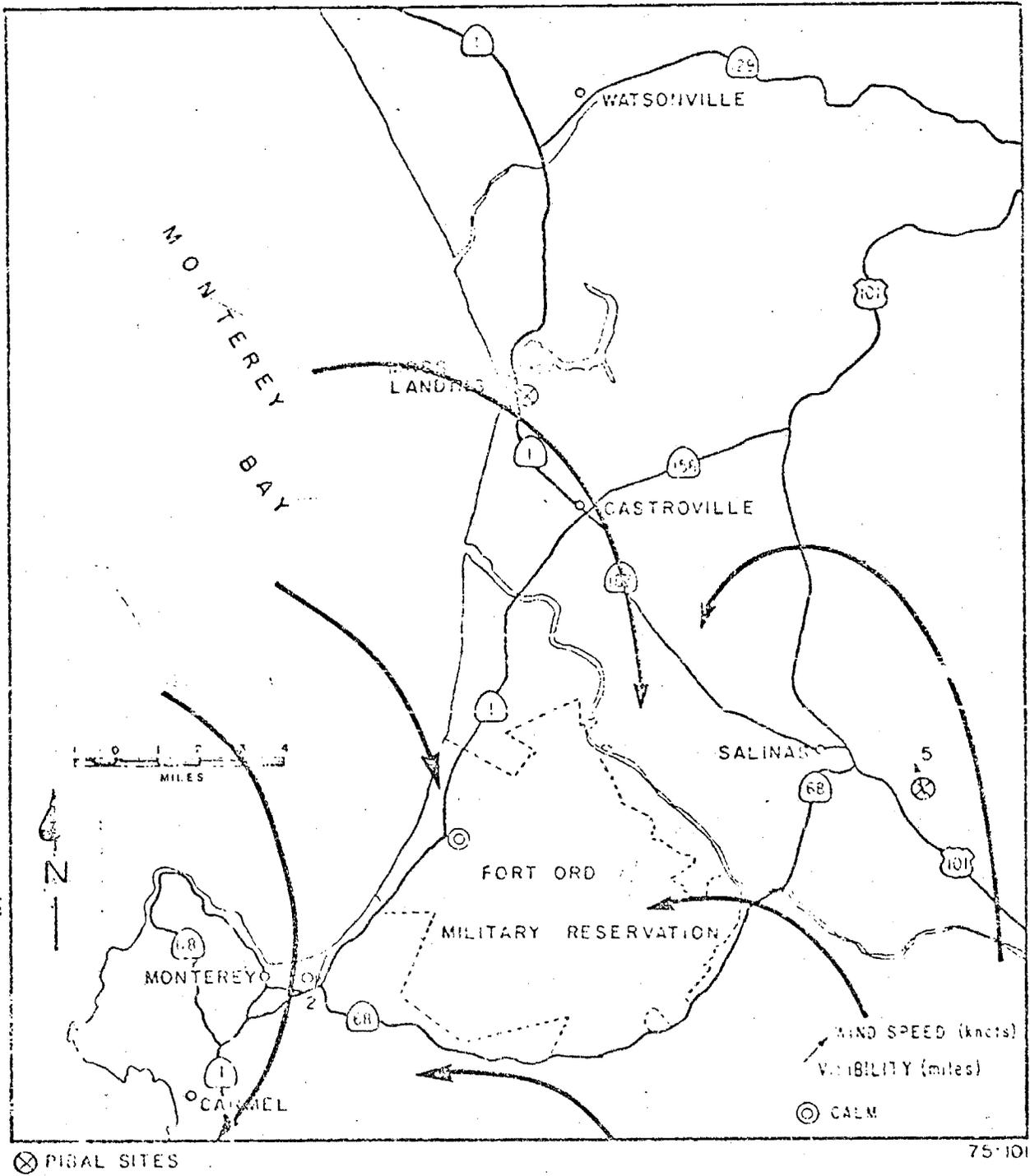


Fig. 4.1
 Surface Streamline Analysis - 0900 PST
 10 September 1974

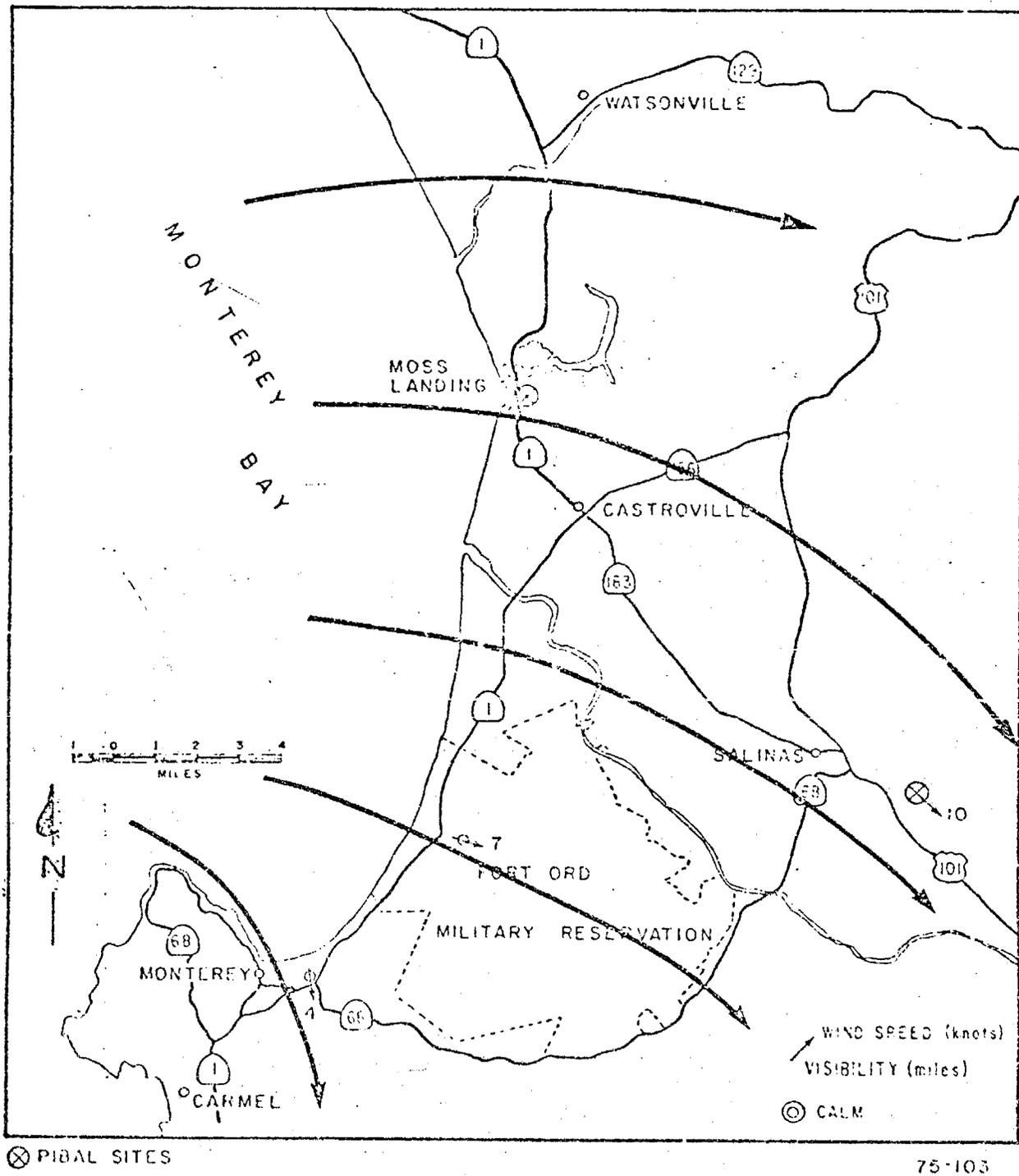
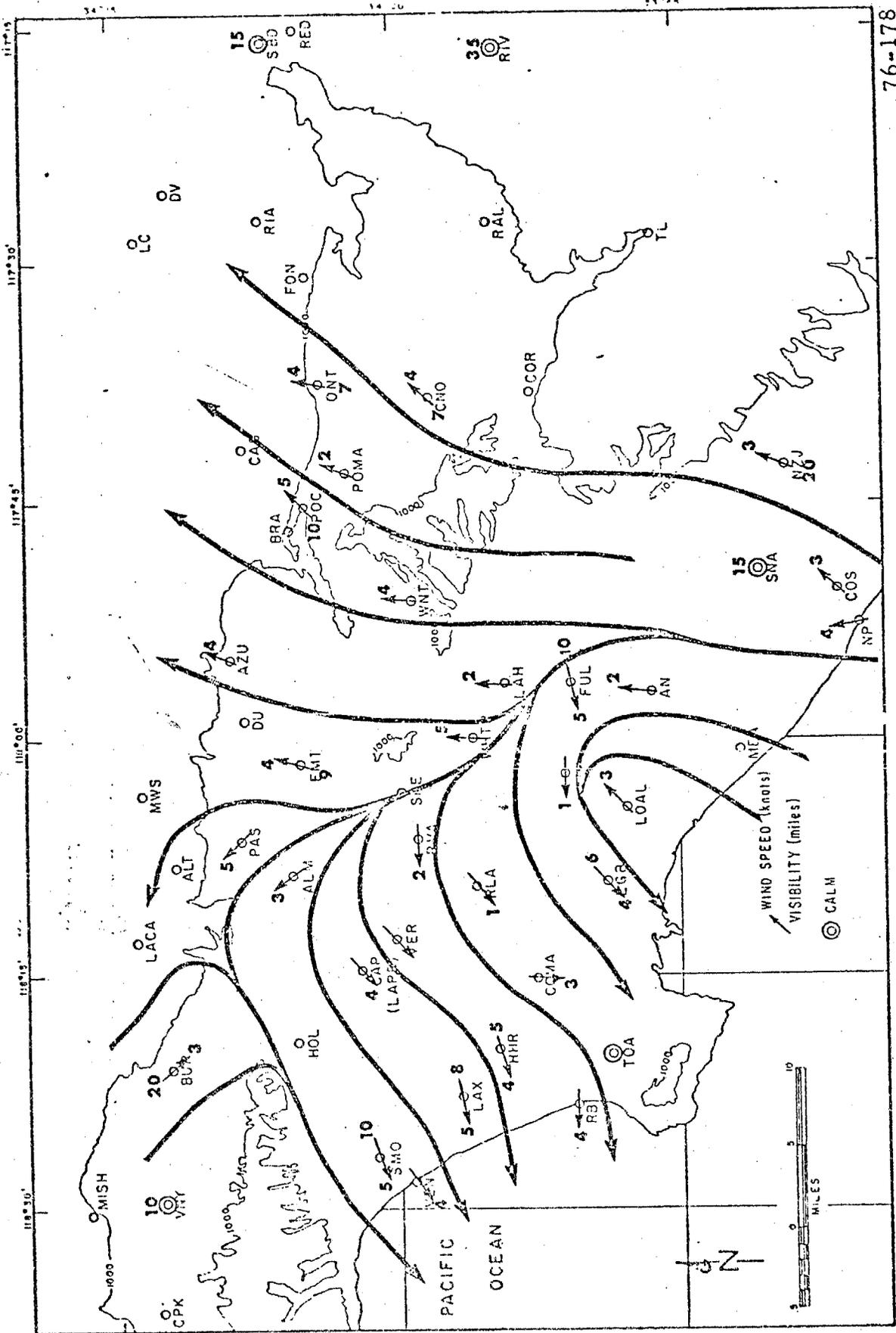
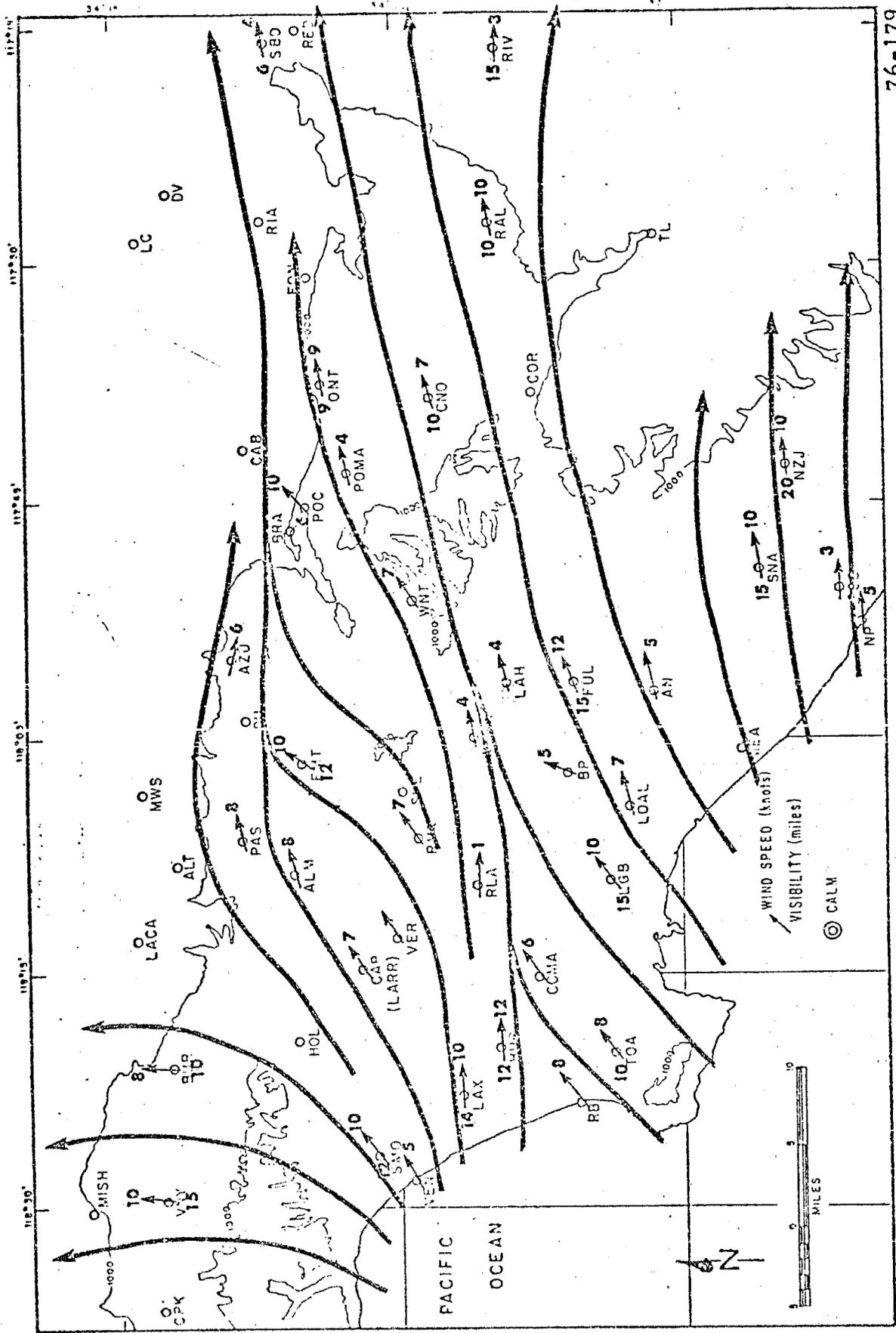


Fig. 4.2
 Surface Streamline Analysis - 1500 PST
 10 September 1974



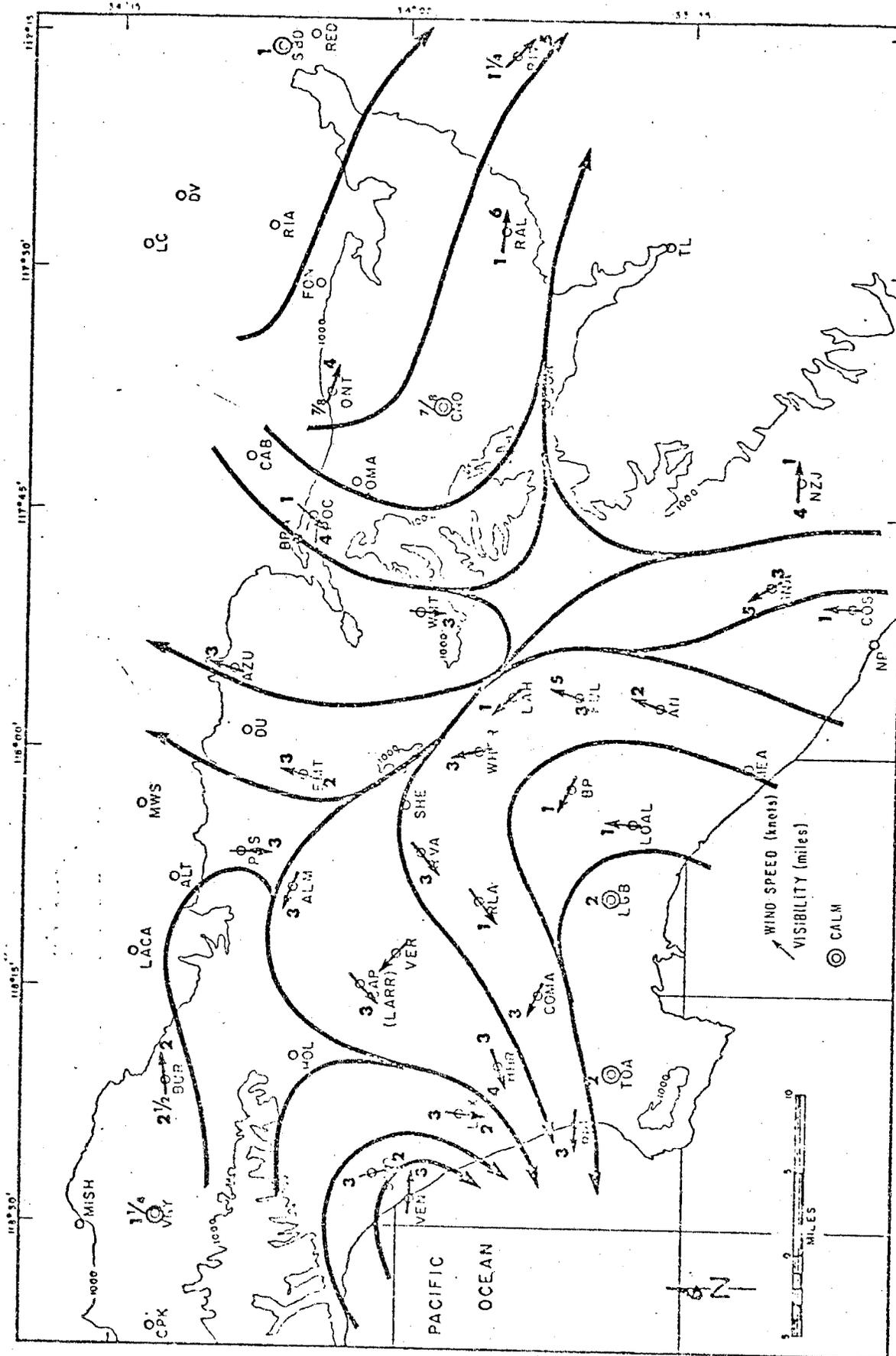
76-178

Fig. 4.3
 Surface Streamline Analysis - 0900 PST
 30 October 1974



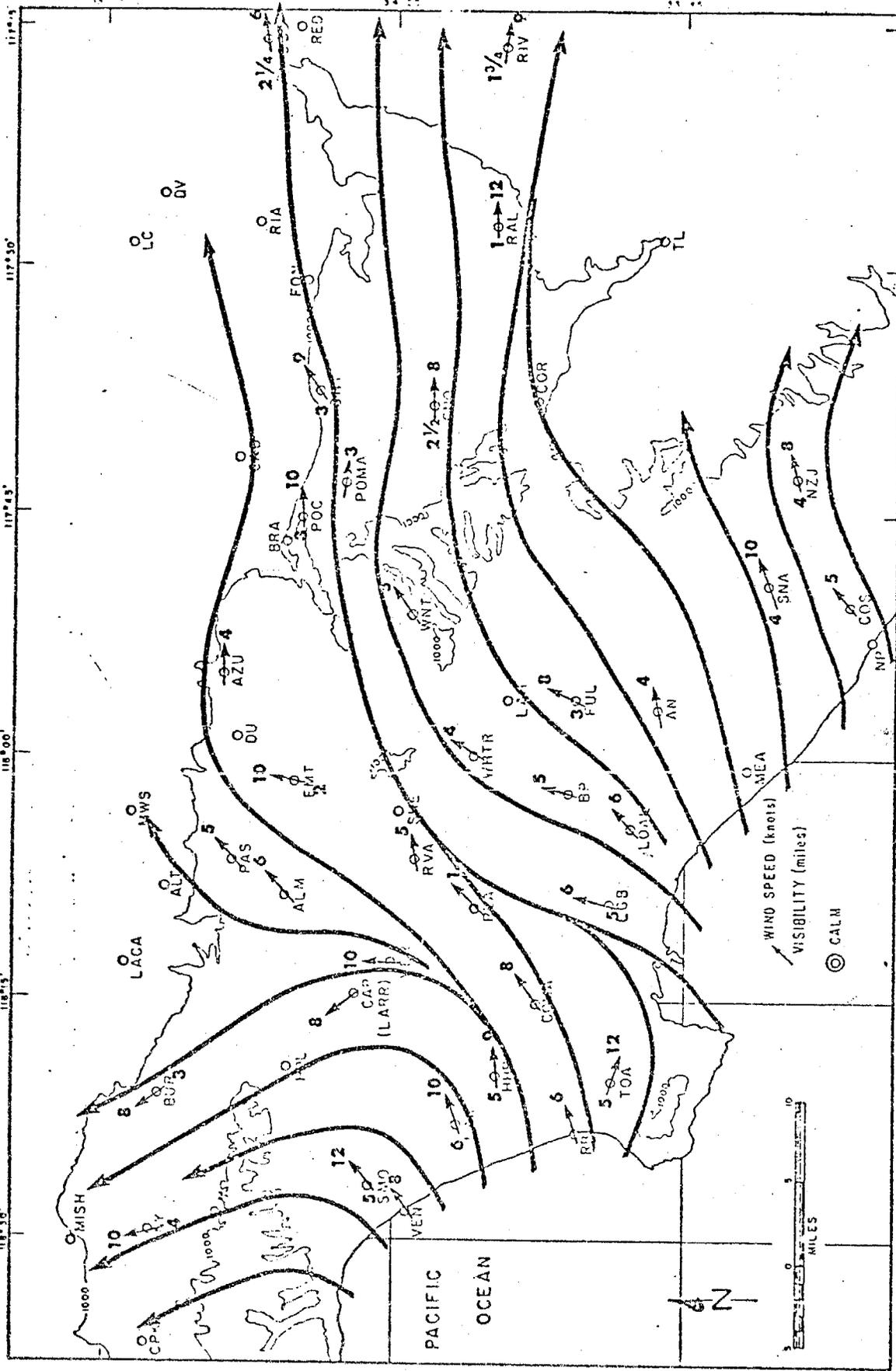
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Fig. 4.4
 Surface Streamline Analysis - 1500 PST
 30 October 1974



76-180

Fig. 4.5
 Surface Streamline Analysis - 0900 PST
 11 October 1974



76-181

Fig. 4.6
 Surface Streamline Analysis - 1500 PST
 11 October 1974

Background pollutant data are shown for plume height levels but in areas outside of the plume. These data indicate a wide variation in background levels with the three sampling days at the Haynes Plant representing the highest levels.

4.2.1 September 10, 1974 (Moss Landing)

Fog and low clouds extended inland beyond Salinas during the early morning, clearing by 1100 PDT. A well developed sea breeze was present during the afternoon with maximum winds at 13 kts at Salinas. A strong temperature inversion existed on all vertical soundings. An example is shown in Fig. 3.1. The 1407 sounding was made near the coast while the 1700 PDT sounding was made over the golf course at Salinas and indicates the inland modification of the temperature profile. Top of the temperature inversion was 400-500 m.

Winds at plume height were light easterly through 1200 PDT, changing to west to west-northwest for the balance of the afternoon.

Mixing Heights

Time (PDT)	Location	Elevation of Top (m msl)
1132	E of plant	290
1251	E of plant	200
1407	NE of plant	135
1655	Golf Course	170

Plume Environment

Time (PDT)	Wind Speed at Plume Height (m/s)	Pasquill Stability	Background Concentrations			
			O ₃ (pphm)	NO _x (ppm)	SO ₂ (ppm)	b _{scat} ($\times 10^{-4}$ m ⁻¹)
1132	1.5	F	1.0	-	0.01	0.2
1251	1.0	F	1.0	-	0.01	0.2
1407	2.5	F	2.0	-	0.0	0.3
1655	6.5	F	3.5	-	0.03	0.2

4.2.2 September 11, 1974 (Moss Landing)

Skies were generally clear inland during the day until fog and low clouds developed about 1800 PDT. A moderate north to northwest flow developed by noon. Concurrently (in the late forenoon), a stratus cloud bank moved into the plant area and persisted for the balance of the day. This cloud bank extended about 8 km downwind of the plant. Winds at plume height indicated a trajectory toward the south at 1100 PDT shifting to southeast by 1300 PDT. A strong inversion was present on both soundings with a top of 500-600 m.

Mixing Heights

Time (PDT)	Location	Elevation of Top (m msl)
1121	E of plant	135
1414	E of plant	260

Plume Environment

Time (PDT)	Wind Speed at Plume Height (m/s)	Pasquill Stability	Background Concentrations			
			O ₃ (pphm)	NO _x (ppm)	SO ₂ (ppm)	b _{scat} (× 10 ⁻⁴ m ⁻¹)
1121	3.8	F	6.5	0.03	0.0	0.9
1414	5.0	F	7.5	0.03	0.02	0.9

4.2.3

September 12, 1974 (Moss Landing - Gas)

Fog and low clouds existed over the area until late morning. Scattered to broken stratus clouds were present throughout the afternoon. A moderate temperature inversion was present, based at around 500-600 m. The low clouds prevented extensive pibal observations, but the available winds indicated northwesterly flow at the golf course and west-northwest winds near the plant.

Mixing Heights

Time (PDT)	Location	Elevation of Top (m msl)
1432	Salinas Airport Plant	505
1659		685

Plume Environment

Time (PDT)	Wind Speed at Plume Height (m/s)	Pasquill Stability	Background Concentrations			
			O ₃ (pphm)	NO _x (ppm)	SO ₂ (ppm)	b _{scat} ($\times 10^{-4}$ m ⁻¹)
1432	8.0	D	4.0	0.03	0.0	1.8
1659	7.4	E	3.5	0.025	0.0	1.4

4.2.4 October 1, 1974 (Haynes)

Fog and low clouds persisted during the morning, clearing about noon along the coast. Visibilities remained low (≤ 10 km) throughout the basin except for the immediate coastal areas during the afternoon. Surface wind patterns showed a typical sea breeze in the southern portion of the basin (south of Whittier), but with remnants of offshore flow in the northern sections. Calculated trajectories at plume height showed southwesterly winds with a slight tendency for the winds to become more west-southwest during the late afternoon.

Mixing Heights

Time (PDT)	Location	Elevation of Top (m msl)
1401	SW of Plant	230
1528	Los Alamitos Airport	625
1636	Fullerton Airport	685
1655	Santa Ana Canyon	595

Plume Environment

Time (PDT)	Wind Speed at Plume Height (m/s)	Pasquill Stability	Background Concentrations			
			O ₃ (pphm)	NO _x (ppm)	SO ₂ (ppm)	b _{scat} ($\times 10^{-4}$ m ⁻¹)
1401	3.0	E	15.0	0.07	0.0	5.2
1528	4.6	E	12.0	0.055	0.0	3.9
1636	4.0	D	4.0	0.110	0.0	2.4
1655	4.9	D	8.0	0.065	0.0	4.0

4.2.5 October 11, 1974 (Haynes)

Fog and low clouds were present in the morning and only partial clearing occurred along the coast in the afternoon. Visibilities were less than or equal to 10 km throughout the area during the entire day. At the surface, a typical sea breeze pattern covered the entire basin by mid afternoon. Trajectories at plume height showed a weak, disorganized pattern beginning at 1100 PDT. The calculated track of the plume would have indicated weak movement toward the west, followed by a reversal of the flow to a more easterly direction after 1400 PDT. After this time, the calculated trajectories indicated movement from the west-southwest.

Mixing Heights

Time (PDT)	Location	Elevation of Top (m msl)
1418	Los Alamitos Airport	440
1701	Santa Ana Canyon	565
1717	Fullerton Airport	595
1802	Los Alamitos Airport	595
1829	Riverside Airport	960

Plume Environment

Time (PDT)	Wind Speed at Plume Height (m/s)	Pasquill Stability	Background Concentrations			
			O ₃ (pphm)	NO _x (ppm)	SO ₂ (ppm)	b _{scat} (× 10 ⁻⁴ m ⁻¹)
1418	1.4	E	8.0	0.05	0.0	4.8
1701	2.2	D	11.5	0.085	0.0	7.3
1717	2.0	E	10.5	0.075	0.0	7.5
1802	2.5	E	13.5	0.06	0.0	5.2
1829	3.0	D	19.0	0.075	0.0	10.0

4.2.6 October 17, 1974 (Haynes)

The South Coast basin was generally clear all day with unusually good visibilities. Exceptions were the Torrance-Hawthorne area in the morning and the eastern portion of the basin in the late afternoon. The day represented the end of a sequence of weak, offshore wind conditions. Calculated trajectories at plume height indicated plume movement toward the northeast.

Mixing Heights

Time (PDT)	Location	Elevation of Top (m msl)
1537	Los Alamitos Airport	215
1650	Fullerton Airport	230
1713	Shepherd Airport	565
1724	El Monte Airport	535
1758	Chino Airport	440
1821	Los Alamitos Airport	200

Plume Environment

Time (PDT)	Wind Speed at Plume Height (m/s)	Pasquill Stability	Background Concentrations			
			O ₃ (pphm)	NO _x (ppm)	SO ₂ (ppm)	b _{scat} ($\times 10^{-4}$ m ⁻¹)
1537	2.9	E	6.5	0.02	0.0	0.7
1650	2.8	E	5.0	0.025	0.0	0.5
1713	2.1	D	6.5	0.03	0.0	0.5
1724	2.3	D	6.5	0.03	0.0	0.5
1758	2.5	E	5.5	0.025	0.06	0.5
1821	2.5	F	5.0	0.02	0.15	2.0

4.2.7 October 25, 1974 (Alamitos)

Skies were generally clear in the South Coast basin. There was little significant restriction to visibility except in the eastern basin. Otherwise, visibilities were seven to ten miles or more. The sea breeze flow developed in a classic manner throughout the area. Trajectories calculated at plume height were consistently toward the northeast.

Mixing Heights

Time (PDT)	Location	Elevation of Top (m msl)
1315	Los Alamitos Airport	655
1657	Fullerton Airport	990
1750	Santa Ana Canyon	655

Plume Environment

Time (PDT)	Wind Speed at Plume Height (m/s)	Pasquill Stability	Background Concentrations			
			O ₃ (pphm)	NO _x (ppm)	SO ₂ (ppm)	^b scat (× 10 ⁻⁴) m
1315	3.4	D	5.5	0.015	0.0	1.2
1657	6.0	D	2.5	0.035	0.0	0.8
1750	7.7	D	2.5	0.030	0.0	0.8

4.2.8 October 30, 1974 (Alamitos)

Skies were clear throughout the basin. Visibilities were very good everywhere except for slight restrictions in the early morning along the coast. Trajectories calculated at plume height showed plume directions toward the north-northeast until around noon, gradually shifting toward the northeast during the afternoon. Temperature lapse rates observed showed little signs of stable layers. Mixing heights were defined in terms of turbulence and condensation nuclei.

Mixing Heights

Time (PDT)	Location	Elevation of Top (m msl)
1243	Los Alamitos Airport	595
1554	Fullerton Airport	840
1641	Santa Ana Canyon	715

Plume Environment

Time (PDT)	Wind Speed at Plume Height (m/s)	Pasquill Stability	Background Concentrations			
			O ₃ (pphm)	NO _x (ppm)	SO ₂ (ppm)	b _{scat} (x 10 ⁻⁴ m ⁻¹)
1243	4.6	D	4.5	0.025	0.0	0.80
1554	4.0	D	4.5	0.02	0.0	0.90
1641	3.3	D	4.5	0.03	0.0	1.2

4.2.9 November 7, 1974 (Alamitos)

Skies were clear in the basin with excellent visibilities throughout the day. A moderate, westerly sea breeze developed during the afternoon. Temperature soundings showed no significant stable layers. Calculated trajectories for the plume showed movement toward the northeast, but with a shift to an easterly direction beginning at 1600 PST.

Mixing Heights

Time (PDT)	Location	Elevation of Top (m msl)
1345	Los Alamitos Airport	410
1557	Fullerton Airport	335

Plume Environment

Time (PDT)	Wind Speed at Plume Height (m/s)	Pasquill Stability	Background Concentrations			
			O ₃ (pphm)	NO _x (ppm)	SO ₂ (ppm)	b _{scat} (× 10 ⁻⁴ /m)
1345	3.5	D	2.5	-	0.0	0.60
1557	6.4	D	3.5	-	0.0	0.60

5. Plume Characteristics

Vertical cross sections of the SO₂ plumes obtained at the three sites are shown in Figs. 5.1 to 5.6 for those days when detailed sampling was carried out. Each data point on the cross sections represents the maximum concentration observed during a horizontal traverse through the plume. Repeated traverses through the plume at one downwind distance give an indication of the vertical section at that distance. Repeated vertical sections downwind were made as shown. Although the horizontal traverses were not made simultaneously the figures approximately represent the plume cross section if a steady state condition is assumed. Also shown in each figure is a vertical temperature sounding and wind profile appropriate to the plume environment.

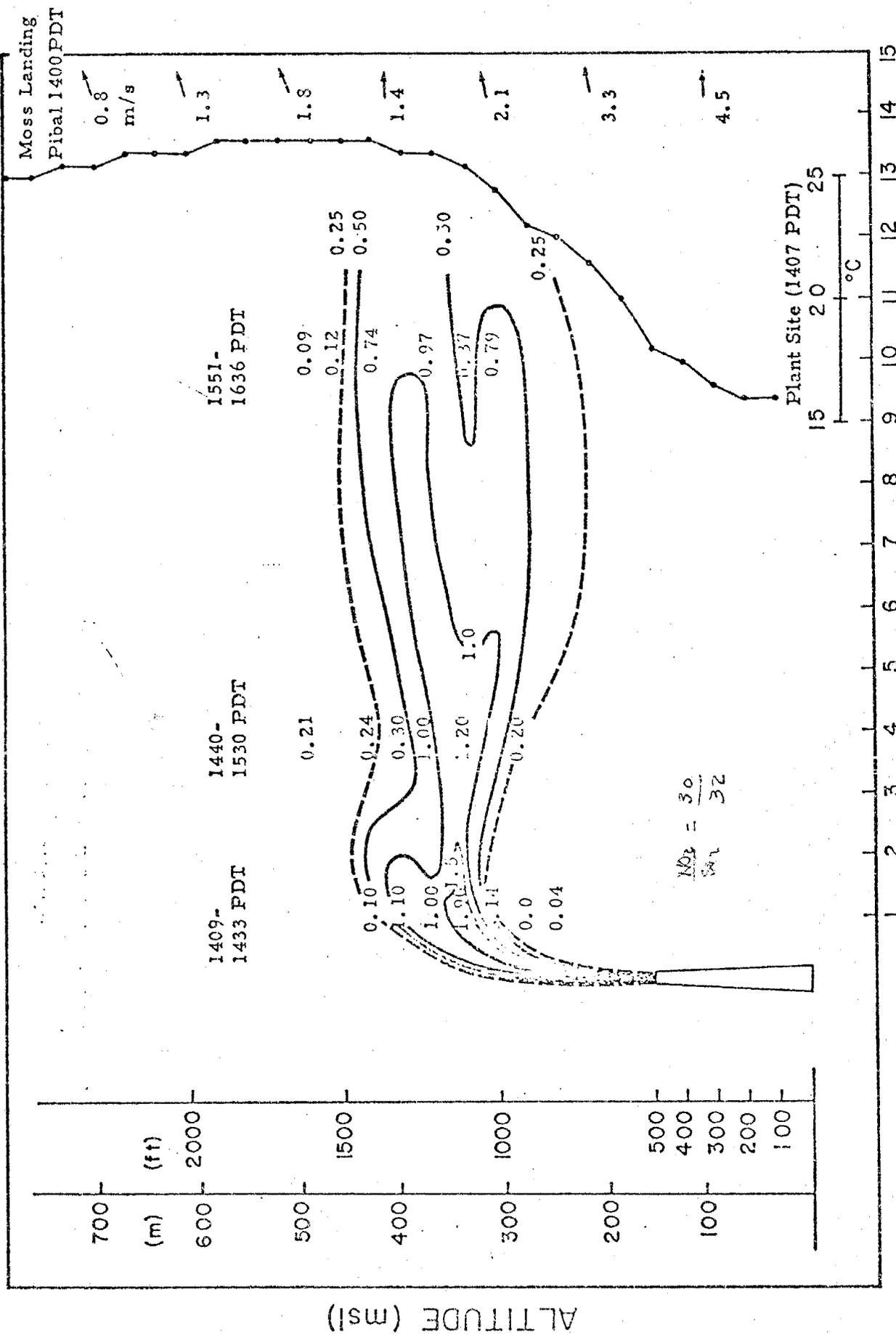
SO₂ plumes (Figs. 5.1 to 5.6) are definable to greater downwind distances than the NO_x plumes. This reflects the higher NO_x background levels encountered in the ambient environment. Under these conditions it was usually not possible to define the NO_x plume at downwind distances greater than about 8 km. Otherwise, the SO₂ and NO_x plumes exhibit similar characteristics.

Table 5.1 summarizes the peak SO₂ concentrations observed at various downwind distances at the plume centerline. Also given in the table are the observed heights (msl) of the centerline and the dimensions of the plume at each location. Dimensions are given in terms of a standard deviation (σ) computed as though the concentration distribution (vertically and horizontally) across the plume could be considered as Gaussian. Some difficulties were encountered in defining the vertical depth of the plumes due to restricted aircraft operations below 1000 ft. above terrain.

Figures 5.7 through 5.15 show estimated plume trajectories each sampling day. These trajectories were found by utilizing observed winds at plume height (pibal observations) to construct a probable trajectory for plumes leaving the specific plant site at several different times of day. An inherent assumption in the plume trajectories is that the pibal wind observation at the plant site is representative of conditions along the entire plume path.

Estimated plume trajectories in the Moss Landing area shown an easterly path on September 10 and a south to southeasterly path on September 11. Low clouds precluded the pibal observations on September 12. In the Southern California area the trajectories generally indicate a path to the northeast but with some variable wind directions indicated for stack releases made prior to 1230 PDT on October 11 and November 7.

SO₂ (ppm)



DOWNWIND DISTANCE (mi)

Fig. 5.1

Plume Profile, Moss Landing Power Plant, 10 September 1974

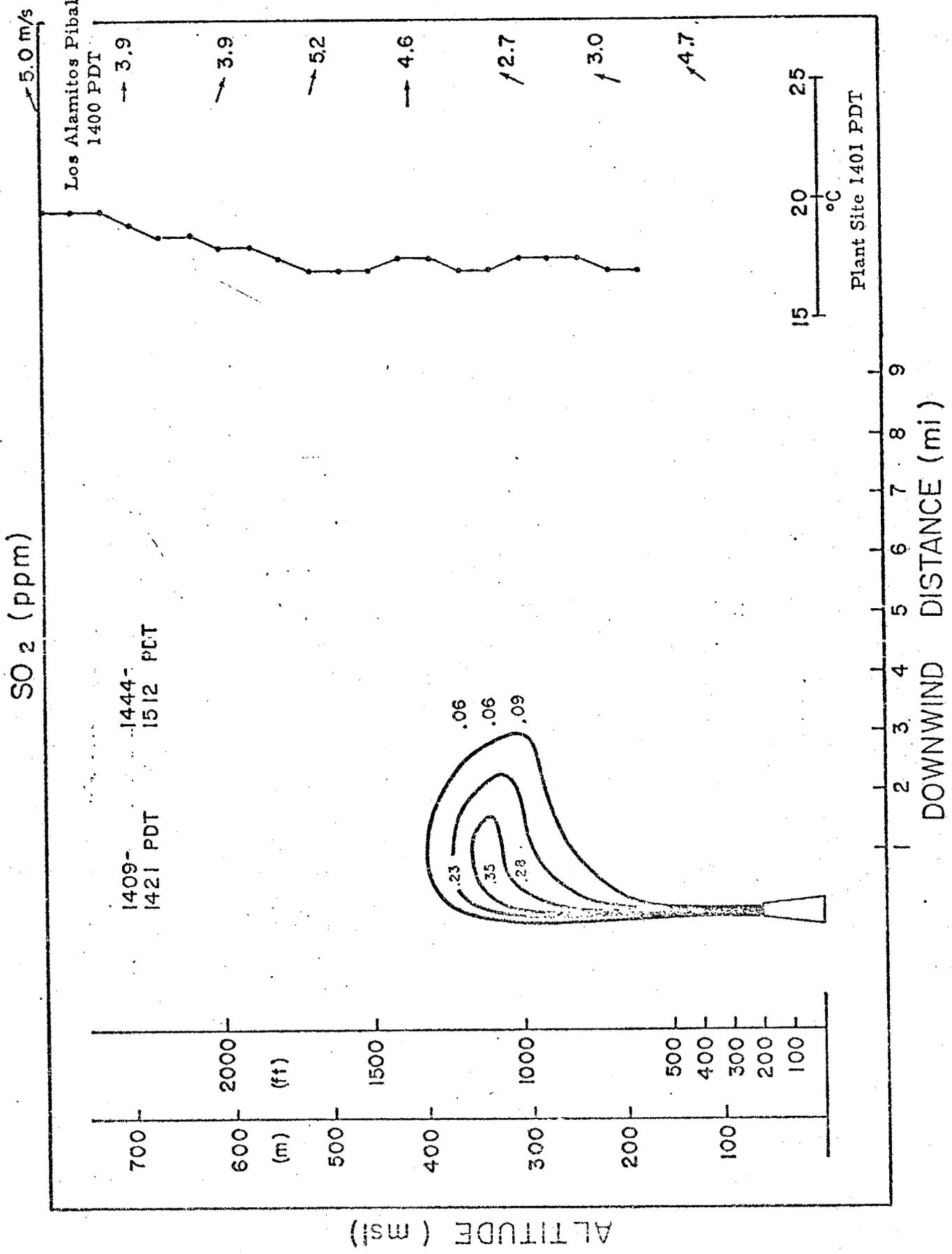


Fig. 5.2
Plume Profile, Haynes Power Plant - 1 October 1974

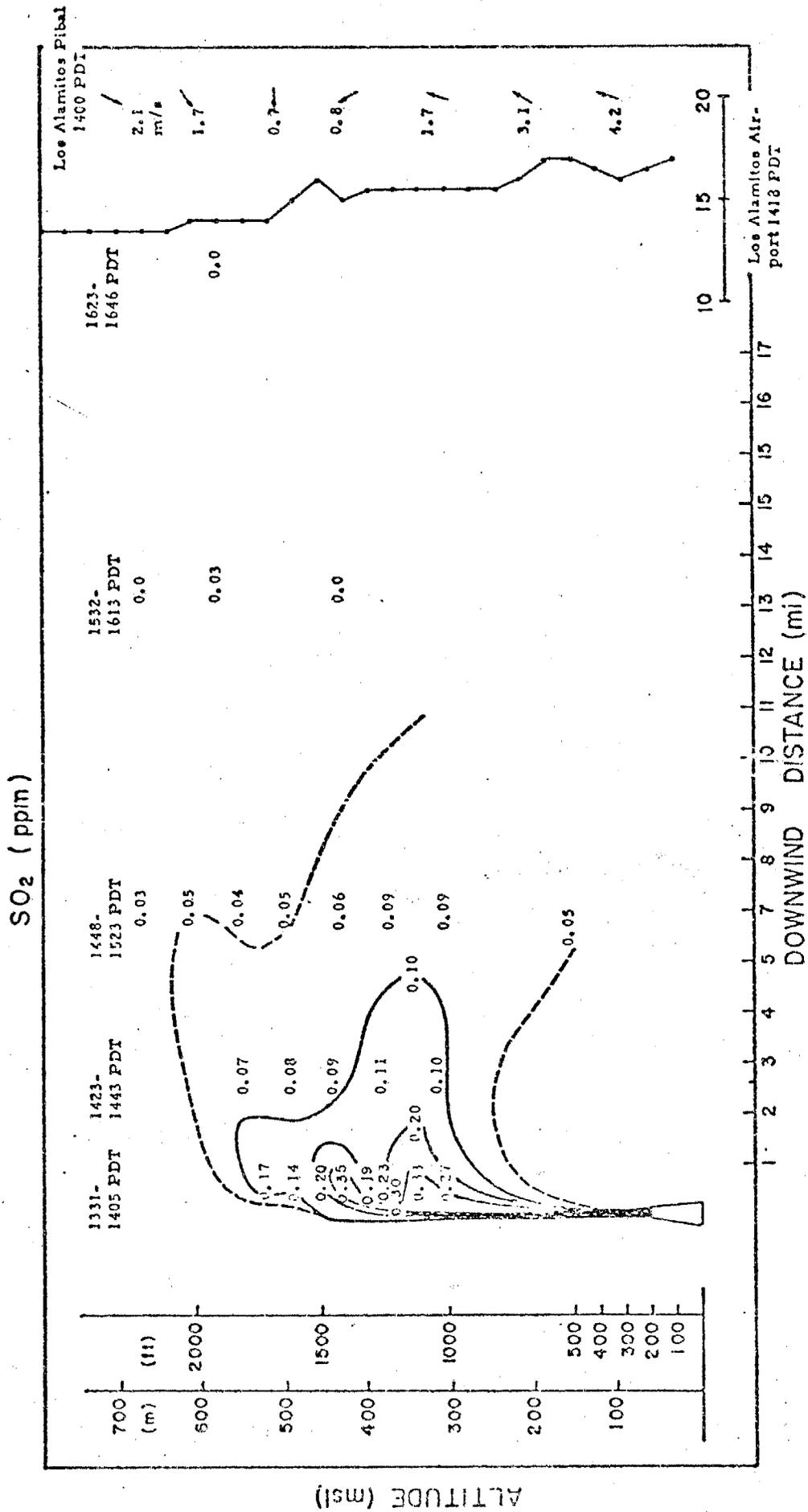


Fig. 5.3

Plume Profile, Haynes Power Plant - 11 October 1974

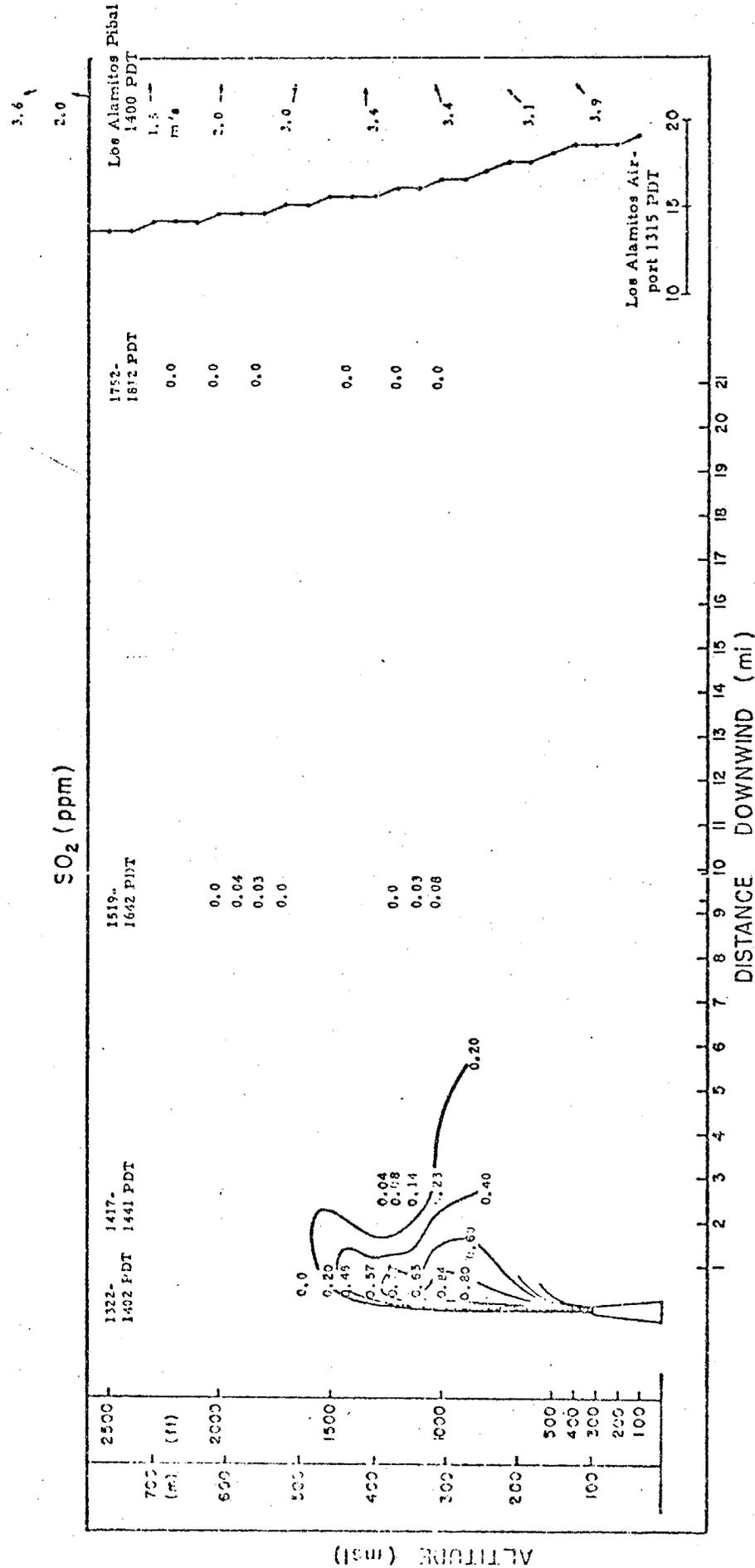


Fig. 5.4

Plume Profile, Los Alamos Power Plant - 25 October 1974

Los Alamos Pibal
1300 PST

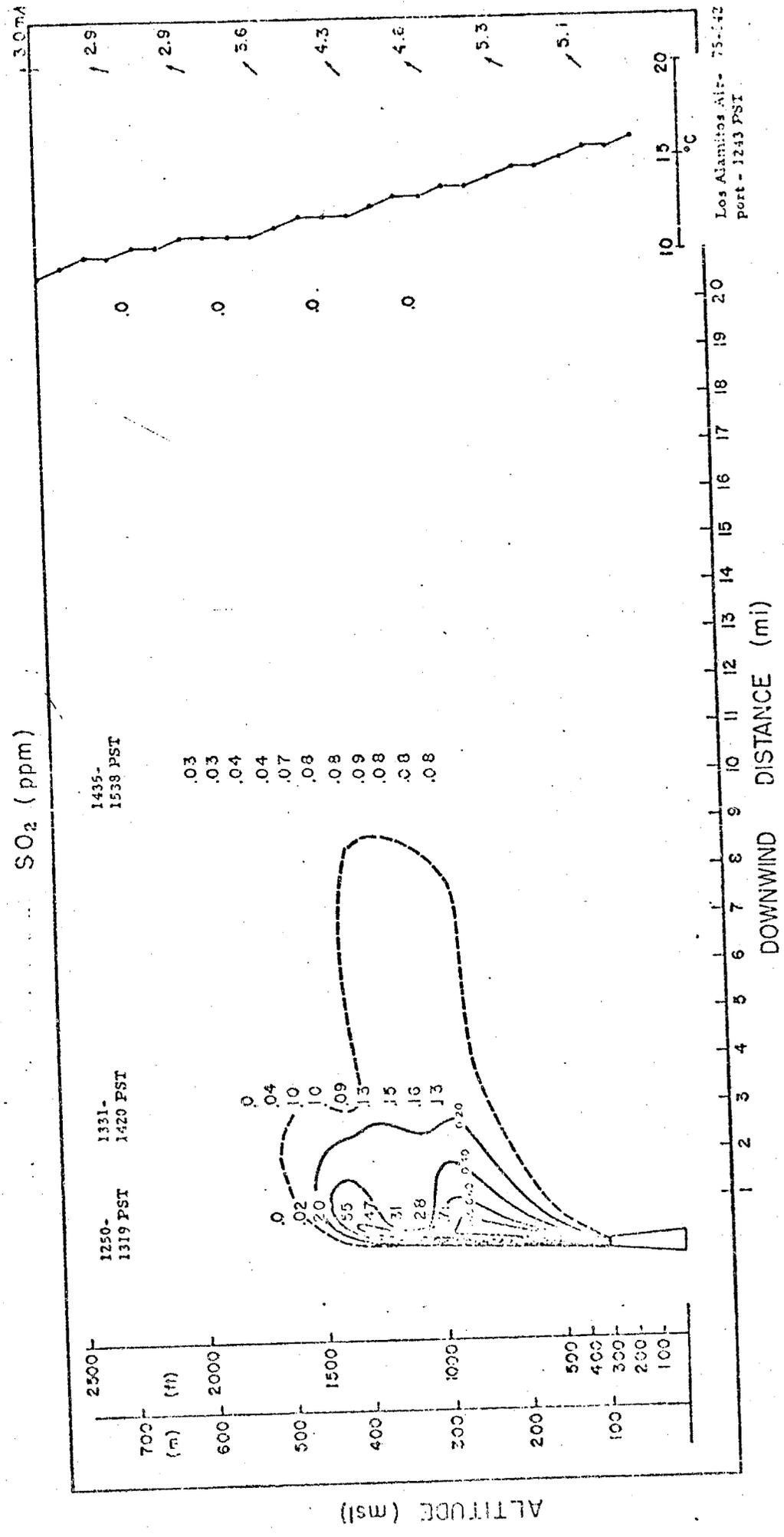


Fig. 5.5

Plume Profile, Los Alamos Power Plant - 30 October 1974

SO₂ (ppm)

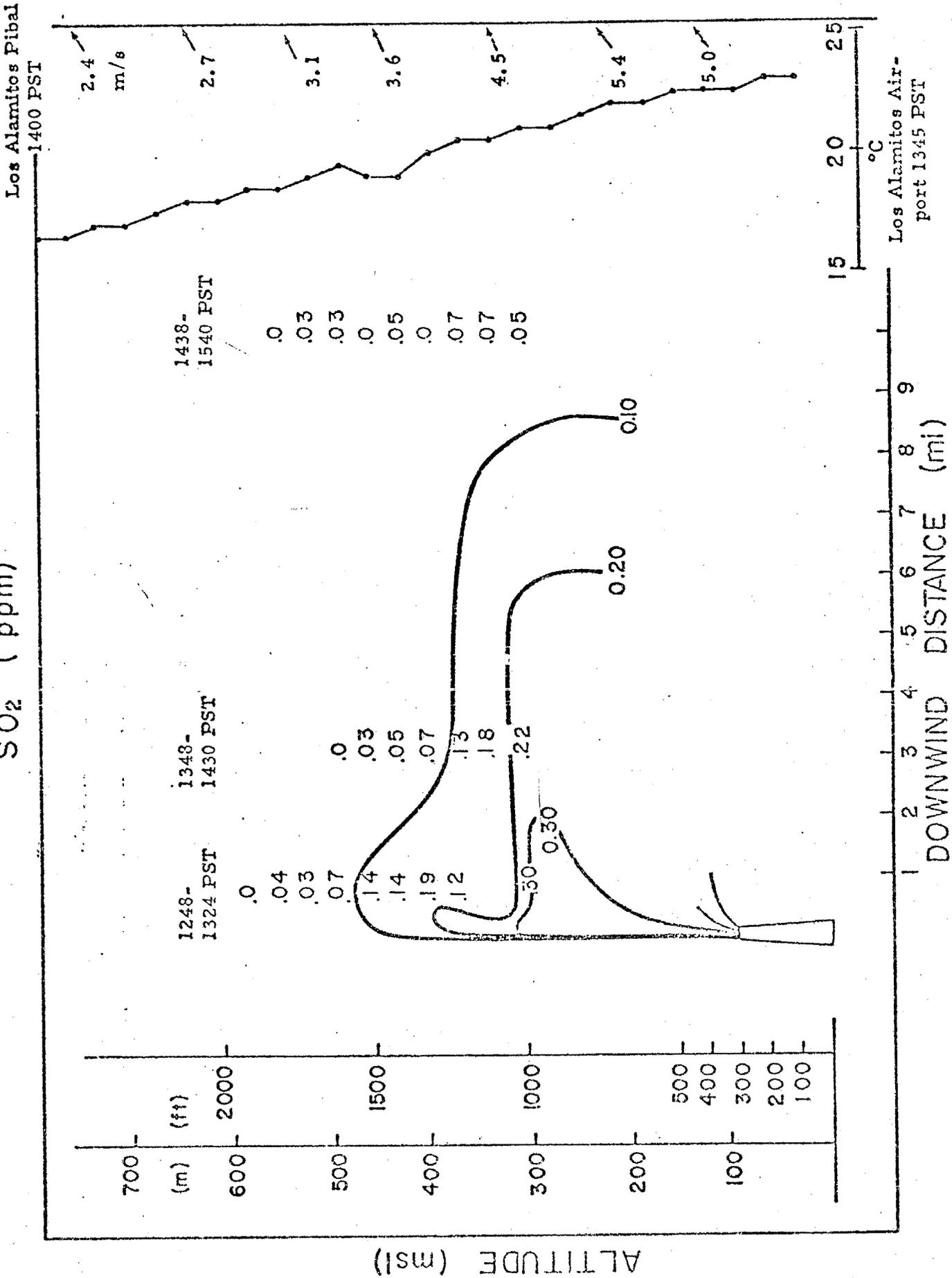
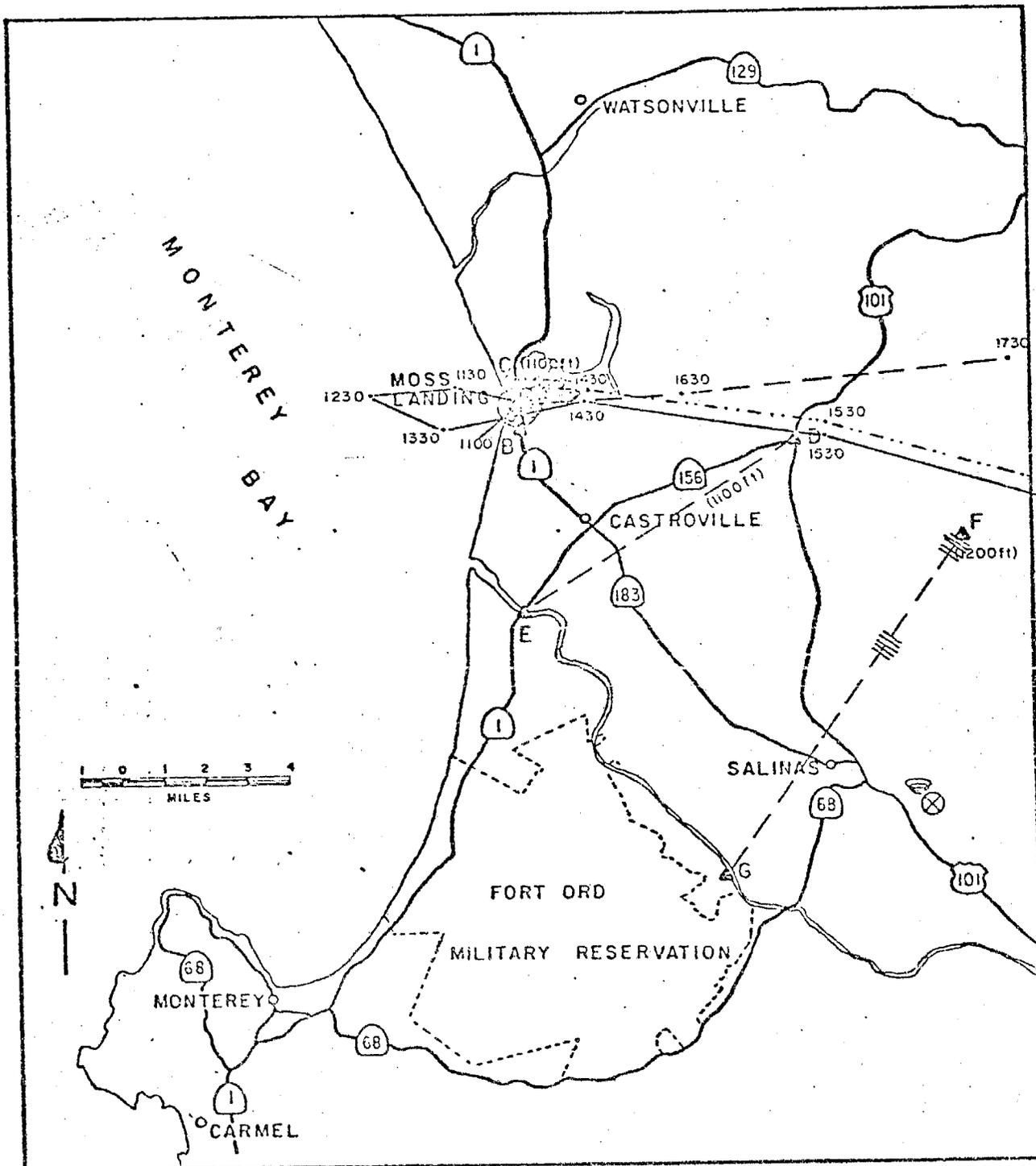


Fig. 5.6

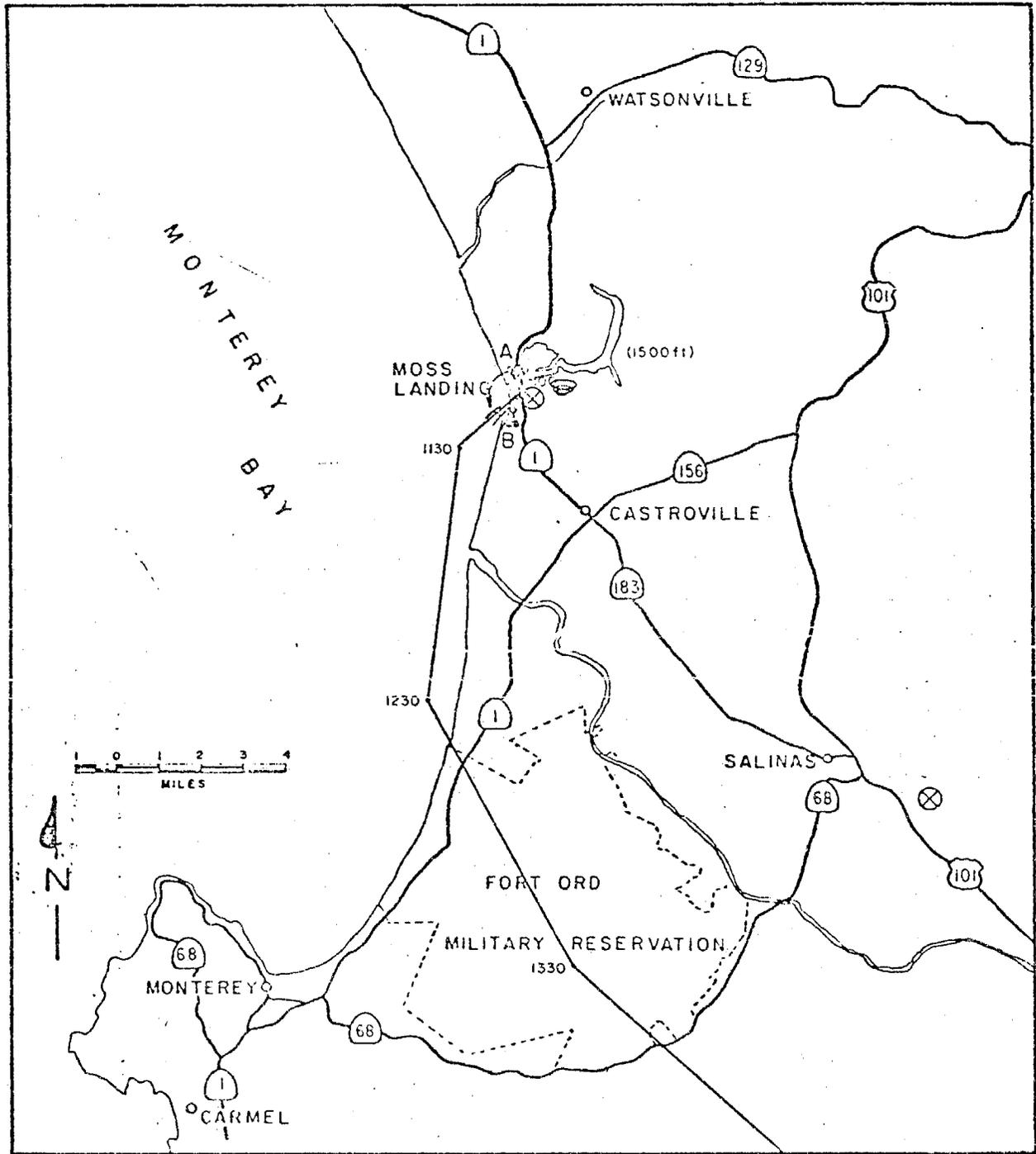
Plume Profile, Los Alamos Power Plant - 7 November 1974



- ⊗ PIBAL SITES
- △ TRAVERSE POINTS
- ☉ SPIRAL LOCATION
- /// Approximate Plume Position
- 1400 PDT
- - - - - 1600 PDT
- 1100 PDT

75-091

Fig. 5.7
 Mean Trajectories at Plume Height
 10 September 1974

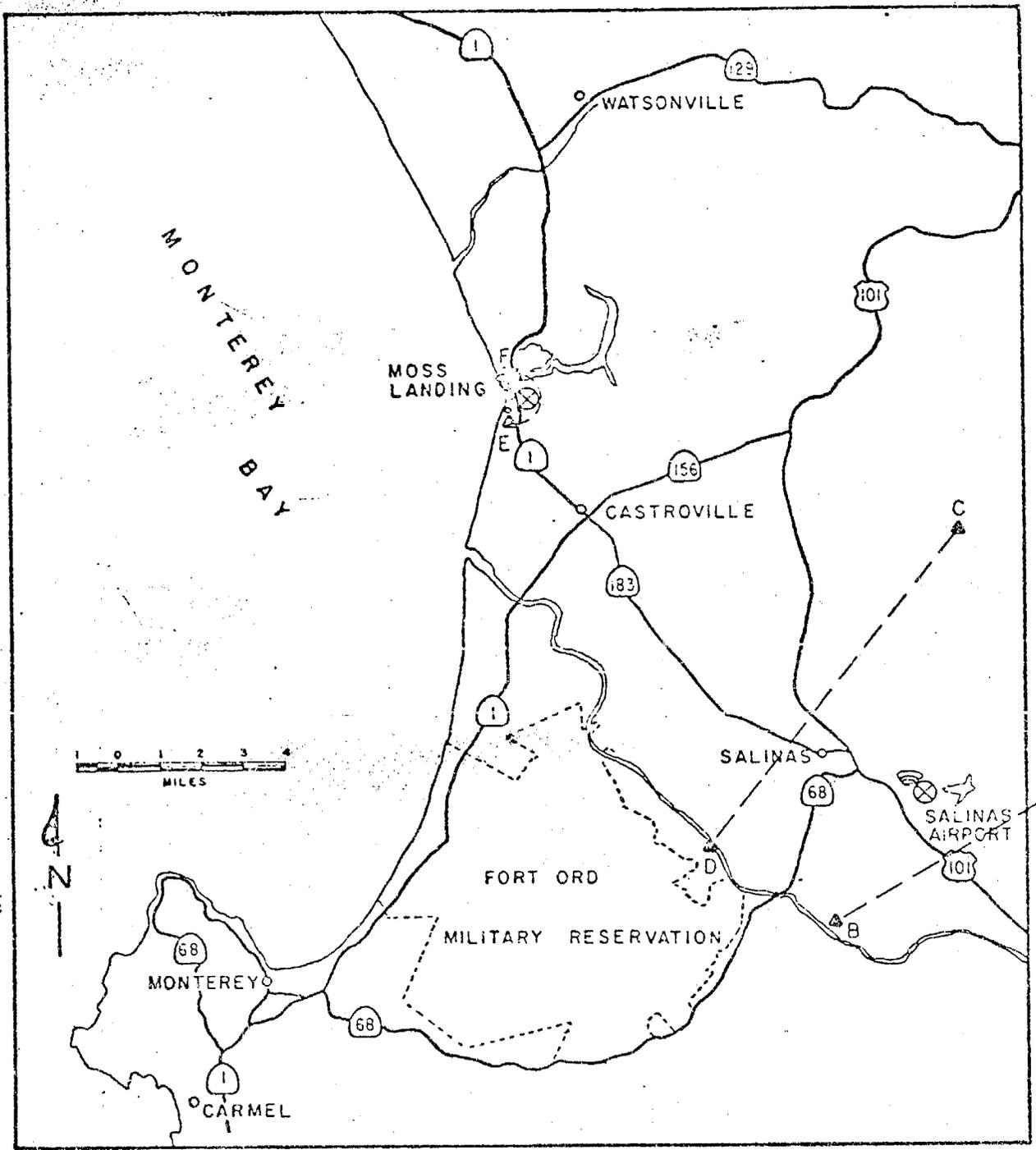


75-090

- ⊗ PIBAL SITES
- ▲ TRAVERSE POINTS
- ☯ SPIRAL LOCATION
- ▨ Approximate Plume Position

1430

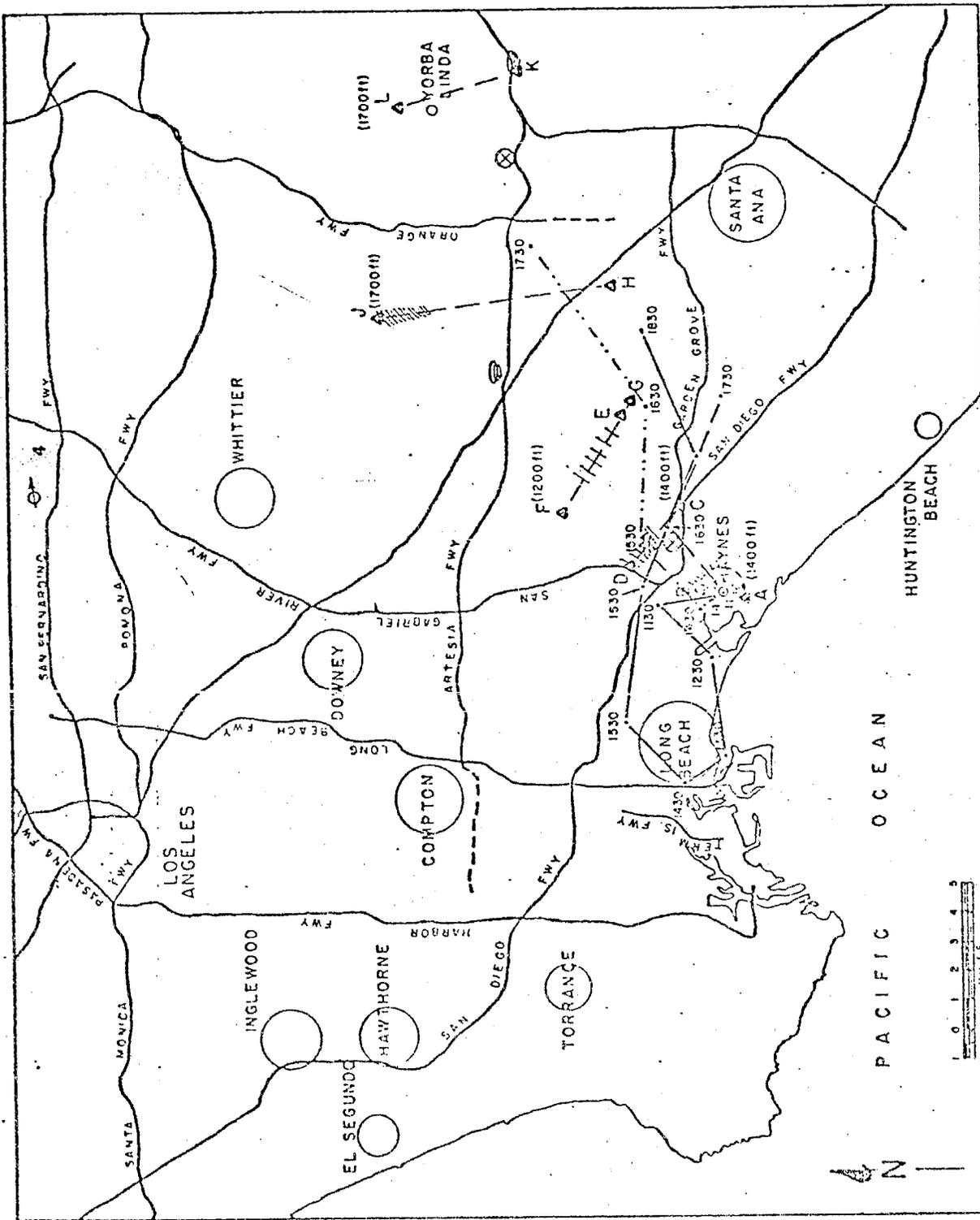
Fig. 5.8
 Mean Trajectories at Plume Height
 11 September 1974



75-030

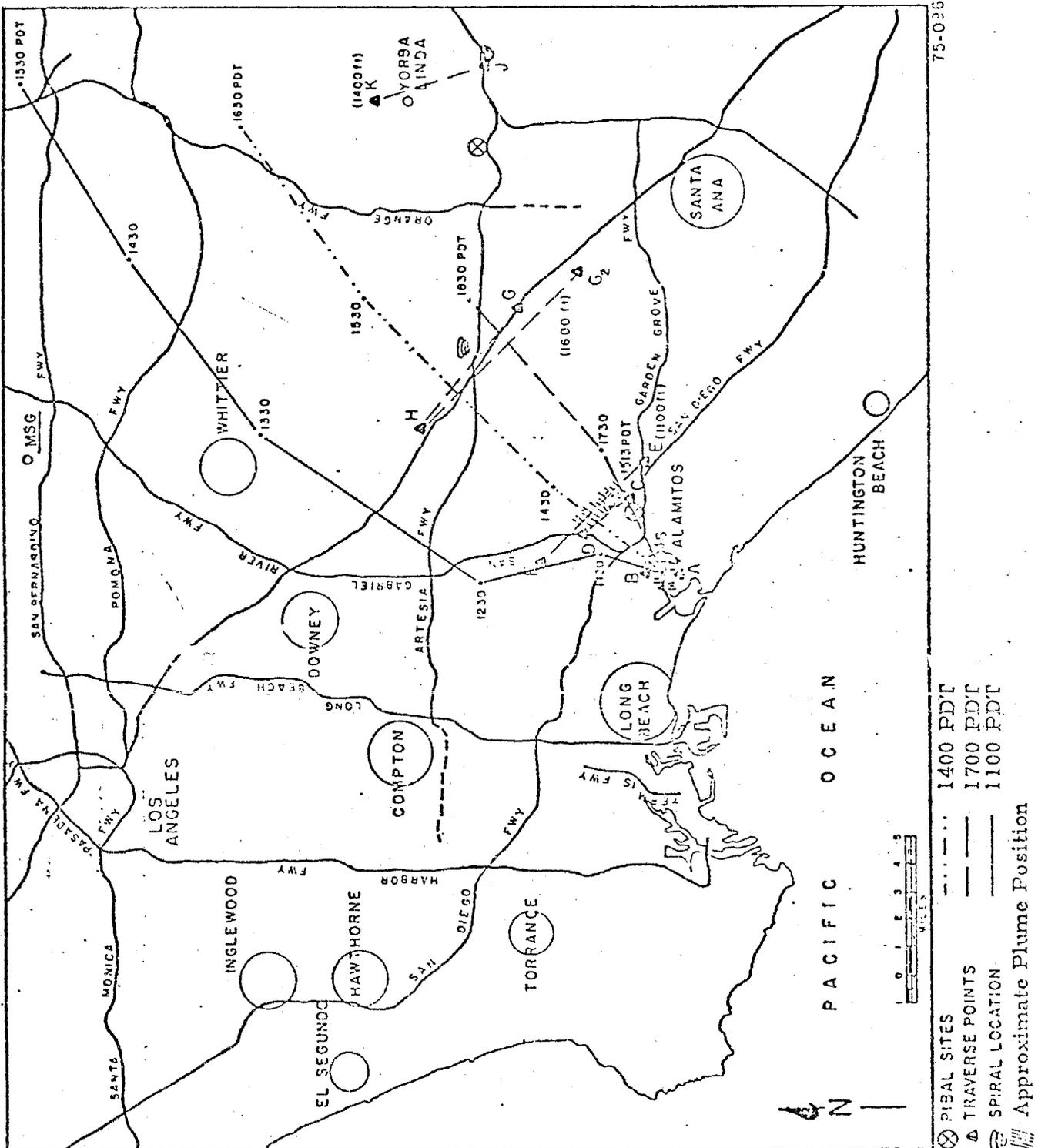
- ⊗ PIBAL SITES
- △ TRAVERSE POINTS
- ☎ SPIRAL LOCATION

Fig. 5.9
 Mean Trajectories at Plume Height
 12. September 1974
 (None Computed)



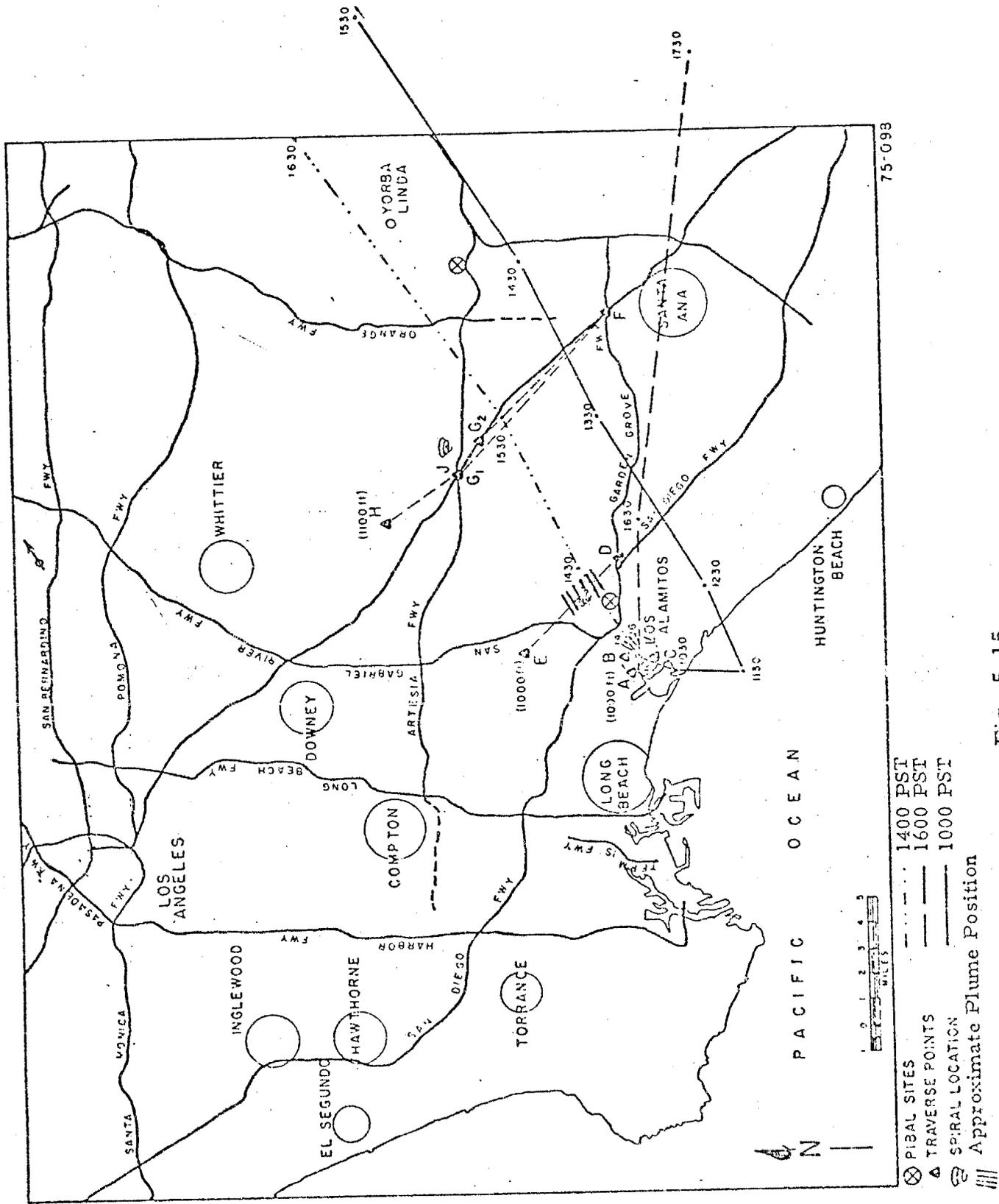
75-093

Fig. 5.11
 Mean Trajectories at Plume Height - 11 October 1974



75-026

Fig. 5.14
 Mean Trajectories at Plume Height - 30 October 1974



75-098

Fig. 5.15

Mean Trajectories at Plume Height - 7 November 1974

TABLE 5.1 PLUME DIMENSIONS AND
MAXIMUM CONCENTRATIONS

Date	Time (PDT)	Distance (km)	SO ₂ X max (ppm)	Plume Centerline m (msl)	2.15 σ_y (m)	2.15 σ_z (m)
<u>Moss Landing</u>						
9/10/74	1227	1.6	1.0	457	626	70
	1428	1.6	1.9	335	313	61
	1524	6.4	1.2	335	684	>107
	1606	16.1	0.97	366	403	> 91
9/11/74	1142	1.6	1.0	457	962	36
9/12/74	1626	1.6	0.18	335	581	>107
<u>Haynes</u>						
10/1/74	1418	0.8	0.35	335	407	> 30
	1450	4.8	0.24	407	183	> 30
10/11/74	1350	0.8	0.35	427	445	>107
	1428	4.8	0.11	381	1136	>122
	1516	9.6	0.09	366	1540	>183
	1554	19.3	0.15	518	---	--
	1634	30.6	0.11	549	971	--
10/17/74	1456	0.8	0.84	305	188	--
	1605	11.3	0.14	366	---	--
	1634	22.5	0.18	396	1966	--
	1738	32.2	0.19	457	---	--
<u>Los Alamitos</u>						
10/25/74	1402	0.8	0.84	305	157	84
	1417	4.8	0.23	305	752	> 38
	1519	14.5	0.08	305	157	--
10/30/74	1250	0.8	1.00	305	250	> 89
	1328	4.8	0.23	335	1008	> 61
	1453	16.1	0.09	396	1253	--
11/7/74	1249	0.8	0.30	305	1018	>107
	1349	4.8	0.22	305	1409	> 61
	1444	16.1	0.07	366	537	--

TABLE 5.1 PLUME DIMENSIONS AND
MAXIMUM CONCENTRATIONS

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	1516	9.6	0.09	366	1540	>183
	1554	19.3	0.15	518	---	--
	1634	30.6	0.11	549	971	--
10/17/74	1456	0.8	0.84	305	188	--
	1605	11.3	0.14	366	---	--
	1634	22.5	0.18	396	1966	--
	1738	32.2	0.19	457	---	--
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10/30/74	1250	0.8	1.00	305	250	> 89
	1328	4.8	0.23	335	1008	> 61
	1453	16.1	0.09	396	1253	--
11/7/74	1249	0.8	0.30	305	1018	>107
	1349	4.8	0.22	305	1409	> 61
	1444	16.1	0.07	366	537	--

Aircraft sampling paths are shown in Figs. 5.7 through 5.15. Indicated on each sampling path, where appropriate, is the location or locations where the plume was encountered by the aircraft. In the Southern California area, particularly, correspondence between computed trajectories and observed airborne plume locations is generally good.

6. Plume Analyses

6.1 Plume Trajectories

Pibal winds at 1000 ft. above ground level for El Monte (noon observations) have been added to Figs. 5.10 to 5.15 to indicate the general flow pattern over the South Coast Basin at the plume level. It can be seen that the El Monte winds provide a useful indication of the plume trajectories for concurrent intervals of time.

As a result of this correlation between El Monte winds and plume trajectories a climatological summary of El Monte winds has been prepared. This summary appears in Table 6.1 and represents the available noon wind directions at 1000 ft. above ground level for 1973 and 1974. The consistency of these wind directions is striking, particularly for June through September. During these months over 60% of the wind directions at El Monte are from the southwest. These data indicate that the plume directions observed during the test program were typical of the most frequent directions to be expected during the spring, summer, and fall months. Only December and January fail to show high wind direction frequencies from the southwest. This suggests that the plumes from the Haynes and Alamitos plants can be expected to affect a rather localized downwind area on a frequent basis.

6.2 Plume Diffusion Characteristics

Measured plume widths as given in Table 5.1 for each site location have been plotted in Figs. 6.1 to 6.3. Data from individual horizontal traverses have been plotted on a standard dispersion graph and labeled by the appropriate stability category as shown in Section 4.2. It can be seen from the figures that the plume widths at short downwind distances generally exceed the widths corresponding to their respective stability categories. At farther downwind distances the widths are in much better agreement with classical diffusion estimates. It is of interest to note that the apparent downwind growth of the plume is not as rapid as indicated by the dispersion graph.

Table 6.2 gives the peak SO_2 concentrations shown in Table 5.1 but normalized to a maximum $\chi u/Q$ value for the various distances shown so that individual tests can be compared. Also shown in the table are stability categories, wind speeds and an estimated value of $\chi u/Q$. The latter values have been determined from standard dispersion graphs³ using specified wind speeds and stability categories and refer to 10-minute average concentrations rather than the instantaneous peak readings measured by the aircraft (modified by instrument time response).

TABLE 6.1 SUMMARY OF EL MONTE WIND DIRECTIONS AT 1000 FEET ABOVE GROUND
(Noon Observations)

Wind Direction	(1973-74) Percentage of Occurrence											
	January	February	March	April	May	June	July	August	September	October	November	December
N				4.3				2.4				
NNE											5.1	
NE											2.5	
ENE	5.0								2.5		5.1	8.6
E	15.0		5.3							10.3		8.6
ESE	5.0	5.6					2.7					5.8
SE	20.0	11.1								5.0	2.5	8.6
SSE	10.0			8.7							5.1	11.4
S	10.0	5.6		8.7	10.0		2.7				12.9	14.3
SSW	10.0	22.2	21.1	34.8	30.0	12.0	16.9	9.5	10.3	2.5		
SW	5.0	38.8	42.1	26.1	40.0	72.0	67.7	66.7	64.1	55.0	33.4	11.4
WSW	15.0	11.1	21.1	13.1	10.0	16.0	5.4	16.6	23.1	15.0	10.3	14.3
W			10.5	4.3	5.0		2.7	2.4	2.5	15.0	10.3	11.4
WNW	5.0									5.0		2.8
NW					5.0							
NNW		5.6						2.4				
TOTAL NUMBER OF DATA	20	18	19	23	20	25	37	42	39	40	39	35

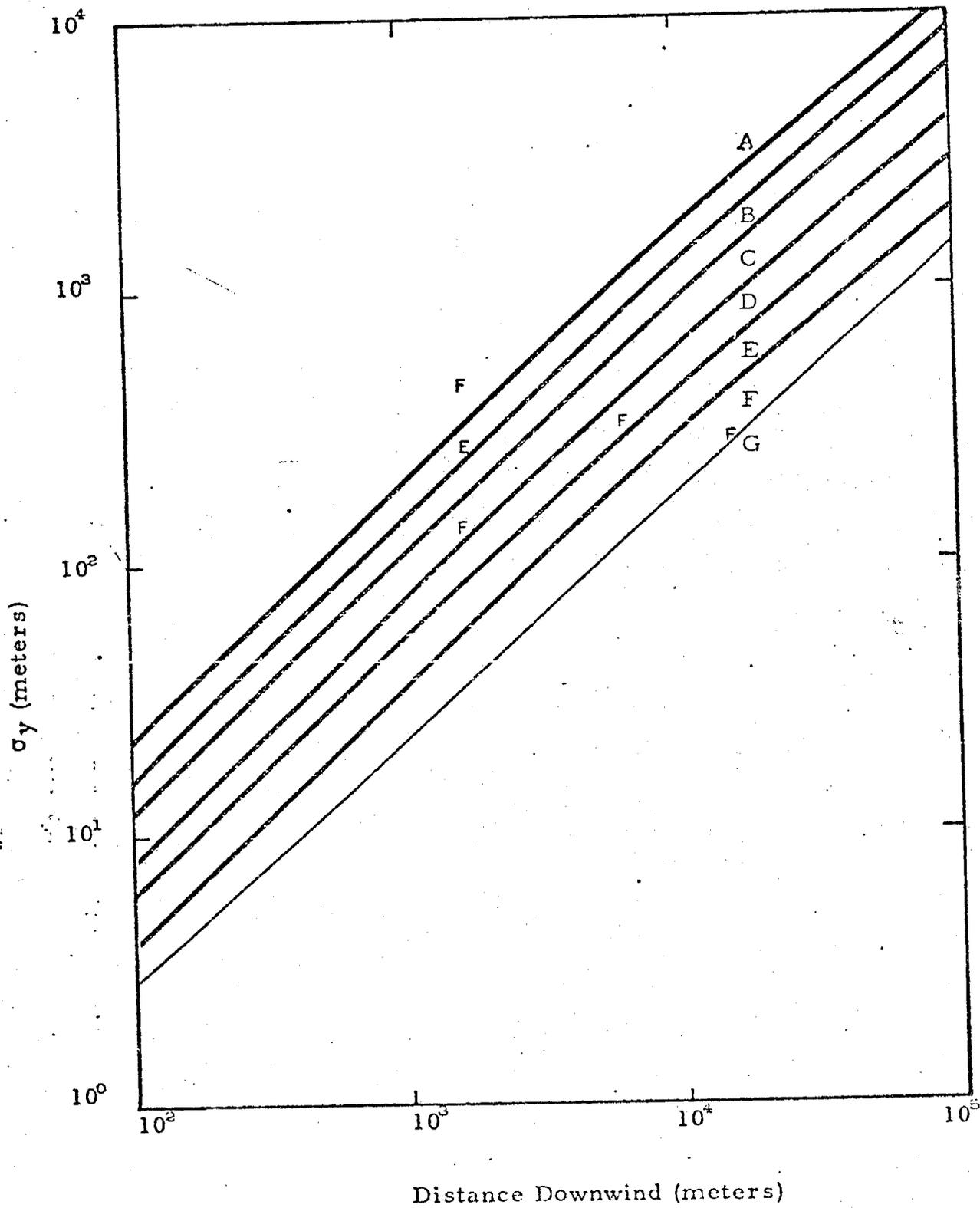


Fig. 6.1 σ_y Versus Distance Downwind - Moss Landing

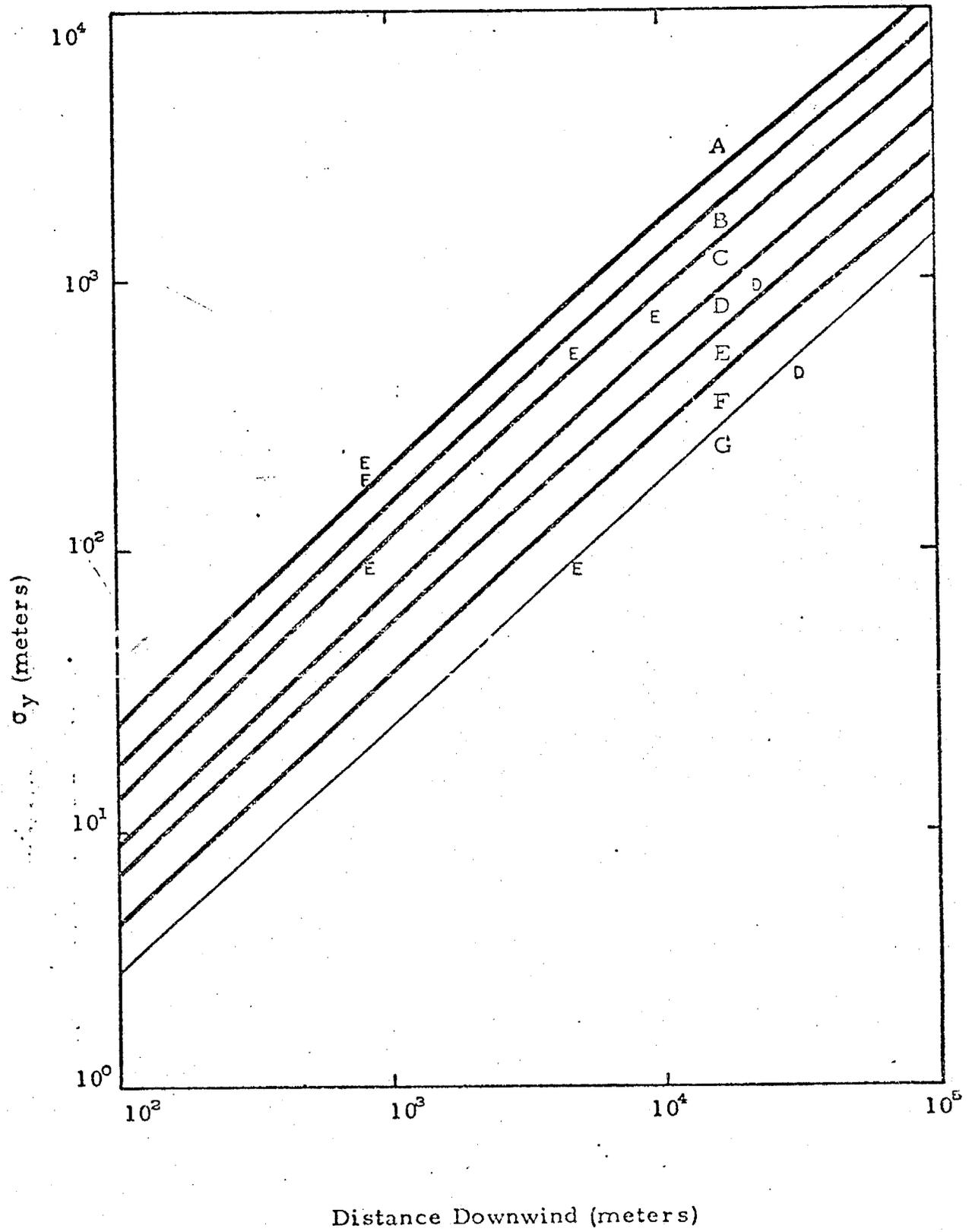


Fig. 6.2 σ_y Versus Distance Downwind - Haynes

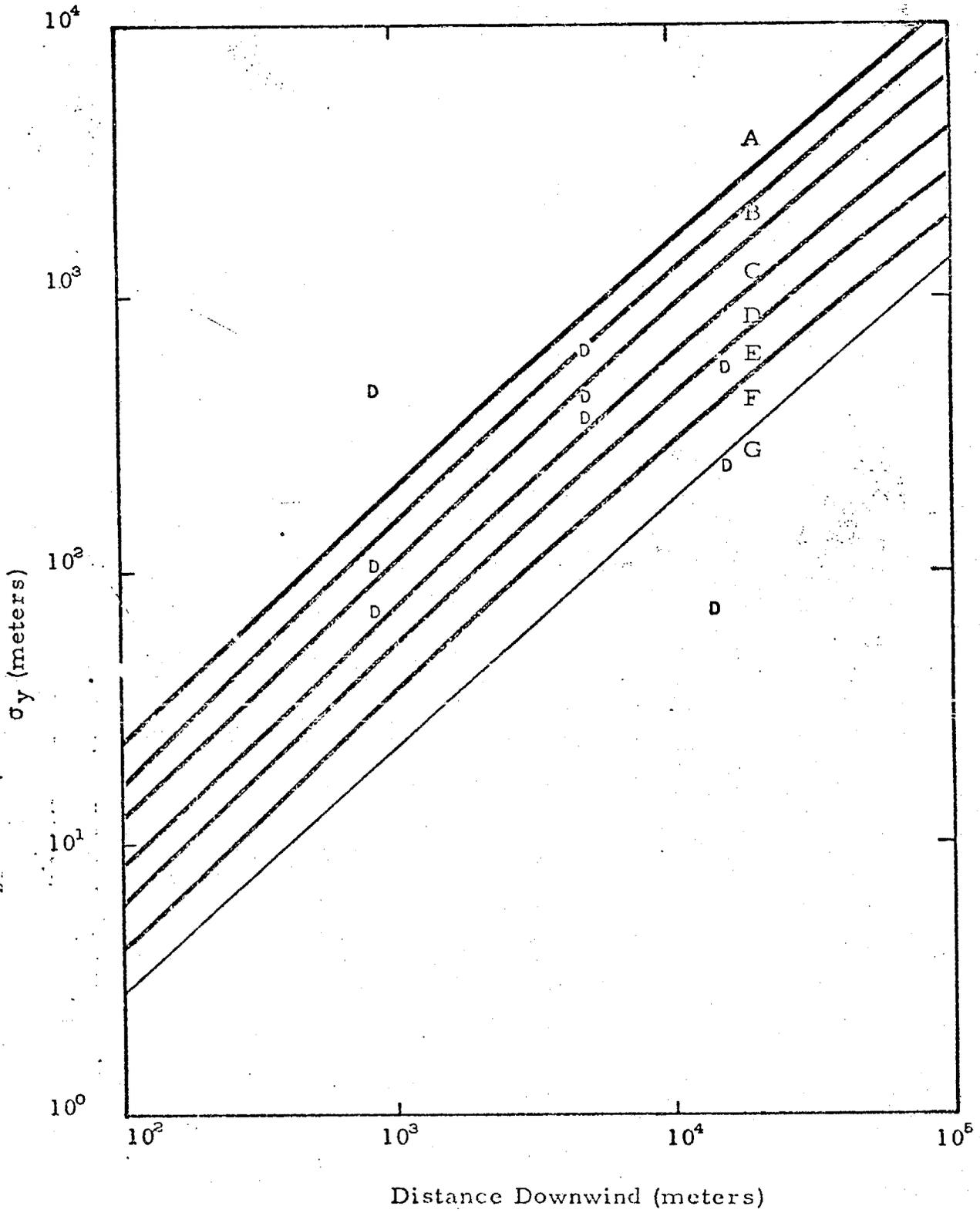


Fig. 6.3 σ_y Versus Distance Downwind - Los Alamitos

TABLE 6.2 MAXIMUM PLUME CENTERLINE SO₂ CONCENTRATIONS (Xu/Q)

Date	Time	Stability	Downwind Distance (km)	Wind Speed at Plume Height (m/s)	Height (m)	Xu/Q	
						Obs. (x 10 ⁻³)	Est. (x 10 ⁻³)
9/10/74	1227	F	1.6	2.5	457	1.15	16.0
	1428	F	1.6	2.5	335	2.18	16.0
	1524	F	6.5	3.8	335	2.09	2.1
	1606	F	16.1	6.5	366	2.90	0.85
9/11/74	1142	F	1.0	3.8	457	1.58	35.0
	1626	E	1.6	7.4	335	----	6.5
10/1/74	1418	E	0.8	3.0	335	1.07	20.0
	1450	E	4.8	4.6	407	1.12	1.3
10/11/74	1350	E	0.8	0.8	427	0.26	20.0
	1428	E	4.8	1.4	381	0.11	1.3
	1516	E	9.6	1.4	366	0.12	0.48
	1554	E	19.3	2.2	518	0.31	0.20
	1634	E	30.6	2.2	549	0.23	0.08
	1738	E	32.2	2.8	457	0.44	0.10
10/17/74	1456	E	0.8	2.9	305	2.01	20.0
	1605	E	11.3	2.8	366	0.33	0.38
	1634	E	22.5	2.8	396	0.41	0.15
	1738	E	32.2	2.8	457	0.44	0.10
10/25/74	1402	E	0.8	3.4	305	1.8	20.0
	1417	E	4.8	3.4	305	0.38	1.3
	1519	E	16.1	6.0	305	0.23	0.24
10/30/74	1250	D	0.8	4.6	305	2.22	9.5
	1328	D	4.8	4.6	335	0.51	0.55
	1453	D	16.1	4.0	396	0.18	0.10
11/7/74	1249	D	0.8	3.5	305	0.51	9.5
	1349	D	4.8	4.5	305	0.48	0.55
	1444	D	16.1	6.4	366	0.21	0.10

Comparison of the observed and estimated values for $\chi u/Q$ indicates good agreement for long distances downwind but lower observed values than estimated at shorter distances. This is in agreement with the comparative plume widths described above which indicate larger widths than given by dispersion graphs for short downwind distances. It is suggested that this difference results partially from the rapid dilution which occurs near the stack and results from the gas velocity and initial buoyancy of the plume. The plume therefore initially cannot be considered as emanating from a point source but must be considered to have internal diffusive energy which is gradually dissipated as the plume travels downwind.

6.3 Plume Rise

Downwind ground concentrations from a tall power plant stack are strongly controlled by the extent of the plume rise above the stack. The plume rise, in turn, is controlled by height of the stack, stack gas velocity and temperature as well as the environment parameters of wind speed and temperature stability. Although newer plume rise models are being developed, the most frequently used models have been summarized by Briggs⁴

Two plume rise models given by Briggs have been used most extensively. These are:

$$\Delta h = 2.4 \left(\frac{F}{us} \right)^{1/3} \quad (1)$$

and

$$\Delta h = 1.6 \frac{F^{1/3}}{u} \times 2/3 \quad (2)$$

where

Δh = plume rise above the stack top

F = $R^2 W g \frac{T_g - T_a}{T_g}$ = flux parameter

R = radius of stack

- W = gas velocity
- T_g = stack gas temperature
- T_a = ambient temperature
- S = $\frac{g}{T_a} \frac{\Delta \theta}{\Delta Z}$
- u = average wind speed between stack top and plume top
- x = downwind distance .

Table 6.3 shows the appropriate parameters used in calculating plume rise from Briggs' models. Table 6.4 gives the results of the two estimation techniques compared to the observed plume heights. As suggested by Briggs, x has been taken to be 10 times the stack height for the purposes of calculating the final equilibrium height of the plume.

Table 6.4 indicates that Equation (1) provides adequate estimates of plume height except for conditions of near-neutral stability (low values of S) and, to some extent, with low values of wind speed. Equation (2) gives an improved estimate of plume height under conditions of low stability but tends to overestimate plume height for low wind speeds. In addition, the higher stack height (152 m) for the Moss Landing plant contributes to larger overestimates for September 10 and 11 using Equation (2).

The data in Table 6.4 suggest that the standard plume rise formulae provide useful estimates of plume height for various ranges of environmental conditions. For extreme cases of low wind speed or low environmental stability, considerable care must be used. It is under these more extreme conditions where the newer, hydrodynamic models may be more useful.

6.4 Characteristics of Peak Ground Concentrations

Table 6.5 gives peak SF₆ ground concentrations as obtained by the Cal Tech sampling. Peak concentrations are given in terms of a normalized value ($\chi u/Q$) which is a function of stability category and downwind distance only. Observed values in the table were determined from the observed SF₆ ground concentration (χ) divided by SF₆ rate of release (Q) and multiplied by the appropriate wind speed (u) at plume height.

TABLE 6.3 PLUME ENVIRONMENT OBSERVATIONS

Date	Time	Downwind Distance	Average Wind Speed	$\Delta\theta/\Delta Z$	$F^{1/3}$
9/10/74	1524 PDT	6.4 km	2.2 m/s	2.22°C/100m	14.37
9/11/74	1142	1.6	3.0	2.46	14.06
9/12/74	1626	1.6	7.7	1.02	13.87
10/1/74	1450	4.8	3.0	0.40	10.34
10/11/74	1428	4.8	1.0	0.47	10.72
10/17/74	1542	6.4	3.5	1.10	10.79
10/25/74	1417	4.8	3.4	0.10	13.08
10/30/74	1328 PST	4.8	4.8	0.33	12.63
11/7/74	1349	4.8	5.0	0.03	12.86

TABLE 6.4 PLUME HEIGHT COMPARISONS

Date	Observed Height	Calculated Height ^A	Calculated Height ^B
9/10/74 M ^c	335 m msl	444 m msl	1369 m msl
9/11/74 M ^c	455	400	982
9/12/74 M ^c	335	393	378
10/1/74 M ^c	405	411	459
10/11/74 M ^c	380	552	1429
10/17/74 H	305	314	411
10/25/74 A	305	708	471
10/30/74 A	335	441	322
11/7/74 A	305	901	315

A - Calculated from: $\Delta h = 2.4 \left(\frac{F}{u s} \right)^{1/3}$

B - Calculated from: $\Delta h = 1.6 \frac{F^{1/3}}{u} x^{2/3}$

TABLE 6.5 PEAK SF₆ GROUND CONCENTRATIONS AND LOCATIONS

Date	Time (pm)	Peak Ground Concentration (normalized)		Downwind Distance	
		$\chi u/Q$		Obs.	Est.
		Obs.	Est.		
9/10/74	5-6 PDT	$1.79 \times 10^{-7} \text{ m}^{-2}$	$5 \times 10^{-7} \text{ m}^{-2}$	12.7 km	17 km
9/11/74	2-3 PDT	12.2	1.6	16.0	27
9/12/74	3-4 PDT	12.2	5.	16.4	17
10/1/74	4-5 PST	12.1	2.	17.4	23
10/11/74	3-4 PST	3.32	3.	24.0	21
10/17/74	12-1 PST	4.27	7.	17.4	13
10/25/74	4-5 PST	6.53	7.	17.4	13
10/30/74	4-5 PST	10.5	5.	15.4	17
11/7/74	2-3 PST	7.21	7.	21.5	13

There was some ambiguity about the wind speed in some of the tests where the wind speed increased downwind as the plume moved inland. In these cases, the wind speed at the plant site at plume height was used for the time period closest to the observed ground maximum concentration. Downwind distances to the peak SF_6 concentration are also given in the table. These maximum values occur at 12 to 24 km downwind although the resolution of the downwind distance is not very good due to the limited number of ground samples.

The observed values of peak ground values $\chi u/Q$ have been compared in Table 6.5 to values estimated from a dispersion graph given in Meteorology & Atomic Energy⁵. These estimated values are appropriate for D stability and the plume heights given in Table 6.2. D stability was used in all cases since it was apparent from the meteorological conditions that neutral lapse rates existed in the lower portions of the plume and resulted in mixing of the plume to the ground. Plume rise, on the other hand, (Section 6.3) is influenced by stability aloft near the stack and was found to range between D and F during the test program.

Comparison of observed and estimated $\chi u/Q$ values and downwind distances show good overall agreement but some variability between tests. In view of the wind speed variations, lack of a dense network for the ground samples and downwind variations in the diffusion environment, the agreement is considered to be satisfactory.

Table 6.6 utilizes the peak SF_6 ground concentrations to estimate the SO_2 impact of each plant at the peak downwind locations. Values of SO_2 output refer to all units at each plant. Equivalent peak SO_2 concentrations are given in $\mu\text{g}/\text{m}^3$ and ppm and refer to one-hour averaged values.

TABLE 6.6 SO₂ GROUND CONCENTRATIONS
ESTIMATED FROM SF₆ VALUES

Date	Windspeed u	SO ₂ Emissions* Q	Dilution factor (from peak SF ₆) yu/Q	Equivalent SO ₂ concentrations (one hour) X	
9/10/74	4.5 m/s	570 g/s	$1.79 \times 10^{-7} \text{ m}^{-2}$	22.6 $\mu\text{g}/\text{m}^3$.009 ppm
9/11/74	4.7	630	1.22×10^{-6}	163.5	.062
9/12/74	7.7	---	----	----	---
10/1/74	4.2	425	1.21×10^{-6}	122.4	.047
10/11/74	3.0	540	3.32×10^{-7}	59.8	.023
10/17/74	3.0	455	4.27×10^{-7}	64.7	.025
10/25/74	5.9	685	6.53×10^{-7}	75.8	.029
10/30/74	3.6	740	1.05×10^{-6}	215.8	.082
11/7/74	5.7	790	7.21×10^{-7}	100.0	.038

* - Total for plant.

6.5 Correspondence Between SF₆ and SO₂

During the sampling periods, SF₆ was injected into one stack at a uniform rate by Caltech personnel. On each sampling traverse, the MRI aircraft collected a sample for later SF₆ analysis at Caltech. The samples were collected with a syringe which drew in air at a constant rate throughout the traverse. The measured SF₆ concentrations, therefore, represent an average for the traverse, both within the plume and without.

The reliability of the SF₆ as a tracer for the emissions of the power plant was checked by comparing the SF₆ plume averages with the continuous SO₂ concentrations recorded by the Theta Sensors, Inc. (TSI) instrument onboard the aircraft. A computer routine (TINT) was written to average the continuous aircraft data over each traverse to make this comparison possible. The results of this comparison are summarized in Tables 6.7 through 6.16 which show the average SO₂ concentrations measured on traverses downwind of the plant and the corresponding average SO₂ concentrations calculated from SF₆ concentrations.

The calculated values for SO₂ are based on the formula

$$[\text{SO}_2] \text{ (Calculated)} = \frac{Q_{\text{SO}_2}}{\text{MW}_{\text{SO}_2}} \times \frac{\text{MW}_{\text{SF}_6}}{Q_{\text{SF}_6}} \times [\text{SF}_6],$$

where MW_{SO₂}, MW_{SF₆} are the molecular weights of SO₂ and SF₆, and Q_{SO₂} and Q_{SF₆} are the mass emission rates of SO₂ and SF₆ at the plant. The emission rate for SF₆ was calculated from the amount released and the emission rate for SO₂ was calculated from stack concentrations and air flow rates or from the fuel flow rate and sulfur content.

Tables 6.7 through 6.16 show comparative observed and calculated SO₂ data for three sampling days. There was generally good correlation between measured and calculated SO₂ averages; that is, between SF₆ and SO₂. From this observation, we can infer that:

- a. At the distances sampled, little SO_2 is lost to sinks such as aerosol and surface deposition.
- b. At the distances sampled, the SF_6 tracer is fairly well mixed into the plume.
- c. Most of the SO_2 encountered in the apparent plume was from the power plants.

TABLE 6.7 COMPARISON OF OBSERVED AND CALCULATED AVERAGE SO_2 CONCENTRATIONS
September 10, 1974 (0.8 km downwind)

Altitude (m msl)	Measured SO_2 (ppm)	Calculated SO_2 * (ppm)
427	0.040	0.017
397	0.170	0.193
366	0.247 **	0.512
355	0.146	0.116
305	0.040	0.007
275	0.020	0.005
244	0.040	0.007

* Contribution of Units 5 and 6 as calculated from SF_6 concentrations.

** Instrument over-ranged.

TABLE 6.8 COMPARISON OF OBSERVED AND CALCULATED
 AVERAGE SO₂ CONCENTRATIONS
 September 10, 1974 (6.4 km downwind)

<u>Altitude</u> <u>(m msl)</u>	<u>Measured SO₂</u> <u>(ppm)</u>	<u>Calculated SO₂*</u> <u>(ppm)</u>
488	0.041	0.013
427	0.078	0.072
366	0.175	0.250
335	0.116	0.177
275	0.035	0.130

* Contribution of Units 5 and 6 as calculated from SF₆ concentrations.

TABLE 6.9 COMPARISON OF OBSERVED AND CALCULATED
AVERAGE SO₂ CONCENTRATIONS

September 10, 1974 (16 km downwind)

<u>Altitude</u> <u>(m msl)</u>	<u>Observed SO₂</u> <u>(ppm)</u>	<u>Calculated SO₂*</u> <u>(ppm)</u>
488	0.049	0.004
457	0.053	0.007
427	0.061	0.018
397	0.049	0.007
366	0.086	0.055
335	0.079	0.051
305	0.090	0.077

* Contribution of Units 5 and 6 as calculated from SF₆ concentrations.

TABLE 6.10 COMPARISON OF OBSERVED AND CALCULATED
AVERAGE SO₂ CONCENTRATIONS

October 11, 1974 (0.8 km downwind)

<u>Altitude</u> <u>(m msl)</u>	<u>Observed SO₂</u> <u>(ppm)</u>	<u>Calculated SO₂*</u> <u>(ppm)</u>
518	0.057	0.042
488	0.038	0.036
457	0.033	0.022
427	0.055	0.067
397	0.041	0.044
366	0.047	0.037
335	0.044	msg

* Contribution of Haynes plant calculated from SF₆ concentrations.

TABLE 6.11 COMPARISON OF OBSERVED AND CALCULATED
AVERAGE SO₂ CONCENTRATIONS

October 11, 1974 (4.8 km downwind)

<u>Altitude</u> <u>(m msl)</u>	<u>Observed SO₂</u> <u>(ppm)</u>	<u>Calculated SO₂*</u> <u>(ppm)</u>
549	0.016	0.026
488	0.031	0.021
442	0.027	0.018
381	0.037	0.028
305	0.023	0.020

* Contribution of Haynes plant as calculated from SF₆ concentrations.

TABLE 6.12 COMPARISON OF OBSERVED AND CALCULATED
AVERAGE SO₂ CONCENTRATIONS

October 11, 1974 (9.6 km downwind)

<u>Altitude</u> <u>(m msl)</u>	<u>Observed SO₂</u> <u>(ppm)</u>	<u>Calculated SO₂ *</u> <u>(ppm)</u>
671	0.006	0.008
610	0.017	0.011
549	0.011	0.009
488	0.021	0.012
427	0.016	0.014
366	0.020	0.021
305	0.022	0.014

* Contribution of Haynes plant as calculated from SF₆ concentrations.

TABLE 6.13 COMPARISON OF OBSERVED AND CALCULATED
AVERAGE SO₂ CONCENTRATIONS

October 25, 1974 (0.8 km downwind)

<u>Altitude (m msl)</u>	<u>Observed SO₂ (ppm)</u>	<u>Calculated SO₂* (ppm)</u>
518	0.015	0.001
488	0.009	0.001
457	0.019	0.018
427	0.032	0.020
397	0.038	0.054
366	0.065	0.021
335	0.041	0.067
305	0.055	0.081

* Contribution of Alamitos plant as calculated from SF₆ concentrations.

TABLE 6.14 COMPARISON OF OBSERVED AND CALCULATED
AVERAGE SO₂ CONCENTRATIONS

October 25, 1974 (4.8 km downwind)

<u>Altitude</u> <u>(m msl)</u>	<u>Observed SO₂</u> <u>(ppm)</u>	<u>Calculated SO₂*</u> <u>(ppm)</u>
427	0.009	0.001
397	0.013	msg
366	0.021	0.023
335	0.022	0.017
305	0.056	0.076

* Contribution of Alamitos and Haynes Plants as calculated from SF₆ concentrations.

TABLE 6.15 COMPARISON OF OBSERVED AND CALCULATED
AVERAGE SO₂ CONCENTRATIONS

October 25, 1974 (16 km downwind)

<u>Altitude (m msl)</u>	<u>Observed SO₂ (ppm)</u>	<u>Calculated SO₂* (ppm)</u>
671	0.005	0.003
610	0.006	0.001
579	0.011	0.007
549	0.006	0.004
518	0.004	0.011
488	0.005	0.010
457	0.002	0.001
427	0.005	0.001
396	0.002	0.001
366	0.002	0.001
335	0.002	msg
305	0.006	msg

* Contribution of Alamitos and Haynes plants as calculated from SF₆ concentrations.

TABLE 6.16 COMPARISON OF OBSERVED AND CALCULATED
AVERAGE SO₂ CONCENTRATIONS

October 25, 1974 (32 km downwind)

<u>Altitude</u> <u>(m msl)</u>	<u>Observed SO₂</u> <u>(ppm)</u>	<u>Calculated SO₂*</u> <u>(ppm)</u>
671	0.005	0.006
610	0.005	0.016
549	0.001	0.001
488	0.001	0.001
427	0.001	0.001

* Contribution of Alamitos and Haynes plants as calculated from SF₆ concentrations.

It should be mentioned at this point that a small number of syringes taken on traverses where all continuous monitors (SO_2 , NO , NO_x , O_3) showed background levels were found to contain high concentrations of SF_6 . These few syringes were assumed to be contaminated.

6.6 Contribution of Plumes to Concentrations Aloft

Flight plans were designed so that the aircraft sampled roughly rectangular cross-wind sections at several distances downwind of the power plants. Tables 6.17 and 6.18 show the average and maximum concentrations of SO_2 , NO , and NO_x sampled in each cross-section. The prominence of a plume in the data can generally be judged by comparing the peak concentrations with the averages.

Also shown in Tables 6.17 and 6.18 are the estimated contributions of the power plants to the observed average concentrations of SO_2 and NO_x . These are scaled from the measured average SF_6 concentrations as described in Section 6.5 and represent only those units for which NO_x emissions were reported. As observed in Section 6.5, the calculated SO_2 contributions of the plumes are similar to the SO_2 concentrations actually measured. This is not the case with NO_x . Averaged over an entire cross-section, the power plants appear generally to have contributed relatively small fractions of the NO_x encountered in the Los Angeles basin.

Close to the stacks, the NO_x emissions of a power plant are largely in the form of NO , as can be seen by comparing the NO and NO_x maxima. At 0.8 km downwind, there is good agreement between measured NO concentrations and the calculated NO_x contribution of the plume. In the Los Angeles basin, the fraction of ambient NO_x which can be attributed to the plume drops with increasing distance from the stacks and the cross-wind averages quickly approach an "urban background" level.

6.7 A Mass Balance for SO_2 and SF_6

The discussions of the preceding two sections were based on comparisons of the relative concentrations of SF_6 , SO_2 , NO , and NO_x measured in the ambient air to the relative concentrations of these gases in the power plant emissions. An advantage of this approach was that conclusions could be drawn for well mixed plumes on the basis of a partial sample. In the present section, we attempt a mass balance for SF_6 and SO_2 in the plume to determine the extent

TABLE 6.17 COMPARISON OF PEAK AND AVERAGE
PLUME CONCENTRATIONS

Downwind Distance (km)	Parameter	Maximum Concentration (ppm)	Average Concentration (ppm)	Calculated * Average Concentration (ppm)
September 10, 1974				
0.0	SO ₂	1.9	0.08	0.12a
6.4	SO ₂	1.2	0.06	0.13
16.0	SO ₂	0.97	0.05	0.03
September 12, 1974				
0.8	NO	0.12	0.009	0.005b
0.8	NO _x	0.18	0.03	0.005
October 11, 1974				
0.8	SO ₂	0.35	0.045	0.023c
4.8	SO ₂	0.11	0.027	0.015
9.6	SO ₂	0.09	0.016	0.007
0.8	NO	0.44	0.025	0.019
0.8	NO _x	0.62	0.126	0.019
4.8	NO	0.11	0.022	0.012
4.8	NO _x	0.22	0.098	0.012
9.6	NO	0.06	0.017	0.006
9.6	NO _x	0.20	0.080	0.006
19.2	NO	0.06	0.013	0.002
19.2	NO _x	0.15	0.082	0.002
32.0	NO	0.06	0.008	0.001
32.0	NO _x	0.15	0.087	0.001

* Calculated concentrations were scaled from measured SF₆ concentrations and represent the estimated contributions (assuming no losses) of:

- a)- Moss Landing Units 5 and 6
- b)- Moss Landing Units 6 and 7
- c)- Haynes Units 4 and 6

TABLE 6.18 COMPARISON OF PEAK AND AVERAGE
PLUME CONCENTRATIONS

October 25, 1974

Downwind Distance (km)	Parameter	Maximum Concentration (ppm)	Average Concentration (ppm)	Calculated* Average Concentration (ppm)
0.8	SO ₂	0.84	0.029	0.026
4.8	SO ₂	0.23	0.021	0.011
16.0	SO ₂	0.08	0.005	0.002
32.0	SO ₂	--	0.002	0.002
0.8	NO	0.40	0.018	0.018
0.8	NO _x	0.46	0.036	0.018
4.8	NO	0.11	0.011	0.007
4.8	NO _x	0.15	0.028	0.007
16.0	NO	0.10	0.014	0.002
16.0	NO _x	0.16	0.049	0.002
32.0	NO	0.02	0.006	0.002
32.0	NO _x	0.06	0.038	0.002

* Calculated concentrations were scaled from measured SF₆ concentrations and represent the estimated concentrations (assuming no losses) from Alamitos Units 5 and 6.

to which emissions are, in fact, accounted for in the aircraft sampling data.

The emission rates of SF_6 on each day were monitored by Caltech personnel. In-stack measurements of SO_2 concentrations confirmed that SO_2 emission rates can be calculated with sufficient accuracy from fuel flow rate and sulfur content. Tables 6.19 through 6.21 give the emission rates of SF_6 and SO_2 obtained in this way for each flight.

Measured ambient concentrations (g/m^3) need to be converted to emission rates (g/sec). Multiplying the average concentration measured in a sample rectangle by the area of that rectangle gives the integral \int (concentration) $dy dz$. The product of this integral (g/m) and the wind speed (m/sec) normal to the rectangle is a mass flow rate (g/sec) which can be compared with the emission rate.

Tables 6.19 through 6.21 show the mass flow rates calculated in this manner for sample rectangles at increasing distances downwind. Since winds were not always in a steady state, the wind speed chosen for each calculation was that measured at plume level near the plant at the approximate time of emission of the material sampled in the rectangle. It is this initial wind speed which governs the longitudinal dispersion of the plume.

There is a good deal of scatter in the tables and there appears to be no consistent relationship with downwind distance. However, there is a strong difference between the results for Moss Landing and the results for the Los Angeles area. While the observed SF_6 and SO_2 flow rates in the Moss Landing plumes are comparable with the plant emission rates, both the SF_6 and SO_2 flow rates observed in the Los Angeles plumes are much smaller than emission rates would indicate. The deficiency suggests that substantial fractions of the Los Angeles plumes were below the altitudes sampled by the aircraft. This interpretation is supported by examination of the data in Figs. 5.3 and 5.4 where it is apparent that the lower portions of the plume are not adequately sampled due to the minimum altitude flying restrictions.

TABLE 6.19 MASS FLOW RATES (g/sec)

Moss Landing 9/10/74

	SF ₆	SO ₂
Emitted by Plant*	9.7	570
Measured Downwind**		
0.8 km	10.3	440
6.4 km	23.8	840
16.0 km	7.0	770

* SF₆ value monitored by Caltech personnel; SO₂ value calculated from sulfur content of fuel.

** Calculated by integrating measured concentration over sampling rectangle and multiplying by wind speed at time and location of emission.

TABLE 6.20 MASS FLOW RATES (g/sec)

Haynes 10/11/74

	SF ₆	SO ₂
Emitted by Haynes*	4.8	540
Emitted by Haynes and Alamitos*	4.8	1210
Measured Downwind**		
0.8 km	0.7	80
4.8 km	0.5	60
9.6 km	1.0	150

*. SF₆ value monitored by Caltech personnel; SO₂ value calculated from sulfur content of fuel.

** Calculated by integrating measured concentration over sampling rectangle and multiplying by wind speed at time and location of emission.

TABLE 6.21 MASS FLOW RATES (g/sec)

Alamitos 10/25/74

	SF ₆	SO ₂
Emitted by Alamitos*	9.0	700
Emitted by Haynes and Alamitos*	9.0	1170
Measured Downwind**		
0.8 km	3.0	180
4.8 km	1.3	70
16.0 km	0.9	140

* SF₆ value monitored by Caltech personnel; SO₂ value calculated from sulfur content of fuel.

** Calculated by integrating measured concentration over sampling rectangle and multiplying by wind speed at time and location of emission.

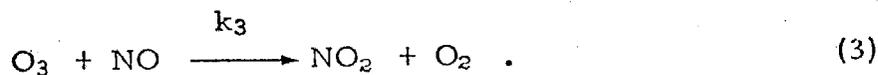
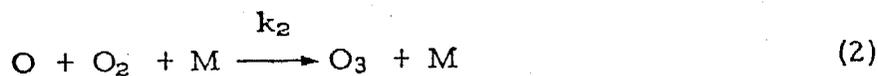
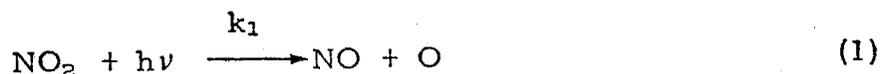
7. Chemistry of the Plume

An objective of the present program has been to examine the chemical transformations in the plume. Principal among these were the conversion of SO_2 to sulfate and the effect of the plume on the oxidant chemistry in the atmosphere. The former reaction is expected to be relatively slow, the latter much more rapid. Due to the relatively short downwind scale of the experiment, only the more rapid reaction could be examined. Data on SO_2 -sulfate comparisons are shown but the conversion rate is judged to be too slow to be evident in the present experimental data with the relatively short downwind travel distances where sampling could be carried out.

7.1 Ozone-Nitrogen Oxide Chemistry of Plume

In those cases where the plumes could be identified in the SO_2 data, the ozone concentrations within the plumes were lower than outside. In this section these ozone "deficits" are related to the basic photochemical kinetics of an $\text{NO-NO}_2\text{-O}_3$ system.

The absorption of UV radiation by NO_2 drives the following set of reactions (Stephens)⁶ :



While chains of reactions involving reactive hydrocarbons and their products play an essential role in the build-up of ozone, reactions (1) - (3) are fast enough that NO , NO_2 , and O_3 are generally in a quasi-equilibrium determined by the rate constants $k_1 - k_3$. This is the so-called photostationary state, in which (Stephens)⁶ :

$$[\text{O}_3] [\text{NO}] / [\text{NO}_2] = k_1 / k_3 \quad (4)$$

The relationship in Equation (4) is not by itself sufficient to determine the concentrations of NO, NO₂, and O₃. A second relationship is imposed by the conservation of oxidizing species in reactions (1) - (3):

$$[O] + [O_3] + [NO_2] = C \quad (5)$$

The constant C in Equation (5) is actually a slowly varying function $C = C(x, y, z, t)$ of space and time, reflecting the participation of free radicals in the photochemical system. The half-life for atomic oxygen in reaction (2) is about 13 μ sec in the atmosphere (Williamson)⁷, so that we can approximate Equation (5) with:

$$[O_3] + [NO_2] = C' \quad (5')$$

Table 7.1 and Figure 7.1 show how the concentrations of NO, NO_x and O₃ measured one-half, 3, and 5 miles downwind of the Haynes plant on 10/11/74 conformed to the theoretical relationships (4) and (5'). The relatively uniform values of $[NO][O_3]/[NO_2]$ and $[NO_2] + [O_3]$ appearing in Table 7.1 and Figure 7.1 contrast with the widely varying pollutant concentrations evident in Figures 7.2, 7.3, and 7.4, which show typical plume traverses at the three distances.

Based on chamber studies of k_1 and k_3 , a value of 10-25 ppb would be predicted for $[NO][O_3]/[NO_2]$. The measured values are in this range, except for those in Table 7.1 taken one-half mile from the stack and those in Figure 7.1 taken as the aircraft first penetrated the plume. Because of the steep concentration gradients involved in these instances, the data may have been distorted by the transient response characteristics of the monitoring instruments.

Figure 7.1 indicates that to a first approximation the oxidant concentration C can be considered constant across the plume at the sampling distances under consideration. With this assumption, Equations (4) and (5') can be solved for [NO], [NO₂], and [O₃] as functions of $[NO_x] = [NO] + [NO_2]$:

$$[NO_2] = \frac{1}{2} \left\{ C + k_1/k_3 + [NO_x] - \left((C + k_1/k_3 + [NO_x])^2 - 4C[NO_x] \right)^{1/2} \right\} \quad (6)$$

TABLE 7.1 NO_x CONCENTRATION AND DERIVED CONCENTRATION PARAMETERS [NO₂] + [O₃] AND [NO][O₃]/[NO₂] AT CENTERLINE OF HAYNES PLUME ON 10/11/74.

Pass	Distance from stacks (miles)	[NO _x] (ppb)	[NO ₂] + [O ₃] (ppb)	[NO][O ₃]/[NO ₂] (ppb)
1	1/2	358	195	40
2	1/2	358	190	64
3	1/2	350	162	41
4	1/2	384	176	53
5	1/2	516	195	37
6	1/2	326	150	56
7	1/2	234	161	25
10	3	175	160	18
11	3	197	138	12
12	3	210	164	15
13	3	209	173	12
14	3	163	142	25
17	5	126	166	17
18	5	145	165	17
19	5	180	180	13
20	5	196	174	10
21	5	200	173	13

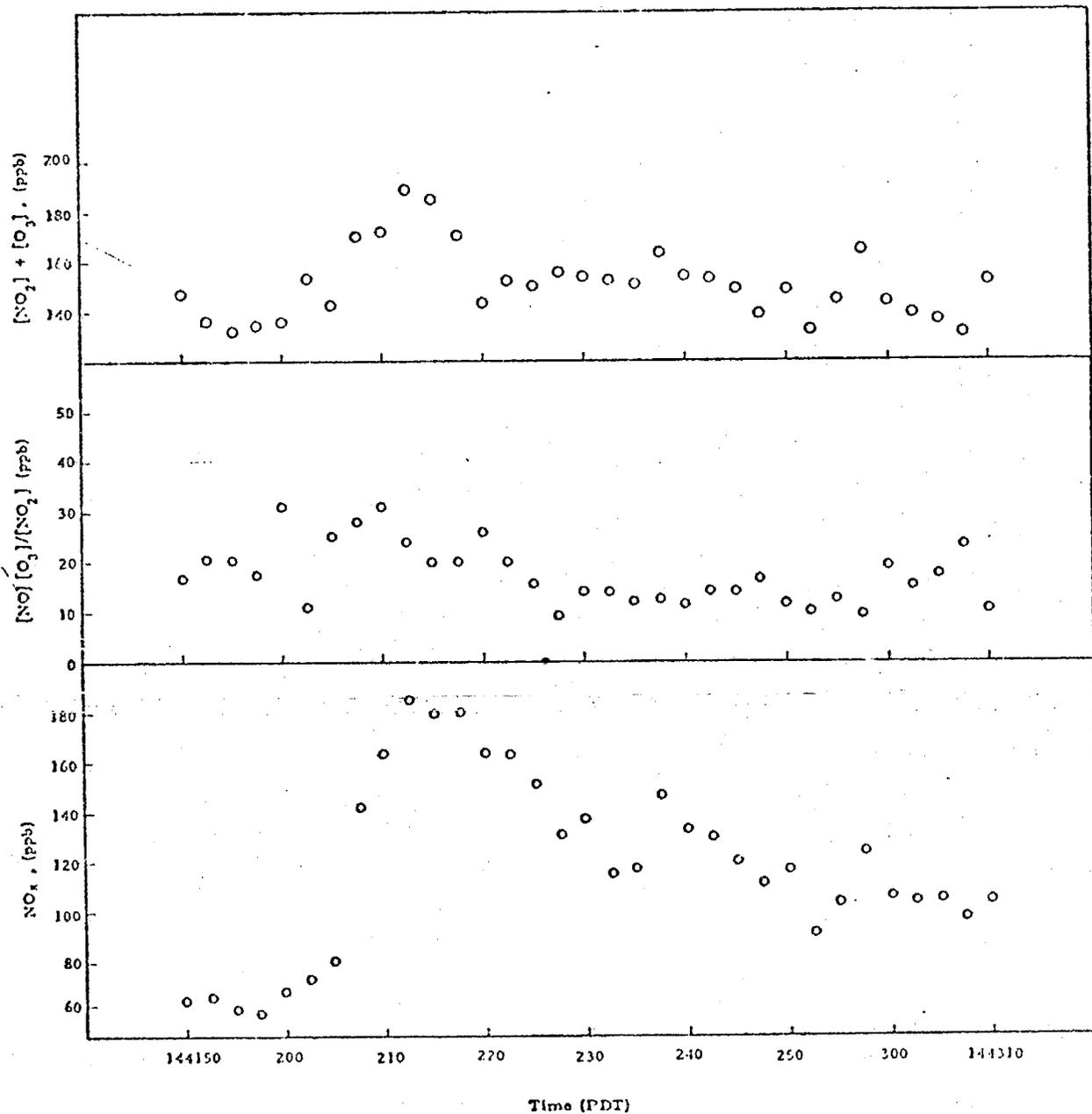


Fig. 7.1 Portion of horizontal cross wind traverse at 1800 ft msl, three miles downwind of Haynes power plant on 11 October 1974. Note NO_x plume, relatively constant values of the derived concentration parameters $[NO_2] + [O_3]$ and $[NO][O_3]/[NO_2]$.

Altitude: 1800 Feet

CO Inoperative
SO2 Offset +0.38 PPM

DATE: 10/11/74
ALPHABET: ZDC
CARTRIDGE NUMBER: 981
PAGE: 14

DESCRIPTION: C TO D

DERIVATIVE CORRECTION
M 000 BETA NOX2 0.000
M 000 BETA SO2 2.000
M 000 BETA SO2 4.000

TIME	PARAMETER	SCALE	SYMBOL
14 40 50	(CO)	50 ppm	C
14 40 59	(O ₂)	0.5 ppm	Z
14 41 1	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 41 3	(Temp)	100M ² /s Sec ⁻¹	E
14 41 5	(Temp)	-5° to 45° C	B
14 41 7	(NOx)	0.5 ppm	B
14 41 9	(NO)	0.5 ppm	B
14 41 11	(SO ₂)	1.0 ppm	B
14 41 13	(GN)	100x10 ³ CM ⁻³	B
14 41 15	(CO)	50 ppm	B
14 41 17	(O ₂)	0.5 ppm	B
14 41 19	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 41 21	(Temp)	100M ² /s Sec ⁻¹	B
14 41 23	(Temp)	-5° to 45° C	B
14 41 25	(NOx)	0.5 ppm	B
14 41 27	(NO)	0.5 ppm	B
14 41 29	(SO ₂)	1.0 ppm	B
14 41 31	(GN)	100x10 ³ CM ⁻³	B
14 41 33	(CO)	50 ppm	B
14 41 35	(O ₂)	0.5 ppm	B
14 41 37	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 41 39	(Temp)	100M ² /s Sec ⁻¹	B
14 41 41	(Temp)	-5° to 45° C	B
14 41 43	(NOx)	0.5 ppm	B
14 41 45	(NO)	0.5 ppm	B
14 41 47	(SO ₂)	1.0 ppm	B
14 41 49	(GN)	100x10 ³ CM ⁻³	B
14 42 1	(CO)	50 ppm	B
14 42 3	(O ₂)	0.5 ppm	B
14 42 5	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 42 7	(Temp)	100M ² /s Sec ⁻¹	B
14 42 9	(Temp)	-5° to 45° C	B
14 42 11	(NOx)	0.5 ppm	B
14 42 13	(NO)	0.5 ppm	B
14 42 15	(SO ₂)	1.0 ppm	B
14 42 17	(GN)	100x10 ³ CM ⁻³	B
14 42 19	(CO)	50 ppm	B
14 42 21	(O ₂)	0.5 ppm	B
14 42 23	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 42 25	(Temp)	100M ² /s Sec ⁻¹	B
14 42 27	(Temp)	-5° to 45° C	B
14 42 29	(NOx)	0.5 ppm	B
14 42 31	(NO)	0.5 ppm	B
14 42 33	(SO ₂)	1.0 ppm	B
14 42 35	(GN)	100x10 ³ CM ⁻³	B
14 42 37	(CO)	50 ppm	B
14 42 39	(O ₂)	0.5 ppm	B
14 42 41	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 42 43	(Temp)	100M ² /s Sec ⁻¹	B
14 42 45	(Temp)	-5° to 45° C	B
14 42 47	(NOx)	0.5 ppm	B
14 42 49	(NO)	0.5 ppm	B
14 42 51	(SO ₂)	1.0 ppm	B
14 42 53	(GN)	100x10 ³ CM ⁻³	B
14 42 55	(CO)	50 ppm	B
14 42 57	(O ₂)	0.5 ppm	B
14 42 59	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 43 1	(Temp)	100M ² /s Sec ⁻¹	B
14 43 3	(Temp)	-5° to 45° C	B
14 43 5	(NOx)	0.5 ppm	B
14 43 7	(NO)	0.5 ppm	B
14 43 9	(SO ₂)	1.0 ppm	B
14 43 11	(GN)	100x10 ³ CM ⁻³	B
14 43 13	(CO)	50 ppm	B
14 43 15	(O ₂)	0.5 ppm	B
14 43 17	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 43 19	(Temp)	100M ² /s Sec ⁻¹	B
14 43 21	(Temp)	-5° to 45° C	B
14 43 23	(NOx)	0.5 ppm	B
14 43 25	(NO)	0.5 ppm	B
14 43 27	(SO ₂)	1.0 ppm	B
14 43 29	(GN)	100x10 ³ CM ⁻³	B
14 43 31	(CO)	50 ppm	B
14 43 33	(O ₂)	0.5 ppm	B
14 43 35	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 43 37	(Temp)	100M ² /s Sec ⁻¹	B
14 43 39	(Temp)	-5° to 45° C	B
14 43 41	(NOx)	0.5 ppm	B
14 43 43	(NO)	0.5 ppm	B
14 43 45	(SO ₂)	1.0 ppm	B
14 43 47	(GN)	100x10 ³ CM ⁻³	B
14 43 49	(CO)	50 ppm	B
14 44 1	(O ₂)	0.5 ppm	B
14 44 3	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 44 5	(Temp)	100M ² /s Sec ⁻¹	B
14 44 7	(Temp)	-5° to 45° C	B
14 44 9	(NOx)	0.5 ppm	B
14 44 11	(NO)	0.5 ppm	B
14 44 13	(SO ₂)	1.0 ppm	B
14 44 15	(GN)	100x10 ³ CM ⁻³	B
14 44 17	(CO)	50 ppm	B
14 44 19	(O ₂)	0.5 ppm	B
14 44 21	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 44 23	(Temp)	100M ² /s Sec ⁻¹	B
14 44 25	(Temp)	-5° to 45° C	B
14 44 27	(NOx)	0.5 ppm	B
14 44 29	(NO)	0.5 ppm	B
14 44 31	(SO ₂)	1.0 ppm	B
14 44 33	(GN)	100x10 ³ CM ⁻³	B
14 44 35	(CO)	50 ppm	B
14 44 37	(O ₂)	0.5 ppm	B
14 44 39	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 44 41	(Temp)	100M ² /s Sec ⁻¹	B
14 44 43	(Temp)	-5° to 45° C	B
14 44 45	(NOx)	0.5 ppm	B
14 44 47	(NO)	0.5 ppm	B
14 44 49	(SO ₂)	1.0 ppm	B
14 45 1	(GN)	100x10 ³ CM ⁻³	B
14 45 3	(CO)	50 ppm	B
14 45 5	(O ₂)	0.5 ppm	B
14 45 7	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 45 9	(Temp)	100M ² /s Sec ⁻¹	B
14 45 11	(Temp)	-5° to 45° C	B
14 45 13	(NOx)	0.5 ppm	B
14 45 15	(NO)	0.5 ppm	B
14 45 17	(SO ₂)	1.0 ppm	B
14 45 19	(GN)	100x10 ³ CM ⁻³	B
14 45 21	(CO)	50 ppm	B
14 45 23	(O ₂)	0.5 ppm	B
14 45 25	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 45 27	(Temp)	100M ² /s Sec ⁻¹	B
14 45 29	(Temp)	-5° to 45° C	B
14 45 31	(NOx)	0.5 ppm	B
14 45 33	(NO)	0.5 ppm	B
14 45 35	(SO ₂)	1.0 ppm	B
14 45 37	(GN)	100x10 ³ CM ⁻³	B
14 45 39	(CO)	50 ppm	B
14 45 41	(O ₂)	0.5 ppm	B
14 45 43	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 45 45	(Temp)	100M ² /s Sec ⁻¹	B
14 45 47	(Temp)	-5° to 45° C	B
14 45 49	(NOx)	0.5 ppm	B
14 46 1	(NO)	0.5 ppm	B
14 46 3	(SO ₂)	1.0 ppm	B
14 46 5	(GN)	100x10 ³ CM ⁻³	B
14 46 7	(CO)	50 ppm	B
14 46 9	(O ₂)	0.5 ppm	B
14 46 11	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 46 13	(Temp)	100M ² /s Sec ⁻¹	B
14 46 15	(Temp)	-5° to 45° C	B
14 46 17	(NOx)	0.5 ppm	B
14 46 19	(NO)	0.5 ppm	B
14 46 21	(SO ₂)	1.0 ppm	B
14 46 23	(GN)	100x10 ³ CM ⁻³	B
14 46 25	(CO)	50 ppm	B
14 46 27	(O ₂)	0.5 ppm	B
14 46 29	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 46 31	(Temp)	100M ² /s Sec ⁻¹	B
14 46 33	(Temp)	-5° to 45° C	B
14 46 35	(NOx)	0.5 ppm	B
14 46 37	(NO)	0.5 ppm	B
14 46 39	(SO ₂)	1.0 ppm	B
14 46 41	(GN)	100x10 ³ CM ⁻³	B
14 46 43	(CO)	50 ppm	B
14 46 45	(O ₂)	0.5 ppm	B
14 46 47	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 46 49	(Temp)	100M ² /s Sec ⁻¹	B
14 47 1	(Temp)	-5° to 45° C	B
14 47 3	(NOx)	0.5 ppm	B
14 47 5	(NO)	0.5 ppm	B
14 47 7	(SO ₂)	1.0 ppm	B
14 47 9	(GN)	100x10 ³ CM ⁻³	B
14 47 11	(CO)	50 ppm	B
14 47 13	(O ₂)	0.5 ppm	B
14 47 15	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 47 17	(Temp)	100M ² /s Sec ⁻¹	B
14 47 19	(Temp)	-5° to 45° C	B
14 47 21	(NOx)	0.5 ppm	B
14 47 23	(NO)	0.5 ppm	B
14 47 25	(SO ₂)	1.0 ppm	B
14 47 27	(GN)	100x10 ³ CM ⁻³	B
14 47 29	(CO)	50 ppm	B
14 47 31	(O ₂)	0.5 ppm	B
14 47 33	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 47 35	(Temp)	100M ² /s Sec ⁻¹	B
14 47 37	(Temp)	-5° to 45° C	B
14 47 39	(NOx)	0.5 ppm	B
14 47 41	(NO)	0.5 ppm	B
14 47 43	(SO ₂)	1.0 ppm	B
14 47 45	(GN)	100x10 ³ CM ⁻³	B
14 47 47	(CO)	50 ppm	B
14 47 49	(O ₂)	0.5 ppm	B
14 48 1	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 48 3	(Temp)	100M ² /s Sec ⁻¹	B
14 48 5	(Temp)	-5° to 45° C	B
14 48 7	(NOx)	0.5 ppm	B
14 48 9	(NO)	0.5 ppm	B
14 48 11	(SO ₂)	1.0 ppm	B
14 48 13	(GN)	100x10 ³ CM ⁻³	B
14 48 15	(CO)	50 ppm	B
14 48 17	(O ₂)	0.5 ppm	B
14 48 19	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 48 21	(Temp)	100M ² /s Sec ⁻¹	B
14 48 23	(Temp)	-5° to 45° C	B
14 48 25	(NOx)	0.5 ppm	B
14 48 27	(NO)	0.5 ppm	B
14 48 29	(SO ₂)	1.0 ppm	B
14 48 31	(GN)	100x10 ³ CM ⁻³	B
14 48 33	(CO)	50 ppm	B
14 48 35	(O ₂)	0.5 ppm	B
14 48 37	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 48 39	(Temp)	100M ² /s Sec ⁻¹	B
14 48 41	(Temp)	-5° to 45° C	B
14 48 43	(NOx)	0.5 ppm	B
14 48 45	(NO)	0.5 ppm	B
14 48 47	(SO ₂)	1.0 ppm	B
14 48 49	(GN)	100x10 ³ CM ⁻³	B
14 49 1	(CO)	50 ppm	B
14 49 3	(O ₂)	0.5 ppm	B
14 49 5	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 49 7	(Temp)	100M ² /s Sec ⁻¹	B
14 49 9	(Temp)	-5° to 45° C	B
14 49 11	(NOx)	0.5 ppm	B
14 49 13	(NO)	0.5 ppm	B
14 49 15	(SO ₂)	1.0 ppm	B
14 49 17	(GN)	100x10 ³ CM ⁻³	B
14 49 19	(CO)	50 ppm	B
14 49 21	(O ₂)	0.5 ppm	B
14 49 23	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 49 25	(Temp)	100M ² /s Sec ⁻¹	B
14 49 27	(Temp)	-5° to 45° C	B
14 49 29	(NOx)	0.5 ppm	B
14 49 31	(NO)	0.5 ppm	B
14 49 33	(SO ₂)	1.0 ppm	B
14 49 35	(GN)	100x10 ³ CM ⁻³	B
14 49 37	(CO)	50 ppm	B
14 49 39	(O ₂)	0.5 ppm	B
14 49 41	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 49 43	(Temp)	100M ² /s Sec ⁻¹	B
14 49 45	(Temp)	-5° to 45° C	B
14 49 47	(NOx)	0.5 ppm	B
14 49 49	(NO)	0.5 ppm	B
14 50 1	(SO ₂)	1.0 ppm	B
14 50 3	(GN)	100x10 ³ CM ⁻³	B
14 50 5	(CO)	50 ppm	B
14 50 7	(O ₂)	0.5 ppm	B
14 50 9	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 50 11	(Temp)	100M ² /s Sec ⁻¹	B
14 50 13	(Temp)	-5° to 45° C	B
14 50 15	(NOx)	0.5 ppm	B
14 50 17	(NO)	0.5 ppm	B
14 50 19	(SO ₂)	1.0 ppm	B
14 50 21	(GN)	100x10 ³ CM ⁻³	B
14 50 23	(CO)	50 ppm	B
14 50 25	(O ₂)	0.5 ppm	B
14 50 27	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 50 29	(Temp)	100M ² /s Sec ⁻¹	B
14 50 31	(Temp)	-5° to 45° C	B
14 50 33	(NOx)	0.5 ppm	B
14 50 35	(NO)	0.5 ppm	B
14 50 37	(SO ₂)	1.0 ppm	B
14 50 39	(GN)	100x10 ³ CM ⁻³	B
14 50 41	(CO)	50 ppm	B
14 50 43	(O ₂)	0.5 ppm	B
14 50 45	(O ₂)	10x10 ⁻⁶ m ⁻³	B
14 50 47	(Temp)	100M ² /s Sec ⁻¹	B
14 50 49	(Temp)	-5° to 45° C	B
14 51 1	(NOx)	0.5 ppm	B
14 51 3	(NO)	0.5 ppm	B
14 51 5	(SO ₂)	1.0 ppm	B
14 51 7	(GN)	100x10 ³ CM ⁻³	B
14 51 9	(CO)	50 ppm	B
14 51 11	(O ₂)	0.5 ppm	

TIME	INSTRUMENT	PARAMETER	SCALE	SYMBOL
14:42:37	IC	(CO)	50 ppm	C
14:42:39	IC	(O ₂)	0.5 ppm	Z
14:42:41	IC	(b _{scat})	10x10 ⁻⁶ m ⁻¹	B
14:42:43	IC	(Turb)	10CM ² /s ²	E
14:42:45	IC	(Temperature)	-5° to 45° C	T
14:42:49	IC	(NO _x)	0.5 ppm	M
14:42:51	IC	(NO)	0.5 ppm	N
14:42:53	IC	(SO ₂)	1.0 ppm	S
14:42:57	IC	(CN)	100x10 ³ CM ⁻³	X
14:43:01	IC	(CO)	50 ppm	C
14:43:03	IC	(O ₂)	0.5 ppm	Z
14:43:05	IC	(b _{scat})	10x10 ⁻⁶ m ⁻¹	B
14:43:07	IC	(Turb)	10CM ² /s ²	E
14:43:09	IC	(Temperature)	-5° to 45° C	T
14:43:11	IC	(NO _x)	0.5 ppm	M
14:43:13	IC	(NO)	0.5 ppm	N
14:43:15	IC	(SO ₂)	1.0 ppm	S
14:43:17	IC	(CN)	100x10 ³ CM ⁻³	X
14:43:19	IC	(CO)	50 ppm	C
14:43:21	IC	(O ₂)	0.5 ppm	Z

PERCENT OF SCALE

Fig. 7.3 (part 2)
Horizontal Cross-wind Traverse at 1800 Ft (msl), 3 mi
Downwind of Haynes Power Plant on 11 October 1974.

CO Inoperative. Altitude: 1400 Ft.
 CO₂ OFFSET + 0.35 ppm

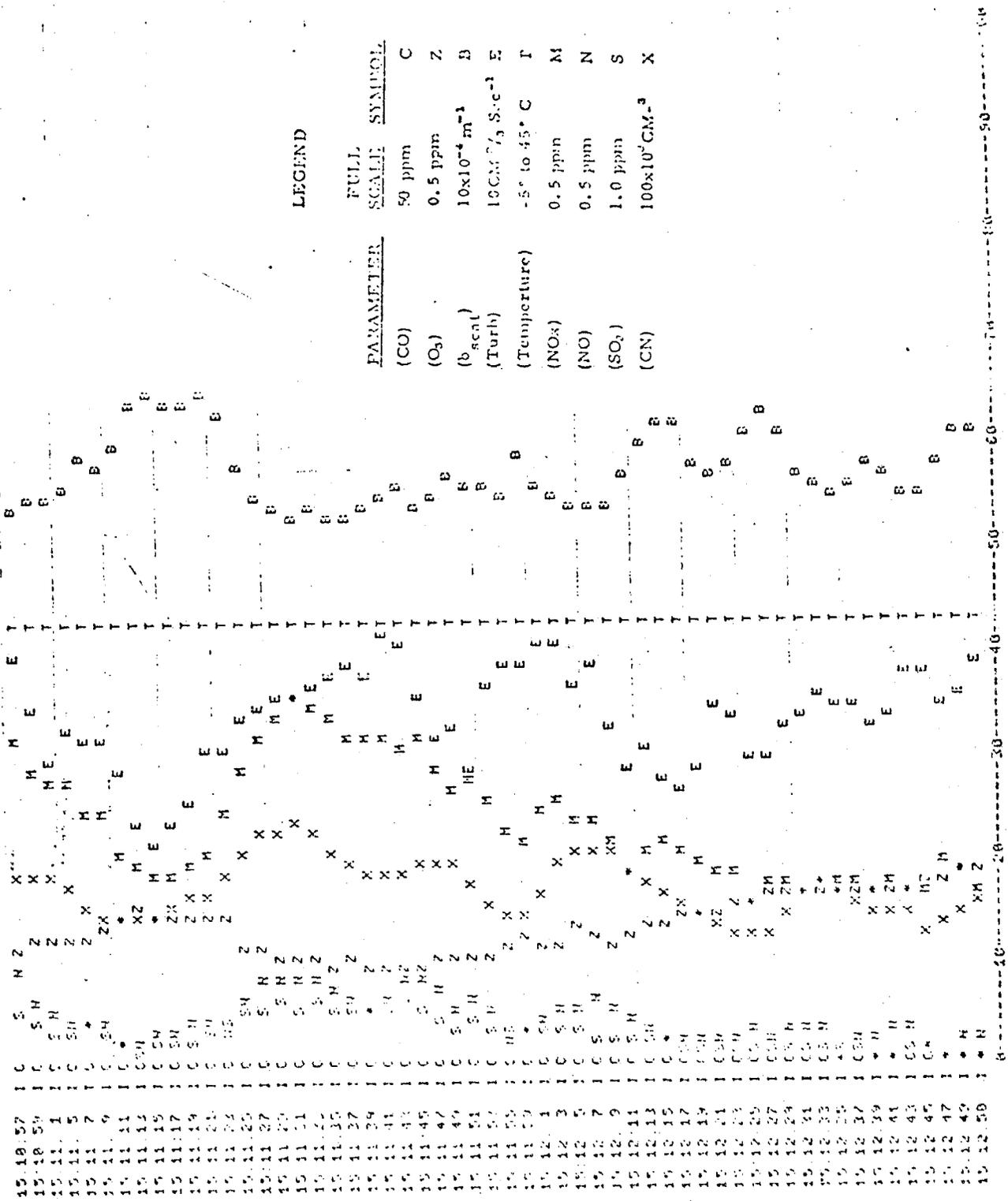
DATE 10/11/74
 AIRCRAFT PWS
 CARTRIDGE NUMBER 981
 PAGE 10

DESCRIPTION G TO F
 DERIVATIVE CORRECTION
 ALPHABETIC
 0.000 BETA 502= 0.000
 4.500 BETA 502= 2.000

TIME	PARAMETER	SCALE	SYMBOL
15 08 11	H	50 ppm	C
15 08 15	HX	0.5 ppm	Z
15 08 19	H X	10x10 ⁻⁶ in ⁻²	B
15 08 21	H X	10CM ³ /s Sec ⁻¹	E
15 08 23	H X	-5° to 45° C	T
15 08 25	H X	0.5 ppm	M
15 08 27	H X	0.5 ppm	N
15 08 29	H X	1.0 ppm	S
15 08 31	H X	100x10 ² CM ⁻²	X
15 08 33	H X		
15 08 35	H X		
15 08 37	H X		
15 08 39	H X		
15 08 41	H X		
15 08 43	H X		
15 08 45	H X		
15 08 47	H X		
15 08 49	H X		
15 08 51	H X		
15 08 53	H X		
15 08 55	H X		
15 08 57	H X		
15 08 59	H X		
15 09 01	H X		
15 09 03	H X		
15 09 05	H X		
15 09 07	H X		
15 09 09	H X		
15 09 11	H X		
15 09 13	H X		
15 09 15	H X		
15 09 17	H X		
15 09 19	H X		
15 09 21	H X		
15 09 23	H X		
15 09 25	H X		
15 09 27	H X		
15 09 29	H X		
15 09 31	H X		
15 09 33	H X		
15 09 35	H X		
15 09 37	H X		
15 09 39	H X		
15 09 41	H X		
15 09 43	H X		
15 09 45	H X		
15 09 47	H X		
15 09 49	H X		
15 09 51	H X		
15 09 53	H X		
15 09 55	H X		
15 09 57	H X		
15 09 59	H X		
15 10 01	H X		
15 10 03	H X		
15 10 05	H X		
15 10 07	H X		
15 10 09	H X		
15 10 11	H X		
15 10 13	H X		
15 10 15	H X		
15 10 17	H X		
15 10 19	H X		
15 10 21	H X		
15 10 23	H X		
15 10 25	H X		
15 10 27	H X		
15 10 29	H X		
15 10 31	H X		
15 10 33	H X		
15 10 35	H X		
15 10 37	H X		
15 10 39	H X		
15 10 41	H X		
15 10 43	H X		
15 10 45	H X		
15 10 47	H X		
15 10 49	H X		
15 10 51	H X		
15 10 53	H X		
15 10 55	H X		
15 10 57	H X		
15 10 59	H X		

DEPTH IN CORE

Fig. 7.4 (part 1)
 Horizontal Cross-wind Traverse at 1400 Ft (msl), 5 mi
 Downwind of Haynes Power Plant on 11 October 1974.



LEGEND

PARAMETER	FULL SCALE	SYMBOL
(CO)	50 ppm	C
(O ₃)	0.5 ppm	Z
(b _{scnl}) (Turh)	10x10 ⁻⁶ m ⁻¹	B
(Temperature)	10CM ² /3 S.c ⁻¹	E
(NO _x)	-5° to 45° C	T
(NO)	0.5 ppm	M
(SO ₂)	0.5 ppm	N
(CN)	1.0 ppm	S
	100x10 ² CM ⁻³	X

Fig. 7.4 (part 2)
Horizontal Cross-wind Traverse at 1400 Ft (msl), 5 mi
Downwind of Haynes Power Plant on 11 October 1974.

$$[\text{NO}] = [\text{NO}_x] - [\text{NO}_2] \quad (7)$$

$$[\text{O}_3] = C - [\text{NO}_2] \quad (8)$$

The species NO_x is chosen as the independent variable in the model because it can be considered conservative over the distances and travel times under consideration. Its concentration is therefore determined solely by the physical mechanisms of dilution and advection.

Figure 7.5 compares calculated and measured concentrations of NO and O_3 for the traverse downwind of the Haynes plant shown in Figures 7.1 and 7.3. The parameter values used in these calculations were $C = 140$ ppb, $k_1/k_3 = 20$ ppb. As expected from Figure 7.1, our model performs well, the largest discrepancies occurring at the point where the aircraft first penetrates the plume.

It should be emphasized that the above model is based on reactions (1) - (3), and does not take into account free radical chemistry within the plume. It appears from the present study that this model adequately describes the effect of power plant plumes on ambient ozone concentrations out to a distance of at least 5 miles, or about one hour, downwind. At larger distances or travel times, the accuracy of the model may be influenced by reactions involving ambient hydrocarbons within the plume. Observational data to evaluate the O_3 concentrations beyond 8 km were not available due to the presence of significant background values.

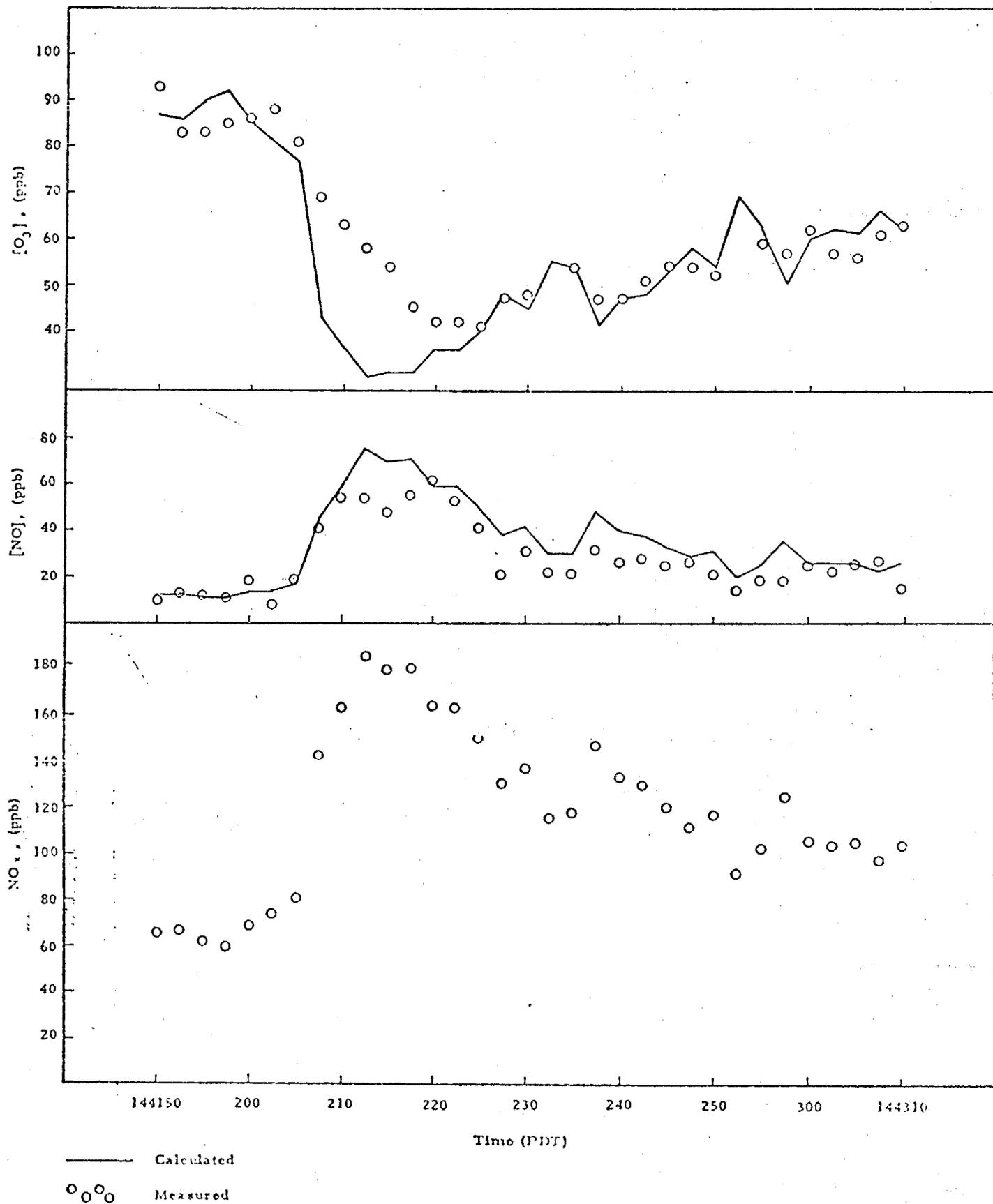


Fig. 7.5. Portion of horizontal cross wind traverse at 1800 ft msl, three miles downwind of Haynes power plant on 11 October 1974. Measured concentrations of NO and O_3 are compared with the concentrations predicted by model described in text.

7.2 Sulfur Chemistry of Plume

The sulfate analyses of the filters collected by the MRI aircraft are summarized in Table 7.2. Each filter was exposed during all of the passes at a given distance from the stacks, so that these sulfate concentrations represent averages over the sampling rectangle. Correspondingly averaged SF_6 , SO_2 , and b_{scat} concentrations are shown in Table 7.3 for comparison.

The concentrations of sulfates found outside the plume were variable and often high. As an illustration, the highest sulfate concentrations measured at Moss Landing occurred on 9/12/74, when the plant was burning sulfur-free gas. Similarly, highest sulfate concentrations in Los Angeles were found on days with high aerosol (b_{scat}) backgrounds. In contrast, the fractions $S_{particulate}/S_{total}$ in Table 7.3 indicate that most of the ambient sulfate at Moss Landing on 9/10/74 could be accounted for by primary sulfate directly emitted by the plant.

The variability of the sulfate background makes it difficult to estimate the rate at which sulfate is produced within the plume. An upper bound for the fraction of SO_2 converted to SO_4 can of course be obtained from the column $S_{particulate}/S_{total}$ in Table 7.3. Taking the low-background days 9/10/74 and 10/25/74, and subtracting out primary sulfate, one gets the following estimates for the fraction α of SO_2 converted to sulfate ten miles from the stacks:

$$9/10/74: \alpha < 2.3\% - 1.5\% = 0.8\%$$

$$10/25/74: \alpha < 12.9\% - 1.8\% = 11.1\%$$

It must be emphasized that these numbers are strictly upper bounds, and may greatly overestimate the extent of conversion if a substantial fraction of the sulfate is from sources other than the power plant.

TABLE 7.2 SULFATE CONCENTRATIONS (ANALYSIS BY STATE OF CALIFORNIA AIR AND INDUSTRIAL HYGIENE LABORATORY)

AIHL Sample Number	Date	Time (PDT)	Distance From Stack (miles)	Sulfate, $\mu\text{g}/\text{m}^3$ ^A
XA0340TV	9/10/74	1139-1242	1	<3.1
XA0342TV	9/10/74	1410-1433	1	6.1 \pm 4.5
YA0344TV	9/10/74	1448-1531	5	4.0 \pm 1.6
ZA0346TV	9/10/74	1552-1636	10	6.3 \pm 1.9
XB0348TV	9/11/74	1126-1636	1	<1.1
XC0312TV	9/12/74	1608-1642	1	<3.0
YC0310TV	9/12/74	1530-1548	10	2.0 \pm 0.4
ZC0306TV	9/12/74	1445-1527	15	11.0 \pm 6.2
ZC0308TV	9/12/74			11.4 \pm 2.7
XD0370TV	10/1/74	1409-1421	0.75	14.9 \pm 9.3
YD0372TV	10/1/74	1433-1513	2-3	8.9 \pm 3.0
ZD0374TV	10/1/74	1550-1614	20-25	4.1 \pm 3.9
WF0467TV	10/11/74	1331-1405	0.5	14.4 \pm 2.5
XF0469TV	10/11/74	1423-1443	3	14.4 \pm 2.2
YF0473TV	10/11/74	1448-1524	6	14.3 \pm 1.9
ZF0475TV	10/11/74	1533-1607	12	8.9 \pm 1.3
XG0483TV	10/17/74	1459-1507	0.5	
YG0485TV	10/17/74	1512-1526		1.3 \pm 0.8
ZG0487TV	10/17/74	1542-1613	6	0.9 \pm 0.5
WG0489TV	10/17/74	1622-1705	15	1.9 \pm 0.3
XH0515TV	10/25/74	1322-1403	1/2	2.2 \pm 0.8
YH0517TV	10/25/74	1417-1442	3	4.6 \pm 1.2
ZH0519TV	10/25/74	1456-1607	10	2.9 \pm 0.6
WH0521TV	10/25/74	1752-1813	20	3.5 \pm 1.3
ZI0525TV	10/30/74	1250-1318 ^B	1/2	4.5 \pm 1.7
YI0527TV	10/30/74	1323-1420	3	2.1 \pm 0.4

^A - Obtained by flash vaporization with flame photometric detection (Roberts)^B.

^B - Times in PST.

TABLE 7.2 (Continued)

AIHL Sample Number	Date	Time (PDT)	Distance From Stack (miles)	Sulfate, $\mu\text{g}/\text{m}^3$ ^A
ZI0529TV	10/30/74	1434-1531	10	1.6 \pm 0.3
WI0499TV	10/30/74	1644-1705	20	0.8 \pm 0.3
WJ0501TV	11/7/74	1248-1324 ^B	1/2	2.6 \pm 0.4
XJ0503TV	11/7/74	1348-1430	3	1.8 \pm 0.3
YJ0509TV	11/7/74	1439-1540	10	3.2 \pm 0.4
ZJ0511TV	11/7/74	1631-1710	10	1.8 \pm 0.3

^A - Obtained by flash vaporization with flame photometric detection (Roberts)⁸.

^B - Times in PST.

TABLE 7.3 AVERAGE CONCENTRATIONS

Date	Distance From Stacks (miles)	Calcu- lated SO ₂ (ppm)	Mea- sured SO ₂ (ppm)	SO ₄ ³ (μg/m ³)	b _{scat} (10 ⁻⁴ in ⁻¹)	S _{particulate}
						S _{total} (%)
9/10/74	1/2	.122 ^A	.100	6.1	.43	1.5
9/10/74	5	.134 ^A	.091	4.0	.37	1.1
9/10/74	10	.031 ^A	.067	6.3	.27	2.3
10/11/74	1/2	.041 ^B	.045	14.4	5.43	7.5
10/11/74	3	.023 ^B	.027	14.4	5.12	12.0
10/11/74	6	.013 ^B	.016	14.3	5.85	18.0
10/11/74	12	.005 ^B	---	8.9	6.44	---
10/25/74	1/2	.032 ^C	.029	2.2	1.54	1.8
10/25/74	3	.025 ^D	.021	4.6	1.36	5.2
10/25/74	10	.003 ^D	.005	2.9	1.28	12.9
10/25/74	20	.004 ^D	---	3.5	1.14	---

Calculated SO₂ concentrations are scaled from measured SF₆ concentrations, and represent the estimated SO₂ contributions (assuming no losses) of:

- a) Moss Landing units 5 and 6
- b) Haynes (all units)
- c) Alamitos (all units)
- d) Alamitos and Haynes (all units)

8. Discussion of Results

Wind flow patterns at the three plant sites are quite similar. Strong diurnal effects are characteristic with light, variable winds until late forenoon when a dominant seabreeze flow develops. The direction of the seabreeze flow appears to be somewhat more variable at Moss Landing than in the Southern California coastal area. In the vicinity of the Haynes and Alamitos plants, the winds at plume height appear to be very frequently from the southwest as long as the seabreeze regime is dominant.

The mixing layer depths were generally lower at Moss Landing in response to a strong temperature inversion which persisted during the test period. At Haynes and Alamitos the mixing layers were not only somewhat deeper but were occasionally not as clearly defined. In both areas the mixing layer height tends to increase with distance inland during daytime conditions. This results in the afternoon being the period of the day with most pronounced mixing of the plume to the ground. During the night (beginning in late afternoon) the low levels become more stable and mixing to the ground becomes less effective. Somewhat later in the evening the organized seabreeze flow at plume height decreases and the inland trajectory of the plume ultimately changes to a light, variable (sometimes offshore) direction. In seven of the nine tests, the peak hourly SF_6 concentration occurred between 1400 and 1700.

In summarizing the meteorological conditions affecting these plants it is clear that the plumes exist in an environment that changes markedly on a diurnal as well as day-to-day basis. These changes occur in wind direction, speed and stability. These variations are made more significant as a result of the changing meteorological conditions which typically occur in an inland direction from the plant sites. In view of these sources of environment variability, it is somewhat remarkable to find such a consistent plume-height wind direction at Haynes-Alamitos during the early afternoon period when the ground impact of the plume is most significant.

Plume heights were similar at all three sites, ranging generally from 300 to 450 m msl. The effect of the added stack height at Moss Landing (152 m) was somewhat lost during the test period because of the strong temperature stability which existed. During one of the test days at Moss Landing (September 10) the plume was sufficiently high into the temperature inversion so that little tracer material appeared at ground level in spite of surface heating inland. In one case at Haynes (October 11) it appeared that the upper portion of the plume

may have penetrated above the mixing layer and may have been carried off in a direction different from the lower part of the plume. Otherwise, the plumes were confined to the mixing layer and, in some cases, did not even penetrate to the top of the mixing layer. Since the mixing layer heights during the test period in the South Coast basin, at least, were typical of seabreeze conditions, it would appear that the plumes are carried through the mixing layer only under rather infrequent, extreme conditions.

Peak ground concentrations, as measured by the SF_6 , occurred about 10-20 km downwind of the plant in all cases. These distances and concentrations correspond reasonably well with calculations based on observed winds, plume heights and D stability category. Peak hourly ground concentrations from each plant ranged from 0.009 to 0.082 ppm of SO_2 , based on the observed SF_6 data.

Dimensions of the SO_2 plumes, measured by the aircraft, showed larger widths (and lower concentrations) at short distances (1-5 km) from the plant than would be estimated from classical dispersion graphs. At larger downwind distances (10-15 km) the dimensions and concentrations were similar to the standard diffusion estimates. It was possible to identify the SO_2 plume to a distance of about 18 km from the plant. At this point (in the South Coast basin) the peak plume concentration for SO_2 was about 0.08 ppm. The NO_x plumes were identified to only about 8 km downwind in the South Coast area. The difference in these distances was due to the large background values of NO_x which made identification of the plume difficult at low concentrations.

Plume rise heights, computed from observed environment and stack parameters, agree well with standard plume rise estimation techniques providing the wind speed and/or temperature stability was not low. In these cases, the calculated plume height was higher than observed.

Plume chemistry observations reflected only changes due to the faster reactions. The ozone deficit in the plume (due to NO) was readily apparent within the observations obtained. A simple chemical model of this reaction was in agreement with observations, at least to a distance of 8 km downwind. SO_2 to SF_6 relationships showed no appreciable change during the identifiable plume lifetime. Sulfate samples obtained during each test appear to reflect variations in background concentrations from day-to-day. These occasionally were significantly large (October 1, 11 and downwind on September 12) on days with moderate amounts of pollution. There were no systematic sulfate data which could be attributed to the conversion of SO_2 to sulfate. This presumably reflects the slow rate of this process rather than the non-existence of the reaction.

The impact of the SO₂ plumes in the South Coast basin appears to exist as an identifiable plume to a distance of, perhaps, 20 km from the plant. Thereafter, the contribution of the SO₂ plume merely adds to the general background levels. Effects of the plants on the environment, therefore, can be modeled in a specific manner to about 20 km downwind and in a general way (contribution to total basin SO₂ budget) at longer downwind distance. Peak ground SO₂ impact observed from each plant did not exceed allowable standards but, (in the South Coast basin) occurred consistently in a rather small geographical area.

[1] Vol. XIII Tab. F. Testimony of Stan Marsh.

[2] Record of 475.1 Vol. IX Tab. b.2 "An Analysis of Air Quality Impact of a Coastal Power Plant During a Period of Excessive Nitrogen Dioxide Concentrations in the South Coast Air Basin." North American Weather Consultants Report No. SBAQ-79-11.

[3] Vol. XV Tab N.10 (Appendix to Reference 2).

[4] Vol. VI Tab. E.2 Shair & Drivas, "The Chemistry, Dispersion and Transport of Air Pollutants Emitted from Fossil Fuel Power Plants in California," June 30, 1975.

[5] Vol. VI Tab. E.3, "Transport and Dispersion of Airborne Pollutants Associated with the Land Breeze- Sea Breeze System," Also see Vol. I Tab A. Appendix to Staff Report.

[6] Vol. VI Tab E.1, Lamb, Lorenzen and Shair, "Tracer Study of Power Plant Emission Transport and Dispersion from the Oxnard/Ventura Plan."

[7] AR-2 Vol. III Tab C.30a.