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16. ABSTRACT

Introduction:

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The purpose of this report is to present to the highway engineer the basic fundamentals of meteorology and their effect on pollutant concentrations on and within the highway corridor. The objectives of this report are to acquaint the highway engineer with:

(1) The general relationship between meteorology and air pollution.
(2) The role of meteorology in the transport and dispersion of air pollutants.
(3) A method to estimate the surface stability of the atmosphere.
(4) Meteorological surveys; the instrument used, and the proper instrument exposure for measuring the surface winds.
(5) Important meteorological factors that should be considered in route location.

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Throughout these manuals the reader is directed to certain California agencies for assistance with various phases of the analysis. Readers in other states should contact parallel agencies in their state for similar assistance.

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INTRODUCTION

A meteorological survey can be of value to the highway engineer in determining the impact on air quality of proposed highway routes. An analysis of the survey (1) reveals the prevailing surface wind patterns for proposed routes, (2) determines the number of light wind days throughout the year to indicate the most unfavorable wind conditions, (3) locates areas of potentially high pollutant concentrations, (4) indicates certain types of highway designs which may disperse the pollutants more efficiently and (5) determines the most favorable meteorological route. In addition, wind speed and direction, and the stability of the atmosphere can be used in a highway line source dispersion model to estimate air pollution concentrations.

The purpose of this report is to present to the highway engineer the basic fundamentals of meteorology and their effect on pollutant concentrations on and within the highway corridor. The objectives of this report are to acquaint the highway engineer with:

(1) The general relationship between meteorology and air pollution.

(2) The role of meteorology in the transport and dispersion of air pollutants.

(3) A method to estimate the surface stability of the atmosphere.

(4) Meteorological surveys, the instruments used, and the proper instrument exposure for measuring the surface winds.

(5) Important meteorological factors that should be considered in route location.

(6) A method of analysis to reduce the meteorological data for input into a highway line source dispersion model [1].

(7) Sources of meteorological data.

DEFINITIONS OF METEOROLOGICAL TERMS

This section describes fundamental terms and definitions used in air pollution meteorology. In preparing a quantitative air quality impact pollution report one will obtain information from meteorologists at local weather stations and from local air pollution districts which employ meteorologists. To be able to communicate with them it is important to understand the terminology of air pollution meteorology. Some of the basic terms are described below. These definitions were obtained from references [2], [3], and [4].

Turbulence

Turbulence is defined [3] as a state of flow in which the instantaneous velocities exhibit irregular and apparently random fluctuations.

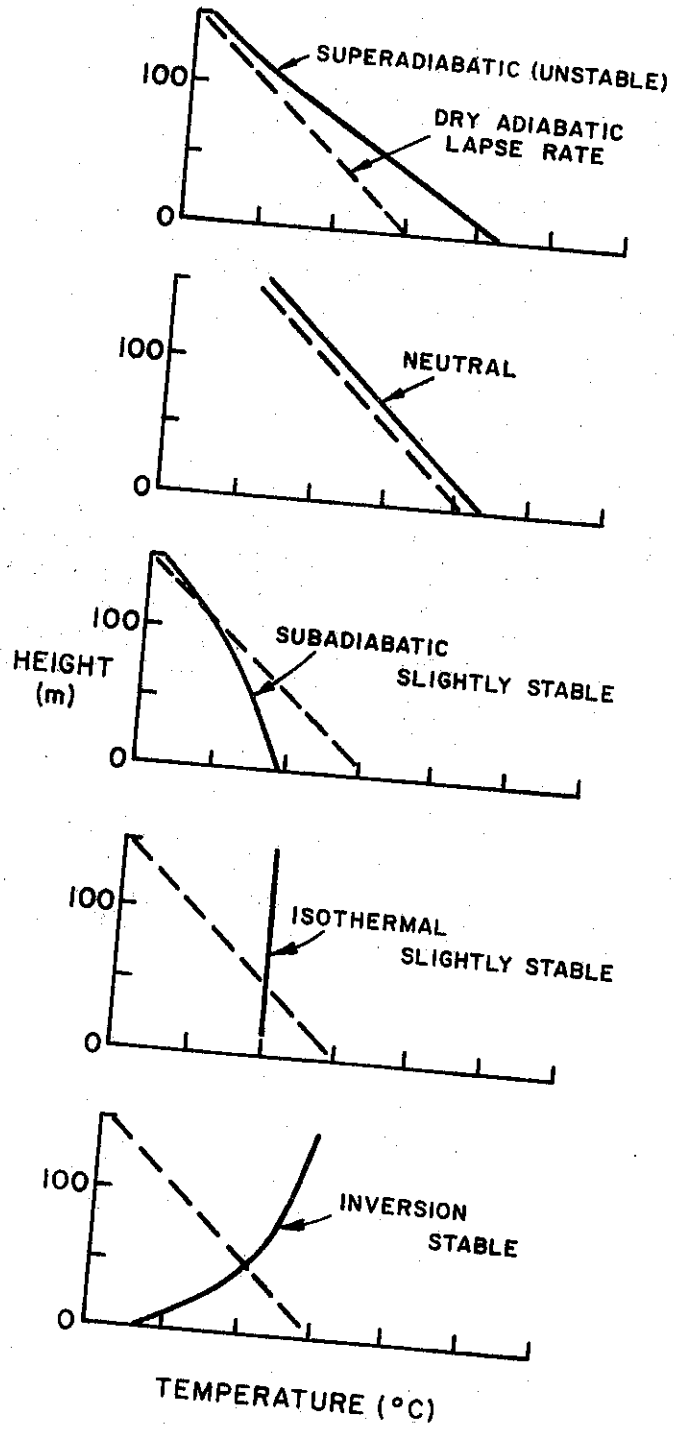
The primary factors creating atmospheric turbulence [2] are the flow of air over roughness elements on or of the ground surface, and convection associated with differences between the surface and ambient air temperatures. In general, an increase in the gradient wind flow or an increase in the air temperature close to the earth's surface compared to that aloft creates a corresponding increase in turbulence. The gradient flow can be said to be a frictionless, horizontal flow where the tangential acceleration is zero. This implies that the flow is along the isobars.

Stability and Instability

The tendency of the atmosphere to either enhance or damp out vertical motion affects the concentration of air pollutants. In simplest terms, a stable atmosphere has the tendency to suppress vertical motion while an unstable atmosphere tends to enhance vertical motion. A stable atmosphere tends to increase pollutant concentrations while an unstable atmosphere tends to minimize the concentrations. Stability is related both to vertical temperature structure and wind shear. However, the temperature structure is generally used as the measure of stability.

Dry Adiabatic Lapse Rate

Theoretically, when a small volume of air is forced upward in the atmosphere it will encounter lower pressure, expand and cool [2]. If it is assumed that there is no exchange of heat between the environment and the small volume, a rate at which cooling occurs during the ascent can be defined as the dry adiabatic lapse rate (-5.4 F/1000 ft) or (-1.0 C/100 m). A perfectly mixed layer will also exhibit a dry adiabatic lapse rate. Such a process never actually occurs in the atmosphere since turbulence tends to destroy the theoretically isolated volume, and exchange of heat does occur, but the concept has considerable value as a yardstick to assess the turbulent characteristics of the real atmosphere.



SOURCE: "Prediction of the Dispersion of Airborne Effluent" 1968 (ASME)

Fig. 1 TYPICAL ENVIRONMENTAL LAPSE RATES

Environmental Lapse Rate

The actual vertical distribution of temperature is known as the "environmental lapse rate," and it seldom approximates the adiabatic lapse rate in the lowest 100 meters over any extended time period [2]. In Figure 1, examples of typical environmental lapse rates are shown. In the figure, vertical temperature profiles are compared with the dry adiabatic lapse rate (1.0 C/100 m) which serves as a reference for distinguishing unstable from stable cases. The position of the dashed lines represents the dry adiabatic lapse rate and is significant only as far as its slope is concerned.

Superadiabatic Lapse Rate

On days with strong solar radiation or when cold air is transported over a much warmer surface, the rate of temperature decrease with height usually exceeds -5.4 F/1000 ft. This implies that any small volume displaced upward would be warmer and, therefore, lighter than its surroundings and tend to continue its upward motion [2]. A superadiabatic condition, as illustrated in the top section of Figure 1, favors strong convection, instability, and turbulence. Superadiabatic conditions are usually confined to the lowest 10 meters of the atmosphere.

Neutral Lapse Rate

With a neutral condition, in which the environmental lapse rate is nearly identical to the dry adiabatic lapse rate, there is little tendency for a displaced parcel to gain or lose buoyancy [2]. Neutral conditions are associated with overcast skies and moderate to strong wind speeds.

Subadiabatic Lapse Rate

An atmosphere in which the temperature decreases more gradually than -5.4 F/1000 ft is actually slightly stable, since a small parcel displaced upward will cool, become heavier than it originall was and tend to descend to its original position, whereas a parcel displaced downward will become warmer and lighter and rise to the original level [2].

Isothermal Lapse Rate

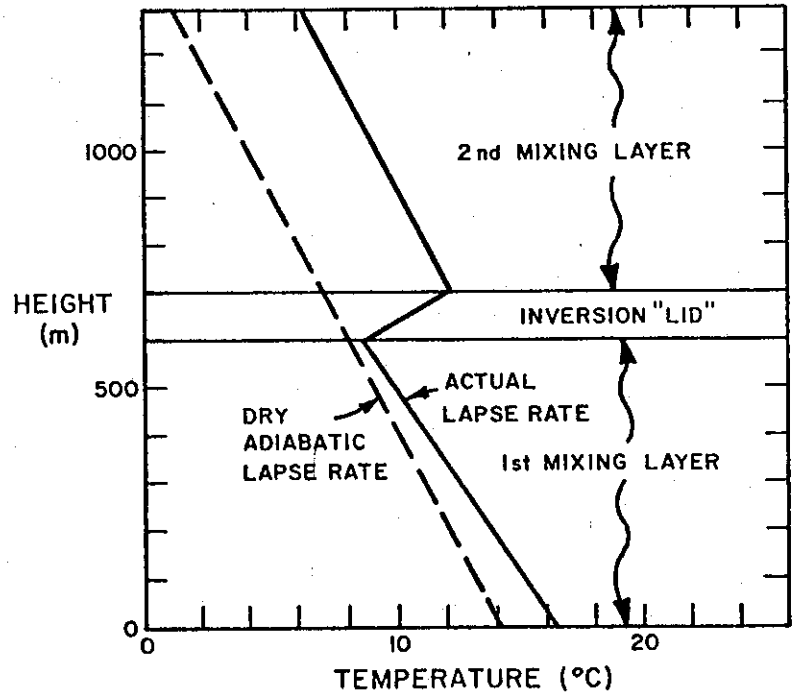
When the ambient temperature remains constant with height, the la is termed isothermal, and as in the subadiabatic case there is a slight tendency for a parcel to resist vertical motion [2]. Thi is generally a translatory condition that exists when going from inversion to an unstable lapse rate. Isothermal lapse rates are generally short lived.

Temperature Inversion

A stable atmospheric layer, in which temperature increases with height, strongly resists vertical motion and tends to suppress turbulence [2]. It is therefore of particular interest in air pollution, since it places a limit on vertical dispersion. Types of temperature inversions are as follows:

(a) Surface or Radiation Inversion: One form of inversion is shown in the bottom section of Figure 1. This structure is usually found at night with light winds and clear skies, when the loss of heat by long-wave radiation from the ground surface cools the surface and subsequently the air adjacent to it. The condition is usually found in open country. With the proper relative humidity, these same conditions will lead to a formation of radiation fog.

(b) Elevated Inversions: Sometimes an inversion exists above the ground surface, acting as a barrier between the mixed layer close to the surface and that aloft. In Figure 2 the temperature decreases with height up to 600m and then is capped by an inversion layer. Above the inversion there is a normal decrease of temperature with height. Such inversion may be caused by:



SOURCE: Prediction of the Dispersion of Airborne Effluent 1968. (ASME)

Fig. 2 ELEVATED INVERSION

(1) Subsidence - The gradual descent of air aloft, accompanied by adiabatic warming of the descending layer resulting from the increase in pressure, [2 and 5]. This subsidence inversion is most persistent during the summer and fall months in California and can last for days.

(2) Sea Breeze - Introduction of a layer of cool air beneath a warmer airmass results in an elevated inversion [2 and 5]. These are generally not as persistent as a subsidence inversion and are short lived.

(3) Frontal - A meteorological front in the atmosphere is also a boundary between cold air below and warm air aloft, marked by an inversion in the temperature structure [2 and 5]. A frontal inversion is generally short lived and is not as persistant as a subsidence inversion.

The key factor to remember is that vertical motion is inhibited in the inversion layer. If it exists aloft, it tends to act as a "lid"; if it develops near the ground it will inhibit upward dispersion of low-level pollutants.

Temporal and Spatial Variability of Surface Based Inversions

Stability in the lowest few hundred meters of the atmosphere usually exhibits marked diurnal variations [2, 5, and 6], alternating between stable and unstable conditions according to the time of day. Figure 3 illustrates the typical diurnal variation in open country. The mean diurnal variation in the lapse rate between temperature sensors at 60m and 10m above a station in open country is shown [2]. Typically, the temperature decreases with height during the daylight hours (unstable) and increases with height during the night (stable).

Winds

The following are typical examples of the types of wind patterns that can occur under different meteorological conditions within California.

Sea or Lake Breeze

On summer days with clear skies and light winds the heating of the land surface adjacent to a large lake or ocean is much more rapid than the heating of the body of water [3]. This results in a temperature difference and consequently a density and pressure difference between the air just above the land surface and the air over the water. Because of the pressure gradient forces, a local circulation is set up with the wind blowing from the water towards the land. The temperatures of oceans and large

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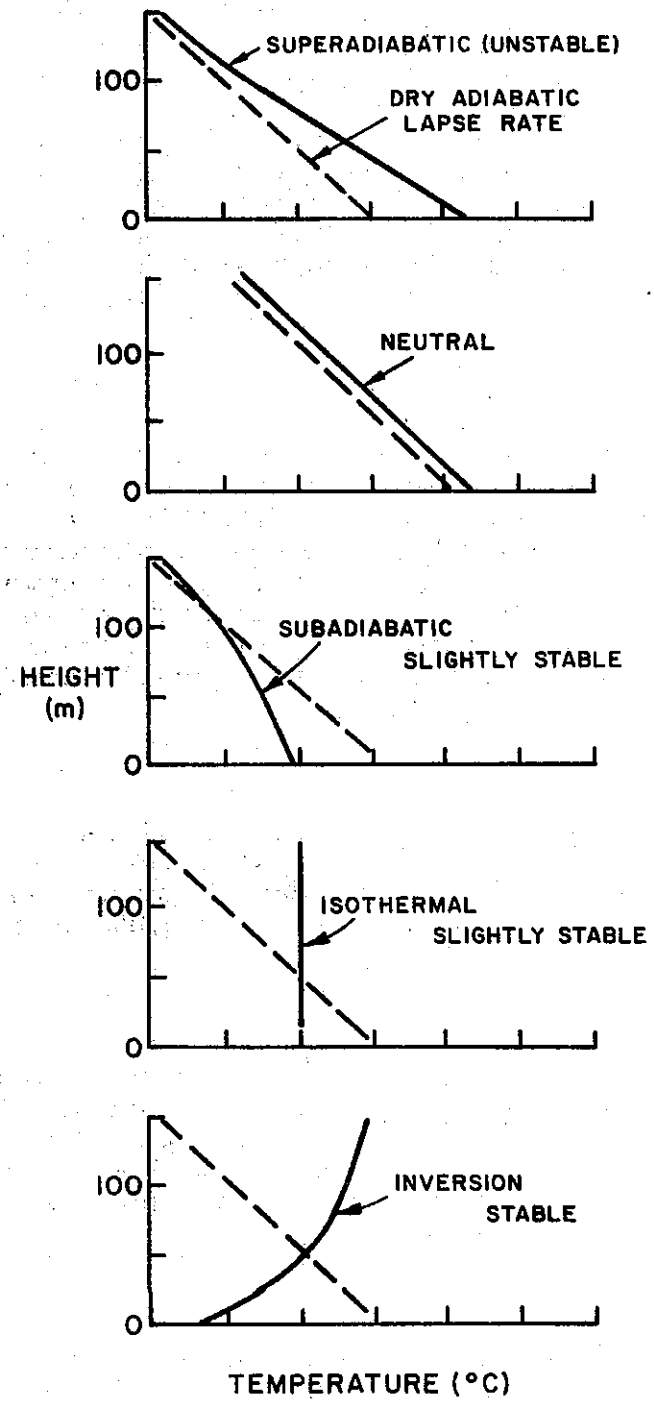
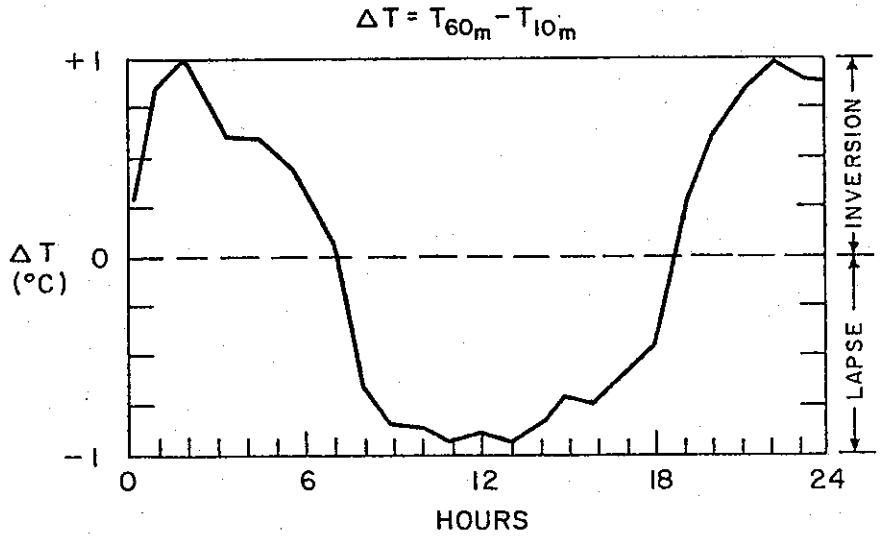


SOURCE: "Prediction of the Dispersion of Airborne Effluent" 1968 (ASME)

Fig. 1 TYPICAL ENVIRONMENTAL LAPSE RATES

lakes remain relatively constant throughout the year as compared to the land surface. The land reaches its highest temperatures during the summer months. Therefore, in the absence of a frontal system, lake or sea breezes are generally strongest during the summer months and generally weaker during the winter months.



SOURCE: "Prediction of the Dispersion of Airborne Effluent" 1968 (ASME)

Fig. 3 DIURNAL VARIATION OF LAPSE RATE OPEN COUNTRY

Drainage Winds (Slope Winds)

When the general wind flow is light and skies are clear, the differences in rates of heating and cooling of various portions of valley floors and sides cause slight density and pressure differences resulting in small scale circulations [3]. During the evening hours, radiation of heat from the earth's surface and consequent cooling of the ground and air adjacent to the ground cause density changes. The air adjacent to the ground becomes cooler and heavier and flows downhill under the influence of gravity. The steeper the slopes of the valleys and side walls

and the drainage area the stronger the down slope winds become. Vegetation will tend to reduce the flow due to frictional effects. Drainage winds are generally strongest during the winter months and lighter during the remaining part of the year.

Valley Winds

In well-defined valleys, complex flow patterns are usually encountered [3 and 7]. At night, a thin layer of drainage wind is usually found flowing down the valley sides toward the center. Over the center, one normally finds a well developed flow towards the lower end of the valley. During daytime hours there is a tendency toward a poorly defined flow up the center of the valley.

Local Winds

Local winds are any wind flow systems caused by large scale pressure patterns [6]. Typical examples are the Santa Ana Winds in Southern California and the Northern Winds in the Central Valley. Under these meteorological conditions, a high pressure area exists within the highland plateaus with an associated low pressure area in the lowlands. This creates a strong pressure gradient force. These large scale pressure patterns can develop very strong wind speeds with gusts up to 20 to 50 miles per hour.

Land Breezes

At night, the rapid radiational cooling of the land causes lower temperatures above the land surface than over the water. Thus, a land breeze may result [3]. The land breeze does not generally achieve as high a wind speed as lake or sea breezes. Land breezes, similar to the drainage winds, are generally strongest during the winter months.

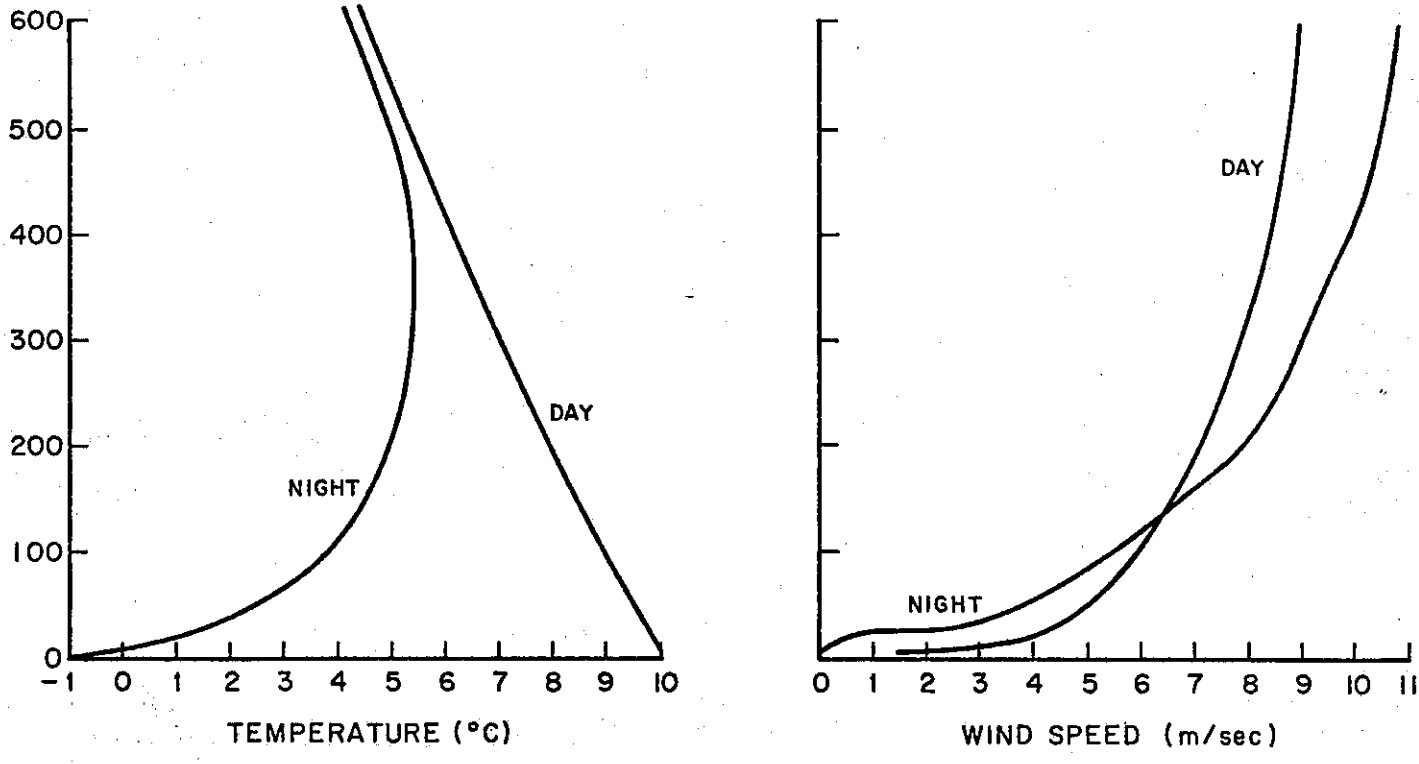
Channeling Winds

When a wind flows through a valley, the valley tends to channel the general flow along the valley axis resulting in a bi-directional wind frequency distribution [3]. This type of wind depending on the width of the valley can cause rather strong wind speeds.

Wind Shear

Wind shear is defined as the variation of horizontal wind speed and direction with height. Close to the ground the effects of friction retard the wind flow and cause it to change direction as well [2]. Figures 4 and 5 illustrate how the vertical wind speed profile is affected by changes in underlying terrain and thermal

stability [4]. In Figures 4 and 5 it can be seen that the frictional drag reduces the wind speed close to the ground. The profile at night when the air is stable is usually steeper than that found during the day. Figure 5 indicates that with decreasing roughness, the depth of the affected layer becomes shallower and the profile steeper.



SOURCE: "Prediction of the Dispersion of Airborne Effluent" 1968 (ASME)

Fig. 4 CHANGE OF WIND SPEED PROFILE WITH STABILITY

Wind Rose

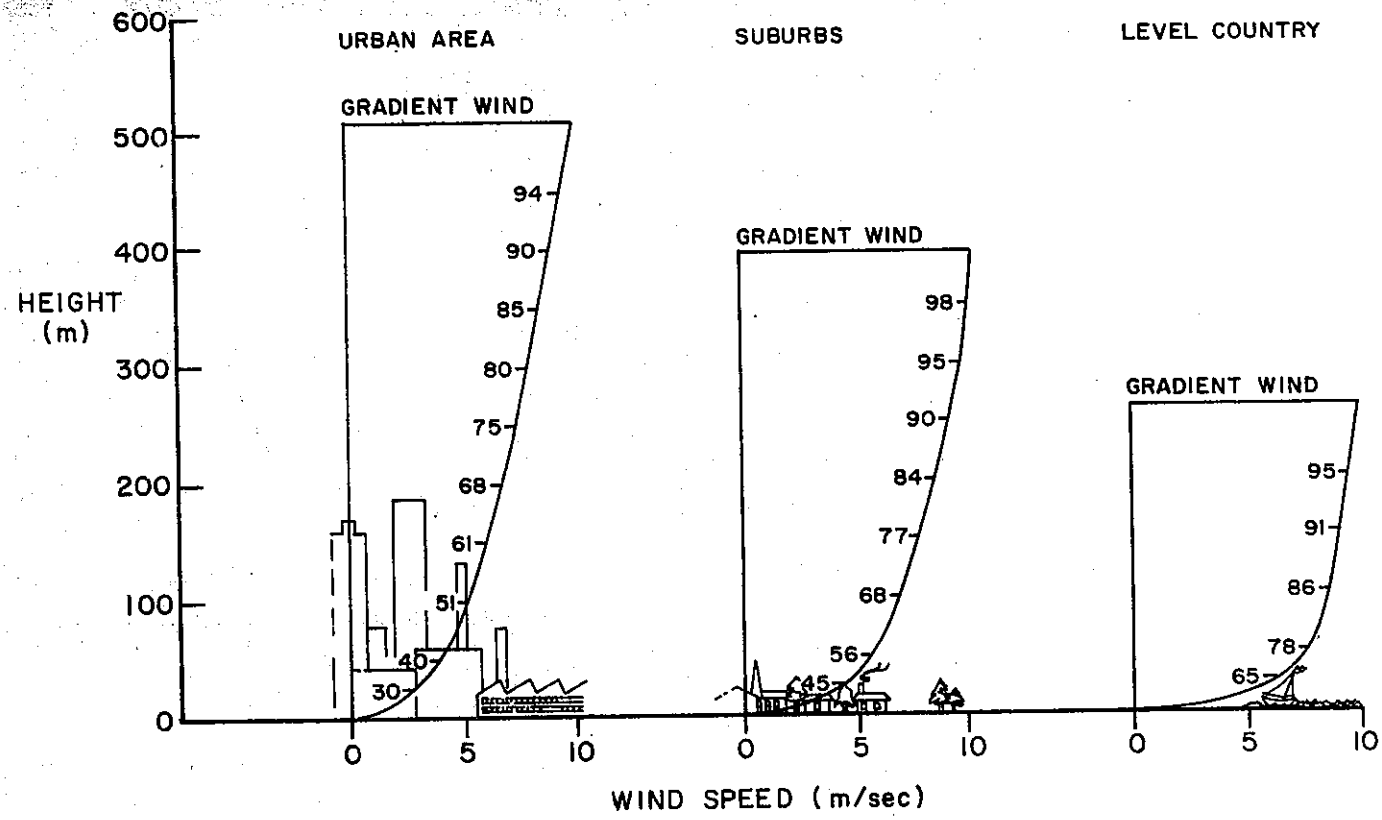
A wind rose is a diagram designed to show the frequency distribution of wind direction experienced at a given location over some period of time. A wind rose gives the prevailing wind direction and speed.

Streamline

Streamlines [8] are curves which at a particular time are everywhere parallel to the wind velocity.

Trajectory

A trajectory [8] is an actual path of an air particle.



SOURCE: "Prediction of the Dispersion of Airborne Effluent" 1968 (ASME)

Fig. 5 EFFECT OF TERRAIN ROUGHNESS ON THE WIND SPEED PROFILE

SOURCES OF METEOROLOGICAL DATA

There are various organizations that will give assistance and guidance in the collection of meteorological data. Some organizations may have very complete records while others may have very limited records. In any event the following organizations should be contacted for technical assistance on proposed routes:

1. U. S. Weather Bureau Service (local offices)
2. Local Airports
3. Local Air Pollution Districts (see Appendix A)
4. State Fire Weather Service Stations.
5. *Air Pollution Meteorologist
6. Military Installations (Navy Bases, etc.)
7. Pacific Gas and Electric Company (P.G. & E.) at locations where they have steam generating plants.
8. Local Utility Districts that have steam generating plants.
9. Industrial Complexes
10. Local High Schools, Colleges, and Universities
11. National Weather Records Center, Asheville, N.C.
12. Materials and Research Department, Sacramento

Historical meteorological data for the State Fire Weather Station can be obtained from the State Division of Forestry. The address is as follows:

Mr. William Innes
Department of Conservation
Division of Forestry
1416 9th Street
Sacramento, CA 95814

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*Air Pollution Meteorologists are located in Los Angeles, Fresno, San Francisco, and Sacramento. They are employed by the National Oceanic and Atmospheric Administration and are a service organization giving technical assistance to agencies concerned with air pollution control. They are located in the same buildings as the U. S. Weather Bureau's Meteorologists.

The National Weather Records Center (NWRC) in Asheville, N.C. contains over 400,000,000 punched cards of meteorological data [7]. Every effort is made to ensure that a copy of each meteorological record collected in the United States is stored in the NWRC depository. Data are available on microfilm and on magnetic tape. Copies of the raw data are also available. The data can be obtained from the Director of the NWRC. The address is as follows:

Director, National Climate Center
Federal Building
Asheville, North Carolina 28801

The center will prepare, on request, a summary of all pertinent data available for a given geographical area. The Materials and Research Department has been in close communication with the NWRC and has found that the most economical way to order the data would be on microfilm or magnetic tape. The cost of obtaining this information is described in detail in the section "Data Requirements for Computer Programs."

It is very probable that if a meteorological source is available near a proposed route all the records except for the past few months have been sent to NWRC. In some cases, however, the weather stations may keep copies of the records that were sent to the NWRC.

Ideally, meteorological records should be collected for a minimum of five years [9]. Records consisting of less than five years or less than twenty-four observations per day may be biased. It should be pointed out that U. S. Weather Bureau sources report the meteorological data based on Pacific Standard time. Some of the local meteorological sources may report the data on Pacific Daylight time. Care should be taken when compiling any meteorological data for a given time period. It is recommended that all meteorological records be collected for Pacific Standard Time (PST).

Before obtaining any meteorological records from the NWRC contact the Materials and Research Department in Sacramento for guidance. This department may have already obtained the records desired.

The analysis of the meteorological records will allow the engineer to evaluate the seasonal surface wind patterns and atmospheric stability along proposed highway routes.

AERODYNAMIC AND TOPOGRAPHICAL INFLUENCES

Only small portions of the earth's surface are truly level and there is growing evidence that relatively minor undulations of the surface can influence wind behavior for considerable distances [2]. Surface irregularities range from an isolated projection (building, hills, etc.) or depression on level ground to a dense succession of such features, collectively described as ground roughness. Although there have been few quantitative dispersion experiments in irregular terrain, visual observations of smoke plume behavior in a variety of situations have been made. These, together with limited surface concentration measurements, permit an approximate description of the expected behavior of smoke plumes from factory stacks. These studies have been adapted, in this report, to describe pollutant emissions from elevated highways.

Lack of quantitative data for line sources in a cut or depressed section limits our knowledge as to exactly how dispersion of the pollutants takes place. However, it is agreed that cuts or depressed sections tend to confine the pollutants and that dispersion from these sections is more difficult, especially on stagnated days with low wind speeds and an inversion aloft. The dispersion of pollutants within cut sections will require more research.

For highways located at grade, or level with the surrounding terrain, there is again a lack of quantitative data to adequately define the dispersion of pollutants from the line source. However, one can extrapolate from the plume behavior of elevated sources and apply the basic concepts to line sources at grade.

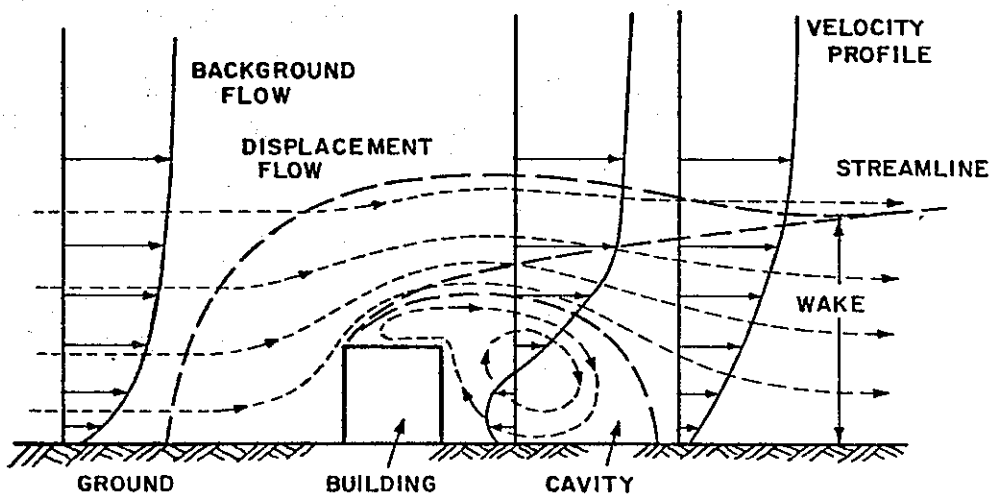
It should be stressed that the following discussion is general in relation to topographic effect on plume behavior applied to highway line sources. Presently there are no accurate analytical procedures for predicting the influence of building and topography for line sources. Further quantitative data will be required to completely analyze dispersion of the pollutants. Also the shapes of buildings and topography can vary widely between proposed routes so that results for one case may have only limited application to another.

Aerodynamic Effects of Obstructions on Wind Flow

Where a large building is situated in the vicinity of an elevated point source of pollutants, the pollutant plume becomes distorted even if it does not actually contact the building [2] and [7]. This effect occurs because the plume is carried in an air stream that

accommodates itself to the shape of the building. If the airflow is disturbed locally, that portion of the plume which penetrates the disturbed flow region will also become distorted. Descriptions of plume distortions near buildings will be more readily appreciated if prefaced by a description of the local air motions.

The presence of a bluff structure in otherwise open terrain will produce perturbations in the wind flow generally similar to those shown in Figure 6. Figure 6 shows characteristic flow zones around a sharp-edged cubical building oriented with one wall normal to the wind direction. The background flow, (undisturbed air flow) or the flow which would have existed in the absence of the building is shown at the left, where the streamlines are horizontal. The mean velocity increases upward from zero at the ground, rapidly at first and more slowly at higher elevations. In the center of the figure, the building creates a disturbance in the flow, whose main characteristic is the highly turbulent wake.



SOURCE: "Prediction of the Dispersion of Airborne Effluent" 1968 (ASME)

Fig. 6 MEAN FLOW AROUND A CUBICAL BUILDING.

Within the upwind portion of the wake, adjacent to the ground and lee walls and roof of the building, there exists a roughly elliposidal region called a cavity in which the mean flow is toroidal, moving in the direction of the background flow in the outer portion and opposite to the background flow near the axis. This can be thought of as a lee cyclone with its axis parallel to the ground on the lee side of the building. Other studies made by Johnson [10] on the dispersion of carbon monoxide within street canyons have indicated this same aerodynamic effect.

Changes in building shape and orientation to the wind affect the cavity dimensions and flow to a marked degree [2] and [7], but the gross dimensions of the displacement zone and wake for sharp edged buildings appear to be a function primarily of the frontal area of the building presented to the wind. For rounded buildings, both the displacement zone and wake are smaller than for sharp edged buildings since separation usually occurs downwind of the center of the building where the direction of the surface flow just prior to separation is horizontally downwind rather than normal to the wind.

These transitional zones in Figure 6, in which the wind flow is readjusting itself to a new set of boundary conditions, will influence the ground level concentrations. Within the cavity zone strong eddy currents can take a cloud of pollutants emitted near the highway source and quickly bring it to the ground level. This can result in relatively high ground level concentrations as compared to the undisturbed air flow case.

Suppose a highway is located on a fill section. The question arises as to how far downwind from the toe of the fill will the wind profile return to its undisturbed state? To analyze this type of highway problem recall that the introduction of a building into the background air flow causes a change in the velocity and pressure fields (Figure 6). The amount of distortion is measured by the difference between the distorted and the background properties. The flow field around highway fills, which can vary in height and slope, has not been explored in much detail. However the flow field around a suspended flat plate, which is not a structure encountered in practical dispersion problems, has been explored more thoroughly. The test results can be used as guidelines to estimate the length of the distorted air flow field.

Methods* of estimating the aerodynamic effects of the air flow field on suspended plates were made by Fail [11], Cooper [12], and Lutzky [12]. A summary of their results is given in Figure 7. The

*This paragraph was extracted from reference [7] and applied to highway fills.

dashed lines on Figure 7 are interpolated values between Fail's and Cooper's and Lutzky's measurements. In Figure 7 "q" is local resultant mean velocity. For practicality it was assumed that velocity distortions of less than 5% of the local background velocity do not exist. This assumption limits the extent of the distorted flow field. Accordingly, the wake does not extend outside the Q = 0.95V contour and the length of the wake is approximately 17L from the plate. In substituting the plate for a highway fill, assume that the horizontal ground boundary can be introduced through the center of the plate and the upper half of the plate can be made coincident with the upwind face of the fill. This will give the suspended flat plate the same geometrical proportions as the fill, with the fill height being equal to one-half its width and its length, in the direction of wind, very small.

The introduction of a solid plane through the center of the plate would impose severe restrictions on the flow in the cavity since the velocity of real fluids such as air must fall to zero at all solid boundaries [7]. In general, the plate would exert a drag force on the flow along the plate and would prevent the transverse movement of eddies from one side of the cavity to the other. These restrictions should be borne in mind when the suspended plate data are applied to highways located on fills.

The use of Figure 7 can be helpful in estimating the aerodynamic effects of highways located on fills that cross canyons, gullies, flat areas, etc. It will enable one to estimate the length of the cavity zone where ground level concentrations may be high and also estimate the length required for the wind profile to return to its undisturbed upwind state. In Figure 7, "L" represents the height of the highway fill.

Preliminary field measurements with hand held wind systems were made by the Materials and Research Department [13] to determine the aerodynamic effects of a highway fill on the undisturbed air flow. The fill analyzed was 20 feet high with 2:1 side slopes. Wind speeds ranged from 10 to 25 mph and wind direction was generally normal to the highway alignment. The results from the study indicated good correlation with Figure 7 for estimates of the cavity zone (3 to 5 L). No measurements were made to determine the distance downwind from the fill where the air flow came back to its undisturbed state. More extensive field measurement programs will be made by the Materials and Research Department to evaluate the aerodynamic effects of fills.

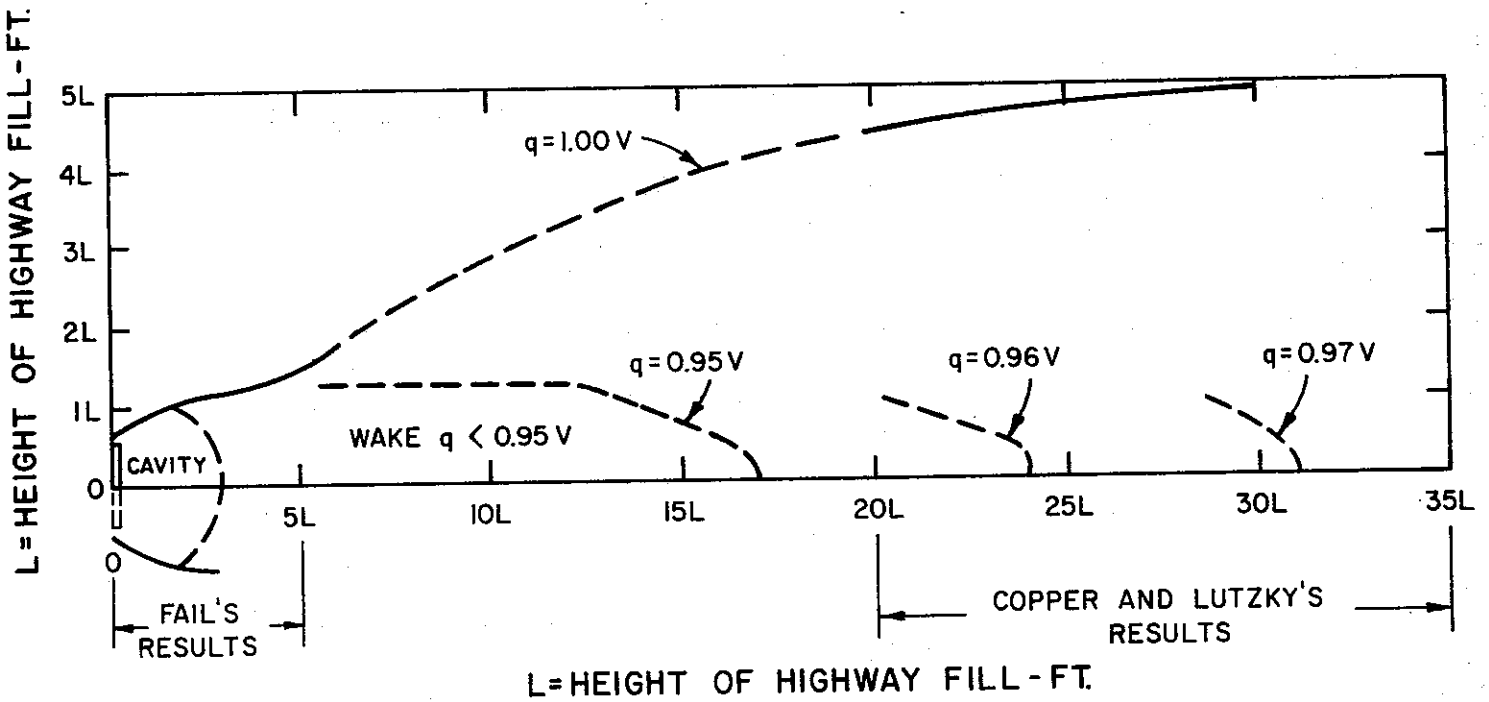


Fig.7 FLOW AROUND A SUSPENDED PLATE

SOURCE: Meteorology and Atomic Energy 1968

When a highway is located on a fill section that crosses a valley, gully, or similar depression, in an area where drainage winds occur, the ground level concentrations upwind, and to a certain extent in the downwind direction, can be influenced by the aerodynamic effects of the highway fill. Recall that drainage winds are a function of relative air densities and the slope of the drainage area. Since drainage winds are influenced primarily by gravity, the fill section itself acts as a barrier or a dam (the reservoir being filled up with cold air) and prevents the movement of this cold air mass which may contain pollutants. Generally with drainage wind conditions a surface based inversion occurs. This surface based inversion restricts the dispersion of pollutants vertically while the highway fill restricts the downwind dispersion. High ground level concentrations can be expected upwind of the fill during this period because of the restriction of the dispersion of pollutants caused by the fill and the surface inversion. The size of the cold air reservoir is a function of fill height, relative air densities and topography.

The cold air within the reservoir may under certain conditions over-top the highway fill. If there is a surface based inversion downwind of the fill, the pollutants within the air mass will be trapped in the stable air layer. In both cases, in the upwind and downwind directions, the morning break up of the surface inversion is usually quite rapid. A super adiabatic lapse rate is established near the ground and convection quickly erodes the inversion leading to fumigations [3 and 14]. When the morning turbulence reaches the plume height, pollution is carried down to the ground level by vigorous mixing in relatively high concentrations. The fumigation can last about 15 minutes [15]. The procedures discussed here can be used as a general guide. Field measurements will be required to fully analyze the aerodynamic effects of highway fill sections on drainage winds and to relate this to the expected ground level concentrations.

In view of the previous discussion, it is readily seen that a plume which lies above the displacement zone and wake will not be affected by the presence of an obstruction* but a low lying plume will. Figures 8 and 9 show characteristic plume behavior for sources of various heights and locations with respect to a building.

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*The following discussion was taken from reference [2] and modified and applied to highway line sources.

In the upwind location, an elevated line source such as a viaduct section (Figure 8a), will produce a plume that substantially clears the displacement zone but whose lower portion may or may not clear the wake [2] depending upon the turbulent state of the atmosphere. If intersection with the wake occurs, downward dispersion becomes more rapid at the bottom of the plume due to the larger turbulence. None of the contaminant, however, flows back toward the source. A line source on a low viaduct section will allow the bulk of the plume to enter the displacement zone and then the cavity and wake. If the plume centerline falls in the vicinity of the cavity boundary it will descend rapidly in the lee of the building. The concentration level in the cavity depends upon the position of the plume in reference to the cavity boundary, but it may be quite high.

An elevated line source in the vicinity of the downwind end of the cavity (Figure 9) is advantageously located, but a decrease in height will result in the repeated striking of the plume by wake gusts [2], and a very low elevated line source will be in a region of very strong downwash. The cavity will not be contaminated in any case, but the low elevated source will produce strong ground concentrations in the wake.

A similar analogy can be made with a highway fill section in which the air flow over the fill is similar to that of Figure 6. The fill in this case acts as a building. Also a similar analogy can be made if a house or building were located downwind or upwind of a highway located on a fill section such as in Figure 7 and 8. Topographic influences such as hills, ridges, etc. can also produce flow patterns similar to those shown in Figure 6.

Distortion Near Natural Terrain Irregularities

Figure 10 shows a highway located on a side hill fill near one side of a wide valley in a cross wind. When the wind direction is normal to the axis of the valley (Section a), the source is in the cavity and the effluent becomes thoroughly mixed before passing downwind to the wake where the flow is in the direction of the upper wind [2]. Turbulence is still high and the plume is distributed vertically through much of the valley depth. With a wind from left to right as shown in Section (a), the plume may be brought quickly to ground level by aerodynamic eddies where it can create high concentrations for very short periods of time. In section (b) the source is upwind of the valley side. The air stream, and hence the plume, is deflected up over the edge of the hill. If the edge is sharp, a wake and cavity will form on the plateau. A rounded edge will produce smooth accelerated flow. In either case, high concentrations may be found on the higher ground [2].

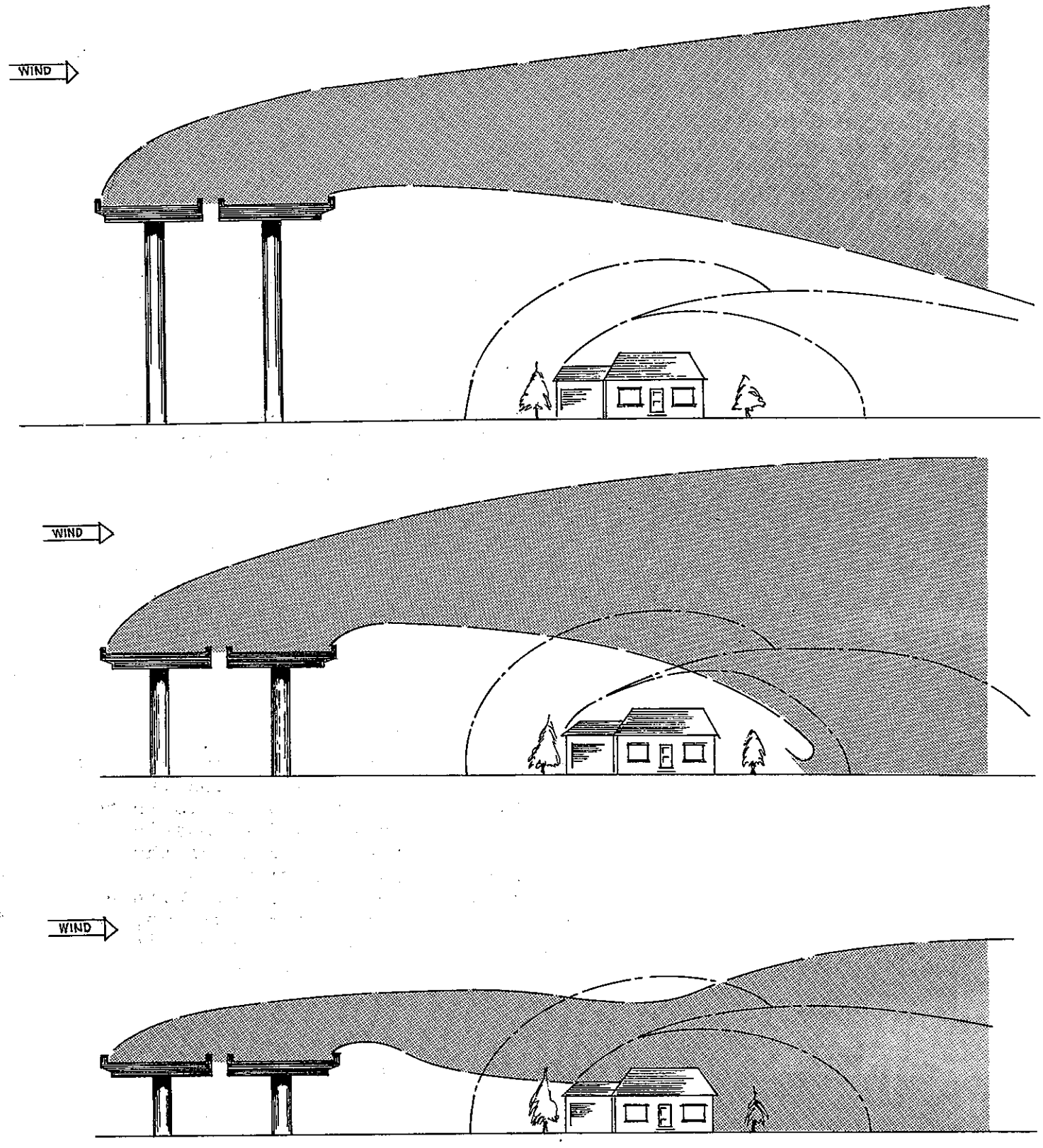


Fig. 8 DOWNWIND AERODYNAMIC EFFECTS ON DISPERSION OF POLLUTANTS FROM HIGHWAY LINE SOURCE ON VIADUCT SECTION

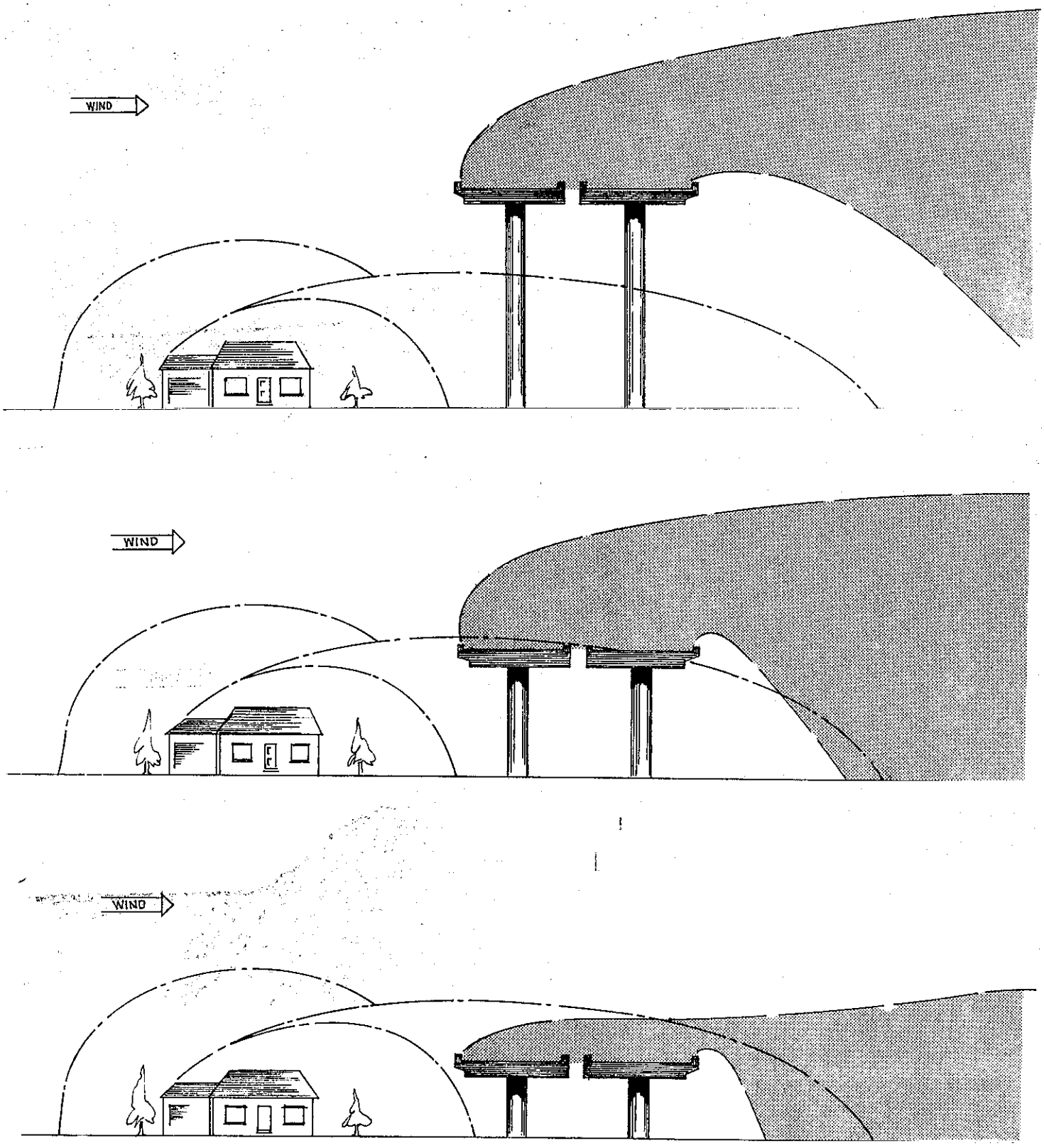
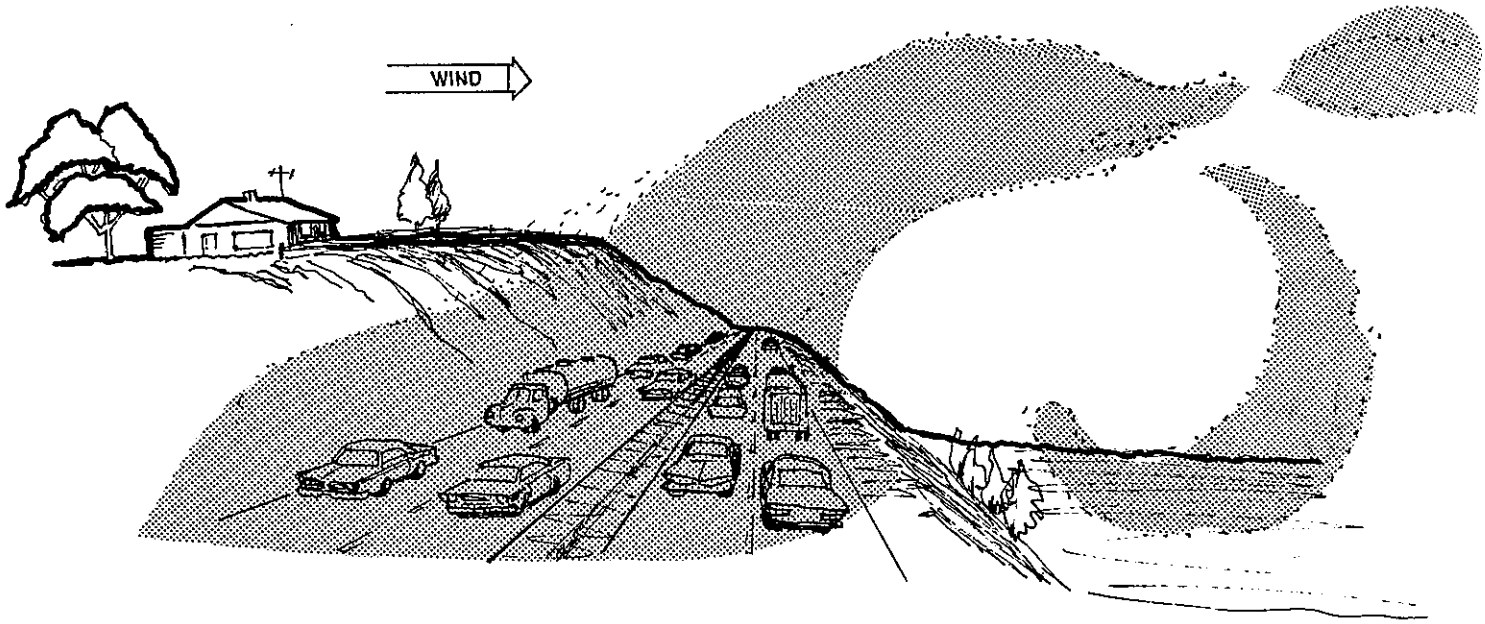
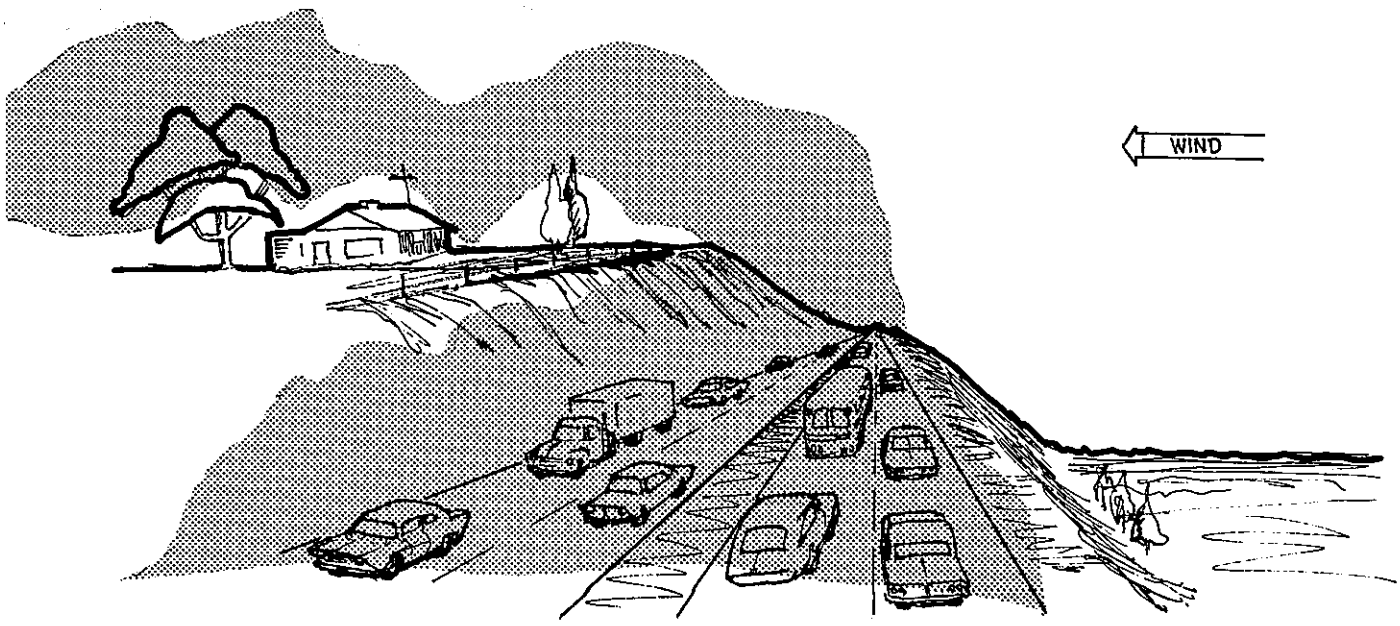


Fig. 9 UPWIND AERODYNAMIC EFFECTS ON DISPERSION OF POLLUTANTS FROM HIGHWAY LINE SOURCE ON VIADUCT SECTION



Section A



Section B

Fig. 10 DISPERSION OF POLLUTANTS FROM A HIGHWAY LINE SOURCE IN A DEEP WIDE VALLEY

Figure 11 shows a highway on a side hill fill in a valley with a channeling wind along the axis of the valley. The streamlines within the valley remain straight but lateral dispersion is suppressed in the vicinity of the valley walls [2]. Therefore, when the wind is parallel to the valley, dispersion tends to occur fairly normally until confined by the valley walls.

Very large and prominent land forms (mountains and hills) may affect the air flow patterns somewhat differently than would be true of small buildings or hills [2] and [3]. The entire plume may rise over a large hill in unstable conditions and possibly contact the surface to some degree. In stable conditions, the air flow (and the plume) may be diverted around the obstacle. Figure 12 illustrates these conditions.

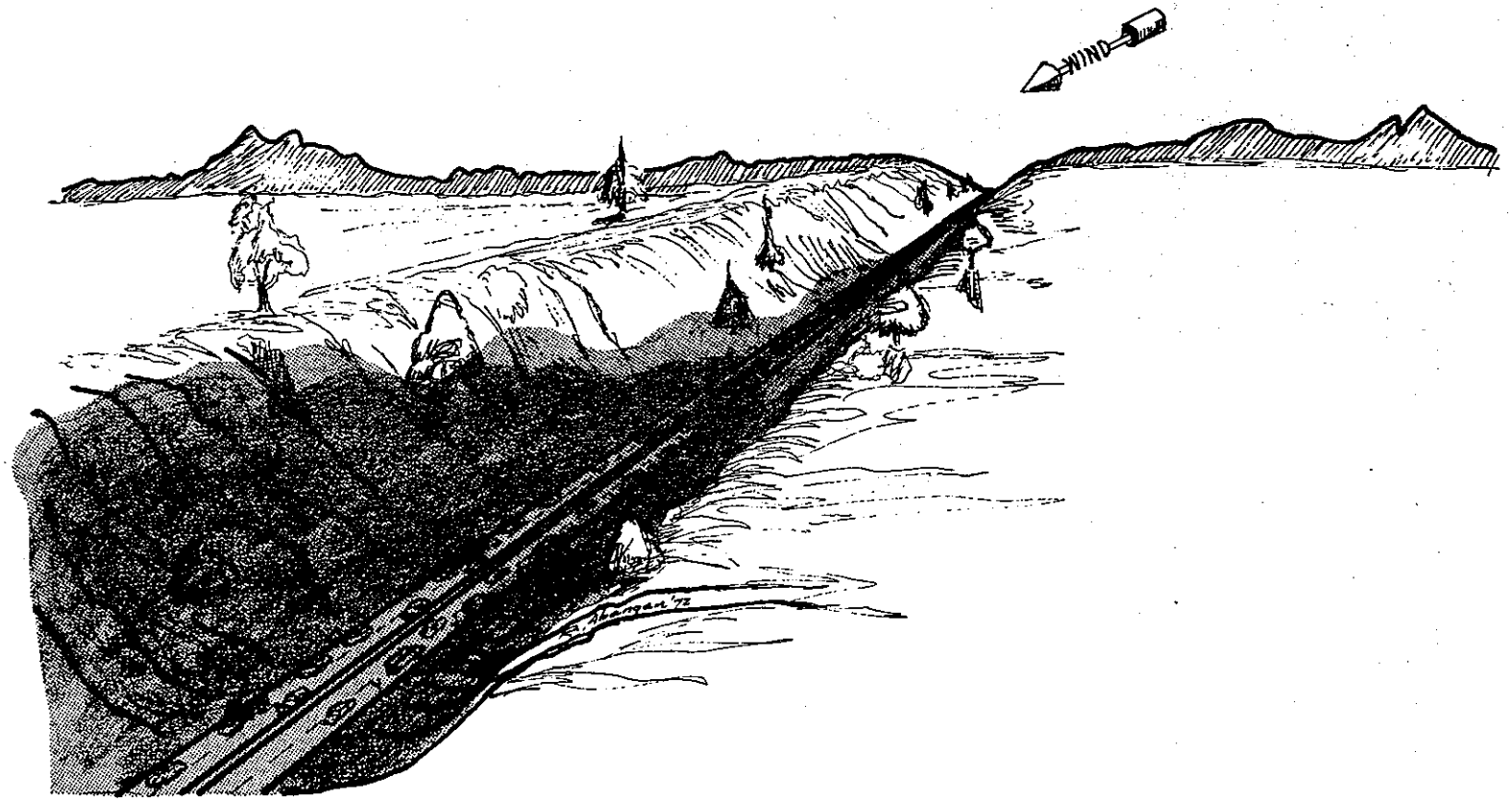


Fig.11 DISPERSION OF POLLUTANTS FROM A HIGHWAY LINE SOURCE IN A VALLEY – WINDS PARALLEL TO VALLEY AXIS

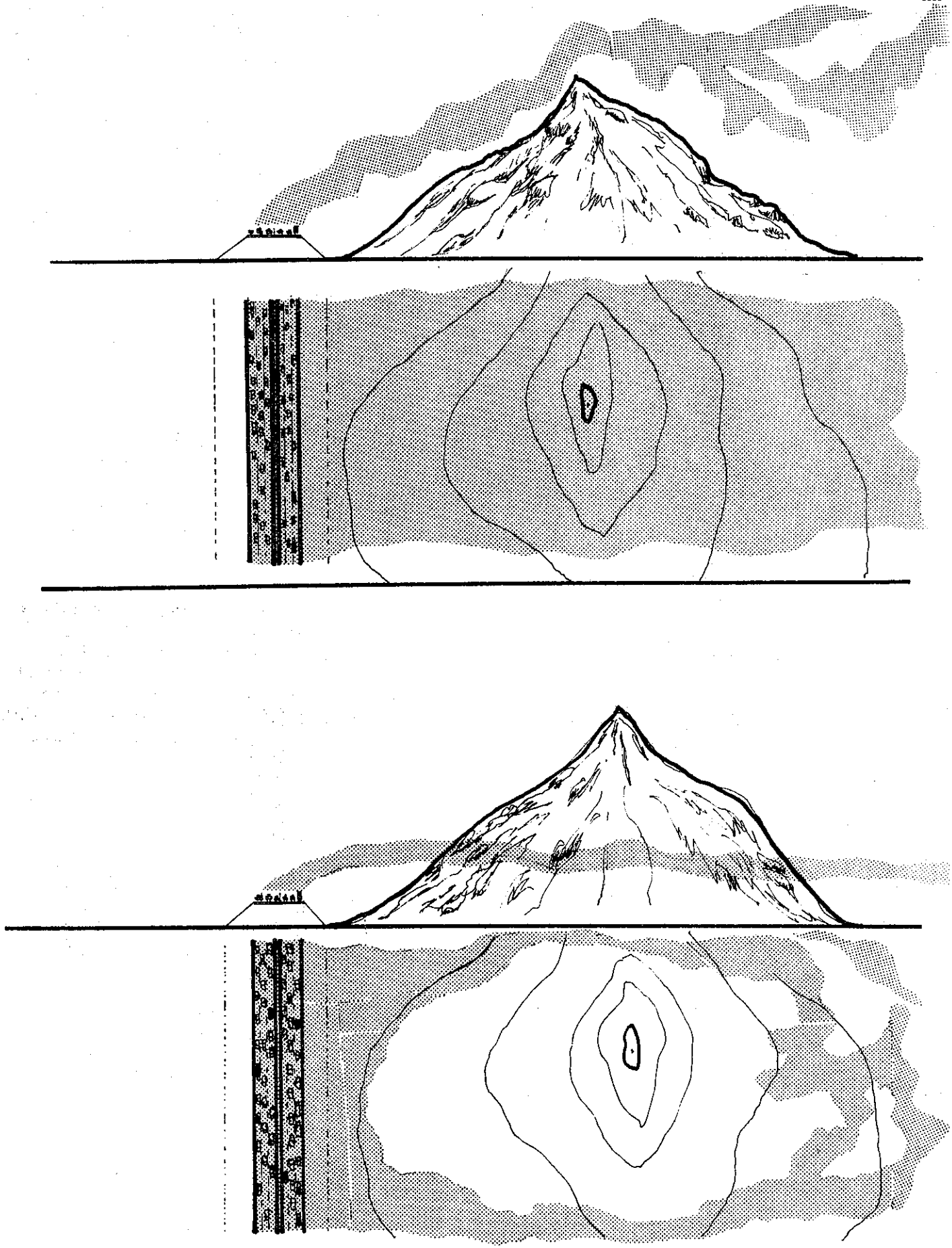


Fig. 12 DISPERSION OF POLLUTANTS FROM A HIGHWAY LINE SOURCE NEAR VERY LARGE LAND FORMS

THERMAL EFFECTS

Thermal characteristics of buildings, cities, and topography may have a marked influence on plume behavior [2], [3], and [15]. In rare cases, a building which houses a heat producing process may emit sufficient heat to the atmospheric air permitting convective transport, especially at low wind speeds. This would be favorable if a plume was immersed in it. However, off to the sides of the large plume there may be a downdraft which is locally unfavorable.

Most cities create their own modifications of the weather. The most notable of these effects is the urban "heat island" [2 and 3]. The bulk heat emissions from fuel consumption and the stored heat in buildings and streets warm the urban area more than the surrounding countryside. This effect is more easily seen at night when measurements show there is seldom a surface inversion in large metropolitan areas. The effect on line source emissions in the urban areas is to enhance vertical spreading (Figure 13). A plume entering the city area from a line source in the rural environment seems to mix rapidly in the vertical. High plume concentrations are unlikely and instead there is more dispersion with lower pollutant concentrations. The mechanical turbulence created by the buildings also enhances mixing.

Thermal influences from topography vary widely in scale. Studies of fumigating plumes in valleys involved topographical thermal actions in which the rising sun heated one slope of the valley and caused overturning of the air mass [2] and [3]. Differential heating or cooling between different land surfaces is the cause of many thermal effects. A typical example of such thermal effects is in agricultural areas where a bare open ground surface exists in contrast with an adjacent field with agricultural crops. In the agricultural field there is less reflected radiation as compared to the bare open ground surface. In all cases there is a marked vertical temperature gradient.

In summary of the above discussion, the thermal and topographic irregularities can occur simultaneously and it is difficult to distinguish their influences on the pollutant behavior. However, from the discussion above one can obtain a general qualitative feel for topographic and thermal effects on the dispersion of pollutants.

It should also be noted that meteorological conditions and local topography along proposed routes can vary considerably depending on location. Meteorological data must be collected and analyzed for each route with the effects of local topography included in the analysis.

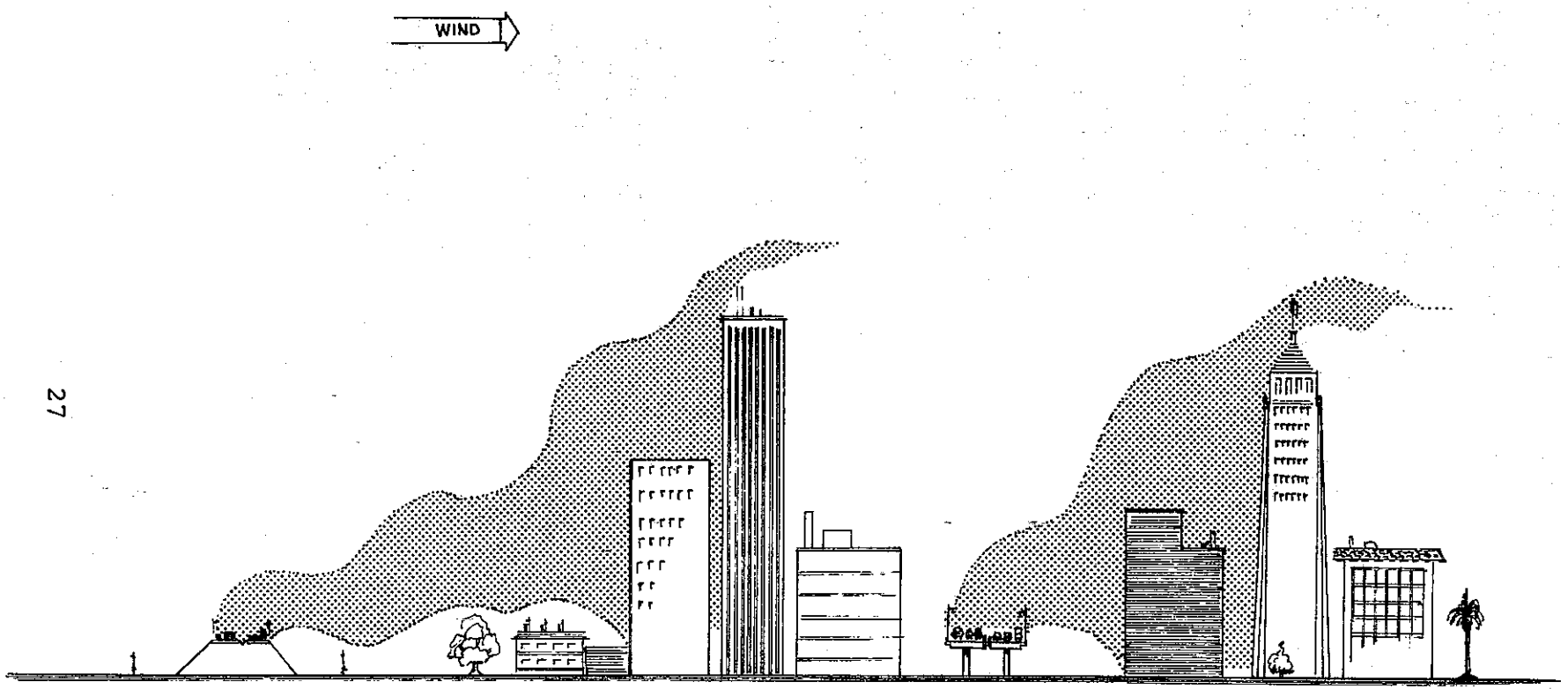


Fig. 13 DISPERSION OF POLLUTANTS TOWARD AND WITHIN A CITY FROM A HIGHWAY LINE SOURCE

EXPOSURE OF METEOROLOGICAL WIND SYSTEMS

Exposure of Surface Instruments

The wind data which are collected and analyzed from meteorological sources can be used in a highway line source dispersion model [16]. The wind speeds and directions are direct inputs into such a model. It is extremely important to input wind speeds and directions that are representative of the area. Improper exposures of wind systems (anemometer and vane) can produce mean surface wind speeds which vary according to the wind shear within the surface boundary layer. This will result in over or under estimating the pollutant concentrations. Improper exposure of wind systems located near obstructions can drastically change the wind direction and speed. This is caused by the aerodynamic effects of air flow around obstructions (see Figure 6). This can also result in wrong estimates of pollutant concentrations.

The general rules [3] for keeping the sensor located within the undisturbed air flow when the wind system is located on or near an obstruction are:

1) In upwind locations, the sensor must be located a distance upwind of the building equal to the building height.

2) If the sensor is to be located on the roof of the building it must be at least one building height above the roof.

3) For downwind locations, the sensor must be located a distance of 5 to 10 building heights in the downwind direction.

These general guidelines apply to a cubical obstruction located in open level terrain [3]. If a wind system is located within a built up area with tall buildings, it is very probable that the guidelines above would not be met. This results in the close proximity of the building or obstructions to the wind system. However, modification of these guidelines can be made as follows [3]:

1) The sensor should be mounted on the roof of the tallest obstruction available, a distance above the roof determined by the proximity of the taller obstruction (using guidelines 1 and 2).

2) The sensor should be located a distance equal to the height of the obstruction above the surrounding obstructions (using guideline 2).

Figures 14 and 15 illustrate general boundaries for the proper exposure of wind systems near cubical buildings and built up areas.

Figures 14 and 15, along with the general guidelines, apply to a cubical obstruction with the wind normal to one side. Other types of geometric designs (cylindrical buildings, etc.) and conditions where the prevailing surface winds are not normal to the side of a building result in different aerodynamic influences. The general rules given above may be conservative, that is, the sensor may not be required to be located a distance of one height above the obstruction. For borderline cases in the proper exposure of wind systems consult with the Materials and Research Department for guidance and assistance.

If a surface wind exhibiting a 180° diurnal variation exists within an area of wind measurement, a system located at point 1 in Figure 14 would measure the representative surface wind when the wind is from left to right as illustrated in the figure. If the wind changes directions (right to left in Figure 14) the sensor is improperly exposed based on the general guidelines and the measurements are not representative of the area.

If the wind system is improperly exposed (based on the criteria above with special consideration given to the type building design, etc.) the data are not representative of the mean surface wind and should not be used as input into the highway line source dispersion model [16]. Only data from properly exposed wind systems should be used.

For a proposed highway route, the surface wind streamlines may be impossible to determine. This can occur when the existing meteorological sources have improperly exposed instruments or there are no meteorological sources within the area of the proposed highway route. Under these conditions a meteorological survey will be required using mechanical weather stations*.

These wind systems (mechanical weather stations) will be located for proper exposure based on the general guidelines presented in this section. However, in recent years [3] an attempt has been made at standardizing the height above ground at which surface wind measurements should be taken. The World Meteorological Organization and the National Oceanic and Atmospheric Administration have standardized this height at 10 meters (33 feet). These measurements should be taken over level, open terrain. For meteorological surveys made by the Division of Highways it is recommended that all wind systems be located at distance of 10 meters above the ground surface in open terrain. In many areas open level terrain will not exist. For these conditions use the general guidelines presented in this report as illustrated in Figures 14 and 15.

*The details of the meteorological survey will be discussed in a later section.

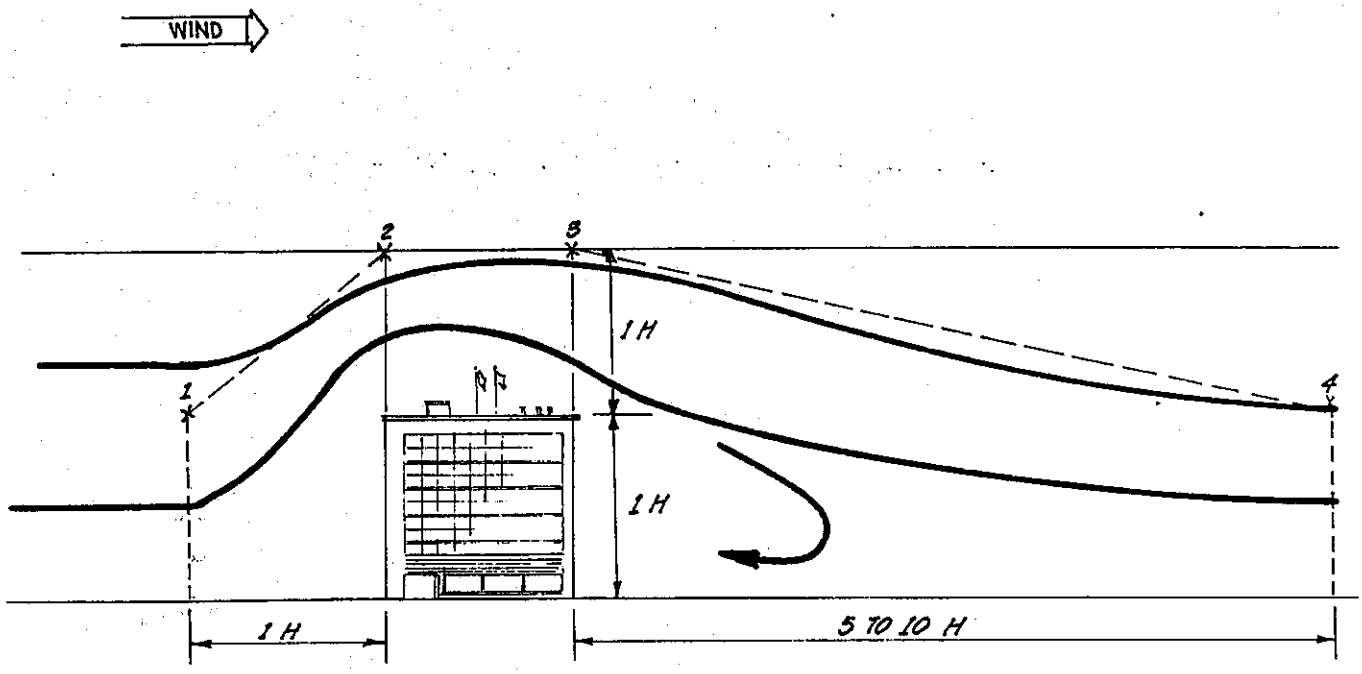


Fig. 14 PROPER EXPOSURE OF WIND SYSTEMS NEAR CUBICAL BUILDINGS

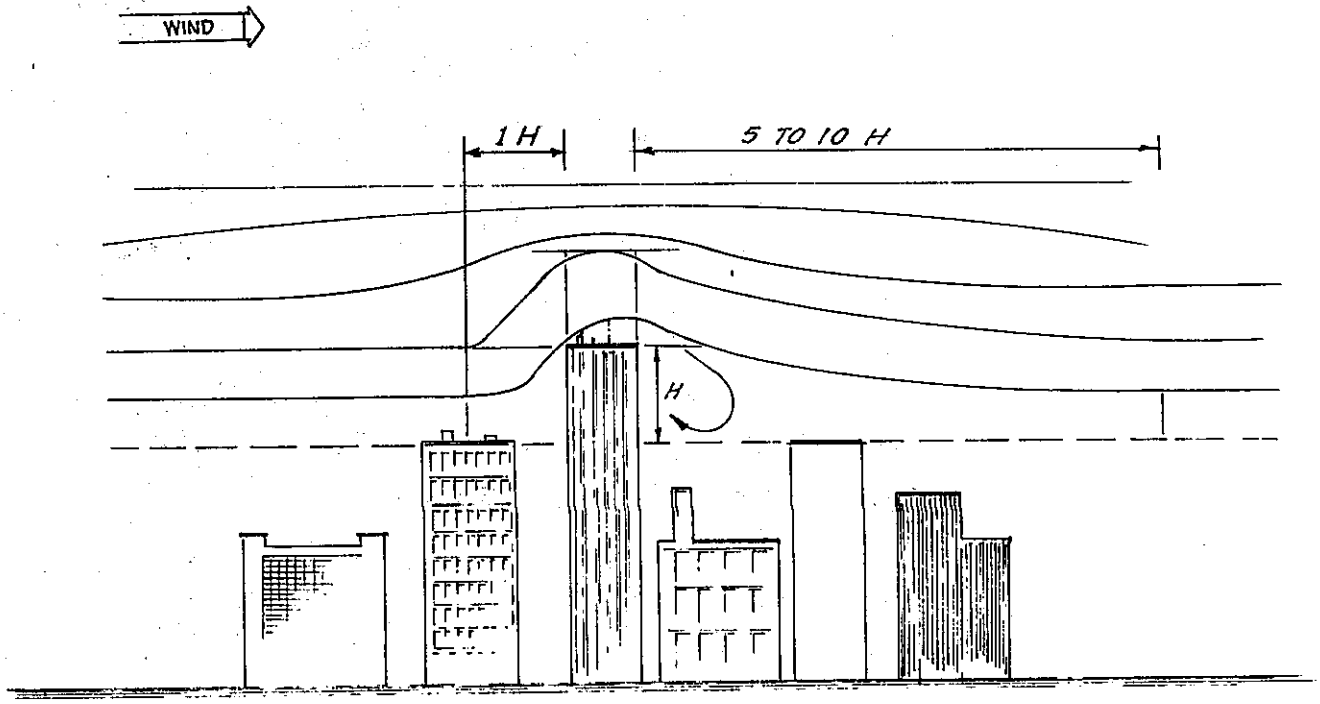


Fig. 15 PROPER EXPOSURE OF WIND SYSTEMS IN BUILT-UP AREAS

It is recommended, before any surface wind data are collected and analyzed, that the wind system be inspected for proper exposure.

Exposure of Instruments on Towers or Stacks*

In collecting meteorological data a wind system may be located and mounted on a tower or stack. This will be the probable condition if data are obtained from an industrial complex. Unless the sensors are mounted properly, the measurement will be under the aerodynamic effects of the tower or stack.

If a wind system is to be mounted on top of a tower, little concern is needed as to exposure. If, however, wind equipment is to be installed on the side of the tower, precautions should be taken to ensure that the wind measurements are not influenced by the tower.

Figure 16 illustrates the correct exposure of a wind sensor on an open tower. The following exposure criteria should be observed:

1) The boom should extend outward from a corner of the tower into the wind direction of primary concern.

2) The boom should place the sensor out from the tower a distance not less than the width of a side of the tower (length D in Figure 16).

3) The wind sensors should be located at heights of minimum tower density, and above or below horizontal cross members.

If the above guidelines are followed, the following accuracies can be expected:

1) For a boom length of 1D, measurements of wind speed are true within $\pm$ 10% for a 310° sector of arc.

2) For a boom length of 2D the wind speed is accurate within $\pm$ 10% for a 330° sector of arc.

3) For these two arcs, wind direction is accurate to within approximately $\pm$ 5%.

With a boom length of 1 -2D, wind speed and direction measurements within $\pm$ 5% can only be obtained for a 240 - 270° sector of arc. This is the case illustrated in Figure 16.

It has been found in practice that the maximum practical boom length is about 20-30 feet. If the wind sensors are to be mounted on very large towers (TV towers or fire look-out towers), the sector of arc yielding accurate wind measurements may drop to 180° due to the fact that the boom length may be less than 1D.

*The following discussion was extracted and summarized from a paper "Exposure of Instruments on Towers or Stacks" by R. C. Hilfiker, Meteorologist with the Laboratory and Surveillance Section, Office of Air Programs, Environmental Protection Agency, Research Triangle Park, North Carolina.

In any case, if accurate wind measurements are required for an arc sector greater than that produced by the above exposure criteria, it is recommended that two sets of speed and direction sensors be placed at 180° apart in the manner prescribed in the above guidelines.

Closed towers or stacks should not be used to support meteorological sensors. If a stack must be used, the following exposure guidelines should be observed:

1) The boom should place the sensor out from the stack a distance not less than 2 stack diameters.

2) Instruments should never be located within 2-5 stack diameters of the top of an active stack.

Figure 17 illustrates the correct exposure of a wind sensor on a stack. If the above guidelines are used one can expect accurate wind measurements (± 5 to 10% of true value) through an arc of only 180° as shown in Figure 17. As with towers, if accurate wind measurements through a full 360° of Azimuth are desired, it is recommended that two sets of wind systems be used. These two systems should be located 180° apart, and exposed according to the above guidelines.

Again as was previously mentioned a field inspection of wind systems mounted on towers or stacks should be made for proper exposure.

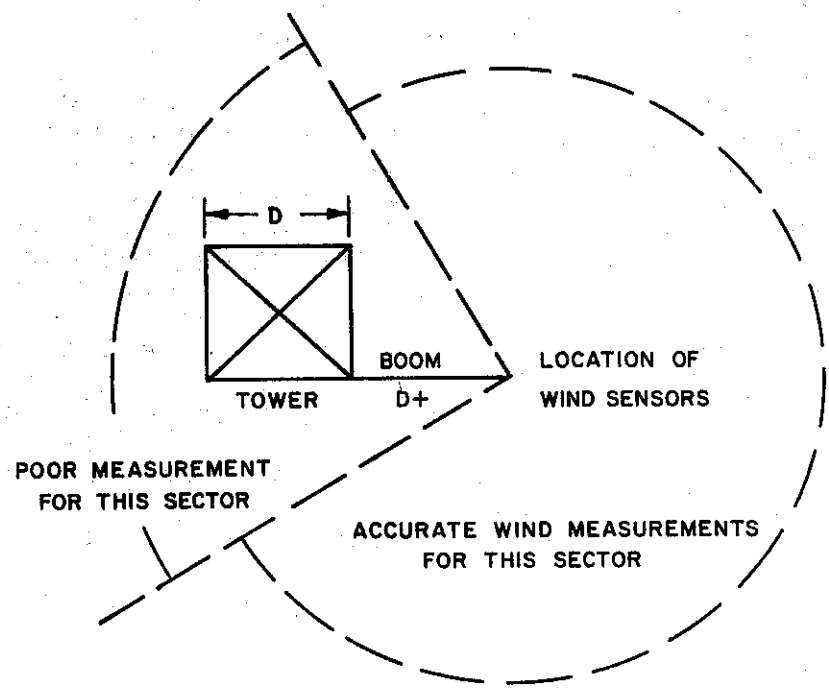


Fig. 16 WIND SENSOR EXPOSURE ON A TOWER

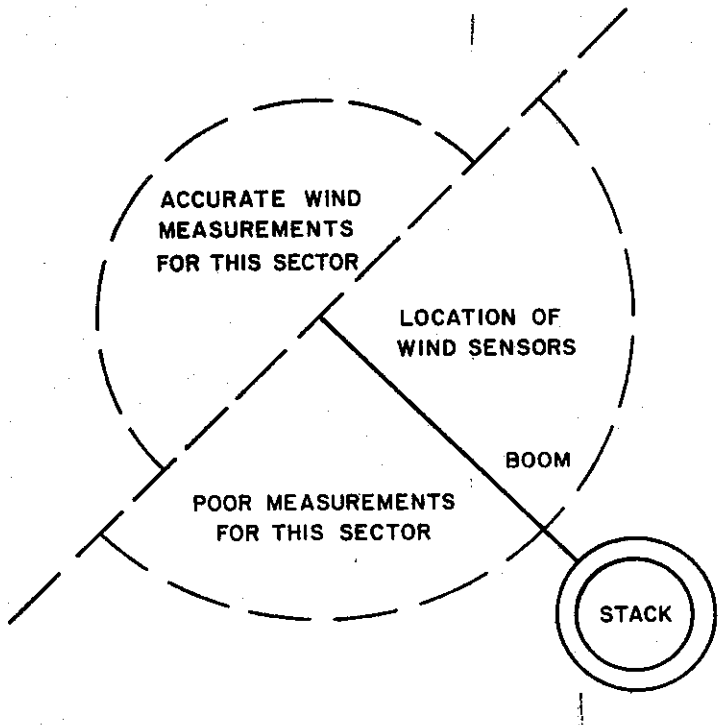


Fig.17 WIND SENSOR EXPOSURE ON A STACK

METEOROLOGICAL SURVEY

One of the main purposes of the meteorological survey is to develop streamlines for surface winds along the proposed highway route. Before any meteorological survey is undertaken, a search of meteorological data sources should be made within and near the proposed route area. The sources should be inspected for proper exposure of instruments. The meteorological records should be analyzed to determine the prevailing wind directions and speeds and surface atmospheric stabilities*. This should be done on a seasonal** basis and for the time periods corresponding to the peak traffic volumes and for off peak conditions. Before a complete meteorological survey is undertaken, one should obtain a topographic map of the area for the proposed routes and locate all of the sensitive areas such as schools, hospitals, etc. that are near the proposed route. The aid of a topographic map with terrain features shown can indicate the following conditions:

1) Channeling effects of winds in canyons and valleys.

2) Areas of drainage winds.

3) General wind flow around hills and mountains for different inversion bases.

4) Areas where surface inversion may exist due to cool air drainage.

5) Areas of limited dispersion due to valley walls.

Some general meteorological conclusions that can be determined from a topographic map are:

1) Drainage winds will generally be greater at the mouth of a valley because there is more time for air to flow under the influence of gravity.

2) At the upper end of a valley, low drainage winds can generally be expected.

3) At the mouth of a valley, a surface based inversion is likely to occur because of accumulation of cold air drainage.

4) At the upper end of valleys, surface inversions are more likely to be closer to the surface due to a reduction in the thickness of the cold air mass caused by downslope drainage.

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*A method for estimating the surface stability will be discussed in the section on "Reduction of Meteorological Data".

**The time periods for which the meteorological records should be analyzed will be discussed in details in the section on "Reduction of Meteorological Data".

5) The only way to burn off surface inversions is to heat the ground surface with incoming solar radiation. Shallow surface inversions at the upper end of valleys tend to burn off faster because there is less cold air to heat up. Therefore, the deeper surface inversions at the mouth of the valley will generally last longer before being burned off.

The wind roses (prevailing wind speed and direction) obtained from the meteorological sources with proper exposure of instruments should be plotted on a topographic map of the proposed route area. This will allow one to evaluate the applicability of the available wind data to describe the streamlines of the surface winds within the highway corridor. If there are insufficient meteorological sources to describe the surface wind streamlines within the highway corridor, then actual field measurements will be required*.

The best location for a mechanical weather station can be established by a preliminary meteorological survey with hand-held wind systems. This survey will require at least two men with some form of communication (car radios, walkie-talkies, etc). These hand-held wind systems should be located at various points along the proposed highway route. This will allow a spatial and temporal distribution of the surface winds to be evaluated. The communication system will allow each man in the field to discuss the influences of topography on the surface winds if they exist. The proper exposure of the hand-held wind systems should follow, when possible, the general guidelines presented earlier in this report. Mapping the general distribution of surface winds will help to locate the mechanical weather stations in the most sensitive areas (areas where wind speeds appear to be low). This preliminary survey is important and may last from a few days up to a month. Measurements of wind speed and direction should be made from morning, mid-day, and evening conditions. This will parallel the daily peak traffic patterns and provide data on the diurnal variation of surface winds. All of the measurements should be made in the absence of frontal activity.

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*Each Highway District should purchase mechanical weather stations. The exact number depends on the projected number of highway projects and the nature of the meteorology and topography. Specifications are given in Appendix B. At least two hand-held wind systems should also be purchased. The specifications are also given in Appendix B.

The number of mechanical weather stations required for a highway route will depend on topographic features. In some cases where level open terrain exists, one mechanical weather station may be sufficient. In other cases where the highway route is located in hilly areas two or more mechanical weather stations may be required. Once the exact location of the mechanical weather station is determined the general guidelines for proper instrument exposure should be followed. Guidance and assistance may be obtained from the Materials and Research Department in Sacramento as to the exact location of the weather stations.

The collection of data should be at least one year in duration to completely cover the seasonal meteorological cycle. The length of time required for the field measurements can be reduced if a correlation between the actual field measurements and the closest meteorological source can be made. Under these conditions the closest meteorological source should be located in a similar topographic area. The collection of data may be reduced to a period of a few months provided a correlation exists. It should be stressed that before any correlation procedures are attempted, a calibration of the mechanical weather stations used by the Division of Highways and that of the closest meteorological source must be made. The reasons for this calibration are as follows [14]:

1) The response characteristics of instruments of various manufacture are seldom similar and although their directional indications are usually comparable there may be only general agreement in wind speed.

2) The exposure of wind instruments varies with some being completely shielded from the natural air flow, whereas others have no nearby obstructions within several hundred yards.

3) Instrument maintenance techniques can vary considerably. Some stations service the instruments routinely while others attend to an instrument only after it has broken down.

It should also be brought out in obtaining meteorological records that operational practices for determining representative hourly wind direction and speed range from an observation ten seconds in length to one of an hour's duration. At some stations the hourly observations represent a period which include one-half hour on each side of the stated hour whereas others represent the preceeding hour. In addition, depending on the threshold sensitivity of the instrument, some stations record the occurrence of calms (no wind flow) while other stations do not. Also, some stations record wind directions to sixteen points of the compass whereas others record to only eight or to as much as thirty-six points. All of the items mentioned above should be given consideration when performing a meteorological survey or an instrument correlation.

If a highway route is located in a valley and adjacent to hills, there may be numerous localized drainage winds that can occur. These localized drainage winds may be channeled through small canyons and gullies within the hills. The surface wind streamlines may intersect the highway route at different angles depending on the location of the axis of the canyon or gullies with respect to highway alignment. To measure all of the possible drainage winds with mechanical weather stations would be an impossible task. Under these conditions it is recommended that at least one mechanical weather station be located to measure the localized drainage winds for the most sensitive area. To supplement this, measurements of wind speed and direction can be made at other locations with the hand-held wind systems. These measurements are not required each day. They can be made perhaps two or three times a week. These measurements should continue until general drainage wind streamlines can be evaluated.

Figure 18 shows a system flow chart for a meteorological survey.

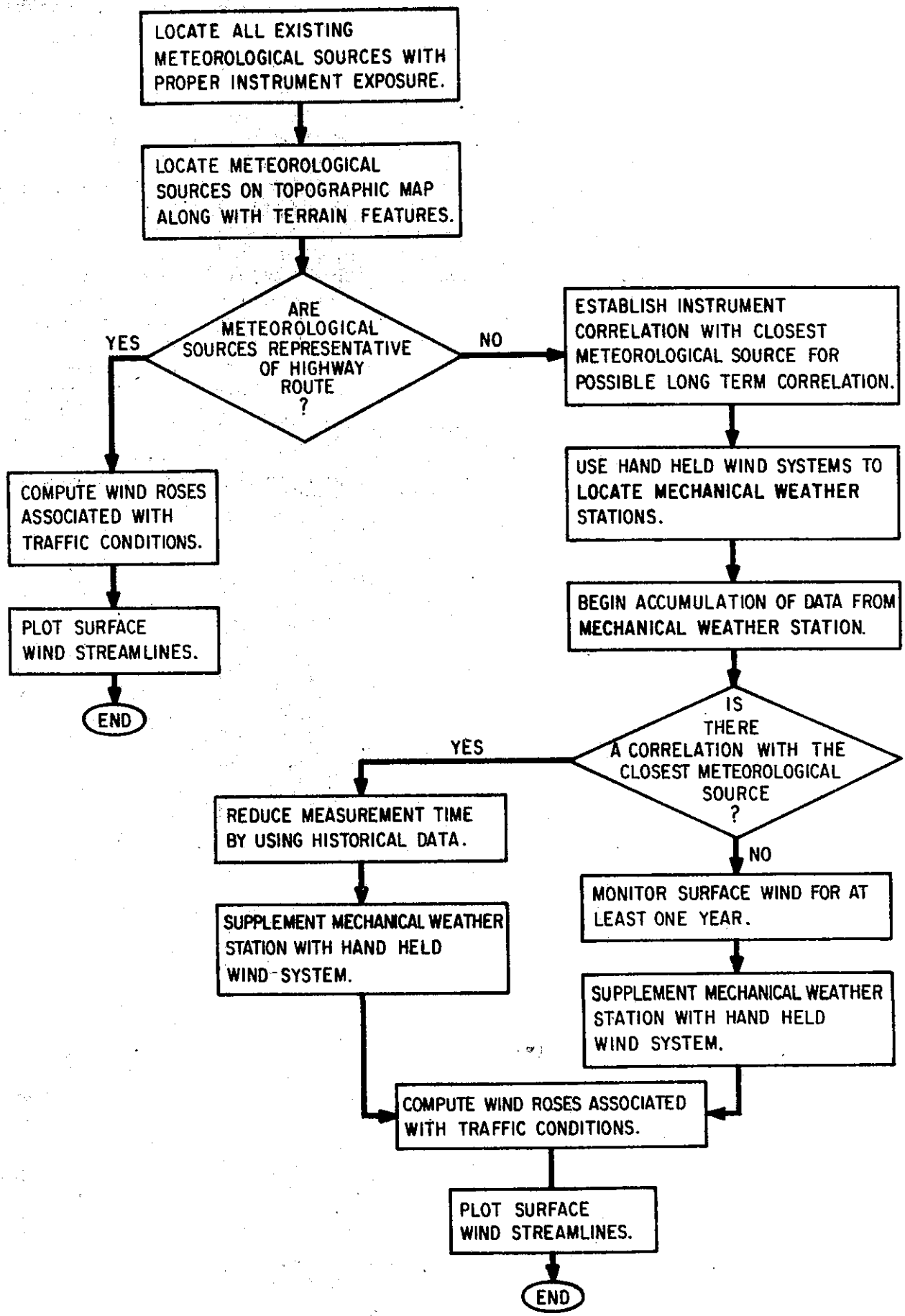

Figure 18 FLOW CHART FOR A METEOROLOGICAL SURVEY

EXAMPLE METEOROLOGICAL SURVEY

Given

A proposed freeway is to be constructed within the Las Posas Valley (Route AB). Another freeway bypass (Route CD) is proposed between Highway 101 and Highway 1. The freeway within the Las Posas Valley is 12 miles in length and the length of the bypass freeway is 6 miles. Route AB is located in a valley of mild slope. Route CD is located in a flat plain area.

The existing meteorological sources are at Hilfikerville, Oxnard, Shirleyville, Santa Paula, and Camarillo Airport. All records at these sources are recorded on a 24-hour daily basis.

Find:

1) Describe the general diurnal surface wind flow patterns within the area indicated on Figure 19 for the proposed freeway routes.

2) From the information given, are there sufficient meteorological sources to determine the surface wind flow patterns for Routes AB and CD? Why?

3) If there are insufficient meteorological sources to describe the surface winds for Routes AB and CD, answer the following:

   a) Where would you place mechanical weather stations to supplement the existing meteorological sources?

   b) What distance from the surrounding terrain, buildings, trees, etc. would you place the instrument? What distance from the ground surface would you locate the weather station?

Solution:

1) The general diurnal surface winds will consist of two types of surface wind regimes: (1) sea breeze and (2) drainage winds. The sea breeze regime dominates from mid-morning and extends throughout the day. It will generally dissipate near sunset. The sea breeze regime will probably develop uniform surface wind on the flat plain areas and a channeling condition into the valleys. The hills north of the airport will influence the surface wind patterns depending on the elevation of the inversion aloft.

When the base of the elevated inversion is below the hills, the surface winds will follow the topographic features and flow around the hills. This will cause a convergence of the wind flow field near the middle of the proposed highway route. For meteorological conditions where the base of the elevated inversion is above the hills the wind will rise over hills. This may cause increased turbulence depending on the slope of the surface on the down wind side. The general surface wind flows discussed above are in the absence of a frontal system. Figures 20 and 21 show plots of surface wind streamlines for a low and a high based elevated inversion for a sea breeze regime.

Drainage winds will follow the basic slope of the terrain. In the La Posas Valley this cool air will collect and then generally be channeled following the axis of the valley. A divergence of the surface winds may occur near the opening at point E (Figure 19). The drainage winds will most probably be stronger within the smaller valleys where the wind is channeled than in a flat plain area. These drainage winds generally occur from evening through early morning hours. Figure 22 illustrates the surface wind streamlines for a drainage wind regime in the absence of a frontal system.

2) From all of the meteorological sources it is most probable that sufficient information is available to describe the surface winds for Route CD only. The Oxnard station located about three miles from proposed Route CD is probably measuring the representative surface winds if there is proper exposure of the wind system. The station is probably far enough away from the hills to minimize aerodynamic and topographic effects. These are general statements that can be made from the topographic map given in Figure 19. Field measurements with hand-held wind systems should be made to validate the representativeness of the surface winds measured at Oxnard Station as applied to the Route CD.

For Route AB within the Las Posas Valley there is insufficient meteorological data to quantitatively describe the surface wind streamlines. This results from the fact that all of the existing meteorological sources are located in the flat plain area. Surface winds for Route AB, however, are influenced by topography. A meteorological survey would be required for Route AB to measure the surface winds.

3) The primary purpose of a meteorological survey is to determine the surface wind streamlines and locate sensitive meteorological areas where light wind may exist.

From Figures 20, 21 and 22 the most probable location of light wind is likely to be where the valley is the widest (FG). Light wind tends to increase the pollutant concentrations. This would be a good site to locate a mechanical weather station.

In the area where converging and diverging wind flow fields exist (near point E) the winds probably are greater than at location FG. A meteorological station is not required at this location. Some wind information will be required near the end of the project where a channeling wind exists. This may be another possible site for a mechanical weather station.

Before determining the exact location and number of mechanical weather stations required, it is recommended that a field survey with the hand-held wind system be made. This will afford some knowledge of the surface wind streamlines and will assist in the location of the mechanical weather stations.

The location of the mechanical weather stations above the ground surface will be based on the general guidelines presented earlier in this report.

To supplement the data monitored with the weather stations, wind speed and direction measurements can be made with the hand-held wind system. These measurements can be made at various points along the proposed highway route. This information can be used when evaluating the surface wind streamlines between the mechanical weather station locations.

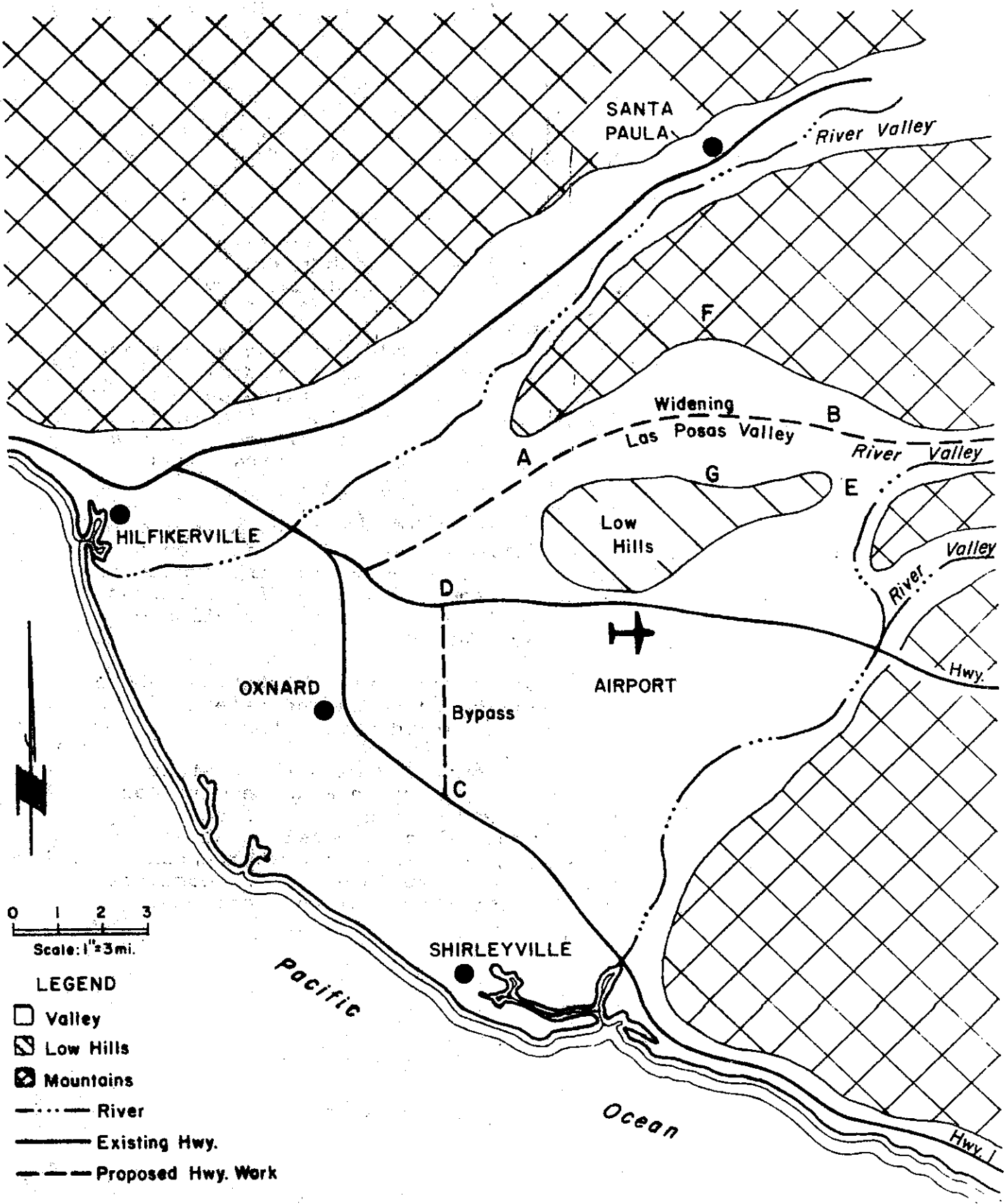

Fig. 19 GENERAL AREA OF PROPOSED HIGHWAY ROUTE

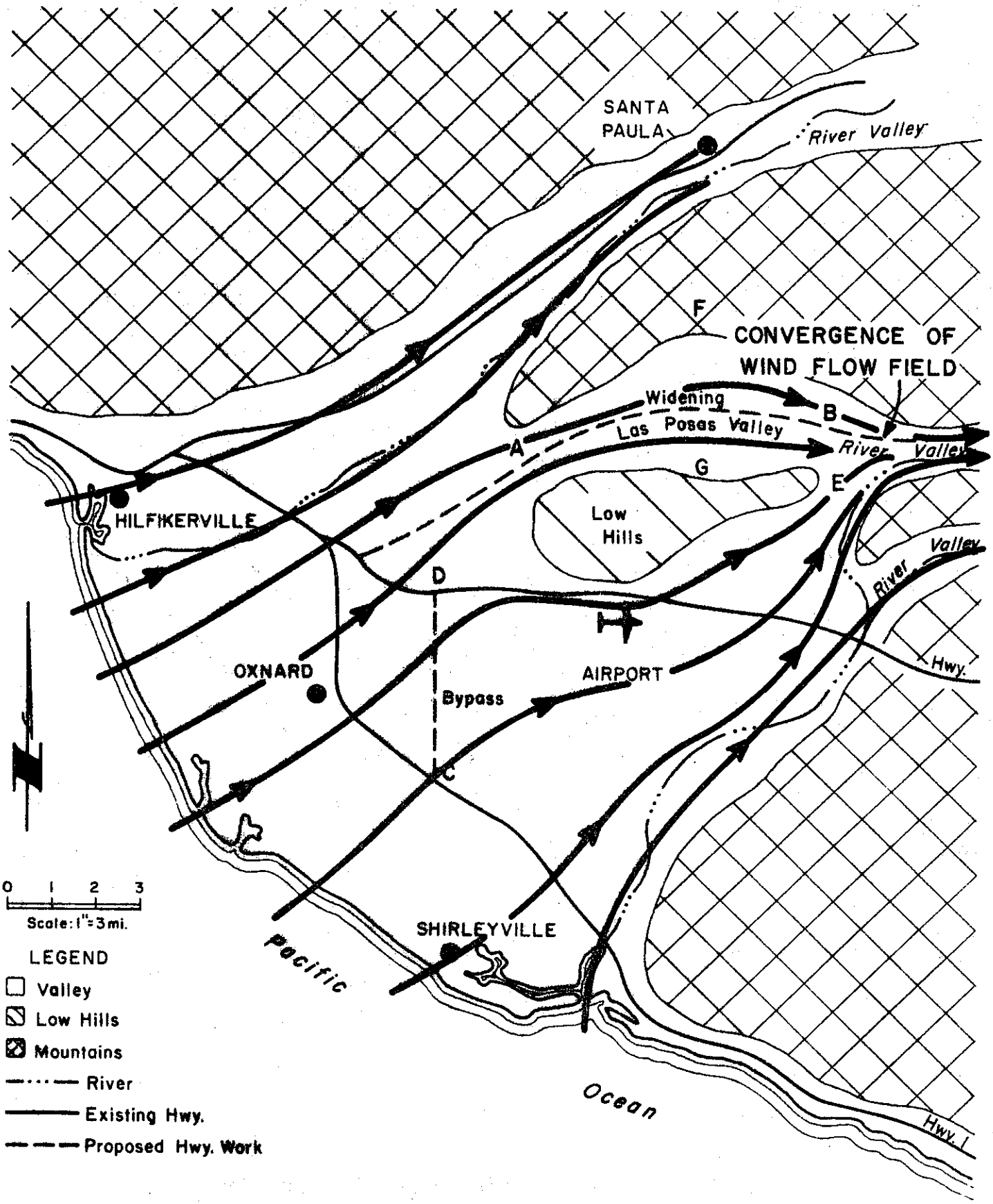

Fig. 20 SURFACE WIND STREAMLINES FOR SEA BREEZE REGIME WITH LOW BASED ELEVATED INVERSION

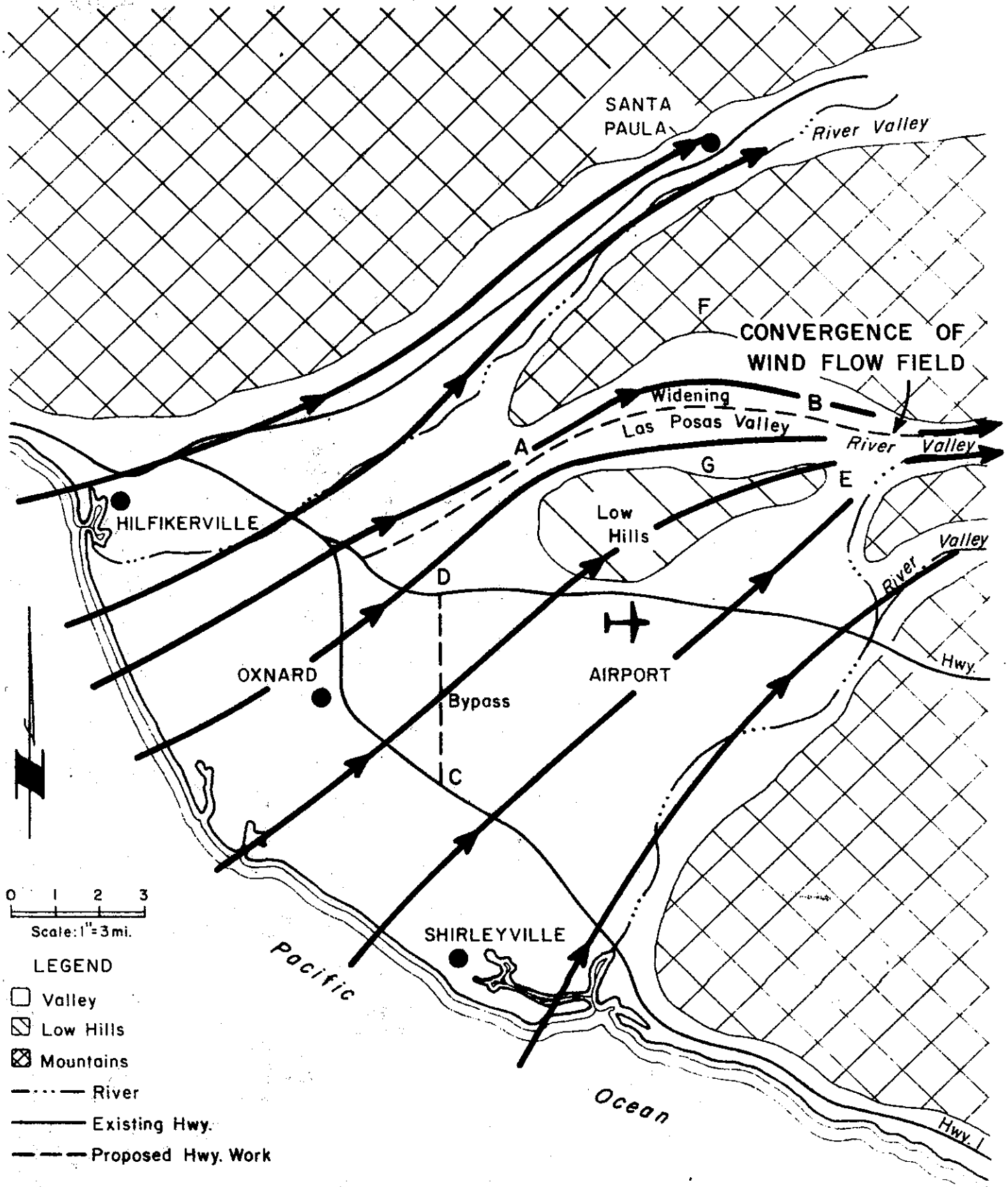

Fig. 21 SURFACE WIND STREAMLINES FOR SEA BREEZE REGIME WITH HIGH BASED ELEVATED INVERSION

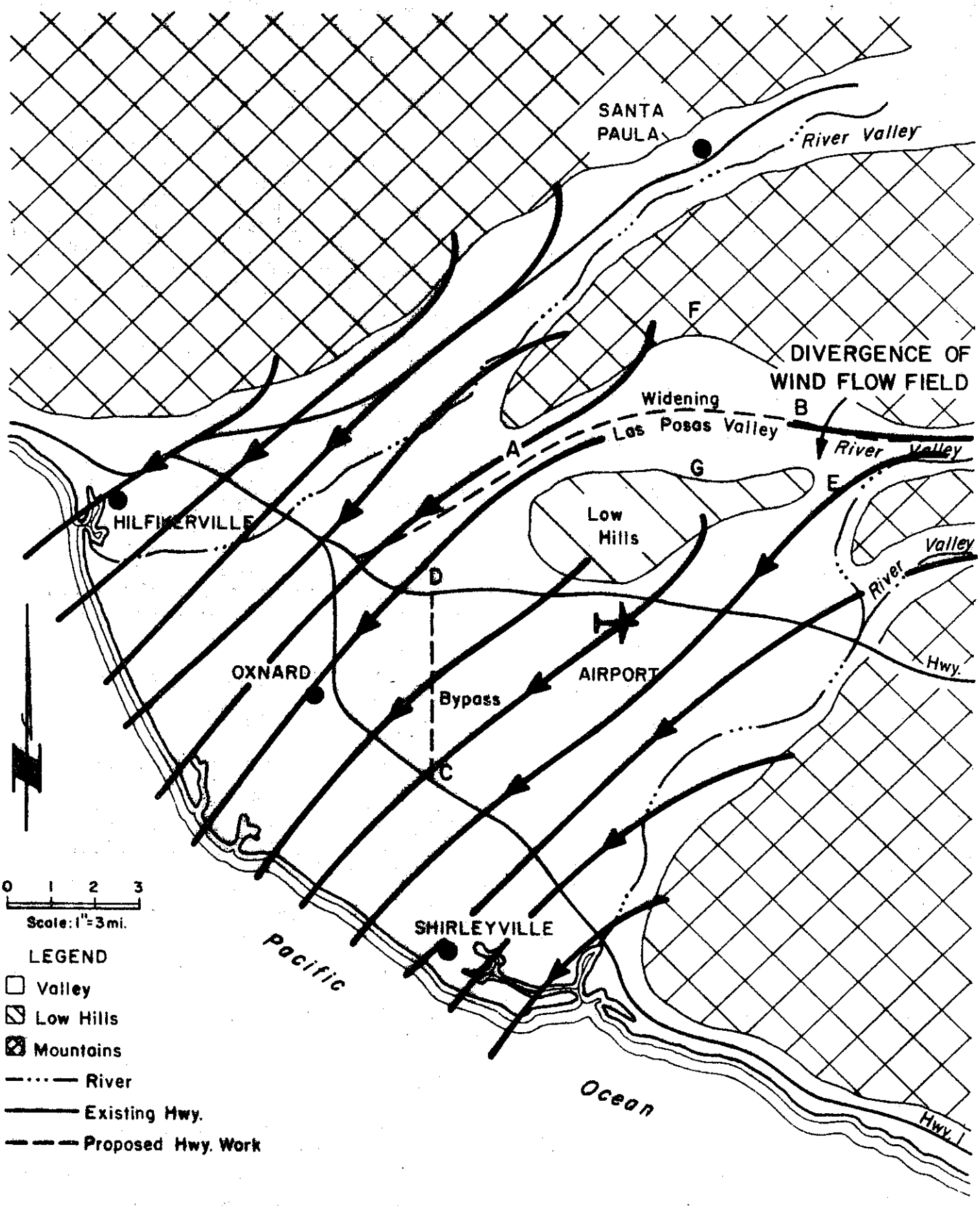

Fig. 22 SURFACE WIND STREAMLINES FOR DRAINAGE WINDS

METEOROLOGICAL RECORDING FORMS

When meteorological data are obtained from existing sources it is very probable that the information will be recorded on the standardized U.S. Weather Bureau Tabulation form (see Figure 23). The data required for the wind rose analysis are wind speeds and directions while the stability analysis requires information on wind speed, cloud cover, and concurrent ceiling height. The data required for the wind rose and stability analysis are given in columns (2), (9) and (10) in Figure 23. The remaining portion of the data tabulated on the summary forms is not used in a mathematical model [1]. A detailed discussion on cloud cover and ceiling heights is given in Appendix D.

In special cases the only meteorological data measured will be wind speed and direction on a strip chart recorder. This information will have to be reduced to obtain the hourly wind speed and direction which will be used to compute wind roses. Figure 24 shows a typical output of wind speed and direction on a strip chart recorder where one hour is equal to 20 millimeters. To summarize these data, estimates must be made for the hourly wind speed and direction. Depending on the meteorological conditions, the wind direction can fluctuate considerably within a given hour. The following procedure should be followed to estimate the hourly wind direction:

> Use a half hour averaging time, 15 minutes before the hour and 15 minutes after the hour. These averaging times can visually be estimated.

To compute the wind speed use the sloping line that is labeled wind run. The procedure is as follows:

1. For half hour averaging, read the wind run in miles for 15 minutes before the hour and 15 minutes after the hour.

2. Compute the wind speed in miles per hour by the following equation:

$$\text{Wind speed} = \frac{(WRV)_{t_2} - (WRV)_{t_1}}{\Delta T}$$

Where ΔT = Averaging time in hours

$(WRV)_{t_2}$ = wind run value in miles at $\Delta T/2$ minutes after the hour

$(WRV)_{t_1}$ = wind run value in miles at $\Delta T/2$ minutes before the hour.

This is the general equation applicable to any averaging time period for a half hour averaging time, $\Delta T = 0.5$ hrs., $t_1 = 15$ minutes before the hour and $t_2 = 15$ minutes after the hour.

This 30 minute averaging time can be used when one hour of time represents at least 20 millimeters. In some cases one hour of time may represent 10 millimeters. For this case it may not be possible to use the one half hour averaging time and a one hour averaging time may be required. Judgment will have to be used in reducing the data as to whether the visual estimates can be made at 30 minute or one hour averaging time. The wind speed in miles per hour is calculated by the equation previously mentioned with the wind run values corresponding to a one hour averaging time. The mechanical weather stations used by the Division of Highways will record the wind speed and direction on a strip chart recorder. The reduction of this data will follow the procedures presented above.

MF1–10A
(4–70)

U.S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU

STATION

DATE

TO CONVERT LST TO GMT
ADD_____hrs. SUBTRACT_____hrs.

SURFACE WEATHER OBSERVATIONS

TYPE (1)	TIME (LST) (2)	SKY AND CEILING (Hundreds of Feet) (3)	VISIBILITY (Statute Miles) SURFACE (4)	VISIBILITY (Statute Miles) TOWER (4a)	WEATHER AND OBSTRUCTIONS TO VISION (5)	SEA LEVEL PRESS. (Mbs.) (6)	TEMP (°F) (7)	DEW PT. (°F) (8)	WIND DIRECTION (00–36) (9)	WIND SPEED (Kts.) (10)	WIND CHARACTER (11)	ALTIMETER SETTING (Ins.) (12)	REMARKS AND SUPPLEMENTAL CODED DATA (13)	OBSERVER'S INITIALS (15)

A synoptic observation, in WMO code format FM11D, is entered on line following related aviation observation.

Fig.23 STANDARD U.S. WEATHER BUREAU TABULATION FORM

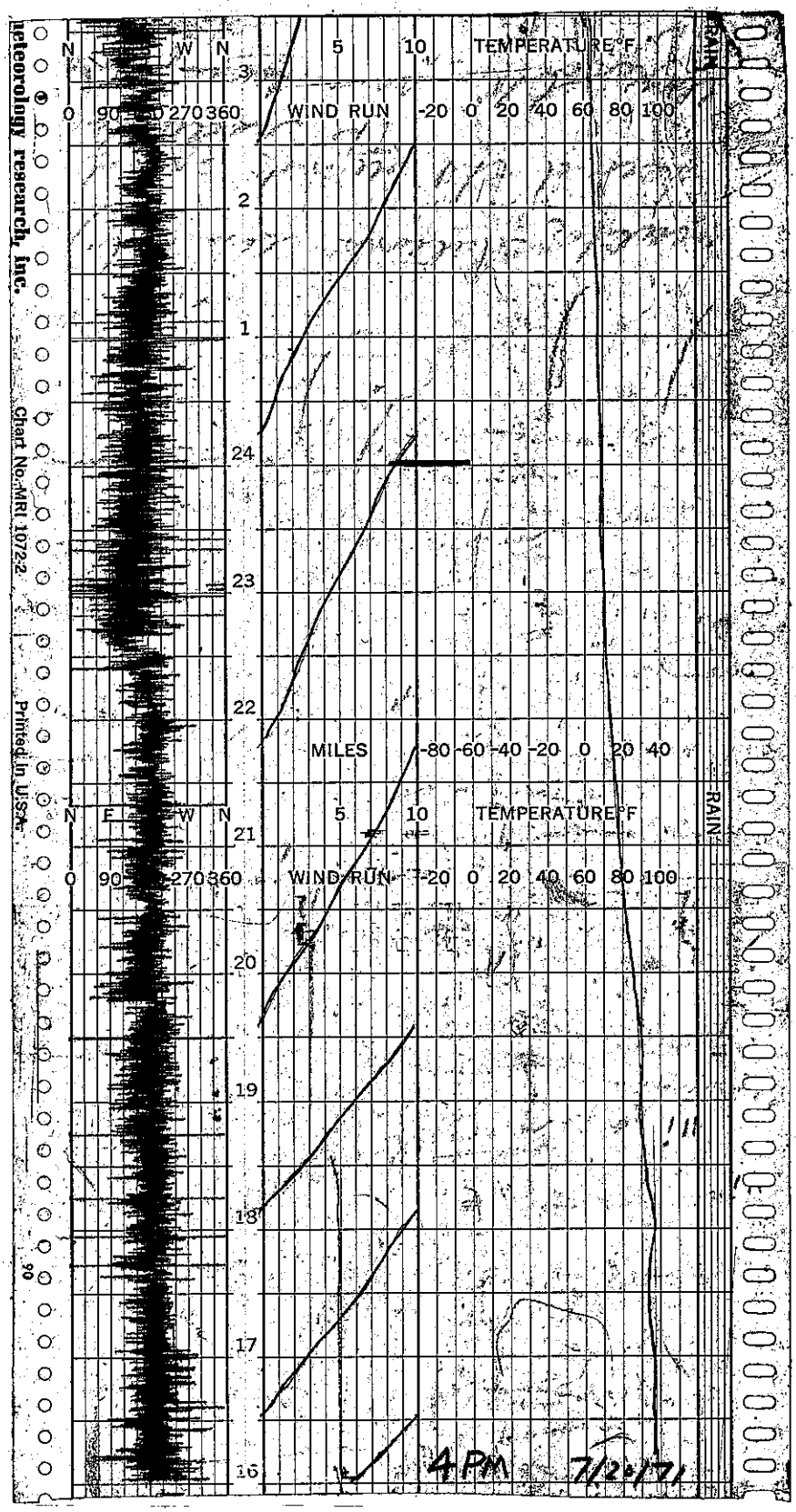

Fig. 24 TYPICAL OUTPUT FROM STRIP CHART RECORDER FOR WIND SPEED AND DIRECTION

REDUCTION OF METEOROLOGICAL DATA

Mathematical models [1] to estimate air pollution levels on and within the highway corridor have meteorological parameters as inputs. The meteorological inputs include (1) surface atmospheric stability and (2) the prevailing surface wind speed and direction (wind rose). Two primary meteorological conditions will be analyzed in a mathematical model to predict future air quality. They are (1) the most probable meteorological condition (surface stability and wind rose) and (2) the worst meteorological conditions (surface stability and wind rose). This comparison of the most probable and worst meteorological conditions along with their associated probabilities will give a range for the estimated pollution concentrations. This will provide an estimate for pollutant concentration within the highway corridor on a "typical day" and for a "bad day".

Stability*

The system of classifying hourly surface stability is based upon work accomplished by Pasquill [16]. The atmospheric stability near the ground is dependent primarily upon the net radiation and wind speed. Without influence of clouds, insolation (incoming solar radiation) during the day is dependent upon solar altitude, which is a function of time of day and time of year. When clouds exist, their cover and thickness decrease incoming and outgoing radiation. In this system, insolation is estimated by solar altitude and modified for existing conditions of total cloud cover and ceiling height. At night, estimates of outgoing radiation are made by considering cloud cover. The stability classes used, based on Pasquill's work, are classified as follows:

Stability	Description of Atmosphere
A	Extremely Unstable
B	Unstable
C	Slightly Unstable
D	Neutral
E	Slightly Stable
F	Stable

Table 1 gives the summary of Pasquill's stability classes as a function of wind speed, insolation, and cloud cover [3]. Night refers to the period from one hour before sunset to one hour after sunrise. Stability Class D should be used for all overcast conditions during day or night regardless of wind speed. The values of insolation which are functions of solar altitude, time of day, and month of year for the State of California can be estimated from Table 2.

---

*The primary text of this section on stability was extracted and summarized from a publication by Turner [17].

Table 1

Stability Classes

Surface Wind Speed (m/sec)	Daytime Insolation			Night	
	Strong	Moderate	Slight	Thinly Overcast or ≥ 4/8 Low Cloud	≤ 3/8 Cloud
2	A	B	B	--	--
2-3	B	B	C	E	F
3-5	B	C	C	D	E
5-6	C	D	D	D	D
6	C	D	D	D	D

Table 2

Insolation For California

Month	Insolation
Jan, Feb, Mar, April	Moderate
May, June, July, Aug	Strong
Sept, Oct. Nov.	Moderate
Dec	Slight

Turner [17] developed a method for estimating the Pasquill surface stability based on existing meteorological records. This method is used by the Division of Highways. Computer programs were designed and developed to estimate the surface stability classes along with the probability of occurrence of each class. The computer programs will be discussed in detail in a later section.

Meteorological Wind Roses*

A wind rose is defined [3] as any one of a class of diagrams designed to show the distribution of wind direction experienced at a given location over a considerable period; it thus shows the prevailing wind direction. The most common form consists of a circle from which sixteen lines emanate, one for each compass point. The length of each line is proportional to the frequency of wind from that direction; and the frequency of calm conditions is entered in the center. Many variations exist. Some indicate the range of wind speeds from each direction; some relate wind direction with other weather occurrences. Wind roses may be constructed for data from a given time period such as a particular month or may be for a particular time of day or season from a number of years of data. In constructing or interpreting wind roses, it is necessary to keep in mind the meteorological convention that wind direction refers to the direction from which the wind is blowing. A line or bar extending to the north on a wind rose indicates the frequency of winds blowing from the north, not the frequency of winds blowing toward the north. As previously mentioned, the wind rose information can be used in a mathematical model [1] to estimate pollution levels on and within the highway corridor.

Wind Roses - Data and Presentation

Prior to January 1964, surface wind direction was reported by U. S. Weather Bureau stations as one of the 16 compass points corresponding to the mariner's compass card or compass rose, on which each direction is equivalent to a 22-1/2° sector of a 360° circle. Table 3 illustrates a 16-point wind rose summary in the form of a frequency table of wind direction versus wind speed groups. It is an example of wind roses prepared as summaries of hourly observations published monthly (until January 1964) by the U. S. Weather Bureau Service in the Local Climatological Data (LCD) Supplement. A quick look at this tabulation indicates the highest directional frequency is from the ENE and the highest speed frequency is the 4 to 7 mph column. The speed interval with the highest speed frequency corresponding to the highest directional frequency should be used in the mathematical model [1]. This will allow a range of the estimated pollution concentrations for the prevailing wind speed and direction. Average speeds have been computed for each direction. Provided there are enough data for statistical analysis, the average speed should fall within the highest speed frequency range.

---

*The primary text of this section on wind roses was extracted and summarized from an Environmental Protection Agency publication "Air Pollution Meteorology" [3].

TABLE 3

WIND DIRECTION
AND SPEED OCCURRENCES:

16-POINT REPORTING SYSTEM

DIR	HOURLY OBSERVATIONS OF WIND									TOTAL	AVERAGE SPEED	
	KNOTS											
	0-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41 Over		KNOTS	MPH
	MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 Over			
N	8	13	15	18	12	3				69	10.8	12.4
NNE	1	16	28	30	7	1				83	10.2	11.7
NE	7	34	36	5						82	6.7	7.7
ENE	11	51	46	5						113	6.3	7.3
E	6	19	14	4						43	6.4	7.3
ESE	4	15	13	3						35	6.5	7.5
SE	1	13	4	2						20	6.3	7.2
SSE	2	6	20	11						39	8.3	9.6
S	3	11	21	10	1					46	8.2	9.4
SSW	3	9	9	9	4					34	9.3	10.6
SW	1	8	7							16	6.3	7.2
WSW		4	3	1						8	6.9	7.9
W	1	5	7							13	6.5	7.4
WNW	1	16	6	1						24	6.0	6.9
NW	2	3	6	1						12	7.2	8.2
NNW	1	11	29	26	6	1				74	10.6	12.2
CALM	33									33	0.0	0.0
TOT.	85	234	264	126	30	5				744	7.7	8.9

The average wind speed is based on the sums of frequency times the class midpoint value for each class and divided by the total number of observations.

This computational method is the standard approach described in most elementary statistics books [18, 19 and 20], and is recommended. This is expressed by the following formula:

$$\bar{X} = \frac{\Sigma f_i \, X_i}{\Sigma f_i}$$

where f_i = frequency of any value

X_i = value of observation

On January 1, 1964, the U. S. Weather Bureau changed the wind direction reporting procedure from 16-22 1/2° intervals to 36 - 10° intervals. The reference for the 36-point wind direction reporting procedure is the north pole. This is zero degrees. All degrees are read in a clockwise direction from north. A reading of 09 (90 degrees) indicates a wind direction from due east. Each direction, 01, 02, 03, etc., refers to an angle of 10°, 20°, 30°, etc. The reported wind speed will be in miles per hour (mph) or knots. Table 4 illustrates a 36 point wind rose summary in the form of a frequency table of wind direction versus wind speed groups.

Problems have developed with the 36-point wind system; first, a 36-point system tends to spread tabulated frequencies and obscure directional significance; second, a list of 36 directions is often too lengthy for convenience; lastly, it is almost impossible to construct the standard radial bar-type wind rose with 36 bars. The bars crowd together at the center and variations of radial length, proportional to directional percentage frequency, between given wind directions are minimized. To offset this disadvantage the readings are commonly grouped in sets of 3 thus resulting in a 12-sided wind rose.

Some meteorological stations give wind direction on an 8-point reporting system. Since the method of reporting directions varies between 36, 16, and 8, the California Division of Highways has standardized on a 16 sided wind rose computational analysis. Therefore the 36 and 8 point reporting systems are converted to a 16 point reading according to the table shown in Appendix E.

TABLE 4

WIND DIRECTION
AND SPEED OCCURRENCES:

36-POINT REPORTING SYSTEM

DIR	HOURLY OBSERVATIONS OF WIND									TOTAL	AVERAGE SPEED	
	KNOTS											
	0-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41 Over			
	MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 Over			
01	3	5	2	3						13	6.9	8.0
02	7	9	8							24	5.3	6.0
03	3	9	7							19	5.4	6.2
04	7	22	2	1						32	5.3	6.1
05	9	15	7	4						35	5.9	6.8
06	11	27	17	6						61	6.2	7.1
07	4	27	16	3						50	6.2	7.1
08	3	7	13	3						26	7.2	8.3
09	1	9	6	5						21	7.7	8.8
10	5	9	4							18	5.1	5.8
11	5	11	5	1						22	4.8	5.5
12	5	5	4							14	4.9	5.7
13	2	4	3							9	6.0	6.9
14	5	7	6							18	5.2	6.0
15	1	7	5		1					22	4.8	5.5
16	1	8	4							13	5.9	6.8
17	1	6	4							11	6.2	7.1
18		6	9	6						21	8.8	10.1
19	2	2	3							7	5.7	6.6
20	3	5	2	5						15	7.1	8.1
21	2	2	3	1						8	6.6	7.6
22	2	2	5	6						15	8.6	9.9
23	4	2	7	3						16	7.3	8.3
24	5	2	2	1						10	5.3	6.1
25	3	1		1						5	5.0	5.8
26	2	3	4	4						13	7.6	8.8
27	2	6	1							9	5.0	5.8
28	3	5	4							12	5.5	6.3
29		2	9	7						18	9.7	11.2
30		3	4	7						14	10.1	11.7
31	2	2	2	12						18	10.3	11.9
32	2	3	12	10	1					28	9.9	11.4
33	1	7	9	13						30	9.4	10.8
34	1	2	11	11						25	9.6	11.0
35	3	1	1	2						7	6.7	7.7
36	4	6	8	2						20	7.0	8.1
00	53									53	0.0	0.0
TOT	167	249	209	117	2					744	6.4	7.4

Removing Bias in 16-Point Wind Roses

Wind direction, such as for hourly observations where no recorder is used, is determined by an observer watching the wind direction indicator dial for one minute and recording direction as one of 16 points. It has been found that the eight primary directions (N, NE, E, etc.) are more frequently recorded than are the secondary directions (NNE, ENE, ESE, etc.). Depending upon the purpose for constructing a wind rose, it may be desirable to remove this bias. Removal of the bias may be by total frequencies for each direction or by wind speed classes. In order to determine if there is bias, the sums should be determined separately for the principal direction frequencies (N_e) and the secondary direction frequencies (N_o).

Bias usually occurs if one exceeds the other on the order of 10% to 20%. Assuming that the primary frequencies (N_e) exceed the sum of the secondary frequencies (N_o), the frequencies have the bias removed by subtracting the quantity

$$n_e \; \frac{N_e - N_o}{2 \quad N_e}$$

from the frequency of each primary direction where N_e is the frequency for that direction and adding* the quantity

$$n_o \; \frac{N_e - N_o}{2 \quad N_o}$$

to the frequency of each secondary direction where N_o is the frequency for the secondary direction.

---

*All values should be rounded off to the nearest whole number.

It is important at this point to realize that not all wind data reported on a 16 point procedure are biased. If natural phenomena or topographic conditions exist such as a valley where a channeling wind is predominant, the reported wind data from a weather station will show this prevailing direction and the data are not necessarily biased. These data reported do not require debiasing. If a debiasing technique were applied to the data in this situation, the indicated wind rose would not be realistic. Erroneous estimates of pollution levels would occur when the wind speed and direction were used in a mathematical model [1].

Distribution of Calms

In some cases, it is also desirable to distribute the calms in the lowest wind speed class among the 16 directions. It is usually better to use the frequencies of the lowest two speed classes (0-7 mph) to distribute the calms in order to have a more representative sample of light winds. If N_C is the total number of calms, N_W is the total frequency of winds in the 0-7 mph range, and n_W is the frequency of winds in the 0-7 mph range for one direction, the number of calms assigned to this direction* is:

$$\frac{n_W \, N_C}{N_W}$$

The threshold sensitivity of the wind instrument should be known when obtaining meteorological data from a source. If the threshold speed is 3 mph or greater, then a distribution of the calms is required. If wind data are obtained from a very sensitive instrument (threshold speeds less than 3 mph) and a recorder is used, a distribution of calms is not required. In obtaining historical meteorological records it is most probable that the calms will have to be distributed.

Removing Bias in 36-Point Wind Roses

One of the primary reasons for changing from a 16 point to a 36 point wind direction reporting procedure is to eliminate the bias readings in the 16 point wind rose reporting scheme. It is therefore not necessary to make any debiasing calculations before constructing wind roses for a 36 point reporting procedure.

Problems in Constructing Wind Roses

The following examples illustrate typical procedures for constructing wind roses. The examples include the construction of 16 point wind roses with debiasing techniques employed in the data reduction. These procedures should be followed when constructing any type of wind rose.

*All values should be rounded off to the nearest whole number.

Example 1: Removing Bias in a Wind Rose (16 point). Below is given the hourly wind direction and speed frequencies for October, 1962, for St. Louis, Mo.

Table 5. Wind Direction and Speed Occurrences

Direction	Hourly observations of wind speed (mph) 0-3	4-7	8-12	13-18	19-24	Total
N	1	5	11	3		20
NNE	5	10	4	1		20
NE	7	9	3	1		20
ENE	5	6	8	3		22
E	2	4	5	1		12
ESE	3	4	3	1		11
SE	13	8	17	6		44
SSE	5	19	21	5		50
S	15	23	26	6		70
SSW	6	29	19	2		56
SW	5	44	33	8		90
WSW	4	17	17	8		46
W	8	25	13	8		54
WNW	4	15	15	14		48
NW	4	3	17	30	6	60
NNW	0	6	18	8		32
CALM	89					89
Total	176	227	230	105	6	744

Problem: To remove the bias by distributing between two separate speed classes:

0-7 mph, and $\geq$ 8 mph.

First remove the bias in the 0-7 mph class. Determine N_e and N_o by adding the primary and secondary direction frequencies separately.

Table 6. 0-7 mph FREQUENCIES

Primary Direction		Secondary Direction	
N	6	NNE	15
NE	16	ENE	11
E	6	ESE	7
SE	21	SSE	24
S	38	SSW	35
SW	49	WSW	21
W	33	WNW	19
NW	7	NNW	6

$N_e = \overline{176}$ $N_o = \overline{138}$

Table 7. REMOVING BIAS FOR 0-7 mph CLASSES

Primary Direction $n_e - (n_e)(0.108)$		Secondary Direction $n_o + (n_o)(0.138)$	
N	6 - 1 = 5	NNE	15 + 2 = 17
NE	16 - 2 = 14	ENE	11 + 2 = 13
E	6 - 1 = 5	ESE	7 + 1 = 8
SE	21 - 2 = 19	SSE	24 + 3 = 27
S	38 - 4 = 34	SSW	35 + 5 = 40
SW	49 - 5 = 44	WSW	21 + 3 = 24
W	33 - 4 = 29	WNW	19 + 3 = 22
NW	7 - 1 = 6	NNW	6 + 1 = 7
	156		158

Next, remove the bias for the $\geq$8 mph classes.

Table 8. $\geq$ 8 mph FREQUENCIES

Primary Direction		Secondary Direction	
N	14	NNE	5
NE	4	ENE	11
E	6	ESE	4
SE	23	SSE	26
S	32	SSW	21
SW	41	WSW	25
W	21	WNW	29
NW	53	NNW	26
N_e =	194	N_o =	147

Table 9. REMOVING BIAS FOR ≥ 8 mph CLASSES

Primary Direction $n_e - (n_{e)}$ (0.121)		Secondary Direction $n_o - (n_o)$ (0.160)	
N	14 - 2 = 12	NNE	5 + 1 = 6
NE	4 - 0 = 4	ENE	11 + 2 = 13
E	6 - 1 = 5	ESE	4 + 1 = 5
SE	23 - 3 = 20	SSE	26 + 4 = 30
S	32 - 4 = 28	SSW	21 + 3 = 24
SW	41 - 5 = 36	WSW	25 + 4 = 29
W	21 - 3 = 18	WNW	29 + 5 = 34
NW	53 - 6 = 47	NNW	26 + 4 = 30
	170		171

The debiased wind frequencies are now completed for the two wind speed classes.

The debiased wind frequencies can now be distributed among the lower speed class intervals. The ratio of a lower speed class frequency to the total number of occurrences in either of the two largest speed classes times the total number of debiased wind frequencies for each largest class will result as shown in Table 11. Each direction must be considered separately and the ratios are gathered from the debiased values in Table 5.

Example: Distribution of Debiased Wind Frequencies into the 0-3 mph Speed Class Considering Only the 0-7 mph Speed Class Interval.

Direction	(Table 5) 0-3 mph Class	Total Occurrences (0-7 mph), (Table 5)	x	Debiased Values (Table 7)	=	Debiased 0-3 mph Class
N	1	6		5		1
NNE	5	15		17		6
NE	7	16		14		6
ENE	5	11		13		6
E	2	6		5		2
ESE	3	7		8		3
SE	13	21		19		12
SSE	5	24		27		6
S	15	38		34		13
SSW	6	35		40		7
SW	5	49		44		4
WSW	4	21		24		5
W	8	33		29		7
WNW	4	19		22		5
NW	4	7		6		3
NNW	0	6		7		1

Similar patterns of distribution of debiased wind frequency in other speed classes will result in a completely debiased wind table.

Problem: Distribute the calms for the 0-7 mph wind frequencies of Table 5 and distribute calms in the 0-3 mph speed interval.

Before distributing the calms, it is necessary to remove the bias in the 16 point wind rose observations for the 0-7 mph class. This was done in Table 7. After the bias is removed for 0-7 mph class, the distribution of calms is as follows:

N_c = 89 (Table 5)

N_w = total frequency of winds in the 0-7 mph class

N_w = 227 + 176 - 89 (calms) = 314 (Table 5)

$$\frac{N_c}{N_w} = \frac{89}{314} = 0.283$$

Table 10. DISTRIBUTION OF CALMS

Direction	n_w (debiased)	(0.283	
N	5	=	1
NNE	17	=	5
NE	14	=	4
ENE	13	=	4
E	5	=	1
ESE	8	=	2
SE	19	=	5
SSE	27	=	8
S	34	=	10
SSW	40	=	11
SW	44	=	13
WSW	24	=	7
W	29	=	8
WNW	22	=	6
NW	6	=	2
NNW	7	=	2
			89

The resulting debiased and decalmed wind frequencies in the usual classes are in Table 11 with distributed calms shown in parenthesis.

TABLE 11. WIND DIRECTION AND SPEED OCCURRENCES,

BIAS REMOVED AND CALMS DISTRIBUTED
(Distributed Calms in Parenthesis)

Direction	0-3	4-7	8-12	13-18	19-24	Total
N	1 (1)	4	9	3		18
NNE	6 (5)	11	5	1		28
NE	6 (4)	8	3	1		22
ENE	6 (4)	7	9	4		30
E	2 (1)	3	4	1		11
ESE	3 (2)	5	4	1		15
SE	12 (5)	7	15	5		44
SSE	6 (8)	21	24	6		65
S	13 (10)	21	23	5		72
SSW	7 (11)	33	22	2		75
SW	4 (13)	40	29	7		93
WSW	5 (7)	19	20	9		60
W	7 (8)	22	11	7		55
WNW	5 (6)	17	18	16		62
NW	3 (2)	3	15	27	5	55
NNW	1 (2)	6	20	9	1	39
Total	176	227	231	104	6	744

Example 2: Construct a wind rose from the following data for time 0600.

Wind direction and speed
ABC Airport
November 1965

Day	Time 0600
1	07/07
2	27/04
3	08/05
4	01/03
5	06/07
6	24/05
7	03/02
8	03/03
9	06/03
10	14/08
11	05/04
12	09/04
13	31/04
14	02/04
15	33/05
16	06/05
17	05/05
18	36/04
19	05/05
20	35/05
21	02/03
22	06/03
23	09/03
24	05/05
25	27/08
26	24/09
27	07/05
28	07/15
29	09/15
30	09/15

This is an illustrative example only. Ideally, to construct a wind rose for 0600 for the month of November, a minimum of 5 years of record should be used.

The wind speed recorded for this station is in knots.

1 knot = 1.15 mph

The data as given 07/07, 27/04, etc. is read, wind from 70° at 7 knots and wind from 270° at 4 knots. This is a typical reporting scheme for the 36 point wind rose.

Solution: The first step is to reduce the data into the standard format for the 16-point frequency table for direction. (See Appendix E). Then convert the speed from knots to miles per hour and finally group the occurrences in the correct classes to give the following tabular format:

WIND SPEED IN MPH

Direction	0-3	4-7	8-12	13-18	Total	Average	Frequency
N (35-36-01)	1	2			3	4.2	10.0
NNE (02-03)	3	1			4	2.5	13.3
NE (04-05)		4			4	5.5	13.3
ENE (06-07)	2	2	2	1	7	7.1	23.3
E (08-09-10)	1	2	0	2	5	8.7	16.7
ESE (11-12)					0	0	0
SE (13-14)			1		1	10.0	3.3
SSE (15-16)					0	0	0
S (17-18-19)					0	0	0
SSW (20-21)					0	0	0
SW (22-23)					0	0	0
WSW (24-25)	0	1	1		2	7.7	6.7
W (26-27-28)	0	1	1		2	7.7	6.7
WNW (29-30)					0	0	0
NW (31-32)	0	1	0		1	5.5	3.3
NNW (33-34)	0	1	0		1	5.5	3.3
CALM							0
TOTAL					30		

From the % frequency column in the above table the prevailing wind direction is from ENE with a frequency of occurrence of 23.3% for the wind speed range of 0 to 12 mph.

The above speed for this prevailing wind direction is computed by the following statistical equation:

$$\bar{U} = \frac{\Sigma(u_i f_i)}{\Sigma f_i}$$

U_i = midpoint of speed class interval

f_i = frequency of occurrence within a speed class interval

Σf_i = total number of occurrences

$$\bar{U} = \frac{1.5(2) + 5.5(2) + 10(2) + 15.5(1)}{2 + 2 + 2 + 1} = 7.1 \text{ mph}$$

This average speed is used as a guide to select the speed class interval which has the highest frequency of occurrence for the prevailing wind direction. However, in this example, because of insufficient data, the speed distribution for the prevailing direction of ENE does not follow the normal statistical distribution and is highly skewed. Therefore some judgement must be exercised in selecting the speed class interval to be used in a mathematical model [1].

In this example the average speed for the prevailing wind direction is 7.1 mph. This wind speed is nearer to the 4-7 mph class interval (which is a conservative estimate*). The wind speed interval of 4 to 7 mph and with its associated prevailing wind direction ENE will be inputs into a mathematical model [1].

*In a mathematical model [1] to estimate pollution levels on and within the highway corridor, concentration is inversely proportional to wind speed. Therefore, to be conservative for the estimated pollutant concentration select the lower speed class interval associated with the average wind speed.

TIME PERIODS TO DETERMINE WIND ROSES AND STABILITY

There are two primary time periods that must be considered when constructing wind roses for proposed highway routes. They are (1) time of day and (2) months or seasons of the year.

The daily time period for which the construction of wind roses is usually most critical falls between 0700 and 1800. This period encompasses the peak morning and evening traffic flow periods and the mid-day off-peak traffic hours. Depending on the situation, other periods may need to be examined.

The peak morning and evening traffic hours generally fall between 0700 and 0900 and 1600 and 1800 respectively. The off-peak hours generally occur between 0900 and 1600. These time periods may change depending on geographic location in California and should be reflected in constructing the wind rose. The exact time for the periods of record will depend on the wind data that are available for each hour and changes in the wind speed and direction between the peak traffic hours. If there is small change in wind patterns during peak morning traffic between the hours of 0700 and 0900 then a wind rose can be constructed for the combined records for this time period. The same applies for the evening peak and off-peak traffic.

The importance of the months or seasons of the year is in their relation to atmospheric stability. A stable atmosphere restricts the dispersion of pollutants resulting in high ground level concentrations. A stable atmosphere is therefore, the most unfavorable meteorological condition. An unstable atmosphere enhances the dispersion of pollutants resulting in low ground level concentrations, thus being the most favorable of meteorological conditions in terms of dispersion of pollutants. The most unfavorable meteorological conditions usually exist in early morning and late evenings as surface based inversions. These occur generally with clear skies and light winds. The winter surface based inversions are usually the most persistent. These surface based inversions generally last until mid-morning when the incoming solar radiation warms the ground surface and burns off the inversion. It is during these winter months that high concentrations of carbon monoxide can generally be expected. The concentrations of ozone during these months will be kept to a minimum because of the lesser amount of ultraviolet radiation received from the sun. The other seasons of the year, spring, summer, and fall are generally when the persistent inversions aloft occur. It is during these months that the concentrations of ozone can be expected to be the highest because of the increased ultraviolet radiation.

Table 12 gives general guidelines for collection of data to construct wind roses and estimate the stability classes over the four seasons.

TABLE 12

Guidelines For Time Periods to Collect Meteorological Data

Season	Months	Morning Peak* Traffic Hours	Off-Peak Traffic Hours	Evening Peak* Traffic Hours
Winter	December, January and February	0700-0900	1100-1300	1600-1800
Spring	March, April and May	" "	" "	" "
Summer	June, July and August	" "	" "	" "
Fall	September, October and November	" "	" "	" "

*Although the table shows the same time period applicable to all seasons, the local meteorological conditions (topography, climate, etc.), the surface wind flow patterns, and the peak traffic hours may dictate other hours for data collection. If there is any uncertainty, consult with the Materials and Research Department in Sacramento.

It may be desirable to collect wind records for a particular month and use this in the mathematical model to estimate air pollution levels for different periods of the year depending on the nature of the receptor(s). It should be stressed that the primary purpose of combining the months and time periods for the minimum records (5 years recommended) collected is to have enough unbiased data to use in the statistical analysis of wind roses and to estimate the probability of occurrence for each of the six stability classes.

COMPUTER PROGRAMS FOR WIND ROSES AND STABILITY

The Materials and Research Department in Sacramento has developed computer programs to analyze meteorological records for: (1) the surface stability of the atmosphere and (2) wind rose construction. The computer programs that are on file are listed below with a brief description of their use:

1. STAR2 - determines the probability of occurrence of each of the six stability classes (A through F) and their associated wind roses based on meteorological records stored on microfilm (NWRC) or compiled from accessible meteorological records that exist at local airports, etc.

2. WNDROS - determines the probability of occurrence of each of the six stability classes (A through F) and their associated wind roses based on meteorological records stored on magnetic tape (NWRC).

3. WIND2 - determines wind roses only compiled from any meteorological record without regard to stability class.

A complete users manual for these computer programs is presented in Appendices C, D and F along with examples of the computer outputs.

Data Requirements For Computer Programs

As previously mentioned most all of the meteorological records of U. S. Weather Bureau Stations are sent to the National Weather Record Center (NWRC) in Asheville, North Carolina. Each Highway District will probably have occasion to write to the NWRC and request certain meteorological records for a particular project under study. There are two different formats in which the meteorological records at NWRC can be obtained. They are described below with their purchase cost:

1. Magnetic tape - $60 per reel per station for at least five years of records.

2. Microfilm - $9.00 per year per station.

In Appendix G is the name of each NWRC station, period of records, and locations (latitude and longitude) for the information stored on magnetic tape or microfilm.

The best way to order meteorological records from NWRC is on magnetic tape. Following is a discussion of possible alternatives for meteorological records and associated computer programs.

Computer Program WNDROS

If the meteorological records purchased from NWRC are on magnetic tape, the District should send the tape to the Materials and Research Department in Sacramento. Headquarter's personnel will reduce the information using the computer program WNDROS on the Division of Highways IBM 360 computer and will send the results back to the Districts.

Computer Program STAR2

If the meteorological records purchased from NWRC are on microfilm, each District will reduce the data into the prescribed format for computer program STAR2. These format sheets compiled by the Districts can then be run on the State-wide Time Sharing System within each district. For assistance in operation of program STAR2 consult the Materials and Research Department in Sacramento.

Computer Program WIND2

There may be some local meteorological sources such as a fire weather station, local school, etc. whose records may not be complete and where the only useful information for the air quality study will be wind speed and direction. To analyze these data, computer program WIND2 should be used. The input sheets should be completed by District Personnel and then be run on the State-wide Time Sharing System within each district. For assistance in operation of program WIND2 consult the Materials and Research Department in Sacramento.

Output From Computer Programs WNDROS and STAR2

The primary output from these computer programs will be the probability of occurrence for each of the six stability classes and their associated wind roses based on meteorological records.

Output From Computer Program WIND2

The output from computer program WIND2 will be a wind rose from which the prevailing wind speed and direction can be determined. There will be no output as to stability class. For this special case the stability class will be determined from Tables 1 and 2. No statistical probabilities can be associated with the stability classes as determined from Tables 1 and 2. Judgment will have to be exercised to determine what stability class to use in the analysis. Guidance can be obtained from the Materials and Research Department, Sacramento.

METEOROLOGICAL INPUTS INTO THE HIGHWAY LINE SOURCE DISPERSION MODEL

The primary meteorological inputs into the highway line source dispersion model[1] are for the most probable and the worst meteorological conditions. The inputs require the probability of occurrence of each stability class (most probable and worst conditions) along with their associated wind roses. These meteorological conditions can be determined from computer programs STAR2 or WNDROS. In Appendix D is a typical computer output for the Hayward Airport for the combined hours of 1400 through 1600 for five years of historical data.

The following is a summary of the probabilities of each stability class from Appendix D for the Hayward Airport.

Stability Class	Probability of Occurrence* %
A	1
B	4
C	12
D	52
E	22
F	9

The most probable meteorological conditions are for Stability Class D (52% of the time). For Stability Class D the prevailing surface wind direction is from the West occurring 44% of the time. The most frequent surface wind speed interval for the prevailing surface wind direction of West is the 13 to 18 mph interval (76 occurrences). The worst meteorological conditions are for Stability Class F (9% of the time). For Stability Class F the prevailing surface wind direction is from the WNW occurring 44.8% of the time. The most frequent surface wind speed interval for the prevailing surface wind direction of ENE is to 7 mph interval (19 occurrences).

To fully assess the impact of a highway on the air environment, one should examine wind directions, speeds, and surface stabilities other than the most probable, particularly where pollutants may be transported toward a sensitive receptor. These meteorological conditions may have an extremely low probability of occurrence; however, they should be used as inputs to the highway line source model to complement the primary inputs.

Computer program WIND2 gives only the prevailing surface wind speed interval and direction. The stability class must be assumed. No statistical probabilities of any stability class can be calculated as previously mentioned. Assistance and guidance can be obtained from the Materials and Research Department, Sacramento.

*All values are rounded off to the nearest whole number.

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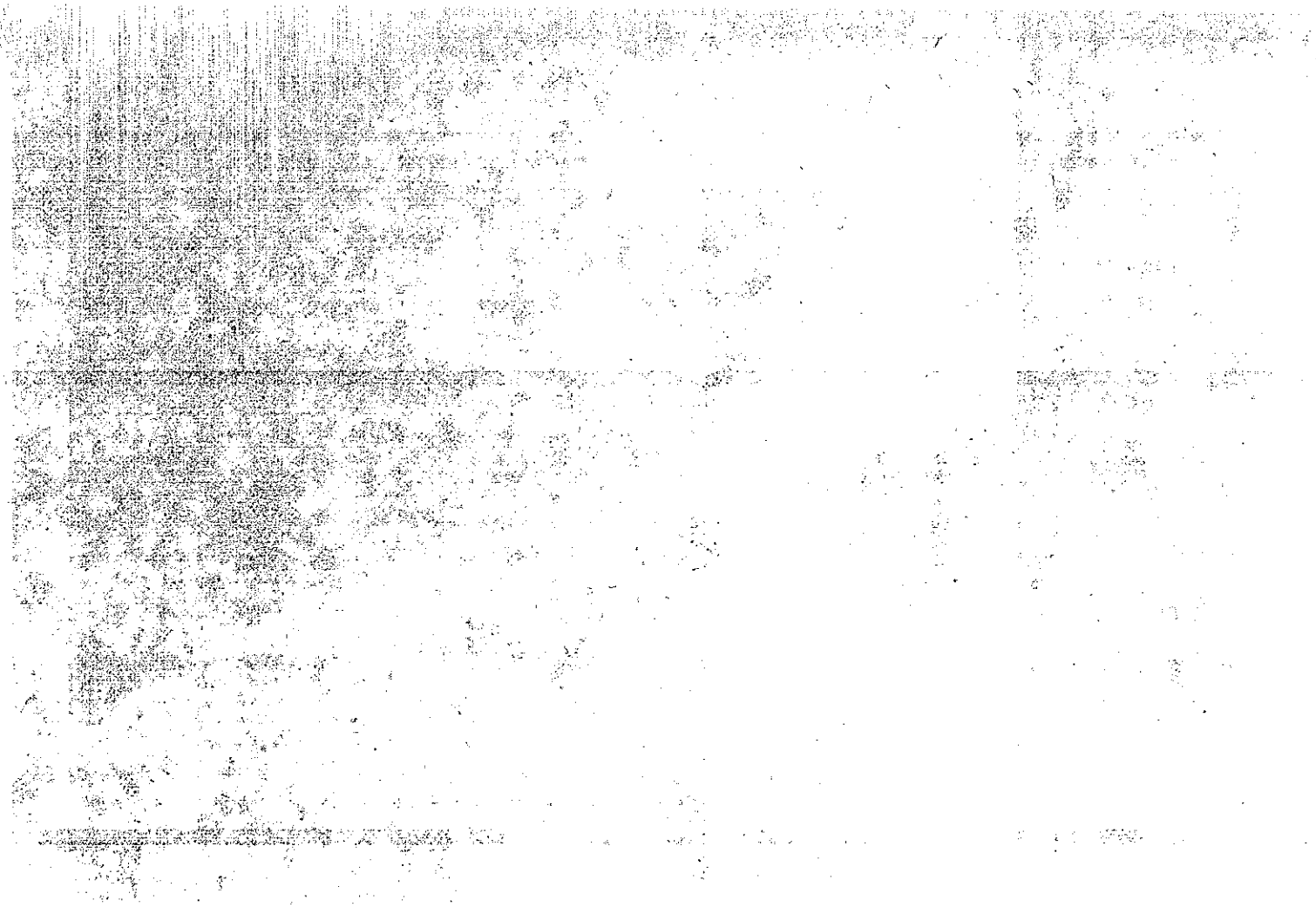
APPENDIX A

AIR POLLUTION DISTRICTS IN CALIFORNIA



AIR POLLUTION CONTROL DISTRICTS IN CALIFORNIA

BAY AREA APCD
939 Ellis Street
San Francisco, CA 94109
(415) 771-6000 Activated September 1955
Mr. J. D. Callagan
Chief Administrative Officer

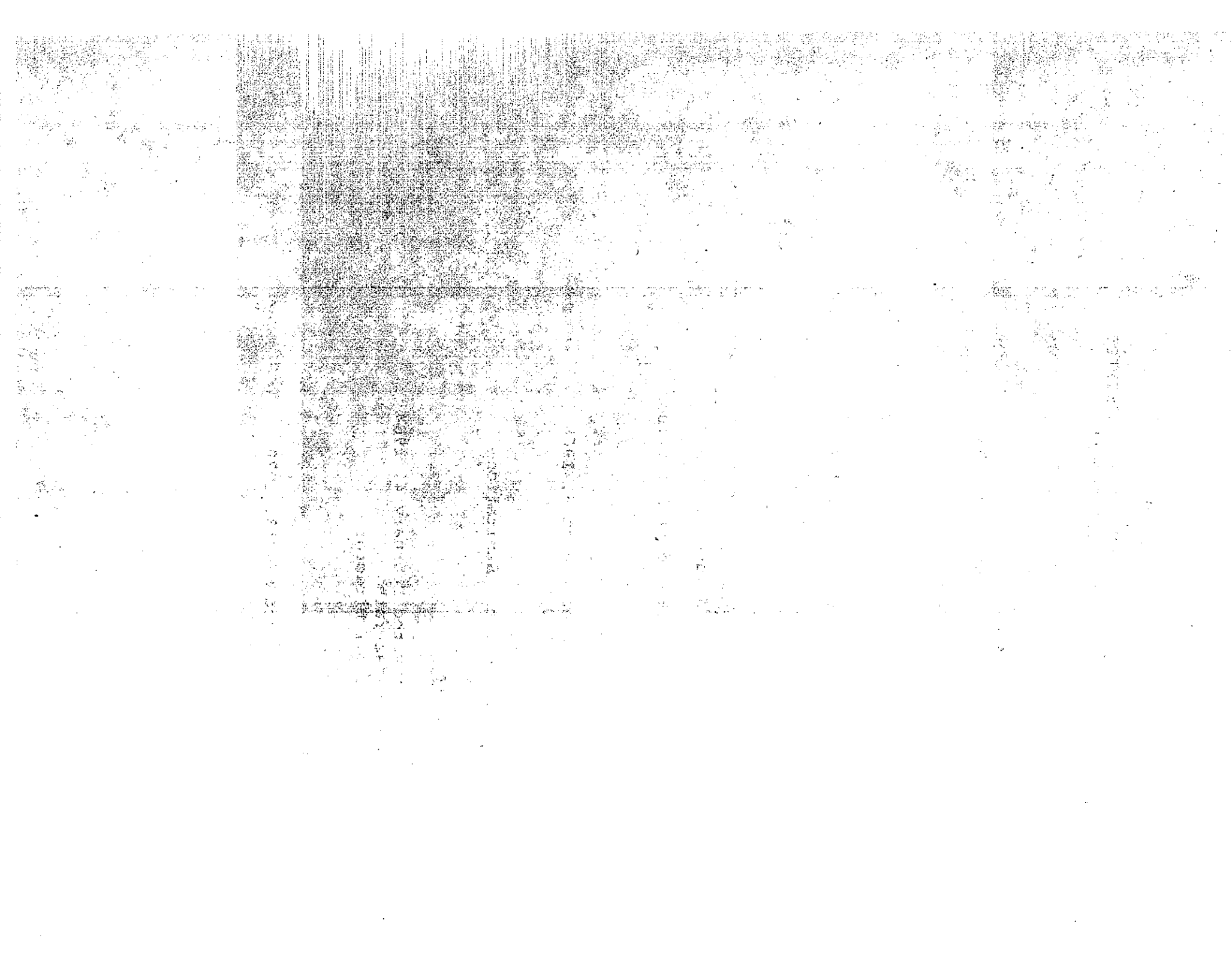
CALAVERAS COUNTY APCD
Government Center
El Dorado Road
San Andreas, CA 95249
(209) 754-4251 Activated March 6, 1970
D. L. Albasio, M.D.*
Senior Sanitarian

COLUSA COUNTY APCS
County Court House
Colusa, CA 95932
(916) 458-4516 Activated June 3, 1969
Mr. Andrew R. Clark
Executive Secretary to Board of Supervisors

FRESNO COUNTY APCD
516 South Cedar Avenue
Fresno, CA 93702
(209) 485-8000 Activated August 8, 1968
William A. DeFries, M.D.*
Health Officer
Mr. R. E. Bergstrom**
Director of Environmental Sanitation

HUMBOLDT COUNTY APCD
5630 South Broadway
Eureka, CA 95501
(707) 443-3091 Activated February 4, 1964
Mr. Charles P. Sassenrath
Air Pollution Control Director

INYO COUNTY APCD
P. O. Box 218
Independence, CA 93526
(714) 878-2411 Activated May 18, 1970
Victor H. Hough, M.D.*
Health Officer
Walter S. Carrington, R.S.**
Director Division of Sanitation



KERN COUNTY APCD
P. O. Box 997
Bakersfield, CA 93302
(1700 Flower Street)
(805) 325-5051 Activated March 12, 1968
Owen A. Kearns, M.D.*
Health Officer
Mr. Citron Toy**
Senior Sanitarian

KINGS COUNTY APCD
1221 West Lacey Boulevard
Hanford, CA 93230
(209) 582-3211 Activated March 19, 1968
Douglas B. Wilson, M.D.*
Health Officer
Mr. Tony Maniscalo
Director of Sanitation

LOS ANGELES COUNTY APCD
434 South San Pedro Street
Los Angeles, CA 90013
(213) 629-4711 Activated October 14, 1947
Mr. Robert L. Chass
Control Officer

MADERA COUNTY APCD
216 West Sixth Street
Madera, CA 93637
(209) 674-4641 Activated June 11, 1968
Douglas F. Pratt**
Director of Sanitation
(Acting APCO)

MARIPOSA COUNTY APCD
P. O. Box 5
Mariposa, CA 95338
(on Hwy. 140, next door to Frosty Shop)
(209) 966-3689 Activated April 9, 1968
Robert John Evans, M.D.*
Acting Health Officer
Mr. Herb Davis**
Chairman, Board of Supervisors
County Court House
(209) 966-2396
Home (209) 966-2109

MERCED COUNTY APCD
P. O. Box 1350
Merced, CA 95341
(240 East 15th Street,
next to General Hospital)
(209) 723-2861 Activated January 14, 1969
A. Frank Brewer, M.D.*
Health Officer
Mr. Bill Norman**
Director of Sanitation

MONTEREY-SANTA CRUZ COUNTY UNIFIED APCD
P. O. Box 487
Salinas, CA 93901
(Courthouse)
(408) 758-3583 or 424-8611 Ext. 383
Activated July 1, 1968
Mr. Edward W. Munson
Control Officer

NEVADA COUNTY APCD
Willow Valley Road
East Basement Wing
Nevada City, CA 95959
(916) 265-2461 Ext. 264
Activated April 28, 1970
Peter J. Keenan, M.D.*
Health Officer
Mr. Hal Cox**
Senior Sanitarian

ORANGE COUNTY APCD
1010 South Harbor Boulevard
Anaheim, CA 92805
(714) 774-0284 Activated September 1950
Mr. William Fitchen
Control Officer

PLACER COUNTY APCD
155 Fulweiler Avenue
Auburn, CA 95603
(916) 885-4517 Activated March 3, 1970
Gordon Seck, M.D.*
Health Officer
Mr. Albert A. Marino**
Chief, Division of Environmental Health

PLUMAS COUNTY APCD
P. O. Box 207
Quincy, CA 95971
(916) 283-1800 Activated May 18, 1970
Robert H. Hunter**
Supervisor
William Cullen
Chief Sanitarian

RIVERSIDE COUNTY APCD
Room 234, Health-Finance Building
3575 Eleventh Street
Riverside, CA 92501
(714) 787-2416 Activated June 13, 1955

SACRAMENTO COUNTY APCS
2221 Stockton Boulevard
Sacramento, CA 95817
(916) 454-5458 Activated December 7, 1959
James T. Harrison, M.D.*
Director of Public Health
Mr. Philip S. Tow**
Chief, Division of Air Sanitation

SAN BERNARDINO COUNTY APCD
172 West Third Street
San Bernardino, CA 92401
(714) 889-0111, Ext. 376, 456, 548, 549
Activated June 19, 1956
Mr. John H. Fairweather
Control Officer

SAN DIEGO COUNTY APCD
Civic Center
1600 Pacific Highway
San Diego, CA 92101
(714) 239-7711 Activated May 1955
J. B. Askew, M.D.*
Health Officer
Mr. Clark L. Gaulding**
Chief, Air Pollution Control Services

SAN JOAQUIN COUNTY APCD
P. O. Box 2009
Stockton, CA 95201
(1601 East Hazelton Avenue)
(209) 466-6781 Activated May 9, 1967
Mr. J. Don Layson
Director of Environmental Health

SANTA CRUZ (See MONTEREY-SANTA CRUZ)

SAN LUIS OBISPO COUNTY APCD
P. O. Box 1499
San Luis Obispo, CA 93402
(2191 Johnson Avenue)
(805) 548-121 Activated April 6, 1970
Mr. Jim Gates**
Director of Sanitation

SONOMA COUNTY APCD
3313 Chante Road
Santa Rosa, CA 95404
(707) 527-1111 Activated March 30, 1970
Walter C. Clowers, M.D.*
Health Officer

STANISLAUS COUNTY APCD
902 Scenic Drive
Modesto, CA 95350
(209) 524-1251 Activated August 20, 1968
Robert S. Westphal, M.D.*
Health Officer
Mr. James Rankin**
Director of Sanitation

SUTTER COUNTY APCD
Department of Agriculture
142 Garden Way
Yuba City, CA 95991
(916) 742-3276 Activated July 28, 1969
William A. Greene*
Air Pollution Control Officer

TULARE COUNTY APCD
County Civic Center
Visalia, CA 93277
(209) 732-5511 Activated June 25, 1968
Lowell F. Chemberlen, M.D.*
Health Officer
Mr. Pete Hanson**
Director of Sanitation

VENTURA COUNTY APCD
3147 Loma Vista Road
Ventura, CA 93001
(805) 648-6181 Activated March 12, 1968
Stephen A. Coray, M.D.*
Health Officer
Mr. Richard B. Atherton**
Air Pollution Control Engineer

SAN BENITO COUNTY APCD
439 Fourth Street
Hollister, CA 95023
(403) 637-5367 Activated August 24, 1970
James G. Telfer, M.D.*
Director of Public Health

SANTA BARBARA COUNTY APCD
P. O. Box 119
4440 Calle Real
Santa Barbara, CA
(805) 967-2311 Activated September 14, 1970
Joseph T. Nardo, M.D.
Director of Public Health and Acting APCO

*Also appointed Air Pollution Control Officer

**In direct charge of Air Pollution Control Program

APPENDIX B

SPECIFICATIONS FOR WIND SYSTEMS

SPECIFICATIONS - MECHANICAL WEATHER STATION

BASIC MEASUREMENT FUNCTION - To measure wind direction, speed and air temperature in a remote self sufficient package.

WIND RUN - Fast response aluminum cups

1. Response Distance - 8 feet (63% recovery)
2. Flow per recording transverse - 10 miles
3. Flow coefficient - 7.90 feet/rev
4. Starting Threshold - 0.2 to 0.5 mph
5. Accuracy - ± 2% overall

WIND DIRECTION - Aluminum Vane

1. Delay Distance - 8 feet (50% recovery)
2. Damping Ratio - 0.5 to 0.6
3. Starting Threshold - Less than 0.75 mph
4. Accuracy - ± 1% full scale

TEMPERATURE - Shielded bimetal coil sensor

1. Range - 30°F to 120°F
2. Accuracy - ± 3°F Absolute
   ± 1°F Relative

RECORDER - Precision Escapement Timed Drive

1. Chart Width - 4 inches
2. Chart Paper - Pressure sensitive with black trace
   52' rolls
3. Battery wound drive - 20 mm/hr.

HOUSING - Finish - Weather proof - white corrosion resistant paint

SIZE - 25" overall height
8" diameter
Vane Length 33.5"

SPECIFICATIONS

HAND-HELD WIND MEASURING SET

Basic Function - To measure wind speed and direction by means of a rotor and a vane.

	Speed	Direction
Range:	0 - 15 Knots	360°
	0 - 60 Knots	"

Accuracy: ±2% direction ±3% speed

Starting Speed: 1.0 Knot

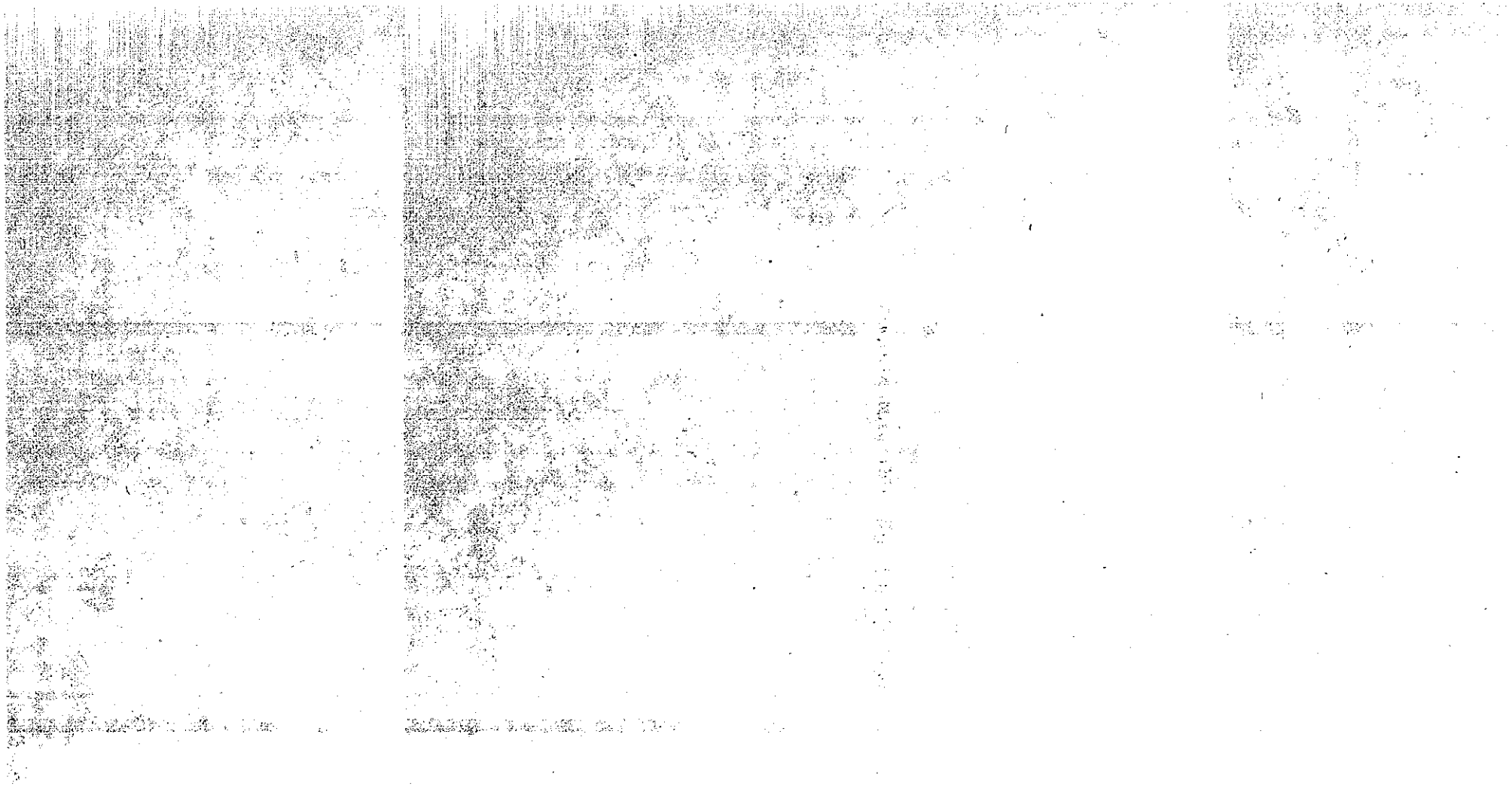
Readout: Speed - Direct reading dial
Direction - Lockable vane w/360° direction dial

Miscellaneous

1. Must meet Specification MIL-W-55153 (Sig.C).
2. Dimensions - Approximately
   8 1/2" Dia. x 18 1/2" High
3. Shall be supplied with a sturdy carrying case.
4. Shall include one spare wind speed rotor and one spare wind direction vane.
5. Weight - Approximately 3 1/2 pounds.

APPENDIX C

USER'S MANUAL FOR COMPUTER PROGRAM WNDROS



USER'S GUIDE

PROGRAM TITLE: WNDROS

PURPOSE: This program computes frequency histograms for 16-sided wind roses and prints tables of relative frequency distribution with regard to different stability classes requested by the user. Also as an option, it plots the computed wind roses.

PROGRAMMED BY: M. Farrockhrooz
Materials and Research Department
California Division of Highways
Sacramento, California

SECTION: Environmental Improvement - Air Quality Unit

DATE: January 1972

COMPUTER: IBM System/360 and Cal-Comp Plotter

LANGUAGE: Fortran IV G Level

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INPUT REQUIRED: Input to the program consists of job control cards, a selection card, identification cards, control cards, and magnetic tape containing weather information. (The tape must be prepared in accordance with the National Weather Records Center Format TDF 14)*

A. Job Control Cards:

There are four job control cards as shown in "PROGRAM WNDROS Input Sheet."

These cards are used essentially for accounting purposes. The user must enter his district labor cost code letter designation, Source, Charge, Expenditure Authorization for the job, and California Highway Tape number in lines 1-4 according to the instructions given in the form.

B. Selection Card:

This card selects up to 12 individual hours of the day for wind rose computation. Any hour appearing in the Part D under "Control Cards" must be shown in this card.

C. Identification Cards:

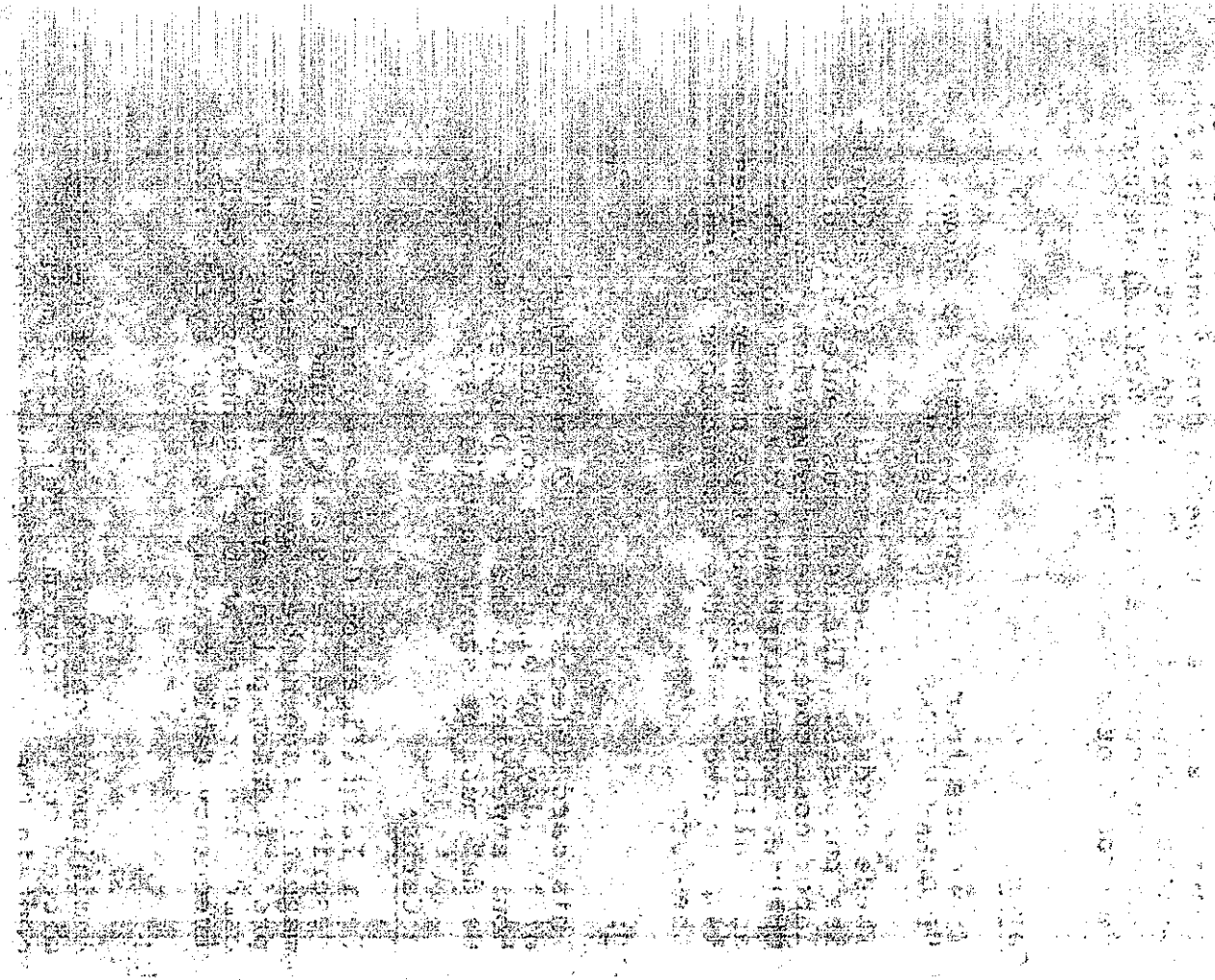
Four Identification Cards are required to describe the weather station name and number, magnetic tape number, period of record, project description, and charge codes. These cards are printed at the beginning of each frequency table exactly as input by the user.

D. Control Cards:

A minimum of one control card must be submitted to the program. This card must contain the following information according to the input sheet instructions:

Knots, Calm, Bias, months of study (up to 3 months and a combining code), stability classes (up to 6 stability classes and a combining code), hours of study (up to 3 hours of study and a combining code) and plot option.

*See Appendix A-1 for the detail of how to obtain the magnetic tapes.



Column No.

2	Knots = 1	if wind speed in knots*
	Knots = 0	if wind speed in MPH
4	Calm = 1	for calm distribution
	Calm = 0	for no calm distribution
6	Bias = 1	Secondary directions are debiased for all wind speed classifications.
	Bias = 0	The secondary directions are not debiased.

MONTHS OF STUDY:

7-8	Enter the number of month for first month of study (01 = Jan., 02 = Feb., etc.)
9-10	Enter the number of month for second month of study (leaveit blank if not requested)
11-12	Enter the number of month for third month of study (leave it blank if not requested)
13-14	Month = 00 if a combination of the above months is not requested
	Month = 77 if both individual months and a combination is requested.
	Month = 88 if only a combination is requested.

STABILITY CLASSES: Based on Pasquill's Stability Classes

Definition	Computer Code	Equivalent Pasquill Stability Class
Extremely unstable	1	A
Unstable	2	B
Slightly unstable	3	C
Neutral	4	D
Slightly Stable	5	E
Stable	6	F
Special Code	9	Sum all classes together

*Most U.S. Weather Bureau Stations record speed in knots.

Column No.		
16	1	Stability Class A requested
	0	" " " not requested
18	2	" " B requested
	0	" " " not requested
20	3	" " C requested
	0	" " " not requested
22	4	" " D requested
	0	" " " not requested
24	5	" " E requested
	0	" " " not requested
26	6	" " F requested
	0	" " " not requested
28	9	Sum of all classes requested
	0	" not requested

HOURS OF STUDY:

29-30 Enter the first hour of study (08 for 8:00 A.M. & 16 for 4:00 P.M., Pacific Standard Time*)

31-32 Enter the second hour of study (leave it blank if not requested)

33-34 Enter the third hour of study (leave it blank if not requested)

35-36 Hour = 00 if a combination of the above hours is not requested.

Hour = 88 if only a combination of the above hours is requested.

Hour = 99 if both individual hours and a combination is requested.

---

*Daylight Savings Time (DST) months May-October should be converted to Pacific Standard Time (PST) by the following equation:

$$PST = DST - 1 \text{ hr.}$$

PLOT OPTION:

Column No.

38 Plot = 1 Wind Rose Plots on Cal-Comp Plotter is requested.

Plot = 0 Wind Rose Plots on Cal-Comp Plotter not requested.

If additional months and/or hours are required, more control cards can be added following this same format.

COMPUTATIONAL METHOD USED IN THE PROGRAM:

A wind rose may be defined as a circular histogram designed to show distribution of wind direction and speed at a given location for a particular time of day.

The standard statistical method for computing histograms is utilized in this program. The wind speed class intervals and the method of distributing the calms within the two lowest wind speed classes are based on a paper written by D. B. Turner and L. E. Truppi entitled "Meteorological Roses" as described in the training manual, "Air Polluttion Meteorology," published by the Environmental Protection Agency.

The estimation of stability classes is based on Pasquill's class structure. The following explanation of Pasquill's stability classification has been extracted from an article by D. Bruce Turner in February 1964 Journal of Applied Meteorology:

> "This system of classifying stability on an hourly basis for research in air pollution is based upon work accomplished by Dr. F. Pasquill of the British Meteorological Office (1961). Stability near the ground is dependent primarily upon net radiation and wind speed. Without the influence of clouds, insolation (incoming radiation) during the day is dependent upon solar altitude, which is a function of time of day and time of year. When clouds exist their cover and thickness decrease incoming and outgoing radiation. In this system insolation is estimated by solar altitude and modified for existing conditions of total cloud cover

and cloud ceiling height. At night estimates of outgoing radiation are made by considering cloud cover. This stability classification system has been made completely objective so that an electronic computer can be used to compute stability classes. The stability classes are as follows: 1) Extremely unstable, 2) Unstable, 3) Slightly unstable, 4) Neutral, 5) Slightly stable, 6) Stable, 7) Extremely stable. Table A-1 gives the stability class as a function of wind speed and net radiation. The net radiation index ranges from 4, highest positive net radiation (directed toward the ground), to -2, highest negative net radiation (directed away from the earth). Instability occurs with high positive net radiation and low wind speed, stability with high negative net radiation and light winds, and neutral conditions with cloudy skies or high wind speeds.

The net radiation index used with wind speed to obtain stability class is determined by the following procedure:

1) If the total cloud cover is 10/10 and the ceiling is less than 7000 feet, use net radiation index equal to 0 (whether day or night).

2) For night-time (night is defined as the period from one hour before sunset to one hour after sunrise):

   a) If total cloud cover $\leq$ 4/10, use net radiation index equal to -2.

   b) If total cloud cover > 4/10, use net radiation index equal to -2.

3) For daytime:

   a) Determine the insolation class number as a function of solar altitude from Table A-2.

   b) If total cloud cover $\leq$ 5/10, use the net radiation index in Table A-1 corresponding to the insolation class number.

   c) If cloud cover > 5/10, modify the insolation class number by following these six steps:

1) Ceiling < 7000 ft., subtract 2.

2) Ceiling ≥ 7000 ft. but < 16,000 ft., subtract 1.

3) Total cloud cover equal 10/10, subtract 1. (This will only apply to ceilings ≥ 7000 ft since cases with 10/10 coverage below 7000 ft are considered in item 1 above.)

4) If insolation class number has not been modified by steps (1), (2), or (3) above, assume modified class number equal to insolation class number.

5) If modified insolation class number is less than 1, let it equal 1.

6) Use the net radiation index in Table A-1 corresponding to the modified insolation class number."

STABILITY CLASS AS A FUNCTION OF NET RADIATION AND WIND SPEED*

WIND SPEED (KNOTS)	NET RADIATION INDEX 4	3	2	1	0	-1	-2
0, 1	1	1	2	3	4	6	6**
2, 3	1	2	2	3	4	6	6**
4, 5	1	2	3	4	4	5	6
6	2	2	3	4	4	5	6
7	2	2	3	4	4	4	5
8, 9	2	3	3	4	4	4	5
10	3	3	4	4	4	4	5
11	3	3	4	4	4	4	4
≥ 12	3	4	4	4	4	4	4

*Source in table from an article by D. Bruce Turner in February 1964 Journal of Applied Meteorology.

**Stability class 7 (extremely stable) was combined with the stability class 6 (stable) in Calif. Div. of Highways, WNDROS program.

INSOLATION AS A FUNCTION OF SOLAR ALTITUDE*

SOLAR ALTITUDE (a)	INSOLATION	MONTH**	INSOLATION CLASS NUMBER
$60° < a$	Strong	May, June July, Aug.	4
$35° < a \leq 60°$	Moderate	Jan., Feb., Mar.,April Sept.,Oct., Nov.	3
$15° < a \leq 35°$	Slight	Dec.	2
$a \leq 15°$	Weak		1

*Source for table from an article by D. Bruce Turner in February 1964 Journal of Applied Meteorology.

**This column was derived for an average latitude for the State of California and added to this table for reference.

In this program, six stability classes, 1 through 6 or A through F, are considered. These range from extremely unstable conditions to stable conditions. Also, as an option, one can ignore the different stability classes and get a wind direction and speed histogram for requested data along with a relative frequency table.

DETERMINATION OF CEILING HEIGHT AND CLOUD COVER:

In order to determine the stability class at any given time, one must know time of the day and time of the year (for solar altitude computation), wind speed, cloud cover, and ceiling height.

Cloud cover might be different for various cloud heights. Therefore, in this program, the cloud layer having the maximum coverage is used as cloud cover.

The ceiling is defined as the height of the first layer of clouds which cover more than 5/10 of the sky. If there is no

cloud layer greater than 5/10, then ceiling height is defined as unlimited.

NOTE: This program is written to use meteorological data stored on magnetic tape according to the TDF-14 format of the "Tape Reference Manual" of the U. S. Department of Commerce, National Weather Record Center, Asheville, North Carolina.

PROCEDURE TO REQUEST DATA TAPES CONTAINING METEOROLOGICAL DATA PERTAINING TO A CERTAIN STATION:

The National Weather Bureau Center has magnetic tapes containing meteorological data for many stations in California. Attached to this manual (Appendix A-2) is a list of station numbers, names, and period of record for tapes at the center.

GENERAL TAPE INFORMATION

Prior to 1965, all weather bureau stations recorded 24 observations, on the hour, per day. Since January 1965, however, only certain weather bureau stations and most Air Force and Navy stations continued with the 24 hour observations. The bulk of the Weather Bureau Stations record only 8 observations per day on magnetic tape. These 3-hour observations are 00:00, 03:00, 06:00, etc., Pacific Standard Time. It is not recommended to purchase the tapes containing only 8 observations per day. In such a case tapes previous to 1965 should be purchased.

These tapes cost $60.00 per reel. If a ten-year period is selected from more than one reel, an additional cost of $15.00 per reel is applied. Before ordering any tape, check with M & R to see if that particular tape is in M & R's file. If it is not, then a written request must be sent to National Weather Record Center along with required money and stating the station number, station name, and years of record on the reel (selected from Appendix A-2). The magnetic tape should be sent to Headquarters M & R to be filed and processed when requested.

For any assistance please call:

Headquarters Materials and Research in Sacramento
Environmental Improvement Section, Air Quality Unit.

The tapes are available from the following address:

U. S. Department of Commerce
Environmental Science Services Administration
Environmental Data Service
National Weather Records Center
Federal Building
Asheville, North Carolina 28801

List of magnetic tapes available for California weather stations from National Weather Record Center.

STATION NO.	NAME	PERIOD OF RECORD	NO. OF REELS
23239	Alameda FWC	3/45-12/54; 1/55-12/64; 1/65-12/69; 1/70-12/70	4
24283	Arcata FAA	1/49-12/58; 1/59-5/70	2
23155	Bakersfield	01/48-12/58; 1/59-12/68	2
23157	Bishop	1/48-12/58; 1/59-12/65	2
23225	Blue Canyon	1/48-12/58; 1/59-12/62	2
23158	Blythe FAA	11/48-12/54	1
23152	Burbank	1/48-12/58; 1/59-12/51; 7/66-12/68	3
03154	Camp Pendleton MCB	7/66-12/70	1
93104	China Lake NAF	4/45-12/55; 1/56-12/65; 1/66-12/70	3
24286	Crescent City FAA	1/49-12/54	1
03147	Cuddlebak AF	7/63-10/68	1
23161	Daggett FAA	11/48-12/58; 1/59-12/68	2
23226	Donner Summit	11/48-1/52	1
23114	Edwards AFB	1/49-12/58; 1/59-12/68	2
23199	El Centro NAAS	2/45-12/54; 1/55-10/60	2
93101	El Toro MCAS	3/43-12/54; 1/55-12/64; 1/65-12/70	3

STATION NO.	NAME	PERIOD OF RECORD	NO. OF REELS
23202	Fairfield/Travis AFB	1/49-12/58; 1/59-11/68	2
93193	Fresno	1/49-12/58; 1/59-4/68	2
93115	Imperial Beach NAS	1/52-12/61; 1/62-12/70	2
93218	Jolon Sig Corps	1/69-12/70	1
23110	Lemoore NAS	7/61-12/70	1
23129	Long Beach	1/49-12/58; 1/59-3/69	2
93106	Los Alamitos NAS	4/45-12/54; 1/55-12/64; 1/65-12/70	3
23174	Los Angeles	1/47-12/56; 1/57-12/66; 1/67-4/69	3
23203	Merced/Castle AFB	1/49-12/59; 1/60-12/68	2
23197	Miramar NAS	4/47-12/54; 1/55-12/64; 1/65-12/70	3
03129	Mojave MCAS	10/55-9/58	1
24259	Montague	1/50-12/58; 1/59-12/65	2
23245	Monterey NAF	3/45-12/48; 1/49-12/58; 1/59-12/68; 1/69-12/70	4
24215	Mount Shasta	4/48-12/58; 1/59-12/61	2

STATION NO.	NAME	PERIOD OF RECORD	NO. OF REELS
23179	Needles FAA	11/48-12/54	1
23230	Oakland	1/48-12/58; 1/59-4/68	2
23136	Oxnard AFB	12/52-12/62; 1/63-11/68	2
23182	Palmdale FAA	1/61-12/64	1
93215	Point Arguello WBO	7/59-3/65	1
93111	Point Mugu NAS	3/46-12/55; 1/56-12/65; 1/66-12/70	3
24216	Red Bluff	1/48-12/58; 1/59-4/68	2
23119	Riverside/March AFB	1/49-12/58; 1/59-11/68	2
23232	Sacramento	7/47-12/57; 1/58-12/67; 1/68-12/69	3
23233	Salinas FAA	12/48-12/54	1
23122	San Bernardino AFB	1/49-12/58; 1/59-12/68	2
92117	San Clemente NAS	4/60-12/69	1
93112	San Diego FWC	4/45-12/55; 1/56-12/65; 1/66-12/70	3
23188	San Diego WBAS	1/48-12/58; 1/59-12/68	2
23234	San Francisco	1/48-12/58; 1/59-12/62; 1/65-12/70	3

STATION NO.	NAME	PERIOD OF RECORD	NO. OF REELS
93116	San Nicolas Isl NAS	4/45-12/49; 1/50-12/59; 1/60-12/69	3
23211	San Rafael AFB	1/53-12/62	1
93114	Santa Ana MCAF	3/45-12/58; 1/59-12/68; 1/69-12/70	3
23190	Santa Barbara FAA	11/48-12/54; 1/57-12/64	2
23191	Santa Catalina	1/48-6/53	1
23273	Santa Maria	10/54-7/65	1
23236	Santa Maria	1/48-10/54	1
23237	Stockton	11/48-12/54; 6/67-12/69	2
23244	Sunnyvale NAS	3/45-12/54; 1/55-12/64; 1/65-12/70	3
23275	Ukiah FAA	9/49-12/54	1
93214	Vandenberg AFB	1/50-12/60; 1/60-12/68	2
23131	Victorville/George AFB	9/50-12/60; 1/61-11/68	2
23238	Williams CAA	11/48-12/52	1

Example Problem

This is an example for ALAMEDA FWC Station.

The morning hours are from 7-9 PST.

The afternoon hours are 16-18 PST (see hour selection card).

For detail input of Control Cards, see page 101 and 102.

A partial output is shown in pages 103 and 104.

In this problem the plot of wind rose was also requested and is shown in page 105.

PROGRAM WNDROS

INPUT SHEET

USER INSTRUCTIONS:

1. ENTER YOUR DISTRICT LABOR COST CODE LETTER DESIGNATION ON LINE NO.1 COLUMN 19 AND AGAIN ON LINE NO. 9 COLUMN 48. (ie. Dist 1=A, Dist 2 =B, etc.)
2. ENTER PROJECT SOURCE CODE, CHARGE CODE AND EA NUMBER ON LINE NO 1 COLUMNS 22-39 AND ON LINE NO. 9.
3. ENTER YOUR DISTRICT NUMBER IN LINE NO. 2 COLUMNS 20-21 (01 etc.)
4. ENTER THE HWY. DESIGNATION NUMBER OF THE MAGNETIC TAPE CONTAINING THE METEOROLOGICAL DATA ON LINE NO. 3 COLUMNS 33-37 & AGAIN ON LINE NO.7 COLUMNS 20-24.

OPERATING INSTRUCTIONS:

1. MOUNT THE TAPE SHOWN IN LINE NO.3 COLUMNS 32-37 AS INPUT.
2. ATTACH PLOTTER INSTRUCTIONS TO PLOT TAPE AND SEND TO PLOTTER. WRITE ENG. WNDROSE ON GREEN LABEL AND ATTACH TO PLOT TAPE. (30 DAYS RETENTION)

JOB CONTROL CARDS

	SOURCE	CHARGE	EXP. AUTH.	DO NOT PUNCH
//ENGØWR JOB (IE4ØDL,	197Ø1,	197Ø1,	762650,	01
// DIST04, CLASS=C, MSGLEVEL=(2,Ø)				02
// EXEC PROC=ENGWROSE, SERIAL=Ø3Ø1ØØ				03
//G.FT05FØØ1 DD *				04

HOUR SELECTION CARD

ENTER ALL THE HOURS YOU WISH TO EXAMINE i.e. 07, 09, 16 etc.
-UP TO 12 HOURS ALLOWED (PST)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Ø	6	Ø	7	Ø	8	Ø	9	1	5	1	6	1	7	1	8									05

PROJECT DESCRIPTION

WEATHER STATION NO. 23239 NAME: ALAMEDA	06
MAGNETIC TAPE NO. 3Ø1ØØ PERIOD OF RECORD: 1/65 TO 12/69	07
PROJECT DESCRIPTION: ALAMEDA AREA AIR STUDIES	08
SOURCE: 197Ø1 CHARGE: 197Ø1 EA: 762650 LCC: E4ØDL	09

Jan. '72

CONTROL CARDS

2	4	6	7 8	9 10	11 12	13 14	16	18	20	22	24	26	28	29 30	31 32	33 34	35 36	38	
1	1	1	01	02	12	88	1	2	3	4	5	6	9	07	08	09	88	1	10
1	1	1	01	02	12	88	1	2	3	4	5	6	9	16	17	18	88	1	11
1	1	1	03	04		88	1	2	3	4	5	6	9	07	08	09	88	1	12
1	1	1	03	04		88	1	2	3	4	5	6	9	16	17	18	88	1	13
1	1	1	05			0	1	2	3	4	5	6	9	06	07	08	88	1	14
1	1	1	05			0	1	2	3	4	5	6	9	15	16	17	88	1	15
1	1	1	06	07	08	88	1	2	3	4	5	6	9	06	07	08	88	1	16
1	1	1	06	07	08	88	1	2	3	4	5	6	9	15	16	17	88	1	17
1	1	1	09	10		88	1	2	3	4	5	6	9	06	07	08	88	1	18
1	1	1	09	10		88	1	2	3	4	5	6	9	15	16	17	88	1	19
1	1	1	11			0	1	2	3	4	5	6	9	07	08	09	88	1	20
1	1	1	11			0	1	2	3	4	5	6	9	16	17	18	88	1	21
																			22
																			23

ENTER 0 IF WIND SPEED IN MPH
" 1 " " " KNOTS

ENTER 1 FOR CALM DISTRIBUTION
" 0 " NO "

ENTER 1 FOR DEBIAS OF SECONDARY DIRECTIONS
" 0 " NO " " "

ENTER FIRST NUMBER OF MONTH OF STUDY
i.e. 01 = JAN., 02 = FEB. etc.

ENTER 2nd NUMBER OF MONTH OF STUDY

ENTER 3rd NUMBER OF MONTH OF STUDY

ENTER 0 IF ABOVE MONTHS REQUESTED INDIVIDUALLY
" 77 " " " " & COMBINED
" 88 " " " " COMBINED ONLY

ENTER 1 IF STABILITY CLASS A REQUESTED
" " " " A NOT "

ENTER 2 IF STABILITY CLASS B REQUESTED
" 0 " " " B NOT "

ENTER 3 IF STABILITY CLASS C REQUESTED
" 0 " " " C NOT "

ENTER 4 IF STABILITY CLASS D REQUESTED
" 0 " " " D NOT "

ENTER 5 IF STABILITY CLASS E REQUESTED
" 0 " " " E NOT "

ENTER 6 IF STABILITY CLASS F REQUESTED
" 0 " " " F NOT

ENTER 9 IF SUMMARY OF ALL CLASSES REQUESTED
" 0 " " " " " NOT "

ENTER THE FIRST HOUR OF STUDY 24 HR CLOCK P.S.T.

ENTER THE SECOND HOUR OF STUDY

ENTER THE THIRD HOUR OF STUDY

ENTER 0 IF PREVIOUS HOURS REQUESTED INDIVIDUALLY
" 88 " " " " COMBINED ONLY
" 99 " " " " INDIVIDUALLY & COMBINED

ENTER 1 IF WINDROS PLOT REQUESTED
" 0 " NO " " "

BY .....
CHECK .....
DATE .....

REMARKS .....

IN CASE OF QUESTION
NAME J. A. HOLVERSTOTT
916
PHONE 445-5760 DATE 2-16-72

VERIFY

Jan '72

WEATHER STATION NO.23239 NAME. ALAMEDA
MAGNETIC TAPE NO. 30100 PERIOD OF RECORD: 1/65 TO 12/69
PROJECT DESCRIPTION: ALAMEDA AREA AIR STUDIES
SOURCE: 19701 EA:762650 SD:
FOLLOWING TABLE IS DEBIASED FOR SECONDARY DIRECTION

IN THE FOLLOWING TABLE THE CALMS ARE DISTRIBUTED

THE FOLLOWING TABLE IS FOR :

MONTHS OF SEP OCT COMBINED
HOURS 15 16 17 COMBINED
STABILITY CLASS D

********** FREQUENCY DISTRIBUTION **********

DIRECTION	SPEED,MPH 0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%
N	0	0	2	2	2	1	0	0	0	8	17.9	1.3
NNE	0	0	0	2	0	2	0	0	0	4	21.7	0.6
NE	0	0	0	0	1	0	0	0	0	1	21.5	0.1
ENE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
E	0	0	1	1	0	0	0	0	0	1	12.7	0.2
ESE	0	0	0	4	2	0	0	0	0	5	17.5	0.9
SE	0	0	0	3	1	0	0	0	0	3	16.7	0.6
SSE	0	0	4	4	0	2	0	0	0	9	15.8	1.5
S	1	1	4	3	2	2	0	0	0	13	15.6	2.2
SSW	0	0	7	12	2	0	0	0	0	21	14.2	3.6
SW	0	1	3	5	2	1	0	0	0	12	14.7	2.1
WSW	0	4	7	77	14	0	0	0	0	102	15.6	16.9
W	0	4	24	183	39	1	0	0	0	250	15.8	41.7
WNW	0	4	14	119	9	0	0	0	0	146	15.1	24.3
NW	1	3	2	2	1	0	0	0	0	9	10.1	1.4
NNW	0	4	5	4	2	2	0	0	0	16	13.4	2.7
CALM	1	0	0	0	0	0	0	0	0	1	0.0	0.0
TOT	1	20	74	420	76	11	0	0	0	601	0.0	0.0

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS D = 49.0164 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES= 1220

DIRECTION	SPEED, MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	0.0	0.0	0.1709	0.1709	0.1709	0.1140	0.0	0.0	0.0	0.6268
NNE	0.0	0.0	0.0	0.1460	0.0	0.1460	0.0	0.0	0.0	0.2920
NE	0.0	0.0	0.0	0.0	0.0570	0.0	0.0	0.0	0.0	0.0570
ENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0570	0.0570	0.0	0.0	0.0	0.0	0.0	0.1140
ESE	0.0	0.0	0.0	0.2920	0.1460	0.0	0.0	0.0	0.0	0.4379
SE	0.0	0.0	0.0	0.2279	0.0570	0.0	0.0	0.0	0.0	0.2849
SSE	0.0	0.0	0.2920	0.2920	0.0	0.1460	0.0	0.0	0.0	0.7299
S	0.0502	0.0502	0.3419	0.2849	0.1709	0.1709	0.0	0.0	0.0	1.0691
SSW	0.0	0.0	0.5839	1.0219	0.1460	0.0	0.0	0.0	0.0	1.7518
SW	0.0	0.1004	0.2849	0.3989	0.1709	0.0570	0.0	0.0	0.0	1.0121
WSW	0.0	0.3013	0.5839	6.2771	1.1678	0.0	0.0	0.0	0.0	8.3302
W	0.0	0.3013	1.9373	14.9860	3.1909	0.1140	0.0	0.0	0.0	20.5296
WNW	0.0	0.3013	1.1678	9.7806	0.7299	0.0	0.0	0.0	0.0	11.9797
NW	0.0502	0.2511	0.1709	0.1709	0.0570	0.0	0.0	0.0	0.0	0.7002
NNW	0.0	0.3013	0.4379	0.2920	0.1460	0.1460	0.0	0.0	0.0	1.3232

WEATHER STATION NO.23239 NAME. ALAMEDA

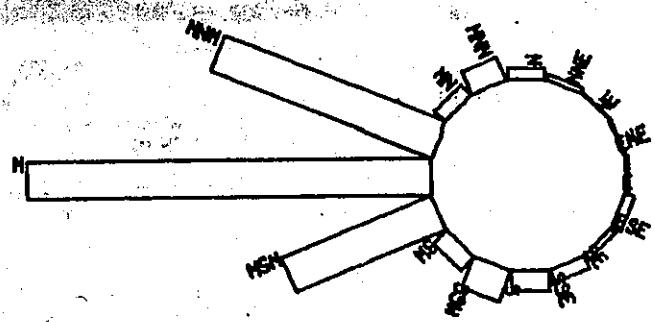
MAGNETIC TAPE NO. 30100 PERIOD OF RECORD: 1/65 TO 12/69

PROJECT DESCRIPTION: ALAMEDA AREA AIR STUDIES

SOURCE: 19701 EA:762650 SD:

TIME OF STUDY 15:00 16:00 17:00 COMBINED ....STABILITY CLASS D

WIND ROSE FOR MONTH(S) OF SEP OCT COMBINED



APPENDIX D

USER'S MANUAL FOR COMPUTER PROGRAM STAR2

USER GUIDE

PROGRAM TITLE: STAR2 (Wind Rose with Stability Classes)

PURPOSE: This program computes frequency histograms for 16-sided wind roses and prints tables of Relative Frequency Distributions with regard to different stability classes requested by the user.

PROGRAMMED BY: M. Farrockhrooz
Materials and Research Department
California Division of Highways
Sacramento, California

SECTION: Environmental Improvement - Air Quality Unit

DATE: June 1972

COMPUTER: IBM System/360

LANGUAGE: Fortran IV

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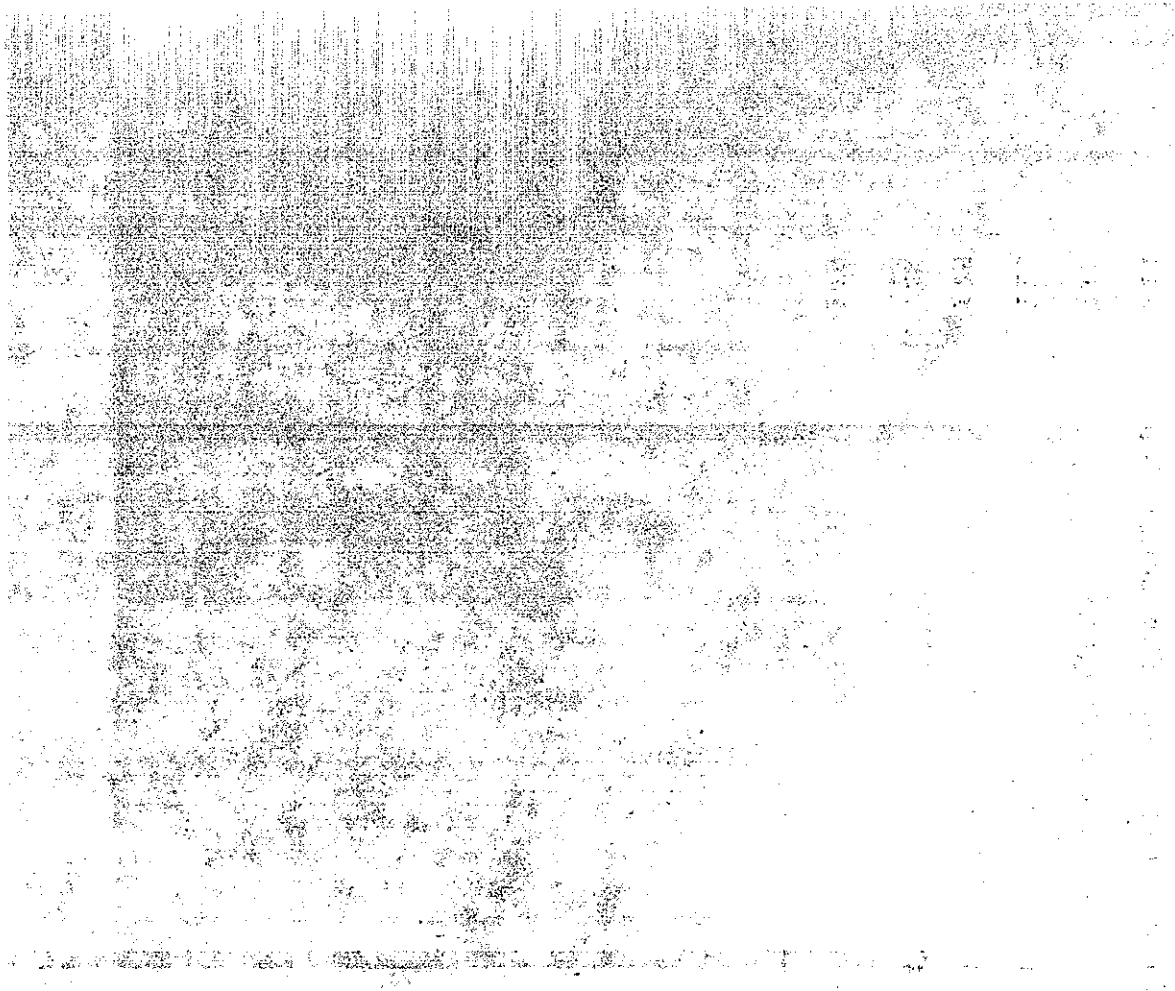
Determination of Ceiling Height and Sky Condition	111
Computational Method Used in the Program	112
Example Problem No. 1	116
Example Problem No. 2	125
Example Problem No. 3	132
Job Deck Setup	149



Input Required: Input to the program consists of Job control cards, Project description cards, control card and data cards.

A. Job Control Cards:

There are four job control cards as shown in "Program STAR2 Input Sheet"(see example problems). These cards are essentially for accounting purposes. The user enters his district letter designation, source, charge, and expenditure authorization according to the instructions given on the form.

B. Project Description Cards

Four cards are required to describe the weather station name, location, period of record, project description and charge codes. This information will be printed out at beginning of each frequency table exactly as it is input by the user.

C. Control Card

This card should contain the following information: knots, calms, bias, degrees and classification.

Column No.

6 Knots = 0 if input wind speed is in MPH
Knots = 1 if input wind speed is in knots

8 Calm = 0 for no calm distribution
Calm = 1 for calm distribution

10 Bias = 0 the secondary directions are not debiased
Bias*= 1 the secondary directions are debiased for all wind speed classifications

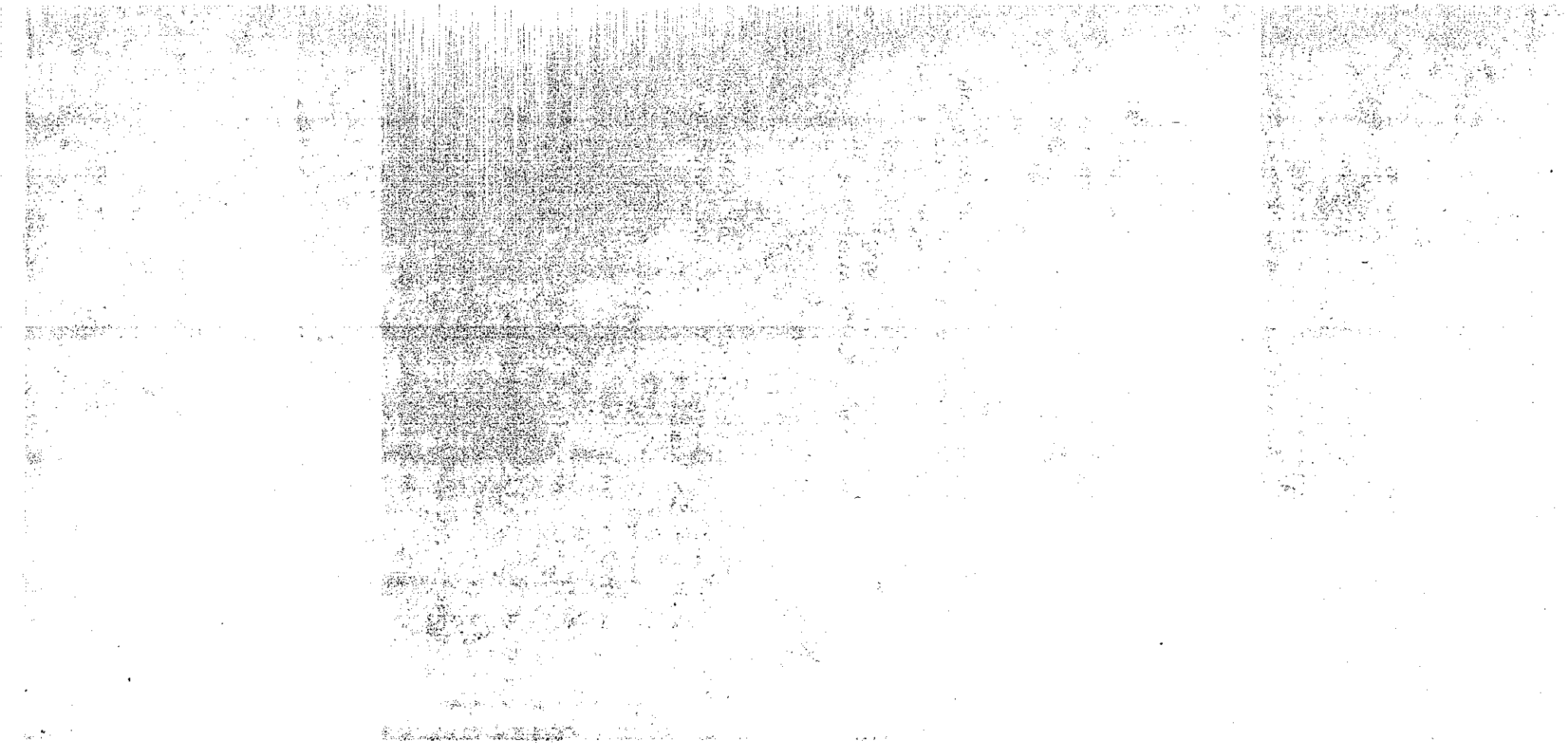
12 Degree = 0 if directions are reported on an 8 or 16 point compass

Degree = 1 if directions reported on a 36 point compass

Classifications: Based on Pasquill's Stability Classes:

Definition	Computer Code	Equivalent Pasquill Stability Class
Extremely unstable	1	A
Unstable	2	B
Slightly unstable	3	C
Neutral	4	D
Slightly stable	5	E
Stable	6	F
Special Code	9	Sum of all classes together

* Note: Debiasing is not required for 36 point compass reporting system.



Column No.	
14	0 Stability Class A not requested 1 " " A requested
16	0 " " B not requested 1 " " B requested
18	0 " " C not requested 1 " " C requested
20	0 " " D not requested 1 " " D requested
22	0 " " E not requested 1 " " E requested
24	0 " " F not requested 1 " " F requested
26	0 Sum of all classes not requested 1 " " " " requested

D. Data Cards: The following information is entered on data cards: sequence no. year, month, day, hour, ceiling height, wind direction, wind speed and sky condition as described below:

Column No.	
1-4	Sequence number starting with 6 for the 1st data card.
5-6	Year: Last two digits of the year of record.
7-8	Month: Numbered month of the year: 01 = Jan. 02 = Feb., etc.
9-10	Day: Day of the month 01 through 31
11-12	Hour: Based on 24 hour clock 00 through 23 Pacific standard time
13-15	Ceiling Height* Ceiling in hundreds of feet (unlimited ceiling = 200)
16-19	Wind Direction: Based on an 8 or 16 point compass, (i.e., N,NNW,Calm) or based on 36 compass points, (i.e. 4,6,35 represent 40 degrees, 60 degrees, and 350 degrees respectively)
20-21	Wind Speed: In MPH or Knots
22	Sky Conditions* Code for sky condition as follows:

EXAMPLE PROBLEM NO. 1

36 Compass Point Recording System

Note: Options asked in this problem involve calm distribution, but no debiasing.

Determination of Ceiling Height and Sky Condition:

The clouds are usually reported from one to four skies. Each sky having some cloud cover with a related cloud height. The cloud cover is reported as a ratio, such as 0/10 for clear sky and 10/10 overcast. ◯ and ⊕ are symbolic representation for clear and overcast, respectively

Ceiling Definition: The Ceiling is height of the cloud which has coverage greater than 5/10 and is closest to the ground.

Sky Condition: The highest ratio reported for all four or as many skies reported.

Based on the above definitions, it is not necessary that the cloud with the maximum coverage constitutesthe ceiling.

These following examples will help to clarify the subject:

Reported Skies				Ceiling Height	Total Cloud Cover
1	2	3	4	ft÷100	
C-10 ◐	15 ◐	30 ◍	50 ⊕	30	⊕ or 10/10
20 ◍	30 ◐	70 ◍		20	◍ or 7/10
30 +◐	40 ◐	60 + ◐		unlimited = 200	+ ◐ or 5/10

The following table may be of some help when interpreting the recorded Sky and Ceiling readings; it shows how the Ceiling Height was obtained:

A Aircraft

B Balloon (Pilot or Ceiling)

D Estimated height of cirriform clouds on basis of persistency

E Estimated heights of noncirriform clouds

M Measured

R Radiosonde Balloon or Radar

W Indefinite

U Height of cirriform ceiling layer unknown

/ Height of cirriform nonceiling layer unknown

"V" Immediately following numerical value indicates a varying ceiling

An unlimited number of data lines may be entered into the program. The limit is the actual data that is available for the number of years under study.

NOTE: All Identification, Control, and Data Lines should be numbered sequentially for ease of checking and changing.

COMPUTATIONAL METHOD USED IN THE PROGRAM: A wind rose may be defined as a circular histogram, designed to show the distribution of wind direction and speed at a given location, for a particular time of the day.

In this program, however, the circular histogram is not drawn, but the values are given as percentages, and with a quick visual inspection of this column of data, one can readily obtain the most probable wind direction and speed.

The standard statistical method for computing histograms is utilized in this program. The class intervals and distribution of calms within the lower two wind speed classes are based on a paper written by D. B. Turner and L. E. Truppi entitled "Meteorological Roses" as described in the training manual, "Air Pollution Meteorology," published by the Environmental Protection Agency.

The method of computation for the Pasquill Stability Classes was derived from an article by D. Bruce Turner in February 1964, of the "Journal of Applied Meteorology."

> "This system of classifying stability on an hourly basis for research in air pollution is based upon work accomplished by Dr. F. Pasquill of the British Meteorological Office (1961). Stability near the ground is dependent primarily upon net radiation and wind speed. Without the influence of clouds, insolation (incoming radiation) during the day is dependent upon solar altitude, which is a function of time of day and time of year. When clouds exist, their cover and thickness decrease incoming and outgoing radiation. In this system insolation is estimated by solar altitude and modified for existing conditions of total cloud cover and cloud ceiling height. At night estimates of outgoing radiation are made by considering cloud cover. This stability classification system has been made completely objective

so that an electronic computer can be used to compute stability classes. The stability classes are as follows: 1) Extremely unstable, 2) Unstable, 3) Slightly unstable, 4) Neutral, 5) Slightly stable, 6) Stable, 7) Extremely stable. Table A-1 gives the stability class as a function of wind speed and net radiation. The net radiation index ranges from 4, highest positive net radiation (directed toward the ground), to -2, highest negative net radiation (directed away from the earth). Instability occurs with high positive net radiation and low wind speed, stability with high negative net radiation and light winds, and neutral conditions with cloudy skies or high wind speeds.

The net radiation index used with wind speed to obtain stability class is determined by the following procedure:

1) If the total cloud cover is 10/10 and the ceiling is less than 7000 feet, use net radiation index equal to 0 (whether day or night).

2) For night-time (night is defined as the period from one hour before sunset to one hour after sunrise):

   a) If total cloud cover $\leq$ 4/10, use net radiation index equal to -2.

   b) If total cloud cover >4/10, use net radiation index equal to -1.

3) For daytime:

   a) Determine the insolation class number as a function of solar altitude from Table A-2.

   b) If total cloud cover $\leq$5/10, use the net radition index in Table A-1 corresponding to the insolation class number.

   c) If cloud cover $\geq$5/10, modify the insolation class number by following these six steps:

1) Ceiling <7000 ft, subtract 2.

2) Ceiling ≥7000 ft but < 16,000 ft, subtract 1.

3) Total cloud cover equal 10/10, subtract 1. (This will only apply to ceilings ≥7000 ft since cases with 10/10 coverage below 7000 ft are considered in item 1 above.)

4) If insolation class number has not been modified by steps (1), (2), or (3) above, assume modified class number equal to insolation class number.

5) If modified insolation class number is less than 1, let it equal 1.

6) Use the net radiation index in Table A-1 corresponding to the modified insolation class number."

TABLE A-1. STABILITY CLASS AS A FUNCTION OF NET RADIATION AND WIND SPEED*

WIND SPEED (KNOTS)	NET RADIATION INDEX 4	3	2	1	0	-1	-2
0, 1	1	1	2	3	4	6	6**
2, 3	1	2	2	3	4	6	6**
4, 5	1	2	3	4	4	5	6
6	2	2	3	4	4	5	6
7	2	2	3	4	4	4	5
8, 9	2	3	3	4	4	4	5
10	3	3	4	4	4	4	5
11	3	3	4	4	4	4	4
≥12	3	4	4	4	4	4	4

*Source for table: An article by D. Bruce Turner in February 1964 Journal of Applied Meteorology.

**Stability class 7 (extremely stable) was combined with the stability class 6 (stable) in Calif. Div. of Highways WNDROS program.

TABLE A-2. INSOLATION AS A FUNCTION OF SOLAR ALTITUDE*

SOLAR ALTITUDE (a)	INSOLATION	MONTHS**	INSOLATION CLASS NUMBER
$60° < a$	Strong	May, June, July, Aug.	4
$35° < a \leq 60°$	Moderate	Jan., Feb., Mar., April, Sept.,Oct., Nov.	3
$15° < a \leq 35°$	Slight	Dec.	2
$a \leq 15°$	Weak		1

*Source for table: An article by D. Bruce Turner in February 1964 Journal of Applied Meteorology.

**This column was derived for an average latitude for the State of California and added to this table for reference.

In this program, six stability classes, 1 through 6, or A through F, are considered. These range from extremely unstable conditions to stable conditions. Also, as an option, one can ignore the different stability classes and get a wind direction and speed histogram for all the data given along with a relative frequency distribution table.

EXAMPLE PROBLEM NO. 1

16 COMPASS POINT REPORTING SYSTEM

Note:

a) Options asked in this problem involve no debiasing or calm distribution.

b) Only Pasquill Stability Classes 2, 4, and 9 or B, D and all classes combined are requested.

PROGRAM STAR2
INPUT SHEET

User Instructions:

1. Enter your district labor cost code letter designation on line 1. column 20 (ie Dist. 1 = A etc.)
2. Enter project source code, charge code and E.A. number on line 1. columns 23–40 and on line 8.
3. Enter your district number on line 2, columns 20-21. (ie 01, 02 etc.)
4. Fill in project description information in spaces provided on lines 5 thru. 8.
5. Fill in control card.
6. Enter data on data sheets.

JOB CONTROL CARDS

SOURCE (columns 23–27) CHARGE (columns 29–33) E.A. (columns 35–40)

Card	LINE NO. DO NOT
//ENGØSR JOB (IE4ØCL,19700,19700,762000,ØØØØ,PMA,1Ø,1Ø)	1
// DIST03,CLASS=4,MSGLEVEL=(2,Ø)	2
// EXEC PROC=ENGSRŌSE	3
//G.FTØ5FØØ1 DD *	4

PROJECT DESCRIPTION CARDS

Card	LINE NO.
1 WEATHER STATIŌN NAME: TAHOE CITY LŌCATIŌN: LAKE TAHOE	5
2 YEARS ŌF RECŌRD: 1969 MŌNTH(S): SEPTEMBER	6
3 HŌUR(S) ŌF DAY: 5 PM	7
4 PRŌJECT ID: 19700 762000 USER: SK DISTRICT: 03	8

CONTROL CARD

Column	4	6	8	10	12	14	16	18	20	22	24	26
Value	5	1	0	0	0	0	2	0	4	0	0	9

- Column 6: Wind Speed in knots = 1; Wind Speed in MPH = 0
- Column 8: Calm distribution = 1; No Calm distribution = 0
- Column 10: Debias for secondary direction = 1; No debias for secondary direction = 0
- Column 12: Directions reported on 36 Pt compass = 1; Directions reported on 8 or 16 Pt. compass = 0
- Column 14: 1 = Stability class A requested.
- Column 16: 2 = Stability class B requested.
- Column 18: 3 = Stability class C requested.
- Column 20: 4 = Stability class D requested.
- Column 22: 5 = Stability class E requested.
- Column 24: 6 = Stability class F requested.
- Column 26: 9 = Summary of all classes.

PROGRAM STAR2

Station TAHOE CITY DATA CARDS

SEQUENCE NUMBER				YEAR		MO.		DAY		HOUR		CEILING HEIGHT ÷ 100'			WIND DIRECTION				WIND SPEED		SKY CODE
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			6	6	9		9		1	1	7	2	0	0				N		1	1
			7	6	9		9		2	1	7	2	0	0		N	N	E		2	1
			8	6	9		9		3	1	7	2	0	0			N	E		3	0
			9	6	9		9		4	1	7	2	0	0				N		4	1
		1	0	6	9		9		5	1	7	2	0	0		N	N	E		5	0
		1	1	6	9		9		6	1	7	2	0	0			N	E		6	1
		1	2	6	9		9		7	1	7	2	0	0				E		6	2
		1	3	6	9		9		8	1	7	2	0	0				E		5	3
		1	4	6	9		9		9	1	7	2	0	0			S	E		5	4
		1	5	6	9		9	1	0	1	7	2	0	0			S	E		5	5
		1	6	6	9		9	1	1	1	7		5	5		E	S	E		7	6
		1	7	6	9		9	1	2	1	7		4	5		W	S	W		5	7
		1	8	6	9		9	1	3	1	7		6	0				S		6	8
		1	9	6	9		9	1	4	1	7		4	0				S		4	9
		2	0	6	9		9	1	5	1	7	2	0	0			N	E		6	1
		2	1	6	9		9	1	6	1	7	2	0	0			S	E		5	0
		2	2	6	9		9	1	7	1	7	2	0	0			S	W		1	2
		2	3	6	9		9	1	8	1	7	2	0	0		W	S	W		1	2
		2	4	6	9		9	1	9	1	7	2	0	0		S	S	W	1	0	3
		2	5	6	9		9	2	0	1	7	2	0	0		S	S	W	2	0	3
		2	6	6	9		9	2	1	1	7	2	0	0			N	E	1	0	4
		2	7	6	9		9	2	2	1	7	2	0	0		N	W	N		5	4
		2	8	6	9		9	2	3	1	7	2	0	0				W		5	5
		2	9	6	9		9	2	4	1	7	2	0	0			S	W	1	0	5
		3	0	6	9		9	2	5	1	7		6	0			S	W		5	6
		3	1	6	9		9	2	6	1	7		7	5			S	W	1	0	6
		3	2	6	9		9	2	7	1	7		5	0			N	W		5	7
		3	3	6	9		9	2	8	1	7		4	0			N	W		7	9
		3	4	6	9		9	2	9	1	7	2	0	0		N	N	W		3	1
		3	5	6	9		9	3	0	1	7	2	0	0		W	N	W		1	3

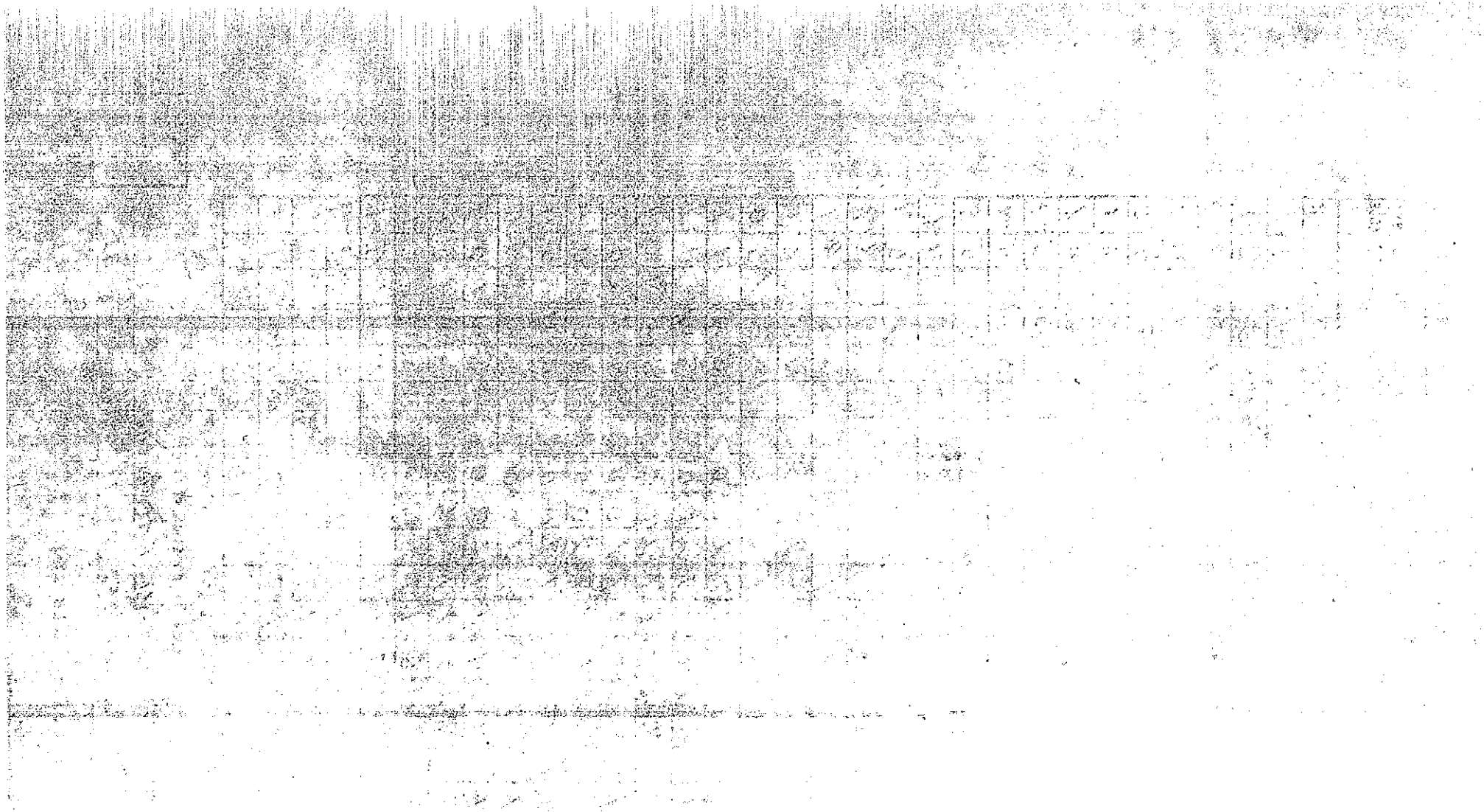
NOTE: RIGHT JUSTIFIED DATA IN ALL ABOVE FIELDS

BY: J. KASSEL
CHECK: M. FARROKHROOZ
DATE: 6-8-72

IN CASE OF QUESTION CONTACT:
NAME M. FARROKHROOZ
PHONE 452-5481 DATE 6-8-72

VERIFY

JUNE 1972



WEATHER STATION NAME: TAHOE CITY LOCATION: LAKE TAHOE
YEARS OF RECORD: 1969 MONTH(S): SEPTEMBER
HOUR(S) OF DAY: 5 PM
PROJECT ID: 19700 762000 USER: SK DIST:03

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS B **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	0	1	0	0	0	0	0	0	0	1	5.5	7.1
NNE	1	1	0	0	0	0	0	0	0	2	3.5	14.3
NE	1	2	0	0	0	0	0	0	0	3	4.2	21.4
ENE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
E	0	2	0	0	0	0	0	0	0	2	5.5	14.3
ESE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SE	0	3	0	0	0	0	0	0	0	3	5.5	21.4
SSE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
S	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
WSW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
W	0	1	0	0	0	0	0	0	0	1	5.5	7.1
WNW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NNW	1	1	0	0	0	0	0	0	0	2	3.5	14.3
CALM	0	0	0	0	0	0	0	0	0	0	0.0	0.0
TOT	3	11	0	0	0	0	0	0	0	14	0.0	0.0

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS B = 46.6667 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 30
OCCURRENCES WITHIN THIS STABILITY CLASS = 14.

DIRECTION	SPEED,MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.33
NNE	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67
NE	3.33	6.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.00
ENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	6.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67
ESE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	10.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.00
SSE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.33
WNW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NNW	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67

WEATHER STATION NAME: TAHOE CITY LOCATION: LAKE TAHOE
YEARS OF RECORD: 1969 MONTH(S): SEPTEMBER
HOUR(S) OF DAY: 5 PM
PROJECT ID: 19700 762000 USER: SK DIST:03

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS D **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NNE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ENE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
E	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ESE	0	0	1	0	0	0	0	0	0	1	10.0	11.1
SE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
S	0	2	0	0	0	0	0	0	0	2	5.5	22.2
SSW	0	0	0	0	1	0	0	0	0	1	21.5	11.1
SW	0	1	1	0	0	0	0	0	0	2	7.8	22.2
WSW	0	1	0	0	0	0	0	0	0	1	5.5	11.1
W	0	0	0	0	0	0	0	0	0	0	0.0	0.0
WNW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NW	0	1	1	0	0	0	0	0	0	2	7.8	22.2
NNW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
CALM	0	0	0	0	0	0	0	0	0	0	0.0	0.0
TOT	0	5	3	0	1	0	0	0	0	9	0.0	0.0

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS D = 30.0000 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 30
OCCURRENCES WITHIN THIS STABILITY CLASS = 9.

DIRECTION	SPEED,MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT
N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NNE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	3.33
SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	6.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67
SSW	0.0	0.0	0.0	0.0	3.33	0.0	0.0	0.0	0.0	3.33
SW	0.0	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	6.67
WSW	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.33
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WNW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NW	0.0	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	6.67
NNW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

WEATHER STATION NAME: TAHOE CITY LOCATION: LAKE TAHOE
YEARS OF RECORD: 1969 MONTH(S): SEPTEMBER
HOUR(S) OF DAY: 5 PM
PROJECT ID: 19700 762000 USER: SK DIST:03

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS ALL **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	1	1	0	0	0	0	0	0	0	2	3.5	6.7
NNE	1	1	0	0	0	0	0	0	0	2	3.5	6.7
NE	1	2	1	0	0	0	0	0	0	4	5.6	13.3
ENE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
E	0	2	0	0	0	0	0	0	0	2	5.5	6.7
ESE	0	0	1	0	0	0	0	0	0	1	10.0	3.3
SE	0	3	0	0	0	0	0	0	0	3	5.5	10.0
SSE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
S	0	2	0	0	0	0	0	0	0	2	5.5	6.7
SSW	0	0	1	0	1	0	0	0	0	2	15.8	6.7
SW	1	1	2	0	0	0	0	0	0	4	6.8	13.3
WSW	1	1	0	0	0	0	0	0	0	2	3.5	6.7
W	0	1	0	0	0	0	0	0	0	1	5.5	3.3
WNW	1	0	0	0	0	0	0	0	0	1	1.5	3.3
NW	0	1	1	0	0	0	0	0	0	2	7.8	6.7
NNW	1	1	0	0	0	0	0	0	0	2	3.5	6.7
CALM	0	0	0	0	0	0	0	0	0	0	0.0	0.0
TOT	7	16	6	0	1	0	0	0	0	30	0.0	0.0

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS ALL =100.0000 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 30
OCCURRENCES WITHIN THIS STABILITY CLASS = 30.

DIRECTION	SPEED,MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67
NNE	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67
NE	3.33	6.67	3.33	0.0	0.0	0.0	0.0	0.0	0.0	13.33
ENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	6.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67
ESE	0.0	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	3.33
SE	0.0	10.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.00
SSE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	6.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67
SSW	0.0	0.0	3.33	0.0	3.33	0.0	0.0	0.0	0.0	6.67
SW	3.33	3.33	6.67	0.0	0.0	0.0	0.0	0.0	0.0	13.33
WSW	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67
W	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.33
WNW	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.33
NW	0.0	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	6.67
NNW	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67

EXAMPLE PROBLEM NO. 2

36 COMPASS POINT REPORTING SYSTEM

Note:

a) Options asked in this problem involve no debiasing or calm distribution.

b) Only Pasquill Stability Classes 2 and 9 or B and all classes combined are requested.

PROGRAM STAR2

INPUT SHEET

User Instructions:

1. Enter your district labor cost code letter designation on line 1. column 20 (ie Dist. 1 = A etc.)
2. Enter project source code, charge code and E.A. number on line 1. columns 23–40 and on line 8.
3. Enter your district number on line 2, columns 20–21. (ie 01, 02 etc.)
4. Fill in project description information in spaces provided on lines 5 thru. 8.
5. Fill in control card.
6. Enter data on data sheets.

JOB CONTROL CARDS

	SOURCE	CHARGE	E.A.		LINE NO. / DO NOT PUNCH
/ENGØSR JOB (IE4ØCL,	19700,	19700,	760000,	ØØØØ, PMA, 1Ø, 1Ø)	1
/ DIST03, CLASS=4, MSGLEVEL=(2,Ø)					2
/ EXEC PRØC=ENGSRØSE					3
/G.FTØ5FØØ1 DD *					4

PROJECT DESCRIPTION CARDS

1 WEATHER STATIØN NAME: TRUCKEE			LØCATIØN: LAKE TAHOE		5
2 YEARS ØF RECØRD: 1970		MØNTH(S): SEPTEMBER			6
3 HØUR(S) ØF DAY: 8 AM					7
4 PRØJECT ID: 19700 760000		USER: SK	DISTRICT: 19		8

CONTROL CARD

1–5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
5	Ø	Ø	Ø	1	Ø	2	Ø	Ø	Ø	Ø	9										

- Wind Speed in knots = 1 / Wind Speed in MPH = 0
- Calm distribution = 1 / No Calm distribution = 0
- Debias for secondary direction = 1 / No debias for secondary direction = 0
- Directions reported on 36 Pt compass = 1 / Directions reported on 8 or 16 Pt. compass = 0
- 1 = Stability class A requested.
- 2 = Stability class B requested.
- 3 = Stability class C requested.
- 4 = Stability class D requested.
- 5 = Stability class E requested.
- 6 = Stability class F requested.
- 9 = Summary of all classes.

PROGRAM STAR2

Station TRUCKEE — DATA CARDS —

SEQUENCE NUMBER				YEAR		MO.		DAY		HOUR		CEILING HEIGHT ÷100'			WIND DIRECTION				WIND SPEED		SKY CODE
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			6	7	0		9		1		8	2	0	0				1		2	1
			7	7	0		9		2		8	2	0	0				1		2	2
			8	7	0		9		3		8	2	0	0				2		2	3
			9	7	0		9		4		8	2	0	0				3		2	4
		1	0	7	0		9		5		8	2	0	0				3		3	5
		1	1	7	0		9		6		8		2	0				3		3	6
		1	2	7	0		9		7		8		2	0				4		3	8
		1	3	7	0		9		8		8		2	5				6		4	7
		1	4	7	0		9		9		8		3	5			1	0		4	8
		1	5	7	0		9	1	0		8		3	0			3	5		6	9
		1	6	7	0		9	1	1		8		2	0			3	6		5	9
		1	7	7	0		9	1	2		8		2	5			3	4		3	8
		1	8	7	0		9	1	3		8		1	5			3	6		3	7
		1	9	7	0		9	1	4		8		1	5			3	3		1	6
		2	0	7	0		9	1	5		8	2	0	0			2	5		6	4
		2	1	7	0		9	1	6		8	2	0	0			2	4		2	2
		2	2	7	0		9	1	7		8	2	0	0			2	0		3	3
		2	3	7	0		9	1	8		8	2	0	0			2	2		4	1
		2	4	7	0		9	1	9		8		2	5			2	1		3	6
		2	5	7	0		9	2	0		8	2	0	0			1	8		2	5
		2	6	7	0		9	2	1		8	2	0	0			1	7		3	4
		2	7	7	0		9	2	2		8	2	0	0			1	6		4	3
		2	8	7	0		9	2	3		8	2	0	0			1	5		6	2
		2	9	7	0		9	2	4		8		2	0			1	4		1	7
		3	0	7	0		9	2	5		8		2	5				0		0	8
		3	1	7	0		9	2	6		8		2	0			1	2		2	9
		3	2	7	0		9	2	7		8		1	5			1	3		3	8
		3	3	7	0		9	2	8		8		1	8			1	4		4	7
		3	4	7	0		9	2	9		8	2	0	0			1	6		5	5
		3	5	7	0		9	3	0		8	2	0	0			1	8		6	4

NOTE: RIGHT JUSTIFIED DATA IN ALL ABOVE FIELDS

BY: S. KASSEL
CHECK: M. FARRUKHROOZ
DATE: 6-8-72

IN CASE OF QUESTION CONTACT:
NAME M. FARRUKHROOZ
PHONE 452-5481 DATE 6-8-72

VERIFY

JUNE 1972

WEATHER STATION NAME: TRUCKEE LOCATION: LAKE TAHOE
YEARS OF RECORD: 1970 MONTH(S): SEPTEMBER
HOUR(S) OF DAY: 8 AM
PROJECT ID: 19700 760000 USER: SK DISTRICT: 19

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS B **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NNE	1	0	0	0	0	0	0	0	0	1	1.5	11.1
NE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ENE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
E	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ESE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSE	0	3	0	0	0	0	0	0	0	3	5.5	33.3
S	1	1	0	0	0	0	0	0	0	2	3.5	22.2
SSW	1	0	0	0	0	0	0	0	0	1	1.5	11.1
SW	0	1	0	0	0	0	0	0	0	1	5.5	11.1
WSW	0	1	0	0	0	0	0	0	0	1	5.5	11.1
W	0	0	0	0	0	0	0	0	0	0	0.0	0.0
WNW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NNW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
CALM	0	0	0	0	0	0	0	0	0	0	0.0	0.0
TOT	3	6	0	0	0	0	0	0	0	9	0.0	0.0

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS B = 30.0000 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 30
OCCURRENCES WITHIN THIS STABILITY CLASS = 9.

DIRECTION	SPEED,MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NNE	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3
NE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	10.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.
S	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6
SSW	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3
SW	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3
WSW	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WNW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NNW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

WEATHER STATION NAME: TRUCKEE LOCATION: LAKE TAHOE
YEARS OF RECORD: 1970 MONTH(S): SEPTEMBER
HOUR(S) OF DAY: 8 AM
PROJECT ID: 19700 760000 USER: SK DISTRICT: 19

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS ALL **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	3	1	0	0	0	0	0	0	1	5	2.0	16.7
NNE	4	0	0	0	0	0	0	0	0	4	1.5	13.3
NE	1	0	0	0	0	0	0	0	0	1	1.5	3.3
ENE	0	1	0	0	0	0	0	0	0	1	5.5	3.3
E	0	1	0	0	0	0	0	0	0	1	5.5	3.3
ESE	1	0	0	0	0	0	0	0	0	1	1.5	3.3
SE	2	1	0	0	0	0	0	0	0	3	2.8	10.0
SSE	0	3	0	0	0	0	0	0	0	3	5.5	10.0
S	2	1	0	0	0	0	0	0	0	3	2.8	10.0
SSW	2	0	0	0	0	0	0	0	0	2	1.5	6.7
SW	0	1	0	0	0	0	0	0	0	1	5.5	3.3
WSW	1	1	0	0	0	0	0	0	0	2	3.5	6.7
W	0	0	0	0	0	0	0	0	0	0	0.0	0.0
WNW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NNW	2	0	0	0	0	0	0	0	0	2	1.5	6.7
CALM	1	0	0	0	0	0	0	0	0	1	0.0	3.3
TOT	19	10	0	0	0	0	0	0	1	30	0.0	0.0

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS ALL =100.0000 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 30
OCCURRENCES WITHIN THIS STABILITY CLASS = 30.

DIRECTION	SPEED,MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	10.00	3.33	0.0	0.0	0.0	0.0	0.0	0.0	3.33	16.67
NNE	13.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.33
NE	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.33
ENE	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.33
E	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.33
ESE	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.33
SE	6.67	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.00
SSE	0.0	10.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.00
S	6.67	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.00
SSW	6.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67
SW	0.0	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.33
WSW	3.33	3.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67
W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WNW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NNW	6.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.67

EXAMPLE PROBLEM NO. 3

NOTE: This is an actual problem from the Hayward Airport for the month of October, 1966-70 - 4:00, 5:00, 6:00 P.M. combined.

Only the partial input is shown and is followed by complete computer output.

PROGRAM STAR2
INPUT SHEET

User Instructions:

1. Enter your district labor cost code letter designation on line 1. column 20 (ie Dist. 1 = A etc.)
2. Enter project source code, charge code and E.A. number on line 1. columns 23-40 and on line 8.
3. Enter your district number on line 2, columns 20-21. (ie 01, 02 etc.)
4. Fill in project description information in spaces provided on lines 5 thru. 8.
5. Fill in control card.
6. Enter data on data sheets.

JOB CONTROL CARDS

	SOURCE	CHARGE	E.A.		LINE NO.
				DO NOT PUNCH	
//ENGØSR JOB (IE4ØSL	19701	19701	76250	ØØØØ PMA 1Ø 1Ø)	1
// DIST 19 CLASS=4 MSGLEVEL=(2 Ø)					2
// EXEC PROC=ENGSRØSE					3
//G.FT Ø5FØØI DD *					4

PROJECT DESCRIPTION CARDS

1 WEATHER STATIØN NAME: HAYWARD AIRPORT LOCATIØN: HAYWARD, CA		5
2 YEARS ØF RECØRD: 66 67 68 69 70 MØNTH(S): OCTOBER		6
3 HØUR(S) ØF DAY: 1600 1700 1800		7
4 PROJECT ID: 19701 - 76250 USER: AR DISTRICT: 19		8

CONTROL CARD

				5	1	1	0	1	1	2	3	4	5	6	9										

Wind Speed in knots = 1
Wind Speed in MPH = 0

Calm distribution = 1
No Calm distribution = 0

Debias for secondary direction = 1
No debias for secondary direction = 0

Directions reported on 36 Pt compass = 1
Directions reported on 8 or 16 Pt. compass = 0

1 = Stability class A requested.
2 = Stability class B requested.
3 = Stability class C requested.
4 = Stability class D requested.
5 = Stability class E requested.
6 = Stability class F requested.
9 = Summary of all classes.

PROGRAM STAR2

Station HAYWARD — DATA CARDS —

SEQUENCE NUMBER				YEAR		MO.		DAY		HOUR		CEILING HEIGHT ÷100'			WIND DIRECTION		WIND SPEED		SKY CODE
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			6	7	0	1	0		1	1	6	2	0	0			2	9	1	0	0
			7	7	0	1	0		1	1	7	2	0	0			2	7	1	2	0
			8	7	0	1	0		1	1	8	2	0	0			2	3	1	0	0
			9	7	0	1	0		2	1	6	2	0	0			2	7	1	0	0
		1	0	7	0	1	0		2	1	7	2	0	0			2	7	1	3	0
		1	1	7	0	1	0		2	1	8	2	0	0			2	8	1	1	0
		1	2	7	0	1	0		3	1	6	2	0	0			2	8	1	4	0
		1	3	7	0	1	0		3	1	7	2	0	0			3	0	1	0	0
		1	4	7	0	1	0		3	1	8	2	0	0			2	9	1	3	2
		1	5	7	0	1	0		4	1	6			7			2	6	2	0	1
		1	6	7	0	1	0		4	1	7	3	0	0			2	6	2	3	1
		1	7	7	0	1	0		4	1	8	3	0	0			2	7	1	8	1
		1	8	7	0	1	0		5	1	6	3	0	0			2	9	1	8	2
		1	9	7	0	1	0		5	1	7	3	0	0			2	5	1	5	2
		2	0	7	0	1	0		5	1	8	3	0	0			2	7		9	1
		2	1	7	0	1	0		6	1	6	3	0	0			2	8	1	4	1
		2	2	7	0	1	0		6	1	7	3	0	0			2	9	1	2	0
		2	3	7	0	1	0		6	1	8	2	0	0			2	8	1	0	0
		2	4	7	0	1	0		7	1	6	2	0	0			3	0	1	5	0
		2	5	7	0	1	0		7	1	7	2	0	0			3	1	1	6	0
		2	6	7	0	1	0		7	1	8	2	0	0			3	0	1	4	0
		2	7	7	0	1	0		8	1	6	2	0	0			2	8	1	0	0
		2	8	7	0	1	0		8	1	7	2	0	0			2	8		8	0
		2	9	7	0	1	0		8	1	8	2	0	0			2	6	1	0	0
		3	0	7	0	1	0		9	1	6	2	0	0			2	8	1	2	0
		3	1	7	0	1	0		9	1	7	2	0	0			2	8	1	2	0
		3	2	7	0	1	0		9	1	8	2	0	0			2	8	1	2	0
		3	3	7	0	1	0	1	0	1	6	2	0	0			2	8	1	2	0
		3	4	7	0	1	0	1	0	1	7	2	0	0			2	8	1	2	0
		3	5	7	0	1	0	1	0	1	8	2	0	0			2	8	1	2	0
		3	6	7	0	1	0	1	1	1	6	2	0	0			2	8	1	0	0

NOTE: RIGHT JUSTIFIED DATA IN ALL ABOVE FIELDS.

BY: K.G. HANSON
CHECK: M. FARROKHROOZ
DATE: 10-28-71

IN CASE OF QUESTION CONTACT:
NAME M. FARROKHROOZ
PHONE 452-5481 DATE 6-9-72

VERIFY

JUNE 1972

PROGRAM STAR2

Station HAYWARD — DATA CARDS — Page 16 of 16

SEQUENCE NUMBER				YEAR		MO.		DAY		HOUR		CEILING HEIGHT ÷100'			WIND DIRECTION				WIND SPEED		SKY CODE
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	4	4	2	6	6	1	0	2	6	1	7	2	0	0			2	8	1	2	4
	4	4	3	6	6	1	0	2	6	1	8	2	0	0			2	7	1	1	4
	4	4	4	6	6	1	0	2	7	1	6	2	0	0				1	1	4	0
	4	4	5	6	6	1	0	2	7	1	7	2	0	0				3	1	4	0
	4	4	6	6	6	1	0	2	7	1	8	2	0	0				1	1	5	0
	4	4	7	6	6	1	0	2	8	1	6	2	0	0			2	7		8	0
	4	4	8	6	6	1	0	2	8	1	7	2	0	0			2	8		8	0
	4	4	9	6	6	1	0	2	8	1	8	2	0	0			3	0		8	0
	4	5	0	6	6	1	0	2	9	1	6	2	0	0			2	0	2	3	2
	4	5	1	6	6	1	0	2	9	1	7	2	0	0			2	1	2	0	2
	4	5	2	6	6	1	0	2	9	1	8	2	0	0			2	0	2	0	2
	4	5	3	6	6	1	0	3	0	1	6	2	0	0			3	1	1	8	0
	4	5	4	6	6	1	0	3	0	1	7	2	0	0			3	2	1	7	0
	4	5	5	6	6	1	0	3	0	1	8	2	0	0			3	1	1	6	0

NOTE: RIGHT JUSTIFIED DATA IN ALL ABOVE FIELDS.

BY: K. C. HANSON
CHECK: M. FARRUCKHROOZ
DATE: 10-28-71

IN CASE OF QUESTION CONTACT:
NAME M. FARROCKHROOZ
PHONE 452-5481 DATE 6-9-72

VERIFY

JUNE 1972

WEATHER STATION NAME:HAYWARD AIRPORT LOCATION:HAYWARD,CA.
YEARS OF RECORD:66,67,68,69,70 MONTH(S):OCTOBER
HOUR(S) OF DAY:1600,1700,1800 COMBINED
PROJECT ID: 19701- 762650 USER: AR DISTRICT: 19

IN THE FOLLOWING TABLE THE CALMS ARE DISTRIBUTED

NO OF OCCURRENCES IN THIS CLASSIFICATION IS ZERO

THEREFORE NO RESULT IS PRINTED

NO OF CALMS = 2.

RELATIVE FREQUENCY OF STABILITY CLASS A = 0.4301 %

WEATHER STATION NAME:HAYWARD AIRPORT LOCATION:HAYWARD,CA.
YEARS OF RECORD:66,67,68,69,70 MONTH(S):OCTOBER
HOUR(S) OF DAY:1600,1700,1800 COMBINED
PROJECT ID: 19701- 762650 USER: AR DISTRICT: 19

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS B **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	0	1	0	0	0	0	0	0	0	1	5.5	5.3
NNE	0	1	0	0	0	0	0	0	0	1	5.5	5.3
NE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ENE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
E	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ESE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
S	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SW	0	1	0	0	0	0	0	0	0	1	5.5	5.3
WSW	0	1	1	0	0	0	0	0	0	2	7.8	10.5
W	0	2	5	0	0	0	0	0	0	7	8.7	36.8
WNW	0	4	3	0	0	0	0	0	0	7	7.4	36.8
NW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NNW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
CALM	0	0	0	0	0	0	0	0	0	0	0.0	0.0
TOT	0	10	9	0	0	0	0	0	0	19	0.0	0.0

Moore Business Forms, Inc.

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS B = 4.0860 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 465
OCCURRENCES WITHIN THIS STABILITY CLASS = 19.

DIRECTION	SPEED,MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.22
NNE	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.22
NE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.22
WSW	0.0	0.22	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.43
W	0.0	0.43	1.08	0.0	0.0	0.0	0.0	0.0	0.0	1.51
WNW	0.0	0.86	0.65	0.0	0.0	0.0	0.0	0.0	0.0	1.51
NW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NNW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

WEATHER STATION NAME:HAYWARD AIRPORT LOCATION:HAYWARD,CA.
YEARS OF RECORD:66,67,68,69,70 MONTH(S):OCTOBER
HOUR(S) OF DAY:1600,1700,1800 COMBINED
PROJECT ID: 19701- 762650 USER: AR DISTRICT: 19

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS C **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	0	0	1	0	0	0	0	0	0	1	10.0	1.8
NNE	0	0	0	1	0	0	0	0	0	1	15.5	1.8
NE	0	0	1	0	0	0	0	0	0	1	10.0	1.8
ENE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
E	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ESE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
S	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SW	0	0	1	0	0	0	0	0	0	1	10.0	1.8
WSW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
W	0	0	22	1	0	0	0	0	0	23	10.2	41.1
WNW	0	0	22	4	0	0	0	0	0	26	10.8	46.4
NW	0	0	2	1	0	0	0	0	0	3	11.8	5.4
NNW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
CALM	0	0	0	0	0	0	0	0	0	0	0.0	0.0
TOT	0	0	49	7	0	0	0	0	0	56	0.0	0.0

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS C = 12.0430 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 465
OCCURRENCES WITHIN THIS STABILITY CLASS = 56.

DIRECTION	SPEED, MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.22
NNE	0.0	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.22
NE	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.22
ENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.22
WSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	0.0	0.0	4.73	0.22	0.0	0.0	0.0	0.0	0.0	4.95
WNW	0.0	0.0	4.73	0.86	0.0	0.0	0.0	0.0	0.0	5.59
NW	0.0	0.0	0.43	0.22	0.0	0.0	0.0	0.0	0.0	0.65
NNW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

WEATHER STATION NAME:HAYWARD AIRPORT LOCATION:HAYWARD,CA.
YEARS OF RECORD:66,67,68,69,70 MONTH(S):OCTOBER
HOUR(S) OF DAY:1600,1700,1800 COMBINED
PROJECT ID: 19701- 762650 USER: AR DISTRICT: 19

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS D **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	0	0	0	5	3	1	0	0	0	9	18.9	3.7
NNE	0	0	0	4	0	0	0	0	0	4	15.5	1.6
NE	0	0	0	3	0	0	0	0	0	3	15.5	1.2
ENE	0	0	0	1	0	0	0	0	0	1	15.5	0.4
E	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ESE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SE	0	0	0	2	2	1	0	0	0	5	20.4	2.1
SSE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
S	0	0	1	4	0	2	0	0	0	7	18.3	2.9
SSW	0	0	1	2	0	0	0	0	0	3	13.7	1.2
SW	0	0	0	2	1	0	0	0	0	3	17.5	1.2
WSW	0	0	2	10	2	0	0	0	0	14	15.6	5.8
W	0	0	13	76	16	2	0	0	0	107	16.0	44.0
WNW	0	1	14	52	5	0	0	0	0	72	14.7	29.6
NW	0	0	7	3	3	0	0	0	0	13	13.9	5.3
NNW	0	0	1	1	0	0	0	0	0	2	12.8	0.8
CALM	0	0	0	0	0	0	0	0	0	0	0.0	0.0
TOT	0	1	39	165	32	6	0	0	0	243	0.0	0.0

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS D = 52.2581 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 465
OCCURRENCES WITHIN THIS STABILITY CLASS = 243.

DIRECTION	SPEED,MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	0.0	0.0	0.0	1.08	0.65	0.22	0.0	0.0	0.0	1.94
NNE	0.0	0.0	0.0	0.86	0.0	0.0	0.0	0.0	0.0	0.86
NE	0.0	0.0	0.0	0.65	0.0	0.0	0.0	0.0	0.0	0.65
ENE	0.0	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.22
E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.43	0.43	0.22	0.0	0.0	0.0	1.08
SSE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.22	0.86	0.0	0.43	0.0	0.0	0.0	1.51
SSW	0.0	0.0	0.22	0.43	0.0	0.0	0.0	0.0	0.0	0.65
SW	0.0	0.0	0.0	0.43	0.22	0.0	0.0	0.0	0.0	0.65
WSW	0.0	0.0	0.43	2.15	0.43	0.0	0.0	0.0	0.0	3.01
W	0.0	0.0	2.80	16.34	3.44	0.43	0.0	0.0	0.0	23.01
WNW	0.0	0.22	3.01	11.18	1.08	0.0	0.0	0.0	0.0	15.48
NW	0.0	0.0	1.51	0.65	0.65	0.0	0.0	0.0	0.0	2.80
NNW	0.0	0.0	0.22	0.22	0.0	0.0	0.0	0.0	0.0	0.43

WEATHER STATION NAME:HAYWARD AIRPORT LOCATION:HAYWARD,CA.
YEARS OF RECORD:66,67,68,69,70 MONTH(S):OCTOBER
HOUR(S) OF DAY:1600,1700,1800 COMBINED
PROJECT ID: 19701- 762650 USER: AR DISTRICT: 19

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS E **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	0	0	0	0	0	0	0	0	0	0	0.0	0.0
NNE	0	0	3	0	0	0	0	0	0	3	10.0	2.9
NE	0	0	2	0	0	0	0	0	0	2	10.0	2.0
ENE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
E	0	0	1	0	0	0	0	0	0	1	10.0	1.0
ESE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
S	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SW	0	0	2	0	0	0	0	0	0	2	10.0	2.0
WSW	0	0	2	0	0	0	0	0	0	2	10.0	2.0
W	0	4	27	0	0	0	0	0	0	31	9.4	30.4
WNW	0	2	46	0	0	0	0	0	0	48	9.8	47.1
NW	0	2	7	0	0	0	0	0	0	9	9.0	8.8
NNW	0	1	3	0	0	0	0	0	0	4	8.9	3.9
CALM	0	0	0	0	0	0	0	0	0	0	0.0	0.0
TOT	0	9	93	0	0	0	0	0	0	102	0.0	0.0

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS E = 21.9355 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 465
OCCURRENCES WITHIN THIS STABILITY CLASS = 102.

DIRECTION	SPEED, MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NNE	0.0	0.0	0.65	0.0	0.0	0.0	0.0	0.0	0.0	0.65
NE	0.0	0.0	0.43	0.0	0.0	0.0	0.0	0.0	0.0	0.43
ENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.22
ESE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.0	0.43	0.0	0.0	0.0	0.0	0.0	0.0	0.43
WSW	0.0	0.0	0.43	0.0	0.0	0.0	0.0	0.0	0.0	0.43
W	0.0	0.86	5.81	0.0	0.0	0.0	0.0	0.0	0.0	6.67
WNW	0.0	0.43	9.89	0.0	0.0	0.0	0.0	0.0	0.0	10.32
NW	0.0	0.43	1.51	0.0	0.0	0.0	0.0	0.0	0.0	1.94
NNW	0.0	0.22	0.65	0.0	0.0	0.0	0.0	0.0	0.0	0.86

WEATHER STATION NAME:HAYWARD AIRPORT LOCATION:HAYWARD,CA.
YEARS OF RECORD:66,67,68,69,70 MONTH(S):OCTOBER
HOUR(S) OF DAY:1600,1700,1800 COMBINED
PROJECT ID: 19701- 762650 USER: AR DISTRICT: 19

IN THE FOLLOWING TABLE THE CALMS ARE DISTRIBUTED

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS F **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	1	0	0	0	0	0	0	0	0	1	1.5	3.4
NNE	0	3	0	0	0	0	0	0	0	3	5.5	6.9
NE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ENE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
E	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ESE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
S	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SSW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
WSW	0	3	0	0	0	0	0	0	0	3	5.5	6.9
W	0	7	0	0	0	0	0	0	0	7	5.5	17.2
WNW	0	19	0	0	0	0	0	0	0	19	5.5	44.8
NW	1	7	0	0	0	0	0	0	0	9	4.8	20.7
NNW	0	0	0	0	0	0	0	0	0	0	0.0	0.0
CALM	14	0	0	0	0	0	0	0	0	14	0.0	0.0
TOT	3	40	0	0	0	0	0	0	0	43	0.0	0.0

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS F = 9.2473 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 465
OCCURRENCES WITHIN THIS STABILITY CLASS = 43.

DIRECTION	SPEED, MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	0.32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.32
NNE	0.0	0.64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.64
NE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSW	0.0	0.64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.64
W	0.0	1.59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.59
WNW	0.0	4.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.15
NW	0.32	1.59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.91
NNW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

WEATHER STATION NAME:HAYWARD AIRPORT LOCATION:HAYWARD,CA.
YEARS OF RECORD:66,67,68,69,70 MONTH(S):OCTOBER
HOUR(S) OF DAY:1600,1700,1800 COMBINED
PROJECT ID: 19701- 762650 USER: AR DISTRICT: 19

IN THE FOLLOWING TABLE THE CALMS ARE DISTRIBUTED

********** FREQUENCY DISTRIBUTION **********

********** STABILITY CLASS ALL **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	1	1	1	5	3	1	0	0	0	13	15.0	2.7
NNE	0	4	3	5	0	0	0	0	0	12	10.8	2.6
NE	0	0	3	3	0	0	0	0	0	6	12.8	1.3
ENE	0	0	0	1	0	0	0	0	0	1	15.5	0.2
E	0	0	1	0	0	0	0	0	0	1	10.0	0.2
ESE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SE	0	0	0	2	2	1	0	0	0	5	20.4	1.1
SSE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
S	0	0	1	4	0	2	0	0	0	7	18.3	1.5
SSW	0	0	1	2	0	0	0	0	0	3	13.7	0.6
SW	0	1	3	2	1	0	0	0	0	7	12.3	1.6
WSW	0	4	5	10	2	0	0	0	0	21	12.9	4.5
W	0	15	67	77	16	2	0	0	0	177	13.3	38.0
WNW	0	27	85	56	5	0	0	0	0	173	11.4	37.1
NW	1	9	16	4	3	0	0	0	0	34	10.1	7.2
NNW	0	1	4	1	0	0	0	0	0	6	9.9	1.4
CALM	16	0	0	0	0	0	0	0	0	16	0.0	0.0
TOT	3	62	190	172	32	6	0	0	0	465	0.0	0.0

Moore Business Forms, Inc.

..... RELATIVE FREQUENCY DISTRIBUTION .....

RELATIVE FREQUENCY OF STABILITY CLASS ALL =100.0000 %
TOTAL NO. OF OCCURRENCES IN ALL CLASSES = 465
OCCURRENCES WITHIN THIS STABILITY CLASS = 465.

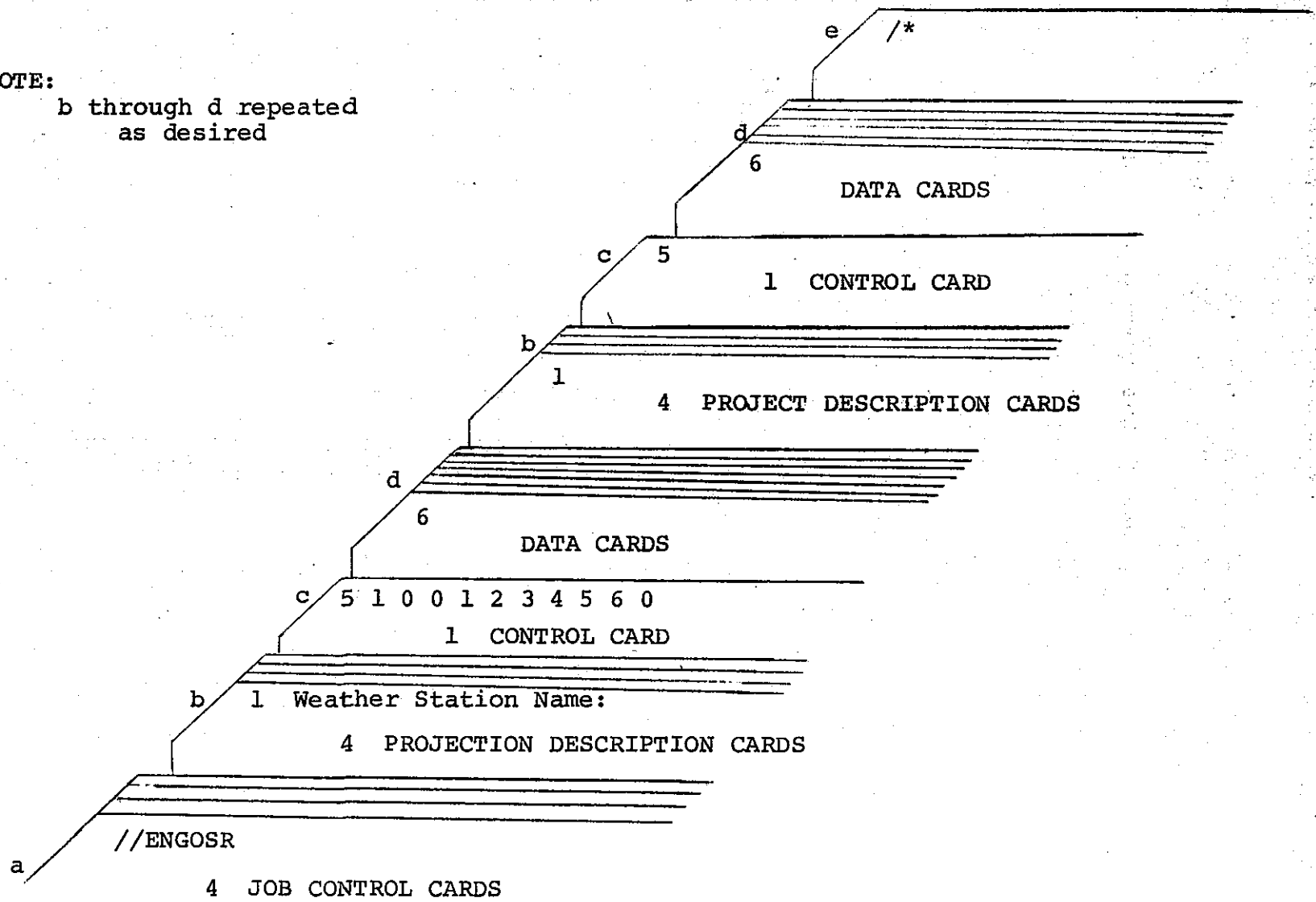
DIRECTION	SPEED, MPH									
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	%TOT
N	0.29	0.29	0.22	1.08	0.65	0.22	0.0	0.0	0.0	2.72
NNE	0.0	0.86	0.65	1.08	0.0	0.0	0.0	0.0	0.0	2.58
NE	0.0	0.0	0.65	0.65	0.0	0.0	0.0	0.0	0.0	1.29
ENE	0.0	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.22
E	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.22
ESE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.43	0.43	0.22	0.0	0.0	0.0	1.08
SSE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.22	0.86	0.0	0.43	0.0	0.0	0.0	1.51
SSW	0.0	0.0	0.22	0.43	0.0	0.0	0.0	0.0	0.0	0.65
SW	0.0	0.29	0.65	0.43	0.22	0.0	0.0	0.0	0.0	1.58
WSW	0.0	0.86	1.08	2.15	0.43	0.0	0.0	0.0	0.0	4.51
W	0.0	3.14	14.41	16.56	3.44	0.43	0.0	0.0	0.0	37.98
WNW	0.0	5.71	18.28	12.04	1.08	0.0	0.0	0.0	0.0	37.10
NW	0.29	2.00	3.44	0.86	0.65	0.0	0.0	0.0	0.0	7.23
NNW	0.0	0.29	0.86	0.22	0.0	0.0	0.0	0.0	0.0	1.36

JOB DECK SETUP

Program STAR2 is set up so that more than one set of data can be run on one set of Job Control Language Cards. This option allows for more efficient and shorter run times.

The schematic of job deck setup is shown on the next page, under Example of Job Deck Setup.

NOTE:
b through d repeated
as desired



EXAMPLE OF JOB DECK SETUP

APPENDIX E

CONVERSION OF 36 SIDED COMPASS READINGS TO 16

The conversion of 36 sided reporting system to a 16 sided reporting system was done using the following table extracted from U. S. Weather Bureau Tape Reference Manual, TDF14:

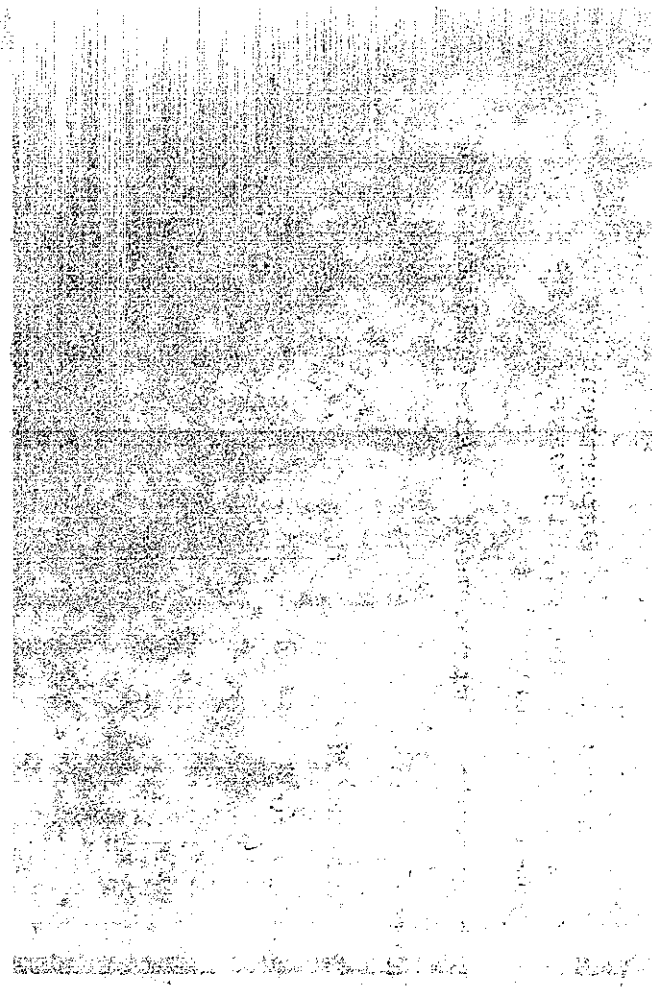
WIND DIRECTION CONVERSION TABLE

	Direction	Degree - 10
1	North	35-36-01
2	North-Northeast	02-03
3	Northeast	04-05
4	East-Northeast	06-07
5	East	08-09-10
6	East-Southeast	11-12
7	Southeast	13-14
8	South-Southeast	15-16
9	South	17-18-19
10	South-Southwest	20-21
11	Southwest	22-23
12	West-Southwest	24-25
13	West	26-27-28
14	West-Northwest	29-30
15	Northwest	31-32
16	North-Northwest	33-34

PROGRAM WIND2
USERS GUIDE

PROGRAM TITLE	WIND2 (16-Sided Wind Rose Calculation)
PURPOSE	This program computes a frequency histogram for 16-sided wind rose. The input data may be in the form of 8, 16, or 36 compass point system.

PROGRAM BY	M. Farrockhrooz Materials and Research Department California Division of Highways Sacramento, California
Section	Environmehtal Improvement - Air Quality Unit
Date	November, 1972
Computer	IBM System/370
Language	Fortran IV



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Input Required:

Input to the program consists of Job Control Cards, Identification Cards, Control Cards, and Data Cards as described below:

A. Job Control Cards:

There are four Job Control Cards as shown on "Program WIND2 Input Sheet" (See example problems). These cards are essentially for accounting purposes. The user enters his District letter designation, source, charge and expenditure authorization according to the instructions given on the form.

B. Project Description Cards:

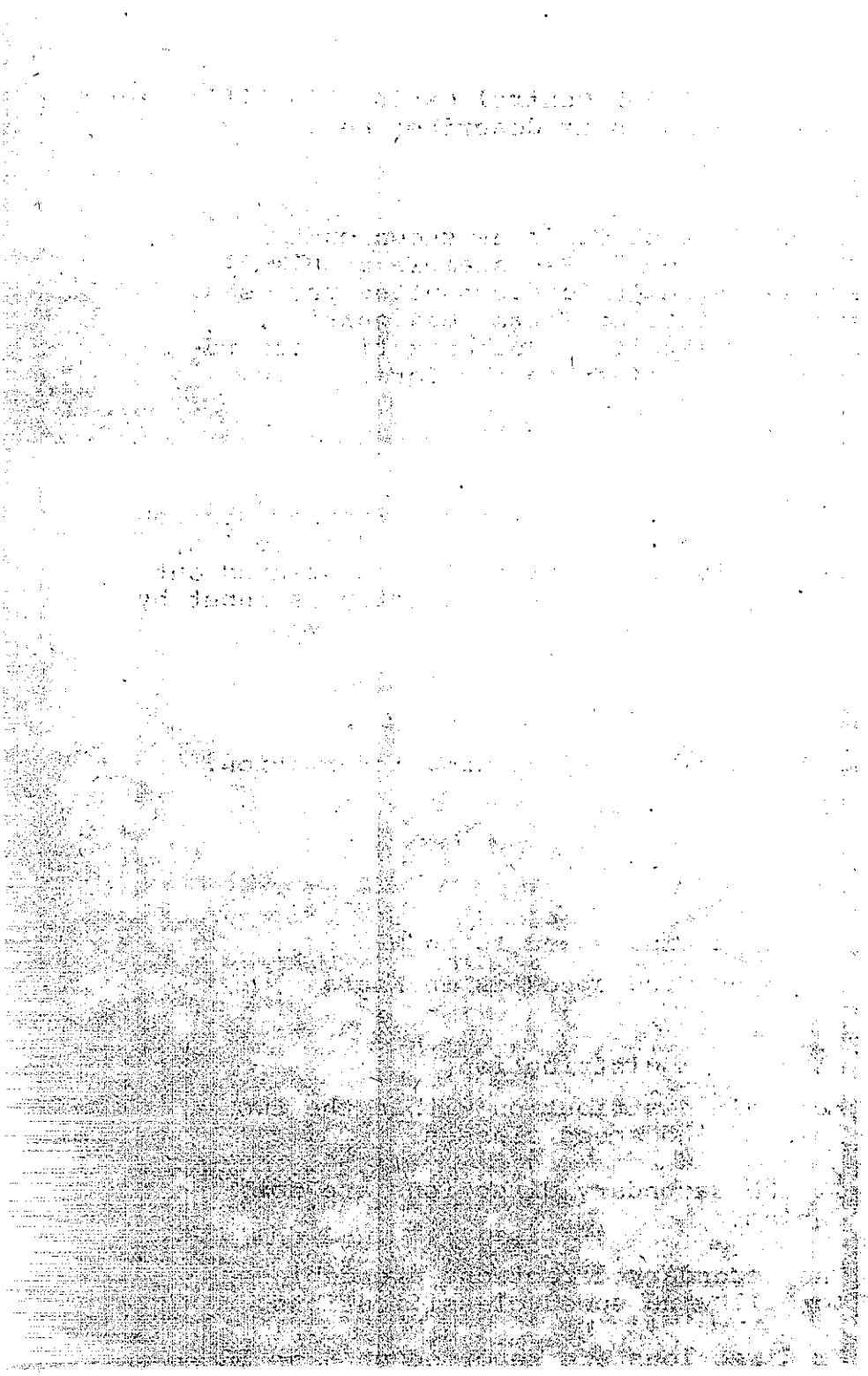
Four cards are required to describe the weather station name, location, period of record, project description, and charge code. This information will be printed out at the beginning of frequency table exactly as input by the user.

C. Control Card:

This card should contain the following information:

Knots, calm, bias and degree

Column No.		
6	Knots = 0	If input wind speed is in MPH
	Knots = 1	If input wind speed is in Knots
8	Calm = 0	If no calm distribution
	Calm = 1	For calm distribution within the two lowest wind speed classes.
10	Bias = 0	If the secondary directions are not debiased.
	Bias* = 1	The secondary directions are debiased for all wind speed classifications.
12	Degree = 0	If directions are reported on 8 or 16 compass points.
	Degree = 1	If directions reported on 36 compass points.



D. Data Cards:

The following information is entered on data cards:

Sequence no., wind direction and wind speed as described below:

Column No.	
1 - 4	Sequence number starting with 6 on the first data card
5 - 8	Wind direction: Based on an 8 or 16 point compass, (i.e., N, NNW, Calm**) or based on 36 compass points, (i.e. 4, 6, 35 represents 40 degrees, 60 degrees, and 350 degrees respectively ***)
9 - 10	Wind speed in MPH or Knots

Note: *Debiasing is NOT REQUIRED for 36 point compass reporting system.

**A calm condition is designated as CALM direction with zero wind speed.

***A calm condition is designated with 0 direction and 0 speed.

EXAMPLE PROBLEM NO. 1

36 Compass Point Recording System

Note: Options asked in this problem involve calm distribution, but no debiasing.

PROGRAM WIND2
INPUT SHEET

User Instructions:

1. Enter your district labor cost code letter designation on line 1. column 20 (ie Dist. 1 = A etc.)
2. Enter project source code, charge code and E.A. number on line 1. columns 23–40 and on line 8.
3. Enter your district number on line 2, columns 20-21. (ie 01, 02 etc.)
4. Fill in project description information in spaces provided on lines 5 thru. 8.
5. Fill in control card.
6. Enter data on data sheets.

JOB CONTROL CARDS

					SOURCE	CHARGE	E.A.		LINE NO.
								DO NOT PUNCH	
//ENGØSR	JOB (IE4Ø	S	L, 1970 1,		1970 1,	76256 1,	,,ØØØØ, PMA, 1Ø, 1Ø)		1
//	DIST	19,	CLASS=M,	MSGLEVEL=(2, Ø)					2
// EXEC	PRØC=ENGWIND2								3
//G.FTØ5FØØ1 DD	*								4

PROJECT DESCRIPTION CARDS

1	WEATHER STATIØN NAME: TAHOE City	LØCATIØN: Lake TAHOE		5
2	YEARS ØF RECØRD: 1969	MØNTH(S): AUG & SEPT.		6
3	HØUR(S) ØF DAY: 9 AM Every Day			7
4	PRØJECT ID: 19701-76256 1	USER: SK	DISTRICT: 19	8

CONTROL CARD

	5	0	1	0	1

Wind Speed in knots = 1
Wind Speed in MPH = 0

Calm distribution = 1
No Calm distribution = 0

Debias for secondary direction = 1
No debias for secondary direction = 0

Directions reported on 36 Pt compass = 1
Directions reported on 8 or 16 Pt. compass = 0

PROGRAM WIND2
DATA CARDS

STATION TAHOE CITY

SEQUENCE NO.				WIND DIRECTION				WIND SPEED	
1	2	3	4	5	6	7	8	9	10
			6				0		0
			7			2	9		5
			8			3	4		7
			9			2	5	1	0
		1	0			2	0		3
		1	1			2	3	1	5
		1	2			2	0		6
		1	3			3	4		3
		1	4			3	6		2
		1	5			3	6		2
		1	6			3	5		4
		1	7			3	4		3
		1	8			3	3		9
		1	9			3	1		8
		2	0			2	9		3
		2	1			2	7	1	6
		2	2			2	5	3	0
		2	3			2	3	4	0
		2	4			2	1	1	9
		2	5			1	9	1	9
		2	6			1	7		4
		2	7			1	5		2
		2	8			1	3		1
		2	9				0		0
		3	0				0		0
		3	1				0		0
		3	2			1	0		2
		3	3				0		0
		3	4				3		3
		3	5				2	1	0
		3	6			3	5		9

SEQUENCE NO.				WIND DIRECTION				WIND SPEED	
1	2	3	4	5	6	7	8	9	10
		3	7			3	6	1	5
		3	8			3	4	2	0
		3	9			3	6	1	0
		4	0			3	6		5
		4	1			3	5		3
		4	2				1		2
		4	3				0		0
		4	4				0		0
		4	5			3	6		3
		4	6			3	2		9
		4	7			3	0	1	5
		4	8			3	1	2	0
		4	9			3	5		9
		5	0			2	7		6
		5	1			2	5		4
		5	2			3	3		8
		5	3			2	9		7
		5	4			3	1	1	1
		5	5			3	5	1	5
		5	6			3	6	1	0
		5	7			3	5	1	0
		5	8			3	1		9
		5	9				0		0
		6	0			2	1		6
		6	1				0		0
		6	2			1	5		5
		6	3			2	0		2
		6	4				0		0
		6	5			1	6		3
		6	6			1	7		1

SEQUENCE NO.				WIND DIRECTION				WIND SPEED	
1	2	3	4	5	6	7	8	9	10

NOTE: RIGHT JUSTIFIED DATA IN ALL ABOVE FIELDS

BY: M. Farrockhrooz

CHECK:

DATE: 11-28-72

IN CASE OF QUESTION CONTACT:

NAME M. Farrockhrooz

PHONE ATSS 431-2328 DATE 11-29-72

VERIFY

NOV. 1972

WEATHER STATION NAME: TAHOE CITY LOCATION:LAKE TAHOE
YEARS OF RECORD: 1969 MONTH(S):AUG & SEPT.
HOUR(S) OF DAY: 9 AM EVERY DAY
PROJECT ID: 19701-762561 USER: SK DISTRICT: 19

IN THE FOLLOWING TABLE THE CALMS ARE DISTRIBUTED

********** FREQUENCY DISTRIBUTION **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	7	3	5	2	0	0	0	0	0	17	6.4	27.2
NNE	1	0	1	0	0	0	0	0	0	2	5.1	3.9
NE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
ENE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
E	1	0	0	0	0	0	0	0	0	1	1.5	2.2
ESE	0	0	0	0	0	0	0	0	0	0	0.0	0.0
SE	1	0	0	0	0	0	0	0	0	1	1.5	2.2
SSE	3	1	0	0	0	0	0	0	0	4	2.8	6.7
S	1	1	0	0	0	0	0	0	0	4	8.3	6.1
SSW	3	3	0	0	1	0	0	0	0	6	6.3	10.6
SW	0	0	0	1	0	0	0	1	0	2	29.0	3.3
WSW	0	1	1	0	0	1	0	0	0	3	13.5	5.5
W	0	1	0	1	0	0	0	0	0	2	9.7	3.9
WNW	1	3	0	1	0	0	0	0	0	5	6.4	8.4
NW	0	0	4	0	1	0	0	0	0	5	12.3	8.2
NNW	3	1	2	0	1	0	0	0	0	7	7.5	11.7
CALM	10	0	0	0	0	0	0	0	0	10	0.0	0.0
TOT	22	15	13	5	4	1	0	1	0	61	0.0	0.0

EXAMPLE PROBLEM NO. 2

16 Compass Point Recording System

Note: Options asked in this problem involve debiasing, but no calm distribution.

PROGRAM WIND2
INPUT SHEET

User Instructions:

1. Enter your district labor cost code letter designation on line 1. column 20 (ie Dist. 1 = A etc.)
2. Enter project source code, charge code and E.A. number on line 1. columns 23–40 and on line 8.
3. Enter your district number on line 2, columns 20-21. (ie 01, 02 etc.)
4. Fill in project description information in spaces provided on lines 5 thru. 8.
5. Fill in control card.
6. Enter data on data sheets.

JOB CONTROL CARDS

					SOURCE	CHARGE	E.A.		LINE NO.
//ENGØSR	JOB	(IE4ØS	L		19701,	19701,	762561,	ØØØØ, PMA, 1Ø, 1Ø)	1
//		DIST 19,	CLASS=M,	MSGLEVEL=(2, Ø)					2
//	EXEC	PRØC=ENGWIND2							3
//G.FTØ5FØØ1	DD	*							4

PROJECT DESCRIPTION CARDS

1	WEATHER STATION NAME: MARYSVILLE	LOCATION: YUBA Co	5
2	YEARS OF RECORD: 1968 TO 1970	MONTH(S): SEPTEMBER	6
3	HOUR(S) OF DAY: 2 P.M.		7
4	PROJECT ID: 19701 _ 762561	USER: SK DISTRICT: 03	8

CONTROL CARD

5	0	0	1	0	

Wind Speed in knots = 1
Wind Speed in MPH = 0

Calm distribution = 1
No Calm distribution = 0

Debias for secondary direction = 1
No debias for secondary direction = 0

Directions reported on 36 Pt compass = 1
Directions reported on 8 or 16 Pt. compass = 0

PROGRAM WIND2
DATA CARDS

STATION Marysville

SEQUENCE NO.				WIND DIRECTION				WIND SPEED	
1	2	3	4	5	6	7	8	9	10
			6		N	N	E	1	0
			7	C	A	L	M		0
			8			N	E		2
			9		E	N	E		3
		1	0		E	N	E	1	0
		1	1			N	E	1	2
		1	2		N	N	W	1	0
		1	3		N	N	W	2	0
		1	4			N	W	1	5
		1	5		W	N	W		3
		1	6		W	S	W		5
		1	7			S	W		3
		1	8		W	S	W		2
		1	9		S	S	W		9
		2	0				S	1	0
		2	1				S	1	4
		2	2			S	E		2
		2	3		S	S	E		8
		2	4				S		7
		2	5			N	E		3
		2	6				N	1	0
		2	7				N		7
		2	8				N		4
		2	9			N	E		5
		3	0		N	N	E	1	0
		3	1			N	W	1	1
		3	2				N	1	1
		3	3			N	W	1	2
		3	4			N	E	1	2
		3	5			N	W	1	5
		3	6		E	N	E		7

SEQUENCE NO.				WIND DIRECTION				WIND SPEED	
1	2	3	4	5	6	7	8	9	10
		3	7				E		3
		3	8				E		1
		3	9			S	E		9
		4	0		E	N	E		7
		4	1			N	E		3
		4	2				E		2
		4	3	C	A	L	M		0
		4	4	C	A	L	M		0
		4	5				N		1
		4	6		N	N	E		3
		4	7	C	A	L	M		0
		4	8			S	E		4
		4	9		E	S	E	1	5
		5	0		S	S	E	2	0
		5	1			S	E	1	1
		5	2				S	1	2
		5	3		S	S	E		2
		5	4		W	S	W		4
		5	5			S	W		3
		5	6		S	S	W		6
		5	7			N	W		7
		5	8		W	N	W		4
		5	9				N		7
		6	0		N	N	E		3
		6	1			N	W		4
		6	2		N	N	E		6
		6	3		N	N	W		3
		6	4				N	1	4
		6	5		N	N	E	1	2
		6	6				N	1	0
		6	7			N	E		7

SEQUENCE NO.				WIND DIRECTION				WIND SPEED	
1	2	3	4	5	6	7	8	9	10
		6	8				S		2
		6	9			S	E		4
		7	0				S		1
		7	1			N	E		2
		7	2				N		4
		7	3				N		7
		7	4	C	A	L	M		0
		7	5			N	W		4
		7	6				W		3
		7	7				N	1	0
		7	8			N	W	1	7
		7	9				W		7
		8	0				N		9
		8	1			N	E		2
		8	2				S		6
		8	3			S	E		3
		8	4				S		2
		8	5				S	1	0
		8	6			S	E	1	2
		8	7				S		6
		8	8			S	W		3
		8	9				W		1
		9	0				W		2
		9	1				W		4
		9	2				W	1	0
		9	3			N	W		3
		9	4				W		7
		9	5				W		1

NOTE: RIGHT JUSTIFIED DATA IN ALL ABOVE FIELDS

BY: M. Farrockhrooz

CHECK:

DATE: 11-28-72

IN CASE OF QUESTION CONTACT:

NAME M. Farrockhrooz

PHONE ATSS 431-2328 DATE 11-29-72

VERIFY

NOV 1972

WEATHER STATION NAME: MARYSVILLE LOCATION: YUBA CO
YEARS OF RECORD: 1968 TO 1970 MONTH(S): SEPTEMBER
HOUR(S) OF DAY: 2 P.M.
PROJECT ID: 19701 - 762561 USER: SK DISTRICT: 03

FOLLOWING TABLE IS DEBIASED FOR SECONDARY DIRECTION

********** FREQUENCY DISTRIBUTION **********

DIRECTION	SPEED,MPH											
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47	TOT	AVE	%TOT
N	1	3	3	1	0	0	0	0	0	8	7.9	8.9
NNE	4	2	5	0	0	0	0	0	0	11	6.3	12.3
NE	3	1	1	0	0	0	0	0	0	6	4.3	6.7
ENE	2	4	2	0	0	0	0	0	0	8	5.6	8.3
E	2	0	0	0	0	0	0	0	0	2	1.5	2.2
ESE	0	0	0	2	0	0	0	0	0	2	15.5	2.0
SE	1	1	2	0	0	0	0	0	0	5	6.3	5.2
SSE	2	0	2	0	2	0	0	0	0	6	10.8	6.1
S	2	2	2	1	0	0	0	0	0	7	6.7	7.4
SSW	0	2	2	0	0	0	0	0	0	4	7.7	4.1
SW	2	0	0	0	0	0	0	0	0	2	1.5	2.2
WSW	2	4	0	0	0	0	0	0	0	6	4.2	6.3
W	2	2	1	0	0	0	0	0	0	5	5.2	5.9
WNW	2	2	0	0	0	0	0	0	0	4	3.5	4.2
NW	1	2	1	2	0	0	0	0	0	6	9.4	6.7
NNW	2	0	2	0	2	0	0	0	0	6	10.8	6.1
CALM	5	0	0	0	0	0	0	0	0	5	0.0	5.5
TOT	33	26	24	5	4	0	0	0	0	92	0.0	0.0

JOB DECK SETUP

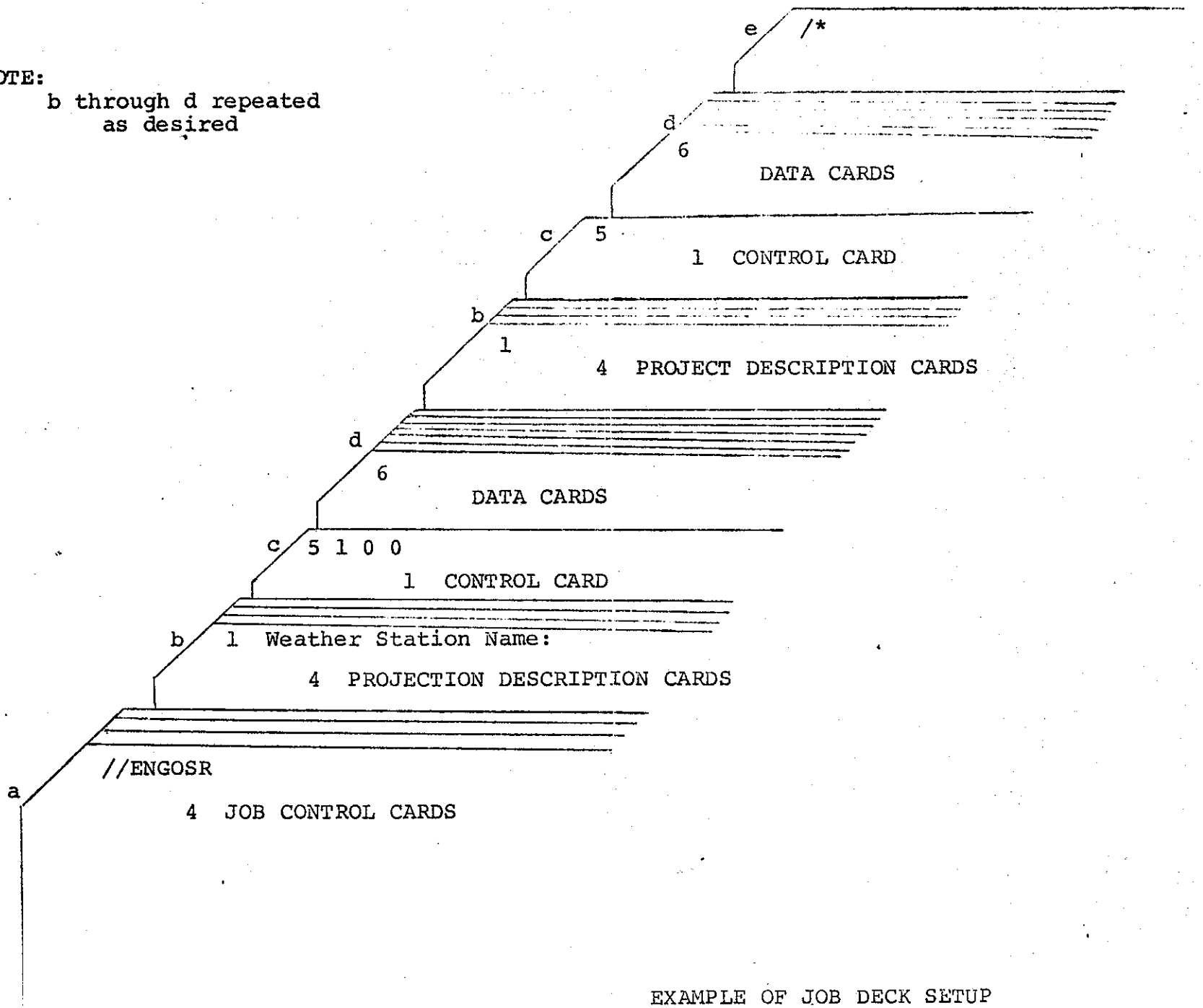
Program WIND2 is set up so that more than one set of data can be run on one set of Job Control Language Cards.

This option allows for more efficient and shorter run time.

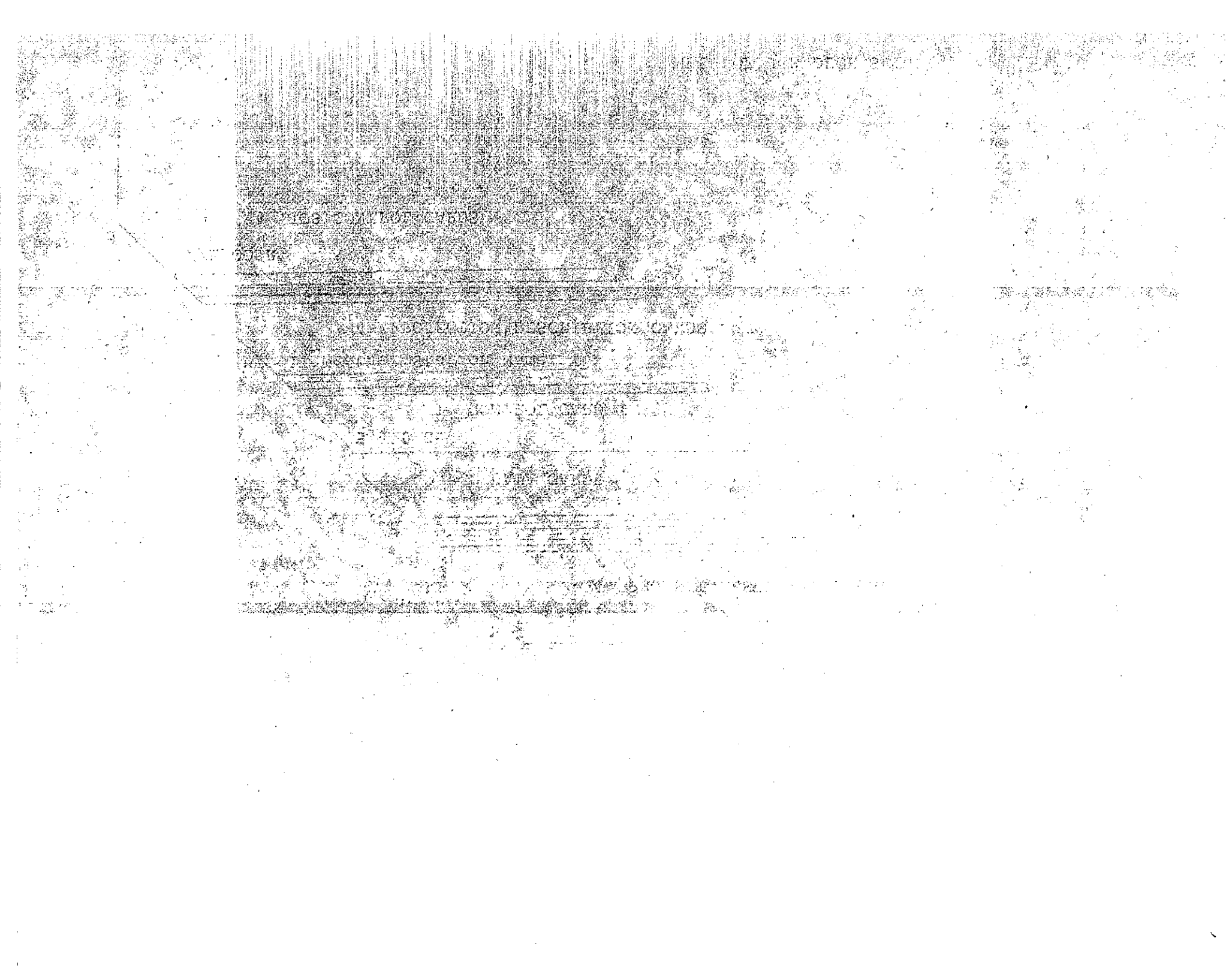
The schematic of Job Deck Setup is shown on the next page, under Example of Job Deck Setup.

Note: Only the first card of the project description cards should have sequence no. = 1. The program searches through the data cards. Upon finding a card with sequence no. = 1, it assumes the previous set of data is ended and a new set is starting

NOTE:
b through d repeated
as desired



EXAMPLE OF JOB DECK SETUP



APPENDIX G

METEOROLOGICAL DATA SOURCES FOR CALIFORNIA

MAGNETIC TAPE WEATHER SERVICE

No.	Name	Period of Record	#Reels	Lat.	Long.
1	Alameda FWC	3/45-12/54; 1/55-12/64; 1/65-12/69; 1/70-12/70	4	37:46	122:16
2	Arcata FAA	1/49-12/58; 1/59-5/70	2	41:00	124:06
3	Bakersfield	01/48-12/58; 1/59-12/68	2	35:25	119:03
4	Bishop	1/48-12/58; 1/59-2/65	2	37:22	118:22
5	Blue Canyon	1/48-12/58; 1/59-12/62	2	39:17	120:42
6	Blythe FAA	11/48-12/54	1	33:37	114:43
7	Burbank	1/48-12/58; 1/59-12/61; 7/66-12/68	3	34:12	118:22
8	Camp Pendleton MCB	7/66-12/70	1	33:20	117:21
9	China Lake NAF	4/45-12/55; 1/56-12/65; 1/66-12/70	3	35:45	117:41
10	Crescent City FAA	1/49-12/54	1	41:47	124:14
11	Cuddeback AF	7/63-10/68	1	35:16	117:26
12	Daggett FAA	11/48-12/58; 1/59-12/68	2	34:52	116:47
13	Donner Summit	11/48-1/52	1	39:20	120:18
14	Edwards AFB	1/49-12/58; 1/59-12/68	2	34:54	117:51
15	El Centro NAAS	2/45-12/54; 1/55-10/60	2	32:50	115:40
16	El Toro MCAS	3/43-12/54; 1/55-12/64; 1/65-12/70	3	33:40	117:40
17	Fairfield/Travis AFB	1/49-12/58; 1/59-11/68	2	38:16	121:55
18	Fresno	1/49-12/58; 1/59-4/68	2	36:45	119:43
19	Imperial Beach NAS	1/52-12/61; 1/62-12/70	2	32:34	117:08
20	Jolon Sig Corps	1/69-12/70	1	35:58	121:08
21	Lemoore NAS	7/61-12/70	1	36:20	119:56

No.	Name	Period of Record	#Reels	Lat.	Long.
22	Long Beach	1/49-12/58; 1/59-3/69	2	33:49	118:10
23	Los Alamitos NAS	4/45-12/54; 1/55-12/64; 1/65-12/70	3	33:50	118:05
24	Los Angeles	1/47-12/56; 1/57-12/66 (24 obs); 1/67-4/69 (24 obs)	3	33:56	118:23
25	Merced/Castle AFB	1/49-12/59; 1/60-12/68	2	37:25	120:32
26	Miramar NAS	4/47-12/54; 1/55-12/64; 1/65-12/70	3	32:52	117:09
27	Mojave MCAS	10/55-9/58	1	35:03	118:11
28	Montague	1/50-12/58; 1/59-12/65	2	41:47	122:28
29	Monterey NAF	3/45-12/48; 1/49-12/58; 1/59-12/68; 1/69-12/70	4	36:58	121:55
30	Mount Shasta	4/48-12/58; 1/59-12/61	2	41:19	122:19
31	Needles FAA	11/48-12/54	1	34:46	114:37
32	Oakland	1/48-12/58; 1/59-4/68	2	37:41	122:05
33	Oxnard AFB	12/52-12/62; 1/63-11/68	2	34:10	119:05
34	Palmdale FAA	1/61-12/64	1	34:37	118:05
35	Point Arguello WBO	7/59-3/65	1	34:34	120:40
36	Point Mugu NAS	3/46-12/55; 1/56-12/65; 1/66-12/70	3	34:08	119:07
37	Red Bluff	1/48-12/58; 1/59-4/68	2	40:09	122:15
38	Riverside/March AFB	1/49-12/58; 1/59-11/68	2	33:53	117:15
39	Sacramento	7/47-12/57; 1/58-12/67; 1/68-12/69	3	38:32	121:30
40	Salinas FAA	11/48-12/54	1	36:40	121:36
41	San Bernardino AFB	1/49-12/58; 1/59-12/68	2	34:07	117:13
42	San Clemente NAS	4/60-12/69	1	33:25	117:40
43	San Diego FWC	4/45-12/55; 1/56-12/65; 1/66-12/70	3	32:43	117:12
44	San Diego WBAS	1/48-12/58; 1/59-12/68	2	32:49	117:08

No.	Name	Period of Record	#Reels	Lat.	Long.
45	San Francisco	1/48-12/58; 1/59-12/62; 1/65-12/70	3	37:37	122:23
46	San Nicolas Isl NAS	4/45-12/49; 1/50-12/59; 1/60-12/69	3	33:15	119:27
47	San Rafael AFB	1/53-12/62	1	38:05	122:31
48	Santa Ana MCAF	3/45-12/58; 1/59-12/68; 1/69-12/70	3	33:42	117:50
49	Santa Barbara FAA	11/48-12/54; 1/57-12/64	2	34:28	119:50
50	Santa Catalina	1/48-6/53	1	33:25	118:28
51	Santa Maria	10/54-7/65	1	34:50	120:28
52	Santa Maria	1/48-10/54	1	34:50	120:36
53	Stockton	11/48-12/54; 6/67-12/69	2	37:54	121:15
54	Sunnyvale NAS	3/45-12/54; 1/55-12/64; 1/65-12/70	3	37:20	122:05
55	Ukiah FAA	9/49-12/54	1	39:08	123:12
56	Vandenberg AFB	1/50-12/59; 1/60-12/68	2	34:45	120:34
57	Victorville/George AFB	9/50-12/60; 1/61-11/68	2	34:36	117:22
58	Williams CAA	11/48-12/52	1	39:10	122:08

MICRO FILM TAPE DATA

WEATHER BUREAU OFFICES AND STATIONS

No.	Station Name	Airport Name	Lat.	Long.	Elev.
100	Anacapa Island		34:01	119:22	0169
101	Anaheim	Heliport	33:49	117:55	0140
102	Avalon Bay	Pier	33:20	118:20	0010G
103	Beale Air Force Base		39:09	121:26	
104	Beaumont		33:56	116:57	2600G
105	Blunts Reef LS		40:26	124:30	0025
106	Burney		40:53	121:40	3141
107	Campo		32:37	116:28	2630
108	Carlsbad	Palomar	33:08	117:17	0328A
109	Chico	Municipal	39:48	121:51	0237A
110	Concord	Buchanan FO	37:59	122:03	0023
111	Eureka		40:48	124:10	0060
112	Farallon Island SE		37:42	123:00	0030
113	Fort Bragg		39:24	123:49	0074
114	Fort Ord		36:35	121:45	0327
115	Fresno	Chandler Mun	36:44	119:48	0278A
116	Fullerton	Municipal	33:52	117:58	0096A
117	Half Moon Bay	HAF Co.	37:36	122:30	0036A
118	Hamilton Air Force Base		38:04	122:31	
119	Hawthorne	Municipal	33:55	118:20	0063
120	Hayward	Air Terminal	37:39	122:07	0049A
121	Imperial	County	32:50	115:34	-048

No.	Station Name	Airport Name	Lat.	Long.	Elev.
122	Inyokern	Kern Co. No. 8	35:40	117:50	2426
123	Lancaster	Wm. J. Fox	34:45	118:13	2349A
124	Laverne	Brackett Field	34:06	117:47	1000A
125	Marysville	Yuba Co.	39:06	121:34	0073
126	Mather Air Force Base		38:34	121:18	
127	Merced	Municipal	37:17	120:31	0155A
128	Modesto	Municipal	37:38	120:57	0096
129	Mt. Wilson		34:14	118:04	5710
130	Napa	County	38:13	122:17	56
131	Ontario	International	34:03	117:37	0960
132	Palm Springs	Municipal	33:50	116:30	0480
133	Paso Robles	San Luis Obispo Co.	35:40	120:38	0817
134	Pt Arena		38:57	123:44	0063
135	Pt Piedras Blancas		35:40	121:17	0069
136	Pomona		34:04	117:46	0835
137	Redding	Municipal	40:30	122:18	0500A
138	Sandberg		34:45	118:44	4523
139	San Diego	Brown	32:34	116:59	0523A
140	San Diego	Gillespie	32:49	116:58	0385A
141	San Francisco SC		37:47	122:25	0052G
142	San Jose	Municipal	37:22	121:55	0056A
143	San Jose	Reid/Hillview	37:20	121:49	0134A
144	Santa Ana	Orange Co.	33:40	117:53	0053A
145	Santa Monica	Municipal	34:01	118:27	0175A

No.	Station Name	Airport Name	Lat.	Long.	Elev.
146	Santa Rosa	Sonoma Co.	38:31	122:49	148
147	Susanville	Municipal	40:23	120:34	4199
148	Tahoe City		39:11	120:07	6233G
149	Tahoe Valley	Lake Tahoe	38:54	120:00	6273
150	Thermal	Airport	33:38	116:10	-112
151	Torrance	Municipal	33:48	118:20	0101A
152	Truckee	Truckee-Taho	39:19	120:08	5900G
153	Van Nuys	Airport	34:13	118:29	0799A
154	Visalia	Municipal	36:20	119:24	0292A