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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Environmental Research Laboratories

Effluent Dilutions Over Mountainous Terrain

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MASTER

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Air Resources Laboratory
IDAHO FALLS, IDAHO

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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EFFLUENT DILUTIONS OVER MOUNTAINOUS TERRAIN

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Idaho Falls, Idaho
December 1974

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ABSTRACT

The second portion of a two-phase study of atmospheric dilutions of airborne effluents, conducted in the vicinity of mountainous terrain near Garfield, Utah, is described. The first phase of this study was investigated during inversion and neutral cases at another site in a deep, steep-walled canyon and was reported by Start et al. The second phase of the study was designed to quantify atmospheric dilution in rough mountainous terrain, without the strong channeling influences of the deep canyon. Aerial and ground-level sampling of sulfur hexafluoride gaseous tracer were performed. Tracer was released mainly from the 122-m chimney of an operating smelter. Gas analyses were performed using an electron capture gas chromatograph. Meteorological observations included pibals, radiosondes, surface winds from a network of stations, and trajectories of radar-tracked tetroons.

Sampled tracer concentrations during lapse conditions are compared with Pasquill's predicted values for flat terrain. Elevated centerline concentrations for a plume having minimal contact with rough topography fit the appropriate Pasquill curve well; plumes crossing the rough terrain averaged two to four times more dilution than predicted for flat terrain. Plume impaction was observed against the elevated terrain. Lateral spreadings of plumes were nearly twice that amount predicted by Pasquill's flat-terrain σ_y-curves.

Ground-level concentrations over the elevated terrain may be strongly influenced by an elevated stable layer. In the presence of a low, strongly capping layer, the plume may become trapped in a nearly stagnant elevated layer. With a stable layer somewhat higher, the plume may flow over the ridgetops, contained within a shallow layer. In this case, the plume becomes somewhat uniformly distributed in the vertical direction and, because of ground-reflection effects, ground-level concentrations may be nearly twice as large as aerial concentrations. Without a significant capping stable layer, the plume deflects aloft over the ridges and disproportionately small concentrations are measured at the surface as compared to concentrations aloft.

Pibal winds at the plume height were the best indicator of the area of greatest surface-measured tracer concentrations. Winds measured at 3 m above the ground at the inland end of the canyon were nearly as successful as pibal winds for estimating the ground-level plume centerline position.

Some aspects of the study are reviewed to aid others involved in similar work, including tracer material used and prediction of plume path using windfield data.

A complete data appendix is provided.

EFFLUENT DILUTIONS OVER MOUNTAINOUS TERRAIN[1]

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1. INTRODUCTION

The siting of coal-fired or nuclear power plants, smelters, and other industry in mountainous locations has become more commonplace in the last several years. Changes in our attitude toward the nation's energy outlook have emphasized our large coal reserves as a source of energy, and power plants are being built or enlarged in mountainous areas near the mines. Likewise, the increasing number of nuclear power stations indicates an increased need for dilution data obtained in mountainous terrain to better estimate the diffusion and transport of airborne material within this type of setting.

Actual field data quantifying the atmospheric dilution in rough, mountainous terrain are very desirable—not only to support theoretical work being done to plan emission controls at the plants, but to check the fundamental assumptions of the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC) dispersion models.

This memorandum presents the second portion of a two-phase study designed to measure and quantify the characteristics of atmospheric dispersion in rough, mountainous terrain. Phase one consisted of a study conducted within a deep, steep-walled canyon at Huntington, Utah (Start et al., 1974a). Phase two, reported herein, was conducted in a short

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[1]Research was carried out under the joint sponsorship of the Energy Research and Development Administration, Division of Reactor Research and Development, under the Interagency Agreement AT(49-5) 1289, and the National Oceanic and Atmospheric Administration.

canyon surrounded by steep slopes near Garfield, Utah, in the Oquirrh Mountains along the south shore of the Great Salt Lake, as shown in figure 1. A comparison of the data obtained at the two sites is made by Start et al. (1974b). The Garfield site provided a rugged mountainous setting without deep, steep-walled canyons in which the flow may be overwhelmed by topographic channeling of the canyon. Of greater complexity at this site is the diurnal cycling of lake-valley winds. Nighttime winds from the south drain from the mountains to the south-southeast through the Salt Lake (Jordan) Valley and out over the Great Salt Lake. Daytime winds from the northwest flow from the Great Salt Lake inland across the valley and along the mountain slopes. A lake-valley breeze, like the familiar sea breeze, develops at times within a layer hundreds of meters in depth. The presence of this layer over the Garfield measurement site may influence atmospheric vertical dispersion and the magnitude of ground-level effluent concentrations. Figure 2 provides an aerial view across the Garfield smelter during daytime onshore flow. The ruggedness of the terrain is evident.

The sampling program at the Garfield site was undertaken to achieve three main objectives. The first goal was to measure the ground-level and elevated centerline concentrations to quantify the dilution, if any, attributable to rough terrain. The second goal was to examine the degree of plume impaction against the mountain slopes; impaction has been inadequately investigated. Its potential importance in the impact assessment criteria needs to be ascertained. The third goal was to establish a modest data base as an aid in the mathematical analysis of atmospheric diffusion at this and similar sites.

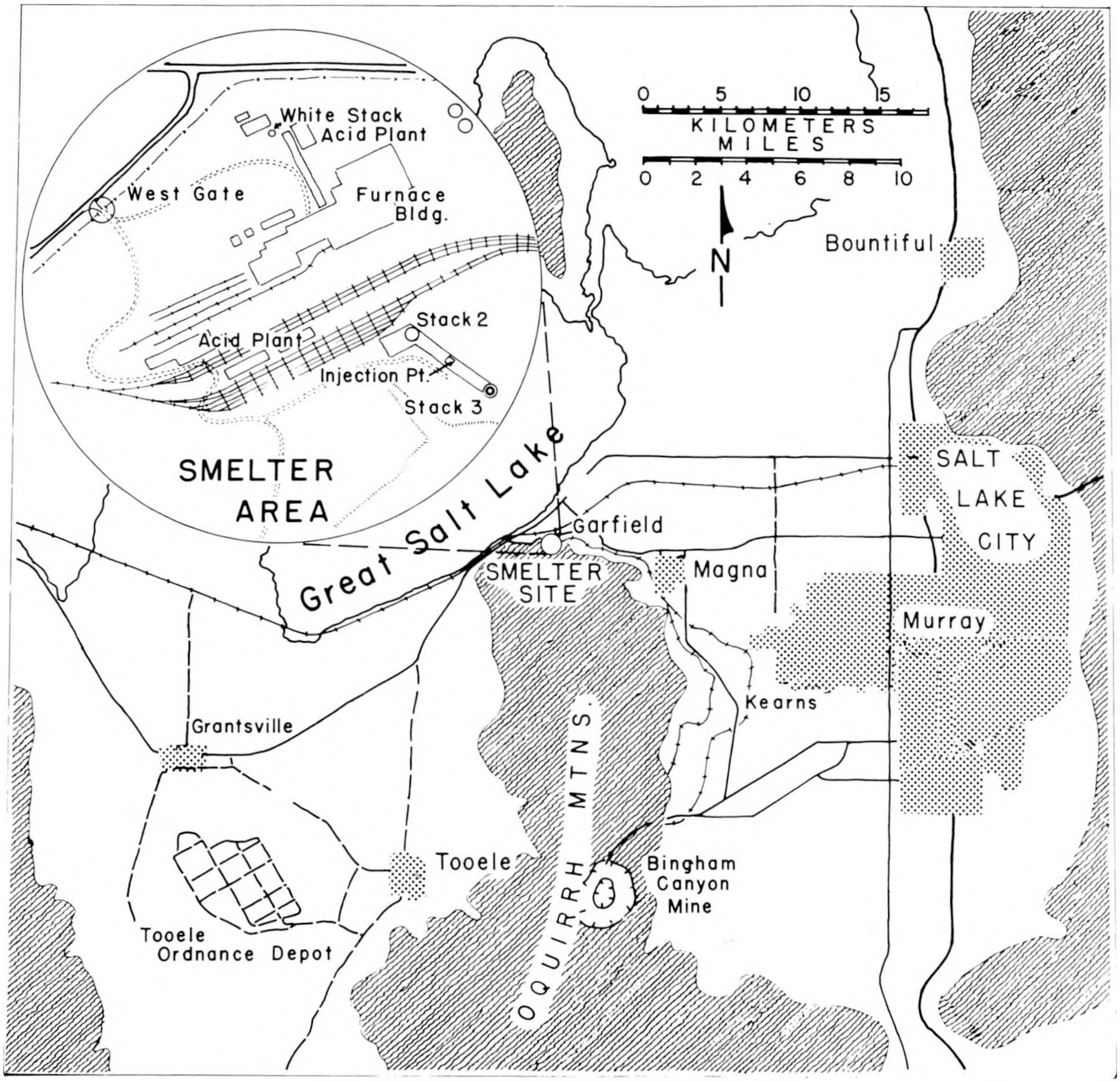


Figure 1. Garfield smelter-testing location at the northern tip of the Oquirrh Mountains.

Figure 2. Typical onshore airflow with the snow-covered Oquirrah Mountains in the background. The lakeshore is at the lower right. (Photo source: Emission Abatement Research Project Final Report, II, Appendix IX, Kennecott Copper Corp.)

In this study, the tracer concentration data are related to previously conducted flat-terrain work so that characteristic differences might be further determined. Measurements included radiosonde and pibal observations, precision surveying of the sampling sites and terrain features, and the release of two independent gaseous tracers. This releasing of a second tracer was a means of determining the contributions made by other facilities, such as a powerplant and an acid plant, to the effluent load attributed to the stack. Appendix F includes discussion of second tracer analyses and some reasons for the failure to measure it selectively in this sampling program.

Appendix E is included at the end of this memorandum to elaborate upon details of the conduct of a large field study such as this one. Details of sampler density, tracer selection, siting of meteorological sensors, and many other aspects are reviewed to assist others contemplating similar field studies.

2. HISTORICAL NOTES

Present dispersion estimates are based on empirical formulas derived from data obtained over flat terrain; these estimates may underpredict the dilution experienced by a plume in rough terrain. The pioneering work done by Sutton (1932) and by Bosanquet and Pearson (1936) were based on theoretical considerations of eddy transfer which results from shear and buoyancy, occurring over simple, flat terrain. Hay and Pasquill (1957) were able to show experimentally that the angular spread of the plume was related to the standard deviation of the wind direction in the vertical and horizontal. These data were obtained in carefully controlled tests over flat terrain. Pasquill (1961) later presented another method of arriving at plume spread when detailed bivane data were unavailable. Using easily obtained weather parameters, such as cloud cover, to arrive at various stability categories, he calculated curves of plume height and angular spread which were based on empirical flat-terrain data. Gifford (1961) adapted Pasquill's plume height and angular spread data to standard deviations of plume concentration in the horizontal and vertical (σ_y and σ_z) for each stability class.

Pasquill's empirical estimates with Gifford's conversion have become the customary numbers for most diffusion calculations. Turner (1964) presented a simple scheme for arriving at a correct stability category; Yanskey et al. (1966), for example, have presented modifications of the Pasquill curves based upon experimental studies for a given area. Present-day methodology for estimating the dispersion of airborne material assumes flat underlying terrain; the actual measurements of diffusion were primarily collected at sites in flat-terrain settings.

This weakness in the diffusion data base has been a cause of concern not only for operators of emission sources in rough terrain, but also for those agencies regulating and planning future policy in those locales. Selecting the best alternative then available for estimating plume behaviors, Van der Hoven et al. (1972) arrived at a set of upper bounds for concentration estimates by using flat-terrain models and by assuming that the plume impacted upon elevated terrain at centerline concentration strength under certain conditions. At that time, it was uncertain whether plumes in mountainous areas would tend to flow into elevated terrain and impact at full strength, or would flow around rough terrain with minimal contact, or would flow with some combination of these two possibilities.

3. THE DIFFUSION EQUATION

The windspeed-normalized relative concentrations are given in the form $\frac{\chi\bar{u}}{Q}$ where χ is the concentration (in gm m^{-3}), $\bar{u}$ is the mean windspeed through the effluent-carrying layer (in m s^{-1}), and Q is the source strength (in gm s^{-1}). These concentration values are related to the plume axis height above the ground (H) and spacial Cartesian coordinates (x,y,z) through the Gaussian diffusion equation

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

Additional description of equation 1 may be found in the literature (e.g., Meteorology and Atomic Energy, 1968, D. Slade, ed., 1968). Values for σ_y and σ_z, the standard deviations of effluent concentrations in the lateral and vertical coordinate directions (Pasquill (1961) and Gifford (1961), e.g.) have been determined for various stability categories. By direct measurement of some of the variables (χ, $\bar{u}$, Q) and plume centerline sampling (y=0, z=0, H=0), the above equation simplifies so that comparisons may be made with σ_y- and σ_z-values commonly accepted for a given stability.

If the receptors are at ground level, equation (1) may be expressed as

$$\chi(x,y,0;H) = \frac{Q}{\pi\sigma_y\sigma_z\bar{u}} \exp\left[-\quad \frac{y^2}{2\sigma_y{}^2} + \frac{H^2}{2\sigma_z{}^2}\right]. \quad (2)$$

The factor of two accounting for ground reflection of the plume is included as is customary. This reflection effect should be kept in mind when both aerial and ground-level measured concentrations are examined in later portions of the memorandum. Integration of equation (2) with respect to y yields the familiar expression for the crosswind integrated concentration from a continuous, elevated-point source.

$$CIC(x,H) = \frac{\sqrt{2}\ Q}{\sqrt{\pi}\sigma_z\bar{u}} \exp\left[-\frac{H^2}{2\sigma_z^2}\right]. \quad (3)$$

Equations (1), (2), and (3) are widely known Gaussian plume formulas and may be examined in greater detail by referring to numerous books and papers (e.g., Meteorology and Atomic Energy, 1968, D. Slade, ed., 1968, or Pasquill (1962)).

If measurements of Q, $\bar{u}$, $\chi(x,y,H)$, and $\chi(x,y,0)$ are obtained, some additional forms of equations (1), (2), and (3) are desirable along with a formula for computing σ_y. With crosswind-orientated samples of ground-level concentrations $\chi(x,y,0)$, the second moment of the lateral effluent-concentration distribution is, for a fixed downwind-distance x,

$$\sigma_y^2 = \sum\left[\chi(Y)\cdot(Y-Y_o)^2\right] \Big/ \sum\chi(Y) \quad (4)$$

where the position of the center of mass of the mean plume Y_o is

$$Y_o = \sum\chi(Y)\cdot Y \Big/ \sum\chi(Y).$$

The Gaussian continuous point-source equation for the center of an elevated plume far from a reflecting boundary is, after solving for σ_z,

$$\sigma_z = Q\ 2\pi\bar{u}\sigma_y\ \chi(x,0,H;H). \quad (5)$$

Using σ_y from equation (4) and the measured quantities 0, $\bar{u}$, and $\chi(x,0,H;H)$, an effective value of σ_z may be determined from equation (5). By combining equations (2) and (5), the Gaussian plume formula becomes

$$\chi(x,0,0;H) = 2\chi(x,0,H;H) \exp\left[-\frac{H^2}{2\sigma_z^2}\right] \quad (6)$$

where H is the mean-plume axis height (at downwind distance x) over the entire sampling period. Solving for H^2,

$$H^2 = -2\sigma_z^2\cdot\ln\left[\chi(x,0,0;H) \big/ 2\cdot\chi(x,0,H;H)\right]. \quad (7)$$

One additional type of calculation may be made using CIC(x,H) calculated from the same $\chi(x,y,o)$ set of measurements utilized in equation (4). Equation (3) may be solved for σ_z, or alternately for H, and the results compared with σ_z or H from equations (5) or (7). Solving equation (3) for the plume axis height and denoting the result as HC to distinguish it from the H in equation (7) yield

$$(HC)^2 = -2\cdot\sigma_z^{2}\cdot \ln\left[CIC(x,H)\cdot\sigma_z\cdot\bar{u}\cdot\sqrt{\pi}/Q\cdot\sqrt{2}\right]. \quad (8)$$

Some coarse implications about the vertical gradient of effluent concentration may be gained through a comparison of H and HC. From examination of equation (3), it is apparent that the CIC at the ground surface differs from a corresponding CIC through the elevated plume centerline by a constant whose value depends upon H and σ_z. If the height variation of plume concentration is Gaussian, then HC and H should be the same value (within experimental error). However, if HC is larger than H, the implication is that the concentrations sampled along the ground surface are less than would be expected were a Gaussian vertical-concentration profile correct (i.e., more σ_z-increments may be fitted within HC than within the height interval H). Likewise, if HC is less than H, the ground-surface concentrations are more similar to the elevated concentrations than a Gaussian gradient would predict from $\exp\left[-(H^2)/2\sigma_z^{2}\right]$ (i.e., the vertical distribution is tending toward uniform).

If the lateral distribution of concentration were especially peaked or flattened by comparison to the Gaussian distribution (the Kurtosis type of statistic), the comparisons of HC and H could be affected. For example, from equations (5) and (7), it is evident that if the peak ground-level concentration were too small (a flattened distribution), the calculation of H would be a larger number than determined from a Gaussian distribution (presuming the

CIC in equation (3) is maintained constant). Likewise, if the ground-level concentration were especially peaked, the value of H would be smaller.

4. TEST PROCEDURES

The seven tests reported and examined in detail herein were 1-hr releases of sulfur hexafluoride (SF_6) from a 122-m chimney (number three stack) at the operating Garfield smelter. Approximately 40 samplers were positioned on the mountain slopes and canyon floor for sampling of total integrated concentrations. Figure 3 shows the ground sampler array used for these tests. Figure 4 shows one of these samplers in which a small battery-powered pump would fill a sample bag during a 2- to 3-hr period. Aerial plume concentration samples were collected using a helicopter-borne sampler. A 28-m sampling inlet extended below the helicopter to allow sampling of air undisturbed by the rotor downwash and is shown in figure 5. Winds, temperature, and general weather conditions were observed and recorded to assist the identification of the atmospheric stability category during each gaseous tracer test. Figure 6 shows the location of the 10 windspeed and direction sensors within and near the primary testing area (depicted by the rectangular box).

Before testing, pibals were taken to indicate the winds aloft. Sampler boxes were calibrated and readied. The source at the release

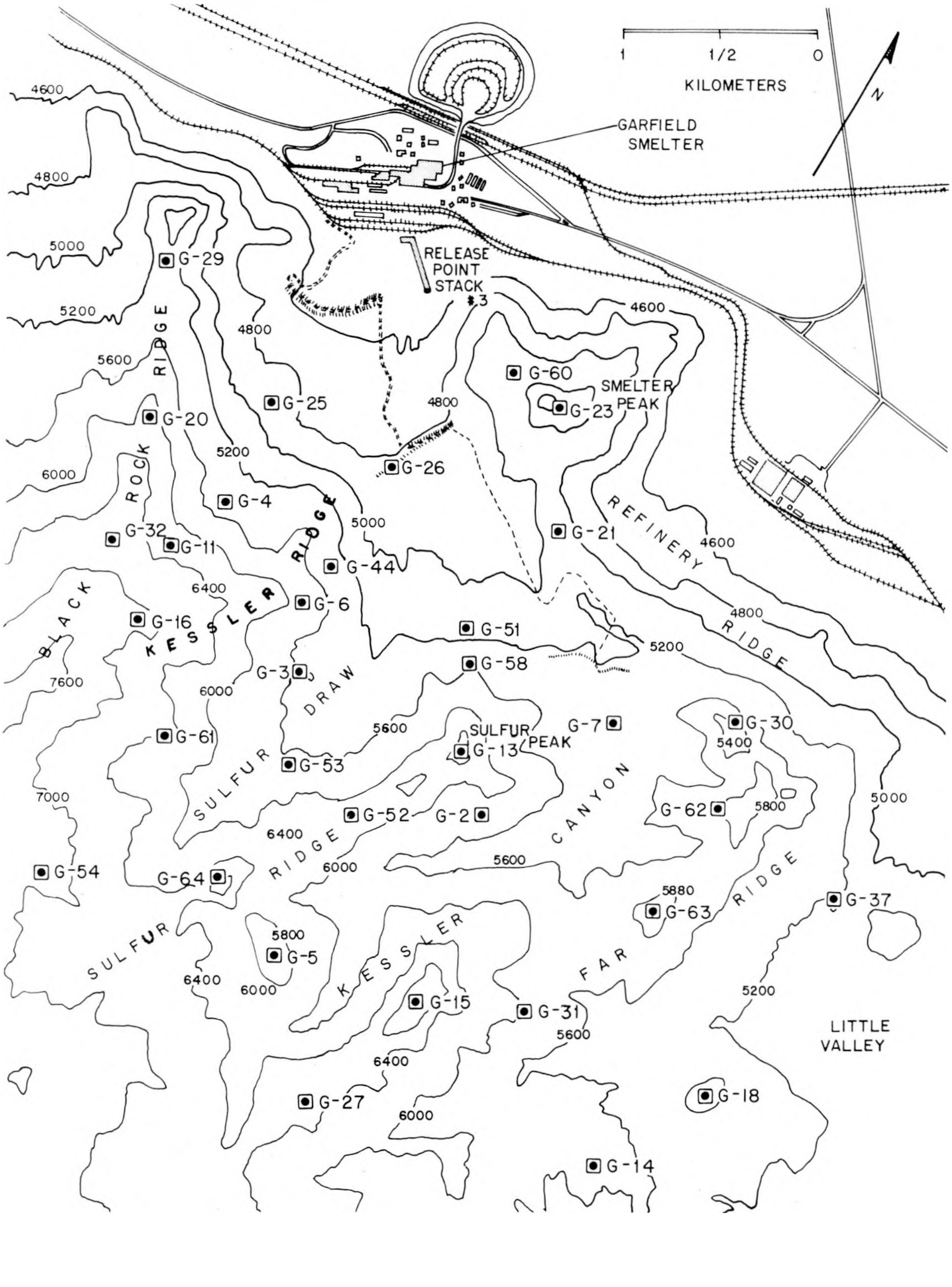


Figure 3. Distribution of ground-level samplers and terrain heights (feet above mean sea level) for tests 1 through 7.

Figure 4. Example sampler used to fill saran bags at the fixed ground-level positions. The sampler pump is seen at the upper right corner of the box.

Figure 5. Sampling helicopter enroute to the next sampling position. The sampling inlet is at the bottom of the hose shown below the helicopter.

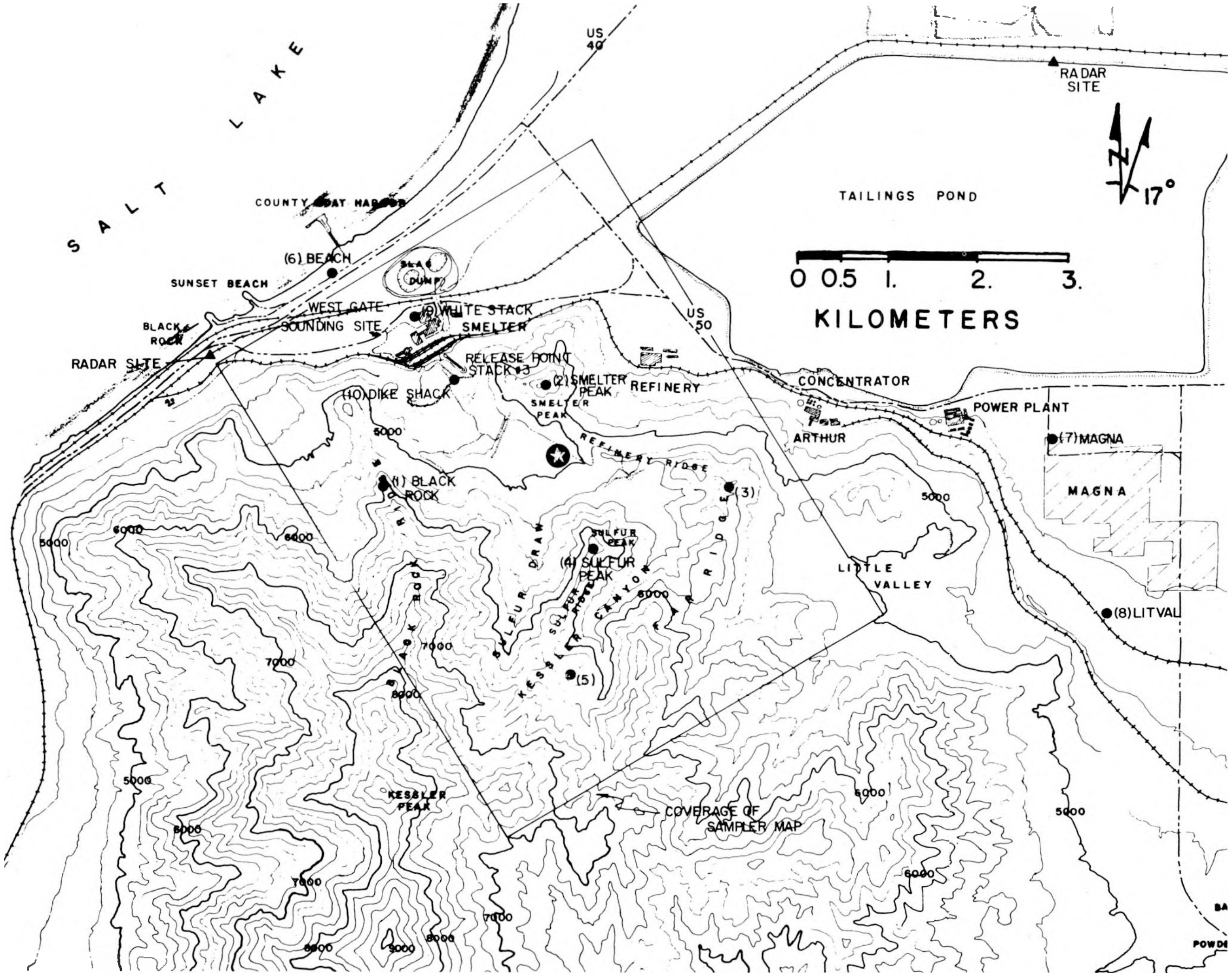


Figure 6. Location of surface-based wind measurement sensors and the primary measurement area within the northwest-southeast orientated rectangle.

point was weighed and prepared, and, when the helicopter was ready, the release commenced. Observers on the canyon walls aided in vectoring the helicopter sampling system as needed, and notes were made on plume behavior. Additional pibals and the radiosonde ascents were made during testing. At the completion of the tracer release, the source was again weighed. After allowance of time for the plume to clear the sampling area, as estimated from pibal winds, samplers were turned off and the ground-level sampler bags collected.

Analyses of the gas collected by the samplers were performed with an electron capture gas chromatograph (Lovelock et al. 1971). For the SF_6-analyses, the column was packed with 5A molecular sieve, 80 to 100 mesh. The fluorocarbon-dibromotetrafluoroethane or 114B2-tracer analyses made later in the test series (tests 5, 6, and 7) utilized a column packed with Durapak low K/carbowax 400/Porosil F. Appendix F discusses analysis of 114B2 and some problems encountered resulting from suspected smelter-plume constituents.

5. RESULTS

The first seven tests of the series consisted of SF_6-releases made during lapse conditions from the number three stack, with sampling locations (refer to fig. 3) on the rough terrain to the south. Test 8, an airborne release made to simulate a 366-m stack, was unsuccessful because the proper release procedure was not followed. Tests 9 and 10 consisted of near surface releases made from the plant area during inversion conditions.

For tests 9 and 10, the samplers were removed from the mountain locations and relocated in the lowlands along the beach. With the samplers in this configuration, an effort was made to measure typical concentration values and evaluate SF_6-dilutions as the plume moved over the beach under nighttime inversion conditions.

These nighttime tests were characterized by low windspeeds and large variations in wind direction. The locating of a defined plume centerline (no visible tracer was released with the SF_6) was impossible because of near stagnation of the tracer plume when transporting windspeeds dropped below the response threshold of the available wind instruments. Also, without knowledge of the height of the plume axis, further analysis seemed inadvisable. The data from tests 9 and 10 are found in appendix A and are not further analyzed in this paper.

Table 1 summarizes the general conditions and times for the 10 tests. The release point, data and time, weather and cloud cover, stability category, source strength, and mean windspeed are listed. The objective stability category selection criteria suggested by Pasquill (1961), as given by Turner (1964 and 1970), were used to determine stability categories. The continuous emission of the visible smelter plume from two separate chimneys made estimation of plume speed of movement difficult, especially as photography was restricted. Accelerations of air flowing across the mountaintops (Chang et al., 1972) probably make wind data measured at the ridge crests a poor indicator of windspeeds at equivalent heights away from the high terrain. Therefore, the mean windspeeds used for each of the tests were derived from pibal winds appropriate to the plume height. A summary of the pibal data taken during the tests is given in table 2. A complete listing of all pibal data is given in appendix B. Radiosonde data are listed in appendix C.

Table 1. General Conditions and Times During SF_6 Sampling

Test #	Release pt.	Date	SF_6 (kg)	Time*	Weather/sky	$\bar{U}$ ** ($m\ s^{-1}$)	Stability
1	Stack 3	6/15/73	8.2	0957-1057	Scattered cumulus at 6000 ft and at 10,000 ft; some cirrus. Temp. 61°F; dewpoint 37°F.	3.5	C
2	Stack 3	6/18/73	8.9	1500-1600	Clear. Cumulus visible distance east. Temp. 58°F; dewpoint 30°F.	3.9	C
3	Stack 3	6/19/73	7.9	1619-1749	Clear. Temp. 66°F; dewpoint 30°F.	3.5	C
4	Stack 3	6/22/73	12.0	1534-1634	Scattered cumulus at 7000 ft; scattered altocumulus at 18,000 ft. Temp. 82°F; dewpoint 57°F.	2.0	B
5	Stack 3	6/25/73	12.0	1604-1705	Thin broken layer at 1000 ft; 9/10 of sky obscured by smoke. Temp. 88°F; dewpoint 44° F.	4.2	C
6	Stack 3	6/26/73	11.3	1728-1828	Clear. Few cumulus north. Temp. 89°F; dewpoint 45°F.	2.3	C
7	Stack 3	6/27/73	11.6	1438-1538	Clear. Few cumulus, distant north. Temp. 89°F; dewpoint 65°F.	1.5	B
8	Helicopter over smelter, 366 m above sfc.	6/28/73	41.3	0517-0552	Overcast altocumulus layer at 12,000 ft. Some breaks in overcast. Temp. 78°; dewpoint 50°F. Wind began suddenly at 0420 MST.	6.7	D
9	Smelter furnace building	6/30/73	14.1	2036-2136	Overcast altocumulus layer at 8000 ft. Temp. 83°F; dewpoint 40°F.	4.1(1.4)[a,b]	E
10	Acid plant stack	7/2/73	15.7	1946-2046	Thin scattered layer at 1000 ft; 5/10 of sky obscured by smoke. Temp. 79°F; dewpoint 46°F.	3.1(1.5)[a]	F

*Mountain Standard Time.

** $\bar{U}$ derived from mean pibal wind during test period for the 5500- to 6500-ft layer.

[a]Approximate $\bar{U}$ near release point.

[b]Actual value used to normalize concentrations.

Table 2. Summary of Pibal Data at Test Time

ft,MSL	Direction[a]	Speed[b]	Direction	Speed	Direction	Speed	Direction	Speed	Direction	Speed	Direction	Speed	Direction	Speed	Direction	Speed	Direction	Speed	Direction	Speed
16000					33	16	22	15	29	24					27	17			25	15
15000					33	15	22	14	28	29					25	12	23	28	25	15
14000			32	33	32	14	21	13	27	33	31	27			24	11	23	30	26	13
13000			32	31	33	12	20	12	26	27	32	24			23	15	22	33	26	11
12000	31	18	32	27	34	08	20	11	25	22	33	22			22	14	23	37	26	07
11000	31	17	31	23	31	07	21	10	25	18	32	14			23	05	23	36	24	02
10000	30	15	32	19	30	08	20	07	25	15	31	10			23	05	23	26	15	02
9000	29	13	32	17	28	07	13	03	26	11	32	07	32	07	20	04	22	15	12	01
8500																				
8000	30	10	32	13	25	06	10	02	23	06	33	06	33	06	23	09	18	02	12	02
7500	30	10	32	12	28	05	04	03	19	05	34	06	33	06	24	13	11	06	09	02
7000	30	10	32	11	31	06	02	04	13	08	35	06	34	05	25	14	09	10	07	03
6500	30	10	32	10	33	07	03	04	08	09	35	06	35	04	25	13	07	13	09	05
6000	30	11	32	08	33	06	03	04	07	08	35	04	36	02	25	13	07	14	10	07
5500	30	14	32	06	33	05	03	04	05	07	34	03	01	02	25	13	07	11	10	07
5000	29	14	32	04	34	04	01	05	04	07	31	03	01	02	25	13	08	08	09	06
4500	29	12	29	03																
SFC	29	12	29	03	01	04	33	07	36	08	33	03	35	05	26	10	13	10	06	07
ft,MSL	Test 1		Test 2		Test 3		Test 4		Test 5		Test 6		Test 7		Test 8		Test 9		Test 10	
	6-15-73 1005 MST		6/18-73 1600 MST		6-19-73 1700 MST		6-22-73 1530 MST		6-25-73 1600 MST		6-26-73 1735 MST		6-27-73 1615 MST		6-28-73 0535 MST		6-30-73 0920 MST		7-2-73 2000 MST	

[a]Direction in tens of degrees.

[b]Speed in miles per hour.

A. Concentration Measurements

The normalized SF_6-concentration measurements for daytime lapse releases are shown in figures 7a through 7d and 8a through 8c. Airborne plume centerline samples, collected while flying in a helicopter, are denoted by the letter H for all tests except test 1; in that test, aerial samples are given by a zero because the plume did not flow across the elevated terrain. Centerline ground-level samples are denoted by the letter G. Ground sample values represent a mean integrated concentration resulting from sampling times on the order of 120 to 180 min (tracer releases were 60 min). In practice, most SF_6-tracer present in a given sample bag was probably collected during a 1-hr interval. Therefore, ground-level sampled concentrations have been normalized through multiplication by the time of sample collection and division by the length of the tracer release. Aerial concentration measurements were made during sampling times on the order of 1 min and were not scaled by any time ratios. The straight line on each diagram of figures 7 and 8 represents the ground-level receptor solution of the Gaussian diffusion equation (from Turner's (1970) presentation of the Pasquill-Gifford curves) for the stability category of the particular test. The data points shown on these graphs represent near-axial locations. A complete tabulation of all sample points, listing their locations, concentration, sampling time, and elevation, is found in appendix A.

During test 1, northwesterly winds carried the plume through the saddle behind Smelter Peak (somewhat as shown in fig. 2) and over the flat terrain of the Salt Lake Valley. The aerial concentrations sampled from the helicopter conform very well with the expected flat-terrain ground-

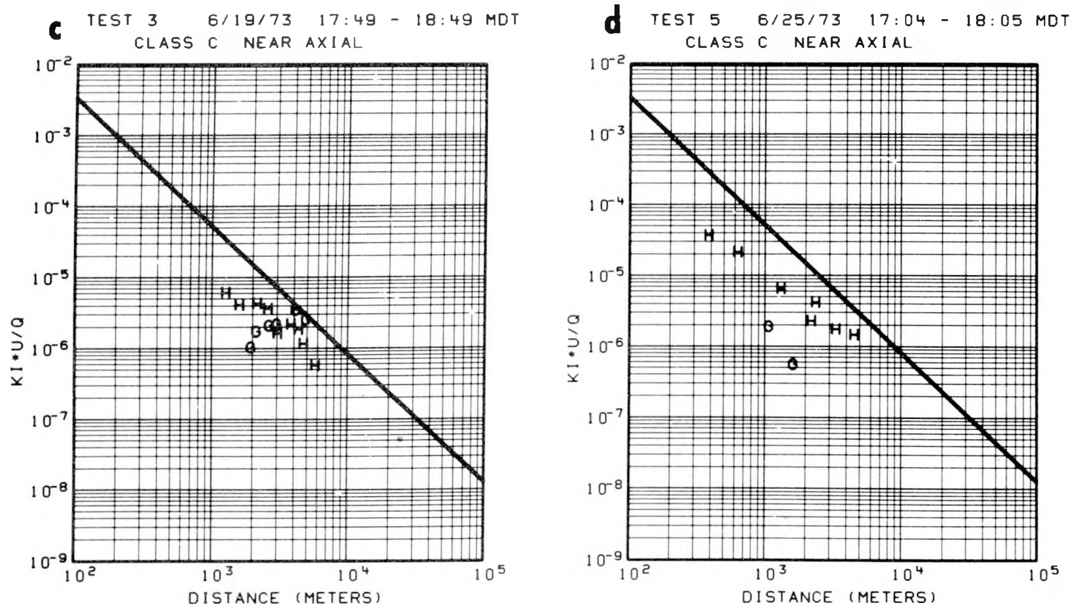
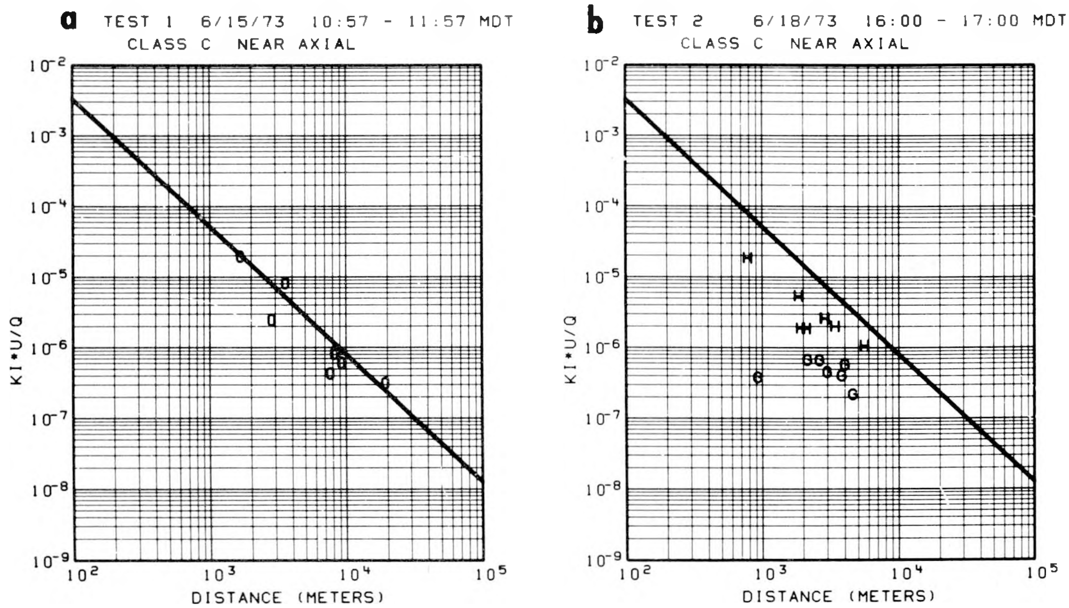


Figure 7. Near-axial relative concentrations versus downwind distances. H and O symbols represent aerial samples; G symbols denote ground-level samples. The solid curves are the appropriate Pasquill (1961)-Gifford (1961) curves for each test. The separate symbols O are used for test 1 because the plume trajectory was not over the elevated terrain.



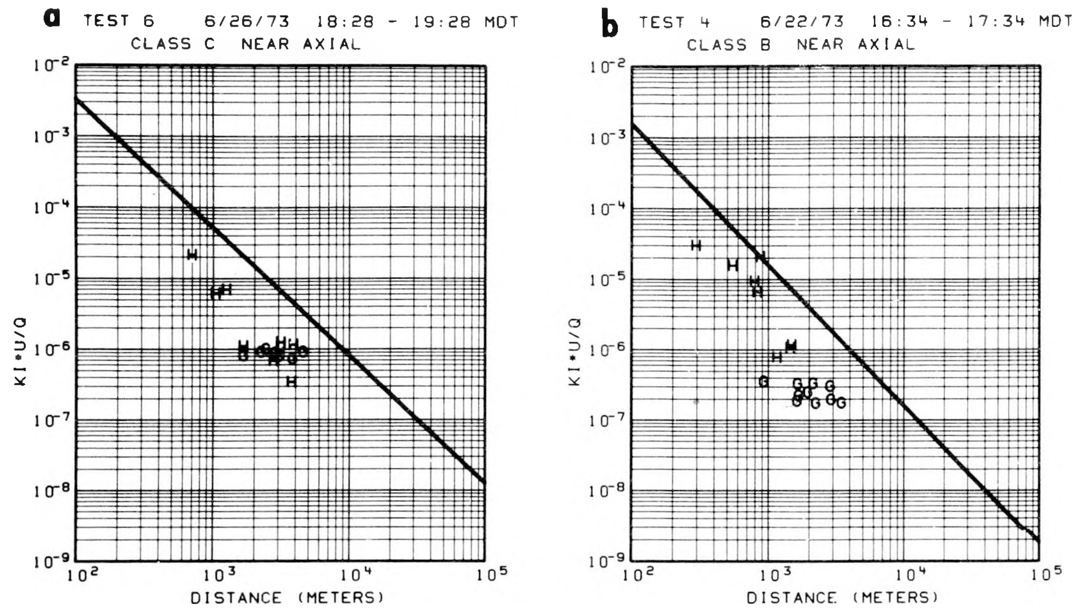
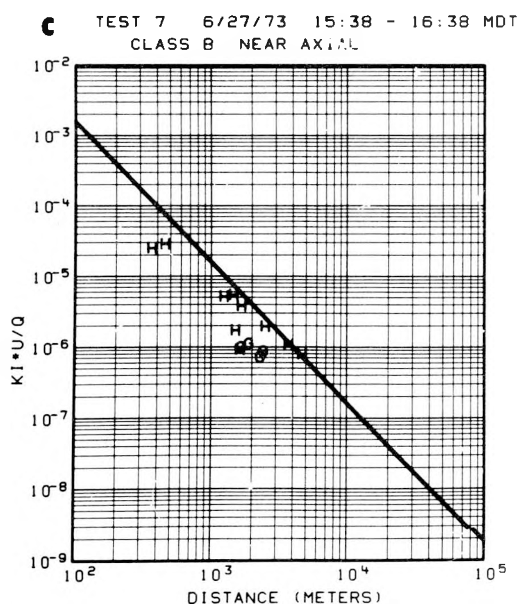


Figure 8. Near-axial relative concentrations versus downwind distances. H symbols represent aerial samples; G symbols denote ground-level samples. The solid curves are the appropriate Pasquill (1961)-Gifford (1961) curves for each test.



source values (solid line). This test demonstrated the lack of deviation of measured concentrations from expectations for flat-terrain when the plume failed to be carried across the elevated terrain. It showed that the Pasquill-Gifford curves predict downwind concentrations over flat terrain reasonably well. Except for two data values from test 3, ground-level concentrations are less than helicopter concentrations. Helicopter samples for test 7 converge to the Pasquill-Gifford curve at the longer distances in a manner not observed in any other tests. These exceptions will be discussed in the section describing vertical plume spreading.

A plot of all helicopter samples for each stability class has been made on figures 9a and 9b. The dashed line running through the points is a first-order, least-squares curve fit of the H data points. Except for test 1 (denoted by an O symbol instead of H), in which the plume transport was over the valley and away from the mountain slopes, the preponderance of data points fall significantly below the appropriate Pasquill-Gifford curve. The dashed-line, least-squares curve fit of class B aerial samples, shown in figure 9a, converges toward the Pasquill-Gifford curve at greater distance because the test 7 data points at the longer distances are disproportionately large. The line of least-square curve fit should more nearly parallel the Pasquill-Gifford curve when it is realized that these aerial samples were collected close to the elevated terrain and have been influenced by ground reflection of the plume.

In table 3, taken from Start et al.(1974b), the concentrations of the elevated centerline samples taken by helicopter during each test are compared with the concentrations predicted by the Pasquill-Gifford curves for the same stability and downwind distances. On the average, there are

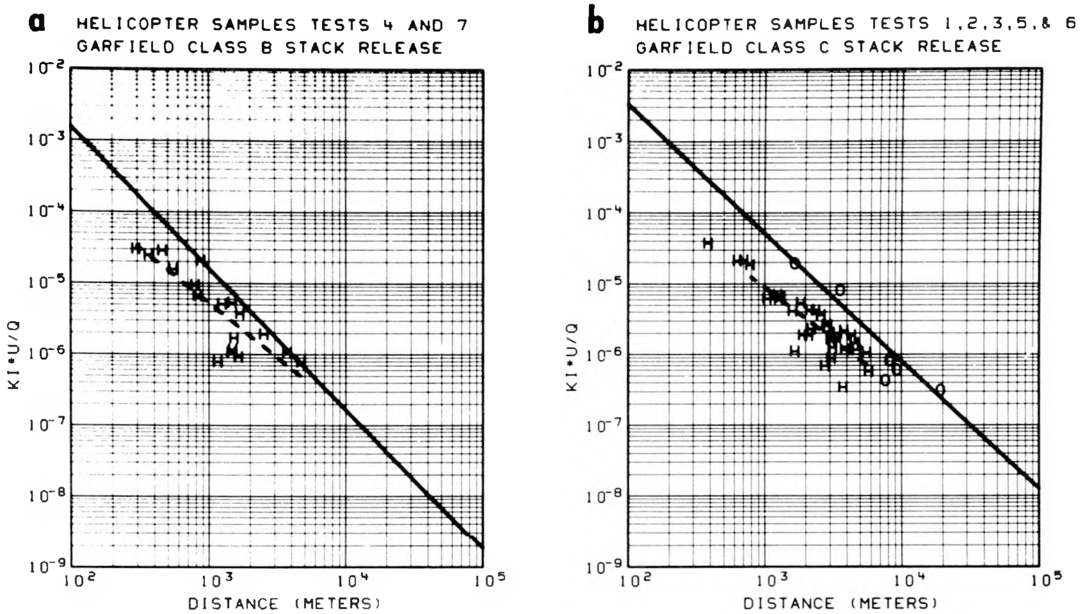


Figure 9. Aerial samples grouped by stability classes. The dashed line is a least-squares, first-order curve fitting of the data points. O symbols are plotted for reference, but were not included in the class C data fit by the dashed curve. The solid lines are the appropriate Pasquill-Gifford curves.

Table 3. Summary of Comparisons of Concentrations From Pasquill-Gifford Curves for Ground-Level Receptors to Helicopter-Measured Aerial Concentrations

Test #	Stability	Mean ratio
1	C	1.5
2	C	3.9
3	C	3.1
4	B	4.9
5	C	4.3
6	C	4.4
7	B	2.7
All class B N = 16+		3.7
All class C N = 28+ (except #1)		3.8

+ Total number of axial plume measurements for this stability class.

overall increased dilution factors of 3.8 and 3.7 for stability classes C and B, respectively.

Before proceeding to other results, the meaning of the ratios presented in table 3 should be clearly understood. Pasquill-Gifford values of normalized concentration (Turner, 1970), against which aerial-measured concentrations are compared, are for ground-level receptors and are solutions to equation 2. Ground reflection effects are included in these values. Therefore, the Pasquill-Gifford concentration values may be twice as large as those that should be used if concentration estimates are desired at an elevated plume centerline which is free from ground reflection effects. The condition of minimal reflection effects is probably violated for distances beyond 1.5 to 2.5 km downwind of the release stack (where the underlying terrain has risen significantly). Over and downwind of the elevated terrain, unless the plume is deflected far aloft while passing across the ridges, some reflection effects are likely to influence the elevated concentrations. In the limiting sense, the ground reflection and vertical mixing effects may become so great that the plume becomes almost uniformly distributed throughout its vertical extent.

For the Garfield test series, neither the vertical depths within which the plumes were dispersed nor the profiles of the vertical distributions of concentration were measured. Therefore, from a failure to have something better to utilize, the Pasquill-Gifford curves (including ground reflection effects) were used for all comparisons; this usage did maintain a consistency throughout the comparisons. The dilutions expressed by the Pasquill-Gifford curves in table 3 may be too large by a factor between one and two. A large fraction of the comparisons of observed versus predicted (Gaussian model using Pasquill-Gifford values of σ_y and σ_z) concentrations was made for observations over and downwind of the elevated terrain. Therefore, the comparative dilutions listed in table 3 are more likely to be close to the values as listed than to be closer to one-half of those values; reflection and mixing effects are more likely over and downwind of the elevated terrain.

The Pasquill-Gifford curves of σ_y and σ_z and the corresponding curves of normalized concentration estimates versus distance are appropriate to averaging times (sampling or travel times) on the order of 10 min (Turner, 1970) and of 10 to 60 min (D. Slade, 1968). For shorter times (travel or sampling duration), the measured concentrations will likely exceed the longer term (10-min) average. Stewart, Gale, and Crooks (1954), along with many others (summarized in Meteorology and Atomic Energy, 1968), have found that measured average concentrations decreased in proportion to the fifth root of sampling time. Therefore, helicopter-collected samples (1-min duration) at short distances (travel times) will tend to be larger than the 10- to 60-min average concentrations if they had been measured. For the range of windspeeds observed during tests 1 through 7 (refer to table 1), travel times of 10 min correspond to downwind distances of 1.2 to 2.5 km. These distances generally correspond to the downwind distances at which the terrain begins to rise steeply. Over and downwind of the elevated terrain, because of longer times of travel (averaging) and because of terrain-roughness influences upon average concentrations during short-sampling intervals (Singer et al., 1963), the averaging effects upon aerial samples of 1-min duration may be set aside. For downwind distances of 400 to 600 m (for observed windspeeds of 2 to 4 m s^{-1}), travel times are on the order of 100 to 300 s. For these times, when related to an averaging time of 600 s (10 min), the fifth root timescaling adjustment results in estimates of equivalent 10-min average concentrations which are 70 to 87 percent of the observed 1-min concentrations. The conclusion reached is that the effects of 1-min sampling duration upon aerial concentration measurements are generally minimal for the measurements presented in this memorandum. The effect will raise slightly the values of the ratios shown in table 3, partially offsetting the ground reflection effects noted earlier.

Figures 10a through 10g show isopleths of ground-level SF_6-concentrations for tests 1 through 7, with units of 10^{-7} gm m^{-3}. Plume centerlines are shown by the heavy dashed lines. Different local-flow situations are represented by these tests. Tests 2 and 3 were conducted during fairly steady airflows in which the plumes were carried inland over the ridges at the south-southeast end of the short, steep-floored canyon. Test 5 was conducted during more easterly winds. This plume was transported across the ridge forming the western edge of the canyon (Black Rock Ridge) and westward along the northern tip of the Oquirrh Mountains.

Test 7 occurred during north-northeasterly winds. The resultant plume transport was partially up-canyon, but in a direction which carried it to Kessler Ridge on the west side of the canyon. Because of the steeply rising terrain, the plume impacted significantly against the mountain slopes and was displaced upward to a considerable height in crossing Kessler Ridge. Figure 11 shows the test 7 plume against the slopes of Kessler Ridge.

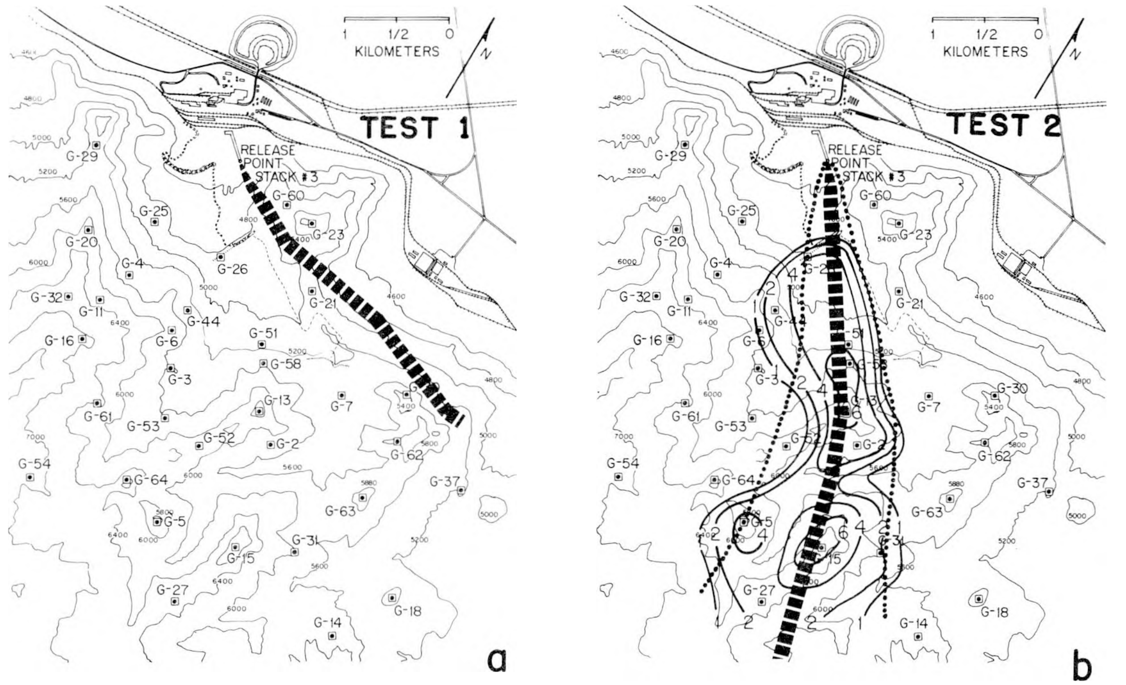
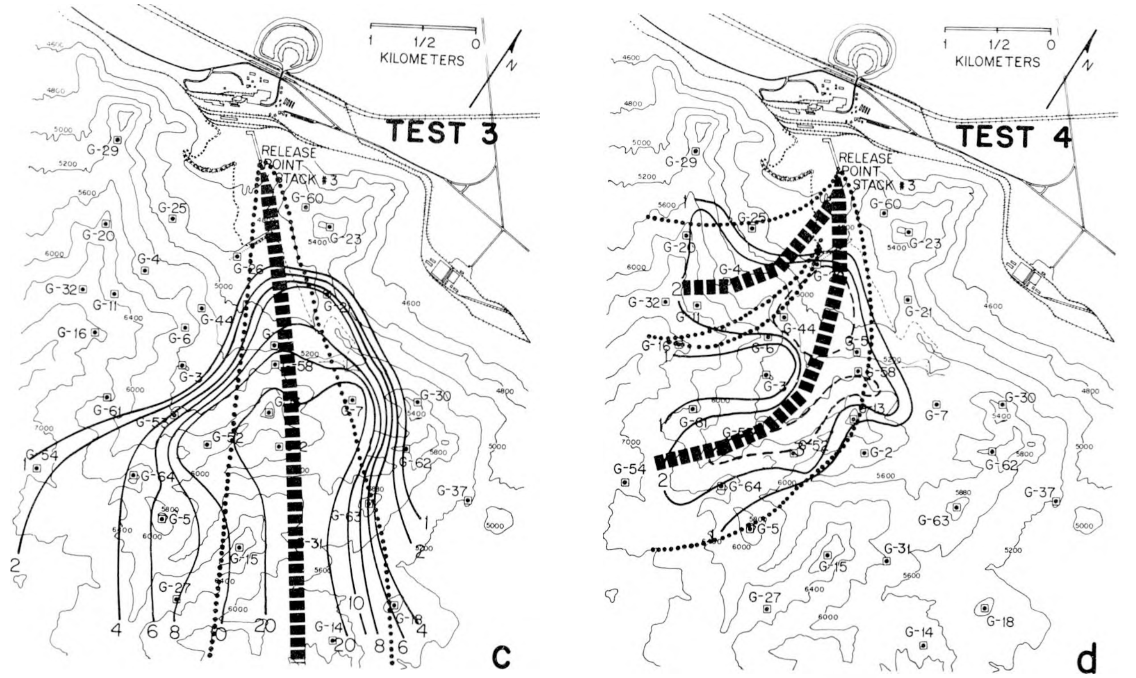


Figure 10. Horizontal depictions of surface concentration. The heavy dashed line shows the plume axis locations. Isolines of SF_6-concentrations $\chi\bar{u}/Q$ (10^{-7} m^{-2}) are shown. The dotted lines are envelopes of Pasquill-Gifford σy at ±2.15σy distances about the centerlines.



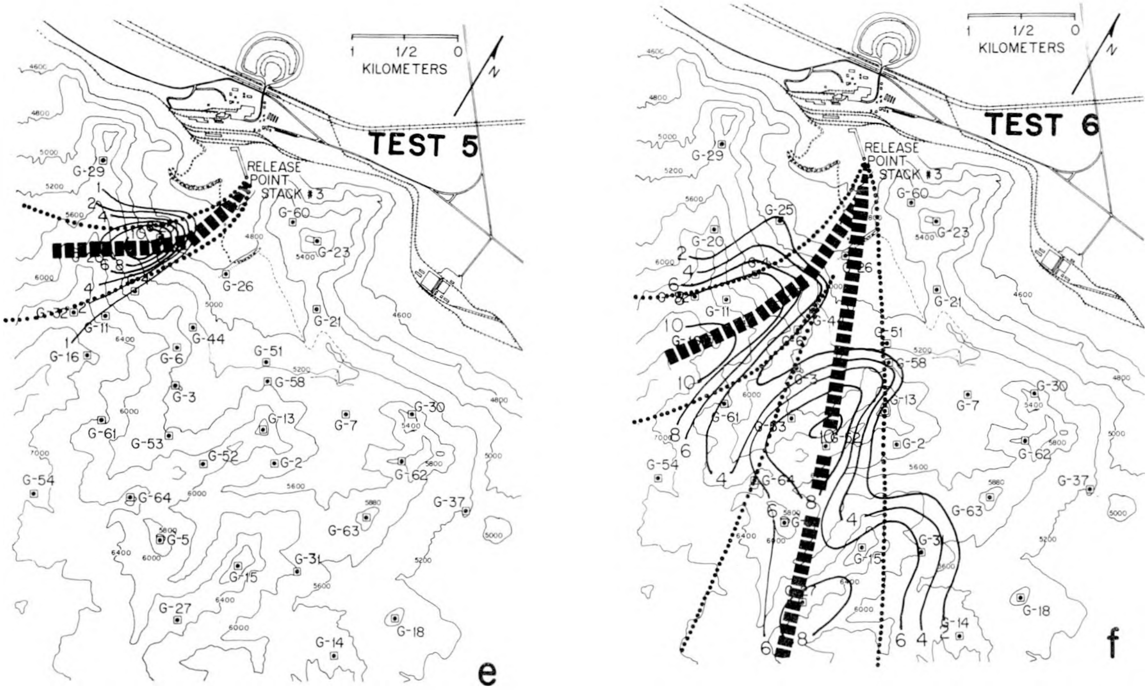


Figure 10. Horizontal depictions of surface concentration. The heavy dashed line shows the plume axis locations. Isolines of SF_6-concentrations $\chi\bar{u}/Q$ (10^{-7} m^{-2}) are shown. The dotted lines are envelopes of Pasquill-Gifford σy at ±2.15σy distances about the centerlines.

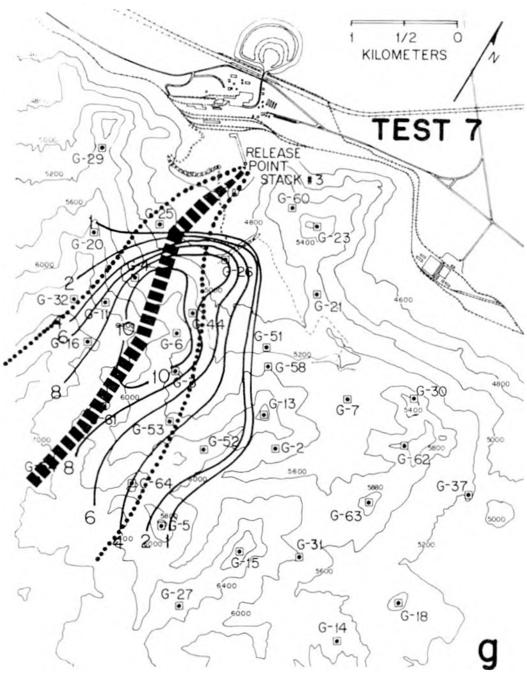


Figure 11. Plume impaction against the steep slope of Kessler Ridge during test 7.

Tests 4 and 6 were conducted during more complex windflows in which a splitting of the plume occurred. Two principal axes of ground-level concentrations are evident. Tests 2, 3, and 7 will be examined in greater detail in later sections of the memorandum to explore aspects of lateral and vertical dispersion. Tests 1, 4, 5, and 6 will not be examined in detail because either the isopleths of tracer concentration were of complicated geometry or a minimal number of ground-level samplers intercepted the plume, and the isopleth pattern was developed from the sparse amounts of SF_6-concentration data.

B. Lateral Plume Spreading

In addition to the plume centerlines and concentration isopleths shown in figures 10a through 10g, envelopes of one-tenth centerline concentration as determined from the Pasquill-Gifford curves (at $\pm 2.15\sigma_y$ about the plume axis) are shown by dotted lines on the ground-level concentration patterns. A discussion of lateral diffusion, the Gaussian distribution, and $2.15\sigma_y$ versus the ordinate value of the Gaussian curve is given by Pasquill (1962). From inspection of the figure 10 plots, the actual plume spreading exceeds the dotted-line flat-terrain widths given by Pasquill-Gifford curves by a factor of two or more. To examine lateral spreading in a more quantitative manner, the ground-level isopleths of concentration for tests 2, 3, and 7 were utilized. Because symmetrical, concentric arrays of samplers were not established, several slices across the isopleth patterns were selected. These slices across the isopleths are shown in figures 12a through 12c. Along each of these slices, analyzed values of concentration versus lateral position were extracted. These data are listed in appendix G. In this manner, reasonable approximations of the concentration distributions for the symmetrical

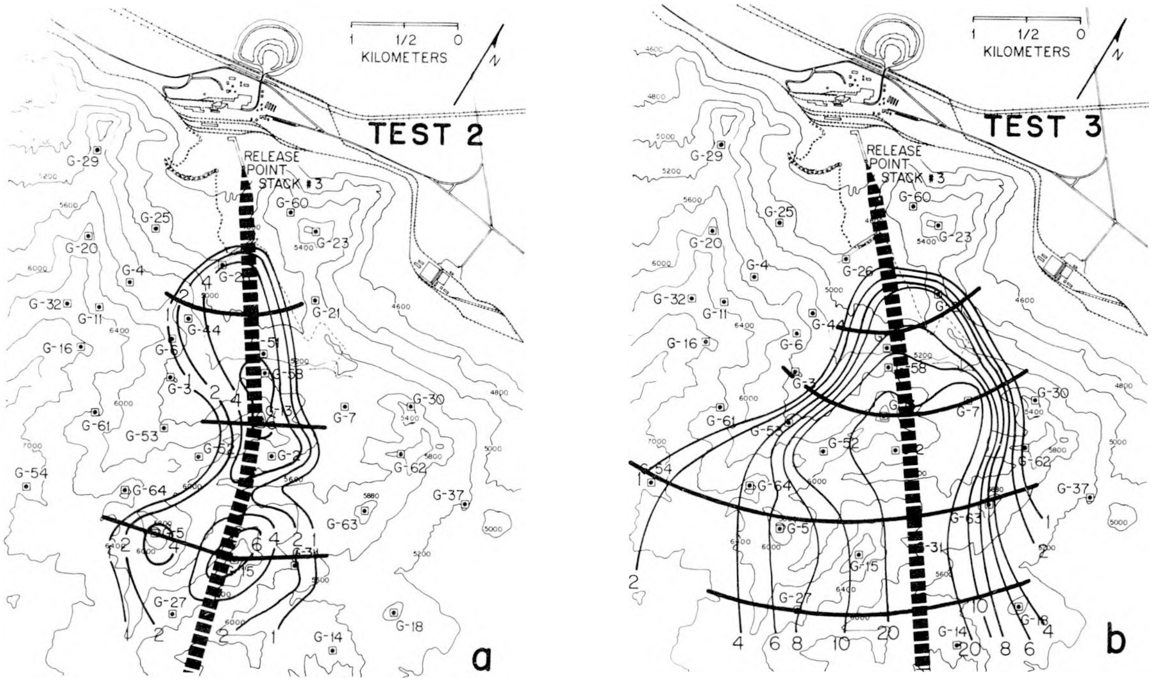
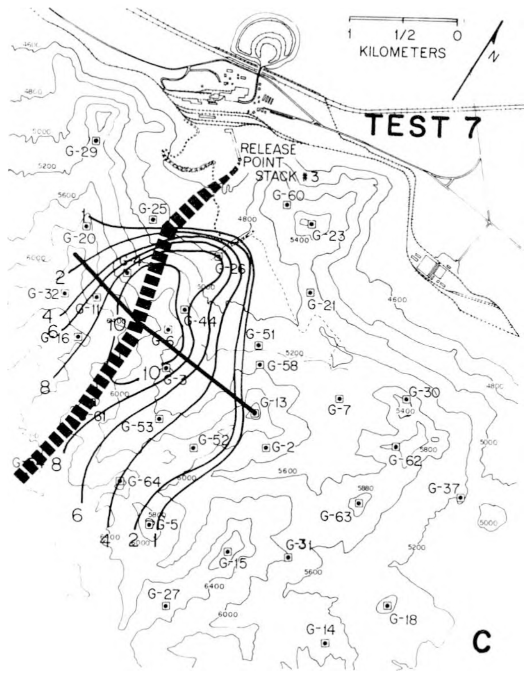


Figure 12. Locations of ground-level slices across analyzed concentration isopleths for test 2(a), test 3(b), and test 7(c).



arrays of samplers, if they had been so positioned, were obtained. From these data, estimates of σ_y were calculated (example calculations are shown in appendix G); the results are summarized in table 4.

Two methods (Pasquill, 1962) were utilized to calculate σ_y-values. The first method, denoted as "Plume width" in table 4, is related to the Gaussian distribution in which isolines of one-tenth the peak ordinate value encompass 97 percent of the total area under the Gaussian curve. These isolines are contained within a total span of 4.3 standard deviations. The other method, referred to as "Second moment" in table 4, is the second-moment of the lateral distribution of tracer mass about the center of gravity of the mass distribution. Observed lateral spreading was almost twice as great as flat-terrain predictions extracted from the Pasquill-Gifford curves for σ_y (Turner, 1970). Estimates of σ_y from the "Plume width" and "Second moment" methods are essentially of equal value. This agreement suggests that the departures from a Gaussian distribution are probably insignificant.

Obvious physical mechanisms are believed to contribute to these greater plume widths. First, as the plumes approach the steeply rising terrain, there is a tendency for the plumes to be deflected laterally in an attempt to flow out and around the blocking obstacles. Tests 3, 4, 6, and 7 most clearly demonstrate this tendency along the upwind sides of steeply rising terrain. The second mechanism for enhanced lateral spreading is suggested by the isopleth analyses for tests 2, 3, and 4. During looping, plume segments frequently approached the ground near sampler position 26, a site about one-half way up the steeply rising canyon floor. As the descending segments neared the

Table 4. Sigma-y Values Versus Pasquill-Gifford Flat-Terrain Values

		Sigma y		
Test	Distance	Pasquill-Gifford	Plume width	Second moment
2	1522	153.	357.	392.
	2648	256.	230.	194.
	4053	373.	534.	549.
3	1742	175.	335.	395.
	2714	262.	462.	540.
	3779	352.	858.	740.
	4705	427.	728.	735.
7	2037	295.	558.	581.

Average ratio (Plume width/Pasquill-Gifford) = 1.79.

Average ratio (second moment/Pasquill-Gifford) = 1.86.

All distances and σ-values are in units of meters.

Plume-width estimates are related to the Gaussian distribution in which isolines of one-tenth axial concentration encompass 4.3σ.

Second moment σ-values are calculated from the concentration distributions identified in figures 12a through 12c.

Data values are given in appendix G.

ground, they were laterally spread by deflection from the surface. A typical example of this spreading during looping is shown in figure 13. The third obvious mechanism for greater lateral spreading is an enhanced turbulent state as a result of mechanical turbulence believed to arise over and around the peaks and ridges of the mountainous terrain. An effect from directional shearing of the wind with height is shown in figure 13. The plume from number three stack is carried directly up-canyon by the airflow at lower elevations, while the plume from number two stack, rising into the more easterly winds aloft, is carried across the ridge toward and to the left of the camera. In this case, the differences in plume directions of motion approached 90°.

C. Vertical Plume Spreading

As the plume carrying air is moved to the high terrain, two important things may happen. If the upward motion of the plume is not significantly retarded, the plume may flow across the ridges in an undulating manner which is somewhat similar to the shape of the underlying terrain. In the case of significant retardation of upward-plume displacements, the plume could either remain blocked in the volume upwind of the high terrain or flow across these high ridges in a vertically confined layer, the top of which lies a short distance above the ridges. Obviously, in the presence of saddles, passes, and gaps through and around the high terrain, the plume would tend to stream through these openings. In this situation, there would be a partial blockage of plume movement by the high terrain.

Figures 14a through 14h provide perspectives of the test 2 through 7 plume movements across the mountain slopes during daytime, unstable conditions (see table 1). Depictions of height versus downwind distances

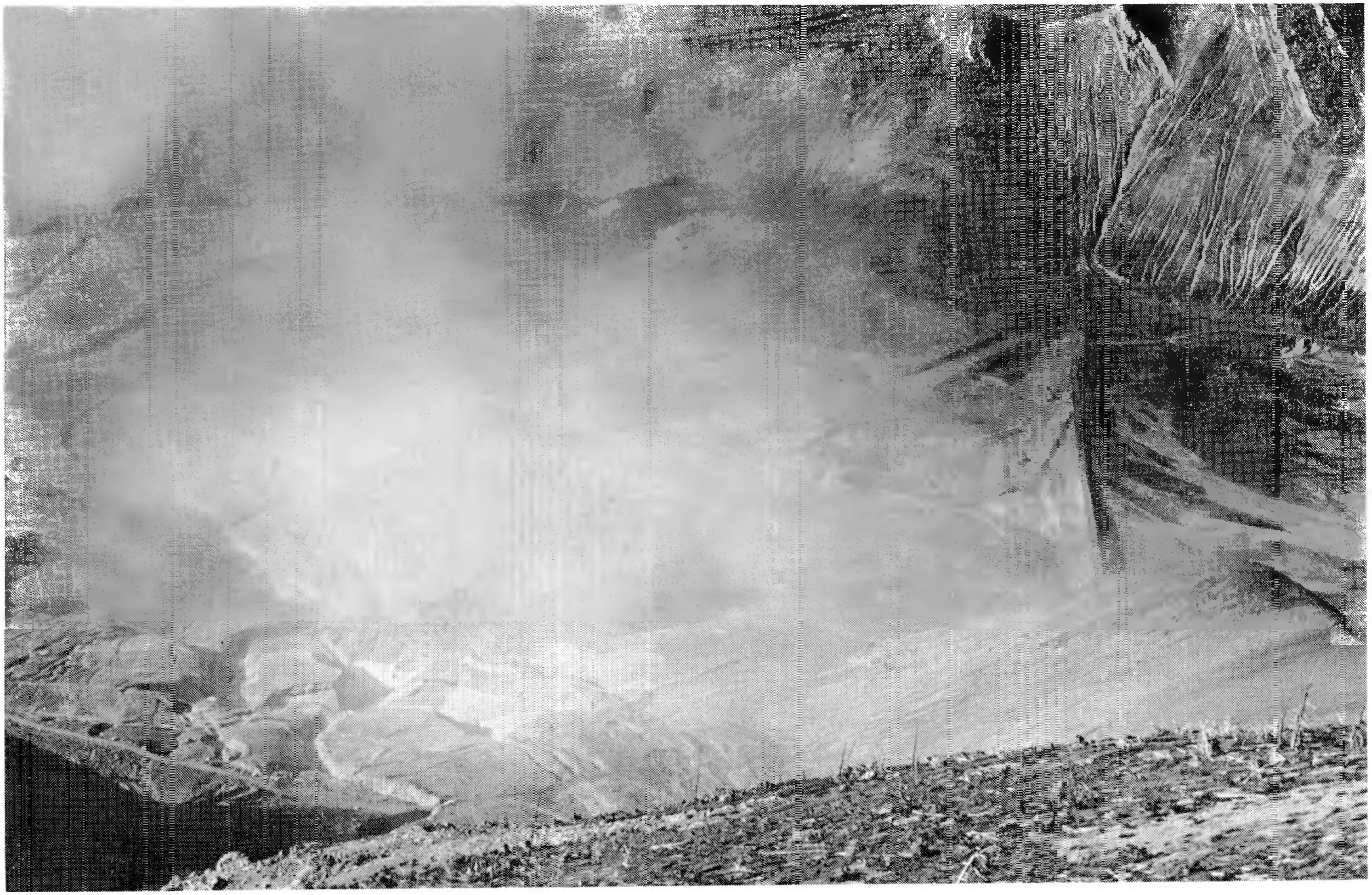


Figure 13. Example of looping plume spreading laterally near the ground and then moving up-canyon to the right. The plume from the other smelter stack has risen much higher and is being transported toward and to the left of the camera location, allowing plume separations along different transport directions.

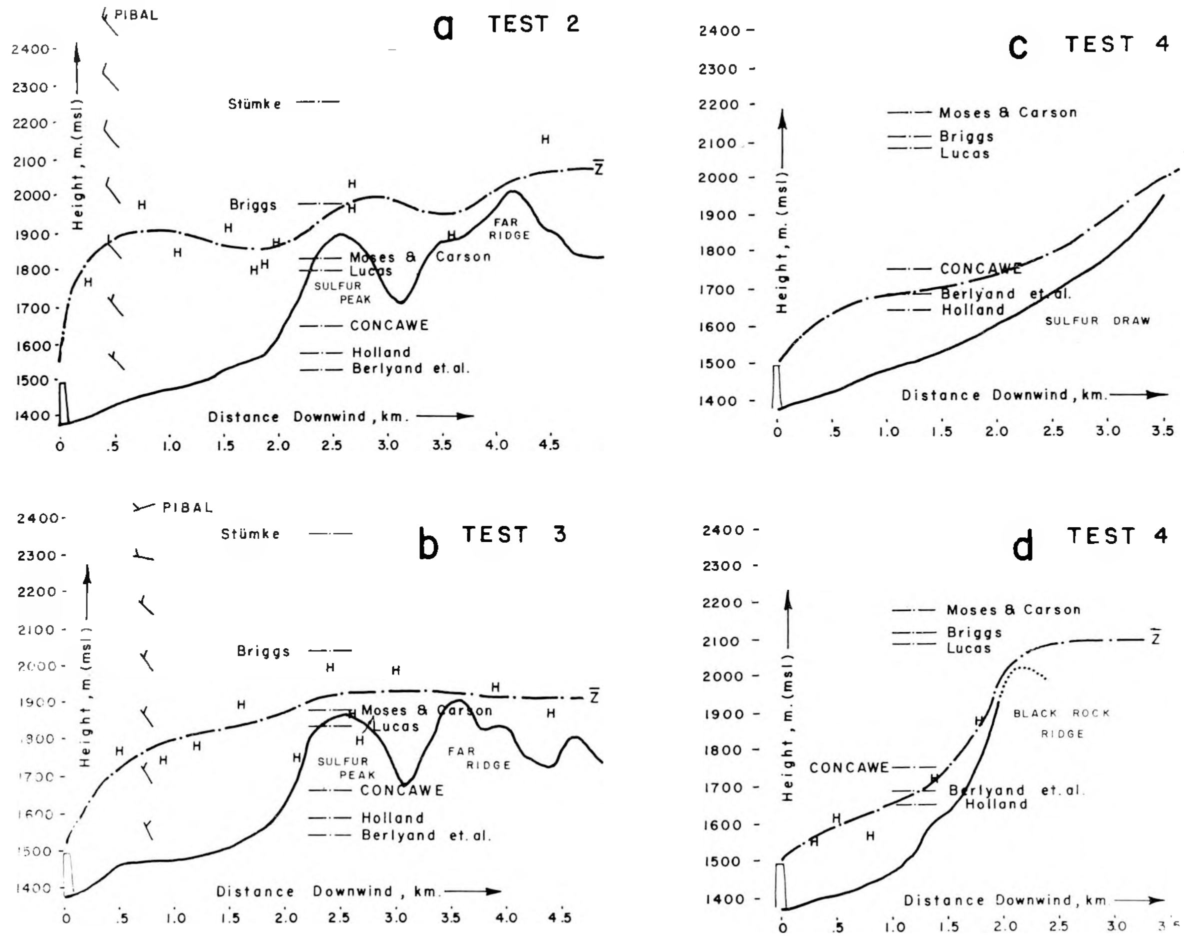


Figure 14. Height versus downwind distance depictions along plume axes for tests 2 through 4. H symbols denote locations of aerial sample collection. Estimates of plume centerline height are shown for seven different plume-rise formulas; variation of the height of the underlying terrain was not incorporated into the centerline height estimates. $\overline{Z}$ denotes a subjectively drawn line through the heights of aerial sampling.

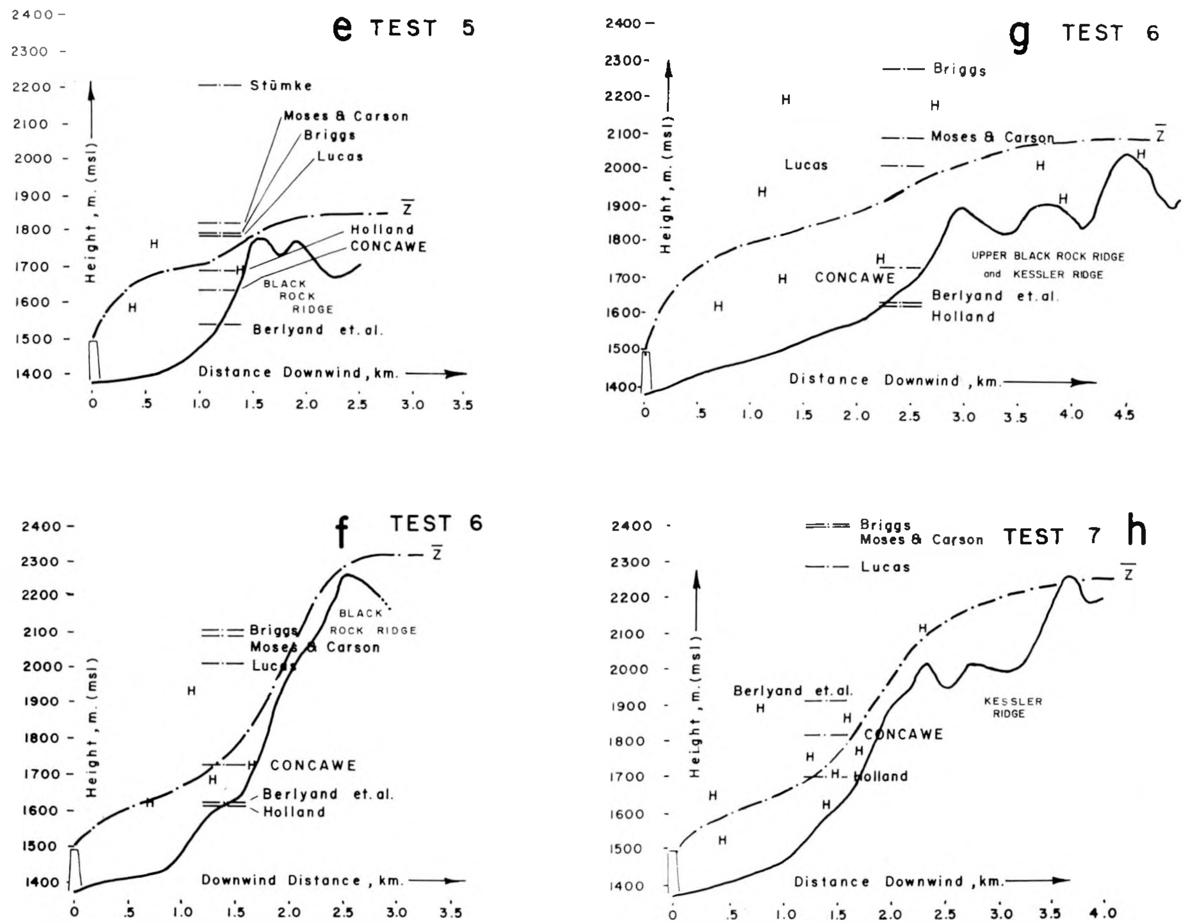


Figure 14. Height versus downwind distance depictions along plume axes for tests 5 through 7. H symbols denote locations of aerial sample collection. Estimates of plume centerline height are shown for seven different plume-rise formulas; variation of the height of the underlying terrain was not incorporated into the centerline height estimates. $\bar{Z}$ denotes a subjectively drawn line through the heights of aerial sampling.

are shown. The shape of the underlying topography indicates the very rugged nature of the Garfield setting. The very high, steeply rising topography is clearly shown for test 7. The locations of near-axial aerial-sample collection points are shown by the symbol H. As a first approximation, the plume-axis height is represented by a dot-dash line, denoted $\bar{z}$, which was subjectively drawn through these symbols.

Test 3 observations and plume behaviors represent a case in which the plume crossed the higher ridges but was trapped in the air layer close to the ridgetops. Measured aerial and ground sample concentrations were about equal (accounting for plume reflection). Ground samples at 4- to 5-km downwind (fig. 7c) exceeded aerial (presumed "axial") concentrations by nearly a factor of two. Ground reflection effects upon a plume of quasi-uniform vertical distribution could explain why these ground-level concentrations exceed measured aerial concentrations.

Test 2 represents a case in which the plume is not constrained to flow across the ridges in a relatively shallow layer. Ground-sampled concentrations are substantially less than aerial samples, as shown in figure 7b.

Radiosonde temperature data were not available to confirm the existence of a capping stable layer during test 3. From figure 14b, it is apparent (in comparison to test 2, fig. 14a) that aerial samples over and downwind of the higher terrain had to be collected at relatively lower altitudes to be within the plume. Examination of the pibal winds for test 3 (and as contrasted with those winds for test 2) shows a small but significant vertical shearing of wind direction, beginning somewhere between 200 and 400 m above the ridges. Therefore, the existence of a capping or more-stable layer between 200 and 400 m above the ground seems highly probable during test 3.

Test 7 is similar to test 3 in that ground concentrations are nearly the same as helicopter-collected samples. Figure 11 pictured the impaction of the dense plume against the steep slopes of Kessler Ridge. Apparently the extreme steepness of Kessler Ridge resulted in the plume lying against the slope in a very dense state. The very steepness of the slopes seems to provide a confining effect upon the plume along its lower boundary. Figure 15 shows a typical inland and upslope transport of the smelter plumes during the afternoon. Along the downwind portion of the plume, a hint of flatness along the top of the plume is seen, probably much like the vertical capping conditions during test 3. This flattening may be contrasted with the test 7 confining of the plume against Kessler Ridge shown in figure 11.

Figures 16 and 17 show the smelter plume shortly after sunrise. The plume has collected in a large, elevated layer in the pocket at the northeast tip of the Oquirrh Mountains. Nighttime drainage winds are flowing from the south-southeast through the Salt Lake Valley and out across the lake. In figure 16, a large filament of the plume protrudes out of the pocket into the drainage wind along the edge of the layer. Figure 17 shows this diffuse layer along the entire northern lee of the mountains. While no concentration measurements were collected for this situation, the visual plume behavior points out a type of dispersion which may occur during two important situations. In one situation, the plumes are drawn toward the mountain slopes when the Garfield site is on the leeward side of the mountains. The second situation, mentioned earlier, is the

Figure 15. Typical onshore, upslope transport of the visible smelter plumes. Notice a tendency for the capped-off plume to appear about two-thirds of the plume length downwind as it flows across Sulfur Ridge.

Figure 16. Early morning view of the smelter plume trapped in a nearly stagnant pocket. Drainage winds from the upper right have extruded a band of plume from the eastern edge of the pocket. Diffuse material extends around the northern tip of the Oquirrh Mountains, as shown in the bottom of the picture.

Figure 17. Aerial photograph of the early morning plume along the northern slopes of the Oquirrh Mountains. The smelter is located at the upper left of the photograph.

condition in which a strongly stable layer and the elevated terrain combine to block and stagnate the plume-containing layer so that it can neither rise over nor easily flow around the ridges. Without penetration of the drainage wind into the pocket in the lee of the mountains near the Garfield smelter, the elevated emissions are retained in the pocket. With such near stagnation, and particularly during pre-dawn and early morning hours when temperature inversions result in a strongly stable layer, the mountain slopes intersecting the elevated plume layer may experience a prolonged exposure to the airborne effluent. Unfortunately, no concentration measurements were collected during this type of condition, and the degree of contact of the airborne effluents with the mountain slopes is not known.

Vertical diffusion and the height of the plume were examined for tests 2, 3, and 7 using the same cross sections shown in figures 12a through 12c (data values are listed in appendix G). Using the second-moment values of σ_y (termed σ_y(SM)) from table 4, along with the elevated near-axial concentrations ($\chi_A(x,o,H;H)$), equation 5 may be solved for σ_z. These σ_z-values satisfy the Gaussian diffusion equation for the observed elevated centerline concentrations. By use of the ground-level axial concentration, along with σ_z (eq. 5), σ_y(SM), and the measured elevated axial concentration, the test mean plume axis-height H for a Gaussian vertical distribution may be derived from equation 7. Table 5 summarizes these calculations for tests 2, 3, and 7. Pasquill-Gifford values of σ_y and σ_z are listed for comparison. Graphically, σ_y(SM) versus downwind distance is shown in figure 18 along with the Pasquill-Gifford curves of σ_y. σ_z (eq. 5) is shown in figure 19 in a corresponding manner. The

Table 5. Vertical Plume Spreading and Diffusion Parameters

Test no.	Distance (m)	σ_y P/G (m)	σ_y SM (m)	σ_z P/G (m)	σ_z Eq.(5) (m)	H (m)	σ_z CIC (m)	CIC (m)	HC (m)	$\chi_A \bar{U}/Q$[a] (m^{-2})	$\chi_{GO} \bar{U}/Q$[a] (m^{-2})
2	1522	153	392	89	72.5	169	65.6	1729	183	56.	7.49
2	2648	256	194	152	205.1	452	209	2082	444	40.	7.09
2	4053	373	549	220	152.6	285	151.8	834	286	19.	6.67
3	1742	175	395	102	57.6	129	53.9	937	136	70.	11.4
3	2714	262	540	153	68.5	99	61.7	197	105	43.	30.6
3	3779	352	740	207	119.5	9	3.1	201	-122	18.	35.9
3	4705	427	735	252	154.7	I	I	I	-110	14.	34.3
7	2037	295	581	235	94.5	155	87.4	389	163	29.	15.

[a]Normalized concentrations are $\times 10^{-7}$.

I means indeterminate computation.

P/G is the appropriate value given by the Pasquill-Gifford curves.

SM is the second moment value listed in table 4.

H is the height derived from equation 7, using χ_A, χ_{GO}, and σ_z (eq. 5).

HC is the height derived from equation 8, using the crosswind integrated concentrations.

σ_z(CIC) are values computed from equation 3, using H given above.

CIC values are listed in appendix G.

χ_A and χ_{GO} are measured aerial and ground-level axial concentrations.

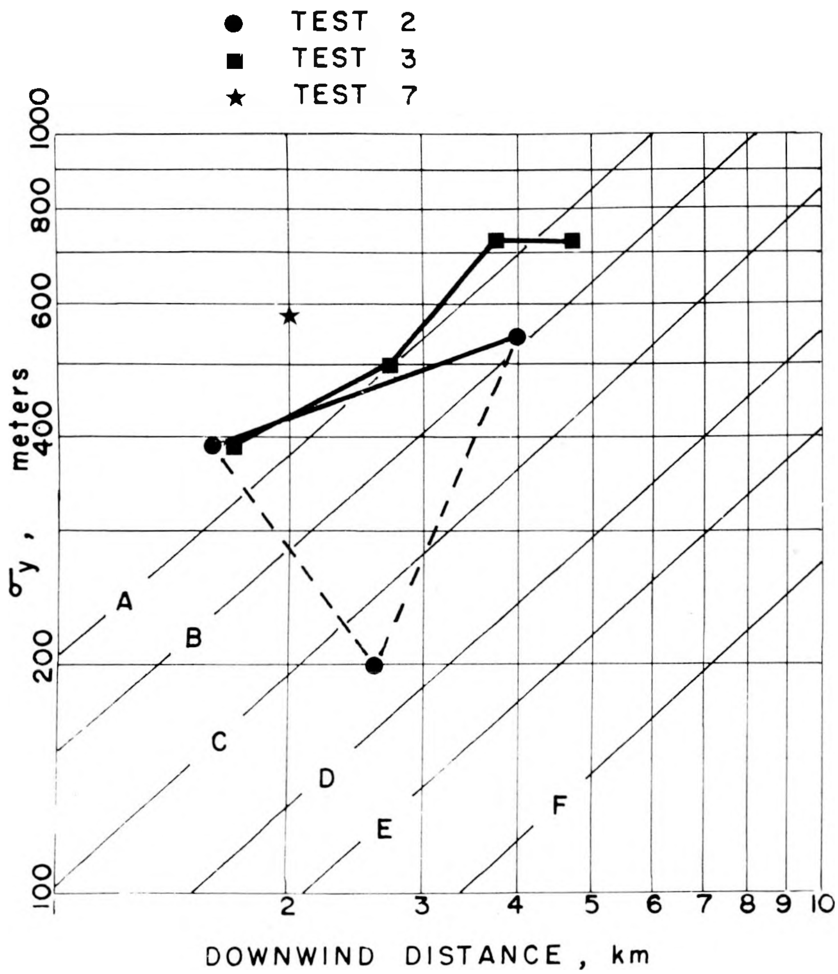


Figure 18. Calculated σy (from table 4) and Pasquill-Gifford σy-values versus downwind distance. Stability categories for tests 2 and 3 were C, for test 7 were B. The dashed line joins the test 2 calculated σy-values; σy at 2.6 km is very small compared to expectations. (A value of about 460 m would seem more appropriate.

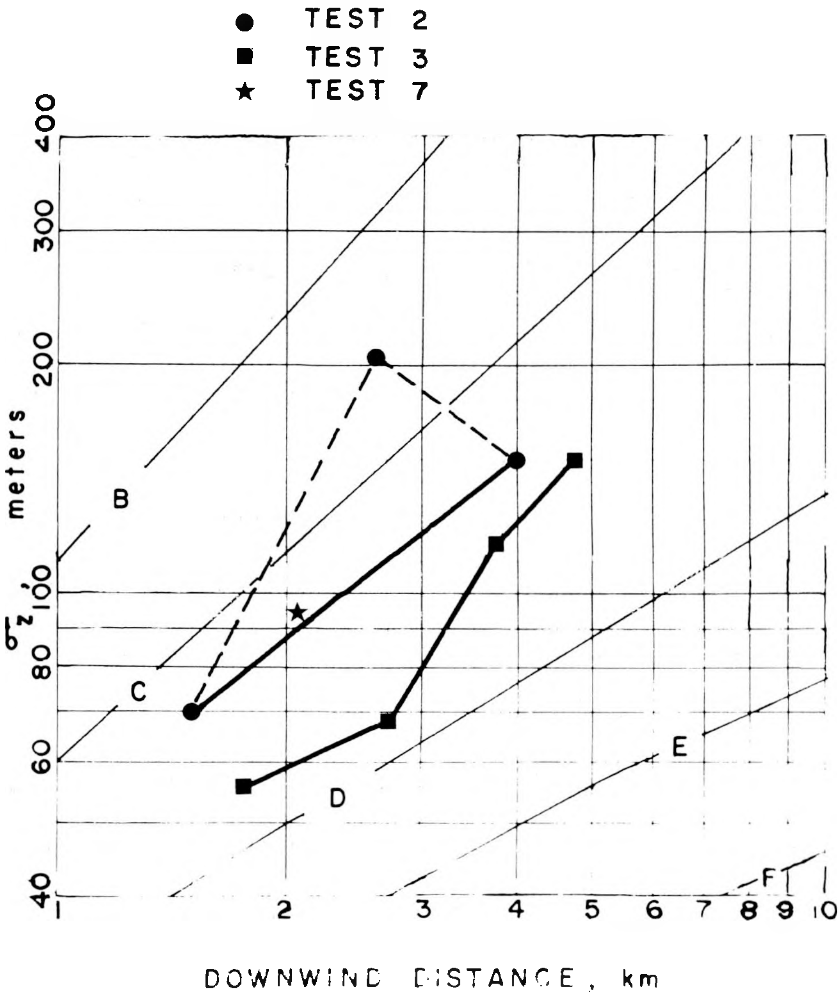


Figure 19. Calculated σz (from table 5, eq. 5) and Pasquill-Gifford σz-values versus downwind distance. The test 2 value at 2.6 km is very large compared to expectations. (A value of about 110 m would seem more appropriate.) Calculated σz-values (eq. 5) are dependent upon σy-values shown in figure 18 and table 4.

value of σ_y(SM) for test 2 at 2648 m (connected by a dashed line) downwind seems disproportionately small; σ_z (eq. 5) is therefore disproportionately large.

The values of σ_y(SM) are nearly twice as large as the corresponding Pasquill-Gifford values, as summarized in table 4. The σ_z (eq. 5)-values, as shown in figure 19, are somewhat smaller than the appropriate Pasquill-Gifford curve values. From table 3, a summary of comparisons of Pasquill-Gifford concentrations versus measured aerial concentrations, the product $\sigma_y\sigma_z$ would be expected to be about 3.8 times larger than the product of Pasquill-Gifford $\sigma_y\sigma_z$. Because σ_y(SM) averages about 1.8 times greater than corresponding Pasquill-Gifford values, σ_z (eq. 5) should be from 1 to 2 times (variable due to degree of ground reflection effects) the size of corresponding Pasquill values of σ_z if the derived $\sigma_y\sigma_z$-product is to be 1.9 to 3.8 times greater than the Pasquill-Gifford product. The derived $\sigma_y\sigma_z$-product is about comparable.

In the calculations summarized in table 5, the values of aerial concentration χ_A are the largest values of observed (the upper envelope or boundary of the scattering of measured) concentrations. For the ratios in table 3, all values of near-axial measured concentrations were utilized. If the average values of aerial-measured concentrations (e.g., least-squares curve fitting of χ_A values) are used for the calculations summarized in table 5, the σ_z (eq. 5)-values equal or exceed the expected Pasquill-Gifford values of σ_z, and the apparent inconsistency between table 3 concentration ratios and the ratios of products of $\sigma_y\sigma_z$ is removed.

Solving equation 3 for σ_z yields a second estimate of σ_z based upon H and the crosswind integrated concentration (CIC). Two solutions for

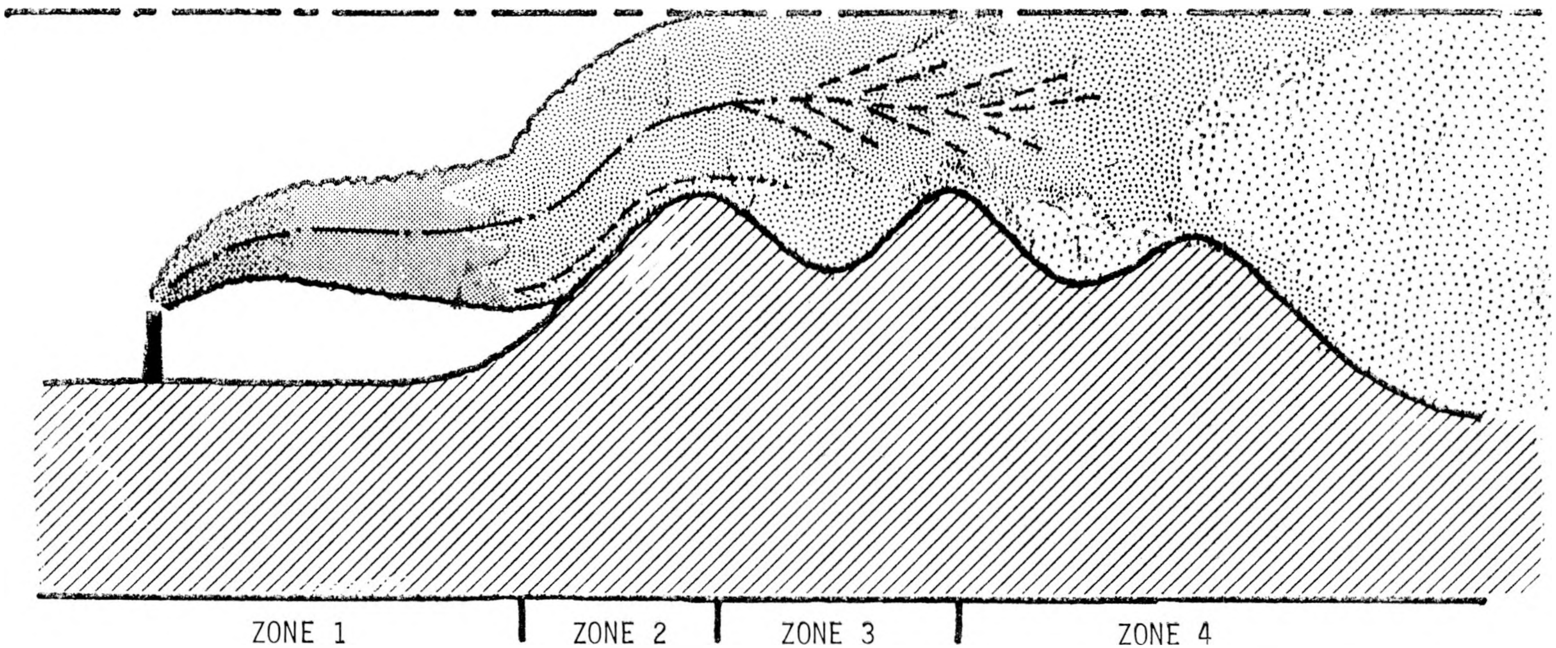
σ_z from equation 3 are possible because σ_z occurs both as a simple multiplier and as part of an argument of an exponential term. The two solutions represent cases in which the exponential term either is close to unity or is decidedly different from unity. When the exponential term differs substantially from one, a Gaussian profile is envisioned between the surface and the plume axis height at H. An appropriate number of σ_z increments span the height interval H. When the exponential term nears unity, the implied vertical profile is quasi-uniform and the resultant σ_z (the larger of the two solutions) is more descriptive of the depth of vertical dispersion. The CIC-derived σ_z-values are also listed in table 5. The credibility of each of the two σ_z (CIC)-values is readily apparent by comparison with σ_z (eq. 5) and by its relative magnitude. The smaller (Gaussian profile) values of σ_z are credible for test 2 and the first distance in test 3; the larger (uniform distribution) values of σ_z are too large to be realistic. At the longer distances for test 3, the larger values (uniform profile) are the credible solutions. Thus, the vertical concentration profiles for test 2 tended to be approximately Gaussian at all downwind distances, while during test 3 the vertical profile was transformed relatively rapidly to a well-mixed, quasi-uniform distribution above and downwind of the elevated terrain.

Equation 3 may also be solved for effective plume-axis height, HC (eq. 8), which is based upon the CIC, and σ_z (eq. 5). A comparison of HC and H supplies some coarse implications about the aerial-to-ground-surface concentration profile. Except in test 3 for distances beyond about 3 km, HC and H are essentially equal and the vertical profile must be approximately Gaussian. These ratios of HC/H average 1.04. Beyond

3 km during test 3, H apparently equals or exceeds HC, if indeed H and HC have any meaning. The ground-level concentrations exceed by about a factor of two the magnitude of the aerial concentrations at heights substantially above the ground surface.

These vertical plume spreading behaviors can be sumarized by the simple physical model shown in figure 20. Four basic zones are identified during the plume discharge and transport across the elevated terrain. In the first zone, the plume effluent is discharged from the chimney, rises, and becomes a "bent-over" plume. In the second zone, the plume is beginning to flow across the steeply rising terrain. This zone is termed the deflection zone. The plume vertical motion is upward in an undulating manner which may be somewhat similar to the shape of the underlying terrain. The last zone is a well-mixed region in which the vertical effluent-concentration distribution is quasi-uniform. In this well-mixed zone, the surface concentrations may exceed aerially sampled concentrations by about a factor of two. Between the well-mixed zone and the deflection zone lies a mixing or transitional zone. In the transitional zone, enhanced mechanical turbulence and turbulent wakes about the ridges and elevated peaks are postulated to mix the plume throughout the vertical dimension more rapidly. As a consequence of this additional mixing, the elevated plume center with its greater effluent concentration becomes rapidly dispersed so that its existence has no practical meaning.

The effect of vertical stability variations may alter the progression of plume dispersion through the four characteristic zones. In the case of a low, vertically capping lid, airborne effluents may remain basically in zone 1 as an elevated, quasi-stagnant layer. In the absence of a capping



ZONE 1: "Simple" elevated plume with buoyant rise, becoming the bent-over form. Near Gaussian vertical distribution.
ZONE 2: Deflection zone with plume tending to parallel ground surface. Near Gaussian vertical distribution.
ZONE 3: Mixing or transitional zone affected by turbulence about the topography. Quasi-Gaussian vertical distribution.
ZONE 4: Well-mixed zone. Quasi-uniform vertical distribution of plume mass.

Plume effluent concentrations are greatest where the shading is the most dense.

Figure 20. Schematic illustration of the dilution of an airborne plume as it approaches and flows over nearby elevated terrain. Four zones of plume behavior and the postulated vertical mass distributions are depicted.

lid, the plume may progress to the deflection zone behavior, but show only slight alteration toward the well-mixed conditions. Finally, with a shallow zone of mixing above the elevated terrain, the plume effluent may rapidly progress into the well-mixed condition after beginning to flow across the elevated terrain.

As a point of interest, numerous plume-rise formulas (summarized by Briggs, 1969, and listed in appendix G) were utilized to see if any formula(s) would provide reasonable estimates of the plume-axis height. The resultant plume heights are plotted in figures 14a through 14h. All formula designations represent plume-axis heights above the terrain at the base of stack number three. No one formula consistently best-estimated the plume height; the rugged topographic setting of the Garfield site represented a great deviation from the relatively flat terrain above which these plume-rise formulas would customarily be utilized. However, the estimates of Briggs (1969), Moses and Carson (1967), and Lucas (1967) most often best-approximated the plume heights relative to the ground height at the release point (see Briggs (1969) equations 4.32', 4.8, and 4.5). Other estimates of plume heights, shown in figures 14a through 14h, were based upon plume-rise equations developed by Berlyard et al. (1964), Holland (1953), Stümke (1963), and a CONCAWE (1966) publication. The Briggs equation is dependent upon downwind distance; the other equations are not.

However, if the predicted plume heights (plume rise plus stack height) above the topographic height at the base of the chimney are added to the varying height of the underlying terrain, the smallest predicted rises would better describe the observed plume heights. Because the topography across which the plumes were transported was usually at a height equal to or greater than the plume height, the plumes essentially tumbled across the elevated terrain relatively close to the ground surface when forced across the elevated terrain. In other words, the plume rise resulting from initial momentum and buoyancy was usually dwarfed by the topographic alterations of the plume height. For the lapse conditions examined at the Garfield site, observations of plume transport across elevated terrain seem to coincide with the simple model proposed in the Report of the Meteorology Work Group, Southwest Energy Study, Appendix E (Van der Hoven et al., 1972), in which plumes roll across the elevated terrain essentially at the ground height.

D. Trajectories

Surface wind data during the Garfield tracer tests are listed in table 6. Appendix D contains a complete list of surface wind observations, including several hours before and after testing. Table 7 summarizes the use of winds measured at the various sensor locations for indication of the plume-centerline impact area. Wind directions and the corresponding equivalent-wind directions to the points of highest sampled ground-level concentrations are given by test number. The summary at the bottom of table 7 suggests that wind data from the ridges to the south-southeast of the smelter and from the lakeside of the plant are most successful. Considerably more data are needed to provide more than the very coarse approximation given here.

During the study, a mobile X-band (M-33 type) tracking radar was used. A series of tetroons were released from the smelter site as a means of identifying typical longer range trajectories (beyond 3 to 5 km) associated

Table 6. Tower Wind Data During SF_6 Tests at KCC Garfield Smelter

		Time (MST)											
Test #	Date	Begin	End	Beach	White Stack	Smelter Peak	Sulfur Peak	Black Rock Ridge	Magna	Litval	Refinery Ridge	Far Ridge	Dike Shack Tower
1	6/15	0957	1057	2707*	3115*		2816		3109*	3309*		3411	
2	6/18	1500	1600	2305	3606*	3210*	3313		3406	3407*	3411*	3410	
3	6/19	1649	1749	2106	3304	3007*	3213		3405	3403*	3308*	3305*	
4	6/22	1534	1634	2308	0508*	2907*	3305		1802*	1709*	3605*		3104
5	6/25	1604	1705	2604	0610*	0207*	0502	1601*	0202*	0104*	0310		3510*
6	6/26	1728	1828	2601	0204*	0506*	3304	0204*	3306	3602*			3506*
7	6/27	1438	1538	2103	3606	2810*		0505*	0305*	3405*			1703*
8	6/28	0517	0552										
9	6/30	2036	2136	1203*	1904*				0000				
10	7/2	1946	2046		1406*				0000				

* Direction varied by more than 90° during test. Direction used is a vector mean direction.

Table 7. Single Wind Stations as Indicators of Plume Impact Area

Test	Direction to highest sampled Concentration	Directions indicated by wind instruments (surface) 1	2	3	4	5	6	7	8	9	10	Pibal
1	288	-	-	-	280	340	270	310	330	310	-	300
2	326, then 344	-	320	340	330	340	230	340	340	360	-	320
3	319	-	300	330	320	330	210	180	170	330	-	330
4	334, then 041	-	290	360	330	-	230	020	010	050	310	030
5	011	160	020	030	050	-	260	330	360	060	350	070
6	330, then 011	020	050	-	330	-	260	030	340	020	350	350
7	357	050	280	-	-	-	210	-	-	360	170	360
Percentage that wind instrument indicated ±10° from actual peak-sampled area		0	17	50	83	67	0	29	29	71	0	86

Sta. code #	Station name	Sta. code #	Station name
1	Black Rock Ridge	6	Beach
2	Smelter Peak	7	Magna
3	Refinery Ridge	8	Litval
4	Sulfur Peak	9	White Stack
5	Far Ridge	10	Dike Shack

with the site. Time and manpower limitations did not permit a large-scale or comprehensive effort in this area; however, the effort did provide a set of trajectories which might be compared with plume photographs and winds to add insight into these longer trajectories. Listed in table 8 is a summary of these balloon flights, giving the date, release times, duration of track, and path of flight. The flight paths, which are depicted in figure 21, typify several local-flow characteristics mentioned by Hardy and Pring (1948) and by Dickson and Ricks (1972). Most common were west-northwesterly flows that carried the balloons eastward as far as Magna, where they turned southward under the influence of up-valley diurnal flows of Salt Lake Valley. Hardy and Pring noted that this pattern was the prevailing daytime path for the plume-carrying layers. The paths made by flights 9 and 11 are the result of up-valley flow resulting from surface heating. The large-scale surface pressure gradients at those times were very small. Flights 5 and 6 were made in post-frontal northwesterly flow.

Flight 2 began on a day when general southerly winds maintained a lee wake adjacent to the northern end of the Oquirrh Mountains. The balloon was initially carried eastward in the eddy flow in the lee of the mountains and then carried well northward under the influence of these southerly winds. This type of eddy circulation was usually observed in the early morning when there were down-valley breezes from the southeast. An example of the plume behavior in such a case is shown in figure 16.

Flights 3, 7, 8, and 14, which terminated in the Tooele Valley, occurred under conditions of morning weak up-valley flow following a period of stagnation in the vicinity of the smelter. The terrain did not allow use of a single radar location suitable for following the balloons

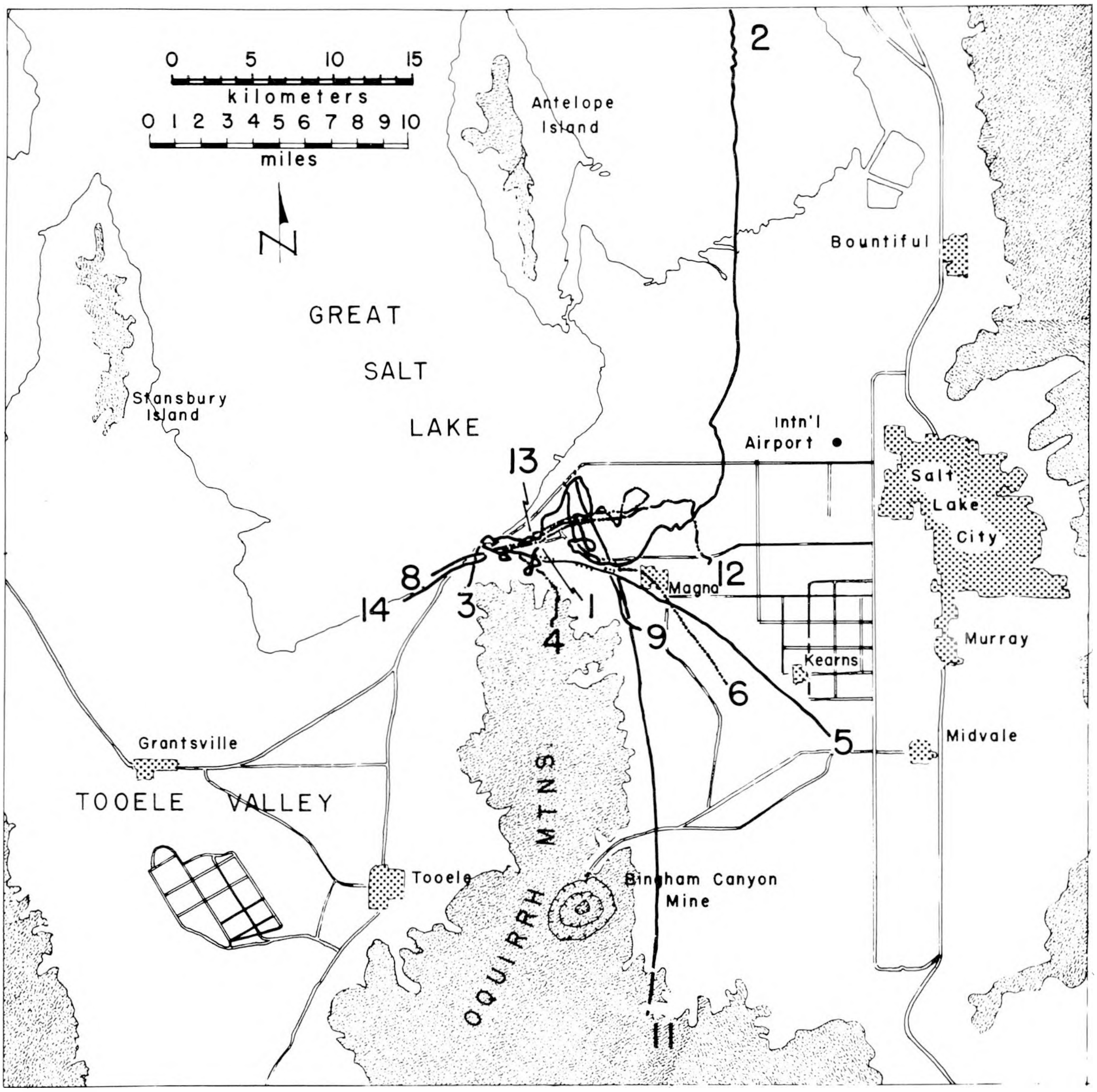


Figure 21. Tetroon trajectories from the Garfield smelter site. Near-stagnation and meandering is shown for many airflows typical of the test site. Numbers at the end of the trajectories identify the various tetroon flights described in table 8.

Table 8. Balloon Trajectory Summary

Flight	Date	Release time*	Release pt.	Length of track (min)	Ending point	Remarks
1	6/12/73	1301	Smelter West gate	69	Smelter Peak	Grounded after stagnating.
2	6/12/73	1442	Smelter West gate	263	Northwest of Ogden	
3	6/13/73	1033	Control trailer	17	Mtns SW of study site	
4	6/13/73	1222	Smelter West gate	111	Upper Kessler Canyon	Large vertical fluctuations, grounded.
5	6/15/73	1002	Stack 3	90	SLC Airport #2	
6	6/15/73	1031	Stack 3	84	Kearns	
7	6/27/73	1131	Stack 3	14	Tooele Valley	
8	6/27/73	1210	Freeway overpass	17	Tooele Valley	Lost behind mountain.
9	6/27/73	1416	Beach wind station	53	S. of Magna	Very low.
10	6/27/73	1550	Beach	8	Beach	Damaged transponder.
11	6/27/73	1602	Beach	104	Camp Williams	
12	6/28/73	0508	Control trailer	298	Magna	Very stagnant.
13	6/28/73	0550	Control trailer	183	Garfield	Returned after circling tailings pond.
14	6/30/73	0724	Control trailer	31	Northern Tooele Valley	Remained near beach.

*Mountain Standard Time.

through the full length of each valley; as a result, tracking on the Tooele side often terminated as the balloons traveled behind the mountains.

Subjective estimates of typical stagnations may be gained by observing the paths of flights 1, 12, and 13. Flight 1, made in the afternoon, moved less than a kilometer from the launch site in an hour. Flights 12 and 13 were made within the very light and variable air motions typical of early morning. (Plume spread and retention in the northern lee of the mountains under similar conditions were pictured in fig. 17).

6. SUMMARY

A series of SF_6-gaseous-tracer measurements have been described in this memorandum. Aerial and ground-level concentrations were collected along with a limited amount of wind and temperature observations over and along the slopes of the Oquirrh Mountains in Utah. These measurements were collected during weakly to moderately unstable atmospheric-diffusion categories (i.e., C and B).

Elevated plume-centerline concentrations appear to be suitably predicted by the Pasquill-Gifford dispersion parameters when the airborne effluents do not flow across the mountainous terrain. Elevated plume-centerline concentrations, measured over the rough terrain, averaged two to four times more dilution than values which would be estimated for corresponding atmospheric conditions over smooth, flat terrain.

Lateral plume spreading was observed to be almost twice as much as would be expected for flat-terrain settings. Several physical processes probably contribute to this greater spreading. As plumes approach steeply rising terrain, there is a tendency for these plumes to be deflected laterally in an attempt to flow out and around the blocking obstacles.

When the lower portions of the looping plumes approach the steeply sloped canyon floor, the descending loops spread laterally by deflection from the ground surface. To some extent, generally enhanced turbulence resulting from the presence of the mountains may contribute to enhanced lateral spreading. Vertical shearing of wind direction with height also disperses plumes extending throughout a considerable vertical depth.

Vertical dispersion at the Garfield site is a very important facet of the ground-level impact of airborne tracer. The vertical spreading and also the resulting ground-level concentrations are greatly affected by the existence and strength of elevated, thermally stable atmospheric layers. Three important categories of plume dispersion are identified. When the stable layer aloft is low enough, strong enough, and when combined with flow-blockage effects of higher terrain, a nearly stagnant air pocket can develop that contains the elevated plume layer. Prolonged ground-surface contact with effluents in this layer is probable for portions of the elevated terrain. Pictures of this condition were presented, but no concentration measurement tests were performed for this layered, stagnant type of plume.

When the stable layer is somewhat higher, the effluent plumes may flow up and across the higher ridges within a vertical layer confined near and below the ridgetops. This trapping of a plume leads to rapid vertical mixing during which the plume tends to be quasi-uniformly mixed in the vertical. Under this situation, ground-level concentrations may exceed concentrations aloft. In the limiting case, ground-reflection effects may yield ground-level concentrations approaching twice the value of concentrations aloft when there is a nearly uniform, vertical concentration profile.

In the absence of appreciable retardation of plume vertical motions, the plumes deflected aloft over the ridges, probably tending to flow along an undulating path similar to the shape of the underlying topography. Under this situation, sampled ground-level concentrations upon the high terrain were essentially equal to concentrations calculated for a Gaussian rate of decrease from the plume center.

The locations of maximum ground-level plume concentrations were predicted best by pibal winds for the elevated layer near the effective plume height. Using surface winds (at the crests of ridges), the plume impact area was identified best by wind measurements collected at the ridgetops to the south-southeast of the Garfield smelter.

It is concluded that atmospheric dilutions of airborne material may be significantly influenced by several special aspects of windflows, vertical stability, atmospheric turbulence, and the emission height of the effluent. The relative importance of each of these factors may be dependent upon subtle influence of the topography or physical setting of the particular site; therefore, the diffusion characteristics may also differ from site to site in subtle ways. Consequently, the estimation of effluent concentrations in rough terrain settings should be undertaken with due caution. The findings at a given site should not be hastily assumed to apply to other locations.

7. ACKNOWLEDGMENTS

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APPENDIX A. MEASURED SF_6-CONCENTRATIONS

This appendix lists all concentrations measured above background levels for individual tests. Most table entries are self-explanatory. Angle is the bearing of the sample from the release point, and distance is measured in meters horizontally from the release point. Elevations are feet above mean sea level (MSL). Duration represents the length of time, in minutes, of sampler collection. H prefixes on sample numbers denote helicopter or aerial samples. G prefixes are for ground samplers. Concentrations are expressed as grams of SF_6 per cubic meter of air at $25^{o}C$.

Figure A-1 shows the locations of ground-level samplers during tests 9 and 10. Test 9 release was made from the furnace building; test 10 source was from near the top of the acid plant stack.

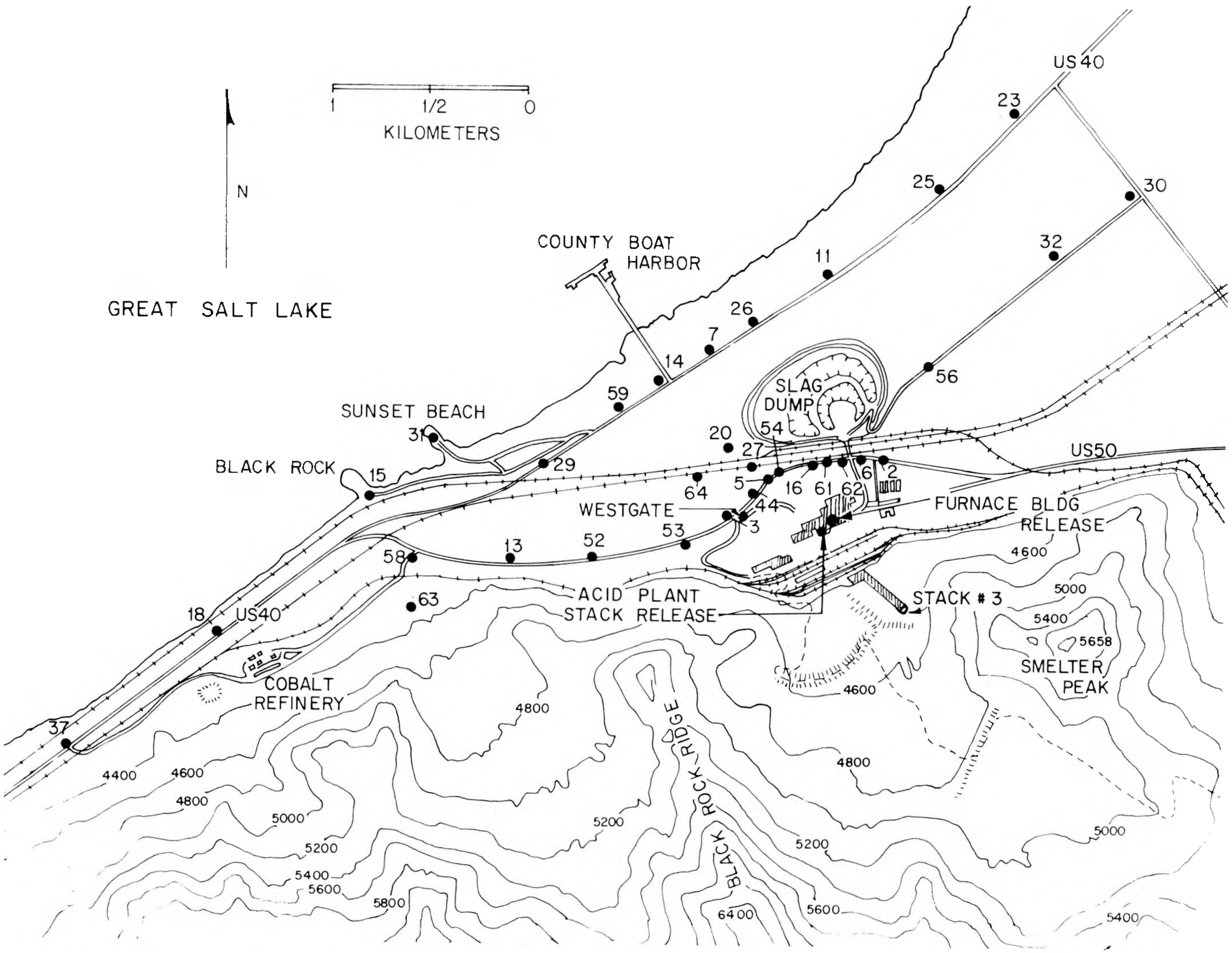

Figure A-1. Location of ground-level samplers during tests 9 and 10.

TEST 1 6/15/73 09:57 - 10:57 MST

STABILITY CLASS C

SAMPLER LOCATION	DISTANCE METERS	ELEVATION FEET	ANGLE DEGREES	CONC. GRAM/M**3	DURATION MIN
H 1	1665.000	6800	119.80	2.040E-05	1.00
H 2	4215.000	5950	115.60	1.880E-05	0.53
H 3	2825.000	5700	106.20	2.550E-06	0.42
H 4	7685.000	6100	110.00	4.440E-07	1.00
H 5	19305.000	6870	122.00	3.240E-07	1.00
H 6	9240.000	5700	119.50	6.360E-07	0.50
H 8	1225.000	5400	96.80	2.500E-06	0.63
H 9	3575.000	6060	116.20	8.460E-06	0.72
H10	8210.000	5800	120.00	8.550E-07	0.68
H11	5190.000	5580	99.00	9.140E-08	1.91

TEST 2 6/18/73 15:00 - 16:00 MST

STABILITY CLASS C

SAMPLER LOCATION	DISTANCE METERS	ELEVATION FEET	ANGLE DEGREES	CONC. GRAM/M**3	DURATION MIN
H 1	784.000	6500	164.00	1.940E-05	0.67
H 2	377.000	5800	161.80	2.690E-05	0.59
H 3	1141.000	6060	131.70	3.690E-05	1.62
H 4	1569.000	6300	130.00	1.240E-06	0.50
H 5	2098.000	6160	138.50	1.950E-06	0.62
H 6	1833.000	5980	148.40	5.610E-06	0.33
H 7	2872.000	6430	149.60	2.700E-06	0.50
H 8	3422.000	6150	156.00	2.080E-06	0.43
H 9	2852.000	6640	142.00	2.710E-06	1.00
H10	5572.000	5600	133.10	1.120E-06	0.83
H11	1905.000	5950	148.20	1.960E-06	0.50
G26	927.000	4800	152.80	3.940E-07	180.00
G58	2129.000	5520	143.80	6.970E-07	138.00
G44	1640.000	5140	164.20	2.670E-07	150.00
G31	4095.000	6000	139.70	2.100E-07	171.00
G27	4553.000	6700	157.10	2.270E-07	169.50
G 2	2984.000	5800	140.70	4.760E-07	150.00
G 5	3809.000	6400	160.70	4.220E-07	157.00
G15	4003.000	6600	148.70	6.000E-07	168.00
G13	2628.000	6200	143.50	6.900E-07	132.00

TEST 3   6/19/73 16:49 - 17:49 MST

STABILITY   CLASS C

SAMPLER LOCATION	DISTANCE METERS	ELEVATION FEET	ANGLE DEGREES	CONC. GRAM/M**3	DURATION MIN
H 1	499.000	5800	143.40	1.030E-05	0.50
H 2	896.000	5720	153.40	4.620E-06	0.40
H 3	2159.000	5740	134.70	4.490E-06	0.59
H 4	2577.000	6040	136.50	7.120E-06	0.57
H 5	2159.000	5980	164.40	4.440E-07	0.33
H 6	4339.000	6140	144.00	1.940E-06	0.75
H 7	3086.000	6520	150.80	8.890E-07	1.00
H 8	1273.000	5830	158.80	6.380E-06	1.00
H 9	1609.000	6210	139.50	4.280E-06	1.18
H10	3025.000	6100	134.80	1.690E-06	0.92
H11	3809.000	6380	135.50	2.270E-06	0.83
H12	2587.000	6550	131.20	3.800E-06	0.67
H13	4716.000	6240	130.00	1.210E-06	0.93
H14	5775.000	7000	128.30	6.020E-07	1.00
G 7	2608.000	5220	126.00	2.220E-06	165.00
G51	1945.000	5160	144.00	1.070E-06	151.00
G58	2129.000	5520	143.80	1.780E-06	151.00
G 2	2984.000	5800	140.70	2.240E-06	228.00
G13	2628.000	6200	143.50	2.160E-06	151.00
G64	3473.000	6470	165.70	4.100E-07	224.00
G52	3025.000	6120	156.00	1.810E-06	222.00
G14	4889.000	5900	136.90	2.630E-06	224.00
G53	2842.000	5860	163.00	9.970E-07	234.00
G63	3687.000	6000	128.20	3.110E-07	228.00
G31	4095.000	6000	139.70	3.590E-06	212.00
G 5	3809.000	6400	160.70	7.490E-07	217.00
G18	4767.000	5580	129.00	4.940E-07	224.00
G21	1500.000	5080	121.00	6.210E-07	208.00
G54	3881.000	7250	179.20	1.940E-07	224.00
G56	2475.000	5800	136.00	1.950E-06	229.00
G27	4553.000	6700	157.10	8.520E-07	221.00

TEST 4 6/22/73 15:34 - 16:34 MST

STABILITY CLASS B

SAMPLER LOCATION	DISTANCE METERS	ELEVATION FEET	ANGLE DEGREES	CONC. GRAM/M**3	DURATION MIN
H 1	295.000	5100	138.30	3.150E-05	0.50
H 2	550.000	5300	150.40	1.640E-05	1.00
H 3	754.000	5150	180.00	3.400E-07	0.72
H 4	1890.000	6150	170.50	1.220E-07	0.59
H 5	825.000	5100	219.40	6.950E-06	1.00
H 6	1160.000	5750	198.80	8.200E-07	1.05
H 7	876.000	5150	197.20	2.170E-05	0.42
H 8	1490.000	5760	224.20	1.230E-06	1.00
H 9	794.000	5100	233.00	9.840E-06	1.00
H10	1450.000	5650	217.60	1.120E-06	1.00
H11	2360.000	5800	223.30	8.630E-08	0.97
G20	1620.000	6020	215.20	1.960E-07	186.00
G32	2231.000	6780	201.00	1.830E-07	178.00
G31	4095.000	6000	139.70	3.880E-08	173.00
G64	3473.000	6470	165.70	1.840E-07	177.00
G56	2475.000	5800	136.00	1.700E-07	177.00
G52	3025.000	6120	156.00	1.980E-07	176.00
G 4	1670.000	5510	186.50	2.350E-07	135.00
G53	2842.000	5860	163.00	3.200E-07	189.00
G44	1640.000	5140	164.20	3.430E-07	177.00
G16	2424.000	6950	186.90	1.020E-07	175.00
G61	2893.000	6380	178.50	2.070E-07	174.00
G29	1426.000	5220	243.20	8.210E-08	90.00
G26	927.000	4800	152.80	3.710E-07	177.00
G21	1500.000	5080	121.00	4.640E-08	193.00
G51	1945.000	5160	144.00	2.610E-07	110.00
G60	642.000	5280	100.30	4.250E-08	136.00
G58	2129.000	5520	143.80	3.490E-07	123.00

TEST 5 6/25/73 16:04 - 17:05 MST

STABILITY CLASS C

SAMPLER LOCATION	DISTANCE METERS	ELEVATION FEET	ANGLE DEGREES	CONC. GRAM/M**3	DURATION MIN
H 2	387.000	5200	245.50	3.880E-05	0.83
H 3	2200.000	5400	238.50	2.390E-06	1.02
H 4	1320.000	5450	230.30	6.780E-06	1.03
H 5	2370.000	5720	244.50	4.360E-06	0.67
H 8	632.000	5800	234.40	3.230E-05	1.13
H 9	3340.000	5750	260.70	1.820E-06	1.00
H10	4550.000	5800	256.00	1.520E-06	1.00
G20	1620.000	6020	215.20	5.750E-07	81.00
G32	2231.000	6780	201.00	1.530E-07	133.00
G25	1070.000	4920	201.80	1.980E-06	162.00

TEST 6 6/26/73 17:28 - 18:28 MST

STABILITY CLASS C

SAMPLER LOCATION	DISTANCE METERS	ELEVATION FEET	ANGLE DEGREES	CONC. GRAM/M**3	DURATION MIN
H 1	703.000	5300	166.00	2.260E-05	0.80
H 2	1250.000	5540	159.80	7.280E-06	0.83
H 3	2300.000	5740	161.40	1.820E-07	1.00
H 4	1290.000	7200	142.40	8.430E-08	1.00
H 5	2760.000	7160	150.00	7.240E-07	1.00
H 6	4580.000	6720	146.00	2.730E-08	1.03
H 7	3750.000	6600	167.20	3.630E-07	1.00
H 8	3120.000	6600	168.20	1.310E-06	1.00
H 9	1040.000	6360	162.30	6.470E-06	1.00
H10	3860.000	6300	146.20	1.220E-06	1.33
H11	1666.000	5500	197.00	9.280E-07	0.72
H12	3060.000	6800	175.00	1.170E-06	1.00
G63	3687.000	6000	128.20	1.990E-07	116.00
G62	3259.000	5800	121.00	2.250E-07	176.00
G 5	3809.000	6400	160.70	7.670E-07	151.00
G27	4553.000	6700	157.10	9.640E-07	149.00
G65	8220.000	4440	110.20	5.830E-08	180.00
G 7	2608.000	5220	126.00	5.770E-08	196.00
G58	2129.000	5520	143.80	5.840E-08	144.00
G 4	1670.000	5510	186.50	8.540E-07	133.00
G31	4095.000	6000	139.70	5.400E-08	160.00
G32	2231.000	6780	201.00	9.640E-07	172.00
G 6	1894.000	5880	167.80	1.820E-07	164.00
G53	2842.000	5860	163.00	9.270E-07	188.00
G52	3025.000	6120	156.00	8.400E-07	188.00
G 3	2292.000	5680	167.80	4.160E-07	188.00
G16	2424.000	6950	186.90	1.060E-06	187.00
G64	3473.000	6470	165.70	5.420E-07	163.00
G25	1070.000	4920	201.80	2.450E-07	164.00
G61	2862.000	6380	178.50	2.380E-07	163.00

TEST 7 6/27/73 14:38 - 15:38 MST

STABILITY CLASS B

SAMPLER LOCATION	DISTANCE METERS	ELEVATION FEET	ANGLE DEGREES	CONC. GRAM/M**3	DURATION MIN
H 1	825.000	6200	182.80	1.490E-05	1.00
H 4	2510.000	6940	179.80	2.030E-06	1.00
H 5	1520.000	5600	185.00	1.790E-06	1.00
H 6	1640.000	6100	181.00	9.630E-07	1.00
H 7	1250.000	5750	173.20	5.380E-06	1.00
H 8	367.000	5400	179.20	2.620E-05	0.67
H10	458.000	4990	221.00	2.990E-05	1.17
H11	1470.000	5300	188.40	5.630E-06	1.08
H12	1680.000	5800	189.50	3.940E-06	1.50
H13	3720.000	7060	176.10	1.110E-06	0.83
H14	4690.000	7400	178.20	8.220E-07	1.00
G 4	1670.000	5510	186.50	1.030E-06	185.00
G26	927.000	4800	152.80	8.510E-07	185.00
G32	2231.000	6780	201.00	2.650E-07	189.00
G 3	2292.000	5680	167.80	7.460E-07	189.00
G61	2893.000	6380	178.50	8.360E-07	189.00
G53	2842.000	5860	163.00	3.590E-07	186.00
G52	3025.000	6120	156.00	2.180E-07	179.00
G64	3473.000	6470	165.70	3.170E-07	189.00
G44	1640.000	5140	164.20	7.100E-07	196.00
G16	2424.000	6950	186.90	8.960E-07	187.00
G 6	1894.000	5880	167.80	1.150E-06	196.00
G20	1620.000	6020	215.20	1.580E-07	191.00

TEST 9 6/30/73 20:36 - 21:36 MST

STABILITY CLASS D

SAMPLER LOCATION	DISTANCE METERS	ELEVATION FEET	ANGLE DEGREES	CONC. GRAM/M**3	DURATION MIN
H 1	10.000	4300	180.00	7.460E-06	1.00
H 2	10.000	4300	180.00	5.290E-04	1.00
H 3	336.000	4440	342.50	4.460E-07	1.00
H 4	968.000	4570	337.00	1.560E-05	1.00
H 5	1212.000	4700	3.00	1.290E-06	1.00
H 6	1100.000	4400	337.00	2.350E-07	1.00
H 7	1395.000	4400	294.20	3.170E-07	1.00
H 8	1314.000	4400	304.60	4.440E-07	1.00
H 9	1314.000	4600	304.60	6.280E-07	1.00
H10	1538.000	4360	351.00	7.280E-07	1.00
G15	2383.000	4210	270.00	2.470E-07	100.00
G58	2282.000	4270	264.50	1.330E-06	163.00
G 2	2282.000	4270	264.50	3.970E-08	105.00
G 5	407.000	4250	310.00	3.100E-06	137.00
G16	418.000	4250	327.00	4.890E-06	126.00
G56	957.000	4225	28.60	4.510E-06	121.00
G06	397.000	4245	14.30	6.430E-05	111.00
G52	377.000	4240	356.20	5.960E-07	115.00
G51	397.000	4240	337.50	1.790E-06	122.00
G32	1477.000	4220	35.00	4.140E-07	91.00
G52	947.000	4235	265.30	2.410E-06	162.00
G13	1844.000	4260	263.80	3.730E-06	165.00
G64	866.000	4225	285.50	7.850E-07	114.00
G53	947.000	4235	265.30	1.680E-06	147.00
G15	2383.000	4210	270.00	3.940E-07	100.00
G 3	581.000	4236	275.30	4.460E-06	148.00
G18	3331.000	4240	260.00	1.930E-07	139.00
G44	489.000	4230	298.70	3.350E-06	147.00
G14	1222.000	4212	308.80	1.910E-07	88.00
G25	1935.000	4210	16.00	6.110E-08	132.00
G20	723.000	4220	310.60	1.240E-06	147.00
G 7	1182.000	4210	325.20	5.330E-08	63.00
G26	1202.000	4230	340.60	1.080E-07	73.00
G23	2597.000	4208	23.50	1.590E-07	51.00
G29	1681.000	4215	282.00	2.770E-07	100.00
G59	1342.000	4210	300.30	3.210E-07	116.00

TEST 10 7/2/73 19:46 - 20:46 MST

STABILITY CLASS F

SAMPLER LOCATION	DISTANCE METERS	ELEVATION FEET	ANGLE DEGREES	CONC. GRAM/M**3	DURATION MIN
H 1	132.000	4480	226.00	3.620E-05	1.00
H 2	367.000	4500	241.00	2.700E-05	1.00
H 3	499.000	4400	217.80	4.490E-05	1.00
H 4	713.000	4660	240.00	2.000E-05	1.00
H 5	642.000	4500	231.20	2.680E-05	1.00
H 6	622.000	4400	318.00	1.240E-07	1.00
H 7	1477.000	5000	239.20	2.170E-05	1.00
H 8	1477.000	4800	239.20	8.560E-08	1.00
H 9	1334.000	5100	208.20	4.700E-08	1.00
H10	1660.000	4280	257.70	1.330E-07	1.00
H11	2394.000	4640	246.30	3.830E-07	1.00
H12	2445.000	4675	270.30	9.020E-08	1.00
H13	1681.000	4720	307.20	6.790E-08	1.00
H14	3596.000	4800	253.00	1.880E-07	1.00
H15	4767.000	5000	248.70	4.520E-07	1.00
H16	5225.000	5560	260.60	7.580E-08	1.00
H17	2638.000	5420	271.70	5.720E-08	1.00
G63	2179.000	4355	251.40	1.480E-06	115.00
G 2	519.000	4240	65.00	2.690E-07	122.00
G 3	387.000	4236	254.30	4.770E-07	137.00
G26	998.000	4208	348.00	1.640E-07	223.00
G11	234.000	4230	279.60	6.850E-08	221.00
G18	3178.000	4240	255.80	4.360E-07	151.00
G32	1457.000	4220	45.30	5.630E-08	102.00
G 5	183.000	4250	304.30	2.010E-07	143.00
G14	947.000	4212	309.00	5.000E-07	224.00
G64	642.000	4225	275.70	4.380E-07	183.00
G29	1426.000	4215	276.60	1.220E-07	224.00
G20	448.000	4220	310.30	2.460E-07	140.00
G44	234.000	4230	279.60	2.360E-07	138.00
G16	173.000	4250	351.70	1.990E-07	135.00
G27	316.000	4230	292.70	2.030E-07	138.00
G52	1253.000	4250	253.40	2.280E-06	124.00
G 6	367.000	4245	55.20	5.500E-07	125.00
G54	194.000	4240	321.80	2.050E-07	138.00
G13	1607.000	4260	256.50	1.950E-06	134.00
G53	774.000	4235	251.20	4.120E-06	135.00
G37	4176.000	4240	249.90	8.900E-07	153.00
G23	2506.000	4208	29.30	4.590E-08	222.00
G 7	927.000	4210	329.10	2.300E-07	223.00
G58	2108.000	4270	258.70	9.910E-07	133.00
G31	1986.000	4200	275.60	1.480E-06	222.00
G30	2434.000	4220	46.40	2.190E-07	130.00
G15	2373.000	4210	270.00	2.680E-07	101.00
G59	1080.000	4210	297.20	8.770E-07	262.00

APPENDIX B. PIBAL OBSERVATIONS

WEST GATE THEODOLITE PIBAL 6/8/73 0930 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	35.0	4.0	4240.			
1.0	59.5	3.0	4948.	1508.	50.2	59.5
2.0	87.8	2.0	5598.	1706.	55.0	70.7
3.0	97.6	3.0	6247.	1904.	53.3	80.9
4.0	123.7	2.8	6867.	2093.	53.5	92.2
5.0	188.6	2.1	7458.	2273.	58.9	104.3
6.0	219.5	2.4	8048.	2453.	64.8	118.0
7.0	223.0	1.9	8638.	2633.	68.5	130.2
8.0	257.5	2.0	9229.	2813.	73.0	142.1
9.0	269.4	1.8	9819.	2993.	76.5	154.3
10.0	279.2	2.3	10410.	3173.	79.5	172.9
11.0	289.2	4.0	11000.	3353.	81.1	214.0
12.0	302.7	4.5	11590.	3533.	79.3	253.1
13.0	295.6	5.2	12181.	3713.	74.2	270.9
14.0	274.3	7.1	12771.	3893.	66.9	272.2
15.0	270.1	9.7	13362.	4073.	58.7	271.5
16.0	271.1	11.8	13952.	4253.	51.0	271.4
17.0	275.7	10.6	14542.	4433.	46.0	272.3
18.0	281.5	8.3	15133.	4612.	43.3	273.6
19.0	289.2	8.2	15723.	4792.	41.2	275.5
20.0	293.7	7.9	16314.	4972.	39.6	277.4

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	44.	4.	5000	62.	3.
5500	84.	2.	6000	94.	3.
6500	108.	3.	7000	138.	3.
7500	191.	2.	8000	217.	2.
8500	222.	2.	9000	264.	2.
10000	272.	2.	11000	289.	4.
12000	298.	5.	13000	273.	8.
14000	271.	12.	15000	280.	9.
16000	291.	8.			

WEST GATE THEODOLITE PIBAL 6/8/73 1130 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	360.0	4.0	4240.			
1.0	357.0	3.6	4948.	1508.	45.0	357.0
2.0	79.2	1.1	5598.	1706.	60.6	12.7
3.0	84.8	2.7	6247.	1904.	62.1	41.6
4.0	135.5	3.6	6867.	2093.	64.8	76.5
5.0	227.0	4.0	7458.	2273.	78.2	111.7
6.0	221.4	4.4	8048.	2453.	76.7	176.8
7.0	237.8	4.9	8638.	2633.	70.0	208.3
8.0	245.3	5.0	9229.	2813.	63.7	222.3
9.0	235.2	5.3	9819.	2993.	58.0	226.1
10.0	241.4	4.5	10410.	3173.	54.8	229.2
11.0	262.6	3.3	11000.	3353.	54.0	233.4
12.0	252.6	5.4	11590.	3533.	51.1	236.8
13.0	256.0	8.2	12181.	3713.	46.7	240.9
14.0	257.9	10.7	12771.	3893.	41.9	244.6
15.0	261.2	12.5	13362.	4073.	37.5	248.0
16.0	258.8	12.1	13952.	4253.	34.3	249.8
17.0	262.6	10.4	14542.	4433.	32.4	251.4
18.0	264.0	8.7	15133.	4612.	31.3	252.6
19.0	274.4	7.3	15723.	4792.	30.8	254.2
20.0	276.2	6.3	16314.	4972.	30.6	255.5

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD
	DEG	MPS
4500	359.	4.
5500	67.	1.
6500	105.	3.
7500	227.	4.
8500	234.	5.
10000	237.	5.
12000	255.	7.
14000	259.	12.
16000	275.	7.

HGT	DIR	SPD
	DEG	MPS
5000	3.	3.
6000	83.	2.
7000	156.	4.
8000	222.	4.
9000	242.	5.
11000	263.	3.
13000	259.	11.
15000	264.	9.

WEST GATE THEODOLITE PIBAL 6/11/73 1100 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	320.0	0.9	4240.			
1.0	320.0	1.3	4948.	1508.	70.0	320.0
2.0	307.1	0.2	5598.	1706.	78.0	318.6
3.0	104.2	0.7	6247.	1904.	84.6	343.2
4.0	219.3	1.9	6867.	2093.	83.3	250.0
5.0	234.7	4.1	7458.	2273.	71.0	238.9
6.0	232.8	4.8	8048.	2453.	61.7	236.1
7.0	227.2	5.3	8638.	2633.	55.0	233.1
8.0	227.6	5.9	9229.	2813.	49.7	231.6
9.0	233.8	6.5	9819.	2993.	45.4	232.1
10.0	239.7	6.3	10410.	3173.	42.5	233.5
11.0	245.8	5.1	11000.	3353.	41.2	235.1
12.0	254.5	4.6	11590.	3533.	40.6	237.1
13.0	260.4	4.9	12181.	3713.	40.0	239.4
14.0	263.2	6.3	12771.	3893.	38.8	242.1

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD
	DEG	MPS
4500	320.	1.
5500	309.	0.
6500	151.	1.
7500	235.	4.
8500	228.	5.
10000	236.	6.
12000	259.	5.

HGT	DIR	SPD
	DEG	MPS
5000	319.	1.
6000	44.	1.
7000	223.	2.
8000	233.	5.
9000	227.	6.
11000	246.	5.

WEST GATE THEODOLITE PIBAL 6/11/73 1445 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	310.0	1.3	4240.			
1.0	355.0	1.6	4948.	1508.	66.7	355.0
2.0	5.3	0.6	5598.	1706.	72.7	357.9
3.0	280.2	1.5	6247.	1904.	74.3	327.3
4.0	273.2	0.9	6867.	2093.	75.4	315.1
5.0	215.2	3.1	7458.	2273.	75.5	269.3
6.0	228.8	5.5	8048.	2453.	64.7	246.3
7.0	243.9	5.4	8638.	2633.	57.0	245.4
8.0	249.1	5.4	9229.	2813.	51.9	246.4
9.0	240.6	5.8	9819.	2993.	47.9	245.1
10.0	233.2	6.8	10410.	3173.	44.1	242.6
11.0	243.2	7.2	11000.	3353.	41.0	242.7
12.0	242.7	7.6	11590.	3533.	38.4	242.7
13.0	238.7	6.8	12181.	3713.	36.8	242.2
14.0	236.0	6.9	12771.	3893.	35.5	241.5
15.0	230.6	7.5	13362.	4073.	34.2	240.3
16.0	225.9	9.2	13952.	4253.	32.6	238.6
17.0	224.9	8.8	14542.	4433.	31.4	237.2
18.0	222.0	8.1	15133.	4612.	30.6	235.9
19.0	215.4	5.4	15723.	4792.	30.6	234.8
20.0	191.4	4.7	16314.	4972.	31.0	233.0

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	327.	1.	5000	356.	1.
5500	4.	1.	6000	313.	1.
6500	277.	1.	7000	260.	1.
7500	216.	3.	8000	228.	5.
8500	240.	5.	9000	247.	5.
10000	238.	6.	11000	243.	7.
12000	240.	7.	13000	234.	7.
14000	226.	9.	15000	223.	8.
16000	204.	5.			

WEST GATE THEODOLITE PIBAL 6/12/73 0915 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	10.0	1.3	4240.			
1.0	349.0	2.1	4948.	1508.	60.0	349.0
2.0	336.4	0.7	5598.	1706.	68.5	346.0
3.0	224.2	3.1	6247.	1904.	74.3	277.8
4.0	183.7	4.2	6867.	2093.	69.9	219.5
5.0	213.3	4.3	7458.	2273.	60.8	216.6
6.0	234.9	5.2	8048.	2453.	53.8	223.2
7.0	237.8	5.2	8638.	2633.	49.3	227.1
8.0	236.1	5.8	9229.	2813.	45.4	229.2
9.0	237.3	6.6	9819.	2993.	41.9	230.9
10.0	238.9	7.3	10410.	3173.	38.9	232.4
11.0	240.2	7.8	11000.	3353.	36.4	233.7
12.0	235.6	9.0	11590.	3533.	33.9	234.0
13.0	229.2	9.5	12181.	3713.	31.8	233.3
14.0	223.9	8.6	12771.	3893.	30.5	232.2
15.0	216.9	6.9	13362.	4073.	30.0	230.9
16.0	195.4	5.9	13952.	4253.	30.1	228.6
17.0	183.1	5.2	14542.	4433.	30.5	226.2
18.0	176.6	6.0	15133.	4612.	30.8	223.4
19.0	170.9	6.2	15723.	4792.	31.1	220.5
20.0	177.1	6.2	16314.	4972.	31.2	218.1

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	2.	2.	5000	348.	2.
5500	338.	1.	6000	267.	2.
6500	208.	4.	7000	190.	4.
7500	215.	4.	8000	233.	5.
8500	237.	5.	9000	237.	6.
10000	238.	7.	11000	240.	8.
12000	231.	9.	13000	221.	8.
14000	194.	6.	15000	178.	6.
16000	174.	6.			

WEST GATE THEODOLITE PIBAL 6/12/73 1545 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	350.0	4.5	4240.			
1.0	321.2	3.1	4948.	1508.	49.2	321.2
2.0	278.5	2.6	5598.	1706.	52.2	301.7
3.0	286.4	0.7	6247.	1904.	59.5	300.0
4.0	263.0	0.4	6867.	2093.	64.5	297.6
5.0	98.8	1.9	7458.	2273.	74.3	305.3
6.0	119.4	2.6	8048.	2453.	83.9	312.6

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	339.	4.	5000	318.	3.
5500	285.	3.	6000	283.	1.
6500	277.	1.	7000	226.	1.
7500	100.	2.	8000	118.	3.

WEST GATE THEODOLITE PIBAL 6/13/73 0800 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	350.0	0.9	4240.			
1.0	4.5	1.9	4948.	1508.	62.0	4.5
2.0	2.2	0.3	5598.	1706.	72.3	4.2
3.0	89.1	0.0	6247.	1904.	77.8	5.3
4.0	214.0	3.0	6867.	2093.	83.7	260.0
5.0	232.0	4.1	7458.	2273.	71.6	239.3
6.0	234.5	4.6	8048.	2453.	62.7	237.1
7.0	223.3	4.7	8638.	2633.	56.9	232.7
8.0	221.5	5.6	9229.	2813.	51.6	229.6
9.0	213.2	5.9	9819.	2993.	47.7	225.9
10.0	198.5	6.3	10410.	3173.	44.8	220.6
11.0	192.3	6.3	11000.	3353.	42.7	216.0
12.0	190.9	6.6	11590.	3533.	40.8	212.3
13.0	188.7	6.7	12181.	3713.	39.2	209.2
14.0	190.5	7.4	12771.	3893.	37.5	206.8
15.0	191.7	9.7	13362.	4073.	35.1	204.6
16.0	193.4	12.6	13952.	4253.	32.2	202.8
17.0	190.6	13.7	14542.	4433.	29.7	201.0
18.0	190.6	14.3	15133.	4612.	27.6	199.6
19.0	191.5	15.0	15723.	4792.	25.8	198.6
20.0	189.7	15.3	16314.	4972.	24.3	197.6

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	355.	1.	5000	4.	2.
5500	3.	1.	6000	56.	0.
6500	140.	1.	7000	218.	3.
7500	232.	4.	8000	234.	5.
8500	226.	5.	9000	222.	5.
10000	209.	6.	11000	192.	6.
12000	189.	7.	13000	191.	8.
14000	193.	13.	15000	191.	14.
16000	191.	15.			

WEST GATE THEODOLITE PIBAL 6/13/73 1130 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	350.0	2.7	4240.			
1.0	345.0	2.8	4948.	1508.	52.5	345.0
2.0	345.2	1.8	5598.	1706.	56.5	345.1
3.0	16.6	1.4	6247.	1904.	60.2	352.5
4.0	66.8	1.1	6867.	2093.	65.0	2.2
5.0	120.2	3.2	7458.	2273.	71.4	33.6
6.0	159.6	2.8	8048.	2453.	77.0	64.4
7.0	161.8	3.0	8638.	2633.	77.3	100.3
8.0	169.2	3.5	9229.	2813.	74.4	127.6
9.0	180.8	3.1	9819.	2993.	71.9	143.1
10.0	180.3	2.8	10410.	3173.	69.6	151.6
11.0	160.6	3.3	11000.	3353.	66.5	153.6
12.0	178.4	3.6	11590.	3533.	63.9	158.4
13.0	189.0	3.7	12181.	3713.	61.9	163.4
14.0	175.4	5.6	12771.	3893.	58.0	165.9
15.0	184.4	7.8	13362.	4073.	53.3	170.0
16.0	169.4	8.8	13952.	4253.	48.7	169.9
17.0	172.4	10.3	14542.	4433.	44.3	170.4

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	348.	3.	5000	345.	3.
5500	345.	2.	6000	5.	2.
6500	37.	1.	7000	79.	2.
7500	123.	3.	8000	156.	3.
8500	161.	3.	9000	166.	3.
10000	181.	3.	11000	161.	3.
12000	186.	4.	13000	179.	6.
14000	170.	9.			

WEST GATE THEODOLITE PIBAL 6/15/73 1005 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	285.0	5.8	4240.			
1.0	290.3	7.5	4948.	1508.	25.6	290.3
2.0	299.3	7.8	5598.	1706.	24.3	294.9
3.0	300.6	5.5	6247.	1904.	26.2	296.4
4.0	304.9	4.4	6867.	2093.	28.0	297.9
5.0	303.0	5.4	7458.	2273.	28.2	298.8
6.0	293.9	5.2	8048.	2453.	28.5	298.1
7.0	294.2	6.6	8638.	2633.	27.9	297.5
8.0	294.0	7.1	9229.	2813.	27.2	297.0
9.0	297.0	7.3	9819.	2993.	26.6	297.0
10.0	304.8	8.3	10410.	3173.	25.8	298.0
11.0	307.7	8.2	11000.	3353.	25.2	299.1
12.0	305.4	9.0	11590.	3533.	24.5	299.8

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	287.	6.	5000	291.	8.
5500	298.	8.	6000	300.	6.
6500	302.	5.	7000	304.	5.
7500	302.	5.	8000	295.	5.
8500	294.	6.	9000	294.	7.
10000	299.	8.	11000	308.	8.

WEST GATE THEODOLITE PIBAL 6/15/73 1057 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	280.0	4.9	4240.			
1.0	294.7	4.6	4948.	1508.	38.3	294.7
2.0	298.2	6.5	5598.	1706.	32.0	296.8
3.0	288.7	5.8	6247.	1904.	31.2	294.0
4.0	301.5	4.9	6867.	2093.	31.6	295.7
5.0	299.9	5.8	7458.	2273.	30.7	296.6
6.0	290.8	5.7	8048.	2453.	30.2	295.6
7.0	279.2	5.5	8638.	2633.	30.1	293.3
8.0	273.6	6.8	9229.	2813.	29.4	290.4
9.0	285.9	7.0	9819.	2993.	28.6	289.8
10.0	292.4	9.3	10410.	3173.	27.1	290.2
11.0	290.9	9.5	11000.	3353.	25.9	290.3
12.0	289.5	10.5	11590.	3533.	24.7	290.2

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	285.	5.	5000	295.	5.
5500	298.	6.	6000	292.	6.
6500	294.	5.	7000	301.	5.
7500	299.	6.	8000	292.	6.
8500	282.	6.	9000	276.	6.
10000	288.	8.	11000	291.	9.

WEST GATE THEODOLITE PIBAL 6/15/73 1330 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	260.0	3.1	4240.			
1.0	267.0	1.8	4948.	1508.	64.0	267.0
2.0	298.4	2.7	5598.	1706.	58.0	286.2
3.0	317.4	3.9	6247.	1904.	52.1	301.1
4.0	310.3	6.4	6867.	2093.	43.1	305.2
5.0	287.1	6.1	7458.	2273.	39.0	299.8

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	263.	3.	5000	269.	2.
5500	294.	3.	6000	310.	3.
6500	315.	5.	7000	305.	6.

WEST GATE THECDOLITE PIBAL 6/15/73 1500 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	325.0	4.5	4240.			
1.0	322.8	4.0	4948.	1508.	42.0	322.8
2.0	304.8	1.3	5598.	1706.	52.5	318.3
3.0	305.0	1.4	6247.	1904.	57.0	315.6
4.0	278.2	3.0	6867.	2093.	55.4	304.1
5.0	271.5	4.5	7458.	2273.	51.1	293.6
6.0	268.7	4.9	8048.	2453.	47.4	286.9
7.0	264.7	5.2	8638.	2633.	44.5	281.9
8.0	269.0	5.2	9229.	2813.	42.3	279.5
9.0	271.1	5.6	9819.	2993.	40.3	278.1
10.0	266.7	7.5	10410.	3173.	37.5	276.0
11.0	263.8	8.5	11000.	3353.	34.9	273.9
12.0	262.9	8.4	11590.	3533.	33.0	272.3
13.0	253.1	10.4	12181.	3713.	30.9	269.4
14.0	250.6	11.0	12771.	3893.	29.1	266.8
15.0	253.8	11.8	13362.	4073.	27.4	265.1
16.0	261.1	12.7	13952.	4253.	25.8	264.6
17.0	256.6	12.9	14542.	4433.	24.5	263.7
18.0	245.4	11.1	15133.	4612.	23.8	262.1
19.0	241.4	9.3	15723.	4792.	23.5	260.7
20.0	251.4	7.7	16314.	4972.	23.4	260.2

MANDATCRY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	324.	4.	5000	321.	4.
5500	308.	2.	6000	305.	1.
6500	294.	2.	7000	277.	3.
7500	271.	4.	8000	269.	5.
8500	266.	5.	9000	267.	5.
10000	270.	6.	11000	264.	9.
12000	256.	10.	13000	252.	11.
14000	261.	13.	15000	248.	12.
16000	246.	9.			

WEST GATE THEODOLITE PIBAL 6/16/73 0800 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	130.0	0.4	4240.			
1.0	28.2	1.6	4948.	1508.	66.0	28.2
2.0	111.9	1.8	5598.	1706.	69.8	73.1
3.0	190.5	2.5	6247.	1904.	75.6	131.2
4.0	224.1	5.4	6867.	2093.	66.2	197.7
5.0	223.8	5.7	7458.	2273.	55.4	210.5
6.0	229.3	5.4	8048.	2453.	49.5	216.6
7.0	241.1	6.1	8638.	2633.	45.2	223.1
8.0	253.1	7.2	9229.	2813.	41.5	230.3
9.0	257.2	8.1	9819.	2993.	38.2	236.1

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	93.	1.	5000	35.	2.
5500	99.	2.	6000	161.	2.
6500	204.	4.	7000	224.	5.
7500	224.	6.	8000	229.	5.
8500	238.	6.	9000	248.	7.

WEST GATE THEODOLITE PIBAL 6/16/73 0925 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	300.0	0.4	4240.			
1.0	302.0	2.0	4948.	1508.	61.5	302.0
2.0	214.8	0.3	5598.	1706.	73.9	293.3
3.0	182.5	0.5	6247.	1904.	79.6	278.8
4.0	184.8	2.2	6867.	2093.	78.1	226.4
5.0	196.1	5.7	7458.	2273.	63.2	206.0
6.0	220.0	6.6	8048.	2453.	52.7	212.2
7.0	224.8	7.6	8638.	2633.	45.1	216.5
8.0	238.7	7.1	9229.	2813.	41.2	221.8
9.0	247.5	7.1	9819.	2993.	38.6	226.8
10.0	247.3	7.4	10410.	3173.	36.4	230.3
11.0	248.8	8.0	11000.	3353.	34.4	233.2
12.0	246.1	8.2	11590.	3533.	32.7	235.0

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	301.	1.	5000	295.	2.
5500	228.	1.	6000	195.	0.
6500	183.	1.	7000	187.	3.
7500	198.	6.	8000	218.	7.
8500	224.	7.	9000	233.	7.
10000	247.	7.	11000	249.	8.

WEST GATE THEODOLITE PIBAL 6/16/73 1215 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	275.0	5.8	4240.			
1.0	271.6	4.6	4948.	1508.	38.0	271.6
2.0	266.1	4.1	5598.	1706.	38.5	269.0
3.0	260.4	3.3	6247.	1904.	40.4	266.6
4.0	339.7	2.4	6867.	2093.	46.0	276.9
5.0	272.2	2.3	7458.	2273.	47.2	276.2

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	274.	5.	5000	271.	5.
5500	267.	4.	6000	263.	4.
6500	293.	3.	7000	325.	2.

WEST GATE THEODOLITE PIBAL 6/16/73 1225 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	270.0	5.4	4240.			
1.0	272.8	3.7	4948.	1508.	44.2	272.8
2.0	303.2	1.3	5598.	1706.	55.0	280.4
3.0	181.3	2.4	6247.	1904.	63.7	252.4
4.0	219.9	5.1	6867.	2093.	53.8	236.0
5.0	227.9	5.7	7458.	2273.	46.6	233.0
6.0	218.1	6.1	8048.	2453.	42.1	228.8
7.0	212.6	10.4	8638.	2633.	35.3	223.5
8.0	208.6	12.8	9229.	2813.	29.9	219.2
9.0	214.5	11.8	9819.	2993.	26.9	218.2
10.0	222.4	9.3	10410.	3173.	25.7	218.8
11.0	228.3	16.3	11000.	3353.	22.9	220.7

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	271.	5.	5000	275.	4.
5500	299.	2.	6000	228.	2.
6500	197.	4.	7000	222.	5.
7500	227.	6.	8000	219.	6.
8500	214.	9.	9000	210.	12.
10000	217.	11.	11000	228.	16.

WEST GATE THEODOLITE PIBAL 6/18/73 0815 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	230.0	4.9	4240.			
1.0	239.7	6.2	4948.	1508.	30.3	239.7
2.0	248.9	8.0	5598.	1706.	26.0	244.9
3.0	272.8	6.4	6247.	1904.	27.0	253.5
4.0	295.6	5.3	6867.	2093.	28.9	261.9

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	234.	5.	5000	240.	6.
5500	248.	8.	6000	264.	7.
6500	282.	6.			

WEST GATE THEODOLITE PIBAL 6/18/73 0930 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	260.0	4.5	4240.			
1.0	263.8	4.2	4948.	1508.	40.4	263.8
2.0	287.8	5.1	5598.	1706.	37.2	276.9
3.0	285.8	4.1	6247.	1904.	37.7	279.7
4.0	292.0	1.3	6867.	2093.	42.7	280.8
5.0	287.8	3.9	7458.	2273.	41.7	282.3
6.0	272.7	3.7	8048.	2453.	41.3	280.7
7.0	262.5	3.4	8638.	2633.	41.5	278.3
8.0	267.7	3.2	9229.	2813.	41.7	277.1
9.0	293.9	4.6	9819.	2993.	40.8	279.4
10.0	311.8	8.0	10410.	3173.	38.2	285.6
11.0	315.5	10.9	11000.	3353.	34.7	291.9
12.0	310.7	13.1	11590.	3533.	31.0	295.8
13.0	296.8	14.7	12181.	3713.	27.7	296.0
14.0	305.5	16.7	12771.	3893.	24.9	297.7
15.0	305.5	17.0	13362.	4073.	22.8	298.9
16.0	303.2	17.7	13952.	4253.	21.1	299.5
17.0	301.1	18.3	14542.	4433.	19.7	299.7
18.0	298.8	20.2	15133.	4612.	18.4	299.6
19.0	297.0	22.1	15723.	4792.	17.2	299.3
20.0	298.5	26.9	16314.	4972.	15.9	299.2

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	261.	4.	5000	266.	4.
5500	284.	5.	6000	287.	4.
6500	288.	3.	7000	291.	2.
7500	287.	4.	8000	274.	4.
8500	265.	3.	9000	266.	3.
10000	299.	6.	11000	315.	11.
12000	301.	14.	13000	305.	17.
14000	303.	18.	15000	299.	20.
16000	298.	24.			

WEST GATE THEODOLITE PIBAL 6/18/73 1140 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	300.0	4.9	4240.			
1.0	301.3	5.4	4948.	1508.	33.6	301.3
2.0	299.4	6.3	5598.	1706.	30.4	300.3
3.0	297.0	5.2	6247.	1904.	31.1	299.3
4.0	262.3	4.3	6867.	2093.	33.1	292.1
5.0	268.8	6.7	7458.	2273.	31.4	286.4
6.0	279.5	8.7	8048.	2453.	28.6	284.7
7.0	286.2	8.6	8638.	2633.	26.9	285.0
8.0	306.8	7.7	9229.	2813.	26.3	288.2
9.0	311.9	9.4	9819.	2993.	25.3	291.8
10.0	306.6	11.1	10410.	3173.	23.9	294.1
11.0	303.8	11.9	11000.	3353.	22.6	295.5
12.0	304.4	12.9	11590.	3533.	21.4	296.7
13.0	300.8	13.2	12181.	3713.	20.4	297.2

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	300.	5.	5000	301.	5.
5500	300.	6.	6000	298.	6.
6500	283.	5.	7000	264.	5.
7500	270.	7.	8000	279.	9.
8500	285.	9.	9000	299.	8.
10000	310.	10.	11000	304.	12.
12000	302.	13.			

WEST GATE THEODOLITE PIBAL 6/18/73 1330 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	340.0	4.0	4240.			
1.0	340.4	3.8	4948.	1508.	43.5	340.4
2.0	307.1	3.0	5598.	1706.	46.7	325.8
3.0	308.4	5.4	6247.	1904.	40.8	317.9
4.0	302.1	5.3	6867.	2093.	38.1	313.0
5.0	296.1	6.4	7458.	2273.	35.1	308.4
6.0	298.2	9.7	8048.	2453.	30.5	305.4
7.0	296.7	10.5	8638.	2633.	27.3	303.3
8.0	299.3	9.4	9229.	2813.	25.7	302.6
9.0	305.7	9.8	9819.	2993.	24.4	303.1
10.0	314.6	9.4	10410.	3173.	23.6	304.6
11.0	325.4	12.3	11000.	3353.	22.4	307.6
12.0	319.3	13.2	11590.	3533.	21.2	309.2
13.0	315.2	14.6	12181.	3713.	20.0	310.0
14.0	312.5	15.0	12771.	3893.	19.0	310.3
15.0	308.4	15.1	13362.	4073.	18.2	310.1
16.0	311.2	13.7	13952.	4253.	17.7	310.2
17.0	312.2	16.6	14542.	4433.	17.0	310.4
18.0	311.3	20.5	15133.	4612.	16.1	310.5
19.0	313.1	24.5	15723.	4792.	15.1	310.8
20.0	313.5	26.2	16314.	4972.	14.2	311.1

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	340.	4.	5000	338.	4.
5500	312.	3.	6000	308.	5.
6500	306.	5.	7000	301.	6.
7500	296.	7.	8000	298.	9.
8500	297.	10.	9000	298.	10.
10000	308.	10.	11000	325.	12.
12000	316.	14.	13000	311.	15.
14000	311.	14.	15000	312.	20.
16000	313.	25.			

WEST GATE THEODOLITE PIBAL 6/18/73 1445 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	330.0	3.6	4240.			
1.0	323.0	1.8	4948.	1508.	64.0	323.0
2.0	346.9	1.7	5598.	1706.	64.0	334.7
3.0	316.2	4.1	6247.	1904.	54.3	324.6
4.0	308.0	4.1	6867.	2093.	49.8	318.7
5.0	290.8	4.6	7458.	2273.	46.5	310.7
6.0	290.8	5.7	8048.	2453.	42.7	305.4
7.0	287.7	6.6	8638.	2633.	39.3	301.2
8.0	287.7	7.9	9229.	2813.	35.9	298.2
9.0	298.2	8.6	9819.	2993.	33.0	298.2
10.0	307.1	8.8	10410.	3173.	30.9	299.7

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	327.	3.	5000	325.	2.
5500	343.	2.	6000	328.	3.
6500	313.	4.	7000	304.	4.
7500	291.	5.	8000	291.	6.
8500	288.	6.	9000	288.	7.
10000	301.	9.			

WEST GATE THEODOLITE PIBAL 6/18/73 1600 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	290.0	1.3	4240.			
1.0	312.5	1.2	4948.	1508.	71.0	312.5
2.0	318.4	2.7	5598.	1706.	60.0	316.6
3.0	321.9	4.4	6247.	1904.	50.7	319.4
4.0	318.3	5.1	6867.	2093.	44.7	319.0
5.0	321.5	6.2	7458.	2273.	39.7	319.8
6.0	323.5	6.2	8048.	2453.	36.8	320.7
7.0	315.0	7.7	8638.	2633.	33.7	319.4
8.0	319.4	8.7	9229.	2813.	31.0	319.4
9.0	321.5	9.8	9819.	2993.	28.6	319.8
10.0	314.6	9.6	10410.	3173.	27.0	319.0
11.0	314.4	11.2	11000.	3353.	25.3	318.3
12.0	314.9	12.8	11590.	3533.	23.6	317.8
13.0	314.2	13.9	12181.	3713.	22.1	317.3
14.0	315.8	15.3	12771.	3893.	20.7	317.1
15.0	319.5	16.2	13362.	4073.	19.5	317.4
16.0	318.3	16.6	13952.	4253.	18.5	317.5

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	298.	1.	5000	313.	1.
5500	318.	3.	6000	321.	4.
6500	320.	5.	7000	319.	5.
7500	322.	6.	8000	323.	6.
8500	317.	7.	9000	318.	8.
10000	319.	10.	11000	314.	11.
12000	314.	14.	13000	317.	16.

WEST GATE THEODOLITE PIBAL 6/19/73 0740 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	280.0	0.9	4240.			
1.0	296.5	1.3	4948.	1508.	70.0	296.5
2.0	17.6	0.6	5598.	1706.	77.4	320.6
3.0	44.5	1.0	6247.	1904.	79.2	352.5
4.0	51.4	1.0	6867.	2093.	79.1	11.0
5.0	31.9	1.2	7458.	2273.	77.3	17.5
6.0	47.4	0.8	8048.	2453.	77.3	22.5
7.0	44.1	1.3	8638.	2633.	75.9	27.5
8.0	43.8	1.2	9229.	2813.	75.0	30.4
9.0	349.8	2.9	9819.	2993.	72.1	18.7
10.0	342.2	6.1	10410.	3173.	65.1	4.2
11.0	337.2	5.9	11000.	3353.	59.8	356.5
12.0	341.5	5.9	11590.	3533.	55.4	353.1
13.0	356.2	6.2	12181.	3713.	51.6	353.7
14.0	3.9	7.3	12771.	3893.	47.9	355.6
15.0	352.9	9.0	13362.	4073.	43.9	355.1
16.0	351.6	10.0	13952.	4253.	40.3	354.5
17.0	346.8	10.9	14542.	4433.	37.2	353.3

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	286.	1.	5000	303.	1.
5500	5.	1.	6000	34.	1.
6500	47.	1.	7000	47.	1.
7500	33.	1.	8000	46.	1.
8500	45.	1.	9000	44.	1.
10000	348.	4.	11000	337.	6.
12000	352.	6.	13000	360.	8.
14000	351.	10.			

WEST GATE THEODOLITE PIBAL 6/19/73 1510 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	350.0	2.7	4240.			
1.0	355.6	2.9	4948.	1508.	50.7	355.6
2.0	351.9	1.9	5598.	1706.	55.2	354.2
3.0	248.9	1.1	6247.	1904.	65.6	340.5
4.0	219.7	2.1	6867.	2093.	73.4	313.2
5.0	223.1	3.3	7458.	2273.	72.4	273.2
6.0	228.6	4.5	8048.	2453.	65.1	252.5
7.0	243.8	3.4	8638.	2633.	61.0	250.1
8.0	304.9	2.8	9229.	2813.	60.8	259.3
9.0	335.5	3.7	9819.	2993.	61.4	272.6
10.0	327.4	3.5	10410.	3173.	60.5	282.0
11.0	322.1	3.6	11000.	3353.	59.0	288.5
12.0	321.3	4.5	11590.	3533.	56.7	294.2
13.0	353.2	4.6	12181.	3713.	56.0	302.6
14.0	351.5	6.5	12771.	3893.	53.7	311.4
15.0	353.0	6.7	13362.	4073.	51.3	318.3
16.0	343.4	6.8	13952.	4253.	48.7	322.1
17.0	329.2	7.1	14542.	4433.	46.1	323.1
18.0	320.9	7.9	15133.	4612.	43.5	322.8
19.0	338.4	7.6	15723.	4792.	41.6	324.6
20.0	342.0	9.6	16314.	4972.	39.3	326.8

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	352.	3.	5000	355.	3.
5500	352.	2.	6000	288.	1.
6500	237.	2.	7000	220.	2.
7500	223.	3.	8000	228.	4.
8500	240.	4.	9000	281.	3.
10000	333.	4.	11000	322.	4.
12000	343.	5.	13000	352.	7.
14000	342.	7.	15000	323.	8.
16000	340.	9.			

WEST GATE THEODOLITE PIBAL 6/19/73 1700 MST

TIME	DIR	SPD	HGT (ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	10.0	2.2	4240.			
1.0	347.4	1.9	4948.	1508.	62.6	347.4
2.0	326.2	2.3	5598.	1706.	59.6	335.8
3.0	340.5	3.5	6247.	1904.	53.5	338.0
4.0	333.7	4.1	6867.	2093.	49.0	336.5
5.0	303.9	2.6	7458.	2273.	49.7	330.7
6.0	262.7	2.7	8048.	2453.	52.1	321.3
7.0	244.5	3.2	8638.	2633.	54.2	310.0
8.0	284.3	3.8	9229.	2813.	52.3	305.2
9.0	299.1	4.4	9819.	2993.	49.8	304.1
10.0	292.9	4.0	10410.	3173.	48.3	302.5
11.0	292.9	3.3	11000.	3353.	47.8	301.5
12.0	321.2	3.4	11590.	3533.	47.4	303.4
13.0	347.7	3.9	12181.	3713.	47.3	307.6
14.0	340.3	5.5	12771.	3893.	45.9	311.7
15.0	328.4	6.7	13362.	4073.	43.7	314.0
16.0	324.1	7.2	13952.	4253.	41.6	315.3
17.0	322.8	7.5	14542.	4433.	39.7	316.2
18.0	327.6	7.4	15133.	4612.	38.2	317.4
19.0	331.4	7.9	15723.	4792.	36.8	318.8
20.0	327.0	8.4	16314.	4972.	35.4	319.6

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	2.	2.	5000	346.	2.
5500	329.	2.	6000	335.	3.
6500	338.	4.	7000	327.	4.
7500	301.	3.	8000	266.	3.
8500	249.	3.	9000	269.	4.
10000	297.	4.	11000	293.	3.
12000	340.	4.	13000	336.	6.
14000	324.	7.	15000	327.	7.
16000	329.	8.			

WEST GATE THEODOLITE PIBAL 6/20/73 0745 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	355.0	1.3	4240.			
1.0	358.0	1.2	4948.	1508.	72.2	358.0
2.0	83.6	1.4	5598.	1706.	74.9	45.4
3.0	107.2	4.8	6247.	1904.	59.8	91.2
4.0	106.6	4.1	6867.	2093.	53.3	97.5
5.0	103.1	5.0	7458.	2273.	47.5	99.4
6.0	98.9	5.2	8048.	2453.	43.8	99.3
7.0	87.3	5.1	8638.	2633.	41.6	96.9
8.0	76.5	6.2	9229.	2813.	39.2	92.9
9.0	70.2	6.0	9819.	2993.	37.7	89.3
10.0	46.2	6.6	10410.	3173.	36.9	83.1
11.0	30.5	7.3	11000.	3353.	36.4	75.9
12.0	26.0	6.8	11590.	3533.	36.1	70.1
13.0	18.6	6.6	12181.	3713.	36.0	64.8
14.0	8.3	5.9	12771.	3893.	36.3	60.0
15.0	13.9	6.3	13362.	4073.	36.1	55.9

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	356.	1.	5000	5.	1.
5500	71.	1.	6000	98.	4.
6500	107.	5.	7000	106.	4.
7500	103.	5.	8000	99.	5.
8500	90.	5.	9000	81.	6.
10000	63.	6.	11000	30.	7.
12000	21.	7.	13000	10.	6.

WEST GATE THEODOLITE PIBAL 6/20/73 1300 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	350.0	3.6	4240.			
1.0	342.0	1.8	4948.	1508.	64.0	342.0
2.0	351.1	0.5	5598.	1706.	72.0	344.0
3.0	56.7	0.9	6247.	1904.	75.5	2.5
4.0	125.9	2.0	6867.	2093.	80.4	48.8
5.0	96.6	1.8	7458.	2273.	77.3	69.6
6.0	74.7	3.8	8048.	2453.	68.8	72.2
7.0	48.8	5.2	8638.	2633.	60.9	62.7
8.0	53.4	4.6	9229.	2813.	56.2	60.2
9.0	40.9	4.0	9819.	2993.	53.8	56.6
10.0	38.9	4.4	10410.	3173.	51.4	53.5
11.0	84.7	2.9	11000.	3353.	51.3	56.6
12.0	93.8	3.6	11590.	3533.	50.8	60.7
13.0	102.9	3.1	12181.	3713.	50.9	64.3
14.0	97.6	0.4	12771.	3893.	52.6	64.7
15.0	28.3	1.7	13362.	4073.	53.3	63.0
16.0	16.8	3.5	13952.	4253.	53.1	59.1
17.0	6.5	4.2	14542.	4433.	52.8	54.3
18.0	354.2	5.0	15133.	4612.	52.5	48.4
19.0	349.5	5.3	15723.	4792.	52.1	42.7
20.0	337.0	5.1	16314.	4972.	52.1	37.1

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	347.	3.	5000	343.	2.
5500	350.	1.	6000	32.	1.
6500	85.	1.	7000	119.	2.
7500	95.	2.	8000	76.	4.
8500	55.	5.	9000	52.	5.
10000	40.	4.	11000	85.	3.
12000	100.	3.	13000	71.	1.
14000	16.	4.	15000	357.	5.
16000	344.	5.			

WEST GATE THEODOLITE PIBAL 6/21/73 1138 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	340.0	3.6	4240.			
1.0	295.8	1.4	4948.	1508.	69.3	295.8
2.0	89.4	1.3	5598.	1706.	85.0	3.0
3.0	112.6	2.2	6247.	1904.	78.4	96.9
4.0	118.9	2.0	6867.	2093.	73.2	107.7
5.0	145.2	1.6	7458.	2273.	71.9	117.9
6.0	164.3	2.2	8048.	2453.	70.1	130.8
7.0	190.0	2.4	8638.	2633.	69.2	144.9
8.0	174.1	4.4	9229.	2813.	63.7	154.8
9.0	191.5	4.2	9819.	2993.	60.4	163.8
10.0	173.9	4.7	10410.	3173.	56.5	166.1
11.0	154.9	3.0	11000.	3353.	55.4	164.7
12.0	141.2	3.3	11590.	3533.	54.4	161.9
13.0	125.1	2.0	12181.	3713.	54.9	159.5
14.0	97.1	1.4	12771.	3893.	56.2	157.1
15.0	63.4	1.6	13362.	4073.	58.0	153.9
16.0	106.3	0.8	13952.	4253.	59.1	152.7
17.0	236.8	0.7	14542.	4433.	60.5	154.1
18.0	283.3	1.3	15133.	4612.	62.5	156.1
19.0	286.8	1.5	15723.	4792.	64.5	158.5
20.0	310.4	1.8	16314.	4972.	66.8	160.3

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	324.	3.	5000	308.	1.
5500	66.	1.	6000	104.	2.
6500	115.	2.	7000	125.	2.
7500	147.	2.	8000	163.	2.
8500	184.	2.	9000	1[illegible].	4.
10000	186.	4.	11000	155.	3.
12000	130.	2.	13000	84.	1.
14000	117.	1.	15000	273.	1.
16000	298.	2.			

WEST GATE THEODOLITE PIBAL 6/22/73 0840 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	27.0	0.0	4240.			
1.0	285.0	1.4	4948.	1508.	68.7	285.0
2.0	337.8	1.3	5598.	1706.	70.6	310.4
3.0	63.5	0.3	6247.	1904.	77.1	316.5
4.0	128.0	1.3	6867.	2093.	85.5	327.1

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	350.	1.	5000	289.	1.
5500	330.	1.	6000	31.	1.
6500	90.	1.			

WEST GATE THEODOLITE PIBAL 6/22/73 1057 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	320.0	0.9	4240.			
1.0	285.4	1.9	4948.	1508.	62.4	285.4
2.0	283.9	1.3	5598.	1706.	65.3	284.8
3.0	104.5	0.9	6247.	1904.	77.6	284.9
4.0	218.0	1.7	6867.	2093.	76.2	257.0

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	307.	1.	5000	285.	2.
5500	284.	1.	6000	173.	1.
6500	151.	1.			

WEST GATE THEODOLITE PIBAL 6/22/73 1300 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	10.0	3.1	4240.			
1.0	15.5	3.0	4948.	1508.	50.0	15.5
2.0	12.0	2.0	5598.	1706.	53.9	14.1
3.0	347.5	1.9	6247.	1904.	56.5	7.0
4.0	307.8	1.1	6867.	2093.	61.0	359.4
5.0	176.1	0.2	7458.	2273.	66.3	359.5
6.0	206.3	3.0	8048.	2453.	76.3	343.0

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	12.	3.	5000	15.	3.
5500	12.	2.	6000	357.	2.
6500	331.	2.	7000	278.	1.
7500	178.	0.	8000	204.	3.

WEST GATE THEODOLITE PIBAL 6/22/73 1535 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	330.0	3.6	4240.			
1.0	0.9	3.4	4948.	1508.	47.0	0.9
2.0	32.7	1.9	5598.	1706.	53.7	12.3
3.0	37.2	2.3	6247.	1904.	54.6	20.1
4.0	22.5	1.9	6867.	2093.	55.7	20.6
5.0	15.2	1.8	7458.	2273.	56.2	19.7
6.0	78.4	0.9	8048.	2453.	59.4	23.6
7.0	111.0	1.4	8638.	2633.	62.6	30.4
8.0	125.1	1.4	9229.	2813.	65.5	37.2
9.0	149.9	1.5	9819.	2993.	68.7	44.5
10.0	205.2	4.1	10410.	3173.	76.9	55.2
11.0	215.7	4.8	11000.	3353.	84.7	85.3
12.0	217.5	5.1	11590.	3533.	84.2	179.1
13.0	200.6	5.7	12181.	3713.	77.0	192.0
14.0	200.3	6.4	12771.	3893.	70.1	195.4
15.0	207.8	6.2	13362.	4073.	64.8	198.9
16.0	209.8	6.2	13952.	4253.	60.5	201.3
17.0	215.8	7.0	14542.	4433.	56.4	204.2
18.0	222.4	7.2	15133.	4612.	53.0	207.3
19.0	224.1	7.3	15723.	4792.	50.1	209.8
20.0	220.3	7.5	16314.	4972.	47.5	211.2

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	341.	3.	5000	3.	3.
5500	28.	2.	6000	36.	2.
6500	31.	2.	7000	21.	2.
7500	20.	2.	8000	73.	1.
8500	103.	1.	9000	120.	1.
10000	167.	2.	11000	216.	5.
12000	206.	6.	13000	203.	6.
14000	210.	6.	15000	221.	7.
16000	222.	7.			

WEST GATE THEODOLITE PIBAL 6/25/73 0920 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	325.0	0.9	4240.			
1.0	290.7	1.2	4948.	1508.	72.2	290.7
2.0	66.1	0.6	5598.	1706.	83.1	322.2
3.0	112.3	0.8	6247.	1904.	87.6	37.0
4.0	187.4	0.3	6867.	2093.	89.0	71.0

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	312.	1.	5000	301.	1.
5500	46.	1.	6000	95.	1.
6500	143.	1.			

WEST GATE THEODOLITE PIBAL 6/25/73 1355 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	280.0	2.2	4240.			
1.0	326.5	1.7	4948.	1508.	64.5	326.5
2.0	40.7	2.2	5598.	1706.	65.4	9.2
3.0	32.0	1.4	6247.	1904.	66.5	16.0
4.0	354.5	0.7	6867.	2093.	69.0	13.0
5.0	297.7	2.3	7458.	2273.	69.5	351.9
6.0	277.2	2.6	8048.	2453.	69.5	331.8
7.0	241.3	4.7	8638.	2633.	69.0	298.8
8.0	238.3	7.3	9229.	2813.	61.6	271.3
9.0	238.8	8.2	9819.	2993.	53.3	259.2
10.0	240.0	8.3	10410.	3173.	47.1	253.8
11.0	238.9	8.3	11000.	3353.	42.7	250.5
12.0	234.6	9.9	11590.	3533.	38.6	247.2
13.0	238.4	11.2	12181.	3713.	34.9	245.5
14.0	246.6	12.3	12771.	3893.	31.7	245.7
15.0	258.9	13.4	13362.	4073.	29.1	247.8
16.0	263.1	14.9	13952.	4253.	26.8	250.1
17.0	267.3	16.8	14542.	4433.	24.7	252.6
18.0	262.0	16.8	15133.	4612.	23.0	253.8
19.0	273.8	16.4	15723.	4792.	21.8	256.0
20.0	279.1	14.1	16314.	4972.	21.1	258.0

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	297.	2.	5000	332.	2.
5500	30.	2.	6000	35.	2.
6500	17.	1.	7000	342.	1.
7500	296.	2.	8000	279.	3.
8500	250.	4.	9000	239.	6.
10000	239.	8.	11000	239.	8.
12000	237.	11.	13000	251.	13.
14000	263.	15.	15000	263.	17.
16000	276.	15.			

WEST GATE THEODOLITE PIBAL 6/25/73 1600 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	355.0	4.0	4240.			
1.0	24.4	4.4	4948.	1508.	39.3	24.4
2.0	56.3	3.3	5598.	1706.	43.0	38.0
3.0	60.2	3.9	6247.	1904.	42.6	45.6
4.0	83.9	5.8	6867.	2093.	39.8	58.5
5.0	140.7	3.7	7458.	2273.	44.0	71.1
6.0	224.5	3.6	8048.	2453.	54.5	77.8
7.0	252.9	3.7	8638.	2633.	65.7	79.6
8.0	259.5	5.3	9229.	2813.	79.3	79.7
9.0	256.6	6.7	9819.	2993.	86.1	248.9
10.0	250.9	7.5	10410.	3173.	73.3	250.5
11.0	253.9	8.6	11000.	3353.	62.4	252.1
12.0	254.7	9.6	11590.	3533.	53.6	253.0
13.0	252.6	11.0	12181.	3713.	46.3	252.9
14.0	254.5	12.7	12771.	3893.	40.2	253.3
15.0	258.4	14.0	13362.	4073.	35.4	254.4
16.0	265.9	15.6	13952.	4253.	31.5	256.6
17.0	269.6	18.3	14542.	4433.	28.0	259.0
18.0	278.0	15.8	15133.	4612.	26.0	261.6
19.0	285.1	13.2	15723.	4792.	24.9	264.0
20.0	291.1	12.0	16314.	4972.	24.2	2[illegible]6.3

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	6.	4.	5000	27.	4.
5500	51.	3.	6000	59.	4.
6500	70.	5.	7000	97.	5.
7500	147.	4.	8000	218.	4.
8500	246.	4.	9000	257.	5.
10000	255.	7.	11000	254.	9.
12000	253.	11.	13000	256.	13.
14000	26[illegible].	16.	15000	276.	16.
16000	288.	13.			

WEST GATE THEODOLITE PIBAL 6/25/73 1930 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	130.0	3.6	4240.			
1.0	126.9	6.1	4948.	1508.	30.7	127.0
2.0	119.8	5.8	5598.	1706.	30.2	123.5
3.0	102.5	4.4	6247.	1904.	32.5	117.9
4.0	68.1	3.0	6867.	2093.	36.4	110.6
5.0	13.0	3.2	7458.	2273.	42.3	100.5
6.0	332.2	3.1	8048.	2453.	50.0	91.9
7.0	308.1	3.9	8638.	2633.	59.3	81.8
8.0	292.3	5.1	9229.	2813.	70.0	65.4
9.0	290.1	5.1	9819.	2993.	76.8	32.7
10.0	295.5	5.7	10410.	3173.	75.3	348.9
11.0	292.7	6.5	11000.	3353.	69.2	324.3
12.0	293.3	8.7	11590.	3533.	60.7	312.0
13.0	298.3	10.3	12181.	3713.	52.4	307.5
14.0	296.9	12.4	12771.	3893.	45.0	304.5
15.0	290.9	14.6	13362.	4073.	38.8	301.1
16.0	282.0	16.5	13952.	4253.	33.9	296.9
17.0	275.9	17.1	14542.	4433.	30.3	293.0
18.0	284.6	16.4	15133.	4612.	27.6	291.7
19.0	290.9	14.8	15723.	4792.	25.8	291.6

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	129.	4.	5000	126.	6.
5500	121.	6.	6000	109.	5.
6500	88.	4.	7000	56.	3.
7500	10.	3.	8000	336.	3.
8500	314.	4.	9000	298.	5.
10000	292.	5.	11000	293.	7.
12000	297.	10.	13000	295.	13.
14000	282.	17.	15000	283.	17.

WEST GATE THEODOLITE PIBAL 6/26/73 0000 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	0.0	0.0	4240.			
1.0	90.0	1.1	4948.	1508.	73.0	90.0
2.0	59.4	2.0	5598.	1706.	66.5	70.2
3.0	65.6	0.5	6247.	1904.	71.3	69.6
4.0	353.9	1.2	6867.	2093.	73.6	52.3
5.0	304.4	2.3	7458.	2273.	76.6	18.1
6.0	324.4	3.5	8048.	2453.	71.1	352.7
7.0	329.6	4.3	8638.	2633.	64.3	343.6
8.0	327.2	5.6	9229.	2813.	57.4	338.0
9.0	315.2	6.5	9819.	2993.	51.7	331.5
10.0	298.8	8.4	10410.	3173.	46.4	322.7
11.0	288.0	11.1	11000.	3353.	41.0	313.5
12.0	280.3	12.7	11590.	3533.	36.4	305.6

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	33.	0.	5000	88.	1.
5500	64.	2.	6000	63.	1.
6500	36.	1.	7000	343.	1.
7500	306.	2.	8000	323.	3.
8500	328.	4.	9000	328.	5.
10000	310.	7.	11000	288.	11.

WEST GATE THEODOLITE PIBAL 6/26/73 1430 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	345.0	3.1	4240.			
1.0	330.6	2.2	4948.	1508.	58.2	330.6
2.0	320.9	1.6	5598.	1706.	61.1	326.6
3.0	343.7	2.5	6247.	1904.	58.7	333.3
4.0	314.8	2.2	6867.	2093.	58.1	328.5
5.0	316.5	2.8	7458.	2273.	55.9	325.5
6.0	322.2	3.6	8048.	2453.	52.9	324.7
7.0	317.5	3.2	8638.	2633.	51.4	323.4
8.0	304.1	3.2	9229.	2813.	50.5	320.5
9.0	307.2	3.3	9819.	2993.	49.6	318.7
10.0	280.4	4.2	10410.	3173.	48.7	313.3
11.0	290.2	4.7	11000.	3353.	47.1	310.0
12.0	270.1	5.2	11590.	3533.	46.0	304.7
13.0	283.3	6.2	12181.	3713.	43.9	301.6
14.0	303.4	8.3	12771.	3893.	40.8	301.9
15.0	314.0	10.6	13362.	4073.	37.4	304.0

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	340.	3.	5000	330.	2.
5500	322.	2.	6000	335.	2.
6500	332.	2.	7000	315.	2.
7500	317.	3.	8000	322.	4.
8500	319.	3.	9000	309.	3.
10000	299.	4.	11000	290.	5.
12000	279.	6.	13000	307.	9.

WEST GATE THEOCOLITE PIBAL 6/26/73 1735 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	325.0	1.3	4240.			
1.0	312.9	1.5	4948.	1508.	67.4	312.9
2.0	313.8	1.2	5598.	1706.	69.0	313.3
3.0	347.2	2.6	6247.	1904.	63.7	330.2
4.0	351.9	2.6	6867.	2093.	60.7	337.5
5.0	347.3	3.3	7458.	2273.	56.7	340.5
6.0	341.9	2.8	8048.	2453.	55.1	340.8
7.0	326.7	2.9	8638.	2633.	53.8	338.3
8.0	320.5	2.7	9229.	2813.	53.2	335.8
9.0	310.0	4.8	9819.	2993.	50.5	330.7
10.0	301.6	4.9	10410.	3173.	48.5	325.8
11.0	314.7	5.8	11000.	3353.	45.8	323.9
12.0	322.4	8.4	11590.	3533.	41.8	323.6
13.0	325.0	11.0	12181.	3713.	37.4	323.9
14.0	325.4	12.7	12771.	3893.	33.5	324.2
15.0	320.4	12.6	13362.	4073.	30.7	323.6
16.0	316.5	12.9	13952.	4253.	28.5	322.6
17.0	307.5	14.1	14542.	4433.	26.6	320.6

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD
	DEG	MPS
4500	321.	1.
5500	314.	1.
6500	349.	3.
7500	347.	3.
8500	330.	3.
10000	307.	5.
12000	324.	10.
14000	316.	13.

HGT	DIR	SPD
	DEG	MPS
5000	313.	1.
6000	335.	2.
7000	351.	3.
8000	342.	3.
9000	323.	3.
11000	315.	6.
13000	323.	13.

WEST GATE THEODOLITE PIBAL 6/26/73 1935 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	20.0	2.7	4240.			
1.0	50.2	3.4	4948.	1508.	46.7	50.2
2.0	77.2	1.8	5598.	1706.	53.9	59.4
3.0	100.9	1.5	6247.	1904.	58.5	68.7
4.0	87.9	0.7	6867.	2093.	62.5	70.7
5.0	333.8	0.5	7458.	2273.	67.1	66.5
6.0	324.2	2.4	8048.	2453.	70.6	46.2
7.0	323.0	2.8	8638.	2633.	71.1	25.2
8.0	317.0	3.0	9229.	2813.	70.0	7.4
9.0	316.0	3.2	9819.	2993.	67.9	354.8
10.0	330.8	3.8	10410.	3173.	64.3	348.9
11.0	334.5	4.7	11000.	3353.	60.2	345.5
12.0	340.0	6.1	11590.	3533.	55.4	344.2
13.0	339.5	8.0	12181.	3713.	50.1	343.1

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	31.	3.	5000	52.	3.
5500	73.	2.	6000	92.	2.
6500	96.	1.	7000	62.	1.
7500	333.	1.	8000	325.	2.
8500	323.	3.	9000	319.	3.
10000	321.	3.	11000	334.	5.
12000	340.	7.			

WEST GATE THEODOLITE PIBAL 6/27/73 1030 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	335.0	1.8	4240.			
1.0	324.4	1.6	4948.	1508.	66.6	324.4
2.0	45.4	2.2	5598.	1706.	67.3	13.2
3.0	95.8	3.0	6247.	1904.	66.5	55.7
4.0	118.6	2.9	6867.	2093.	64.6	80.1
5.0	134.5	2.9	7458.	2273.	62.9	96.5
6.0	167.3	1.9	8048.	2453.	64.6	108.0
7.0	132.8	1.2	8638.	2633.	65.2	110.9
8.0	98.7	1.4	9229.	2813.	65.3	109.5
9.0	36.2	1.4	9819.	2993.	66.8	103.0
10.0	350.9	2.7	10410.	3173.	70.0	90.3
11.0	324.0	3.6	11000.	3353.	74.2	72.9
12.0	316.2	4.6	11590.	3533.	76.9	44.5
13.0	301.6	5.0	12181.	3713.	77.4	11.6
14.0	292.1	5.9	12771.	3893.	75.0	341.9
15.0	290.9	6.3	13362.	4073.	70.6	324.5
16.0	294.8	7.5	13952.	4253.	64.9	315.3
17.0	296.0	9.1	14542.	4433.	58.7	309.9
18.0	293.3	9.9	15133.	4612.	53.2	306.0
19.0	288.9	9.7	15723.	4792.	49.0	302.8
20.0	286.7	10.3	16314.	4972.	45.3	300.1

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	331.	2.	5000	331.	2.
5500	33.	2.	6000	77.	3.
6500	105.	3.	7000	122.	3.
7500	137.	3.	8000	165.	2.
8500	141.	1.	9000	112.	1.
10000	22.	2.	11000	324.	4.
12000	306.	5.	13000	292.	6.
14000	295.	8.	15000	294.	10.
16000	288.	10.			

WEST GATE THEODOLITE PIBAL 6/27/73 1450 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	320.0	1.3	4240.			
1.0	351.2	2.0	4948.	1508.	60.6	351.2
2.0	15.3	1.4	5598.	1706.	64.1	1.0
3.0	44.5	2.4	6247.	1904.	62.3	19.0
4.0	64.7	1.1	6867.	2093.	65.1	26.5
5.0	277.2	1.8	7458.	2273.	70.3	9.5
6.0	281.5	3.6	8048.	2453.	70.1	338.2
7.0	277.3	4.3	8638.	2633.	66.2	315.7
8.0	277.9	4.4	9229.	2813.	61.8	304.3
9.0	282.4	4.5	9819.	2993.	57.8	298.9
10.0	281.6	4.6	10410.	3173.	54.6	295.4
11.0	277.3	4.7	11000.	3353.	52.1	292.3
12.0	279.7	5.4	11590.	3533.	49.4	290.2
13.0	275.8	6.2	12181.	3713.	46.7	287.9
14.0	265.3	7.3	12771.	3893.	44.0	284.3
15.0	260.8	8.3	13362.	4073.	41.4	280.7

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	331.	2.	5000	353.	2.
5500	12.	1.	6000	33.	2.
6500	53.	2.	7000	32.	1.
7500	278.	2.	8000	281.	3.
8500	278.	4.	9000	278.	4.
10000	282.	5.	11000	277.	5.
12000	277.	6.	13000	264.	8.

WEST GATE THEODOLITE PIBAL 6/27/73 1615 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	350.0	2.7	4240.			
1.0	11.6	2.5	4948.	1508.	54.9	11.6
2.0	23.2	0.8	5598.	1706.	64.3	14.4
3.0	355.8	0.9	6247.	1904.	67.6	10.4
4.0	351.7	2.5	6867.	2093.	63.7	3.5
5.0	343.2	2.4	7458.	2273.	61.4	358.1
6.0	332.8	3.3	8048.	2453.	58.3	351.4
7.0	323.6	3.4	8638.	2633.	56.0	345.3

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	358.	3.	5000	12.	2.
5500	21.	1.	6000	6.	1.
6500	354.	2.	7000	350.	2.
7500	342.	2.	8000	334.	3.
8500	326.	3.			

WEST GATE THEODOLITE PIBAL 6/28/73 0355 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	120.0	5.8	4240.			
1.0	126.4	7.2	4948.	1508.	26.5	126.5
2.0	118.5	7.3	5598.	1706.	25.5	122.5
3.0	118.0	7.5	6247.	1904.	24.9	121.0
4.0	125.5	4.0	6867.	2093.	27.2	121.7
5.0	120.1	1.8	7458.	2273.	30.5	121.6
6.0	220.8	0.8	8048.	2453.	35.0	123.3
7.0	239.3	2.0	8638.	2633.	39.8	127.1
8.0	240.4	2.4	9229.	2813.	44.3	131.9
9.0	267.6	2.4	9819.	2993.	49.4	135.9
10.0	275.3	2.7	10410.	3173.	54.6	140.5
11.0	276.4	6.0	11000.	3353.	61.8	153.7
12.0	283.6	6.9	11590.	3533.	68.2	174.5
13.0	276.2	8.4	12181.	3713.	68.9	206.3
14.0	270.6	8.9	12771.	3893.	64.1	228.8
15.0	264.8	7.7	13362.	4073.	59.2	238.2
16.0	271.6	8.2	13952.	4253.	54.8	245.7
17.0	269.2	10.1	14542.	4433.	49.8	250.9
18.0	260.9	13.2	15133.	4612.	44.0	253.2
19.0	259.5	13.5	15723.	4792.	39.5	254.4
20.0	264.2	17.0	16314.	4972.	35.0	256.3

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	122.	6.	5000	126.	7.
5500	120.	7.	6000	118.	7.
6500	121.	6.	7000	124.	4.
7500	127.	2.	8000	213.	1.
8500	235.	2.	9000	240.	2.
10000	270.	3.	11000	276.	6.
12000	278.	8.	13000	268.	8.
14000	271.	8.	15000	263.	13.
16000	262.	15.			

WEST GATE THEODOLITE PIBAL 6/28/73 0535 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	260.0	4.9	4240.			
1.0	263.4	6.4	4948.	1508.	29.5	263.4
2.0	243.7	6.1	5598.	1706.	29.4	253.8
3.0	245.3	7.0	6247.	1904.	28.0	250.7
4.0	251.9	6.7	6867.	2093.	27.3	251.0
5.0	247.8	7.2	7458.	2273.	26.3	250.3
6.0	239.8	6.0	8048.	2453.	26.4	248.7
7.0	218.1	3.3	8638.	2633.	28.1	246.4
8.0	185.1	1.4	9229.	2813.	30.8	244.8
9.0	215.8	2.2	9819.	2993.	32.5	243.4
10.0	231.1	3.1	10410.	3173.	33.4	242.6
11.0	230.2	2.9	11000.	3353.	34.3	241.9
12.0	222.2	2.7	11590.	3533.	35.2	240.9
13.0	223.3	6.5	12181.	3713.	34.3	239.0
14.0	219.5	8.0	12771.	3893.	33.0	236.7
15.0	234.7	7.4	13362.	4073.	32.0	236.5
16.0	236.5	7.0	13952.	4253.	31.3	236.5
17.0	236.5	4.9	14542.	4433.	31.3	236.5
18.0	243.0	5.7	15133.	4612.	31.1	236.9
19.0	258.7	7.4	15723.	4792.	30.6	238.5
20.0	267.9	9.1	16314.	4972.	29.9	240.9

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	261.	5.	5000	262.	6.
5500	247.	6.	6000	245.	7.
6500	248.	7.	7000	251.	7.
7500	247.	7.	8000	240.	6.
8500	223.	4.	9000	198.	2.
10000	220.	3.	11000	230.	3.
12000	223.	5.	13000	225.	8.
14000	236.	7.	15000	242.	6.
16000	263.	8.			

WEST GATE THEODOLITE PIBAL 6/28/73 0810 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	60.0	1.8	4240.			
1.0	54.5	3.0	4948.	1508.	50.1	54.5
2.0	97.2	1.5	5598.	1706.	58.4	68.5
3.0	146.3	0.5	6247.	1904.	66.8	74.7
4.0	283.5	3.2	6867.	2093.	80.6	31.0
5.0	253.0	3.7	7458.	2273.	81.3	289.2
6.0	224.0	4.2	8048.	2453.	73.5	247.4
7.0	214.3	4.8	8638.	2633.	65.7	232.4

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	58.	2.	5000	58.	3.
5500	91.	2.	6000	128.	1.
6500	202.	2.	7000	277.	3.
7500	251.	4.	8000	226.	4.
8500	217.	5.			

WEST GATE THEODOLITE PIBAL 6/28/73 1945 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	120.0	1.3	4240.			
1.0	119.8	4.3	4948.	1508.	39.6	119.9
2.0	121.6	4.4	5598.	1706.	38.2	120.8
3.0	115.4	5.3	6247.	1904.	36.0	118.8
4.0	88.3	3.9	6867.	2093.	37.3	112.3
5.0	354.3	0.5	7458.	2273.	43.4	110.8

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	120.	2.	5000	120.	4.
5500	121.	4.	6000	118.	5.
6500	104.	5.	7000	67.	3.

WEST GATE THEODOLITE PIBAL 6/29/73 0400 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	240.0	0.9	4240.			
1.0	240.2	1.1	4948.	1508.	72.5	240.2
2.0	351.3	1.4	5598.	1706.	78.3	303.5
3.0	333.8	1.7	6247.	1904.	73.7	319.8
4.0	274.1	1.1	6867.	2093.	74.0	308.0
5.0	270.8	2.0	7458.	2273.	71.2	295.4
6.0	226.5	1.7	8048.	2453.	71.8	281.2
7.0	196.9	3.3	8638.	2633.	71.6	255.3
8.0	204.0	6.0	9229.	2813.	64.5	232.7
9.0	205.6	6.8	9819.	2993.	57.0	223.0
10.0	212.9	5.4	10410.	3173.	52.8	220.7
11.0	218.9	4.8	11000.	3353.	50.2	220.4
12.0	229.2	4.1	11590.	3533.	48.8	221.5
13.0	224.4	3.8	12181.	3713.	47.9	221.8
14.0	219.7	3.8	12771.	3893.	47.1	221.6
15.0	237.7	4.5	13362.	4073.	46.1	223.2
16.0	235.7	4.3	13952.	4253.	45.3	224.3
17.0	232.1	4.1	14542.	4433.	44.7	224.9
18.0	232.7	3.7	15133.	4612.	44.4	225.4
19.0	243.0	5.0	15723.	4792.	43.6	226.8
20.0	246.1	5.2	16314.	4972.	42.8	228.3

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	240.	1.	5000	249.	1.
5500	335.	1.	6000	340.	2.
6500	309.	1.	7000	273.	1.
7500	268.	2.	8000	230.	2.
8500	204.	3.	9000	201.	5.
10000	208.	6.	11000	219.	5.
12000	226.	4.	13000	227.	4.
14000	235.	4.	15000	233.	4.
16000	244.	5.			

WEST GATE THEODOLITE PIBAL 6/29/73 0750 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	30.0	4.9	4240.			
1.0	68.2	3.0	4948.	1508.	50.3	68.2
2.0	97.4	2.1	5598.	1706.	54.5	80.2
3.0	54.3	1.8	6247.	1904.	57.2	73.4
4.0	350.4	1.6	6867.	2093.	62.5	60.3
5.0	282.8	2.8	7458.	2273.	72.2	39.3
6.0	223.6	4.8	8048.	2453.	88.3	360.0
7.0	217.7	8.1	8638.	2633.	71.1	220.4
8.0	217.3	8.4	9229.	2813.	57.7	218.8
9.0	229.8	6.6	9819.	2993.	51.5	222.0
10.0	248.7	4.4	10410.	3173.	49.7	226.3

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	44.	4.	5000	70.	3.
5500	93.	2.	6000	71.	2.
6500	28.	2.	7000	335.	2.
7500	279.	3.	8000	228.	5.
8500	219.	7.	9000	217.	8.
10000	236.	6.			

WEST GATE THEODOLITE PIBAL 6/29/73 1000 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	310.0	0.9	4240.			
1.0	308.1	2.4	4948.	1508.	56.7	308.1
2.0	327.3	1.4	5598.	1706.	61.6	315.3
3.0	335.8	0.2	6247.	1904.	69.2	316.1
4.0	179.1	1.3	6867.	2093.	77.2	298.5
5.0	222.2	3.1	7458.	2273.	73.6	260.0
6.0	208.6	5.2	8048.	2453.	64.9	233.1
7.0	206.2	7.1	8638.	2633.	54.8	221.3
8.0	206.9	7.2	9229.	2813.	48.0	216.8
9.0	206.6	7.4	9819.	2993.	43.2	214.3
10.0	216.9	5.4	10410.	3173.	41.4	214.7
11.0	215.4	6.0	11000.	3353.	39.6	214.8
12.0	212.7	7.0	11590.	3533.	37.6	214.5
13.0	221.9	8.5	12181.	3713.	35.3	215.6
14.0	238.7	8.3	12771.	3893.	33.8	218.5
15.0	247.3	8.4	13362.	4073.	32.7	221.7
16.0	249.8	7.9	13952.	4253.	31.9	224.4
17.0	247.8	8.8	14542.	4433.	30.9	226.7
18.0	244.5	8.8	15133.	4612.	30.0	228.3
19.0	241.0	9.2	15723.	4792.	29.1	229.4
20.0	238.9	9.7	16314.	4972.	28.2	230.2
21.0	235.1	10.3	16904.	5152.	27.3	230.6
22.0	236.1	9.9	17494.	5332.	26.6	231.0
23.0	237.6	11.1	18085.	5512.	25.8	231.5
24.0	241.9	10.5	18675.	5692.	25.2	232.2
25.0	243.6	11.9	19266.	5872.	24.5	233.0

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	309.	1.	5000	310.	2.
5500	324.	2.	6000	333.	1.
6500	272.	1.	7000	189.	2.
7500	221.	3.	8000	210.	5.
8500	207.	7.	9000	207.	7.
10000	210.	7.	11000	215.	6.
12000	219.	8.	13000	242.	8.
14000	250.	8.	15000	245.	9.
16000	240.	9.			

WEST GATE THEODOLITE PIBAL 6/29/73 1750 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	340.0	1.3	4240.			
1.0	337.2	3.8	4948.	1508.	43.4	337.2
2.0	353.9	1.7	5598.	1706.	51.8	342.3
3.0	195.8	0.4	6247.	1904.	63.5	339.7
4.0	176.6	0.6	6867.	2093.	71.3	337.5
5.0	339.9	1.8	7458.	2273.	68.9	338.2
6.0	307.2	3.7	8048.	2453.	63.5	326.9
7.0	316.3	5.2	8638.	2633.	56.5	323.2
8.0	321.8	5.9	9229.	2813.	50.8	322.8
9.0	320.6	4.8	9819.	2993.	48.1	322.4
10.0	326.3	4.5	10410.	3173.	46.3	323.0
11.0	306.0	3.6	11000.	3353.	45.8	321.2
12.0	278.6	3.8	11590.	3533.	45.8	317.1
13.0	288.6	5.9	12181.	3713.	44.1	313.2
14.0	297.2	5.0	12771.	3893.	43.0	311.5
15.0	269.3	6.7	13362.	4073.	41.9	306.5
16.0	246.8	8.4	13952.	4253.	41.2	299.1

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	339.	2.	5000	338.	4.
5500	351.	2.	6000	256.	1.
6500	188.	0.	7000	213.	1.
7500	338.	2.	8000	310.	4.
8500	314.	5.	9000	320.	6.
10000	322.	5.	11000	306.	4.
12000	286.	5.	13000	286.	6.

WEST GATE THEODOLITE PIBAL 6/30/73 0530 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	240.0	0.9	4240.			
1.0	253.5	1.8	4948.	1508.	63.5	253.5
2.0	287.2	0.6	5598.	1706.	71.6	261.5
3.0	242.1	1.2	6247.	1904.	71.5	255.0
4.0	217.7	5.1	6867.	2093.	58.9	232.6
5.0	219.3	9.2	7458.	2273.	43.7	225.5
6.0	216.9	11.2	8048.	2453.	34.4	222.1
7.0	212.3	11.8	8638.	2633.	29.2	219.2
8.0	217.3	14.4	9229.	2813.	25.0	218.7
9.0	225.5	16.6	9819.	2993.	21.8	220.3
10.0	231.5	11.0	10410.	3173.	21.0	221.8
11.0	227.2	8.3	11000.	3353.	20.9	222.3
12.0	211.7	5.4	11590.	3533.	21.4	221.7
13.0	207.3	4.2	12181.	3713.	22.1	221.1
14.0	212.9	3.8	12771.	3893.	22.8	220.8
15.0	231.5	5.1	13362.	4073.	23.2	221.3
16.0	237.4	7.3	13952.	4253.	23.2	222.3
17.0	231.9	7.7	14542.	4433.	23.1	222.9
18.0	227.6	8.3	15133.	4612.	22.9	223.2
19.0	226.3	9.2	15723.	4792.	22.6	223.4
20.0	227.5	10.9	16314.	4972.	22.1	223.7
21.0	228.6	9.8	16904.	5152.	21.8	224.0
22.0	227.1	11.0	17494.	5332.	21.4	224.2

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD
	DEG	MPS
4500	245.	1.
5500	282.	1.
6500	232.	3.
7500	219.	9.
8500	213.	12.
10000	227.	15.
12000	209.	5.
14000	237.	7.
16000	227.	10.

HGT	DIR	SPD
	DEG	MPS
5000	256.	2.
6000	259.	1.
7000	218.	6.
8000	217.	11.
9000	215.	13.
11000	227.	8.
13000	220.	4.
15000	229.	8.

WEST GATE THEODOLITE PIBAL 6/30/73 0750 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	280.0	0.9	4240.			
1.0	305.3	1.5	4948.	1508.	66.8	305.3
2.0	346.7	0.5	5598.	1706.	74.5	314.5
3.0	219.8	5.6	6247.	1904.	60.6	239.2
4.0	219.6	10.1	6867.	2093.	40.5	226.7
5.0	224.9	7.5	7458.	2273.	35.2	226.1
6.0	239.0	5.6	8048.	2453.	34.0	228.6
7.0	245.9	7.6	8638.	2633.	31.8	232.2
8.0	250.1	5.4	9229.	2813.	31.6	234.5
9.0	229.6	4.7	9819.	2993.	31.7	234.0
10.0	230.2	5.5	10410.	3173.	31.4	233.6
11.0	230.2	7.0	11000.	3353.	30.5	233.2
12.0	238.3	7.7	11590.	3533.	29.5	233.8
13.0	239.8	8.6	12181.	3713.	28.4	234.5
14.0	240.8	9.4	12771.	3893.	27.3	235.2
15.0	239.8	10.2	13362.	4073.	26.2	235.7
16.0	237.6	11.2	13952.	4253.	25.1	235.9
17.0	231.7	11.2	14542.	4433.	24.2	235.5
18.0	227.0	12.2	15133.	4612.	23.3	234.7
19.0	224.5	12.5	15723.	4792.	22.5	233.8
20.0	221.7	12.8	16314.	4972.	21.8	232.8
21.0	219.3	13.7	16904.	5152.	21.1	231.7
22.0	218.4	13.7	17494.	5332.	20.5	230.7
23.0	217.2	14.6	18085.	5512.	19.9	229.7

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	289.	1.	5000	309.	1.
5500	340.	1.	6000	268.	4.
6500	220.	7.	7000	221.	10.
7500	226.	7.	8000	238.	6.
8500	244.	7.	9000	248.	6.
10000	230.	5.	11000	230.	7.
12000	239.	8.	13000	240.	10.
14000	237.	11.	15000	228.	12.
16000	223.	13.			

WEST GATE THEODOLITE PIBAL 6/30/73 1800 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	360.0	0.4	4240.			
1.0	23.0	2.1	4948.	1508.	60.0	23.0
2.0	24.7	3.6	5598.	1706.	50.4	24.1
3.0	32.1	3.6	6247.	1904.	47.7	27.2
4.0	45.6	2.6	6867.	2093.	48.6	31.2
5.0	64.9	2.4	7458.	2273.	49.8	36.7
6.0	141.0	2.8	8048.	2453.	55.3	48.5
7.0	211.8	2.4	8638.	2633.	63.5	52.0
8.0	215.9	7.8	9229.	2813.	80.5	82.4

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	8.	1.	5000	23.	2.
5500	24.	3.	6000	29.	4.
6500	38.	3.	7000	50.	3.
7500	70.	2.	8000	135.	3.
8500	195.	2.	9000	214.	6.

WEST GATE THEODOLITE PIBAL 6/30/73 1920 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	130.0	5.8	4240.			
1.0	110.5	3.8	4948.	1508.	43.3	110.6
2.0	52.9	5.4	5598.	1706.	40.3	76.3
3.0	65.5	7.1	6247.	1904.	33.9	71.3
4.0	68.8	7.2	6867.	2093.	30.8	70.5
5.0	100.8	6.0	7458.	2273.	30.5	76.8
6.0	118.8	1.7	8048.	2453.	33.7	79.0
7.0	231.4	2.1	8638.	2633.	39.4	81.0
8.0	213.0	7.8	9229.	2813.	48.1	95.7
9.0	218.6	9.8	9819.	2993.	55.8	120.9
10.0	225.1	13.9	10410.	3173.	56.4	161.4
11.0	229.1	17.0	11000.	3353.	47.5	191.3
12.0	225.1	20.2	11590.	3533.	37.0	204.4
13.0	224.2	19.8	12181.	3713.	30.5	210.0
14.0	223.0	18.0	12771.	3893.	26.7	212.7
15.0	222.6	16.7	13362.	4073.	24.3	214.3
16.0	222.5	16.0	13952.	4253.	22.6	215.4
17.0	225.1	15.2	14542.	4433.	21.4	216.5
18.0	228.6	14.7	15133.	4612.	20.5	217.7

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	123.	5.	5000	106.	4.
5500	62.	5.	6000	61.	6.
6500	67.	7.	7000	76.	7.
7500	102.	6.	8000	117.	2.
8500	205.	2.	9000	220.	6.
10000	221.	11.	11000	229.	17.
12000	224.	20.	13000	223.	18.
14000	223.	16.	15000	228.	15.

WEST GATE THEODOLITE PIBAL 7/1/73 1800 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	350.0	1.3	4240.			
1.0	358.7	3.2	4948.	1508.	48.7	358.7
2.0	7.3	2.4	5598.	1706.	51.3	2.4
3.0	50.6	1.7	6247.	1904.	56.5	13.0
4.0	126.5	1.5	6867.	2093.	64.7	25.3
5.0	229.0	1.1	7458.	2273.	72.1	20.3
6.0	221.1	3.2	8048.	2453.	82.4	354.5
7.0	225.0	3.8	8638.	2633.	82.5	267.7
8.0	228.1	4.5	9229.	2813.	74.5	243.6
9.0	222.3	6.8	9819.	2993.	64.3	233.1
10.0	227.4	9.2	10410.	3173.	54.0	230.8
11.0	232.0	11.4	11000.	3353.	45.1	231.2
12.0	241.9	13.4	11590.	3533.	38.2	234.2

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	353.	2.	5000	359.	3.
5500	6.	2.	6000	34.	2.
6500	82.	2.	7000	150.	1.
7500	228.	1.	8000	222.	3.
8500	224.	4.	9000	227.	4.
10000	224.	8.	11000	232.	11.

WEST GATE THEODOLITE PIBAL 7/2/73 1800 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	40.0	1.8	4240.			
1.0	60.0	4.2	4948.	1508.	40.3	60.0
2.0	79.6	5.7	5598.	1706.	35.1	71.3
3.0	93.2	6.1	6247.	1904.	33.1	79.7
4.0	105.9	5.2	6867.	2093.	33.1	86.2
5.0	96.4	5.3	7458.	2273.	32.5	88.3
6.0	117.2	1.7	8048.	2453.	35.5	90.0
7.0	270.0	0.9	8638.	2633.	40.4	90.0
8.0	239.9	2.3	9229.	2813.	46.2	92.7
9.0	236.7	3.6	9819.	2993.	52.8	98.3
10.0	235.3	5.8	10410.	3173.	60.5	111.1
11.0	238.6	6.9	11000.	3353.	67.0	133.3
12.0	234.6	7.0	11590.	3533.	68.3	160.6
13.0	228.0	7.7	12181.	3713.	64.6	182.2
14.0	224.1	10.3	12771.	3893.	57.4	196.6
15.0	226.7	8.5	13362.	4073.	52.7	203.5
16.0	229.3	9.1	13952.	4253.	48.5	208.7
17.0	230.0	10.6	14542.	4433.	44.3	212.8
18.0	231.8	11.4	15133.	4612.	40.6	216.1
19.0	231.4	12.1	15723.	4792.	37.4	218.5
20.0	233.7	13.0	16314.	4972.	34.6	220.7

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	47.	3.	5000	62.	4.
5500	77.	5.	6000	88.	6.
6500	98.	6.	7000	104.	5.
7500	98.	5.	8000	116.	2.
8500	234.	1.	9000	252.	2.
10000	236.	4.	11000	239.	7.
12000	230.	7.	13000	225.	10.
14000	229.	9.	15000	231.	11.
16000	232.	13.			

WEST GATE THEODOLITE PIBAL 7/2/73 2000 MST

TIME	DIR	SPD	HGT(ASL)		ELV	AZ
MIN	DEG	MPS	FEET	METERS	DEG	DEG
0.0	60.0	3.6	4240.			
1.0	82.1	3.1	4948.	1508.	49.2	82.1
2.0	107.4	3.5	5598.	1706.	47.0	95.5
3.0	106.5	3.5	6247.	1904.	45.9	99.4
4.0	84.4	3.0	6867.	2093.	46.1	95.9
5.0	43.5	1.4	7458.	2273.	50.0	91.4
6.0	119.4	1.1	8048.	2453.	52.8	93.4
7.0	135.3	0.6	8638.	2633.	55.9	94.9
8.0	114.9	0.6	9229.	2813.	58.3	95.6
9.0	124.3	1.0	9819.	2993.	59.8	97.2
10.0	149.0	0.7	10410.	3173.	61.6	99.1
11.0	219.4	0.7	11000.	3353.	64.2	101.2
12.0	255.1	2.1	11590.	3533.	68.4	104.7
13.0	267.6	3.2	12181.	3713.	73.7	109.2
14.0	260.6	4.9	12771.	3893.	79.7	126.3
15.0	257.7	5.9	13362.	4073.	82.7	174.5
16.0	257.2	6.6	13952.	4253.	79.2	218.4
17.0	253.7	7.0	14542.	4433.	73.3	233.4
18.0	250.7	7.3	15133.	4612.	67.6	238.9
19.0	247.2	7.7	15723.	4792.	62.4	241.0
20.0	245.0	7.7	16314.	4972.	58.1	241.8

MANDATORY LEVELS
(FEET ASL)

HGT	DIR	SPD	HGT	DIR	SPD
	DEG	MPS		DEG	MPS
4500	68.	3.	5000	84.	3.
5500	104.	3.	6000	107.	3.
6500	98.	3.	7000	75.	3.
7500	49.	1.	8000	113.	1.
8500	132.	1.	9000	123.	1.
10000	132.	1.	11000	219.	1.
12000	264.	3.	13000	260.	5.
14000	257.	7.	15000	251.	7.
16000	246.	8.			

APPENDIX C. RADIOSONDE OBSERVATIONS

SIGNIFICANT LEVEL DATA KCC 06/06/73 0900 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
20.8	1292.	
		-4.65
17.7	1959.	
		-7.94
16.0	2173.	
		-8.68
8.5	3037.	
		-8.57
-6.9	4835.	
		2.14
-6.6	4975.	
		-7.51
-13.1	5840.	
		-8.12
-19.7	6653.	
		-6.63
-25.0	7453.	

SIGNIFICANT LEVEL DATA KCC 06/08/73 0815 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
22.7	1292.	
		-10.12
15.1	2043.	
		-1.31
14.5	2500.	
		-7.99
4.7	3726.	
		-4.15
1.8	4425.	
		-7.72
-4.8	5280.	
		-6.31
-10.5	6184.	
		-8.11
-21.5	7541.	

SIGNIFICANT LEVEL DATA KCC 06/11/73 0815 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
21.8	1292.	
		-9.12
19.2	1577.	
		-5.77
13.1	2635.	
		-7.16
1.5	4255.	

SIGNIFICANT LEVEL DATA KCC 06/12/73 0800 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
22.0	1292.	
		-2.38
20.6	1881.	
		-8.05
11.4	3024.	
		-9.31
-1.8	4442.	
		-4.69
-3.4	4783.	
		-8.38
-13.9	6036.	
		-1.57
-14.2	6227.	
		-8.02
-18.3	6738.	
		-1.65
-18.9	7101.	
		-8.03
-21.8	7462.	

SIGNIFICANT LEVEL DATA KCC 06/13/73 0930 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
22.2	1292.	
		-2.69
20.0	2111.	
		-8.51
8.2	3497.	
		-8.89
-2.0	4645.	
		-9.86
-9.0	5355.	
		-6.45
-17.3	6642.	
		-6.39
-20.5	7143.	
		-7.52
-22.8	7449.	

SIGNIFICANT LEVEL DATA KCC 06/14/73 0900 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
18.4	1292.	
		-9.87
9.8	2163.	
		-8.89
5.7	2624.	
		-5.76
-0.5	3701.	
		-8.77
-7.2	4465.	
		-4.66
-14.8	6095.	
		-6.25
-17.9	6591.	
		-7.08
-22.9	7297.	

SIGNIFICANT LEVEL DATA KCC 06/15/73 0845 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
12.3	1292.	
		-9.41
-1.6	2769.	
		-9.96
-8.4	3452.	
		-2.80
-9.2	3738.	
		-7.81
-11.7	4058.	
		-3.05
-13.4	4615.	
		-8.93
-18.3	5164.	
		-3.15
-19.3	5481.	
		-7.08
-25.5	6357.	
		-8.56
-32.7	7198.	

SIGNIFICANT LEVEL DATA KCC 06/16/73 1100 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
21.6	1292.	
		-12.32
13.9	1917.	
		-12.29
4.2	2706.	
		-9.14
-0.7	3242.	
		-8.96
-5.2	3744.	
		-10.21
-7.6	3979.	
		-8.10
-10.8	4374.	
		-7.59
-12.6	4611.	
		-4.79
-18.1	5760.	
		-10.71
-19.9	5928.	
		-6.72
-24.4	6598.	
		-1.00
-24.6	6799.	
		-7.57
-28.3	7288.	

SIGNIFICANT LEVEL DATA KCC 06/20/73 1450 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
23.2	1292.	
		-46.67
19.0	1382.	
		-4.68
15.1	2215.	
		-6.98
5.6	3576.	
		-8.05
-3.2	4669.	
		-6.61
-9.7	5652.	
		-8.31
-25.3	7529.	

SIGNIFICANT LEVEL DATA KCC 06/21/73 1535 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
25.7	1292.	
		-11.11
23.1	1526.	
		-5.20
18.5	2410.	
		-8.98
7.0	3691.	
		-5.15
5.5	3982.	
		-8.21
0.3	4615.	
		-9.76
-5.7	5230.	
		-6.28
-9.9	5899.	

SIGNIFICANT LEVEL DATA KCC 06/22/73 0942 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
30.2	1292.	
		-42.66
24.1	1435.	
		0.41
24.3	1926.	
		-9.34
10.2	3436.	
		-9.09
3.3	4195.	
		-9.61
-12.4	5828.	
		7.97
-11.3	5966.	
		-7.20
-22.7	7550.	

SIGNIFICANT LEVEL DATA KCC 06/25/73 1500 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
24.5	1292.	
		-7.78
8.1	3401.	
		-8.48
3.2	3979.	
		-7.61
0.3	4360.	
		0.0
0.3	4900.	
		-6.84
-8.8	6230.	
		-7.28
-13.1	6821.	
		-8.49
-18.9	7504.	

SIGNIFICANT LEVEL DATA KCC 06/27/73 1145 MST

TEMP(C)	HEIGHT(M)	LAPSE(DEG C/KM)
27.2	1292.	
		-3.41
26.0	1644.	
		-7.36
21.3	2283.	
		-8.53
8.0	3843.	
		-9.44
-2.9	4998.	
		13.29
-1.0	5141.	
		-5.13
-7.7	6446.	
		-8.15
-17.2	7612.	

APPENDIX D. SURFACE WIND DATA

Surface wind measurements collected at the sites shown in figure 6 are listed by test number. The recorded winds are one-half hour averages for the ending times listed. A wind direction DD, to the nearest 10°, is given. Windspeeds FF, to the nearest mile per hour, follow each direction. An asterisk following the four-digit data group identifies a variable wind direction; the range of wind direction during the 30-min interval exceeded 90°. Wind stations are identified by a number code. The following tabled code (the same as shown in fig. 6) identifies the 10 wind measurement sites. Entries of 99 denote missing data.

Sta. code #	Station name
1	Black Rock Ridge
2	Smelter Peak
3	Refinery Ridge
4	Sulfur Peak
5	Far Ridge
6	Beach
7	Magna
8	Litval
9	White Stack
10	Dike Shack

TEST 1 6/15/73 09:57 - 10:57 MST

STA	TIME											
	800	830	900	930	1000	1030	1100	1130	1200	1230	1300	1330
	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF
6	2716	2614	2712	2812	2708	2806*	3006	2705*	3004*	3005*	2705*	2105*
7	2910	2909*	2909	3109*	3110	3202*	3208*	3307*	3406*	3506*	3505*	3406*
8	3008	2908	3008	3010	3011	3010	3308*	3507*	3407	3507	3506	3406*
9	2920	2818	2917	3220	3116	3112*	3110*	3309*	3208*	3308*	3508*	3307*
4	2916*	2715*	2715*	2819*	2816*	2713*	3014*	2916*	2817*	3115*	3214*	3110*
5	2613*	2610*	2609*	3409*	3411	3510	3410	3412	3413	3311	3506	3505

TEST 2 6/18/73 15:00 - 16:00 MST

STA	TIME											
	1300	1330	1400	1430	1500	1530	1600	1630	1700	1730	1800	1830
	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF
6	1916	2213	2208*	2605*	2404	0	1804*	2104*	0	3403*	2211*	1919
7	3308*	3407	3607	3407*	3406*	3306*	3207*	3307	3407	3505	3505	3504
8	3307	3407*	3407*	3206*	3306*	3406*	3207*	3206	3306	3405	3305	3303*
9	3410	3207*	3607*	3606*	208*	3606*	3204*	3506*	3608	3607	3505*	104
2	3113*	3111*	3113*	3210*	3210*	3110*	3110*	3110*	3112*	3112*	3111*	3111*
3	3211*	3005*	3312*	3308*	3411*	3311*	3412*	3412*	3411	3310	3410	3411
4	3117	3116	3313*	3311	3212	3313	3013	3016	3014	3113	3215	3214
5	3315	3313	3308	3308	3308	3410	3409	3411	3411	3408	3410	3410

TEST 3 6/19/73 16:49 - 17:49 MST

STA	TIME											
	1500	1530	1600	1630	1700	1730	1800	1830	1900	1930	2000	2030
	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF
6	2306	2306	2304*	2103	1802*	0	0	2802*	2704	2705	0	0
7	3404	3404*	3404*	3304*	3405	3405	3304	3303	3101	0	0	0
8	3404*	3503*	3404*	3304*	3404*	3403*	3304*	3403*	3301*	2704	2708	2708
9	308*	208	306*	105*	3304*	3303	3203*	3101*	502*	604	0	0
2	3210*	3110*	3109*	3007*	3008*	3007*	2906*	3005*	3105*	3205*	3203*	0
3	3409*	3409*	3308*	3308*	3209*	3208*	2907*	2904*	3103*	9902	9902	0
4	3407	3409	3309	3310	3213	3212	3113	3011	3109	3106	3204	3001
5	3504*	3405*	3304*	3305*	3306*	3307*	3409*	3408	3406*	3305*	3502*	0

DD=WIND DIRECTION (36 POINT) FF=WIND SPEED (MPH) * DENOTES VARIBLE WIND DIRECTION.

TEST 4 6/22/73 15:34 - 16:34 MST

STA	TIME											
	1330	1400	1430	1500	1530	1600	1630	1700	1730	1800	1830	1900
	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF
6	1705	1505	1906*	1805	2308	2506	2308	1706*	1508*	1207	1110*	605
7	1707*	2005*	1705*	1804*	1803*	1804*	1702*	1804*	2805*	2406*	2307*	2106*
8	1512*	1511*	1612*	1710*	1707*	1709*	1608*	2108*	2607*	2507	2310	2208
9	3304*	3405*	208*	306*	409*	507*	3607	3306	3209*	3110	2912	2112*
1	506*	506*	307*	3307*	3306*	3305*	3205*	3205*	806*	3206*	914*	2015*
2	2807*	2907*	2908*	2909*	2908*	2906*	2805*	2807*	2806*	2810*	1912*	2021*
3	3505*	3505*	205*	3605*	3606*	3605*	504*	3103*	2208	2313	2320	2323
4	3307	3306	3306	3306	3307	3305	3205	3007	1806*	1909*	2117	2120
10	3306*	3007	3408	3208	3608*	306*	3505*	3107*	3006*	3007*	1607*	1712

TEST 5   6/25/73 16:04 - 17:05 MST

STA	TIME 1400	1430	1500	1530	1600	1630	1700	1730	1800	1830	1900	1930
	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF
6	2804	2703	2503	2504	2604	2704	2704	2704	2704	3104	3205	3504
7	3406*	205*	306*	104*	204*	402*	0	0	602*	0	0	2103*
8	3205*	3606*	105*	3604*	104*	3603*	3602*	302*	401*	0	2001	2604
9	406*	309	208*	311	411	808*	1107*	905	1002	1002	1003	1404*
1	508*	507*	507*	709*	910*	910*	908*	808*	809*	810*	1109*	1303*
2	3010*	3011*	3212*	210*	207*	106*	504*	604*	404*	405*	1107*	1411*
3	210	310	310	211	312	210	411	410	307	306	9906	9905
10	3606*	3608*	3510*	3510*	106*	305*	404*	404*	404*	505*	1508	1610

TEST 6   6/26/73 17:28 - 18:28 MST

STA	TIME 1530	1600	1630	1700	1730	1800	1830	1900	1930	2000	2030	2100
	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF
6	2101	2101	2401	2501	2602	2601	2701	2803	3003	3003*	3306	3505
7	3306	3305	3304*	3303*	3303	3203	3402	0	0	0	0	0
8	3305*	3304*	3403*	3403*	3502*	3602*	0	2704	2708	2707	2608	2607
9	3505*	3405*	3504*	305*	203*	404	605	806	1006	1006*	1110	1410*
10	107	3408	3507*	3606*	205*	104*	204*	404*	1505*	1507	1410	1511
1	9999	9999	9999	3006*	3204*	503*	903*	1104*	1303*	1401*	1207*	1110*
2	9906	9907	9908	9906	9906	9906	9907	9904	9903	9904	9910	9910

TEST 7   6/27/73   14:38 - 15:38 MST

STA	TIME											
	1230	1300	1330	1400	1430	1500	1530	1600	1630	1700	1730	1800
	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF
6	2404	2404	2204	1803*	1902*	2103	2202	2605	2604	2704	2805	3107
7	3207	3207*	3206*	3405*	104*	305*	104*	3304	3404	104*	503	0
8	3306*	3305*	3306*	3206*	3405*	3605*	106*	3304*	3304*	3604*	302	401
9	104	306	306	3606	3606	106	307	308	307	406	708	909
10	205*	205*	103*	3606*	3605*	207*	108*	3608*	3607*	3604*	104*	704*
1	810*	710*	610*	608*	507*	605*	504*	503*	604*	804*	705*	909*
2	3007*	3007*	2808*	2809*	2810*	2710*	2710	2709*	2709*	2809*	209*	309*

TEST # 8   6/28/73

STA	TIME											
	300	330	400	430	500	530	600	630	700	730	800	830
	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF
6	3205*	3308	3112*	1209	1312	1412	1506*	1407*	3003*	3106	2906	2705
7	0	0	0	1503*	0	0	1502*	3302*	3303*	3005	3304*	3404*
8	3601*	1601*	1609	2010	3303*	3303*	1804*	2802*	3303*	3205	3304	3504*
9	1005*	1007*	1414*	2116*	2817	2819	2812*	906*	811*	910	1007	707
10	1307	1408	1516	2014*	2505*	804*	505*	405*	606*	1204*	303*	404*
1	1207*	1223*	1321*	2005*	2206*	2109*	2007*	2005*	907*	1005*	9903	9903
2	904*	1016*	1120*	1606*	9902	2003*	1503*	703*	407*	403*	404*	2504*

TEST 9 6/30/73 20:36 - 21:36 MST

STA	TIME											
	1830	1900	1930	2000	2030	2100	2130	2200	2230	2300	2330	2400
	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF
6	3303	3306	3406	3604	1203*	903*	904*	1003*	1002*	3103*	2902*	202*
7	3303*	2201*	2203*	2201*	0	0	0	2103*	2002*	3103	3105	3105
9	904*	1107*	1307*	1304*	1904*	2404*	2704*	1904*	1802*	3405*	2606*	2907*

TEST 10 7/2/73 19:46 - 20:46 MST

STA	TIME											
	1800	1830	1900	1930	2000	2030	2100	2130	2200	2230	2300	2330
	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF	DDFF
7	3601	0	2401	2403*	0	0	0	0	0	0	9999	9999
9	808	908	909	708	707*	1802*	1406*	906*	1005*	1004*	9999	9999

APPENDIX E. ADDITIONAL TESTING CONSIDERATIONS

The Garfield site chosen for the second-phase study was very good for completing the project. Permission was granted by the Utah Division, Kennecott Copper Corporation, to use one of its 122-m stacks at the Garfield Smelter as the main release point and to locate samplers and wind stations on its property on the mountain ridges to the south.

Sulfur hexafluoride (SF_6) was metered into the base of smelter smokestack number three and emitted with the visible buoyant stack plume. This natural visual smelter emission aided in the proper positioning of the helicopter taking aerial samples; but because it was a plume of opportunity, it could not be regulated as was the oil fog visualization used at Huntington Canyon (Start et al., 1974a).

The SF_6 was selected as the primary tracer gas on the basis of its availability, safety, and analysis characteristics. Widely used as an insulating gas in high-capacity switchyard units and available under one-half the costs of fluorocarbons, the logistics favored its use. SF_6 is nontoxic except at extremely high ambient concentrations and is, therefore, safe at the release point. Its low background level meant that a comparatively small amount would suffice for detectability. As the number of samples intended for analysis grew,the reduced analysis time associated with SF_6 became an added advantage.

The samplers used for the experiment were the same units employed for the first-phase Huntington Canyon study. They consisted of a metal box similar to a suitcase, containing a battery-driven pump. These pumps drew air from outside the box and pumped it into a saran bag within the box (fig. 4). The samplers were manually activated at the beginning of each test. On and off times logged by the technician and concentrations of tracer material found in the bag permitted the computation of an integrated concentration value at each sampler location for the period of the sampler operation.

Figure 6 showed the locations of wind stations used during the experiments. The five wind stations located on high terrain downwind of the smelter each consisted of Climet low-threshold cups and vanes operated from battery power; the cup anemometers have a threshold sensitivity below 0.5 mps. They were mounted atop 3.1-m towers located on ridges and peaks at Black Rock, Smelter Peak, Sulfur Peak, Refinery Ridge, and Far Ridge. These sensor outputs were recorded by spring-driven strip-chart recorders. In addition, Kennecott Copper Corporation made available aerovane data taken from its sites at Magna, White Stack, Litval, and Beach. Another aerovane was placed atop a 10-m tower on the lower dike near the release stack. These records were then read and encoded to give one-half hourly average wind vectors.

The wind stations, which were placed on the mountains behind the smelter, not only gave information documenting the air motion at those points during the test, but also provided an opportunity to test their ability to predict the impact areas of the tracer gas. To test this predictive ability, the wind data from each of the release periods were averaged and plotted on a map of the area. A conventional streamline analysis was then drawn, and the predicted plume was drawn from the stack parallel to the streamlines. After comparing this with isopleths of concentrations drawn on a map of sampler positions, a refinement was made. Each of the wind stations was assigned to a strata according to its elevation. The strata selected were: surface to 5000, 5000 to 6000, and 6000 to 7500 ft. Pibal soundings provided data for each of the strata as well. A streamline analysis was drawn for each strata; the predicted plume streamline was drawn only as far on the first (lowest) strata as the distance at which the terrain height equaled the height of the upper boundary of the strata. This ending point was used to begin the predicted path on the next higher strata, and so on. Results of this type of analysis, together with the concentration isopleths for each particular test, are shown in figure 10. Concentrations are in $\frac{10^{-7}g}{m^3}$. Streamline analysis of data from well-placed surface stations is a time-proven technique, but its success depends on the density of the sensor network and upon the accuracy of the data.

The ridgetop and mountaintop locations selected for the stations were chosen to provide the sensor with an unobstructed fetch in each direction. The possibility of a venturi effect as wind passes the ridge line (Chang et al., 1972) left some doubt whether these surface stations were representative of the windspeed at plume level, but the directions were expected to provide representative data. The number and aerial coverage of the five mountain stations proved adequate for the seven tests which were sampled in that area, but additional stations would be necessary to monitor the plume trajectory under all conditions. Methods have been devised to monitor a similar network of wind stations in real-time and to predict accurately the path of a balloon or air parcel (Wendell, 1972). This technique is a promising one for studies of proposed sites or for monitoring existing facilities. The minimum number of stations necessary for such a program is a subject of current investigation.

Pibal-derived winds in the 5000-to 6500-ft MSL layer were used as the best single data source. Table 7 summarized a comparison between the data obtained by means of surface wind stations located on the ridges, by the 10-m tower near the base of the release stack, and by the pibals taken during release time.

Pibals, which by their very nature are not influenced by subtle surface flows, were found to give much better results than any of our individual Eularian (fixed-location) stations when used as a single information source to predict plume direction. This seems especially true for mountainous locations (Hardy and Pring, 1948).

Thirty-gm, single-theodolite pibals were taken regularly during the study period from the Smelter West Gate, a point 1 km from the release point. These data are summarized for the test periods in table 2 and in appendix B for all observations.

Additional studies at this particular smelter site might consider the alternate pibal location shown by the symbol ✪ in figure 4. The streamlines resulting from the mountain wind stations suggest it as a good single station indicator of plume behavior.

Laser anemometers, currently available and capable of providing an integrated speed perpendicular to the beam, would be a likely improvement for similar situations requiring a representative average windspeed at the release point (Lawrence et al., 1972).

Some longer range trajectories were provided by radar-tracked tetroons. These were released near the Smelter West Gate under various wind conditions and tracked into the Salt Lake and Tooele Valleys and northward over the lake.

Temperature profile data were provided by slow ascent radiosondes which were released from a location near the Smelter West Gate. The radiosonde data may be found in appendix C.

Surface observations,including ceiling and sky conditions, surface visibility, temperature, and surface wind were made during each test and have been presented in table 1.

During the test, aerial samples were taken by helicopter. The aircraft used was a turbocharged Bell H-47, below which a 28-m length of sampling tubing was hung (see fig. 5). A battery-powered, hand-held pump built by Unico Environmental Instruments, was used to draw air samples from below the helicopter, through the tube, and into sampling bags for analysis. The length of tubing used below the helicopter insured that the sample taken was below the level of dilution caused by rotor downwash. These factors are cited by Hales et al. (1960).

A radio net was established through which the test director could communicate from the release point to sample teams on the mountain sides and with the helicopter. Personnel servicing samplers on the canyon walls and ridges could vector the helicopter to more accurate plume centerline positions and could report and log significant occurrences during the test.

Photographic documentation of the test was not possible because photography at the study site was prohibited by Kennecott Copper Corporation. Kennecott personnel took some 35-mm photographs from Sulfur Peak, however, and made these slides available as the data analysis was nearing completion.

APPENDIX F. SECOND TRACER STUDIES

The release of a second tracer gas was planned for much of the test series as a means of determining approximately how much of the total pollutant level might be attributable to other nearby sources. The acid plant at the smelter and the coal-fired electrical powerplant at the concentrator were investigated. Beginning with test 5, therefore, dibromotetrafluoroethane (fluorocarbon 114B2) was simultaneously released.

Figure F-1 shows examples of chromatograph traces obtained. In addition to the normal constituents of clean air and the tracer material released, many other compounds resulting from the smelting process appeared on the chromatograms.

Interference resulting from one chemical in particular (later identified as a fluoride) prevented quantitative analysis of the 114B2 because the presence of the chemical masked the tracer position on the chromatogram. Many other substances, apparently in the smelter plume, appeared which would hamper the use of other second tracers. More study is indicated to resolve these problems. Analyses of these second tracer concentrations were terminated because their concentrations could not be discriminated from the "high-level" fluoride background effects.

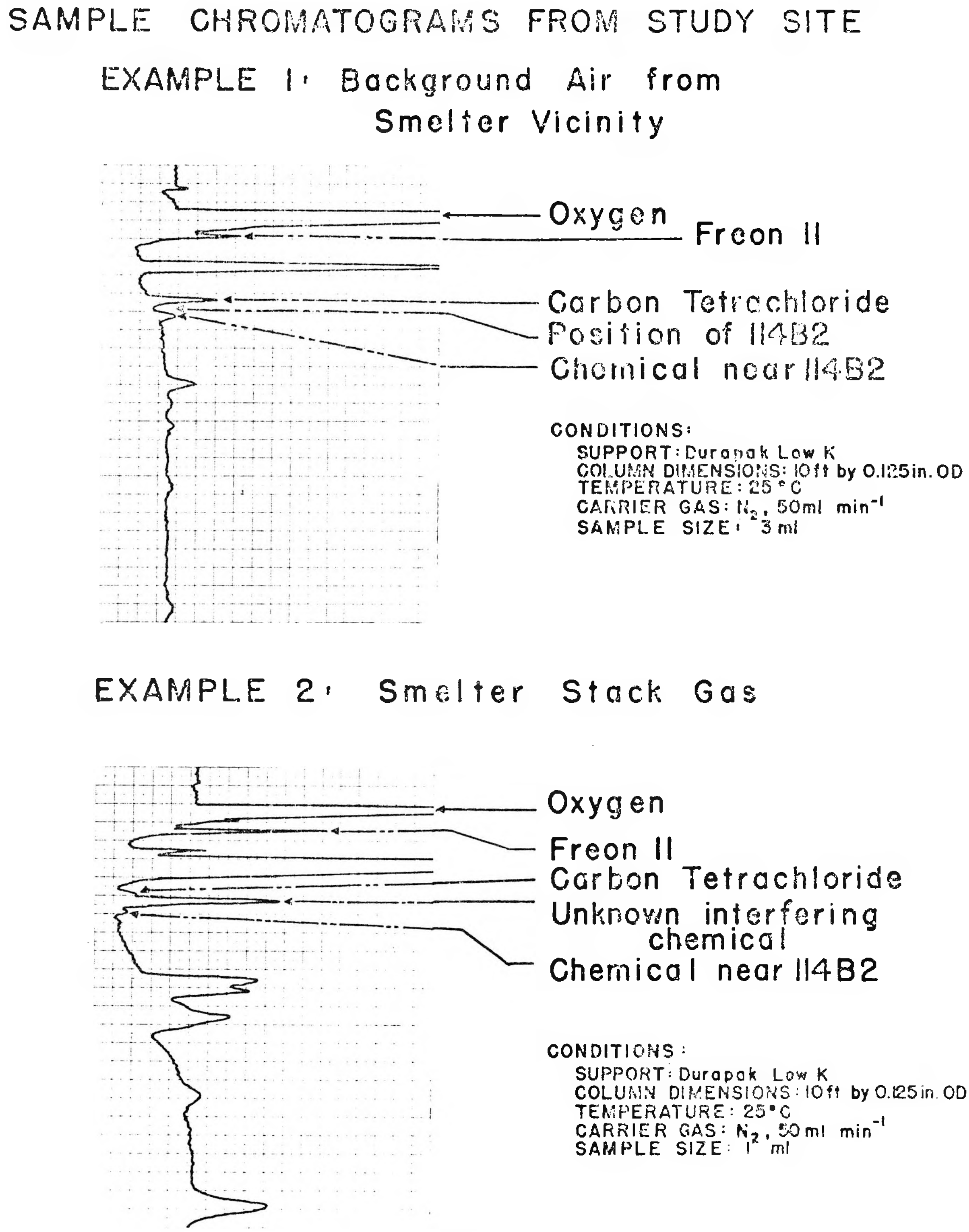

Figure F-1. Sample chromatograms for air near the Garfield Smelter and including stack gases.

APPENDIX G. GROUND-LEVEL CONCENTRATIONS, DIFFUSION STATISTICS, AND PLUME-RISE EQUATIONS

The crosswind distributions of concentrations along selected slices were extracted from the ground-level patterns of normalized concentration isopleths. These slices are shown in figures 12a through 12c. Tables G-1 through G-8 list the paired values of $\chi\bar{u}/Q$ and lateral position y. These values form the basis of lateral and some vertical diffusion estimates.

The ratio of edge-to-peak concentration leads to an estimate of the number of standard deviations contained in the span of a Gaussian distribution. The plume width divided by this number of σ yields the "plume width" estimate of σ_y. Because of edge effects, the CIC (area under the curve of $\chi\bar{u}/Q$ versus y) will be less than 100 percent; the tabled values for the span of σ_y fall short of a sufficient number of standard deviations required to yield an area under a normalized Gaussian curve which equals unity. Thus, the raw calculated values of CIC are divided by the apparent normalized area contained within the plume span. From tables G-1 through G-8, it is apparent that this correction is a small adjustment because the observed areas represented from 92 to 98.7 percent of the total mass expected for a Gaussian lateral distribution.

The seven plume rise equations, which are the basis of the plume heights plotted in figures 14a through 14h, are listed below. For simplicity, they are identified by the author(s) as shown in the figures and by the equation number as given by Briggs (1969). The emission and physical parameters for stack 3 were the following: stack height, 124 m; stack exit diameter, 8.2 m; stack gas exit speed, 4 m s^{-1}; stack gas temperature, 165^{o}C.

	Equation in Briggs (1969)
Berlyand et al. (1964)	
$\Delta h = 1.9\left(\frac{W_o}{u}\right) D + 5.0 \frac{F}{u^3}$	(4.3)
Briggs (1969)	
$\Delta h = 1.6\ F^{1/3}\ u^{-1}\ x^{2/3}$	(4.32')
CONCAWE (1966)	
$\Delta h = 1.40\left[\frac{Q_H^{1/2}}{u^{3/4}}\right]$	(4.7)
Holland (1953)	
$\Delta h = 1.5\left(\frac{W_o}{u}\right) D + 4.4 \times 10^{-4}\ \frac{Q_H}{u}$	(4.1)
Lucas (1967)	
$\Delta h = (134 + 0.3h_s)\ \frac{Q_H^{1/4}}{u}$	(4.5)
Moses and Carson (1967)	
$\Delta h = 1.81\ \frac{Q_H^{1/2}}{u}$	(4.8)
Stümke (1963)	
$\Delta h = 1.5\left(\frac{W_o}{u}\right) D + \frac{118 D^{2/3}}{u}\left[1 + \frac{\Delta T}{T_s}\right]^{1/4}$	(4.4)

Table G-1. Normalized Concentration Versus Lateral Position: Test 2, 1522 m

$\chi\bar{u}/Q$[a] (m^{-2})	y (m)
1	100
2	204
4	519
4.7	968
4	1161
2	1258
1	1355

[a] x 10^{-7}

Δy = 1255 m

$0.3989\left(\frac{1}{4.7}\right) = 0.0849 \rightarrow \pm 1.76$ st. dev. span

Area (-1.76 to +1.76) = 0.9216

y_o = 836.824

σ_y(SM) = 392 m (Second moment) } table 4

$\Delta Y/3.52$ = 357 m (Plume width) } table 4

Raw CIC * $\frac{1.000}{0.9216}$ = 2893.8 x 10^{-7}

$\bar{u}$ = 3.9 m s^{-1} } table 1

Q = 2.457 gm s^{-1} } table 1

Table G-2. Normalized Concentration Versus Lateral Position: Test 2, 2648 m

$\chi\bar{u}/Q$[a] (m^{-2})	y (m)
1	100
2	214
4	326
6	423
6.9	560
6	631
4	794
2	917
1	1003

[a] x 10^{-7}

ΔY = 903 m

$0.3989\left(\frac{1}{6.9}\right) = 0.0578 \rightarrow \pm 1.965$ st. dev. span

Area(-1.965 to +1.965) = 0.9506

y_o = 548.116

$_y$(SM) = 194.2 m (Second moment) } table 4

$\Delta Y/3.93$ = 230 m (Plume width) } table 4

Raw CIC * 1./.9506 = 2359.08 x 10^{-7}

$\bar{u}$ = 3.9 m s^{-1} } table 1

Q = 2.457 gm s^{-1} } table 1

Table G-3. Normalized Concentration Versus Lateral Position: Test 2, 4053 m

$\chi\bar{u}/Q$[a] (m^{-2})	y (m)
1	100
2	199
4	306
4.22	448
4	642
6	978
6.1	1151
6	1446
4	1706
2	1956
1	2131

$\Delta Y = 2031$ m

$0.3989\left(\frac{1}{6.1}\right) = 0.0654 \rightarrow \pm 1.90$ st. dev. span

Area (-1.90 to +1.90) = 0.9426

$y_o = 1010.235$

$\sigma_y(SM) = 549.4$ m (Second moment) } table 4

$\Delta Y/3.80 = 534$ m (Plume width) } table 4

[a] $\times 10^{-7}$

Raw CIC x 1/.9426 = 5684.5×10^{-7}

$\bar{u} = 3.9$ m s^{-1} } table 1

$Q = 2.457$ gm s^{-1} } table 1

Table G-4. Normalized Concentration Versus Lateral Position: Test 3, 1742 m

$\chi\bar{u}/Q$[a] (m^{-2})	y (m)
1	100
2	163
4	270
6	372
8	581
8.1	662
8	845
6	1283
4	1360
2	1395
1	1477

$\Delta Y = 1355$ m

$0.3989\left(\frac{1}{8.1}\right) = 0.04925 \rightarrow \pm 2.055$ st. dev. span

Area (-2.055 to +2.055) = 0.9601

$y_o = 756.750$

$\sigma_y(SM) = 394.7$ m (Second moment) } table 4

$\Delta Y/4.11 = 335$ m (Plume width) } table 4

[a] $\times 10^{-7}$

Raw CIC x 1/.9601 = 5310.3×10^{-7}

$\bar{u} = 3.5$ m s^{-1} } table 1

$Q = 2.205$ gm s^{-1} } table 1

Table G-5. Normalized Concentration Versus Lateral Position: Test 3, 2714 m

$\chi\bar{u}/Q$[a] (m^{-2})	y (m)
1	100
2	183
4	229
6	285
8	356
10	427
20	723
~22	1176
20	2006
10	2072
8	2133
6	2205
4	2256
2	2312
1	2398

[a] $\times 10^{-7}$

$\Delta Y = 2298$ m

$0.3989 \times \left(\frac{1}{22}\right) = 0.01813 \rightarrow \pm 2.486$ st. dev. span

Area (-2.486 to + 2.486) = 0.987

$y_o = 1271.952$

$\sigma_y(SM) = 539.9$ m (Second moment)

$\Delta Y/4.973 = 462$ m (Plume width)

} table 4

Raw CIC x 1/.987 = 22503.17×10^{-7}

$\bar{u} = 3.5\ m\ s^{-1}$

$Q = 2.205\ gm\ s^{-1}$

} table 1

Table G-6. Normalized Concentration Versus Lateral Position: Test 3, 3779 m

$\chi\bar{u}/Q$[a] (m^{-2})	y (m)
1	100
2	362
4	1110
6	1436
8	1996
10	2261
20	2668
~40	2964
20	3269
10	3448
8	3590
6	3677
4	3763
2	3998
1	4140

[a] $\times 10^{-7}$

$\Delta Y = 4040$ m

$0.3989 \left(\frac{1}{40}\right) = 0.0250 \rightarrow \pm 2.353$ st. dev. span

Area(-2.353 to + 2.353) = 0.9814

$y_o = 2832.465$

$\sigma_y(SM) = 739.7$ m (Second moment)

$\Delta Y/4.706 = 858$ m (Plume width)

} table 4

Raw CIC x 1/.9814 = 24893.84×10^{-7}

$\bar{u} = 3.5\ m\ s^{-1}$

$Q = 2.205\ gm\ s^{-1}$

} table 1

Table G-7. Normalized Concentration Versus Lateral Position: Test 3, 4705 m

$\chi\bar{u}/Q$[a] (m^{-2})	y (m)
4	100
6	467
8	686
10	1119
20	1582
~30	1979
20	2341
10	2534
8	2667
6	2840
4	3023

[a] $\times 10^{-7}$

$\Delta Y = 2923$ m

$$0.3989\left(\frac{1}{30}\right) = 0.05319 \rightarrow \pm 2.008 \text{ st. dev. span}$$

Area (-2.008 to +2.008) = 0.9554

$y_0 = 1853.317$

$\sigma_y(SM) = 735$ m (Second moment) } table 4

$\Delta Y/4.016 = 727.8$ m (Plume width) } table 4

Raw CIC x 1/.9554 = 25282.83×10^{-7}

$\bar{u} = 3.5 \text{ m s}^{-1}$ } table 1

$Q = 2.205 \text{ gm s}^{-1}$ } table 1

Table G-8. Normalized Concentration Versus Lateral Position: Test 7, 2037 m

$\chi\bar{u}/Q$[a] (m^{-2})	y (m)
~1	100
2	446
4	640
6	726
8	894
10	1037
~15	1317
10	1811
8	1913
6	2017
4	2274
2	2570
1	2697

[a] $\times 10^{-7}$

$\Delta Y = 2597$ m

$$0.3989\left(\frac{1}{15}\right) = 0.02659 \rightarrow \pm 2.327 \text{ st. dev. span}$$

Area(-2.327 to +2.327) = 0.980

$y_0 = 1402.052$

$\sigma_y(SM) = 580.9$ m (Second moment) } table 4

$\Delta Y/4.654 = 558$ m (Plume width) } table 4

Raw CIC x 1/.980 = 39545.6×10^{-7}

$\bar{u} = 1.54 \text{ m s}^{-1}$ } table 1

$Q = 3.213 \text{ gm s}^{-1}$ } table 1

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