AC 00-50A

DATE 1/23/79

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Washington, D.C.

Subject: LOW LEVEL WIND SHEAR

1. PURPOSE. This advisory circular is intended to provide guidance for recognizing the meteorological situations that produce the phenomenon widely known as low level wind shear. It describes both preflight and in-flight procedures for detecting and predicting this phenomenon as well as pilot techniques that minimize its effects when inadvertently encountered on takeoff or landing.

2, CANCELLATION. AC 00-50, dated April 8, 1976, is canceled.

3. BACKGROUND.

a. Wind shear is best described as a change in wind direction and/or speed in a very short distance in the atmosphere. Under certain conditions, the atmosphere is capable of producing some dramatic shears very close to the ground; for example, wind direction changes of 180 degrees and speed changes of 50 knots or more within 200 feet of the ground have been observed. It has been said that wind cannot affect an aircraft once it is flying except for drift and groundspeed. However, studies have shown that this is not true if the wind changes faster than the aircraft mass can be accelerated or decelerated.

b. The most prominent meteorological phenomena that cause significant low level wind shear problems are thunderstorms and certain frontal systems at or near the airport.

c. Appendix 1 contains a bibliography of FAA publications on wind shear.

Initiated by: AFS-220

4. METEOROLOGY.

a. Thunderstorms. The winds around a thunderstorm are complex (Figure 1). Wind shear can be found on all sides of a thunderstorm cell and in the downdraft directly under the cell. The wind shift line or gust front associated with thunderstorms can precede the actual storm by 15 nautical miles or more. Consequently, if a thunderstorm is near an airport of intended takeoff or landing, low level wind shear hazards may exist.

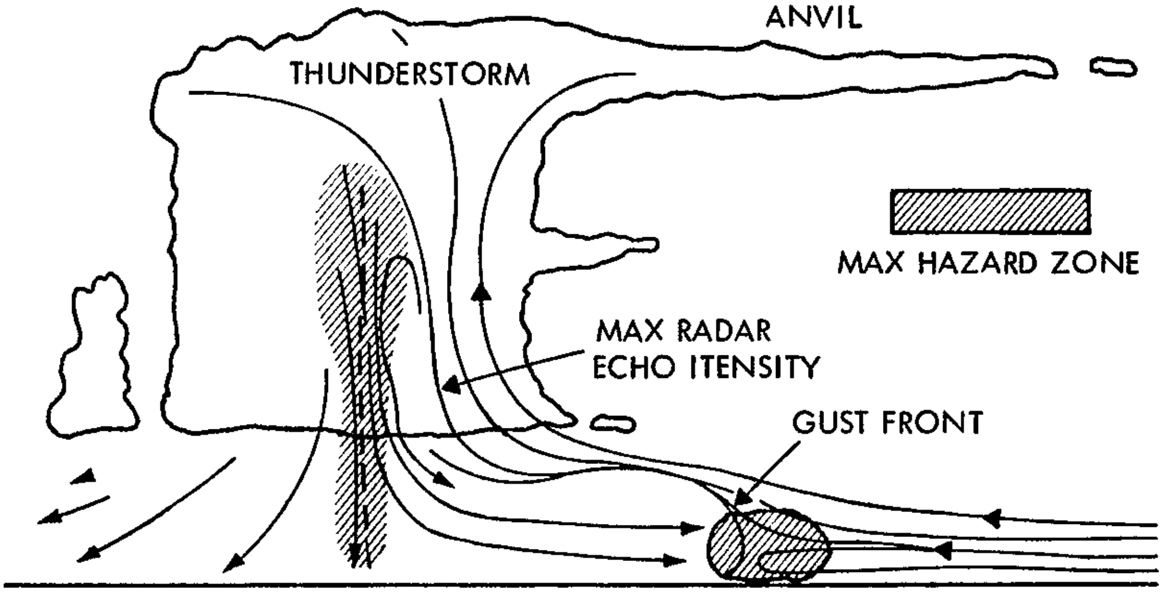

FIGURE 1. THUNDERSTORM HAZARD ZONES

b. Fronts. The winds can be significantly different in the two air masses which meet to form a front. While the direction of the winds above and below a front can be accurately determined, existing procedures do not provide precise, current measurements of the height of the front above the airport. The following is a method for determining the approximate height of the wind shear associated with a front.

(1) Wind shear occurs with a cold front just after the front passes the airport and for a short period thereafter. If the front is moving 30 knots or more, the frontal surface will usually be 5,000 feet above the airport about three hours after the frontal passage.

(2) With a warm front, the most critical period is before the front passes the airport. Warm front shear may exist below 5,000 feet for approximately six hours. The problem ceases to exist after the front passes the airport. Data compiled on wind shear indicates that the amount of shear in warm fronts is much greater than that found in cold fronts.

(3) Turbulence may or may not exist in wind shear conditions. If the surface wind under the front is strong and gusty, there will be some turbulence associated with wind shear.

c. Strong Surface Winds. The combination of strong winds and small hills or large buildings that lie upwind of the approach or departure path can produce localized areas of shear. Observing the local terrain and requesting pilot reports of conditions near the runway are the best means for anticipating wind shear from this source. This type of shear can be particularly hazardous to light airplanes.

d. Sea Breeze Fronts. The presence of large bodies of water can create local airflows due to the differences in temperature between the land and water. Changes in wind velocity and direction can occur in relatively short distances in the vicinity of airports situated near large lakes, bays or oceans.

e. Mountain Waves. These weather phenomena often create low level wind shear at airports that lie downwind of the wave. Altocumulus standing lenticular (ACSL) clouds usually depict the presence of mountain waves, and they are clues that shear should be anticipated.

5. DETECTING WIND SHEAR. Airplanes may not be capable of safely penetrating all intensities of low level wind shear. Pilots should, therefore, learn to detect, predict, and avoid severe wind shear conditions. Severe wind shear does not strike without warning. It can be detected by the following methods:

a. Analyze the weather during preflight.

(1) If thunderstorms are observed or forecast at or near the airport, be alert for the possibility of wind shear in the departure or arrival areas.

(2) Check the surface weather charts for frontal activity. Determine the surface temperature difference immediately across the front and the speed at which the front is moving. A 10° F [5° C] or greater temperature differential, and/or a frontal speed of 30 knots or more, is an indication of the possible existence of significant low level wind shear.

b. Be aware of pilot reports (PIREPS) of wind shear. Part 1 of the Airman's Information Manual recommends that pilots report any wind shear encounter to Air Traffic Control. This report should be in specific terms and include the loss/gain of airspeed due to the shear and the altitude(s) at which it was encountered. For example: "Denver tower, Cessna 1234 encountered wind shear, loss of 20 knots at 400 feet." This simple report is extremely important so that the pilot of the next airplane in sequence can determine the safety of transiting the same location. Reported shear that causes airspeed losses in excess of 15 to 20 knots should be avoided. Reported shears associated with a thunderstorm should also be avoided due to the speed which some storms move across the ground. The storm movement can cause one aircraft to encounter an airspeed increase which may appear harmless where the next aircraft can encounter a severe airspeed loss.

c. Assume that severe wind shear is present when the following conditions exist in combination.

(1) Extreme variations in wind velocity and direction in a relatively short time span.

(2) Evidence of a gust front such as blowing dust on the airport surface.

(3) Surface temperature in excess of 80°F.

(4) Dew point spread of 40°F or more.

(5) Virga (precipitation that falls from the bases of high altitude cumulus clouds but evaporates before reaching the ground).

d. Examine the approach or takeoff area with the airplane's radar set to determine if thunderstorm cells are in the vicinity of the airport. A departure or approach should not be flown through or under a thunderstorm cell.

e. Use the airplane instruments to detect wind shear.

(1) Pilots flying airplanes equipped with inertial navigation system (INS) should compare the winds at the initial approach altitude (1500-2000' above ground level (AGL)) with the reported runway surface winds to see if there is a wind shear situation between the airplane and the runway.

(2) If frontal activity does exist, note the surface wind direction to determine the location of the front with respect to the airport. If the airplane will traverse the front, compare the surface wind direction and speed with the wind direction and speed above the front to determine the potential wind shear during climbout or approach.

(3) Pilots flying airplanes equipped with a device which reads out groundspeed should compare the airplane's groundspeed with its airspeed. Any rapid changes in the relationship between airspeed and groundspeed represents a wind shear. Some operators have adopted the procedure of not allowing their aircraft to slow below a precomputed minimum groundspeed on approach. The minimum is computed by subtracting the surface headwind component from the true airspeed on approach.

(4) Pilots flying airplanes which do not have INS or groundspeed readouts should closely monitor their airplane's performance when wind shear is suspected. When the rate of descent on an ILS approach differs from the nominal values for the aircraft, the pilot should beware of a potential wind shear situation. Since rate of descent on the glide slope is directly related to groundspeed, a high descent rate would indicate a strong tailwind; conversely, a low descent rate denotes a strong headwind. The power needed to hold the glide slope also will be different from typical, no-shear conditions. Less power than normal will be needed to maintain the glide slope when a tailwind is present and more power is needed for a strong headwind. Aircraft pitch attitude is also an important indicator. A pitch attitude which is higher than normal is a good indicator of a strong headwind and vice versa. By observing the aircraft's approach parameters - rate of descent, power, and pitch attitude - the pilot can obtain a feel for the wind he is encountering. Being aware of the wind-correction angle needed to keep the localizer needle centered provides the pilot with an indication of wind direction. Comparing wind direction and velocity at the initial phases of the approach with the reported surface winds provides an excellent clue to the presence of shear before the phenomenon is actually encountered.

f. Utilize the Low Level Wind Shear Alert System (LLWSAS) at airports where it is available. LLWSAS consists of five or six anemometers around the periphery of the airport, which have their readouts automatically compared with the center field anemometer. If a wind vector difference of 15 knots or more exists between the center field anemometer and any peripheral anemometer, the tower will let the pilot know the winds from both locations. The pilot then may assess the potential for wind shear. An example of a severe wind shear alert would be the following: "Center field wind is 230 degrees at 7 knots; wind at the north end of Runway 35 is 180 degrees at 60 knots." In this case, a pilot departing on runway 35 would be taking off into an increasing tailwind condition that would result in significant losses of airspeed and, consequently, altitude.

6. AIRPLANE PERFORMANCE IN WIND SHEAR. The following information provides a basis for understanding the operational procedures recommended in this circular.

a. Power Compensation. Serious consequences may result on an approach when wind shear is encountered close to the ground after power adjustments have been already made to compensate for wind. Figures 2 and 3 illustrate the situations when power is applied or reduced to compensate for the change in aircraft performance caused by wind shear.

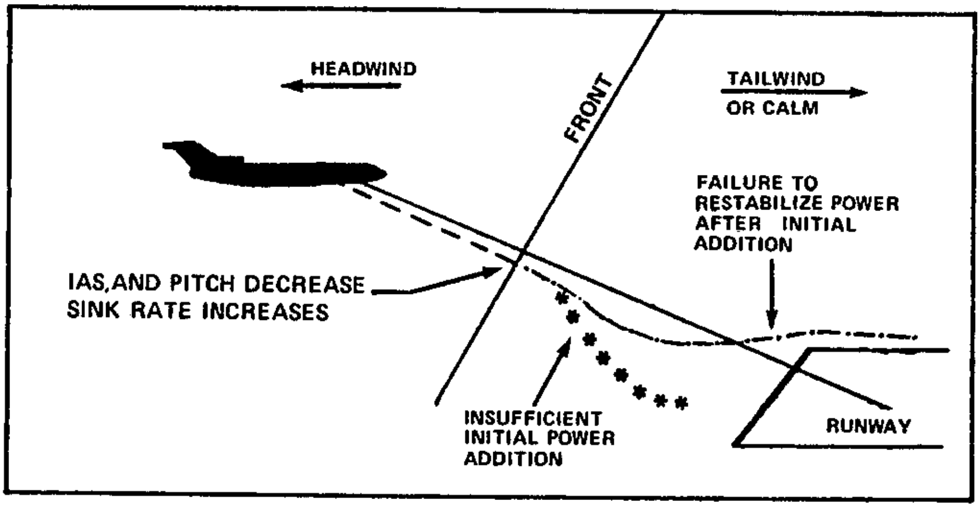

FIGURE 2. HEADWIND SHEARING TO TAILWIND OR CALM

(1) Consider an aircraft flying a 3° ILS on a stabilized approach at 140 knots indicated airspeed (IAS) with a 20-knot headwind. Assume that the aircraft encounters an instantaneous wind shear where the 20-knot headwind shears away completely. At that instant, several things will happen; the airspeed will drop from 140 to 120 knots, the nose will begin to pitch down, and the aircraft will begin to drop below the glide slope. The aircraft will then be both slow and low in a "power deficient" state. The pilot may then pull the nose up to a point even higher than before the shear in an effort to recapture the glide slope. This will aggravate the airspeed situation even further until the pilot advances the throttles and sufficient time elapses at the higher power setting for the engines to replenish the power deficiency. If the aircraft reaches the ground before the power deficiency is corrected, the landing will be short, slow, and hard. However, if there is sufficient time to regain the proper airspeed and glide slope before reaching the ground,

then the "double reverse" problem arises. This is because the throttles are set too high for a stabilized approach in a no-wind condition. So, as soon as the power deficiency is replenished, the throttles should be pulled back even further than they were before the shear (because power required for a 3° ILS in no wind is less than for a 20-knot headwind). If the pilot does not quickly retard the throttles, the aircraft will soon have an excess of power; i.e., it will be high and fast and may not be able to stop in the available runway length (Figure 2).

(2) When on approach in a tailwind condition that shears into a calm wind or headwind, the reverse of the previous statements is true. Initially, the IAS and pitch will increase and the aircraft will balloon above the glide slope. Power should initially be reduced to correct this condition or the approach may be high and fast with a danger of overshooting. However, after the initial power reduction is made and the aircraft is back on speed and glide slope, the "double reverse" again comes into play. An appropriate power increase will be necessary to restabilize in the headwind. If this power increase is not accomplished promptly, a high sink rate can develop and the landing may be short and hard (Figure 3). The double reverse problem arises primarily in downdraft and frontal passage shears. Other shears may require a consistent correction throughout the shear.

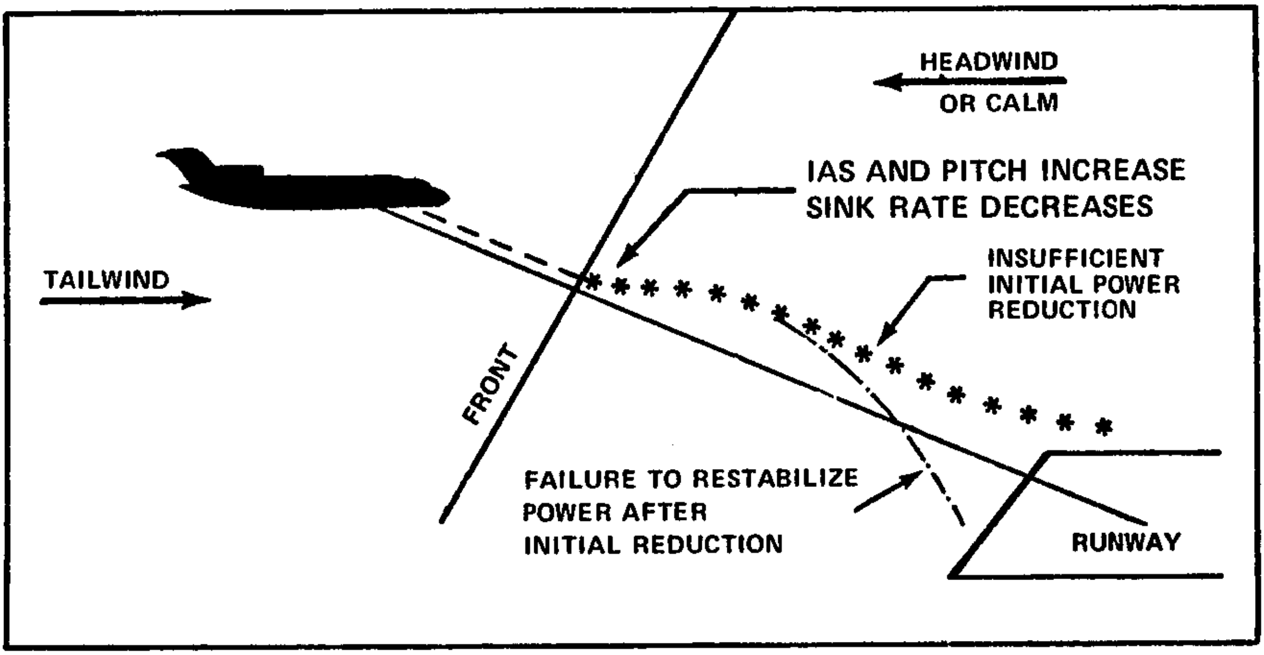

FIGURE 3. TAILWIND SHEARING TO HEADWIND OR CALM

(3) The classic thunderstorm "downburst cell" accident is illustrated in Figure 4. There is a strong downdraft in the center of the cell. There is often heavy rain in this vertical flow of air. As the vertical air flow nears the ground it turns 90 degrees and becomes a strong horizontal wind, flowing radially outward from the center. Point A in Figure 4 represents an aircraft which has not entered the cell's flow field. The aircraft is on speed and on glide slope. At Point B the aircraft encounters an increasing headwind. Its airspeed increases, and it balloons above the glide slope. Heavy rain may begin shortly. At Point C the "moment of truth" occurs. If the pilot does not fully appreciate the situation, he may attempt to regain the glide slope and lose excess airspeed by reducing power and pushing the nose down. Then in the short span of time between Points C and D the headwind ceases, a strong downdraft is entered and a tailwind begins increasing. The engines spool down, the airspeed drops below V_{ref}, and the sink rate becomes excessive. A missed approach initiated from this condition may not be successful. Note that a missed approach initiated at Point C (or sooner) would probably be successful since the aircraft is fast and high at this point. Note also that the pilot of an aircraft equipped with a groundspeed readout would see the telltale signs of a downburst cell shortly after Point B; i.e., rapidly increasing airspeed with decreasing groundspeed.

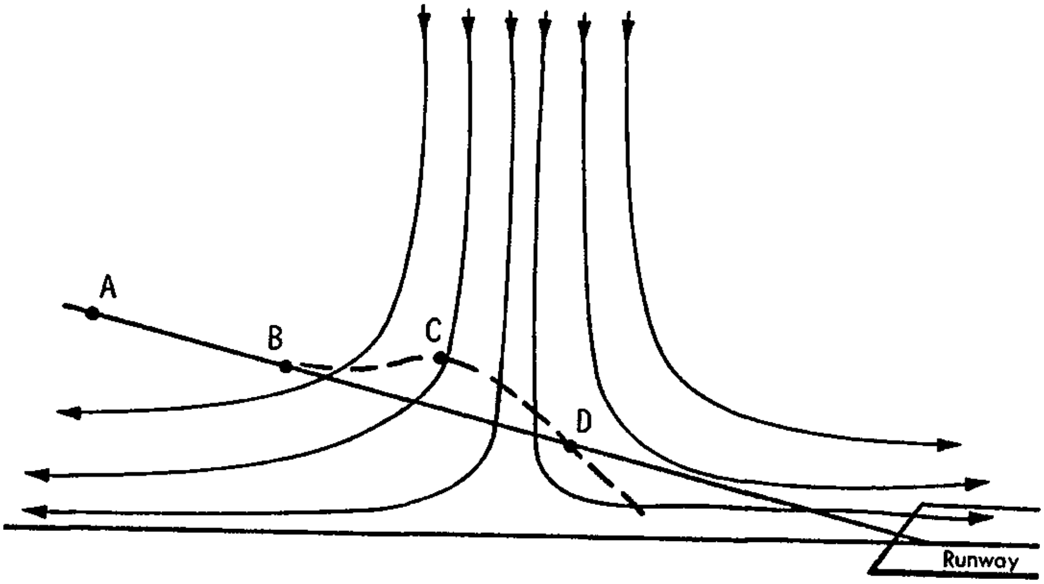

FIGURE 4. DOWNDRAFT SHEAR

b. Angle of Attack in a Downdraft. Downdrafts of falling air in a thunderstorm (sometimes called a "downburst") have gained attention in the last few years due to their role in wind shear accidents. When an airplane flies into a downdraft, the relative wind shifts so as to come down from above the horizon. This decreases angle of attack, which in turn decreases lift, and the airplane starts to sink rapidly. In order to regain the angle of attack necessary to support the weight of the airplane, the pitch attitude must be significantly increased. Such a pitch attitude may seem uncomfortably high to a pilot. However, a normal pitch attitude will result in a continued sink rate. The wing produces lift based on angle of attack - not pitch attitude. Caution should be observed when a pilot has traversed a downdraft and has pitched up sufficiently to stop the sink rate. If that pilot does not lower the nose of the airplane quickly when it exits the downdraft, the angle of attack will become too large and may approach the stall angle of attack. For these reasons, a flight director which senses angle of attack will be preferable to a flight director which calls for a fixed pitch attitude in a downdraft. However, even an angle of attack based flight director may become ineffective if it has an arbitrary pitch up command limit which is set too low (with respect to the downdraft).

c. Climb Performance. In the takeoff and landing configurations, jet transports climb best at speeds near V_2 and V_{ref} (reference speed with landing flaps), respectively. Retracting gear and flaps will even further improve climb performance. However, jet transport airplane manufacturers have pointed out that their airplanes still have substantial climb performance (generally in excess of 1000 fpm) at speeds down to stall warning or stickshaker speed, V_{ss}.

d. Energy Trade. There are only two ways an aircraft can correct for a wind shear. There can be an energy trade or a thrust change. Historically, most pilots have opted for a thrust change since they had no idea how much an energy trade would benefit them. Further information on the energy of flight, therefore, is warranted.

(1) The energy of motion (kinetic energy) is equal to $1/2\ MV^2$ where M is the mass of the airplane and V is the velocity. Kinetic energy is directly convertible to energy of vertical displacement (potential energy). More simply put, airspeed can be traded for altitude or vice versa. It is important to note that adding 10 percent to the speed of the airplane results in a 21 percent increase in kinetic energy because of the velocity being squared. This, of course, explains the concern over stopping an aircraft on the available runway when additional speed is added.

(2) The following table shows the altitude conversion capability of trading 10 or 20 knots of speed for altitude at various initial speeds. Independent of its mass, the capability of the aircraft to trade airspeed for altitude increases as its initial speed increases.

10 Knot Change From - To	Equivalent Altitude, Ft.	20 Knot Change From - To	Equivalent Altitude, Ft.
150-140	128	150-130	247
140-130	119	140-120	230
130-120	111	130-110	212
120-110	102	120-100	195
110-100	93	110-90	177

e. Trading Altitude for Speed. A pilot caught in low level wind shear who finds he is slower than the normal airspeed (even though he has gone to max power) could lower the nose and regain speed by trading away altitude. (This is trading potential energy for kinetic energy.) However, data shows that the penalty for doing this is severe; i.e., a large sink rate is built up and a great deal of altitude is lost for a relatively small increase in airspeed. Therefore, at low altitudes this alternative becomes undesirable. It is preferable to maintain the lower airspeed and rely on the airplane's climb performance at these lower speeds than to push the nose over and risk ground contact. Flight directors which attempt to maintain a given speed (such as V_2 + 10, etc.) will automatically call for trading altitude for airspeed if the airplane is below the proper airspeed. Cases have been observed in simulators where following such a flight director will result in the pilot flying the airplane into the ground. It is the pilot - not the flight director - who should decide if trading altitude for speed is desirable.

f. Trading Speed for Altitude. Conversely, a pilot caught in low level wind shear may pull the nose up and trade speed for altitude; i.e., trade kinetic energy for potential energy. If the speed is above V_2 or V_{ref} (as applicable), then this trade may well be desirable. If at or below V_2 or V_{ref}, such a trade should be attempted only in extreme circumstances. In doing so, the pilot is achieving a temporary increase in climb performance. After he has traded away all the airspeed he desires to trade, he will then be left with a permanent decrease in climb performance. In addition, if ground contact is still inevitable after the trade, there may be no airspeed margin left with which to flare in order to soften the impact. Wind shear simulations have shown, however, that in many cases trading airspeed for altitude (down to V_{SS}) prevented an accident, whereas maintaining V_{ref} resulted in ground impact.

g. Adding Speed for Wind Shear. The possibility of having to trade speed for altitude in wind shear makes it attractive to carry a great deal of extra speed. However, on landing, if the airspeed margin is not used up in the shear and the airplane touches down at an excessive speed, the airplane may not be able to stop on the available runway. It is generally agreed that if a speed margin in excess of 20 knots above V_{ref} appears to be required, the approach should not be attempted or continued.

h. Difficulties of Flying Near V_{ss}. Paragraph f stated that in simulations, wind shear "accidents" had been prevented by trading speed for altitude all the way down to V_{ss}. There are difficulties associated with flying at or near V_{ss} which should be recognized. These include:

(1) The pilot often does not know V_{ss}.

(2) The stickshaker mechanism may be miscalibrated (especially on older aircraft).

(3) The downdraft velocity may vary, which requires a change in pitch attitude to hold speed.

(4) It is hard to fly a precise airspeed in turbulence, which is often associated with wind shear.

(5) Turbulence might abruptly decrease the airspeed from V_{ss} to V_s.

(6) Pilots have historically had little training in maintaining flight at or near V_{ss}.

7. PROCEDURES FOR COPING WITH WIND SHEAR. The most important elements for the flightcrew in coping with a wind shear environment are the crew's awareness of an impending wind shear encounter and the crew's decision to avoid an encounter or to immediately respond if an encounter occurs.

a. Takeoff. If wind shear is expected on takeoff, the PIREPS and weather should be evaluated to determine if the phenomena can be safely traversed within the capability of the airplane. This is a judgment on the part of the pilot based on many factors. Wind shear is not something to be avoided at all costs, but rather to be assessed and avoided if severe. Some rules of thumb for coping with wind shear on takeoff follow:

(1) An increasing headwind or decreasing tailwind will cause an increase in indicated airspeed. If the wind shear is great enough, the aircraft will initially pitch up due to the increase in lift. The pilot should not trim the airplane at the initial high pitch attitude. After encountering the shear, if the wind remains constant, aircraft groundspeed will gradually decrease and indicated airspeed will return to its original value. This situation would normally lead to increased aircraft performance so it should not cause a problem if the pilot is aware of how this shear affects the aircraft.

(2) The worst situation on departure occurs when the aircraft encounters a rapidly increasing tailwind, decreasing headwind, and/or downdraft. Taking off under these circumstances would lead to a decreased performance condition. An increasing tailwind or decreasing headwind, when encountered, will cause a decrease in indicated airspeed. The aircraft will initially pitch down due to the decreased lift in proportion to the airspeed loss. After encountering the shear, if the wind remains constant, aircraft groundspeed will gradually increase and indicated airspeed will return to its original value.

(3) When the presence of severe wind shear is suspected for departure, the pilot should delay takeoff until conditions are more favorable.

(4) If the pilot judges the takeoff wind shear condition to be safe for departure, he should select the safest runway available considering runway length, wind directions, speed, and location of storm areas or frontal areas. He should execute a maximum power takeoff using the minimum acceptable flap position. After rotation, the pilot should maintain an airplane body angle which will result in an acceleration to V_2+25. This speed and takeoff flaps should be held through 1,000 feet AGL. Above 1,000 feet the normal noise abatement profile should be flown. If preflight planning shows that the airplane is runway length limited, or obstruction clearance is a problem, taking off into even a light shear using the V_2+25 procedure should not be attempted. This is because too much of the thrust available for climb is used for acceleration, resulting in the V_2+25 flight path falling below the engine-out flight path at V_2. This would give insufficient clearance for an obstacle in close proximity to the departure end of the runway.

(5) If severe wind shear is encountered on takeoff, the pilot should immediately confirm that maximum rated thrust is applied and trade the airspeed above V_2 (if any) for an increased rate of climb. Depending on the airplane's gross weight, pitch attitudes of 15 to 22 degrees are to be expected during this energy trade, especially if a downdraft is present. A sudden decrease in headwind will cause a loss in airspeed equal to the amount of wind shear. At this point, the pilot should quickly evaluate his airplane's performance in the shear. He/she should monitor airspeed and vertical velocity to ensure that an excessive rate of descent does not develop. If it becomes apparent that an unacceptable rate of descent cannot be prevented at V_2 speed or ground contact appears to be certain at the current descent rate, the pilot should gradually increase the airplane's pitch attitude to temporarily trade airspeed for climb capability to prevent further altitude loss. The trade should be terminated when stickshaker is encountered. The airplane should be held in an attitude that will maintain an airspeed just above the airspeed where the stickshaker was initially encountered. A general rule is to reduce pitch attitude very slightly when stickshaker is encountered. Further pitch reductions in the shear could result in a large descent rate. As the airplane departs the shear, the pilot should reduce the pitch attitude and establish a normal climb. In several recent wind shear accidents, the National Transportation Safety Board (NTSB) has found that the full performance capability of the airplane was not used following a severe wind shear encounter. Post accident studies have shown that, under similar circumstances, had flight techniques of an emergency nature (such as those outlined above) been used immediately, the airplane could have remained airborne and the accident averted.

b. Approach to Landing. Considerations involved in flying an approach and landing or go-around at an airport where wind shear is a factor are similar to those discussed for takeoff.

(1) When wind shear weather analysis, PIREPS, or an analysis of airplane performance indicates that a loss of airspeed will be experienced on an approach, the pilot should add to the V_{ref} speed as much airspeed as he expects to lose up to a maximum of $V_{ref}+20$. If the expected loss of airspeed exceeds 20 knots the approach should not be attempted unless the airplane is specially instrumented and the pilots are specially trained. The pilot should fly a stablized approach on a normal glidepath (using an electronic glidepath and the autopilot when available). In the shear when airspeed loss is encountered, a prompt and vigorous application of thrust is essential, keeping in mind that if airspeed has been previously added for the approach, the thrust application should be aimed at preventing airspeed loss below V_{ref}. An equally prompt and vigorous

reduction in thrust is necessary once the shear has been traversed and normal target speed and glidepath are reestablished to prevent exceeding desired values. Early recognition of the need for thrust is essential. Along with the thrust addition is a need for a noseup rotation to minimize departure below the glidepath. If the airplane is below 500 feet AGL and the approach becomes unstable, a go-around should be initiated immediately. Airspeed fluctations, sink rate, and glide slope deviation should be assessed as part of this decision.

(2) A pilot's chances of safely negotiating wind shear are better if he/she remains on instruments. Visual references through a rain-splattered windshield and reduced visibility may be inadequate to provide him/her with cues that would indicate deviation from the desired flightpath. At least one pilot should, therefore, maintain a continuous instrument scan until a safe landing is assured.

(3) Some autothrottle systems may not effectively respond to airspeed changes in a shear. Accordingly, the thrust should be monitored closely if autothrottles are used. Pilots should be alert to override the autothrottles if the response to increased thrust commands is too slow. Conversely, thrust levels should not be allowed to get too low during the late stages of an approach as this will increase the time needed to accelerate the engines.

(4) Should a go-around be required the pilot should initiate a normal go-around procedure, evaluate the performance of his airplane in the shear, and follow the procedures outlined in the takeoff section of this circular as applicable.

8. SUMMARY. The following summarizes the critical steps in coping with low level wind shear.

a. Be Prepared. Use all available forecasts and current weather information to anticipate wind shear. Also, make your own observations of thunderstorms, gust fronts and telltale indicators of wind direction and velocity available to pilots.

b. Giving and Requesting PIREPS on wind shear are essential. Request them and report anything you encounter. PIREPS should include:

(1) Location of shear encounter.

(2) Altitude of shear encounter.

(3) Airspeed changes experienced, with a clear statement of:

(i) the number of knots involved;

(ii) whether it was a gain or a loss of airspeed.

(4) Type of aircraft encountering the shear.

c. Avoid Known Areas of Severe Shear. When the weather and pilot reports indicate that severe wind shear is likely, delay your takeoff or approach.

d. Know Your Aircraft. Monitor the aircraft's power and flight parameters to detect the onset of a shear encounter. Know the performance limits of your particular aircraft so that they can be called upon in such an emergency situation.

e. Act Promptly. Do not allow a high sink rate to develop when attempting to recapture a glide slope or to maintain a given airspeed. When it appears that a shear encounter will result in a substantial rate of descent, promptly apply full power and arrest the descent with a noseup pitch attitude.

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APPENDIX 1. WIND SHEAR RELATED REPORTS

The following reports based on studies made of the wind shear problem are available from the National Technical Information Center, 5285 Port Royal Road, Springfield, Virginia 22216:

Report No.	Title	Report Date
FAA-RD-76-114	Wind Shear: A Literature Search, Analysis and Annotated Bibliography	Feb 1977
FAA-ED-15-2A	Engineering & Development Program Plan	Aug 1977
FAA-RD-77-36	Wind Shear Modeling for Aircraft Hazard Definition (Interim Report)	Mar 1977
FAA-RD-78-3	Wind Shear Modeling for Aircraft Hazard Definition (Final Report)	Mar 1978
FAA-RD-77-33	Wind Shear Characterization	Feb 1977
FAA-RD-77-166	Piloted Flight Simulation Study of Low-Level Wind Shear Phase I	May 1977
	" Phase II	June 1977
	" Phase III	April 1978
NASA-CR-3002	Turbulent Transport Model of Wind Shear in Thunderstorm Gust Fronts	May 1978
FAA-RD-77-184	Low-Level Frontal Wind Shear Forecasts Test Report	May 1978
FAA-RD-78	Gust Front Model Verification Study	Sep 1978
FAA-RD-77-135	Derivation of Groundspeed Information from Airborne DME Interrogators	Nov 1977

Report No.	Title	Report Date
FAA-RD-77-169	Large Aircraft Accident Analysis	December 1977
FAA-RD-77-119	Gust Front Analytical Study	December 1977
FAA-RD-78-7	Simulation and Analysis of the Wind Shear Hazard	December 1977
FAA-RD-77-120	Wind Shear Requirements and Their Application to Laser Systems	February 1978