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WIND SHEAR AND CLEAR AIR TURBULENCE

KENNETH R. HARDY*

Vertical wind shear is a change in the speed or the direction of the wind with height. If this shear is sufficiently strong within relatively thin layers of the free atmosphere, then the layers can be overturned by the development of waves which grow and finally break down into turbulent flow. The nature of the wave instabilities and the detection of clear air turbulence using sensitive radars will be discussed.

On occasion large vertical wind shears occur within the lowest few hundred meters of the atmosphere. These shears can affect aircraft operations especially in the critical takeoff and landing configurations. Similarly, very large changes in the wind often occur across the boundary of the gust front of active thunderstorms. Weather conditions which lead to strong wind shear near the surface are described and some of the recent advances in the detection of wind shear are presented.

I. INTRODUCTION

WIND SHEAR is a change of wind velocity with distance. A velocity change can be due to a change in wind speed, a change in wind direction, or both. In the general case, there is no restriction on the orientation of the distance over which the shear occurs; that is, shear can refer to the change of the horizontal wind in a north direction, an east direction, or in the vertical. To describe the shear completely in the three dimensions, nine components must be specified. Nevertheless, when used in the aviation industry, wind shear almost universally is taken to mean the vertical wind shear which is the change of the horizontal wind speed or direction with height. It is convenient to use such a definition throughout this article. It is recognized, however, that the change in

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the horizontal wind in the horizontal direction can be extremely large across the boundary of the gust front of active thunderstorms.

Wind shear in the lowest few hundred meters of the surface can be severe and can affect aircraft safety, especially in the critical take-off and landing configurations. As shown by Melvin and Schiff, unexpected wind shear along the path of a landing or departing aircraft could result in a variety of hazardous situations. For example, lack of correction for vertical wind shear during a landing operation can result in a short landing, not enough thrust to compensate for fall speed, improper pitch angle, or landing long and too fast. The effects of vertical wind shear on automatic landing systems may be even more critical, since they may respond incorrectly or too slowly in an emergency. Both the International Commission on Aircraft Operations (ICAO) and the Federal Aviation Administration (FAA) have recognized wind shear as a potential hazard to the safety of aircraft and have taken steps to develop techniques for the early detection of severe shear conditions. Some of these techniques will be described in Section V.

The nature, characteristics, and distribution of strong low-level shears are not fully understood. Routine measurements of winds are made by the radar tracking of a balloon to which a radar target is attached; these balloons are usually only launched twice a day at selected stations around the globe. The measurements are inadequate to resolve the fine scale temporal and spatial detail which are needed during periods of strong shear.

The key objective of this article is to describe some of the features of wind shear and the methods for its detection. Three major shear regions are considered. One is near the surface where large vertical wind shears may be present with little significant turbulence. The second occurs in the free atmosphere and consists of strong shear layers which develop and break down into regions of moderate or severe turbulence in the clear air. The third region of strong shear occurs in the vicinity of thunderstorms where the cold outflow of the storm forms sharp boundaries with the environmental air; large

3 A. Brunstein, Lessons to be Learned from Accidents Attributed to Turbulence, Proc. Int. Conf. on Atmospheric Turbulence (May 18-21, 1971).
changes in the horizontal wind across the boundary coupled with possible large up- or downdrafts associated with strong convection can give rise to extremely hazardous flight conditions.

II. Wind Shear in the Atmosphere

A. Thunderstorm Gust Fronts

The most obvious cause of significant low level wind shear is the gust front associated with thunderstorms or strong convective activity over a deep layer of the atmosphere. Figure 1 is a schematic vertical cross section through a large active thunderstorm. The figure is taken from a paper by Newton* that was one of an excellent collection of papers on severe local storms published as a monograph by the American Meteorological Society.

The main updraft and downdraft regions are shaded and the arrows indicate the flow patterns within the storm. The boundary of the precipitation is indicated by the dotted lines and the cold outflow is contained within the area of the heavy dashed lines.

The storm in Figure 1 is moving toward the right and is embedded in a wind field which increases toward the right with height, as indicated by the wind profile on the left of the figure. The storm itself is moving with a speed representative of a mid-level wind; consequently, relative to the storm, air enters the storm from the right at low levels, and flows out of the storm toward the right at high levels. Much of the air entering the storm at low levels contributes to the strong updrafts which are a feature of active thunderstorms. Although the sketch shows that some of the updraft air becomes part of the downdraft, in large longlived storms most of the downdraft is made up of air which originates at mid levels. This air is often relatively dry, and as the precipitation falls into this drier air, evaporative cooling increases the density of the air and results in a considerable increase in the strength of the downdraft. The downdraft pushes rapidly toward the surface where it spreads out in all directions.

The downdraft air has considerable energy, and it forms a very sharp boundary or gust front with the warm environmental air, particularly at the leading edge of the storm. Changes in the wind

* Newton, Dynamics of Severe Convective Storms, Met. Monographs on Severe Local Storms at 33 (1963).
Schematic section through a large thunderstorm with wind toward right increasing with height. The wind profile of the undisturbed atmosphere is shown on the left. The outline corresponds to visible cloud; the boundary of the cold outflow is indicated by the heavy dashed lines; the area of precipitation is contained within the region bounded by the dotted lines. Note that an aircraft travelling from right to left at low levels through the outflow region would encounter first headwinds and then tailwinds as it passed through the center of the downdraft.

### Figure 1

![Diagram of storm motion](image)

Schematic section through a large thunderstorm with wind toward right increasing with height. The wind profile of the undisturbed atmosphere is shown on the left. The outline corresponds to visible cloud; the boundary of the cold outflow is indicated by the heavy dashed lines; the area of precipitation is contained within the region bounded by the dotted lines. Note that an aircraft travelling from right to left at low levels through the outflow region would encounter first headwinds and then tailwinds as it passed through the center of the downdraft.

Speed across these gust fronts can be at least as large as thirty knots in 0.5 nautical miles. Since aircraft have approach or take-off speeds in the order of 135 knots, they can experience a thirty knots change in their air speed over a time interval of about 15 seconds while traversing the gust front of a large thunderstorm. For the flow depicted in Figure 1, an aircraft travelling from right to left at low levels through the outflow region would encounter first headwinds and then tailwinds as it passed through the center of the downdraft. Super-imposed on this change in the horizontal wind is the actual downdraft which would further complicate or add to the hazard of flight beneath the storm.

Pilots are well aware of the large shears which occur in the vicinity of thunderstorms and consequently avoid them whenever possible. It is important to note, however, that the gust front may move out ahead of the storm and precipitation by as much as eight nautical miles and occasionally pilots may encounter the gust front unexpectedly. If flight in the vicinity of large storms is necessary during takeoff or landing, it would be prudent to determine the
most likely position of the gust front and to modify the flight plans accordingly.

B. Wind Shear at Frontal Surfaces

Weather fronts, the interface or transition zone between two air masses of different characteristics, are usually identified by regions of wind shear. Figure 2 is a schematic drawing of a surface frontal

![Figure 2](image)

**Figure 2**

Schematic drawing of a cold and warm front at the surface. The fronts separate air masses of different temperatures and moisture and strong wind changes occur across them. Since the warm air overrides the cold air, the southwest winds of the warm sector exist above the surface over both points A and D. Consequently, strong vertical wind shears exist near the surface at A and D and occur at greater heights as the horizontal distance from the front increases. This figure is adopted from Figures 7 and 8 of the paper by Sowa.5

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system. The air flows counterclockwise around the low, and sharp changes in the wind occur at the fronts. Fronts are surfaces which separate the cooler, underlying air from the warmer air; Figure 2 shows the intersection of the frontal surfaces with the ground. The winds at points A and D are typical of those which occur in the cold air masses; the warm air flows from the southwest both at the surface and aloft above the cold air. Consequently, strong vertical wind shears occur near the surface at A and D. The frontal surfaces slope upward with increasing distance from the surface frontal position, resulting in layers of strong shear which often give rise to clear air turbulence at jet flight altitudes.

Not all fronts produce significant wind shear, but instead are characterized by broad transition zones which contain gradual changes in wind direction and speed. Certain fronts do, however, have sharp, narrow transition zones which have a significant amount of wind shear. Daniel F. Sowa, Superintendent of Meteorology for Northwest Orient Airlines, notes that the front will usually have significant low level wind shear if the cold or warm front meets one or both of the following criteria:

1. there is a temperature difference immediately (in the order of five nautical miles) across the front at the surface of 5°C (10°F) or more; and
2. the front is moving at ten knots or more.  

Sowa also notes that the wind shear is most critical for aircraft operations when it is close to the ground. The strong shears associated with a cold front occur just after the front passes the airport and continue for a short period thereafter. If the front is moving at 30 knots or more, the frontal surface will usually be 5000 feet above the airport about three hours after the surface passage of the front. With a warm front, the most critical period is before the front passes the airport. Warm front shear usually exists below 5000 feet for about six hours. There is no significant vertical wind shear once the airport is entirely within the warm sector. Generally, the amount of shear in warm fronts is much greater than that found in cold fronts. With cold fronts, cold air is replacing warm air which generally leads to rapid overturning of the air and a weakening of any strong vertical shear; with warm fronts, the warm

\* \* Id.
air replaces cold air and this process is inherently a stable one which permits large vertical shears to develop and persist.

Generally, some degree of turbulence is associated with frontal zones or shear layers. The intensity of the turbulence is dependent on the amount of shear and the vertical depth of the shear layer. This topic will be covered in more detail in Section III.

C. Non-Frontal Shear Zones

Any process in the atmosphere that leads to the development of thermally stable layers creates a condition which allows larger wind shears to exist. Radiational cooling of the earth's surface is an obvious example of a process which increases the stability of the air, and it is well known that, in the absence of large scale changes, the vertical shear near the surface increases during the night. Although this nocturnal cooling alone usually is not important in producing significant shear, it can enhance the shear which existed during the day.

Subsidence, a descending motion of air over broad areas, creates a warming of the air. Often the warmed air will contribute to a strong temperature inversion (an increase of temperature with height); especially when there is extensive vertical mixing in the air layer below the subsiding air. Usually the subsiding warm air will have a different origin than the mixed layer below it and strong vertical wind shears can develop. A notable example of a persistent subsidence inversion occurs along the western coast of California. Descending warm air from the sub-tropical high pressure area caps a relatively cool layer of marine air at the surface. The resulting inversion usually has a marked shear; the change of wind can be more than thirty knots in a height through the inversion of only 650 feet. Normally the base of the inversion is sufficiently far above the surface (greater than 600 feet) that aircraft operations are not seriously affected by it. However, the shear at the inversion layer is large, and small scale turbulence within the layer is a common feature; on occasion the shear and turbulence could combine to be troublesome or hazardous for aircraft operations.

Vertical wind shear can also develop along coastal regions since the land air and sea air usually have quite different characteristics. During the summer months sea breezes will develop along coastal regions and will move inland during the day. The sea breeze front
separates the sea air from the land air and usually will be characterized by some shear. However, the sea breeze will normally not be hazardous to aircraft flight except in those cases when it acts to reinforce or strengthen an already existing strong shear. When the sea is much cooler than the overlying air, the surface layer of air is very stable, and consequently, there is the potential for strong shears to develop. For aircraft operations, pilots should be aware of this potential and be particularly careful at coastal airports.

III. CLEAR AIR TURBULENCE AND ITS DETECTION

Radar echoes from an apparently clear atmosphere have been observed since the early days of radar. Because the origin of the echoes was usually a mystery, the clear-air echoes were often called "radar angels." A variety of angel phenomena is reported in the literature, and there have been numerous attempts to arrive at plausible and satisfactory explanations of their origin. Early investigators were principally concerned with the cause of the echoes, and in some cases they were not able to provide satisfactory explanations of the observations. One of the main reasons for the lack of understanding was the limited quality and quantity of the radar observations. With the application of high-power and high-resolution radars to the investigation of clear-air echoes, there emerged an explanation for the two types of echoes which is now generally accepted.

Perhaps the difficulty in the correct identification of angel echoes arose because of the numerous possible causes of the echoes. These include anomalous propagation which gives rise to the appearance of surface targets at ranges far greater than average, ground targets seen by the sidelobes of the antenna beam, second-sweep echoes beyond the unambiguous range of the radar, birds and insects, and small-scale variations in temperature and moisture in the clear atmosphere. The scattering from fluctuations in temperature and moisture provides the most useful type of radar echoes from the clear atmosphere, although on occasion there are sufficient insects in the air to provide suitable tracers of atmospheric structure and

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motion. Since the scattering from temperature and moisture index variations is generally very weak, it is essential to use sensitive radars for investigations of the clear atmosphere.

Investigators have recognized two sets of atmospheric conditions which favor radar scattering from variations in temperature and moisture. One is associated with the variations in temperature and moisture at the boundaries of convective cells. In this case, radar provides information on the three-dimensional convective structure associated with rising moist air. The other set of conditions occurs above the convective mixing zone where atmospheric layers of enhanced vertical stability often form, and negative bouyancy forces tend to suppress turbulent motions. In essence, the atmosphere is stratified in such a way that all vertical motions are initially suppressed. In these stable regions, turbulence is generated by energy which is extracted from the mean flow either by local breakdown of wind shear or by overturning of unstable waves. High-power radars detect the stable layers once the vertical wind shear is sufficiently large to overcome the stabilizing negative bouyancy force. Breakdown may occur locally over very small depths (a few yards) or, in cases of rapid shear development, breakdown may take place throughout layers having a depth of more than 4000 feet. These deep layers are often associated with clear-air turbulence (CAT) which aircraft experience.

Perhaps high-power radars have made their greatest contribution to the atmospheric sciences by their capability to view or map a variety of wave structures in the clear air. Hicks and Angell carried out the first investigation of the wave-like structures observed by high-power radars in the clear atmosphere, and this was rapidly followed by other studies of atmospheric waves.

An outstanding example of a wave pattern as observed by radar is shown in Figure 3. The wave pattern occurs near a height of 36,000 feet and is above an extensive region of cloud and precipitation. From the meteorological analysis for this case, it was found that the wave was within a region of strong stability and marked

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wind shear. These conditions were consistent with those theoretically required for the development of unstable waves.

![Figure 3](image)

**FIGURE 3**

Photograph of the range-height indicator scope of a radar operating at a wavelength of 10.7 cm, 1509 EST, February 7, 1968, at Wallops Island, Va., azimuth 270°. Cloud and precipitation extend from the surface to about 10 kilometers (one kilometer, km, is equivalent to 0.54 nautical miles). The unusual clear-air echo structure of apparently crossing waves out of phase occurs at 11.3 km. The pattern is indicative of clear-air turbulence which affects aircraft.

Various investigators have described joint radar and aircraft studies of CAT. Using the radars at Wallops Island, Va., Glover and Duquette found that all altitude intervals corresponding to clear-air radar layers between 0.5 and 15 km, when probed with fighter jet-aircraft, were turbulent. Not all turbulence encountered

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by the aircraft was detected, however. The results of fifty-three flights during the winters of 1969 and 1970 showed that about twelve percent of the light or greater turbulence above 20,000 feet was not detected by the radar. However, the stronger turbulence was generally detected by the radar with greater probability than the lighter turbulence.

The clear atmosphere has also been probed in extremely fine detail using a vertically pointing frequency-modulated continuous-wave (FM-CW) radar developed by Richter. It has high sensitivity, a range resolution of about 3 feet, and a minimum of ground clutter problems. This radar has been used for the visualization of a wide variety of atmospheric structures in the marine layer at San Diego which were never before resolved in such detail.

The FM-CW radar often resolves clear-air "billows" or other wave instabilities in the planetary boundary layer in remarkable detail. Figure 4 is an example of the type of structure detected

![](image)

**Figure 4**

Intensity-modulated display of time-height record of February 6, 1970, obtained with an FM-CW radar at San Diego, Calif. The resolution of the radar is about 6 feet. Unstable waves and turbulence are evident in the strongest layer near a height of 500 meters in clear air. The many discrete strong echoes are believed to be caused by the backscattering from insects. Several extremely thin layers are present, some of which also exhibit wave instabilities. (Photograph courtesy of E. E. Gossard, 1971).

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with the radar. It shows a prominent wave structure near a time of 1205 PST at a height of 450 meters (one meter is equivalent to 3.28 feet), and 10-15 minutes later the strongest echoes coincide with the height of the base and crest of the wave occurring earlier. This depicts a portion of the life cycle of an unstable wave. A wide variety of small-scale wave and layered structures in the clear atmosphere have been investigated using similar types of observations. Figure 4 also demonstrates the extreme sensitivity of the system since the discrete echoes appearing as bright elongated echoes are believed to be caused by the backscattering from insects. On occasion, the insects occur in sufficient number that the FM-CW radars, and the high-power radar systems mentioned earlier, are able to observe atmospheric structures by virtue of the scattering from the insects.

IV. WIND SHEAR NEAR THE GROUND AND THE EFFECT ON AIRCRAFT

Schiff has pointed out that wind shear is a unique hazard for aircraft operations not only because it is frequently undetectable, but also because many pilots are unable to acknowledge the threat. They consider it incredible that a change in wind velocity can alter airspeed. Nevertheless, under strong wind shears which occasionally exist within the atmosphere, significant aircraft airspeed changes can occur over very short time intervals.

To understand the effect that wind shear has on aircraft, one must recognize that an airplane has inertia relative to the ground, and as a result it resists a change in its ground speed. An aircraft in flight at a given ground speed tends to remain at the same speed unless acted upon by an exterior force.

An application of this is illustrated in Figure 5. A temperature inversion and strong shear zone overlies a surface edge of fairly stable air. Within the surface layer the wind is easterly at 10 knots. Immediately above the inversion, the wind is westerly at 20 knots. The situation depicted in the figure could occur, for example, along the east coast of the U.S. when cool marine air flows inland from the east and is capped by a warm subsiding westerly flow.

14 Schiff, supra note 2.
Illustration of the changes in air speed and ground speed of an aircraft descending through a layer of large wind shear. The assumed wind profile in the lower atmosphere is shown on the right.

The aircraft descending through the shear layer has an air speed of 120 knots and a ground speed of 100 knots. The ground speed represents momentum with respect to the earth and is the parameter or quantity which tends to resist change. As the aircraft penetrates the shear line and enters the lower layer, the ground speed tends to remain constant at 100 knots, but now the air speed is only 90 knots because the aircraft has gone from a headwind of 20 knots to a tailwind of 10 knots in a very short interval of time. In the real atmosphere, a change of 30 knots can occur over a height of less than 300 feet, and with a descent rate of 1200 feet per minute, the aircraft will experience the reduction in air speed over a period of about 15 seconds.

The reduced airspeed results in reduced drag. Assuming that neither altitude nor power is changed, the aircraft accelerates to its original trimmed air speed of 120 knots at which time thrust and drag are again in balance. But because of inertia, this acceleration takes time; the lost air speed cannot be recaptured instantly.

Schiff further summarizes the results obtained by Major C. L. Hazeltine who determined how long it takes to recover lost air.
Hazelton demonstrated that if a given aircraft, maintaining a constant altitude and power setting, encounters an abrupt 20-knot loss (due to wind shear), recovery of only 10 knots would require 78 seconds; recovery of 16 knots would require 176 seconds. Adding power and/or sacrificing altitude reduces recovery time significantly, but Hazelton's report points out the alarming need for pilots to be particularly alert for a low-level wind shear when on final approach or when climbing out at marginal air speeds.

The aircraft in Figure 5 encountered a rapidly decreasing headwind, which has the same effect as an increasing tailwind: an airspeed loss. If the direction of the aircraft is reversed, so that it flies into an increasing headwind (or decreasing tailwind), airspeed will increase when the shear layer is crossed. The maximum gain is 30 knots, although as pointed out earlier, it takes some time to penetrate the shear zone, and the pilot will probably start to react before the entire zone is traversed.

The actual flight path of an aircraft is dependent both on the atmospheric shear conditions and the pilot's input. Melvin, Sowa, and Schiff have discussed some of the consequences of pilots' responses to wind shear. With the number of alternatives between the wind shear and the response of the pilot, these authors have demonstrated that an improper reaction to the shear conditions can lead to a short landing, not enough thrust to compensate for fall speed, improper pitch angle, or landing long and too fast.

V. THE DETECTION OF WIND SHEAR

There are at least three different techniques which have the potential for measuring low-level wind shear at airports. These are an acoustic Doppler system, microwave Doppler radars, and laser Doppler systems. At present no single system has demonstrated an all-weather capability which will provide the required information in a timely fashion. Beran has discussed several of the methods for

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15 Id.
16 Id.
18 Sowa, supra note 5.
19 Schiff, supra note 2.
wind shear detection and has carried out extensive testing of acoustic Doppler systems.\textsuperscript{20} The Federal Aviation Administration (FAA) is also supporting much of the effort on wind shear prediction.

A. Acoustic Doppler Systems

An acoustic echo sounder transmits a pulse of sound and then receives the energy which is scattered from small-scale turbulent fluctuations of atmospheric temperature or velocity. The mean motion of the atmosphere within the pulse volume of the sounder can be obtained if a Doppler capability is built into the system. Beran has described a wide range of theoretical and experimental results using acoustic Doppler systems.\textsuperscript{21} With various configurations of the transmitting and receiving antennas, he has shown that it is possible to derive a reliable vertical profile of the wind.

Beran and his co-workers at the Wave Propagation Laboratory of the National Oceanic and Atmosphere Administration have received support from the FAA for the development of the remote wind shear system. The system has been calibrated and compared either with anemometers attached to a tethered balloon or with data collected from rawinsondes. Beran has also tested an acoustic wind shear system in an operational environment at Stapleton Airport in Denver. He compared his acoustic wind measurements with the twice daily rawinsondes taken by the National Weather Service. When all systems were functioning properly, very good wind and shear measurements could be obtained.\textsuperscript{22} Similar results were obtained using a system designed and built by Xonics, Inc.; the system and the analysis of the measurements are described in a recent paper.\textsuperscript{23}

The FAA has also collected data on wind shear conditions at Kennedy International Airport and Boston’s Logan International Airport using acoustic systems. The system at Kennedy was built by Avco and was designed primarily to detect the presence of wake vortices as well as to measure their intensity. The acoustic echo system at Logan Airport was produced by Aerovironment Corp.

\textsuperscript{20} 1974 FAA REP. RD-74-3, at 115.
\textsuperscript{21} Id.
\textsuperscript{22} Id.
\textsuperscript{23} AVIATION WEEK & SPACE TECHNOLOGY, Mar. 8, 1976, at 44-45.
Although the acoustic systems utilized for wind shear measurements show a great deal of promise, it is known that heavy precipitation and strong surface winds will degrade or completely prevent the collection of good information. Consequently, it may be that acoustic sounders will have to be combined with other types of sensors in order to have an all-weather capability.  

B. Microwave Doppler Systems

If precipitation is present, Doppler radars operating in the microwave region can provide excellent measurements of the wind profile. Several studies of the detailed air flow within convective storms have been carried out and sharp shear zones have been readily identified. As demonstrated in Figures 3 and 4, sensitive radars detect certain portions of the clear atmosphere. Some sensitive radars have a Doppler capability and are thus able to obtain wind information in limited regions of the atmosphere. For operational purposes, however, microwave radars probably would not offer an economical means for the reliable measurement of wind shear under all conditions.

C. Laser Doppler Systems

Since lasers can detect the scattering from aerosols and molecules, it is feasible to consider a laser system for atmospheric probing, particularly when the sky is clear. Although non-Doppler laser techniques for measuring winds have been demonstrated, a Doppler laser system is highly desirable if profiles of wind are to be obtained efficiently. Successful use of Doppler laser systems for wake vortices has been demonstrated in programs supported by both NASA and FAA. At present the FAA is also testing a laser system for measuring wind shear at Kennedy Airport.

Despite the promise of several different systems for obtaining wind shear data reliably and economically, all of the proposed devices still have unknowns. The unknowns include the reliable availability of adequate tracers of the wind, the ability to operate under all types of meteorological conditions, and the accuracy with which the measurements can be made. There are, however, very

active research and experimental programs being carried out which relate to the development of an acceptable wind shear sensor particularly by the Wave Propagation Laboratory of NOAA. Since several of the techniques being tested show considerable promise, there is reason to be optimistic that an acceptable wind shear sensor for aircraft operations in the vicinity of airports will become available.

Wind shear has been an important factor in several aircraft incidents or accidents. Stuart A. Goldstein, an attorney for the Air Line Pilots Association, has prepared a short summary of two cases involving wind shear, and his report is included as an Appendix to this article.

**APPENDIX**

**WIND SHEAR AS A DEFENSE TO THE "CARELESS OR RECKLESS" CHARGE**

*By* **STUART A. GOLDSTEIN***

Two recent cases involving air carrier aircraft illustrate how wind shear, or other weather phenomena, may constitute an effective defense to a charge by the Federal Aviation Administration that the pilot acted in a careless or reckless manner. In both *Sharpe* and *Thayer and Lunsford* the aircraft were involved in incidents during approach in the vicinity of thunderstorms. In *Sharpe*, a DC-8-63F making a backcourse ILS approach to O'Hare airport descended to a point where it struck trees about one mile from the approach end of the runway. There was a thunderstorm approximately 300 feet to the left of the aircraft at the point where it experienced a sink. When the aircraft began to sink full power was applied immediately and the aircraft was rotated. Despite the

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*Aviation Week & Space Technology*, April 14, 1975, at 53-56.

*Mr. Goldstein is an attorney for the Air Line Pilots Association.


2 "No person may operate an aircraft in a careless or reckless manner so as to endanger the life or property of another." FAA Special Federal Aviation Regulations, 14 CFR § 91.9 (1975).
increase to full power and the rotation, the airspeed decreased 18-20 knots and the aircraft continued to sink for several seconds before it began to climb. The FAA proposed to suspend the captain's ATR for six months.

In Thayer and Lunsford a Boeing 727 was making an ASR (airport surveillance radar) approach at the New Orleans International Airport when it descended to a point where it struck trees about 1 1/2 miles from the end of the runway. The incident occurred at about 3 p.m. on a July afternoon when there were numerous thunderstorms in the area. The aircraft was in actual instrument conditions experiencing heavy rain and turbulence when the incident occurred. The pilots were maintaining an altitude at or slightly above the MDA (minimum descent altitude) of 400 feet when, approximately two miles from the end of the runway, the aircraft commenced a sudden descent. Although maximum power was applied at approximately 320 feet, the aircraft continued to sink before it began to climb. The first officer had been making the approach until the captain took over to initiate the go around. The airspeed decreased during the descent to 122 knots. It had been 162 knots twelve seconds prior to the commencement of the descent. The FAA proposed to suspend both pilots' certificates for a period of 60 days.

In cases of this nature the FAA relies on what has come to be known as the Lindstam Doctrine. Under this doctrine the FAA can meet its burden of proof and establish a prima facie case of negligence by circumstantial evidence, and is not required to allege or prove the specific act or acts of carelessness. Thus, the FAA need only present evidence of the circumstances surrounding an accident or incident, coupled with evidence ruling out causes other than pilot error, such as weather conditions or a malfunction of the aircraft or a component.

Typically, in a case such as Sharpe or Thayer and Lunsford, the FAA can easily establish the fact of the accident or incident and, if the aircraft does not crash, establish that it was functioning properly prior to the accident or incident. This may be all the FAA

\[3\] It is possible that the aircraft flew level for several seconds before it actually began to climb. Administrator v. Sharpe, NTSB Docket No. SE-2458, at 11 (Dec. 13, 1974).

\[4\] Administrator v. Lindstam, 41 CAB 841 (1964).
need do to establish a prima facie case. The burden then shifts to the pilot to present evidence showing that there is another reasonable explanation, apart from pilot error, for the accident or incident. “Thus, the central question to be resolved in these cases is whether carelessness is the only reasonable inference which can be drawn from the record.”

In both Sharpe and Thayer and Lunsford, the pilots presented testimony from a meteorologist who has a sub-speciality in severe storms, and an airline captain who is a recognized expert on the effects of wind shear on aircraft on approach. The FAA called no expert witnesses in either case. The pilots’ expert witnesses were able to present sufficient evidence to enable the NTSB to find that carelessness was not the only reasonable inference which could be drawn from the record, and the FAA’s orders of suspension in both cases were reversed and set aside.

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6 Conclusion of the Administrative Law Judge in Administrator v. Sharpe, Id. at 15.
Comments
and
Case Notes