NOAA Technical Memorandum NWS WR-108

OTHER KINDS OF WIND SHEAR

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OTHER KINDS OF WIND SHEAR

I. INTRODUCTION

Much has been written and said about the importance of low level wind shear on aircraft operations. Most of these discussions have pertained to wind shear associated with thunderstorm cells or with frontal zone shear. Other types of low level shear occur more frequently in mountainous terrain however.

From the meteorological standpoint "wind shear" is the variation (usually the directional derivative) of the wind vector field along a given direction in space [1]. The direction may be taken as either vertical or horizontal so the shear may be:

a. The horizontal variation of vertical winds or

b. The vertical variation of horizontal winds.

These values are expressed by the variation per distance, i.e., knots per thousand feet, meters/second per meter, etc.

The pilot, however, experiences the effect of wind shear as a time/spatial variation of winds rather than purely spatial. This is to say that the resultant vector wind shear acting upon the aircraft is equal to the difference in the wind between two points divided by the flight time between the points. On a flight path a pilot is concerned more about what the wind vector will be when he actually arrives at a given point, than he is with what the wind observation is at that point when he is still several minutes away from reaching it. As a result two components of vector wind shear can be experienced by an aircraft, "crosswind shear" and "headwind (or tailwind) shear." From a meteorological standpoint these "shears" are actually accelerations.

The four most important winds and their effect may be identified as:

1. Crosswind shear - aircraft accelerates to the right or left.

2. Tailwind shear - indicated air speed drops suddenly and aircraft sinks (accelerates downward).

3. Headwind shear - indicated airspeed increases suddenly and aircraft gains altitude (accelerates upward).

4. Up- or downdrafts - aircraft rises or sinks suddenly (accelerates up or down).

In the following discussion the Reno, Nevada International Airport is used to illustrate the three types of wind shear identified. The concept is applicable to any valley airport, however. The primary runway at the Reno airport runs roughly north-south, parallel to the Sierra Nevada to the west and the Virginia Range of the Pinenut Mountains to the east (Figures 1 and 2).

The character of airflow over mountainous terrain is largely a function of airmass stability [2]. Three basic types of shear can occur depending upon the height and configuration of the mountain barrier, structure of the wind field and airmass stability. The first (Type I) is primarily a low-level wind speed shear. Valleys to the east of large mountain ranges are often relatively dry from a climatological standpoint. Eastward moving storms are robbed of their moisture by the mountains and the valleys experience considerable drying by downslope winds which warm the air by adiabatic compression. As a result radiational cooling after sunset, unless inhibited by a cloud deck, is often quite intense and can rapidly establish a shallow stable layer of air near the valley floor. The resultant inversion is generally strongest when a ridge of high pressure aloft is over the station and the airmass is stable. An approaching upper trough of low pressure may bring increasing winds aloft which must attain sufficient strength to scour out the stable layer before winds reach the valley floor. Until the wind velocities reach this critical value a rapid speed shear will be encountered passing vertically through the temperature inversion. The strong winds aloft are "skipping" over the airport at the top of the inversion while below the inversion top winds are relatively calm (Figure 3). The inversion over the Reno airport is generally three to four hundred feet deep. Winds typically may exceed fifty knots at ten thousand feet, and at times can be equally strong at the inversion top. Thus a pilot on final approach may abruptly lose a very strong headwind or tailwind component three hundred feet above the runway. Daytime heating and/or a sufficient increase in the upper wind will destroy the inversion and end this type of shear.

Type II shear is primarily a directional shear and generally occurs during mid-morning. After a Type I has been established, if winds aloft have not reached sufficient velocities to scour the inversion and reach the surface after sunrise, solar heating of the valley floor may permit a "deflection" of the wind (Figure 4). The heating at the surface may create sufficient mixing to establish a vertical temperature profile as illustrated in Figure 5. This creates weak rising motion over the valley floor. The air is still cold and stable along the west slopes of the mountains due to the sun angle. This denser air begins to move down the slopes to replace the rising air over the valley. The strong wind continues to skip over the airport, but upon reaching the eastern mountains may couple with the weak downslope drainage wind and rush back along the valley floor from the east.

The pilot on final approach would encounter Type I shear at the inversion top and to a lesser extent the reverse near the surface. This produces a 180 degree directional shear between three hundred feet and the surface. Continued daytime heating and/or increasing winds aloft will cause mixing into the stable layer and end this type of shear as the strong westerly winds reach the surface.

Type III shear can be produced by rotor activity over the airport. The combination of terrain and meteorological parameters required for the production of rotary motion in the atmosphere is well documented [3]. It will just be pointed out here that the term rotor cloud is a misnomer. The air flow within the cloud is not actually rotary in motion, but gives this illusion because of the strong vertical shear through the layer. However, reverse flow can be found below the base of the "rotor" down to the surface (Figure 6). The directional shear in the case of rotor activity is usually far enough above the airport not to be critical. However, strong up and/or downdrafts may be encountered near the surface. The rotor shear can be encountered aloft at any time, but is most frequently found at low elevations during the afternoon hours.

II. EFFECTS OF THE THREE TYPES OF SHEAR ON AIRCRAFT

For a Type I or "skip" shear under southwesterly flow aloft conditions on final approach from the north (Figure 7a) the plane could experience a strong headwind component over a Point A above 300 feet above ground level (agl). Passing through the inversion the headwind component would be lost. This would be a tailwind shear. The indicated air speed decreases rapidly and increased power along with raising the nose of the aircraft is required to remain on the glideslope. Approaching from the south (Figure 7b) the aircraft would have a tailwind component of similar magnitude at Point B which it would lose at Point A creating a headwind shear. The indicated airspeed will increase suddenly and the aircraft gains altitude (note that in both cases a crosswind shear can also be experienced). This can be most critical when landing from the north since additional altitude may be necessary to permit a heading correction and the aircraft is likely descending below the glideslope due to the tailwind shear.

In a Type II or "deflection" shear the aircraft would experience the same effects upon passing through the inversion as described above for a Type I. If landing from the north, the pilot may find himself below the glideslope due to tailwind shear and in the process of compensating for crosswind shear when he encounters the "deflected" reverse flow. The main problem that could develop in this situation is if the reflected flow has any significant headwind or tailwind component. In this case the pilot would again have to compensate for the shear with very little altitude to work with.

The downdrafts due to rotary flow over a runway are generally more significant to aircraft operation than the associated updraft. The downdraft of a well developed rotor is in many ways analogous to a downburst cell [4]. Figure 8 illustrates that the sequence of shears encountered is the same for either glideslope when landing normal to the axis of rotation. However, the magnitudes may differ. An aircraft at Point A on glideslope I (or Point C on glideslope 2) would encounter headwind shear and a gain in altitude. At B strong sink would be encountered and the plane could be below the glideslope when the additional sink is encountered at Point C (or A) due to tailwind shear. Fortunately the above sequence of events would generally only be encountered if a cross runway at a terminal such as Reno were used, i.e., landing from the east or west. Landing from the north or south on a primary runway the aircraft would in general only experience a downdraft core or a cross-wind component depending on the location of the rotor in relation to the runway. It should be noted that downdraft strengths exceeding the theoretical downburst strengths computed by Fujita [4] have been reported at Reno, and that these strong downdrafts are often not "marked" by clouds or a rain shaft.

III. SPECIFIC EXAMPLES OF THE THREE TYPES OF WINDSHEAR

Type I

An example of inversion induced wind shear occurred on March 20, 1975. At 2110 PST a Cessna 310 pilot reported a 30-knot wind shear at 500 feet over runway 16 at the Reno airport. Figures 9 through 12 depict the synoptic pattern shortly before and after the report. At 1700 PST (Figure 9) weak high pressure at the surface was over the station ahead of an approaching Pacific frontal system. Surface winds at the Reno airport had diminished to light and variable after sunset and at about the time of the pilot report the winds were recorded as 280° at 4 knots. The temperature had dropped to near freezing after a high of 55 degrees Farenheit. Figure 10 shows that by seven hours after the pirep the front had reached the West Coast, but surface pressure gradients over Nevada continued weak. Surface winds at the Reno airport remained light and variable through the night. Figures 11 and 12 show that between 1400 PST on March 20 and 0400 PST on the 21st the 70-KPa winds were increasing over the northern Sierra Nevada. Instantaneous wind and temperature data are remoted from both Slide Mountain and Peavine to the Reno forecast office every ten minutes. In addition both stations may be manually interrogated at anytime. Slide Mountain is located at about twelve nautical miles southwest of the Reno airport with the sensors at 9,650 feet ASL. Peavine is nine miles northwest of the airport at 8,266 feet ASL (see Figure 1). Through the evening winds atop Slide Mountain were from the west southwest and averaging 40 to 50 knots. Shortly before the reported wind shear, velocities began reaching into the 60s. The temperature was reported as 12 degrees Farenheit. Under such strong flow normal to the mountain range the assumption of dry adiabatic compression and warning in the lee-side valley is reasonable. Thus,a temperature of 40 degrees Farenheit would be expected at the Reno airport. This indicates the shallow inversion had formed over the airport which explains the light winds reported there and the reported Type I wind shear. Winds aloft continued to increase through the night. Near 8:00 a.m. PST the following morning the inversion was broken and shortly thereafter gusts in excess of 40 knots were experienced at the airport.

Type II

The 1200 GMT surface analysis for November 14, 1975 (Figure 13) shows very weak pressure gradients over Nevada and northern California. Surface winds at the Reno airport were calm. The 70-KPa analysis valid for the same time (Figure 14) shows that the ridge-top winds over the northern Sierra Nevada were from the southwest at 30 to 40 knots. Temperatures atop Slide Mountain were in the mid 30s while at the airport readings had dropped into the low 20s, indicating very stable air at the low levels. A Type I shear would be strongly suspected under these conditions. About two hours after sunrise a northeasterly flow was experienced over the airport with winds averaging 5 to 10 knots. Around noon the inversion was broken and winds became southwesterly. During the late morning hours, when the "deflection" shear was working, a pilot landing from the south would have lost a significant tailwind (headwind shear) passing through the top of the inversion causing the aircraft to rise above the glideslope. Upon encountering the low level reverse flow the plane would again have a tendency to rise above the glideslope. Approaching from the north both shear components would act to push the aircraft below the glideslope.

Type III

Atmospheric flows that produce mountain lee waves are of course a necessary condition for the occurrence of rotor activity, but not sufficient. Much has been written regarding synoptic scale patterns associated with lee waves (WMO Tech. Note No. 127 has an excellent list of references on this subject). Numerous methods have been devised to investigate lee waves , but to date few have managed to incorporate rotary motion below the waves. Scorer and Klieforth [6] were able to show that waves of large amplitude can support rotors and this has been verified observationally. It has also been shown that rotors can be present at discontinuities in flows resembling hydraulic jumps [5].

The most significant aspect of rotary motion and the associated shears is the location of the rotor with respect to the glideslope. As illustrated in Figure 15 if the axis of the rotor is over the glideslope the aircraft will experience a crosswind shear. The shear will vary in intensity due to differences in the horizontal as well as in the vertical as the plane descends along the glideslope. If the rotary axis is displaced to the left of the glideslope, the maximum downdraft may be encountered as at B in Figure 15 or a crosswind shear as at Point C. Again the shears may vary considerably in both the horizontal and the vertical.

The most serious situation could arise if along glideslope B a strong downdraft is not encountered until the aircraft reaches a low elevation. The potential strength of these downdrafts should not be underestimated. Reports of up to 2,000 fpm have been received. Even if the core of the downdraft is not encountered, downward motion of this strength would produce considerable crosswind shear in the outflow areas.

IV. CONCLUSIONS

Three types of wind shear associated with the airflow over mountain barriers have been identified. The first two types of shear are induced by low level inversions while the third is caused by rotary activity beneath lee waves. Specific examples of the types of synoptic situations which produce the inversion induced shears at the Reno airport were examined and used to substantiate the basic premises of Types I and II shear. The effects of the different types of shears on aircraft operations have been examined with inferences as to possible ways of minimizing the potential hazards involved if a choice of runway orientation is available.

V. SUGGESTIONS FOR FUTURE RESEARCH

The Reno airport may well be one of the most frequently plagued spots with regard to the occurrence of inversion induced wind shear. This is due to the configuration of the basin and climatology. A project involving the use of an acoustic doppler sounder has been proposed. From such an experiment it is felt that sufficient data could be obtained to lead to the predictability of the inversion induced phenomena, at least on a probabilistic level.

It is also suggested that forecasters with terminal sites in mountainous terrain survey the locations with regard to topography and climatology to determine if inversion induced shear can occur. Synoptic flow patterns can be related to orographic orientations and under situations where shear is suspected the forecaster should have NWS or FSS briefers and tower personnel specifically request for pireps related to low level shear.

VI. REFERENCES

[1] AMERICAN METEOROLOGICAL SOCIETY, *Glossary of Meteorology*. 1959.

[2] NICHOLLS, J. M. *The Airflow over Mountains*. Technical Note, No. 127, WMO No. 355, 1973.

[3] HOMBOE, J. and KLIEFORTH, H. *Investigations of Mountain Lee Waves and the Air Flow over the Sierra Nevada*. Final Report, Contract No. AFK(604)-728. 1957.

[4] FUJITA, T. THEODORE. *Spearhead Echo and Downburst Near the Approach end of a John F. Kennedy Airport Runway, New York City*. SMRP Research Paper 137.

[5] FOLDVIK, A. *Two-dimensional Mountain Waves--A Method for the Rapid Computation of Lee Wavelengths and Vertical Velocities*. Quart. J. R. Met. Soc., 88. 1962.

[6] SCORER, R.S. and KLIEFORTH, H. *Theory of Mountain Waves of Large Amplitude*. Quart. J. R. Met. Soc., 85. 1959.

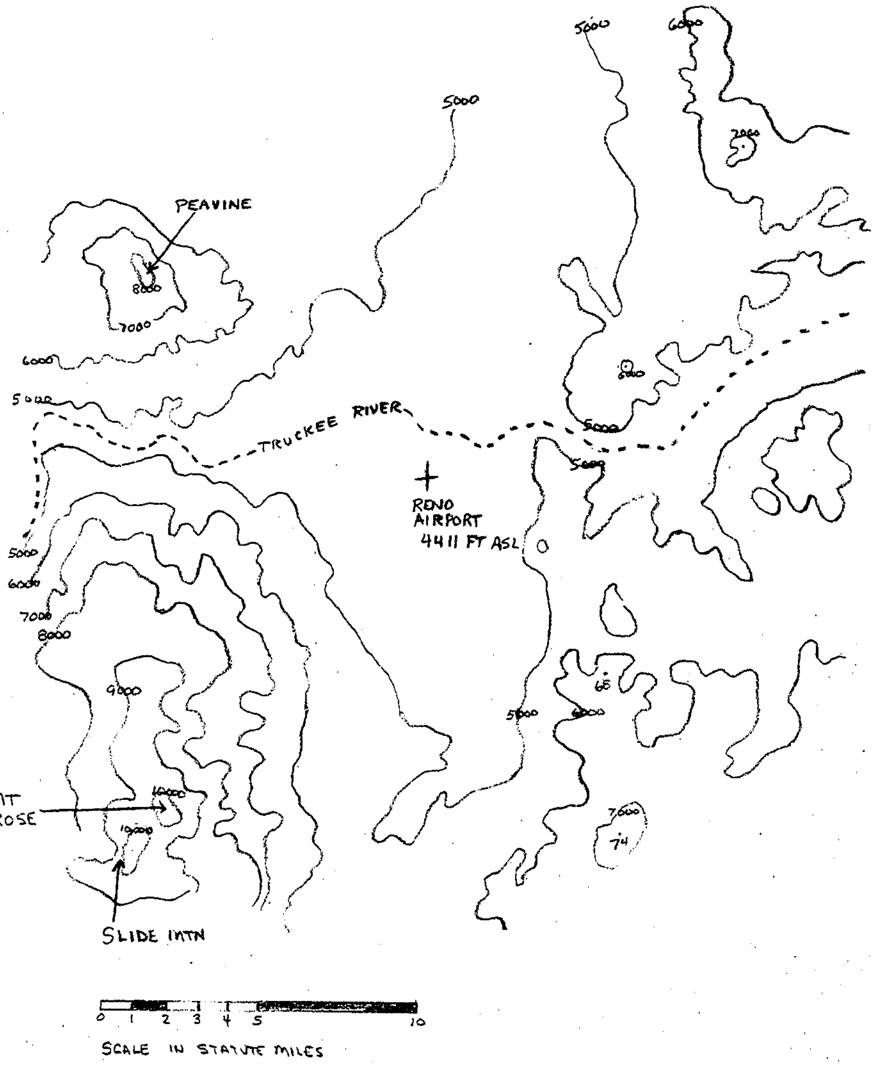

Figure 1. Terrain features surrounding Reno Airport; contours every 1000 feet.

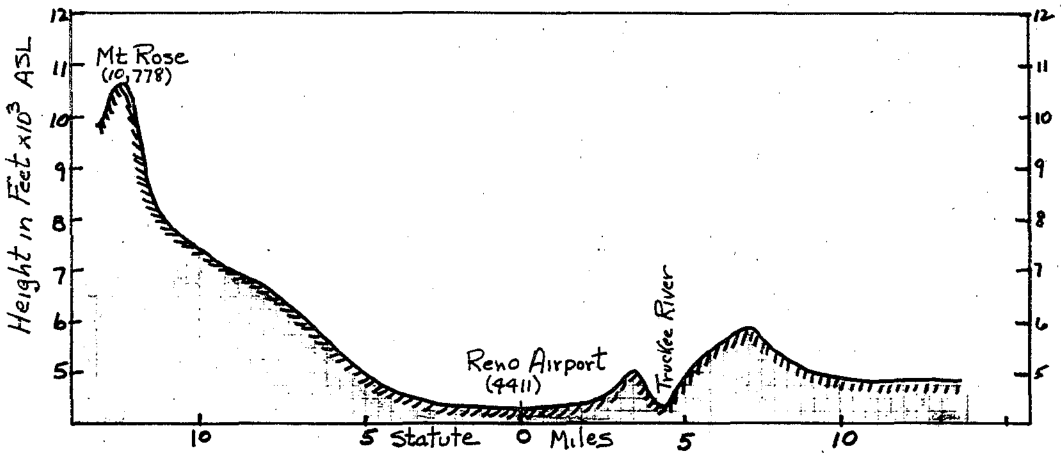

Figure 2. Terrain SW-NE cross section through Reno.

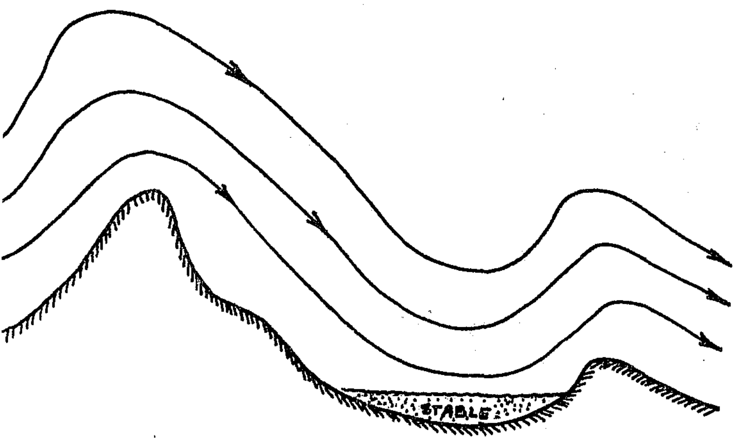

Figure 3. Skip shear. A shallow stable layer develops over the valley floor due to radiational cooling. Increasing winds aloft "skip" over this stable layer until sufficient velocity is reached to scour the valley.

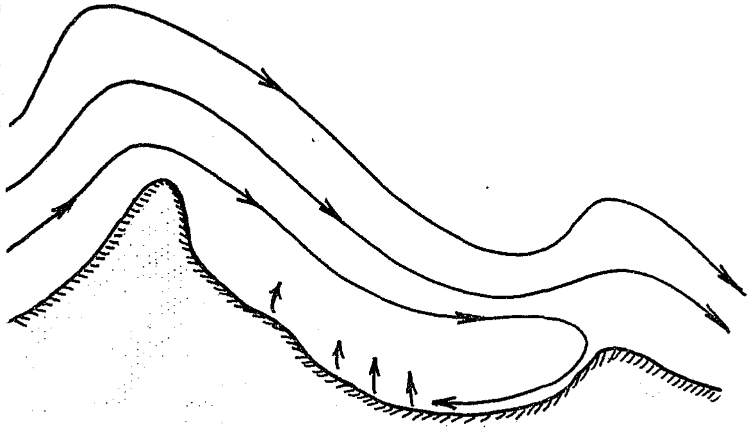

Figure 4. Deflection shear. Morning heating of valley floor initiates weak rising motion. Air begins moving down the east slopes of the mountains to replace the rising air. This flow can become coupled with strong westerly winds aloft producing moderate return flow at low levels.

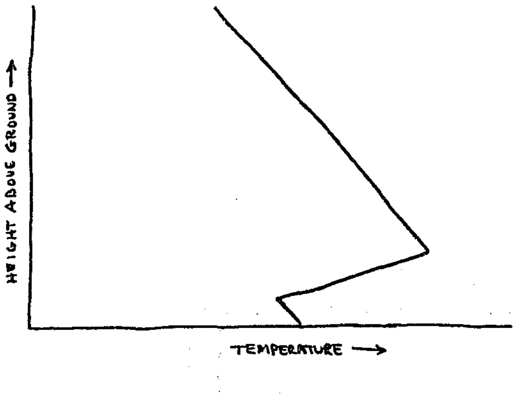

Figure 5. Air close to ground becomes less stable due to solar heating after sunrise.

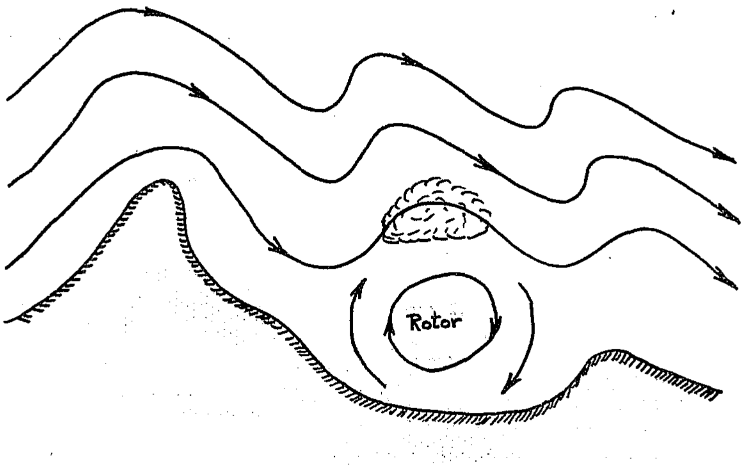

Figure 6. Rotor shear. Rotory action beneath terrain induced waves can produce shear and strong up and downdrafts over the valley.

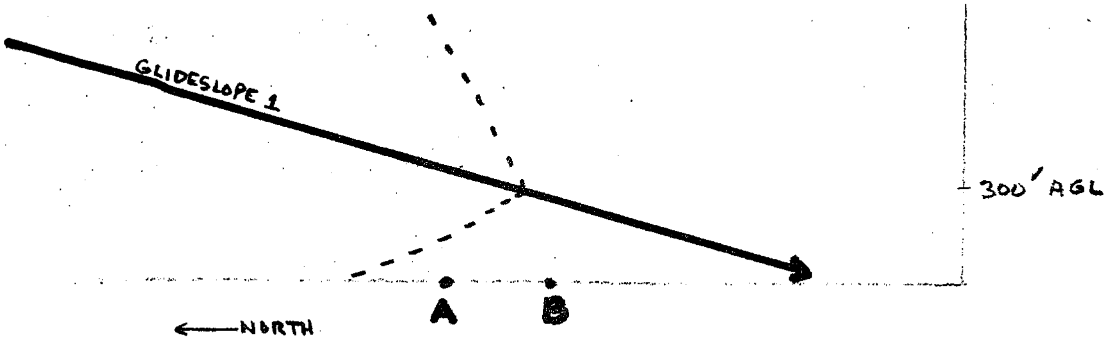

Figure 7a. Landing from the north at Reno International Airport. Dashed line indicates vertical temperature profile.

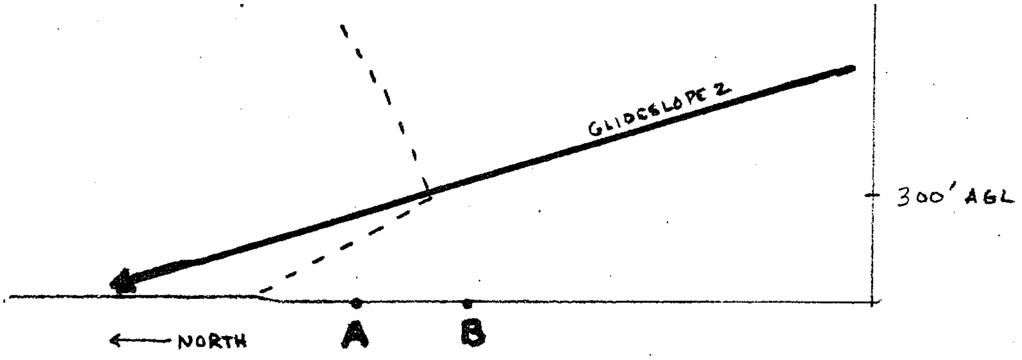

Figure 7b. Landing from the south.

Figure 7. Graphical relationships of Type I wind shear and glideslope when landing at Reno.

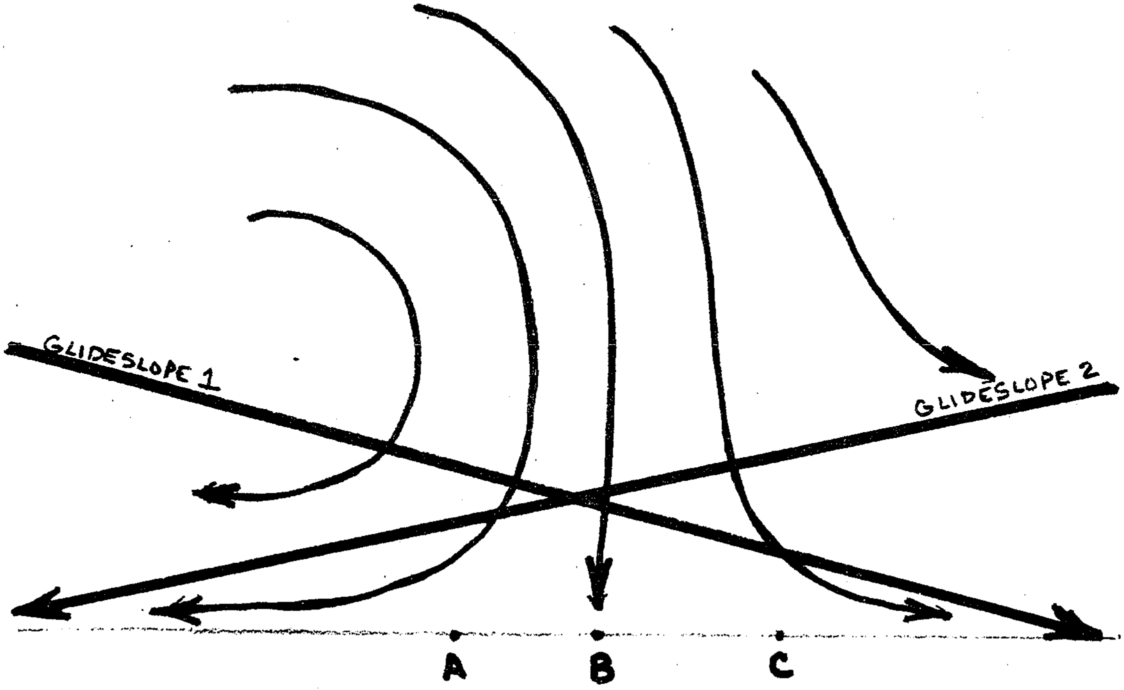

Figure 8. Vertical cross-section through axis of rotation of downdraft portion of rotory motion associated with strong windflow over a mountain barrier.

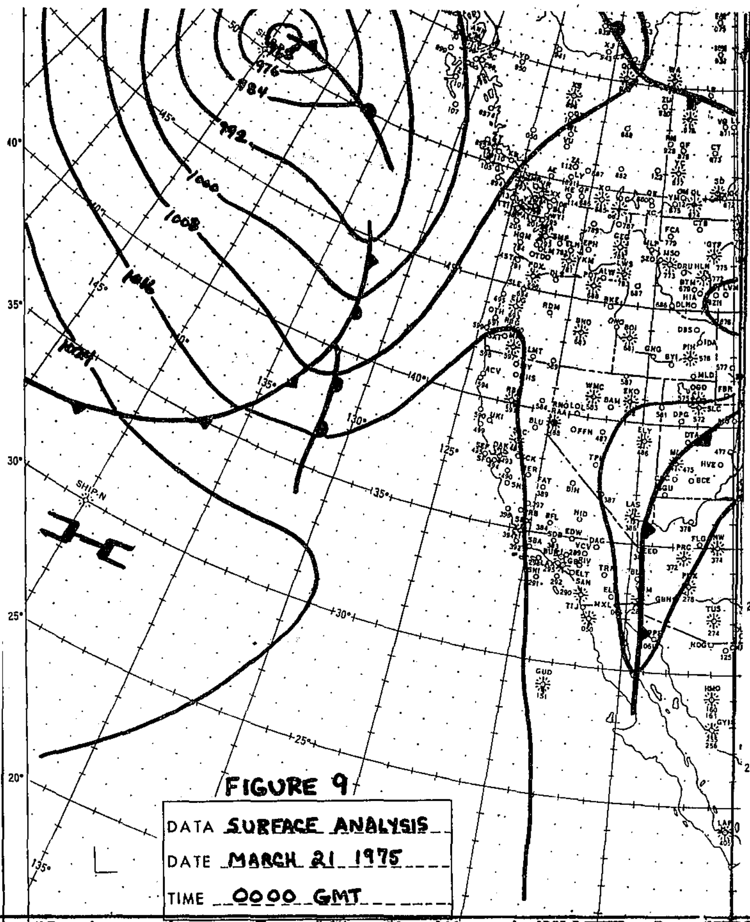

FIGURE 9

DATA SURFACE ANALYSIS

DATE MARCH 21 1975

TIME 0000 GMT

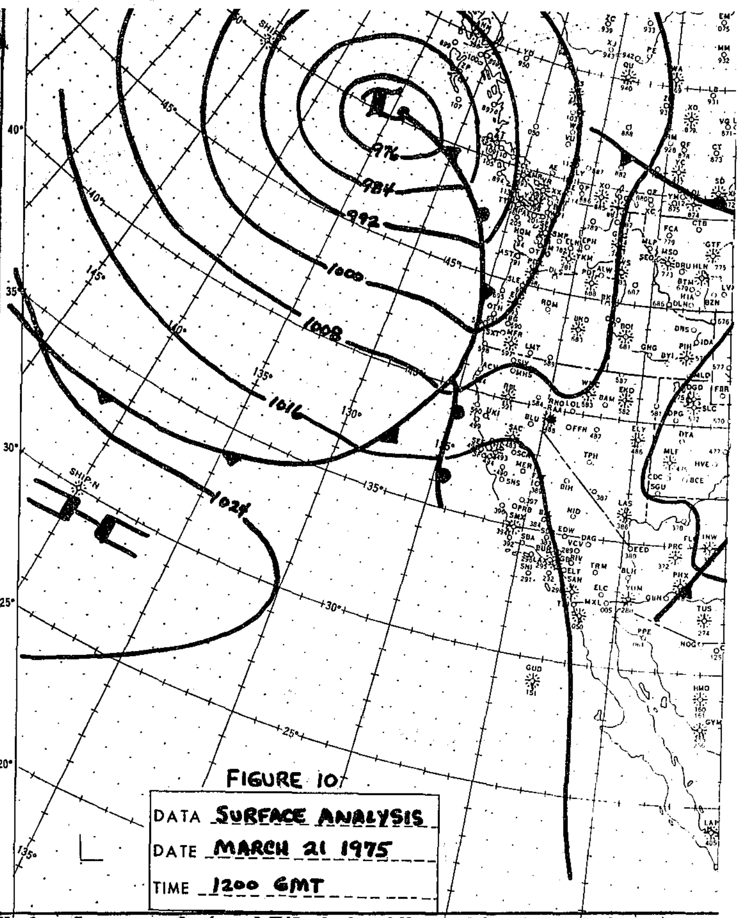

FIGURE 10

DATA SURFACE ANALYSIS

DATE MARCH 21 1975

TIME 1200 GMT

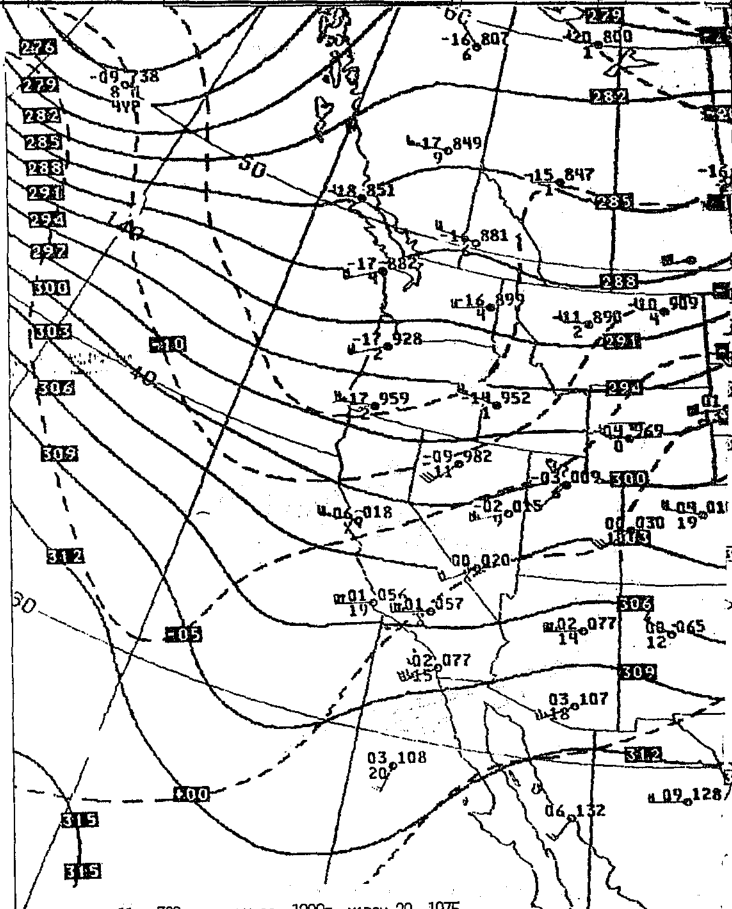

FIGURE 11. 700-MB ANALYSIS, 1200Z, MARCH 20, 1975.

86 00HR ANAL 700MB HEIGHTS/T

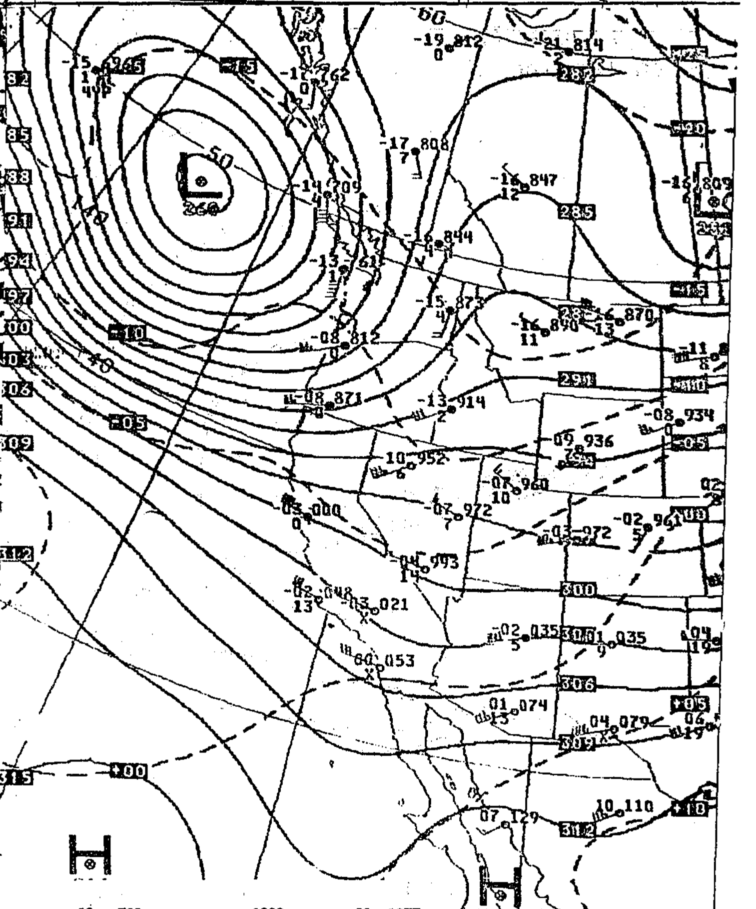

FIGURE 12. 700-MB ANALYSIS, 1200Z, MARCH 21, 1975.

00HR ANAL 700MB HEIGHTS/TEMP

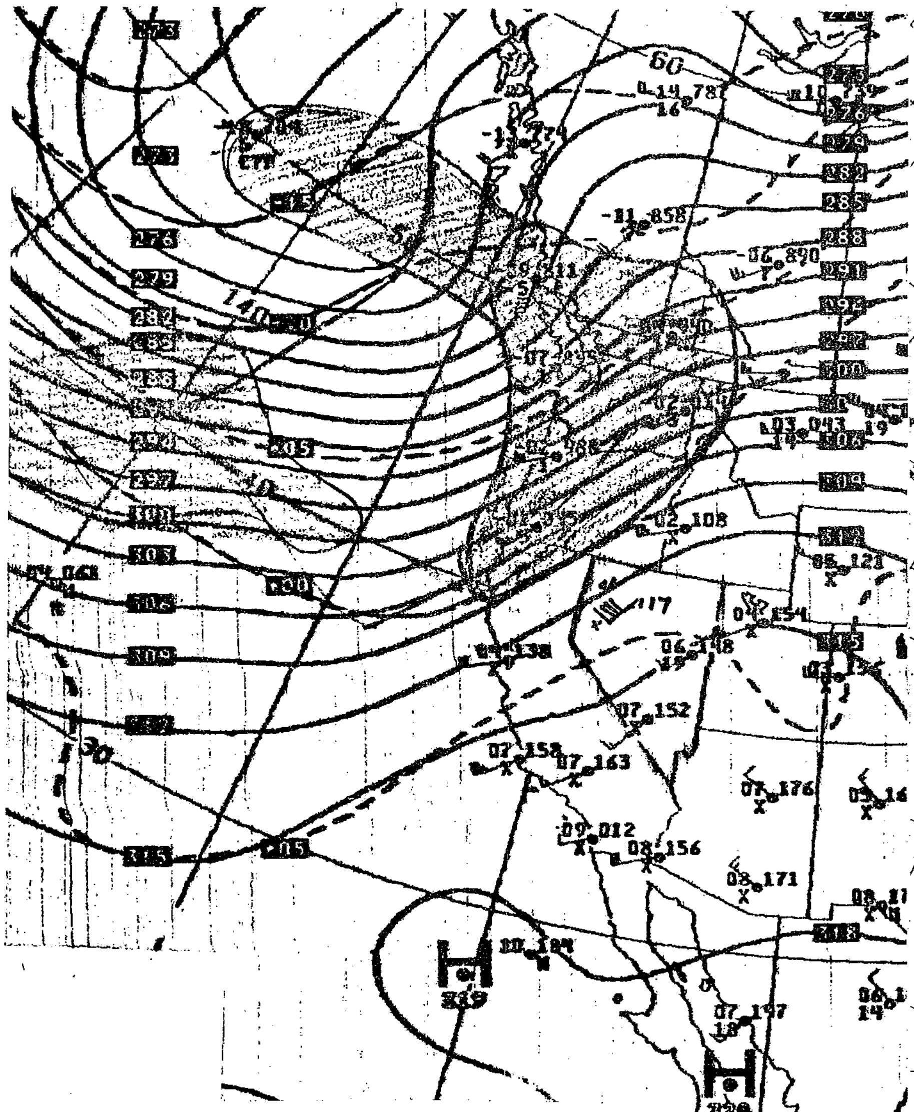

FIGURE 14. 700-MB ANALYSIS, 1200Z, NOVEMBER 14, 1975.

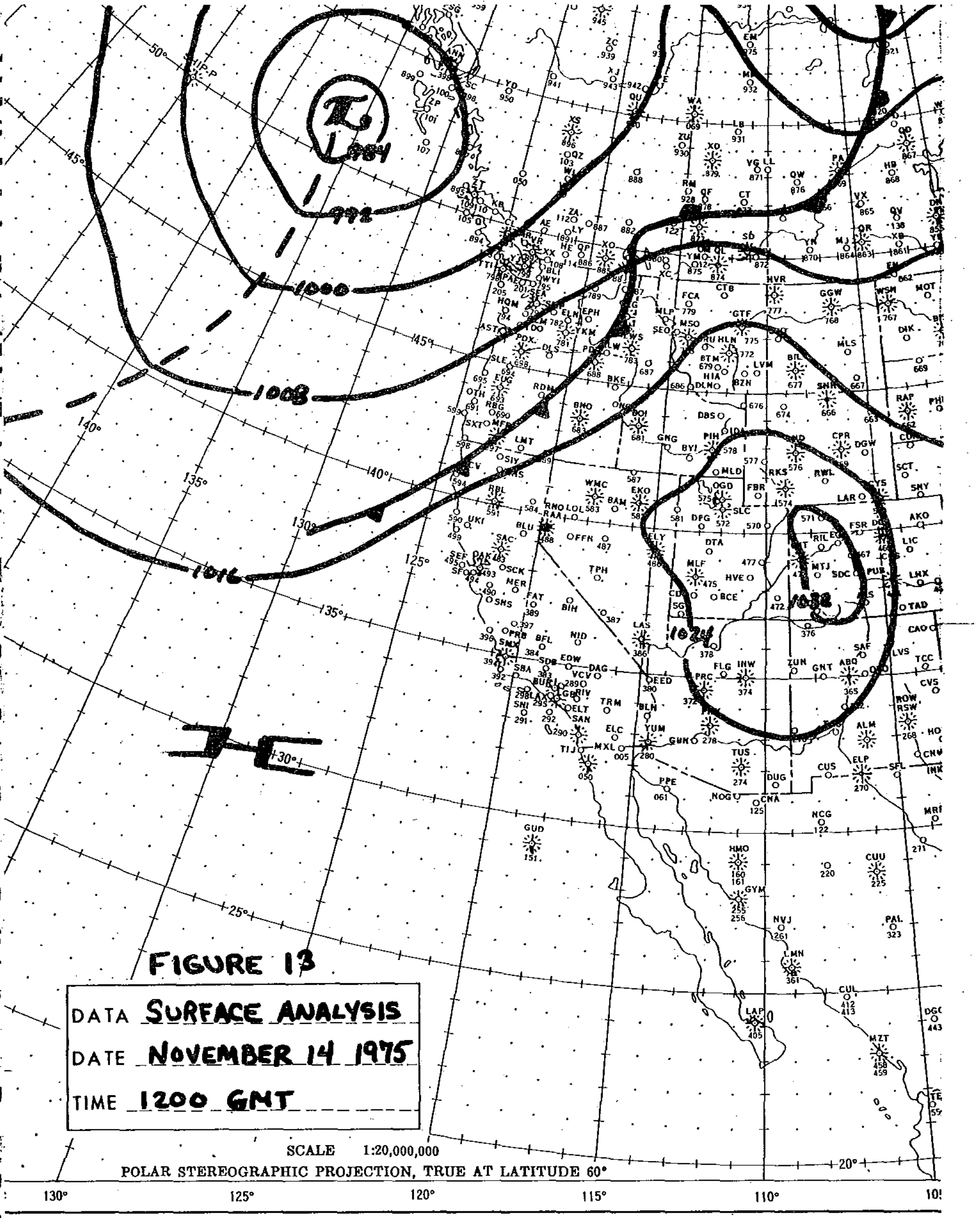

FIGURE 13

DATA SURFACE ANALYSIS

DATE NOVEMBER 14 1975

TIME 1200 GMT

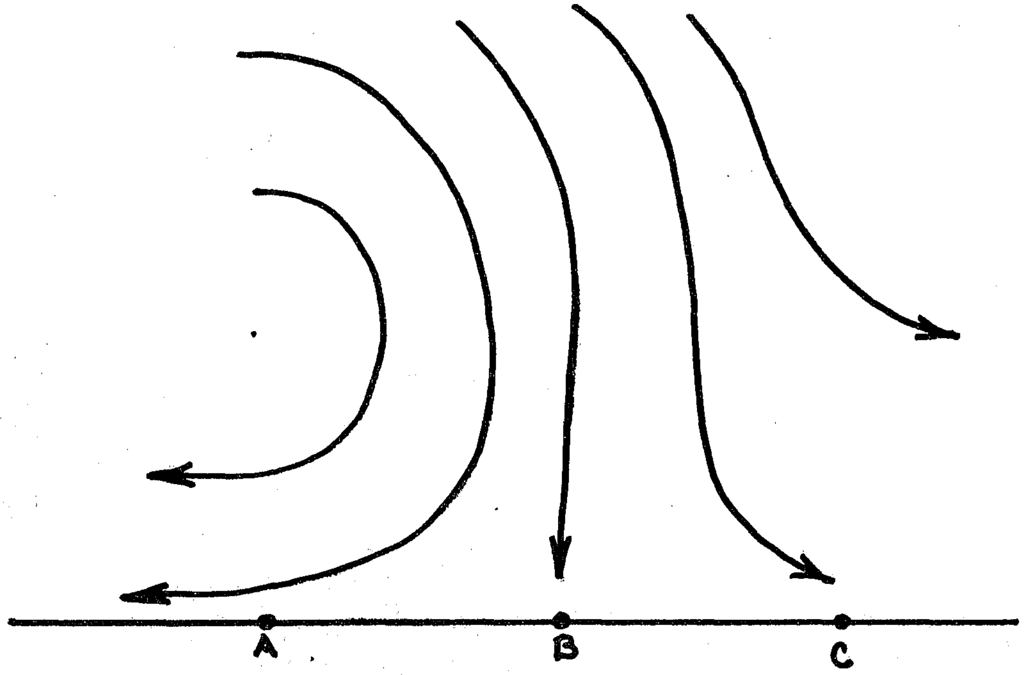

Figure 15. Location of the Rotor with respect to the glideslope (A, B, or C into the page) determines the type and intensity of shear encountered.

Western Region Technical Memoranda: (Continued)

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No. 45/3 Precipitation Probabilities in the Western Region Associated with Summer 500-mb Map Types. Richard P. Augulis, January 1970. (Out of print.) (PB-189414)

No. 45/4 Precipitation Probabilities in the Western Region Associated with Fall 500-mb Map Types. Richard P. Augulis, January 1970. (Out of print.) (PB-189435)

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