Chapter 4

Slow Flight, Stalls, and Spins

INTRODUCTION

The maintenance of lift and control of an airplane in flight requires a certain minimum airspeed. This critical airspeed depends on certain factors, such as gross weight, load factors, and existing density altitude. The minimum speed below which further controlled flight is impossible is called the stalling speed. An important feature of pilot training is the development of the ability to estimate the margin of safety above the stalling speed. Also, the ability to determine the characteristic responses of any airplane at different airspeeds is of great importance to the pilot. The student pilot, therefore, must develop this awareness in order to safely avoid stalls and to operate an airplane correctly and safely at slow airspeeds.

SLOW FLIGHT

Slow flight could be thought of, by some, as a speed that is less than cruise. In pilot training and testing, however, slow flight is broken down into two distinct elements: (1) the establishment, maintenance of, and maneuvering of the airplane at airspeeds and in configurations appropriate to takeoffs, climbs, descents, landing approaches and go-arounds, and, (2) maneuvering at the slowest airspeed at which the airplane is capable of maintaining controlled flight without indications of a stall—usually 3 to 5 knots above stalling speed.

FLIGHT AT LESS THAN CRUISE AIRSPEEDS

Maneuvering during slow flight demonstrates the flight characteristics and degree of controllability of an airplane at less than cruise speeds. The ability to determine the characteristic control responses at the lower airspeeds appropriate to takeoffs, departures, and landing approaches is a critical factor in stall awareness.

As airspeed decreases, control effectiveness decreases disproportionately. For instance, there may be a certain loss of effectiveness when the airspeed is reduced from 30 to 20 m.p.h. above the stalling speed, but there will normally be a much greater loss as the airspeed is further reduced to 10 m.p.h. above stalling. The objective of maneuvering during slow flight is to develop the pilot's sense of feel and ability to use the controls correctly, and to improve proficiency in performing maneuvers that require slow airspeeds.

Maneuvering during slow flight should be performed using both instrument indications and outside visual reference. Slow flight should be practiced from straight glides, straight-and-level flight, and from medium banked gliding and level flight turns. Slow flight at approach speeds should include slowing the airplane smoothly and promptly from cruising to approach speeds without changes in altitude or heading, and determining and using appropriate power and trim settings. Slow flight at approach speed should also include configuration changes, such as landing gear and flaps, while maintaining heading and altitude.

FLIGHT AT MINIMUM CONTROLLABLE AIRSPEED

This maneuver demonstrates the flight characteristics and degree of controllability of the airplane at its *minimum* flying speed. By definition, the term "flight at minimum controllable airspeed" means a speed at which any further increase in angle of attack or load factor, or reduction in power will cause an immediate stall. Instruction in flight at minimum controllable airspeed should be introduced at reduced power settings, with the airspeed sufficiently above the stall to permit maneuvering, but close enough to the stall to sense the characteristics of flight at very low airspeed—which are sloppy controls, ragged response to control inputs, and difficulty maintaining altitude. Maneuvering at minimum controllable airspeed should be performed using both instrument indications and outside visual reference. It is important that pilots form the habit of frequent reference to the flight instruments, especially the airspeed indicator, while flying at very low airspeeds. However, a "feel" for the airplane at very low airspeeds must be developed to avoid inadvertent stalls and to operate the airplane with precision.

To begin the maneuver, the throttle is gradually reduced from cruising position. While the airspeed is decreasing, the position of the nose in relation to the horizon should be noted and should be raised as necessary to maintain altitude.

When the airspeed reaches the maximum allowable for landing gear operation, the landing gear (if equipped with retractable gear) should be extended and all gear down checks performed. As the airspeed reaches the maximum allowable for flap operation, full flaps

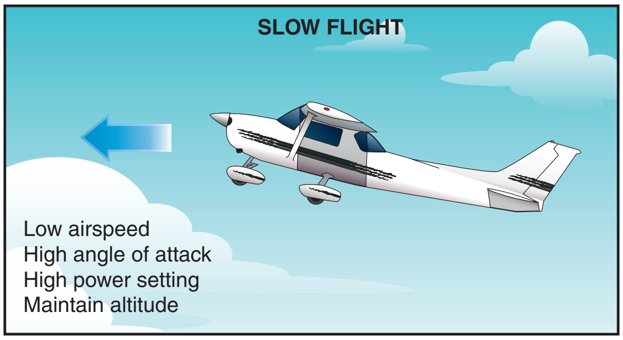

Figure 4-1. Slow flight—Low airspeed, high angle of attack, high power, and constant altitude.

should be lowered and the pitch attitude adjusted to maintain altitude. [Figure 4-1] Additional power will be required as the speed further decreases to maintain the airspeed just above a stall. As the speed decreases further, the pilot should note the feel of the flight controls, especially the elevator. The pilot should also note the sound of the airflow as it falls off in tone level.

As airspeed is reduced, the flight controls become less effective and the normal nosedown tendency is reduced. The elevators become less responsive and coarse control movements become necessary to retain control of the airplane. The slipstream effect produces a strong yaw so the application of rudder is required to maintain coordinated flight. The secondary effect of applied rudder is to induce a roll, so aileron is required to keep the wings level. This can result in flying with crossed controls.

During these changing flight conditions, it is important to retrim the airplane as often as necessary to compensate for changes in control pressures. If the airplane has been trimmed for cruising speed, heavy aft control pressure will be needed on the elevators, making precise control impossible. If too much speed is lost, or too little power is used, further back pressure on the elevator control may result in a loss of altitude or a stall. When the desired pitch attitude and minimum control airspeed have been established, it is important to continually cross-check the attitude indicator, altimeter, and airspeed indicator, as well as outside references to ensure that accurate control is being maintained.

The pilot should understand that when flying more slowly than **minimum drag speed ($LD/_{MAX}$)** the airplane will exhibit a characteristic known as "**speed instability**." If the airplane is disturbed by even the slightest turbulence, the airspeed will decrease. As airspeed decreases, the total drag also increases resulting in a further loss in airspeed. The total drag continues to rise and the speed continues to fall. Unless more power is applied and/or the nose is lowered, the speed will continue to decay right down to the stall. This is an extremely important factor in the performance of slow flight. The pilot must understand that, at speed less than minimum drag speed, the airspeed is unstable and will continue to decay if allowed to do so.

When the attitude, airspeed, and power have been stabilized in straight flight, turns should be practiced to determine the airplane's controllability characteristics at this minimum speed. During the turns, power and pitch attitude may need to be increased to maintain the airspeed and altitude. The objective is to acquaint the pilot with the lack of maneuverability at minimum speeds, the danger of incipient stalls, and the tendency of the airplane to stall as the bank is increased. A stall may also occur as a result of abrupt or rough control movements when flying at this critical airspeed.

Abruptly raising the flaps while at minimum controllable airspeed will result in lift suddenly being lost, causing the airplane to lose altitude or perhaps stall.

Once flight at minimum controllable airspeed is set up properly for level flight, a descent or climb at minimum controllable airspeed can be established by adjusting the power as necessary to establish the desired rate of descent or climb. The beginning pilot should note the increased yawing tendency at minimum control airspeed at high power settings with flaps fully extended. In some airplanes, an attempt to climb at such a slow airspeed may result in a *loss* of altitude, even with maximum power applied.

Common errors in the performance of slow flight are:

- Failure to adequately clear the area.
- Inadequate back-elevator pressure as power is reduced, resulting in altitude loss.
- Excessive back-elevator pressure as power is reduced, resulting in a climb, followed by a rapid reduction in airspeed and "mushing."
- Inadequate compensation for adverse yaw during turns.
- Fixation on the airspeed indicator.
- Failure to anticipate changes in lift as flaps are extended or retracted.
- Inadequate power management.
- Inability to adequately divide attention between airplane control and orientation.

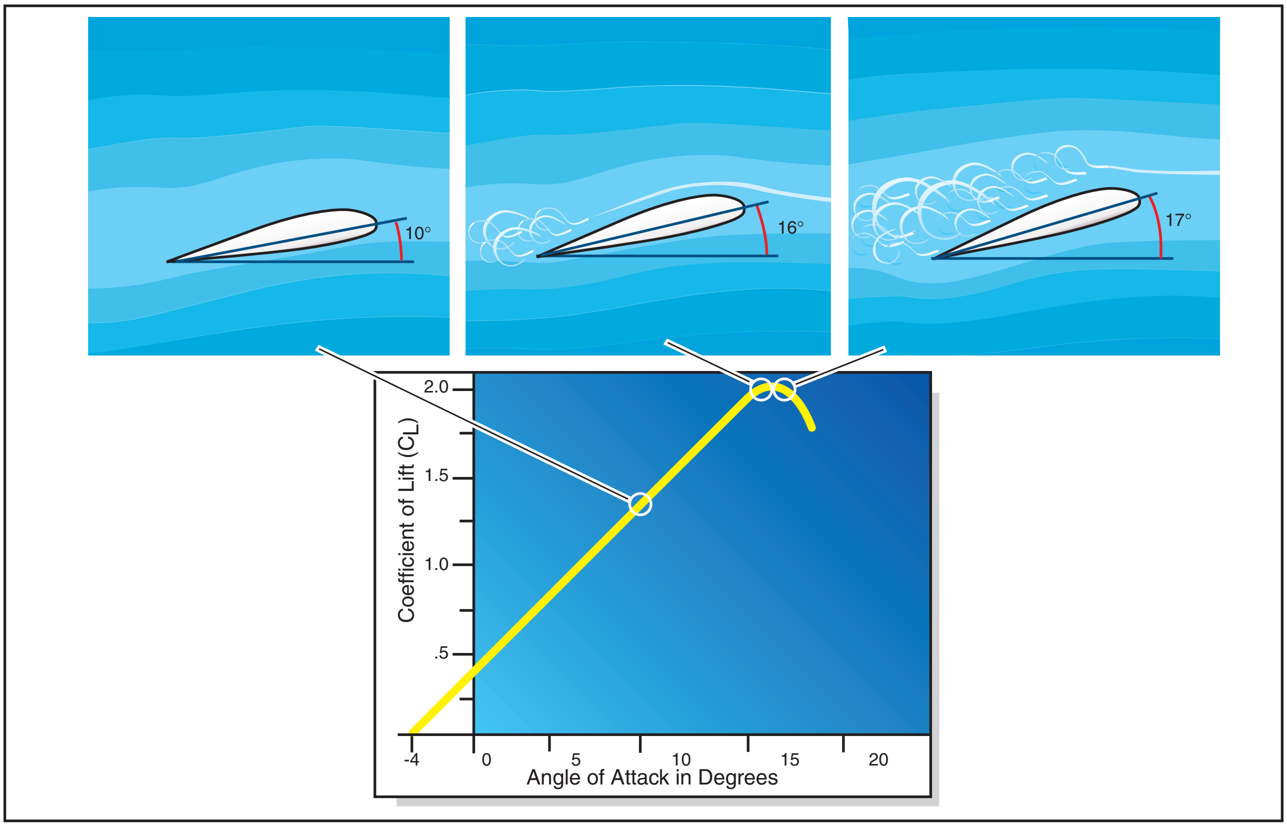

Figure 4-2. Critical angle of attack and stall.

STALLS

A stall occurs when the smooth airflow over the airplane's wing is disrupted, and the lift degenerates rapidly. This is caused when the wing exceeds its critical angle of attack. This can occur at any airspeed, in any attitude, with any power setting. [Figure 4-2]

The practice of stall recovery and the development of awareness of stalls are of primary importance in pilot training. The objectives in performing intentional stalls are to familiarize the pilot with the conditions that produce stalls, to assist in recognizing an approaching stall, and to develop the habit of taking prompt preventive or corrective action.

Intentional stalls should be performed at an altitude that will provide adequate height above the ground for recovery and return to normal level flight. Though it depends on the degree to which a stall has progressed, most stalls require some loss of altitude during recovery. The longer it takes to recognize the approaching stall, the more complete the stall is likely to become, and the greater the loss of altitude to be expected.

RECOGNITION OF STALLS

Pilots must recognize the flight conditions that are conducive to stalls and know how to apply the necessary corrective action. They should learn to recognize an approaching stall by sight, sound, and feel. The following cues may be useful in recognizing the approaching stall.

- Vision is useful in detecting a stall condition by noting the attitude of the airplane. This sense can only be relied on when the stall is the result of an unusual attitude of the airplane. Since the airplane can also be stalled from a normal attitude, vision in this instance would be of little help in detecting the approaching stall.
- Hearing is also helpful in sensing a stall condition. In the case of fixed-pitch propeller airplanes in a power-on condition, a change in sound due to loss of revolutions per minute (r.p.m.) is particularly noticeable. The lessening of the noise made by the air flowing along the airplane structure as airspeed decreases is also quite noticeable, and when the stall is almost complete, vibration and incident noises often increase greatly.
- Kinesthesia, or the sensing of changes in direction or speed of motion, is probably the most important and the best indicator to the trained and experienced pilot. If this sensitivity is properly developed, it will warn of a decrease in speed or the beginning of a settling or mushing of the airplane.
- Feel is an important sense in recognizing the onset of a stall. The feeling of control pressures is very important. As speed is reduced, the resistance to pressures on the controls becomes progressively less. Pressures exerted on the controls tend to become movements of the control surfaces. The

lag between these movements and the response of the airplane becomes greater, until in a complete stall all controls can be moved with almost no resistance, and with little immediate effect on the airplane. Just before the stall occurs, buffeting, uncontrollable pitching, or vibrations may begin.

Several types of stall warning indicators have been developed to warn pilots of an approaching stall. The use of such indicators is valuable and desirable, but the reason for practicing stalls is to learn to recognize stalls without the benefit of warning devices.

FUNDAMENTALS OF STALL RECOVERY

During the practice of intentional stalls, the real objective is not to learn how to stall an airplane, but to learn how to recognize an approaching stall and take prompt corrective action. [Figure 4-3] Though the recovery actions must be taken in a coordinated manner, they are broken down into three actions here for explanation purposes.

First, at the indication of a stall, the pitch attitude and angle of attack must be decreased positively and immediately. Since the basic cause of a stall is always an excessive angle of attack, the cause must first be eliminated by releasing the back-elevator pressure that was necessary to attain that angle of attack or by moving the elevator control forward. This lowers the nose and returns the wing to an effective angle of attack. The amount of elevator control pressure or movement used depends on the design of the airplane, the severity of the stall, and the proximity of the ground. In some airplanes, a moderate movement of the elevator control—perhaps slightly forward of neutral—is enough, while in others a forcible push to the full forward position may be required. An excessive negative load on the wings caused by excessive forward movement of the elevator may impede, rather than hasten, the stall recovery. The object is to reduce the angle of attack but only enough to allow the wing to regain lift.

Second, the maximum allowable power should be applied to increase the airplane's airspeed and assist in reducing the wing's angle of attack. The throttle should be promptly, but smoothly, advanced to the maximum allowable power. The flight instructor

Figure 4-3. Stall recognition and recovery.

should emphasize, however, that power is not essential for a safe stall recovery if sufficient altitude is available. Reducing the angle of attack is the only way of recovering from a stall regardless of the amount of power used.

Although stall recoveries should be practiced without, as well as with the use of power, in most actual stalls the application of more power, if available, is an integral part of the stall recovery. Usually, the greater the power applied, the less the loss of altitude.

Maximum allowable power applied at the instant of a stall will usually not cause overspeeding of an engine equipped with a fixed-pitch propeller, due to the heavy air load imposed on the propeller at slow airspeeds. However, it will be necessary to reduce the power as airspeed is gained after the stall recovery so the airspeed will not become excessive. When performing intentional stalls, the tachometer indication should never be allowed to exceed the red line (maximum allowable r.p.m.) marked on the instrument.

Third, straight-and-level flight should be regained with coordinated use of all controls.

Practice in both power-on and power-off stalls is important because it simulates stall conditions that could occur during normal flight maneuvers. For example, the power-on stalls are practiced to show what could happen if the airplane were climbing at an excessively nose-high attitude immediately after takeoff or during a climbing turn. The power-off turning stalls are practiced to show what could happen if the controls are improperly used during a turn from the base leg to the final approach. The power-off straight-ahead stall simulates the attitude and flight characteristics of a particular airplane during the final approach and landing.

Usually, the first few practices should include only approaches to stalls, with recovery initiated as soon as the first buffeting or partial loss of control is noted. In this way, the pilot can become familiar with the indications of an approaching stall without actually stalling the airplane. Once the pilot becomes comfortable with this procedure, the airplane should be slowed in such a manner that it stalls in as near a level pitch attitude as is possible. The student pilot must not be allowed to form the impression that in all circumstances, a high pitch attitude is necessary to exceed the critical angle of attack, or that in all circumstances, a level or near level pitch attitude is indicative of a low angle of attack. Recovery should be practiced first *without* the addition of power, by merely relieving enough back-elevator pressure that the stall is broken and the airplane assumes a normal glide attitude. The instructor should also introduce the student to a secondary stall at this point. Stall recoveries should then be practiced with the addition of power to determine how effective power will be in executing a safe recovery and minimizing altitude loss.

Stall accidents usually result from an inadvertent stall at a low altitude in which a recovery was not accomplished prior to contact with the surface. As a preventive measure, stalls should be practiced at an altitude which will allow recovery no lower than 1,500 feet AGL. To recover with a minimum loss of altitude requires a reduction in the angle of attack (lowering the airplane's pitch attitude), application of power, and termination of the descent without entering another (secondary) stall.

USE OF AILERONS/RUDDER IN STALL RECOVERY

Different types of airplanes have different stall characteristics. Most airplanes are designed so that the wings will stall progressively outward from the wing roots (where the wing attaches to the fuselage) to the wingtips. This is the result of designing the wings in a manner that the wingtips have less angle of incidence than the wing roots. [Figure 4-4] Such a design feature causes the wingtips to have a smaller angle of attack than the wing roots during flight.

Figure 4-4. Wingtip washout.

Exceeding the critical angle of attack causes a stall; the wing roots of an airplane will exceed the critical angle before the wingtips, and the wing roots will stall first. The wings are designed in this manner so that aileron control will be available at high angles of attack (slow airspeed) and give the airplane more stable stalling characteristics.

When the airplane is in a stalled condition, the wingtips continue to provide some degree of lift, and the ailerons still have some control effect. During recovery from a stall, the return of lift begins at the tips and progresses toward the roots. Thus, the ailerons can be used to level the wings.

Using the ailerons requires finesse to avoid an aggravated stall condition. For example, if the right wing dropped during the stall and excessive aileron control were applied to the left to raise the wing, the aileron deflected downward (right wing) would produce a greater angle of attack (and drag), and possibly a more complete stall at the tip as the critical angle of attack is exceeded. The increase in drag created by the high angle of attack on that wing might cause the airplane to yaw in that direction. This adverse yaw could result in a spin unless directional control was maintained by rudder, and/or the aileron control sufficiently reduced.

Even though excessive aileron pressure may have been applied, a spin will not occur if directional (yaw) control is maintained by timely application of coordinated rudder pressure. Therefore, it is important that the rudder be used properly during both the entry and the recovery from a stall. The primary use of the rudder in stall recoveries is to counteract any tendency of the airplane to yaw or slip. The correct recovery technique would be to decrease the pitch attitude by applying forward-elevator pressure to break the stall, advancing the throttle to increase airspeed, and simultaneously maintaining directional control with coordinated use of the aileron and rudder.

STALL CHARACTERISTICS

Because of engineering design variations, the stall characteristics for all airplanes cannot be specifically described; however, the similarities found in small general aviation training-type airplanes are noteworthy enough to be considered. It will be noted that the power-on and power-off stall warning indications will be different. The power-off stall will have less noticeable clues (buffeting, shaking) than the power-on stall. In the power-off stall, the predominant clue can be the elevator control position (full up-elevator against the stops) and a high descent rate. When performing the power-on stall, the buffeting will likely be the predominant clue that provides a positive indication of the stall. For the purpose of airplane certification, the stall warning may be furnished either through the inherent aerodynamic qualities of the airplane, or by a stall warning device that will give a clear distinguishable indication of the stall. Most airplanes are equipped with a stall warning device.

The factors that affect the stalling characteristics of the airplane are balance, bank, pitch attitude, coordination, drag, and power. The pilot should learn the effect of the stall characteristics of the airplane being flown and the proper correction. It should be reemphasized that a stall can occur at any airspeed, in any attitude, or at any power setting, depending on the total number of factors affecting the particular airplane.

A number of factors may be induced as the result of other factors. For example, when the airplane is in a nose-high turning attitude, the angle of bank has a tendency to increase. This occurs because with the airspeed decreasing, the airplane begins flying in a smaller and smaller arc. Since the outer wing is moving in a larger radius and traveling faster than the inner wing, it has more lift and causes an overbanking tendency. At the same time, because of the decreasing airspeed and lift on both wings, the pitch attitude tends to lower. In addition, since the airspeed is decreasing while the power setting remains constant, the effect of torque becomes more prominent, causing the airplane to yaw.

During the practice of power-on turning stalls, to compensate for these factors and to maintain a constant flight attitude until the stall occurs, aileron pressure must be continually adjusted to keep the bank attitude constant. At the same time, back-elevator pressure must be continually increased to maintain the pitch attitude, as well as right rudder pressure increased to keep the ball centered and to prevent adverse yaw from changing the turn rate. If the bank is allowed to become too steep, the vertical component of lift decreases and makes it even more difficult to maintain a constant pitch attitude.

Whenever practicing turning stalls, a constant pitch and bank attitude should be maintained until the stall occurs. Whatever control pressures are necessary should be applied even though the controls appear to be crossed (aileron pressure in one direction, rudder pressure in the opposite direction). During the entry to a power-on turning stall to the right, in particular, the controls will be crossed to some extent. This is due to right rudder pressure being used to overcome torque and left aileron pressure being used to prevent the bank from increasing.

APPROACHES TO STALLS (IMMINENT STALLS)—POWER-ON OR POWER-OFF

An imminent stall is one in which the airplane is approaching a stall but is not allowed to completely stall. This stall maneuver is primarily for practice in retaining (or regaining) full control of the airplane immediately upon recognizing that it is almost in a stall or that a stall is likely to occur if timely preventive action is not taken.

The practice of these stalls is of particular value in developing the pilot's sense of feel for executing maneuvers in which maximum airplane performance is required. These maneuvers require flight with the airplane approaching a stall, and recovery initiated before a stall occurs. As in all maneuvers that involve significant changes in altitude or direction, the pilot must ensure that the area is clear of other air traffic before executing the maneuver.

These stalls may be entered and performed in the attitudes and with the same configuration of the basic full stalls or other maneuvers described in this chapter. However, instead of allowing a complete stall, when the first buffeting or decay of control effectiveness is noted, the angle of attack must be reduced immediately by releasing the back-elevator pressure and applying whatever additional power is necessary. Since the airplane will not be completely stalled, the pitch attitude needs to be decreased only to a point where minimum controllable airspeed is attained or until adequate control effectiveness is regained.

The pilot must promptly recognize the indication of a stall and take timely, positive control action to prevent a full stall. Performance is unsatisfactory if a full stall occurs, if an excessively low pitch attitude is attained, or if the pilot fails to take timely action to avoid excessive airspeed, excessive loss of altitude, or a spin.

FULL STALLS POWER-OFF

The practice of power-off stalls is usually performed with normal landing approach conditions in simulation of an accidental stall occurring during landing approaches. Airplanes equipped with flaps and/or retractable landing gear should be in the landing configuration. Airspeed in excess of the normal approach speed should not be carried into a stall entry since it could result in an abnormally nose-high attitude. Before executing these practice stalls, the pilot must be sure the area is clear of other air traffic.

After extending the landing gear, applying carburetor heat (if applicable), and retarding the throttle to idle (or normal approach power), the airplane should be held at a constant altitude in level flight until the airspeed decelerates to that of a normal approach. The airplane should then be smoothly nosed down into the normal approach attitude to maintain that airspeed. Wing flaps should be extended and pitch attitude adjusted to maintain the airspeed.

When the approach attitude and airspeed have stabilized, the airplane's nose should be smoothly raised to an attitude that will induce a stall. Directional control should be maintained with the rudder, the wings held level by use of the ailerons, and a constant-pitch attitude maintained with the elevator until the stall occurs. The stall will be recognized by clues, such as full up-elevator, high descent rate, uncontrollable nosedown pitching, and possible buffeting.

Recovering from the stall should be accomplished by reducing the angle of attack, releasing back-elevator pressure, and advancing the throttle to maximum allowable power. Right rudder pressure is necessary to overcome the engine torque effects as power is advanced and the nose is being lowered. [Figure 4-5]

The nose should be lowered as necessary to regain flying speed and returned to straight-and-level flight

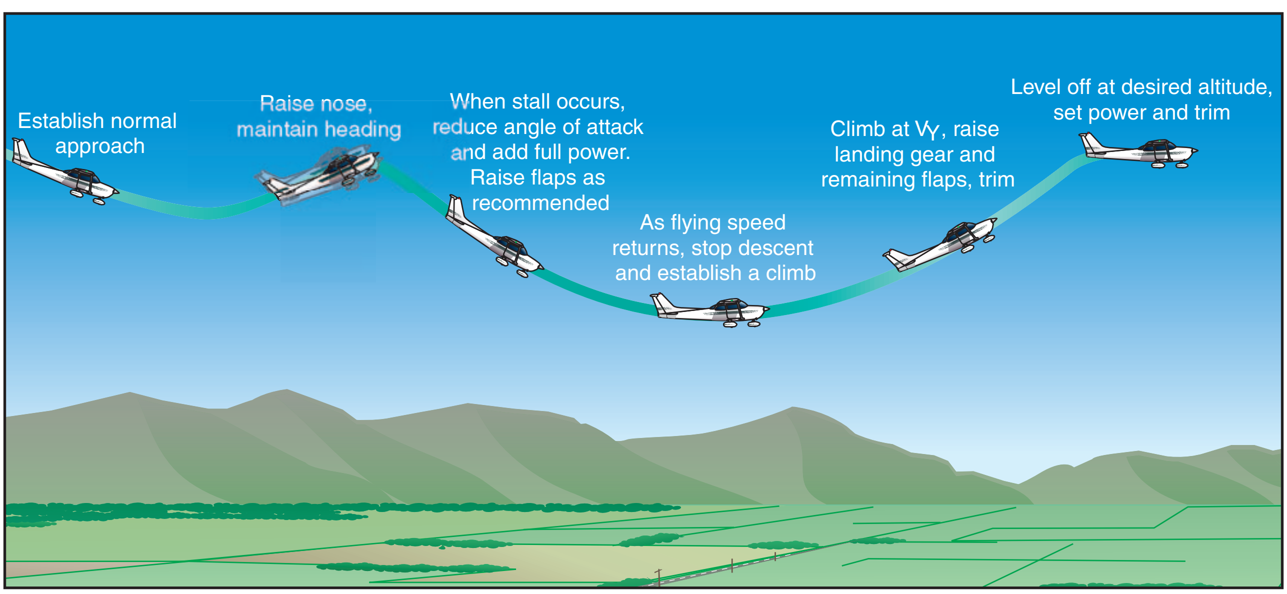

Figure 4-5. Power-off stall and recovery.

attitude. After establishing a positive rate of climb, the flaps and landing gear are retracted, as necessary, and when in level flight, the throttle should be returned to cruise power setting. After recovery is complete, a climb or go-around procedure should be initiated, as the situation dictates, to assure a minimum loss of altitude.

Recovery from power-off stalls should also be practiced from shallow banked turns to simulate an inadvertent stall during a turn from base leg to final approach. During the practice of these stalls, care should be taken that the turn continues at a uniform rate until the complete stall occurs. If the power-off turn is not properly coordinated while approaching the stall, wallowing may result when the stall occurs. If the airplane is in a slip, the outer wing may stall first and whip downward abruptly. This does not affect the recovery procedure in any way; the angle of attack must be reduced, the heading maintained, and the wings leveled by coordinated use of the controls. In the practice of turning stalls, no attempt should be made to stall the airplane on a predetermined heading. However, to simulate a turn from base to final approach, the stall normally should be made to occur within a heading change of approximately 90°.

After the stall occurs, the recovery should be made straight ahead with minimum loss of altitude, and accomplished in accordance with the recovery procedure discussed earlier.

Recoveries from power-off stalls should be accomplished both with, and without, the addition of power, and may be initiated either just after the stall occurs, or after the nose has pitched down through the level flight attitude.

FULL STALLS POWER-ON

Power-on stall recoveries are practiced from straight climbs, and climbing turns with 15 to 20° banks, to simulate an accidental stall occurring during takeoffs and climbs. Airplanes equipped with flaps and/or retractable landing gear should normally be in the takeoff configuration; however, power-on stalls should also be practiced with the airplane in a clean configuration (flaps and/or gear retracted) as in departure and normal climbs.

After establishing the takeoff or climb configuration, the airplane should be slowed to the normal lift-off speed while clearing the area for other air traffic. When the desired speed is attained, the power should be set at takeoff power for the takeoff stall or the recommended climb power for the departure stall while establishing a climb attitude. The purpose of reducing the airspeed to lift-off airspeed before the throttle is advanced to the recommended setting is to avoid an excessively steep nose-up attitude for a long period before the airplane stalls.

After the climb attitude is established, the nose is then brought smoothly upward to an attitude obviously impossible for the airplane to maintain and is held at that attitude until the full stall occurs. In most airplanes, after attaining the stalling attitude, the elevator control must be moved progressively further back as the airspeed decreases until, at the full stall, it will have reached its limit and cannot be moved back any farther.

Recovery from the stall should be accomplished by immediately reducing the angle of attack by positively

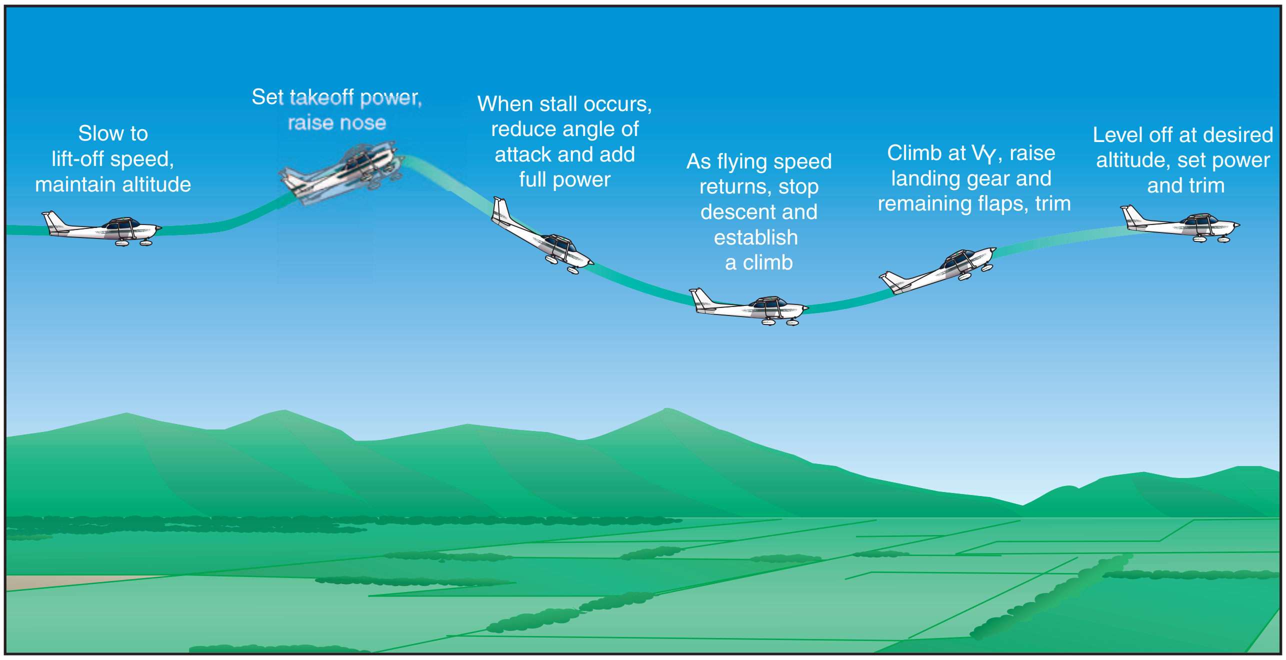

Figure 4-6. Power-on stall.

releasing back-elevator pressure and, in the case of a departure stall, smoothly advancing the throttle to maximum allowable power. In this case, since the throttle is already at the climb power setting, the addition of power will be relatively slight. [Figure 4-6]

The nose should be lowered as necessary to regain flying speed with the minimum loss of altitude and then raised to climb attitude. Then, the airplane should be returned to the normal straight-and-level flight attitude, and when in normal level flight, the throttle should be returned to cruise power setting. The pilot must recognize instantly when the stall has occurred and take prompt action to prevent a prolonged stalled condition.

SECONDARY STALL

This stall is called a secondary stall since it may occur after a recovery from a preceding stall. It is caused by attempting to hasten the completion of a stall recovery before the airplane has regained sufficient flying speed. [Figure 4-7] When this stall occurs, the back-elevator pressure should again be released just as in a normal stall recovery. When sufficient airspeed has been regained, the airplane can then be returned to straight-and-level flight.

This stall usually occurs when the pilot uses abrupt control input to return to straight-and-level flight after a stall or spin recovery. It also occurs when the pilot fails to reduce the angle of attack sufficiently during stall recovery by not lowering pitch attitude sufficiently, or by attempting to break the stall by using power only.

ACCELERATED STALLS

Though the stalls just discussed normally occur at a specific airspeed, the pilot must thoroughly understand that all stalls result solely from attempts to fly at excessively high angles of attack. During flight, the angle of attack of an airplane wing is determined by a number of factors, the most important of which are the airspeed, the gross weight of the airplane, and the load factors imposed by maneuvering.

At the same gross weight, airplane configuration, and power setting, a given airplane will consistently stall at the same indicated airspeed if no acceleration is involved. The airplane will, however, stall at a higher indicated airspeed when excessive maneuvering loads are imposed by steep turns, pull-ups, or other abrupt changes in its flightpath. Stalls entered from such flight situations are called "accelerated maneuver stalls," a term, which has no reference to the airspeeds involved.

Stalls which result from abrupt maneuvers tend to be more rapid, or severe, than the unaccelerated stalls, and because they occur at higher-than-normal airspeeds, and/or may occur at lower than anticipated pitch attitudes, they may be unexpected by an inexperienced pilot. Failure to take immediate steps toward recovery when an accelerated stall occurs may result in a complete loss of flight control, notably, power-on spins.

This stall should never be practiced with wing flaps in the extended position due to the lower "G" load limitations in that configuration.

Accelerated maneuver stalls should not be performed in any airplane, which is prohibited from such maneuvers by its type certification restrictions or Airplane Flight Manual (AFM) and/or Pilot's Operating Handbook (POH). If they are permitted, they should be performed with a bank of approximately 45°, and in no case at a speed greater

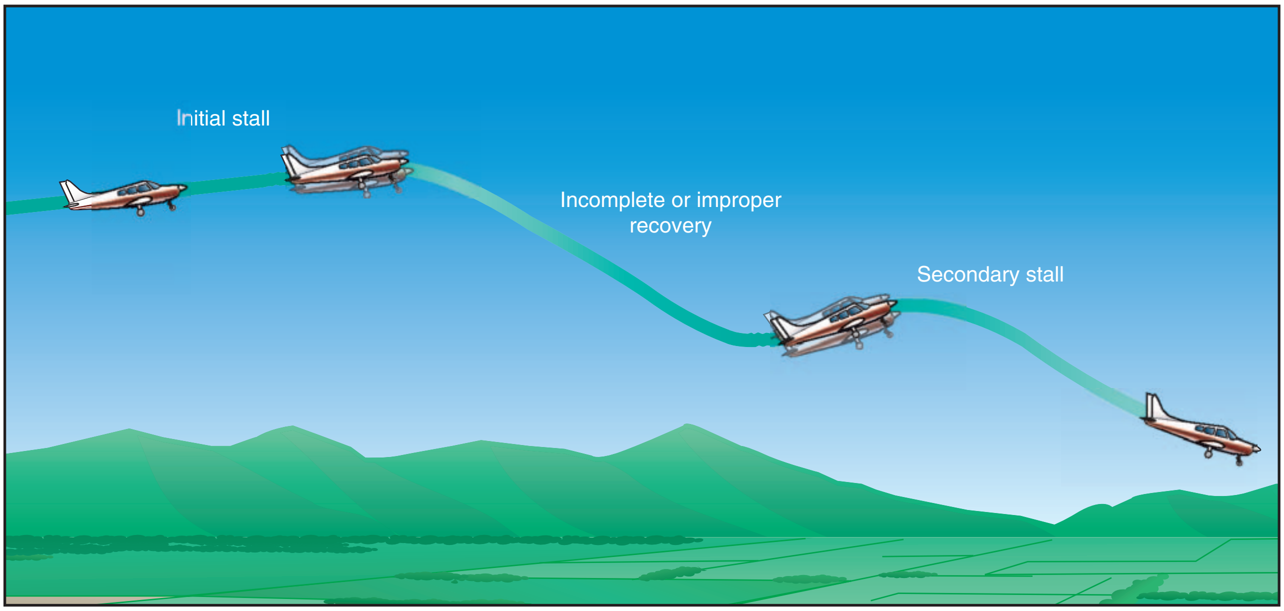

Figure 4-7. Secondary stall.

than the airplane manufacturer's recommended airspeeds or the design maneuvering speed specified for the airplane. The design maneuvering speed is the maximum speed at which the airplane can be stalled or full available aerodynamic control will not exceed the airplane's limit load factor. At or below this speed, the airplane will usually stall before the limit load factor can be exceeded. Those speeds must not be exceeded because of the extremely high structural loads that are imposed on the airplane, especially if there is turbulence. In most cases, these stalls should be performed at no more than 1.2 times the normal stall speed.

The objective of demonstrating accelerated stalls is not to develop competency in setting up the stall, but rather to learn how they may occur and to develop the ability to recognize such stalls immediately, and to take prompt, effective recovery action. It is important that recoveries are made at the first indication of a stall, or immediately after the stall has fully developed; a prolonged stall condition should never be allowed.

An airplane will stall during a coordinated steep turn exactly as it does from straight flight, except that the pitching and rolling actions tend to be more sudden. If the airplane is slipping toward the inside of the turn at the time the stall occurs, it tends to roll rapidly toward the outside of the turn as the nose pitches down because the outside wing stalls before the inside wing. If the airplane is skidding toward the outside of the turn, it will have a tendency to roll to the inside of the turn because the inside wing stalls first. If the coordination of the turn at the time of the stall is accurate, the airplane's nose will pitch away from the pilot just as it does in a straight flight stall, since both wings stall simultaneously.

An accelerated stall demonstration is entered by establishing the desired flight attitude, then smoothly, firmly, and progressively increasing the angle of attack until a stall occurs. Because of the rapidly changing flight attitude, sudden stall entry, and possible loss of altitude, it is extremely vital that the area be clear of other aircraft and the entry altitude be adequate for safe recovery.

This demonstration stall, as in all stalls, is accomplished by exerting excessive back-elevator pressure. Most frequently it would occur during improperly executed steep turns, stall and spin recoveries, and pullouts from steep dives. The objectives are to determine the stall characteristics of the airplane and develop the ability to instinctively recover at the onset of a stall at other-than-normal stall speed or flight attitudes. An accelerated stall, although usually demonstrated in steep turns, may actually be encountered any time excessive back-elevator pressure is applied and/or the angle of attack is increased too rapidly.

From straight-and-level flight at maneuvering speed or less, the airplane should be rolled into a steep level flight turn and back-elevator pressure gradually applied. After the turn and bank are established, back-elevator pressure should be smoothly and steadily increased. The resulting apparent centrifugal force will push the pilot's body down in the seat, increase the wing loading, and decrease the airspeed. After the airspeed reaches the design maneuvering speed or within 20 knots above the unaccelerated stall speed, back-elevator pressure should be firmly increased until a definite stall occurs. These speed restrictions must be observed to prevent exceeding the load limit of the airplane.

When the airplane stalls, recovery should be made promptly, by releasing sufficient back-elevator pressure and increasing power to reduce the angle of attack. If an uncoordinated turn is made, one wing may tend to drop suddenly, causing the airplane to roll in that direction. If this occurs, the excessive back-elevator pressure must be released, power added, and the airplane returned to straight-and-level flight with coordinated control pressure.

The pilot should recognize when the stall is imminent and take prompt action to prevent a completely stalled condition. It is imperative that a prolonged stall, excessive airspeed, excessive loss of altitude, or spin be avoided.

CROSS-CONTROL STALL

The objective of a cross-control stall demonstration maneuver is to show the effect of improper control technique and to emphasize the importance of using coordinated control pressures whenever making turns. This type of stall occurs with the controls crossed—aileron pressure applied in one direction and rudder pressure in the opposite direction.

In addition, when excessive back-elevator pressure is applied, a cross-control stall may result. This is a stall that is most apt to occur during a poorly planned and executed base-to-final approach turn, and often is the result of overshooting the centerline of the runway during that turn. Normally, the proper action to correct for overshooting the runway is to increase the rate of turn by using coordinated aileron and rudder. At the relatively low altitude of a base-to-final approach turn, improperly trained pilots may be apprehensive of steepening the bank to increase the rate of turn, and rather than steepening the bank, they hold the bank constant and attempt to increase the rate of turn by adding more rudder pressure in an effort to align it with the runway.

The addition of inside rudder pressure will cause the speed of the outer wing to increase, therefore, creating greater lift on that wing. To keep that wing from rising and to maintain a constant angle of bank, opposite aileron pressure needs to be applied. The added inside rudder pressure will also cause the nose to lower in relation to the horizon. Consequently, additional back-elevator pressure would be required to maintain a constant-pitch attitude. The resulting condition is a turn with rudder applied in one direction, aileron in the opposite direction, and excessive back-elevator pressure—a pronounced cross-control condition.

Since the airplane is in a skidding turn during the cross-control condition, the wing on the outside of the turn speeds up and produces more lift than the inside wing; thus, the airplane starts to increase its bank. The down aileron on the inside of the turn helps drag that wing back, slowing it up and decreasing its lift, which requires more aileron application. This further causes the airplane to roll. The roll may be so fast that it is possible the bank will be vertical or past vertical before it can be stopped.

For the demonstration of the maneuver, it is important that it be entered at a safe altitude because of the possible extreme nosedown attitude and loss of altitude that may result.

Before demonstrating this stall, the pilot should clear the area for other air traffic while slowly retarding the throttle. Then the landing gear (if retractable gear) should be lowered, the throttle closed, and the altitude maintained until the airspeed approaches the normal glide speed. Because of the possibility of exceeding the airplane's limitations, flaps should not be extended. While the gliding attitude and airspeed are being established, the airplane should be retrimmed. When the glide is stabilized, the airplane should be rolled into a medium-banked turn to simulate a final approach turn that would overshoot the centerline of the runway.

During the turn, excessive rudder pressure should be applied in the direction of the turn but the bank held constant by applying opposite aileron pressure. At the same time, increased back-elevator pressure is required to keep the nose from lowering.

All of these control pressures should be increased until the airplane stalls. When the stall occurs, recovery is made by releasing the control pressures and increasing power as necessary to recover.

In a cross-control stall, the airplane often stalls with little warning. The nose may pitch down, the inside wing may suddenly drop, and the airplane may continue to roll to an inverted position. This is usually the beginning of a spin. It is obvious that close to the ground is no place to allow this to happen.

Recovery must be made before the airplane enters an abnormal attitude (vertical spiral or spin); it is a simple matter to return to straight-and-level flight by coordinated use of the controls. The pilot must be able to recognize when this stall is imminent and must take immediate action to prevent a completely stalled condition. It is imperative that this type of stall not occur during an actual approach to a landing, since recovery may be impossible prior to ground contact due to the low altitude.

The flight instructor should be aware that during traffic pattern operations, any conditions that result in overshooting the turn from base leg to final approach, dramatically increases the possibility of an unintentional accelerated stall while the airplane is in a cross-control condition.

ELEVATOR TRIM STALL

The elevator trim stall maneuver shows what can happen when full power is applied for a go-around and positive control of the airplane is not maintained. [Figure 4-8] Such a situation may occur during a go-around procedure from a normal landing approach

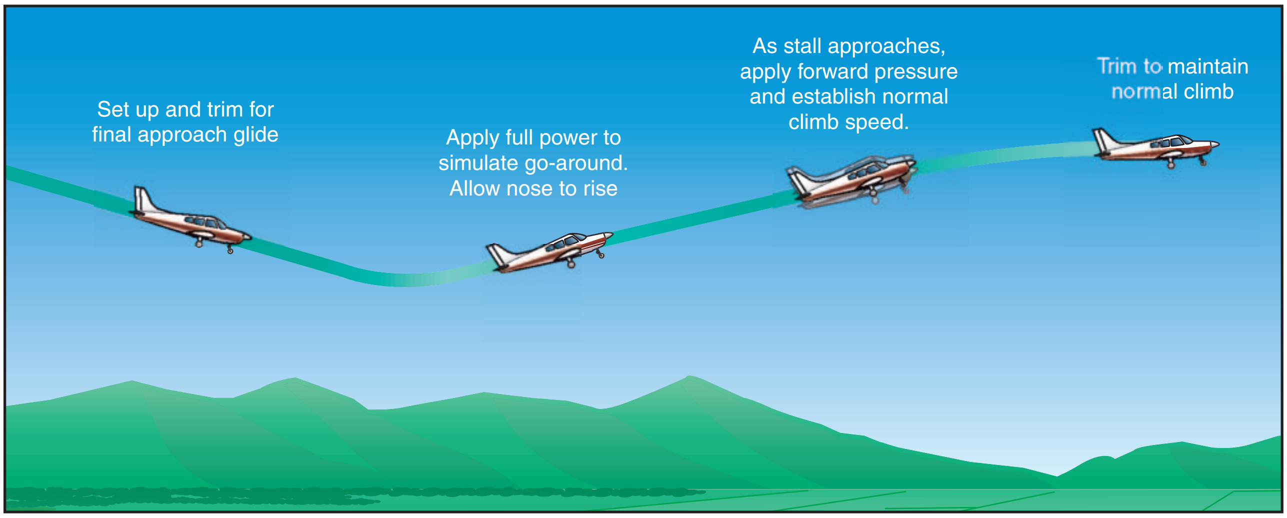

Figure 4-8. Elevator trim stall.

or a simulated forced landing approach, or immediately after a takeoff. The objective of the demonstration is to show the importance of making smooth power applications, overcoming strong trim forces and maintaining positive control of the airplane to hold safe flight attitudes, and using proper and timely trim techniques.

At a safe altitude and after ensuring that the area is clear of other air traffic, the pilot should slowly retard the throttle and extend the landing gear (if retractable gear). One-half to full flaps should be lowered, the throttle closed, and altitude maintained until the airspeed approaches the normal glide speed. When the normal glide is established, the airplane should be trimmed for the glide just as would be done during a landing approach (nose-up trim).

During this simulated final approach glide, the throttle is then advanced smoothly to maximum allowable power as would be done in a go-around procedure. The combined forces of thrust, torque, and back-elevator trim will tend to make the nose rise sharply and turn to the left.

When the throttle is fully advanced and the pitch attitude increases above the normal climbing attitude and it is apparent that a stall is approaching, adequate forward pressure must be applied to return the airplane to the normal climbing attitude. While holding the airplane in this attitude, the trim should then be adjusted to relieve the heavy control pressures and the normal go-around and level-off procedures completed.

The pilot should recognize when a stall is approaching, and take prompt action to prevent a completely stalled condition. It is imperative that a stall not occur during an actual go-around from a landing approach.

Common errors in the performance of intentional stalls are:

- Failure to adequately clear the area.
- Inability to recognize an approaching stall condition through feel for the airplane.
- Premature recovery.
- Over-reliance on the airspeed indicator while excluding other cues.
- Inadequate scanning resulting in an unintentional wing-low condition during entry.
- Excessive back-elevator pressure resulting in an exaggerated nose-up attitude during entry.
- Inadequate rudder control.
- Inadvertent secondary stall during recovery.
- Failure to maintain a constant bank angle during turning stalls.
- Excessive forward-elevator pressure during recovery resulting in negative load on the wings.
- Excessive airspeed buildup during recovery.
- Failure to take timely action to prevent a full stall during the conduct of imminent stalls.

SPINS

A spin may be defined as an aggravated stall that results in what is termed “autorotation” wherein the airplane follows a downward corkscrew path. As the airplane rotates around a vertical axis, the rising wing is less stalled than the descending wing creating a rolling, yawing, and pitching motion. The airplane is basically being forced downward by gravity, rolling, yawing, and pitching in a spiral path. [Figure 4-9]

The autorotation results from an unequal angle of attack on the airplane’s wings. The rising wing has a decreasing angle of attack, where the relative lift increases and the drag decreases. In effect, this wing is less stalled. Meanwhile, the descending wing has an

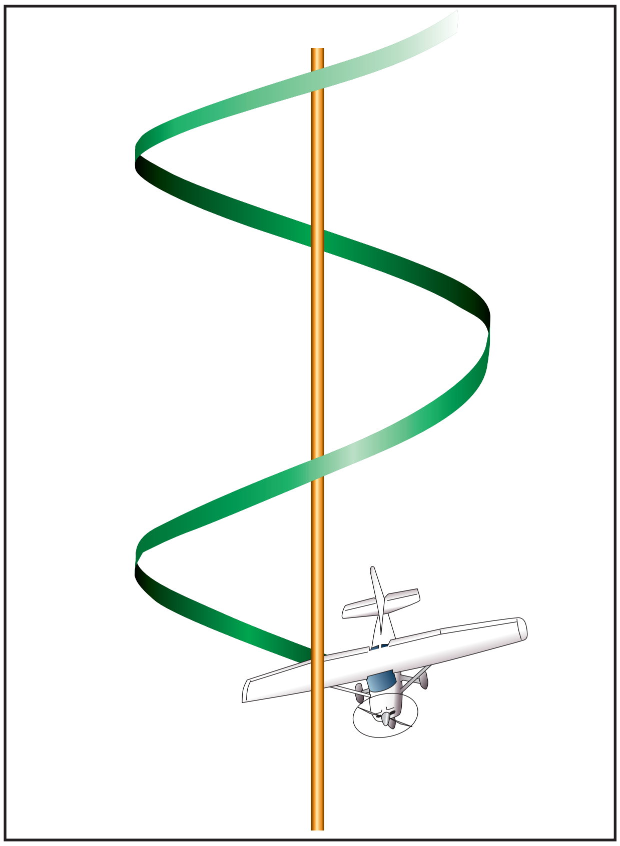

Figure 4-9. Spin—an aggravated stall and autorotation.

increasing angle of attack, past the wing's critical angle of attack (stall) where the relative lift decreases and drag increases.

A spin is caused when the airplane's wing exceeds its critical angle of attack (stall) with a sideslip or yaw acting on the airplane at, or beyond, the actual stall. During this uncoordinated maneuver, a pilot may not be aware that a critical angle of attack has been exceeded until the airplane yaws out of control toward the lowering wing. If stall recovery is not initiated immediately, the airplane may enter a spin.

If this stall occurs while the airplane is in a slipping or skidding turn, this can result in a spin entry and rotation in the direction that the rudder is being applied, regardless of which wingtip is raised.

Many airplanes have to be forced to spin and require considerable judgment and technique to get the spin started. These same airplanes that have to be forced to spin, may be accidentally put into a spin by mishandling the controls in turns, stalls, and flight at minimum controllable airspeeds. This fact is additional evidence of the necessity for the practice of stalls until the ability to recognize and recover from them is developed.

Often a wing will drop at the beginning of a stall. When this happens, the nose will attempt to move (yaw) in the direction of the low wing. This is where use of the rudder is important during a stall. The correct amount of opposite rudder must be applied to keep the nose from yawing toward the low wing. By maintaining directional control and not allowing the nose to yaw toward the low wing, before stall recovery is initiated, a spin will be averted. If the nose is allowed to yaw during the stall, the airplane will begin to slip in the direction of the lowered wing, and will enter a spin. An airplane must be stalled in order to enter a spin; therefore, continued practice in stalls will help the pilot develop a more instinctive and prompt reaction in recognizing an approaching spin. It is essential to learn to apply immediate corrective action any time it is apparent that the airplane is nearing spin conditions. If it is impossible to avoid a spin, the pilot should immediately execute spin recovery procedures.

SPIN PROCEDURES

The flight instructor should demonstrate spins in those airplanes that are approved for spins. Special spin procedures or techniques required for a particular airplane are not presented here. Before beginning any spin operations, the following items should be reviewed.

- The airplane's AFM/POH limitations section, placards, or type certification data, to determine if the airplane is approved for spins.
- Weight and balance limitations.
- Recommended entry and recovery procedures.
- The requirements for parachutes. It would be appropriate to review a current Title 14 of the Code of Federal Regulations (14 CFR) part 91 for the latest parachute requirements.

A thorough airplane preflight should be accomplished with special emphasis on excess or loose items that may affect the weight, center of gravity, and controllability of the airplane. Slack or loose control cables (particularly rudder and elevator) could prevent full anti-spin control deflections and delay or preclude recovery in some airplanes.

Prior to beginning spin training, the flight area, above and below the airplane, must be clear of other air traffic. This may be accomplished while slowing the airplane for the spin entry. All spin training should be initiated at an altitude high enough for a completed recovery at or above 1,500 feet AGL.

It may be appropriate to introduce spin training by first practicing both power-on and power-off stalls, in a clean configuration. This practice would be used to familiarize the student with the airplane's specific stall and recovery characteristics. Care should be taken with the handling of the power (throttle) in entries and during spins. Carburetor heat should be applied according to the manufacturer's recommendations.

There are four phases of a spin: **entry**, **incipient**, **developed**, and **recovery**. [Figure 4-10 on next page]

ENTRY PHASE

The entry phase is where the pilot provides the necessary elements for the spin, either accidentally or intentionally. The entry procedure for demonstrating a spin is similar to a power-off stall. During the entry, the power should be reduced slowly to idle, while simultaneously raising the nose to a pitch attitude that will ensure a stall. As the airplane approaches a stall, smoothly apply full rudder in the direction of the desired spin rotation while applying full back (up) elevator to the limit of travel. Always maintain the ailerons in the neutral position during the spin procedure unless AFM/POH specifies otherwise.

INCIPIENT PHASE

The incipient phase is from the time the airplane stalls and rotation starts until the spin has fully developed. This change may take up to two turns for most airplanes. Incipient spins that are not allowed to develop into a steady-state spin are the most commonly used in the introduction to spin training and recovery techniques. In

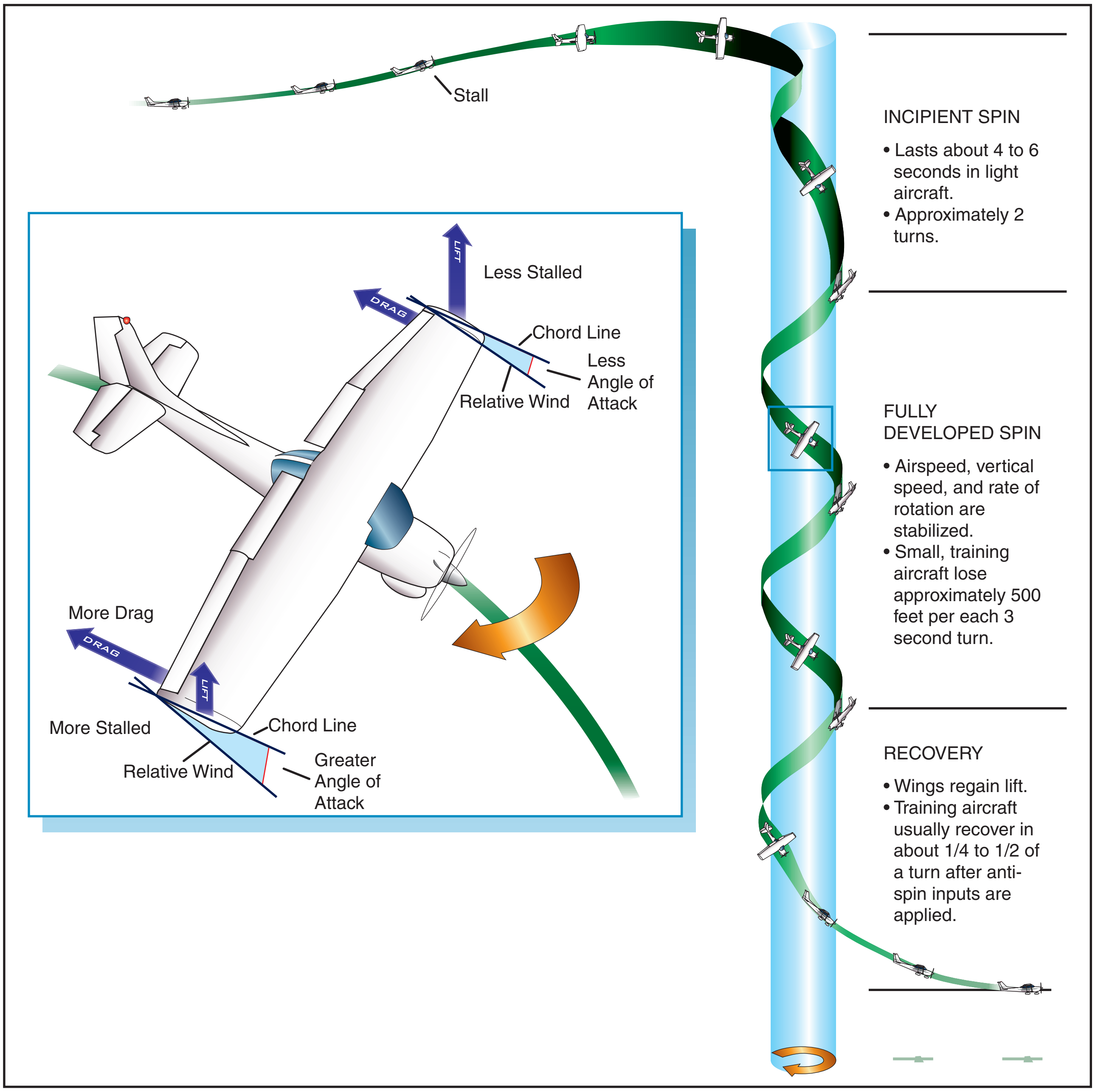

Figure 4-10. Spin entry and recovery.

this phase, the aerodynamic and inertial forces have not achieved a balance. As the incipient spin develops, the indicated airspeed should be near or below stall airspeed, and the turn-and-slip indicator should indicate the direction of the spin.

The incipient spin recovery procedure should be commenced prior to the completion of 360° of rotation. The pilot should apply full rudder opposite the direction of rotation. If the pilot is not sure of the direction of the spin, check the turn-and-slip indicator; it will show a deflection in the direction of rotation.

DEVELOPED PHASE

The developed phase occurs when the airplane's angular rotation rate, airspeed, and vertical speed are stabilized while in a flightpath that is nearly vertical. This is where airplane aerodynamic forces and inertial forces are in balance, and the attitude, angles, and self-sustaining motions about the vertical axis are constant or repetitive. The spin is in equilibrium.

RECOVERY PHASE

The recovery phase occurs when the angle of attack of the wings decreases below the critical angle of attack and autorotation slows. Then the nose steepens and rotation stops. This phase may last for a quarter turn to several turns.

To recover, control inputs are initiated to disrupt the spin equilibrium by stopping the rotation and stall. To accomplish spin recovery, the manufacturer's recommended procedures should be followed. In the absence of the manufacturer's recommended spin recovery procedures and techniques, the following spin recovery procedures are recommended.

Step 1—REDUCE THE POWER (THROTTLE) TO IDLE. Power aggravates the spin characteristics. It usually results in a flatter spin attitude and increased rotation rates.

Step 2—POSITION THE AILERONS TO NEUTRAL. Ailerons may have an adverse effect on spin recovery. Aileron control in the direction of the spin may speed up the rate of rotation and delay the recovery. Aileron control opposite the direction of the spin may cause the down aileron to move the wing deeper into the stall and aggravate the situation. The best procedure is to ensure that the ailerons are neutral.

Step 3—APPLY FULL OPPOSITE RUDDER AGAINST THE ROTATION. Make sure that full (against the stop) opposite rudder has been applied.

Step 4—APPLY A POSITIVE AND BRISK, STRAIGHT FORWARD MOVEMENT OF THE ELEVATOR CONTROL FORWARD OF THE NEUTRAL TO BREAK THE STALL. This should be done immediately after full rudder application. The forceful movement of the elevator will decrease the excessive angle of attack and break the stall. The controls should be held firmly in this position. When the stall is "broken," the spinning will stop.

Step 5—AFTER SPIN ROTATION STOPS, NEUTRALIZE THE RUDDER. If the rudder is not neutralized at this time, the ensuing increased airspeed acting upon a deflected rudder will cause a yawing or skidding effect.

Slow and overly cautious control movements during spin recovery must be avoided. In certain cases it has been found that such movements result in the airplane continuing to spin indefinitely, even with anti-spin inputs. A brisk and positive technique, on the other hand, results in a more positive spin recovery.

Step 6—BEGIN APPLYING BACK-ELEVATOR PRESSURE TO RAISE THE NOSE TO LEVEL FLIGHT. Caution must be used not to apply excessive back-elevator pressure after the rotation stops. Excessive back-elevator pressure can cause a secondary stall and result in another spin. Care should be taken not to exceed the "G" load limits and airspeed limitations during recovery. If the flaps and/or retractable landing gear are extended prior to the spin, they should be retracted as soon as possible after spin entry.

It is important to remember that the above spin recovery procedures and techniques are recommended for use only in the absence of the manufacturer's procedures. Before any pilot attempts to begin spin training, that pilot must be familiar with the procedures provided by the manufacturer for spin recovery.

The most common problems in spin recovery include pilot confusion as to the direction of spin rotation and whether the maneuver is a spin versus spiral. If the airspeed is increasing, the airplane is no longer in a spin but in a spiral. In a spin, the airplane is stalled. The indicated airspeed, therefore, should reflect stall speed.

INTENTIONAL SPINS

The *intentional spinning* of an airplane, for which the spin maneuver is not specifically approved, is NOT authorized by this handbook or by the Code of Federal Regulations. The official sources for determining if the spin maneuver IS APPROVED or NOT APPROVED for a specific airplane are:

- Type Certificate Data Sheets or the Aircraft Specifications.
- The limitation section of the FAA-approved AFM/POH. The limitation sections may provide additional specific requirements for spin authorization, such as limiting gross weight, CG range, and amount of fuel.
- On a placard located in clear view of the pilot in the airplane, NO ACROBATIC MANEUVERS INCLUDING SPINS APPROVED. In airplanes placarded against spins, there is no assurance that recovery from a fully developed spin is possible.

There are occurrences involving airplanes wherein spin restrictions are *intentionally* ignored by some pilots. Despite the installation of placards prohibiting intentional spins in these airplanes, a number of pilots, and some flight instructors, attempt to justify the maneuver, rationalizing that the spin restriction results merely because of a "technicality" in the airworthiness standards.

Some pilots reason that the airplane was spin tested during its certification process and, therefore, no problem should result from demonstrating or practicing spins. However, those pilots overlook the fact that a normal category airplane certification only requires the airplane recover from a one-turn spin in not more than one additional turn or 3 seconds, whichever takes longer. This same test of controllability can also be used in certificating an airplane in the Utility category (14 CFR section 23.221 (b)).

The point is that 360° of rotation (one-turn spin) does not provide a stabilized spin. If the airplane's controllability has not been explored by the engineering test pilot beyond the certification requirements, prolonged spins (inadvertent or intentional) in that airplane place an operating pilot in an unexplored flight situation. Recovery may be difficult or impossible.

In 14 CFR part 23, "Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes," there are no requirements for investigation of *controllability* in a true spinning condition for the Normal category airplanes. The one-turn "margin of safety" is essentially a check of the airplane's controllability in a delayed recovery from a *stall*. Therefore*, in airplanes placarded against spins there is absolutely no assurance whatever that recovery from a fully developed spin is possible under any circumstances.* The pilot of an airplane placarded against intentional spins should assume that the airplane may well become uncontrollable in a spin.

WEIGHT AND BALANCE REQUIREMENTS

With each airplane that is approved for spinning, the weight and balance requirements are important for safe performance and recovery from the spin maneuver. Pilots must be aware that just minor weight or balance changes can affect the airplane's spin recovery characteristics. Such changes can either alter or enhance the spin maneuver and/or recovery characteristics. For example, the addition of weight in the aft baggage compartment, or additional fuel, may still permit the airplane to be operated within CG, but could seriously affect the spin and recovery characteristics.

An airplane that may be difficult to spin intentionally in the Utility Category (restricted aft CG and reduced weight) could have less resistance to spin entry in the Normal Category (less restricted aft CG and increased weight). This situation is due to the airplane being able to generate a higher angle of attack and load factor. Furthermore, an airplane that is approved for spins in the Utility Category, but loaded in the Normal Category, may not recover from a spin that is allowed to progress beyond the incipient phase.

Common errors in the performance of *intentional* spins are:

- Failure to apply full rudder pressure in the desired spin direction during spin entry.
- Failure to apply and maintain full up-elevator pressure during spin entry, resulting in a spiral.
- Failure to achieve a fully stalled condition prior to spin entry.
- Failure to apply full rudder against the spin during recovery.
- Failure to apply sufficient forward-elevator pressure during recovery.
- Failure to neutralize the rudder during recovery after rotation stops, resulting in a possible secondary spin.
- Slow and overly cautious control movements during recovery.
- Excessive back-elevator pressure after rotation stops, resulting in possible secondary stall.
- Insufficient back-elevator pressure during recovery resulting in excessive airspeed.

Chapter 5

Takeoffs and Departure Climbs

GENERAL

This chapter discusses takeoffs and departure climbs in tricycle landing gear (nosewheel-type) airplanes under normal conditions, and under conditions which require maximum performance. A thorough knowledge of takeoff principles, both in theory and practice, will often prove of extreme value throughout a pilot's career. It will often prevent an attempted takeoff that would result in an accident, or during an emergency, make possible a takeoff under critical conditions when a pilot with a less well rounded knowledge and technique would fail.

The takeoff, though relatively simple, often presents the most hazards of any part of a flight. The importance of thorough knowledge and faultless technique and judgment cannot be overemphasized.

It must be remembered that the manufacturer's recommended procedures, including airplane configuration and airspeeds, and other information relevant to takeoffs and departure climbs in a specific make and model airplane are contained in the FAA-approved Airplane Flight Manual and/or Pilot's Operating Handbook (AFM/POH) for that airplane. If any of the information in this chapter differs from the airplane manufacturer's recommendations as contained in the AFM/POH, the airplane manufacturer's recommendations take precedence.

TERMS AND DEFINITIONS

Although the takeoff and climb is one continuous maneuver, it will be divided into three separate steps for purposes of explanation: (1) the takeoff roll, (2) the lift-off, and (3) the initial climb after becoming airborne. [Figure 5-1]

- **Takeoff Roll (ground roll)**—the portion of the takeoff procedure during which the airplane is accelerated from a standstill to an airspeed that provides sufficient lift for it to become airborne.
- **Lift-off (rotation)**—the act of becoming airborne as a result of the wings lifting the airplane off the ground or the pilot rotating the nose up, increasing the angle of attack to start a climb.
- **Initial Climb**—begins when the airplane leaves the ground and a pitch attitude has been established to climb away from the takeoff area. Normally, it is considered complete when the airplane has reached a safe maneuvering altitude, or an en route climb has been established.

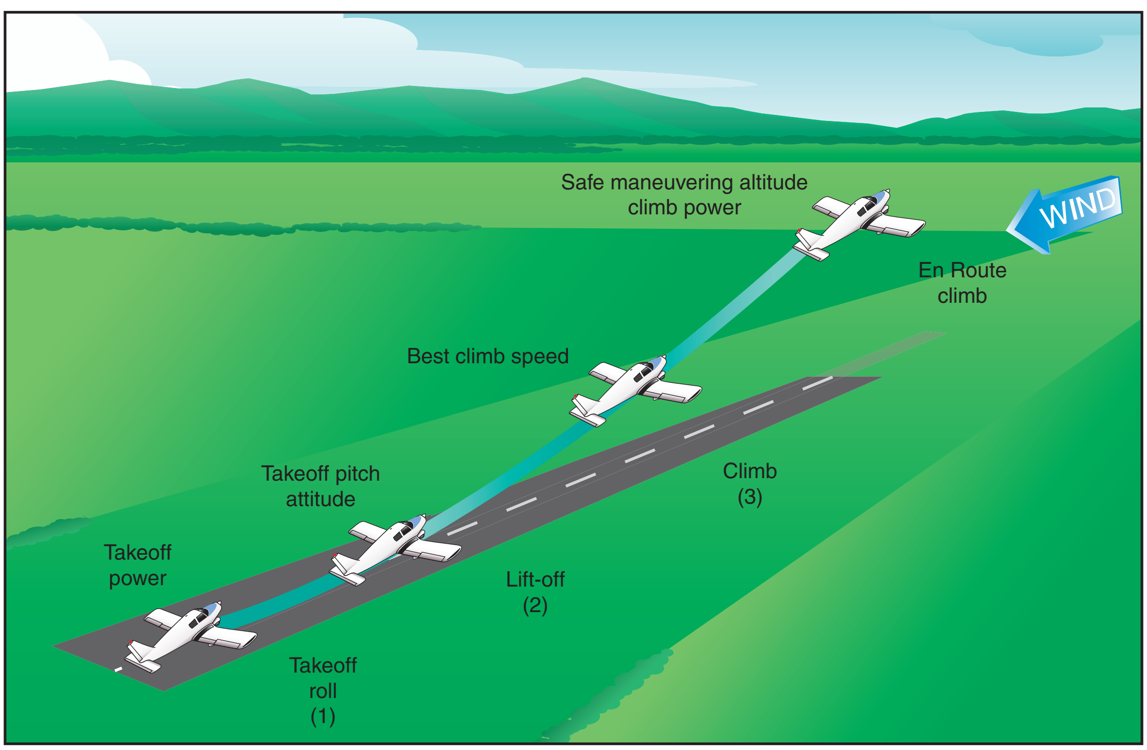

Figure 5-1. Takeoff and climb.

PRIOR TO TAKEOFF

Before taxiing onto the runway or takeoff area, the pilot should ensure that the engine is operating properly and that all controls, including flaps and trim tabs, are set in accordance with the before takeoff checklist. In addition, the pilot must make certain that the approach and takeoff paths are clear of other aircraft. At uncontrolled airports, pilots should announce their intentions on the common traffic advisory frequency (CTAF) assigned to that airport. When operating from an airport with an operating control tower, pilots must contact the tower operator and receive a takeoff clearance before taxiing onto the active runway.

It is not recommended to take off immediately behind another aircraft, particularly large, heavily loaded transport airplanes, because of the wake turbulence that is generated.

While taxiing onto the runway, the pilot can select ground reference points that are aligned with the runway direction as aids to maintaining directional control during the takeoff. These may be runway centerline markings, runway lighting, distant trees, towers, buildings, or mountain peaks.

NORMAL TAKEOFF

A normal takeoff is one in which the airplane is headed into the wind, or the wind is very light. Also, the takeoff surface is firm and of sufficient length to permit the airplane to gradually accelerate to normal lift-off and climb-out speed, and there are no obstructions along the takeoff path.

There are two reasons for making a takeoff as nearly into the wind as possible. First, the airplane's speed while on the ground is much less than if the takeoff were made downwind, thus reducing wear and stress on the landing gear. Second, a shorter ground roll and therefore much less runway length is required to develop the minimum lift necessary for takeoff and climb. Since the airplane depends on airspeed in order to fly, a headwind provides some of that airspeed, even with the airplane motionless, from the wind flowing over the wings.

TAKEOFF ROLL

After taxiing onto the runway, the airplane should be carefully aligned with the intended takeoff direction, and the nosewheel positioned straight, or centered. After releasing the brakes, the throttle should be advanced smoothly and continuously to takeoff power. An abrupt application of power may cause the airplane to yaw sharply to the left because of the torque effects of the engine and propeller. This will be most apparent in high horsepower engines. As the airplane starts to roll forward, the pilot should assure both feet are on the rudder pedals so that the toes or balls of the feet are on the rudder portions, not on the brake portions. Engine instruments should be monitored during the takeoff roll for any malfunctions.

In nosewheel-type airplanes, pressures on the elevator control are not necessary beyond those needed to steady it. Applying unnecessary pressure will only aggravate the takeoff and prevent the pilot from recognizing when elevator control pressure is actually needed to establish the takeoff attitude.

As speed is gained, the elevator control will tend to assume a neutral position if the airplane is correctly trimmed. At the same time, directional control should be maintained with smooth, prompt, positive rudder corrections throughout the takeoff roll. The effects of engine torque and P-factor at the initial speeds tend to pull the nose to the left. The pilot must use whatever rudder pressure and aileron needed to correct for these effects or for existing wind conditions to keep the nose of the airplane headed straight down the runway. The use of brakes for steering purposes should be avoided, since this will cause slower acceleration of the airplane's speed, lengthen the takeoff distance, and possibly result in severe swerving.

While the speed of the takeoff roll increases, more and more pressure will be felt on the flight controls, particularly the elevators and rudder. If the tail surfaces are affected by the propeller slipstream, they become effective first. As the speed continues to increase, all of the flight controls will gradually become effective enough to maneuver the airplane about its three axes. It is at this point, in the taxi to flight transition, that the airplane is being flown more than taxied. As this occurs, progressively smaller rudder deflections are needed to maintain direction.

The feel of resistance to the movement of the controls and the airplane's reaction to such movements are the only real indicators of the degree of control attained. This feel of resistance is not a measure of the airplane's speed, but rather of its controllability. To determine the degree of controllability, the pilot must be conscious of the reaction of the airplane to the control pressures and immediately adjust the pressures as needed to control the airplane. The pilot must wait for the reaction of the airplane to the applied control pressures and attempt to sense the control resistance to pressure rather than attempt to control the airplane by movement of the controls. Balanced control surfaces increase the importance of this point, because they materially reduce the intensity of the resistance offered to pressures exerted by the pilot.

At this stage of training, beginning takeoff practice, a student pilot will normally not have a full appreciation of the variations of control pressures with the speed of the airplane. The student, therefore, may tend to move the controls through wide ranges seeking the pressures that are familiar and expected, and as a consequence over-control the airplane. The situation may be aggravated by the sluggish reaction of the airplane to these movements. The flight instructor should take measures to check these tendencies and stress the importance of the development of feel. The student pilot should be required to feel lightly for resistance and accomplish the desired results by applying pressure against it. This practice will enable the student pilot, as experience is gained, to achieve a sense of the point when sufficient speed has been acquired for the takeoff, instead of merely guessing, fixating on the airspeed indicator, or trying to force performance from the airplane.

LIFT-OFF

Since a good takeoff depends on the proper takeoff attitude, it is important to know how this attitude appears and how it is attained. The ideal takeoff attitude requires only minimum pitch adjustments shortly after the airplane lifts off to attain the speed for the best rate of climb (V_Y). [Figure 5-2] The pitch attitude necessary for the airplane to accelerate to V_Y speed should be demonstrated by the instructor and memorized by the student. Initially, the student pilot may have a tendency to hold excessive back-elevator pressure just after lift-off, resulting in an abrupt pitch-up. The flight instructor should be prepared for this.

Each type of airplane has a best pitch attitude for normal lift-off; however, varying conditions may make a difference in the required takeoff technique. A rough field, a smooth field, a hard surface runway, or a short or soft, muddy field, all call for a slightly different technique, as will smooth air in contrast to a strong, gusty wind. The different techniques for those other-than-normal conditions are discussed later in this chapter.

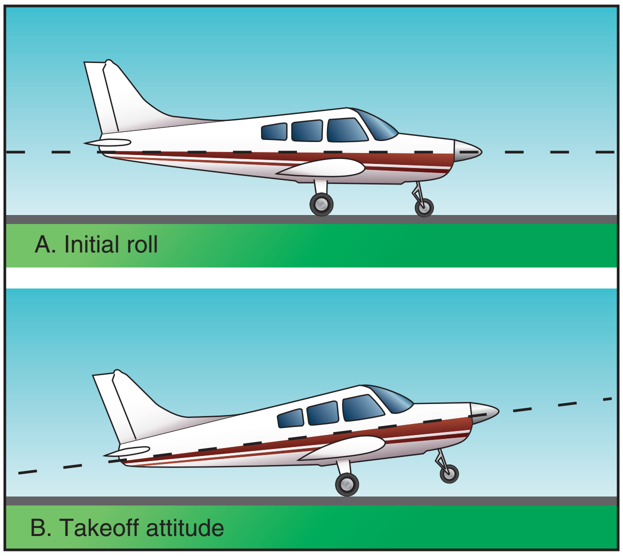

Figure 5-2. Initial roll and takeoff attitude.

When all the flight controls become effective during the takeoff roll in a nosewheel-type airplane, back-elevator pressure should be gradually applied to raise the nosewheel slightly off the runway, thus establishing the takeoff or lift-off attitude. This is often referred to as "rotating." At this point, the position of the nose in relation to the horizon should be noted, then back-elevator pressure applied as necessary to hold this attitude. The wings must be kept level by applying aileron pressure as necessary.

The airplane is allowed to fly off the ground while in the normal takeoff attitude. Forcing it into the air by applying excessive back-elevator pressure would only result in an excessively high pitch attitude and may delay the takeoff. As discussed earlier, excessive and rapid changes in pitch attitude result in proportionate changes in the effects of torque, thus making the airplane more difficult to control.

Although the airplane can be forced into the air, this is considered an unsafe practice and should be avoided under normal circumstances. If the airplane is forced to leave the ground by using too much back-elevator pressure before adequate flying speed is attained, the wing's angle of attack may be excessive, causing the airplane to settle back to the runway or even to stall. On the other hand, if sufficient back-elevator pressure is not held to maintain the correct takeoff attitude after becoming airborne, or the nose is allowed to lower excessively, the airplane may also settle back to the runway. This would occur because the angle of attack is decreased and lift diminished to the degree where it will not support the airplane. It is important, then, to hold the correct attitude constant after rotation or lift-off.

As the airplane leaves the ground, the pilot must continue to be concerned with maintaining the wings in a level attitude, as well as holding the proper pitch attitude. Outside visual scan to attain/maintain proper airplane pitch and bank attitude must be intensified at this critical point. The flight controls have not yet become fully effective, and the beginning pilot will often have a tendency to fixate on the airplane's pitch attitude and/or the airspeed indicator and neglect the natural tendency of the airplane to roll just after breaking ground.

During takeoffs in a strong, gusty wind, it is advisable that an extra margin of speed be obtained before the airplane is allowed to leave the ground. A takeoff at the normal takeoff speed may result in a lack of positive control, or a stall, when the airplane encounters a sudden lull in strong, gusty wind, or other turbulent air currents. In this case, the pilot should allow the airplane to stay on the ground longer to attain more speed; then make a smooth, positive rotation to leave the ground.

INITIAL CLIMB

Upon lift-off, the airplane should be flying at approximately the pitch attitude that will allow it to accelerate to V_Y. This is the speed at which the airplane will gain the most altitude in the shortest period of time.

If the airplane has been properly trimmed, some back-elevator pressure may be required to hold this attitude until the proper climb speed is established. On the other hand, relaxation of any back-elevator pressure before this time may result in the airplane settling, even to the extent that it contacts the runway.

The airplane will pick up speed rapidly after it becomes airborne. Once a positive rate of climb is established, the flaps and landing gear can be retracted (if equipped).

It is recommended that takeoff power be maintained until reaching an altitude of at least 500 feet above the surrounding terrain or obstacles. The combination of V_Y and takeoff power assures the maximum altitude gained in a minimum amount of time. This gives the pilot more altitude from which the airplane can be safely maneuvered in case of an engine failure or other emergency.

Since the power on the initial climb is fixed at the takeoff power setting, the airspeed must be controlled by making slight pitch adjustments using the elevators. However, the pilot should not fixate on the airspeed indicator when making these pitch changes, but should, instead, continue to scan outside to adjust the airplane's attitude in relation to the horizon. In accordance with the principles of attitude flying, the pilot should first make the necessary pitch change with reference to the natural horizon and hold the new attitude momentarily, and then glance at the airspeed indicator as a check to see if the new attitude is correct. Due to inertia, the airplane will not accelerate or decelerate immediately as the pitch is changed. It takes a little time for the airspeed to change. If the pitch attitude has been over or under corrected, the airspeed indicator will show a speed that is more or less than that desired. When this occurs, the cross-checking and appropriate pitch-changing process must be repeated until the desired climbing attitude is established.

When the correct pitch attitude has been attained, it should be held constant while cross-checking it against the horizon and other outside visual references. The airspeed indicator should be used only as a check to determine if the attitude is correct.

After the recommended climb airspeed has been established, and a safe maneuvering altitude has been reached, the power should be adjusted to the recommended climb setting and the airplane trimmed to relieve the control pressures. This will make it easier to hold a constant attitude and airspeed.

During initial climb, it is important that the takeoff path remain aligned with the runway to avoid drifting into obstructions, or the path of another aircraft that may be taking off from a parallel runway. Proper scanning techniques are essential to a safe takeoff and climb, not only for maintaining attitude and direction, but also for collision avoidance in the airport area.

When the student pilot nears the solo stage of flight training, it should be explained that the airplane's takeoff performance will be much different when the instructor is out of the airplane. Due to decreased load, the airplane will become airborne sooner and will climb more rapidly. The pitch attitude that the student has learned to associate with initial climb may also differ due to decreased weight, and the flight controls may seem more sensitive. If the situation is unexpected, it may result in increased tension that may remain until after the landing. Frequently, the existence of this tension and the uncertainty that develops due to the perception of an "abnormal" takeoff results in poor performance on the subsequent landing.

Common errors in the performance of normal takeoffs and departure climbs are:

- Failure to adequately clear the area prior to taxiing into position on the active runway.
- Abrupt use of the throttle.
- Failure to check engine instruments for signs of malfunction after applying takeoff power.
- Failure to anticipate the airplane's left turning tendency on initial acceleration.
- Overcorrecting for left turning tendency.
- Relying solely on the airspeed indicator rather than developed feel for indications of speed and airplane controllability during acceleration and lift-off.
- Failure to attain proper lift-off attitude.
- Inadequate compensation for torque/P-factor during initial climb resulting in a sideslip.
- Over-control of elevators during initial climb-out.

- Limiting scan to areas directly ahead of the airplane (pitch attitude and direction), resulting in allowing a wing (usually the left) to drop immediately after lift-off.
- Failure to attain/maintain best rate-of-climb airspeed (V_Y).
- Failure to employ the principles of attitude flying during climb-out, resulting in "chasing" the airspeed indicator.

CROSSWIND TAKEOFF

While it is usually preferable to take off directly into the wind whenever possible or practical, there will be many instances when circumstances or judgment will indicate otherwise. Therefore, the pilot must be familiar with the principles and techniques involved in crosswind takeoffs, as well as those for normal takeoffs. A crosswind will affect the airplane during takeoff much as it does in taxiing. With this in mind, it can be seen that the technique for crosswind correction during takeoffs closely parallels the crosswind correction techniques used in taxiing.

TAKEOFF ROLL

The technique used during the initial takeoff roll in a crosswind is generally the same as used in a normal takeoff, except that aileron control must be held INTO the crosswind. This raises the aileron on the upwind wing to impose a downward force on the wing to counteract the lifting force of the crosswind and prevents the wing from rising.

As the airplane is taxied into takeoff position, it is essential that the windsock and other wind direction indicators be checked so that the presence of a crosswind may be recognized and anticipated. If a crosswind is indicated, FULL aileron should be held into the wind as the takeoff roll is started. This control position should be maintained while the airplane is accelerating and until the ailerons start becoming sufficiently effective for maneuvering the airplane about its longitudinal axis.

With the aileron held into the wind, the takeoff path must be held straight with the rudder. [Figure 5-3]

Normally, this will require applying downwind rudder pressure, since on the ground the airplane will tend to **weathervane** into the wind. When takeoff power is applied, torque or P-factor that yaws the airplane to the left may be sufficient to counteract the weathervaning tendency caused by a crosswind from the right. On the other hand, it may also aggravate the tendency to

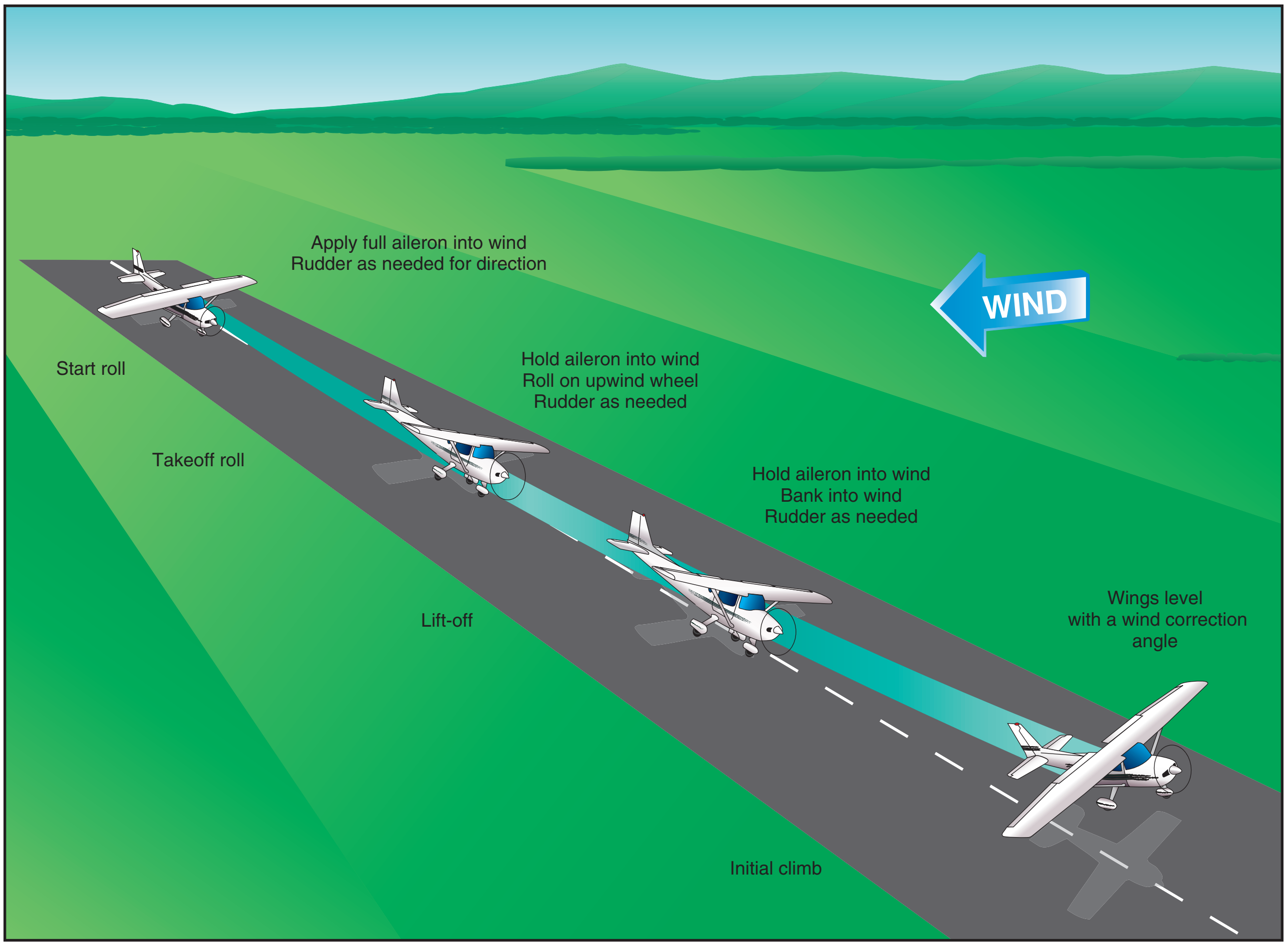

Figure 5-3. Crosswind takeoff roll and initial climb.

swerve left when the wind is from the left. In any case, whatever rudder pressure is required to keep the airplane rolling straight down the runway should be applied.

As the forward speed of the airplane increases and the crosswind becomes more of a relative headwind, the mechanical holding of full aileron into the wind should be reduced. It is when increasing pressure is being felt on the aileron control that the ailerons are becoming more effective. As the aileron's effectiveness increases and the **crosswind component** of the relative wind becomes less effective, it will be necessary to gradually reduce the aileron pressure. The crosswind component effect does not completely vanish, so some aileron pressure will have to be maintained throughout the takeoff roll to keep the crosswind from raising the upwind wing. If the upwind wing rises, thus exposing more surface to the crosswind, a "skipping" action may result. [Figure 5-4]

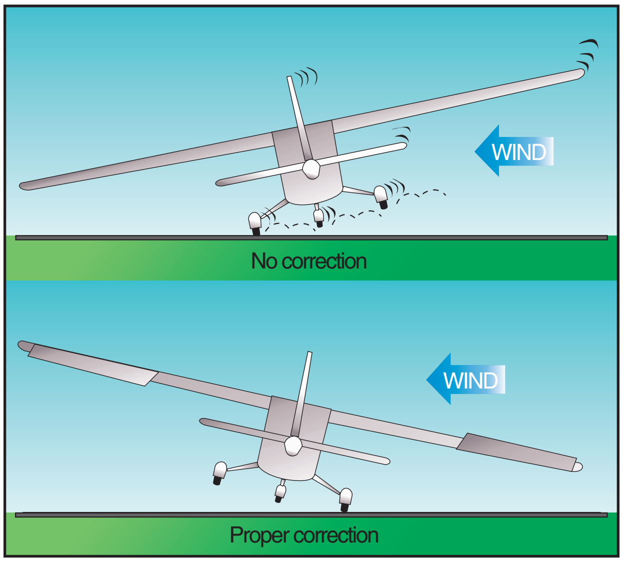

Figure 5-4. Crosswind effect.

This is usually indicated by a series of very small bounces, caused by the airplane attempting to fly and then settling back onto the runway. During these bounces, the crosswind also tends to move the airplane sideways, and these bounces will develop into side-skipping. This side-skipping imposes severe side stresses on the landing gear and could result in structural failure.

It is important, during a crosswind takeoff roll, to hold sufficient aileron into the wind not only to keep the upwind wing from rising but to hold that wing down so that the airplane will, immediately after lift-off, be **sideslipping** into the wind enough to counteract drift.

LIFT-OFF

As the nosewheel is being raised off the runway, the holding of aileron control into the wind may result in the downwind wing rising and the downwind main wheel lifting off the runway first, with the remainder of the takeoff roll being made on that one main wheel. This is acceptable and is preferable to side-skipping.

If a significant crosswind exists, the main wheels should be held on the ground slightly longer than in a normal takeoff so that a smooth but very definite lift-off can be made. This procedure will allow the airplane to leave the ground under more positive control so that it will definitely remain airborne while the proper amount of wind correction is being established. More importantly, this procedure will avoid imposing excessive side-loads on the landing gear and prevent possible damage that would result from the airplane settling back to the runway while drifting.

As both main wheels leave the runway and ground friction no longer resists drifting, the airplane will be slowly carried sideways with the wind unless adequate drift correction is maintained by the pilot. Therefore, it is important to establish and maintain the proper amount of crosswind correction prior to lift-off by applying aileron pressure toward the wind to keep the upwind wing from rising and applying rudder pressure as needed to prevent weathervaning.

INITIAL CLIMB

If proper crosswind correction is being applied, as soon as the airplane is airborne, it will be sideslipping into the wind sufficiently to counteract the drifting effect of the wind. [Figure 5-5] This sideslipping should be continued until the airplane has a positive rate of climb. At that time, the airplane should be turned into the wind to establish just enough wind correction angle to counteract the wind and then the wings rolled level. Firm and aggressive use of the rudders will be required to keep the airplane headed straight down the runway. The climb with a wind correction angle should be continued to follow a ground track aligned with the runway direction. However, because the force of a crosswind may vary markedly within a few hundred feet of the ground, frequent checks of actual ground track should be made, and the wind correction adjusted as necessary. The remainder of the climb technique is the same used for normal takeoffs and climbs.

Common errors in the performance of crosswind takeoffs are:

- Failure to adequately clear the area prior to taxiing onto the active runway.
- Using less than full aileron pressure into the wind initially on the takeoff roll.
- Mechanical use of aileron control rather than sensing the need for varying aileron control input through feel for the airplane.

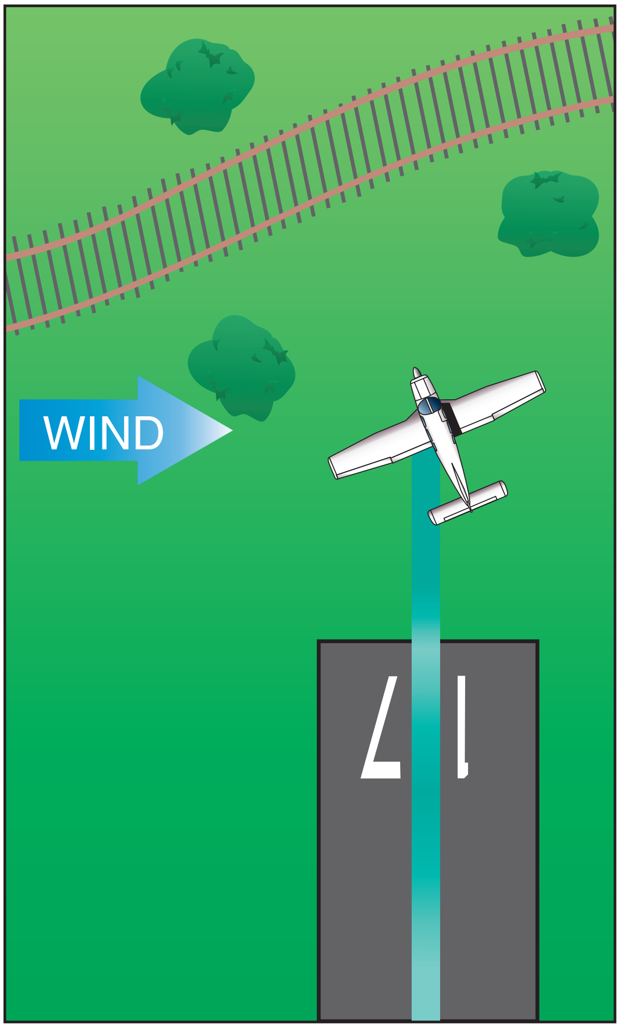

Figure 5-5. Crosswind climb flightpath.

- Premature lift-off resulting in side-skipping.
- Excessive aileron input in the latter stage of the takeoff roll resulting in a steep bank into the wind at lift-off.
- Inadequate drift correction after lift-off.

GROUND EFFECT ON TAKEOFF

Ground effect is a condition of improved performance encountered when the airplane is operating very close to the ground. Ground effect can be detected and measured up to an altitude equal to one wingspan above the surface. [Figure 5-6] However, ground effect is most significant when the airplane (especially a low-wing airplane) is maintaining a constant attitude at low airspeed at low altitude (for example, during takeoff when the airplane lifts off and accelerates to climb speed, and during the landing flare before touchdown).

When the wing is under the influence of ground effect, there is a reduction in upwash, downwash, and wingtip vortices. As a result of the reduced wingtip vortices, induced drag is reduced. When the wing is at a height equal to one-fourth the span, the reduction in induced drag is about 25 percent, and when the wing is at a height equal to one-tenth the span, the reduction in induced drag is about 50 percent. At high speeds where parasite drag dominates, induced drag is a small part of the total drag. Consequently, the effects of ground effect are of greater concern during takeoff and landing.

On takeoff, the takeoff roll, lift-off, and the beginning of the initial climb are accomplished in the ground effect area. The ground effect causes local increases in static pressure, which cause the airspeed indicator and altimeter to indicate slightly less than they should, and usually results in the vertical speed indicator indicating a descent. As the airplane lifts off and climbs out of the ground effect area, however, the following will occur:

- The airplane will require an increase in angle of attack to maintain the same lift coefficient.
- The airplane will experience an increase in induced drag and thrust required.
- The airplane will experience a pitch-up tendency and will require less elevator travel because of an increase in downwash at the horizontal tail.

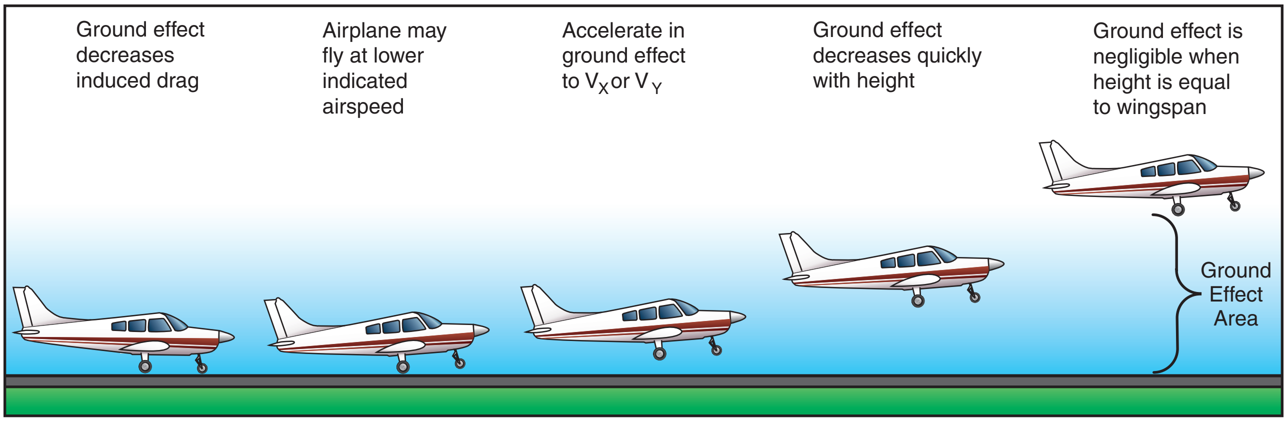

Figure 5-6. Takeoff in ground effect area.

- The airplane will experience a reduction in static source pressure as it leaves the ground effect area and a corresponding increase in indicated airspeed.

Due to the reduced drag in ground effect, the airplane may seem to be able to take off below the recommended airspeed. However, as the airplane rises out of ground effect with an insufficient airspeed, initial climb performance may prove to be marginal because of the increased drag. Under conditions of high-density altitude, high temperature, and/or maximum gross weight, the airplane may be able to become airborne at an insufficient airspeed, but unable to climb out of ground effect. Consequently, the airplane may not be able to clear obstructions, or may settle back on the runway. The point to remember is that additional power is required to compensate for increases in drag that occur as an airplane leaves ground effect. But during an initial climb, the engine is already developing maximum power. The only alternative is to lower pitch attitude to gain additional airspeed, which will result in inevitable altitude loss. Therefore, under marginal conditions, it is important that the airplane takes off at the recommended speed that will provide adequate initial climb performance.

Ground effect is important to normal flight operations. If the runway is long enough, or if no obstacles exist, ground effect can be used to an advantage by using the reduced drag to improve initial acceleration. Additionally, the procedure for takeoff from unsatisfactory surfaces is to take as much weight on the wings as possible during the ground run, and to lift off with the aid of ground effect before true flying speed is attained. It is then necessary to reduce the angle of attack to attain normal airspeed before attempting to fly away from the ground effect area.

SHORT-FIELD TAKEOFF AND MAXIMUM PERFORMANCE CLIMB

Takeoffs and climbs from fields where the takeoff area is short or the available takeoff area is restricted by obstructions require that the pilot operate the airplane at the limit of its takeoff performance capabilities. To depart from such an area safely, the pilot must exercise positive and precise control of airplane attitude and airspeed so that takeoff and climb performance results in the shortest ground roll and the steepest angle of climb. [Figure 5-7]

The achieved result should be consistent with the performance section of the FAA-approved Airplane Flight Manual and/or Pilot's Operating Handbook (AFM/POH). In all cases, the power setting, flap setting, airspeed, and procedures prescribed by the airplane's manufacturer should be followed.

In order to accomplish a maximum performance takeoff safely, the pilot must have adequate knowledge in the use and effectiveness of the best angle-of-climb speed (V_X) and the best rate-of-climb speed (V_Y) for the specific make and model of airplane being flown.

The speed for V_X is that which will result in the greatest gain in altitude for a given distance over the ground. It is usually slightly less than V_Y which provides the greatest gain in altitude per unit of time. The specific speeds to be used for a given airplane are stated in the FAA-approved AFM/POH. It should be emphasized that in some airplanes, a deviation of 5 knots from the recommended speed will result in a significant reduction in climb performance. Therefore, precise control of airspeed has an important bearing on the successful execution as well as the safety of the maneuver.

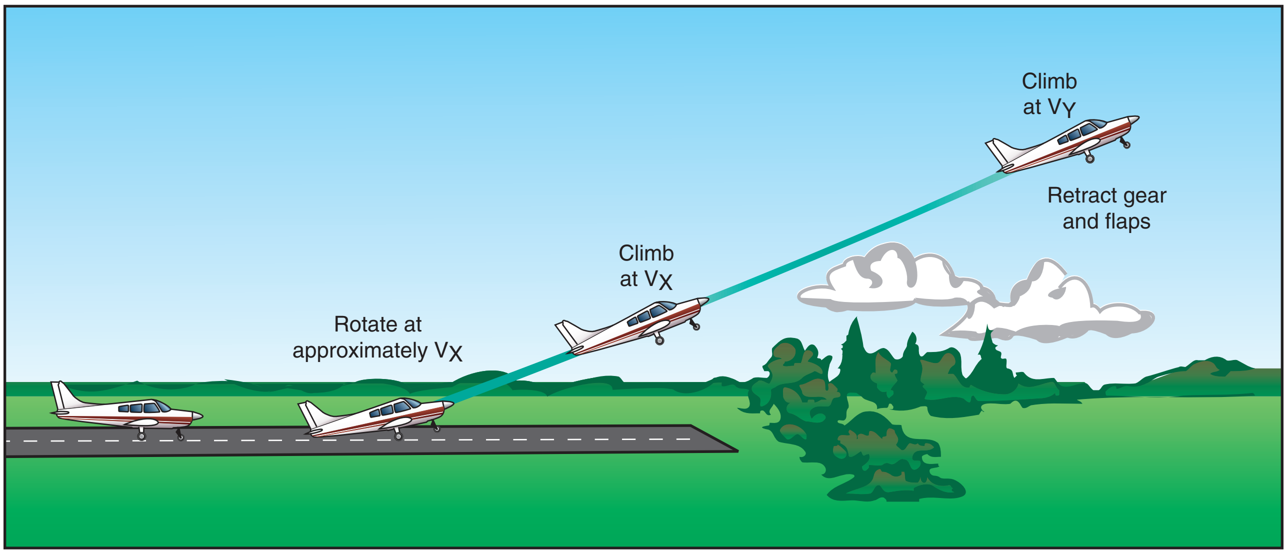

Figure 5-7. Short-field takeoff.

TAKEOFF ROLL

Taking off from a short field requires the takeoff to be started from the very beginning of the takeoff area. At this point, the airplane is aligned with the intended takeoff path. If the airplane manufacturer recommends the use of flaps, they should be extended the proper amount before starting the takeoff roll. This permits the pilot to give full attention to the proper technique and the airplane's performance throughout the takeoff.

Some authorities prefer to hold the brakes until the maximum obtainable engine r.p.m. is achieved before allowing the airplane to begin its takeoff run. However, it has not been established that this procedure will result in a shorter takeoff run in all light single-engine airplanes. Takeoff power should be applied smoothly and continuously—without hesitation—to accelerate the airplane as rapidly as possible. The airplane should be allowed to roll with its full weight on the main wheels and accelerated to the lift-off speed. As the takeoff roll progresses, the airplane's pitch attitude and angle of attack should be adjusted to that which results in the minimum amount of drag and the quickest acceleration. In nosewheel-type airplanes, this will involve little use of the elevator control, since the airplane is already in a low drag attitude.

LIFT-OFF

Approaching best angle-of-climb speed (V_X), the airplane should be smoothly and firmly lifted off, or rotated, by applying back-elevator pressure to an attitude that will result in the best angle-of-climb airspeed (V_X). Since the airplane will accelerate more rapidly after lift-off, additional back-elevator pressure becomes necessary to hold a constant airspeed. After becoming airborne, a wings level climb should be maintained at V_X until obstacles have been cleared or, if no obstacles are involved, until an altitude of at least 50 feet above the takeoff surface is attained. Thereafter, the pitch attitude may be lowered slightly, and the climb continued at best rate-of-climb speed (V_Y) until reaching a safe maneuvering altitude. Remember that an attempt to pull the airplane off the ground prematurely, or to climb too steeply, may cause the airplane to settle back to the runway or into the obstacles. Even if the airplane remains airborne, the initial climb will remain flat and climb performance/obstacle clearance ability seriously degraded until best angle-of-climb airspeed (V_X) is achieved. [Figure 5-8]

The objective is to rotate to the appropriate pitch attitude at (or near) best angle-of-climb airspeed. It should be remembered, however, that some airplanes will have a natural tendency to lift off well before reaching V_X. In these airplanes, it may be necessary to allow the airplane to lift off in ground effect and then reduce pitch attitude to level until the airplane accelerates to best angle-of-climb airspeed with the wheels just clear of the runway surface. This method is preferable to forcing the airplane to remain on the ground with forward-elevator pressure until best angle-of-climb speed is attained. Holding the airplane on the ground unnecessarily puts excessive pressure on the nosewheel, may result in "**wheelbarrowing**," and will hinder both acceleration and overall airplane performance.

INITIAL CLIMB

On short-field takeoffs, the landing gear and flaps should remain in takeoff position until clear of obstacles (or as recommended by the manufacturer) and V_Y has been established. It is generally unwise for the pilot to be looking in the cockpit or reaching for landing gear and flap controls until obstacle clearance is assured. When the airplane is stabilized at V_Y, the gear (if equipped) and then the flaps should be retracted. It is usually advisable to raise the flaps in increments to avoid sudden loss of lift and settling of the airplane. Next, reduce the power to the normal climb setting or as recommended by the airplane manufacturer.

Common errors in the performance of short-field takeoffs and maximum performance climbs are:

- Failure to adequately clear the area.
- Failure to utilize all available runway/takeoff area.
- Failure to have the airplane properly trimmed prior to takeoff.
- Premature lift-off resulting in high drag.
- Holding the airplane on the ground unnecessarily with excessive forward-elevator pressure.
- Inadequate rotation resulting in excessive speed after lift-off.
- Inability to attain/maintain best angle-of-climb airspeed.

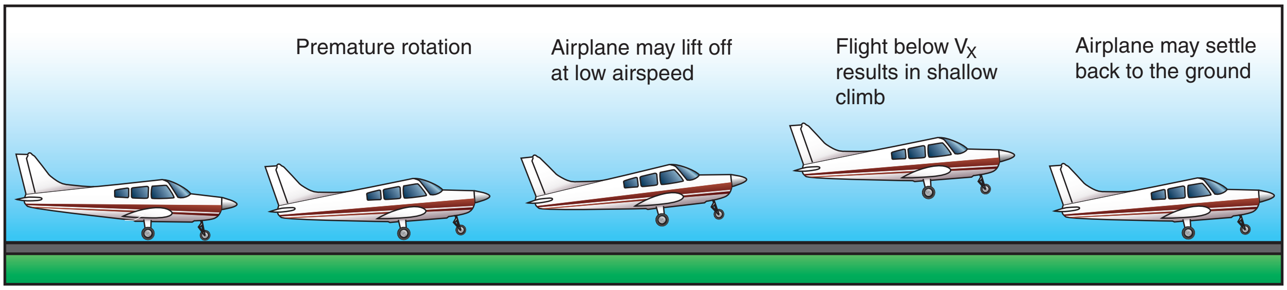

Figure 5-8. Effect of premature lift-off.

- Fixation on the airspeed indicator during initial climb.
- Premature retraction of landing gear and/or wing flaps.

SOFT/ROUGH-FIELD TAKEOFF AND CLIMB

Takeoffs and climbs from soft fields require the use of operational techniques for getting the airplane airborne as quickly as possible to eliminate the drag caused by tall grass, soft sand, mud, and snow, and may or may not require climbing over an obstacle. The technique makes judicious use of ground effect and requires a feel for the airplane and fine control touch. These same techniques are also useful on a rough field where it is advisable to get the airplane off the ground as soon as possible to avoid damaging the landing gear.

Soft surfaces or long, wet grass usually reduces the airplane's acceleration during the takeoff roll so much that adequate takeoff speed might not be attained if normal takeoff techniques were employed.

It should be emphasized that the correct takeoff procedure for soft fields is quite different from that appropriate for short fields with firm, smooth surfaces. To minimize the hazards associated with takeoffs from soft or rough fields, support of the airplane's weight must be transferred as rapidly as possible from the wheels to the wings as the takeoff roll proceeds. Establishing and maintaining a relatively high angle of attack or nose-high pitch attitude as early as possible does this. Wing flaps may be lowered prior to starting the takeoff (if recommended by the manufacturer) to provide additional lift and to transfer the airplane's weight from the wheels to the wings as early as possible.

Stopping on a soft surface, such as mud or snow, might bog the airplane down; therefore, it should be kept in continuous motion with sufficient power while lining up for the takeoff roll.

TAKEOFF ROLL

As the airplane is aligned with the takeoff path, takeoff power is applied smoothly and as rapidly as the powerplant will accept it without faltering. As the airplane accelerates, enough back-elevator pressure should be applied to establish a positive angle of attack and to reduce the weight supported by the nosewheel.

When the airplane is held at a nose-high attitude throughout the takeoff run, the wings will, as speed increases and lift develops, progressively relieve the wheels of more and more of the airplane's weight, thereby minimizing the drag caused by surface irregularities or adhesion. If this attitude is accurately maintained, the airplane will virtually fly itself off the ground, becoming airborne at airspeed slower than a safe climb speed because of ground effect. [Figure 5-9]

LIFT-OFF

After becoming airborne, the nose should be lowered very gently with the wheels clear of the surface to allow the airplane to accelerate to V_Y, or V_X if obstacles must be cleared. Extreme care must be exercised immediately after the airplane becomes airborne and while it accelerates, to avoid settling back onto the surface. An attempt to climb prematurely or too steeply may cause the airplane to settle back to the surface as a result of losing the benefit of ground effect. An attempt to climb out of ground effect before sufficient climb airspeed is attained may result in the airplane being unable to climb further as the ground effect area is transited, even with full power. Therefore, it is essential that the airplane remain in ground effect until at least V_X is reached. This requires feel for the airplane, and a very fine control touch, in order to avoid over-controlling the elevator as required control pressures change with airplane acceleration.

INITIAL CLIMB

After a positive rate of climb is established, and the airplane has accelerated to V_Y, retract the landing gear and flaps, if equipped. If departing from an airstrip with wet snow or slush on the takeoff surface, the gear should not be retracted immediately. This allows for any wet snow or slush to be air-dried. In the event an obstacle must be cleared after a soft-field takeoff, the climb-out is performed at V_X until the obstacle has been cleared. After reaching this point, the pitch attitude is adjusted to V_Y and the gear and flaps are retracted. The power may then be reduced to the normal climb setting.

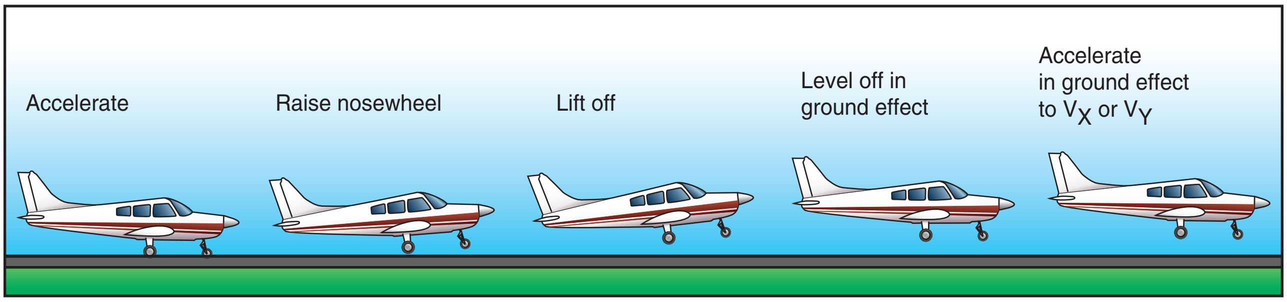

Figure 5-9. Soft-field takeoff.

Common errors in the performance of soft/rough field takeoff and climbs are:

- Failure to adequately clear the area.
- Insufficient back-elevator pressure during initial takeoff roll resulting in inadequate angle of attack.
- Failure to cross-check engine instruments for indications of proper operation after applying power.
- Poor directional control.
- Climbing too steeply after lift-off.
- Abrupt and/or excessive elevator control while attempting to level off and accelerate after lift-off.
- Allowing the airplane to "mush" or settle resulting in an inadvertent touchdown after lift-off.
- Attempting to climb out of ground effect area before attaining sufficient climb speed.
- Failure to anticipate an increase in pitch attitude as the airplane climbs out of ground effect.

REJECTED TAKEOFF/ENGINE FAILURE

Emergency or abnormal situations can occur during a takeoff that will require a pilot to reject the takeoff while still on the runway. Circumstances such as a malfunctioning powerplant, inadequate acceleration, runway incursion, or air traffic conflict may be reasons for a rejected takeoff.

Prior to takeoff, the pilot should have in mind a point along the runway at which the airplane should be airborne. If that point is reached and the airplane is not airborne, immediate action should be taken to discontinue the takeoff. Properly planned and executed, chances are excellent the airplane can be stopped on the remaining runway without using extraordinary measures, such as excessive braking that may result in loss of directional control, airplane damage, and/or personal injury.

In the event a takeoff is rejected, the power should be reduced to idle and maximum braking applied while maintaining directional control. If it is necessary to shut down the engine due to a fire, the mixture control should be brought to the idle cutoff position and the magnetos turned off. In all cases, the manufacturer's emergency procedure should be followed.

What characterizes all power loss or engine failure occurrences after lift-off is urgency. In most instances, the pilot has only a few seconds after an engine failure to decide what course of action to take and to execute it. Unless prepared in advance to make the proper decision, there is an excellent chance the pilot will make a poor decision, or make no decision at all and allow events to rule.

In the event of an engine failure on initial climb-out, the pilot's first responsibility is to maintain aircraft control. At a climb pitch attitude without power, the airplane will be at or near a stalling angle of attack. At the same time, the pilot may still be holding right rudder. It is essential the pilot immediately lower the pitch attitude to prevent a stall and possible spin. The pilot should establish a controlled glide toward a plausible landing area (preferably straight ahead on the remaining runway).

NOISE ABATEMENT

Aircraft noise problems have become a major concern at many airports throughout the country. Many local communities have pressured airports into developing specific operational procedures that will help limit aircraft noise while operating over nearby areas. For years now, the FAA, airport managers, aircraft operators, pilots, and special interest groups have been working together to minimize aircraft noise for nearby sensitive areas. As a result, noise abatement procedures have been developed for many of these airports that include standardized profiles and procedures to achieve these lower noise goals.

Airports that have noise abatement procedures provide information to pilots, operators, air carriers, air traffic facilities, and other special groups that are applicable to their airport. These procedures are available to the aviation community by various means. Most of this information comes from the *Airport/Facility Directory*, local and regional publications, printed handouts, operator bulletin boards, safety briefings, and local air traffic facilities.

At airports that use noise abatement procedures, reminder signs may be installed at the taxiway hold positions for applicable runways. These are to remind pilots to use and comply with noise abatement procedures on departure. Pilots who are not familiar with these procedures should ask the tower or air traffic facility for the recommended procedures. In any case, pilots should be considerate of the surrounding community while operating their airplane to and from such an airport. This includes operating as quietly, yet safely as possible.

PURPOSE AND SCOPE

Ground reference maneuvers and their related factors are used in developing a high degree of pilot skill. Although most of these maneuvers are not performed as such in normal everyday flying, the elements and principles involved in each are applicable to performance of the customary pilot operations. They aid the pilot in analyzing the effect of wind and other forces acting on the airplane and in developing a fine control touch, coordination, and the division of attention necessary for accurate and safe maneuvering of the airplane.

All of the early part of the pilot's training has been conducted at relatively high altitudes, and for the purpose of developing technique, knowledge of maneuvers, coordination, feel, and the handling of the airplane in general. This training will have required that most of the pilot's attention be given to the actual handling of the airplane, and the results of control pressures on the action and attitude of the airplane.

If permitted to continue beyond the appropriate training stage, however, the student pilot's concentration of attention will become a fixed habit, one that will seriously detract from the student's ease and safety as a pilot, and will be very difficult to eliminate. Therefore, it is necessary, as soon as the pilot shows proficiency in the fundamental maneuvers, that the pilot be introduced to maneuvers requiring outside attention on a practical application of these maneuvers and the knowledge gained.

It should be stressed that, during ground reference maneuvers, it is equally important that basic flying technique previously learned be maintained. The flight instructor should not allow any relaxation of the student's previous standard of technique simply because a new factor is added. This requirement should be maintained throughout the student's progress from maneuver to maneuver. Each new maneuver should embody some advance and include the principles of the preceding one in order that continuity be maintained. Each new factor introduced should be merely a step-up of one already learned so that orderly, consistent progress can be made.

MANEUVERING BY REFERENCE TO GROUND OBJECTS

Ground track or ground reference maneuvers are performed at a relatively low altitude while applying wind drift correction as needed to follow a predetermined track or path over the ground. They are designed to develop the ability to control the airplane, and to recognize and correct for the effect of wind while dividing attention among other matters. This requires planning ahead of the airplane, maintaining orientation in relation to ground objects, flying appropriate headings to follow a desired ground track, and being cognizant of other air traffic in the immediate vicinity.

Ground reference maneuvers should be flown at an altitude of approximately 600 to 1,000 feet AGL. The actual altitude will depend on the speed and type of airplane to a large extent, and the following factors should be considered.

- The speed with relation to the ground should not be so apparent that events happen too rapidly.
- The radius of the turn and the path of the airplane over the ground should be easily noted and changes planned and effected as circumstances require.
- Drift should be easily discernable, but not tax the student too much in making corrections.
- Objects on the ground should appear in their proportion and size.
- The altitude should be low enough to render any gain or loss apparent to the student, but in no case lower than 500 feet above the highest obstruction.

During these maneuvers, both the instructor and the student should be alert for available forced-landing fields. The area chosen should be away from communities, livestock, or groups of people to prevent possible annoyance or hazards to others. Due to the altitudes at which these maneuvers are performed, there is little time available to search for a suitable field for landing in the event the need arises.

DRIFT AND GROUND TRACK CONTROL

Whenever any object is free from the ground, it is affected by the medium with which it is surrounded. This means that a free object will move in whatever direction and speed that the medium moves.

For example, if a powerboat is crossing a river and the river is still, the boat could head directly to a point on the opposite shore and travel on a straight course to that point without drifting. However, if the river were flowing swiftly, the water current would have to be considered. That is, as the boat progresses forward with its own power, it must also move upstream at the same rate the river is moving it downstream. This is accomplished by angling the boat upstream sufficiently to counteract the downstream flow. If this is done, the boat will follow the desired **track** across the river from the departure point directly to the intended destination point. Should the boat not be headed sufficiently upstream, it would drift with the current and run aground at some point downstream on the opposite bank. [Figure 6-1]

As soon as an airplane becomes airborne, it is free of ground friction. Its path is then affected by the air mass in which it is flying; therefore, the airplane (like the boat) will not always track along the ground in the exact direction that it is headed. When flying with the longitudinal axis of the airplane aligned with a road, it may be noted that the airplane gets closer to or farther from the road without any turn having been made. This would indicate that the air mass is moving sideward in relation to the airplane. Since the airplane is flying within this moving body of air (wind), it moves or drifts with the air in the same direction and speed, just like the boat moved with the river current. [Figure 6-1]

When flying straight and level and following a selected ground track, the preferred method of correcting for wind drift is to head the airplane (wind correction angle) sufficiently into the wind to cause the airplane to move forward into the wind at the same rate the wind is moving it sideways. Depending on the wind velocity, this may require a large wind correction angle or one of only a few degrees. When the drift has been neutralized, the airplane will follow the desired ground track.

To understand the need for drift correction during flight, consider a flight with a wind velocity of 30 knots from the left and 90° to the direction the airplane is headed. After 1 hour, the body of air in which the airplane is flying will have moved 30 nautical miles (NM) to the right. Since the airplane is moving with this body of air, it too will have drifted 30 NM to the right. In relation to the air, the airplane moved forward, but in relation to the ground, it moved forward as well as 30 NM to the right.

There are times when the pilot needs to correct for drift while in a turn. [Figure 6-2] Throughout the turn the wind will be acting on the airplane from constantly changing angles. The relative wind angle and speed

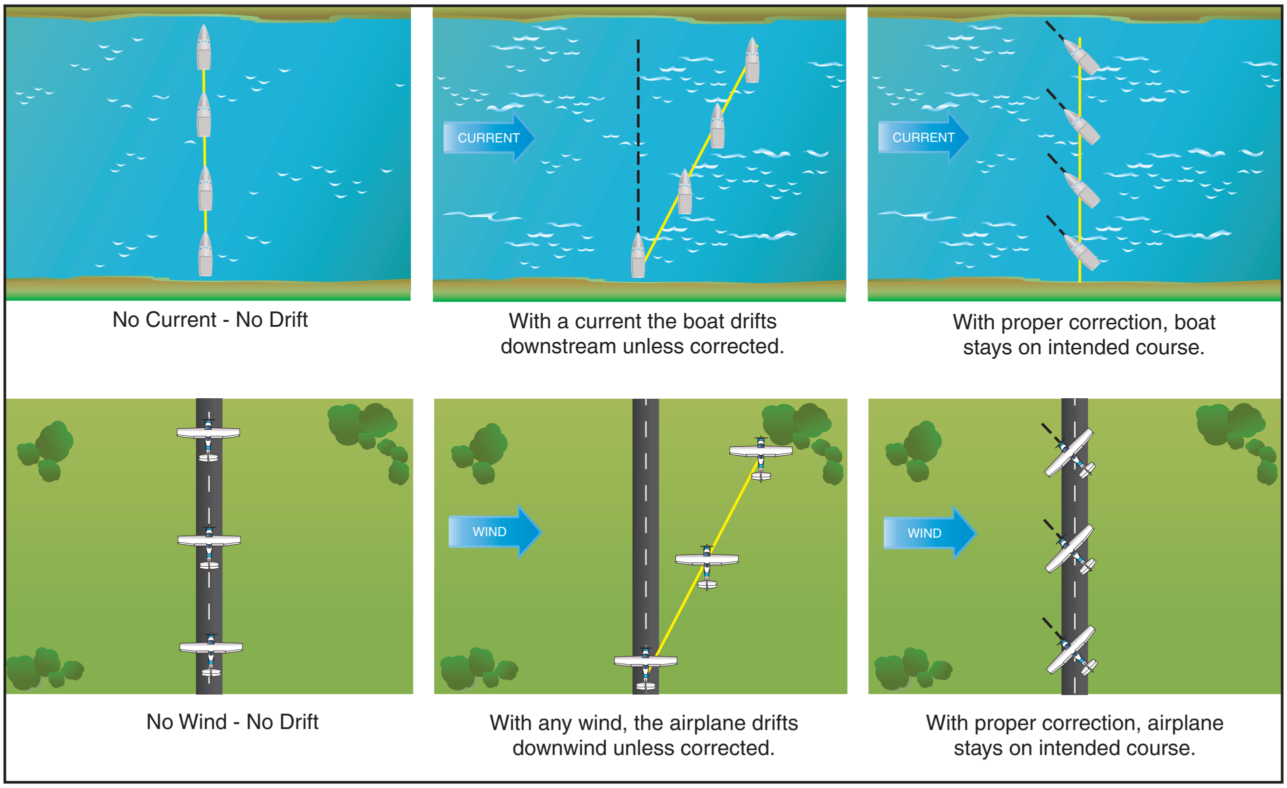

Figure 6-1. Wind drift.

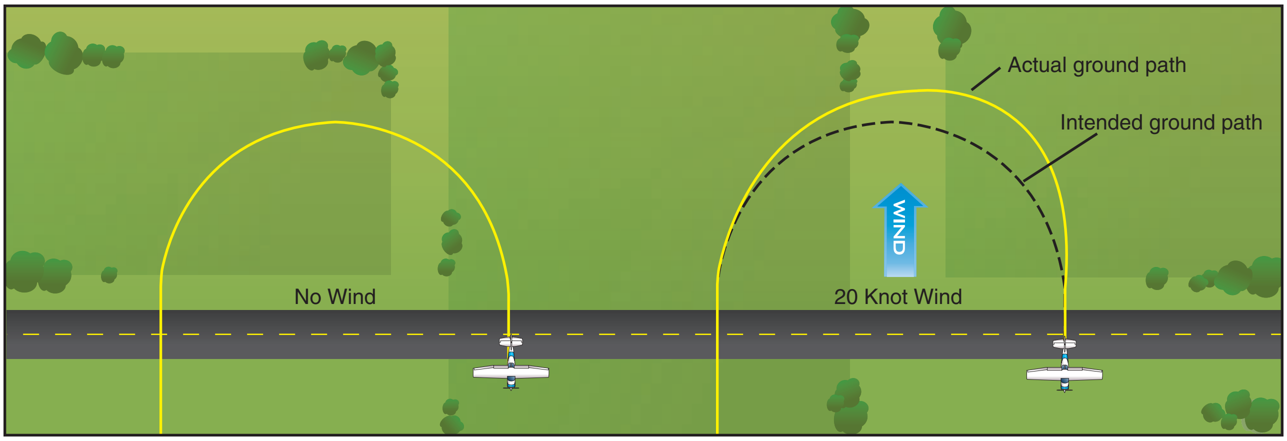

Figure 6-2. Effect of wind during a turn.

govern the time it takes for the airplane to progress through any part of a turn. This is due to the constantly changing **groundspeed**. When the airplane is headed into the wind, the groundspeed is decreased; when headed downwind, the groundspeed is increased. Through the crosswind portion of a turn, the airplane must be turned sufficiently into the wind to counteract drift.

To follow a desired circular ground track, the wind correction angle must be varied in a timely manner because of the varying groundspeed as the turn progresses. The faster the groundspeed, the faster the wind correction angle must be established; the slower the groundspeed, the slower the wind correction angle may be established. It can be seen then that the steepest bank and fastest rate of turn should be made on the downwind portion of the turn and the shallowest bank and slowest rate of turn on the upwind portion.

The principles and techniques of varying the angle of bank to change the rate of turn and wind correction angle for controlling wind drift during a turn are the same for all ground track maneuvers involving changes in direction of flight.

When there is no wind, it should be simple to fly along a ground track with an arc of exactly 180° and a constant radius because the flightpath and ground track would be identical. This can be demonstrated by approaching a road at a 90° angle and, when directly over the road, rolling into a medium-banked turn, then maintaining the same angle of bank throughout the 180° of turn. [Figure 6-2]

To complete the turn, the rollout should be started at a point where the wings will become level as the airplane again reaches the road at a 90° angle and will be directly over the road just as the turn is completed. This would be possible only if there were absolutely no wind and if the angle of bank and the rate of turn remained constant throughout the entire maneuver.

If the turn were made with a constant angle of bank and a wind blowing directly across the road, it would result in a constant radius turn through the air. However, the wind effects would cause the ground track to be distorted from a constant radius turn or semicircular path. The greater the wind velocity, the greater would be the difference between the desired ground track and the flightpath. To counteract this drift, the flightpath can be controlled by the pilot in such a manner as to neutralize the effect of the wind, and cause the ground track to be a constant radius semicircle.

The effects of wind during turns can be demonstrated after selecting a road, railroad, or other ground reference that forms a straight line parallel to the wind. Fly into the wind directly over and along the line and then make a turn with a constant medium angle of bank for 360° of turn. [Figure 6-3] The airplane will return to a point directly over the line but slightly downwind from the starting point, the amount depending on the wind velocity and the time required to complete the turn. The path over the ground will be an elongated circle, although in reference to the air it is a perfect circle. Straight flight during the upwind segment after completion of the turn is necessary to bring the airplane back to the starting position.

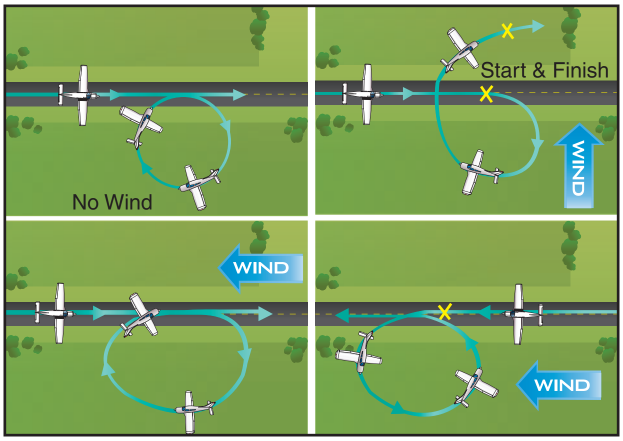

Figure 6-3. Effect of wind during turns.

A similar 360° turn may be started at a specific point over the reference line, with the airplane headed directly downwind. In this demonstration, the effect of wind during the constant banked turn will drift the airplane to a point where the line is reintercepted, but the 360° turn will be completed at a point downwind from the starting point.

Another reference line which lies directly crosswind may be selected and the same procedure repeated, showing that if wind drift is not corrected the airplane will, at the completion of the 360° turn, be headed in the original direction but will have drifted away from the line a distance dependent on the amount of wind.

From these demonstrations, it can be seen where and why it is necessary to increase or decrease the angle of bank and the rate of turn to achieve a desired track over the ground. The principles and techniques involved can be practiced and evaluated by the performance of the ground track maneuvers discussed in this chapter.

RECTANGULAR COURSE

Normally, the first ground reference maneuver the pilot is introduced to is the rectangular course. [Figure 6-4]

The rectangular course is a training maneuver in which the ground track of the airplane is equidistant from all sides of a selected rectangular area on the ground. The maneuver simulates the conditions encountered in an airport traffic pattern. While performing the maneuver, the altitude and airspeed should be held constant. The maneuver assists the student pilot in perfecting:

- Practical application of the turn.
- The division of attention between the flightpath, ground objects, and the handling of the airplane.
- The timing of the start of a turn so that the turn will be fully established at a definite point over the ground.
- The timing of the recovery from a turn so that a definite ground track will be maintained.
- The establishing of a ground track and the determination of the appropriate "crab" angle.

Like those of other ground track maneuvers, one of the objectives is to develop division of attention between the flightpath and ground references, while controlling the airplane and watching for other aircraft in the

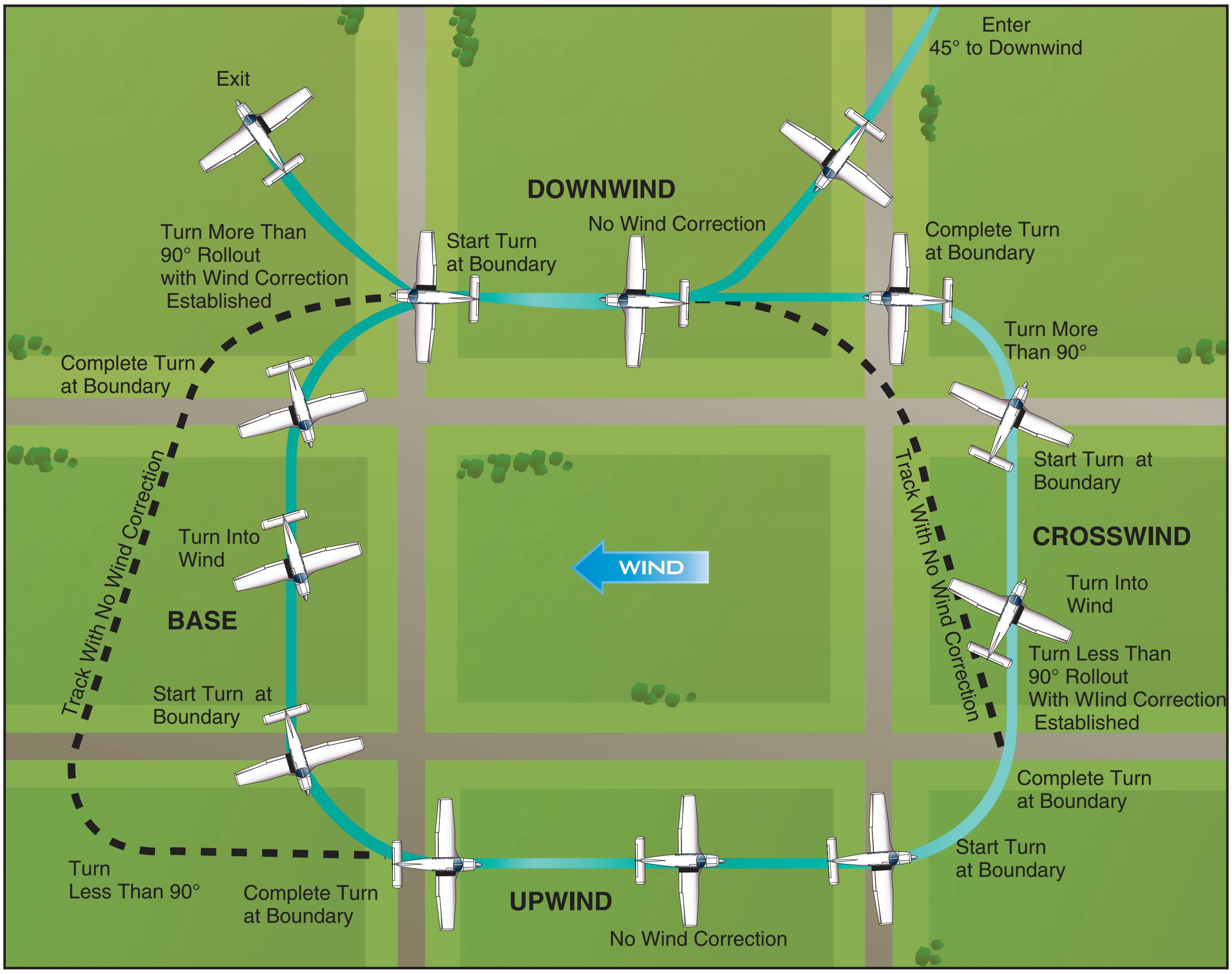

Figure 6-4. Rectangular course.

vicinity. Another objective is to develop recognition of drift toward or away from a line parallel to the intended ground track. This will be helpful in recognizing drift toward or from an airport runway during the various legs of the airport traffic pattern.

For this maneuver, a square or rectangular field, or an area bounded on four sides by section lines or roads (the sides of which are approximately a mile in length), should be selected well away from other air traffic. The airplane should be flown parallel to and at a uniform distance about one-fourth to one-half mile away from the field boundaries, not above the boundaries. For best results, the flightpath should be positioned outside the field boundaries just far enough that they may be easily observed from either pilot seat by looking out the side of the airplane. If an attempt is made to fly directly above the edges of the field, the pilot will have no usable reference points to start and complete the turns. The closer the track of the airplane is to the field boundaries, the steeper the bank necessary at the turning points. Also, the pilot should be able to see the edges of the selected field while seated in a normal position and looking out the side of the airplane during either a left-hand or right-hand course. The distance of the ground track from the edges of the field should be the same regardless of whether the course is flown to the left or right. All turns should be started when the airplane is abeam the corner of the field boundaries, and the bank normally should not exceed 45°. These should be the determining factors in establishing the distance from the boundaries for performing the maneuver.

Although the rectangular course may be entered from any direction, this discussion assumes entry on a downwind.

On the downwind leg, the wind is a tailwind and results in an increased groundspeed. Consequently, the turn onto the next leg is entered with a fairly fast rate of roll-in with relatively steep bank. As the turn progresses, the bank angle is reduced gradually because the tailwind component is diminishing, resulting in a decreasing groundspeed.

During and after the turn onto this leg (the equivalent of the base leg in a traffic pattern), the wind will tend to drift the airplane away from the field boundary. To compensate for the drift, the amount of turn will be more than 90°.

The rollout from this turn must be such that as the wings become level, the airplane is turned slightly toward the field and into the wind to correct for drift. The airplane should again be the same distance from the field boundary and at the same altitude, as on other legs. The base leg should be continued until the upwind leg boundary is being approached. Once more the pilot should anticipate drift and turning radius. Since drift correction was held on the base leg, it is necessary to turn less than 90° to align the airplane parallel to the upwind leg boundary. This turn should be started with a medium bank angle with a gradual reduction to a shallow bank as the turn progresses. The rollout should be timed to assure paralleling the boundary of the field as the wings become level.

While the airplane is on the upwind leg, the next field boundary should be observed as it is being approached, to plan the turn onto the crosswind leg. Since the wind is a headwind on this leg, it is reducing the airplane's groundspeed and during the turn onto the crosswind leg will try to drift the airplane toward the field. For this reason, the roll-in to the turn must be slow and the bank relatively shallow to counteract this effect. As the turn progresses, the headwind component decreases, allowing the groundspeed to increase. Consequently, the bank angle and rate of turn are increased gradually to assure that upon completion of the turn the crosswind ground track will continue the same distance from the edge of the field. Completion of the turn with the wings level should be accomplished at a point aligned with the upwind corner of the field.

Simultaneously, as the wings are rolled level, the proper drift correction is established with the airplane turned into the wind. This requires that the turn be less than a 90° change in heading. If the turn has been made properly, the field boundary will again appear to be one-fourth to one-half mile away. While on the crosswind leg, the wind correction angle should be adjusted as necessary to maintain a uniform distance from the field boundary.

As the next field boundary is being approached, the pilot should plan the turn onto the downwind leg. Since a wind correction angle is being held into the wind and away from the field while on the crosswind leg, this next turn will require a turn of more than 90°. Since the crosswind will become a tailwind, causing the groundspeed to increase during this turn, the bank initially should be medium and progressively increased as the turn proceeds. To complete the turn, the rollout must be timed so that the wings become level at a point aligned with the crosswind corner of the field just as the longitudinal axis of the airplane again becomes parallel to the field boundary. The distance from the field boundary should be the same as from the other sides of the field.

Usually, drift should not be encountered on the upwind or the downwind leg, but it may be difficult to find a situation where the wind is blowing exactly parallel to the field boundaries. This would make it necessary to use a slight wind correction angle on all the legs. It is important to anticipate the turns to correct for groundspeed, drift, and turning radius. When the wind is behind the airplane, the turn must be faster and steeper; when it is ahead of the airplane, the turn must be slower and shallower. These same techniques apply while flying in airport traffic patterns.

Common errors in the performance of rectangular courses are:

- Failure to adequately clear the area.
- Failure to establish proper altitude prior to entry. (Typically entering the maneuver while descending.)
- Failure to establish appropriate wind correction angle resulting in drift.
- Gaining or losing altitude.
- Poor coordination. (Typically skidding in turns from a downwind heading and slipping in turns from an upwind heading.)
- Abrupt control usage.
- Inability to adequately divide attention between airplane control and maintaining ground track.
- Improper timing in beginning and recovering from turns.
- Inadequate visual lookout for other aircraft.

S-TURNS ACROSS A ROAD

An S-turn across a road is a practice maneuver in which the airplane's ground track describes semicircles of equal radii on each side of a selected straight line on the ground. [Figure 6-5] The straight line may be a road, fence, railroad, or section line that lies perpendicular to the wind, and should be of sufficient length for making a series of turns. A constant altitude should be maintained throughout the maneuver.

S-turns across a road present one of the most elementary problems in the practical application of the turn and in the correction for wind drift in turns. While the application of this maneuver is considerably less advanced in some respects than the rectangular course, it is taught after the student has been introduced to that maneuver in order that the student may have a knowledge of the correction for wind drift in straight flight along a reference line before the student attempt to correct for drift by playing a turn.

The objectives of S-turns across a road are to develop the ability to compensate for drift during turns, orient the flightpath with ground references, follow an assigned ground track, arrive at specified points on assigned headings, and divide the pilot's attention. The

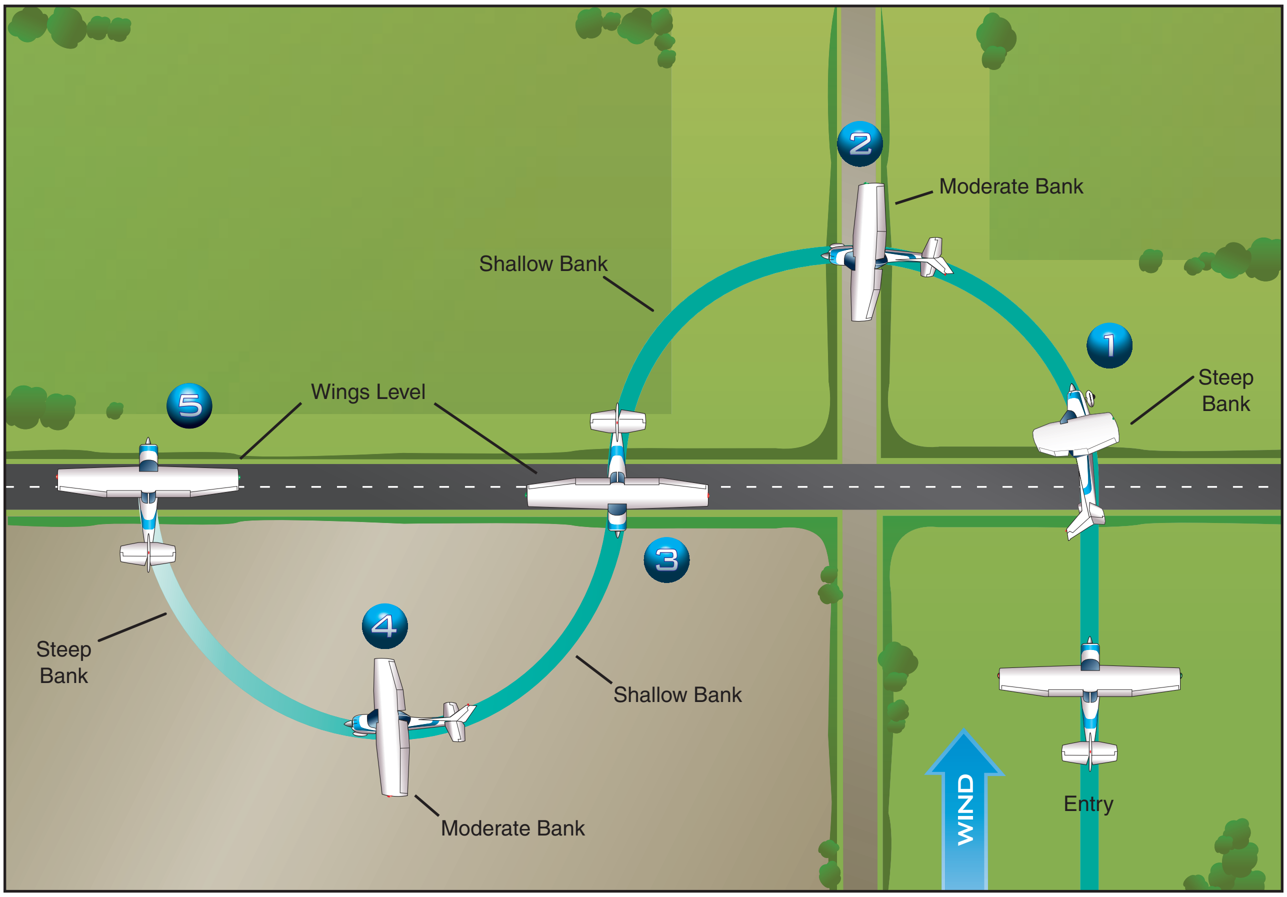

Figure 6-5. S-Turns.

maneuver consists of crossing the road at a 90° angle and immediately beginning a series of 180° turns of uniform radius in opposite directions, re-crossing the road at a 90° angle just as each 180° turn is completed.

To accomplish a constant radius ground track requires a changing roll rate and angle of bank to establish the wind correction angle. Both will increase or decrease as groundspeed increases or decreases.

The bank must be steepest when beginning the turn on the downwind side of the road and must be shallowed gradually as the turn progresses from a downwind heading to an upwind heading. On the upwind side, the turn should be started with a relatively shallow bank and then gradually steepened as the airplane turns from an upwind heading to a downwind heading.

In this maneuver, the airplane should be rolled from one bank directly into the opposite just as the reference line on the ground is crossed.

Before starting the maneuver, a straight ground reference line or road that lies 90° to the direction of the wind should be selected, then the area checked to ensure that no obstructions or other aircraft are in the immediate vicinity. The road should be approached from the upwind side, at the selected altitude on a downwind heading. When directly over the road, the first turn should be started immediately. With the airplane headed downwind, the groundspeed is greatest and the rate of departure from the road will be rapid; so the roll into the steep bank must be fairly rapid to attain the proper wind correction angle. This prevents the airplane from flying too far from the road and from establishing a ground track of excessive radius.

During the latter portion of the first 90° of turn when the airplane's heading is changing from a downwind heading to a crosswind heading, the groundspeed becomes less and the rate of departure from the road decreases. The wind correction angle will be at the maximum when the airplane is headed directly crosswind.

After turning 90°, the airplane's heading becomes more and more an upwind heading, the groundspeed will decrease, and the rate of closure with the road will become slower. If a constant steep bank were maintained, the airplane would turn too quickly for the slower rate of closure, and would be headed perpendicular to the road prematurely. Because of the decreasing groundspeed and rate of closure while approaching the upwind heading, it will be necessary to gradually shallow the bank during the remaining 90° of the semicircle, so that the wind correction angle is removed completely and the wings become level as the 180° turn is completed at the moment the road is reached.

At the instant the road is being crossed again, a turn in the opposite direction should be started. Since the airplane is still flying into the headwind, the groundspeed is relatively slow. Therefore, the turn will have to be started with a shallow bank so as to avoid an excessive rate of turn that would establish the maximum wind correction angle too soon. The degree of bank should be that which is necessary to attain the proper wind correction angle so the ground track describes an arc the same size as the one established on the downwind side.

Since the airplane is turning from an upwind to a downwind heading, the groundspeed will increase and after turning 90°, the rate of closure with the road will increase rapidly. Consequently, the angle of bank and rate of turn must be progressively increased so that the airplane will have turned 180° at the time it reaches the road. Again, the rollout must be timed so the airplane is in straight-and-level flight directly over and perpendicular to the road.

Throughout the maneuver a constant altitude should be maintained, and the bank should be changing constantly to effect a true semicircular ground track.

Often there is a tendency to increase the bank too rapidly during the initial part of the turn on the upwind side, which will prevent the completion of the 180° turn before re-crossing the road. This is apparent when the turn is not completed in time for the airplane to cross the road at a perpendicular angle. To avoid this error, the pilot must visualize the desired half circle ground track, and increase the bank during the early part of this turn. During the latter part of the turn, when approaching the road, the pilot must judge the closure rate properly and increase the bank accordingly, so as to cross the road perpendicular to it just as the rollout is completed.

Common errors in the performance of S-turns across a road are:

- Failure to adequately clear the area.
- Poor coordination.
- Gaining or losing altitude.
- Inability to visualize the half circle ground track.
- Poor timing in beginning and recovering from turns.
- Faulty correction for drift.
- Inadequate visual lookout for other aircraft.

TURNS AROUND A POINT

Turns around a point, as a training maneuver, is a logical extension of the principles involved in the performance of S-turns across a road. Its purposes as a training maneuver are:

- To further perfect turning technique.
- To perfect the ability to subconsciously control the airplane while dividing attention between the flightpath and ground references.
- To teach the student that the radius of a turn is a distance which is affected by the degree of bank used when turning with relation to a definite object.
- To develop a keen perception of altitude.
- To perfect the ability to correct for wind drift while in turns.

In turns around a point, the airplane is flown in two or more complete circles of uniform radii or distance from a prominent ground reference point using a maximum bank of approximately 45° while maintaining a constant altitude.

The factors and principles of drift correction that are involved in S-turns are also applicable in this maneuver. As in other ground track maneuvers, a constant radius around a point will, if any wind exists, require a constantly changing angle of bank and angles of wind correction. The closer the airplane is to a direct downwind heading where the groundspeed is greatest, the steeper the bank and the faster the rate of turn required to establish the proper wind correction angle. The more nearly it is to a direct upwind heading where the groundspeed is least, the shallower the bank and the slower the rate of turn required to establish the proper wind correction angle. It follows, then, that throughout the maneuver the bank and rate of turn must be gradually varied in proportion to the groundspeed.

The point selected for turns around a point should be prominent, easily distinguished by the pilot, and yet small enough to present precise reference. [Figure 6-6] Isolated trees, crossroads, or other similar small landmarks are usually suitable.

To enter turns around a point, the airplane should be flown on a downwind heading to one side of the selected point at a distance equal to the desired radius of turn. In a high-wing airplane, the distance from the point must permit the pilot to see the point throughout the maneuver even with the wing lowered in a bank. If the radius is too large, the lowered wing will block the pilot's view of the point.

When any significant wind exists, it will be necessary to roll into the initial bank at a rapid rate so that the steep-

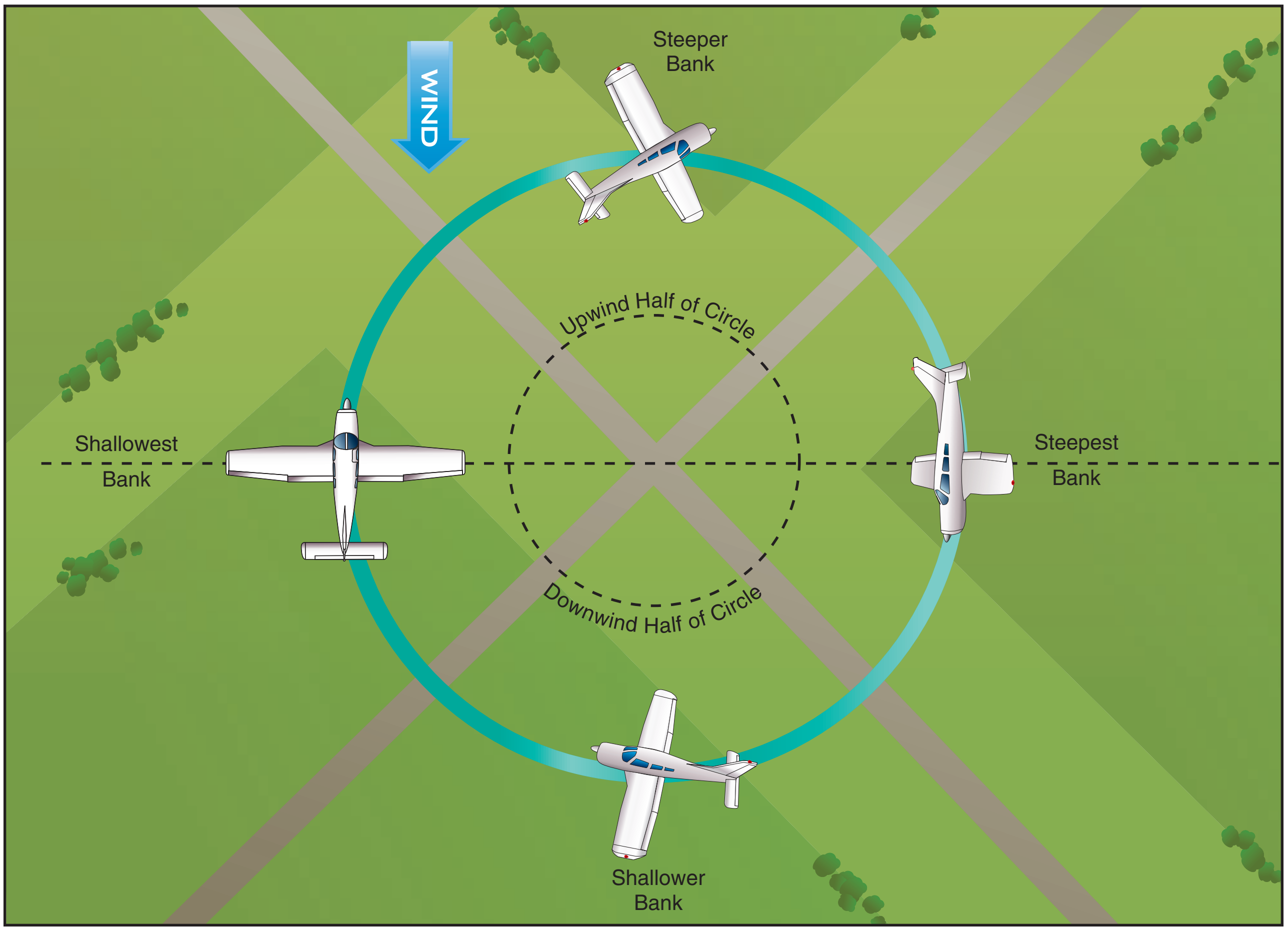

Figure 6-6. Turns around a point.

est bank is attained abeam of the point when the airplane is headed directly downwind. By entering the maneuver while heading directly downwind, the steepest bank can be attained immediately. Thus, if a maximum bank of 45° is desired, the initial bank will be 45° if the airplane is at the correct distance from the point. Thereafter, the bank is shallowed gradually until the point is reached where the airplane is headed directly upwind. At this point, the bank should be gradually steepened until the steepest bank is again attained when heading downwind at the initial point of entry.

Just as S-turns require that the airplane be turned into the wind in addition to varying the bank, so do turns around a point. During the downwind half of the circle, the airplane's nose is progressively turned toward the inside of the circle; during the upwind half, the nose is progressively turned toward the outside. The downwind half of the turn around the point may be compared to the downwind side of the S-turn across a road; the upwind half of the turn around a point may be compared to the upwind side of the S-turn across a road.

As the pilot becomes experienced in performing turns around a point and has a good understanding of the effects of wind drift and varying of the bank angle and wind correction angle as required, entry into the maneuver may be from any point. When entering the maneuver at a point other than downwind, however, the radius of the turn should be carefully selected, taking into account the wind velocity and groundspeed so that an excessive bank is not required later on to maintain the proper ground track. The flight instructor should place particular emphasis on the effect of an incorrect initial bank. This emphasis should continue in the performance of elementary eights.

Common errors in the performance of turns around a point are:

- Failure to adequately clear the area.
- Failure to establish appropriate bank on entry.
- Failure to recognize wind drift.
- Excessive bank and/or inadequate wind correction angle on the downwind side of the circle resulting in drift towards the reference point.
- Inadequate bank angle and/or excessive wind correction angle on the upwind side of the circle resulting in drift away from the reference point.
- Skidding turns when turning from downwind to crosswind.
- Slipping turns when turning from upwind to crosswind.
- Gaining or losing altitude.
- Inadequate visual lookout for other aircraft.
- Inability to direct attention outside the airplane while maintaining precise airplane control.

ELEMENTARY EIGHTS

An "eight" is a maneuver in which the airplane describes a path over the ground more or less in the shape of a figure "8". In all eights except "lazy eights" the path is horizontal as though following a marked path over the ground. There are various types of eights, progressing from the elementary types to very difficult types in the advanced maneuvers. Each has its special use in teaching the student to solve a particular problem of turning with relation to the Earth, or an object on the Earth's surface. Each type, as they advance in difficulty of accomplishment, further perfects the student's coordination technique and requires a higher degree of subconscious flying ability. Of all the training maneuvers available to the instructor, only eights require the progressively higher degree of conscious attention to outside objects. However, the real importance of eights is in the requirement for the perfection and display of subconscious flying.

Elementary eights, specifically eights along a road, eights across a road, and eights around pylons, are variations of turns around a point, which use two points about which the airplane circles in either direction. Elementary eights are designed for the following purposes.

- To perfect turning technique.
- To develop the ability to divide attention between the actual handling of controls and an outside objective.
- To perfect the knowledge of the effect of angle of bank on radius of turn.
- To demonstrate how wind affects the path of the airplane over the ground.
- To gain experience in the visualization of the results of planning before the execution of the maneuver.
- To train the student to think and plan ahead of the airplane.

EIGHTS ALONG A ROAD

An eight along a road is a maneuver in which the ground track consists of two complete adjacent circles of equal radii on each side of a straight road or other reference line on the ground. The ground track resembles a figure 8. [Figure 6-7 on next page]

Like the other ground reference maneuvers, its objective is to develop division of attention while

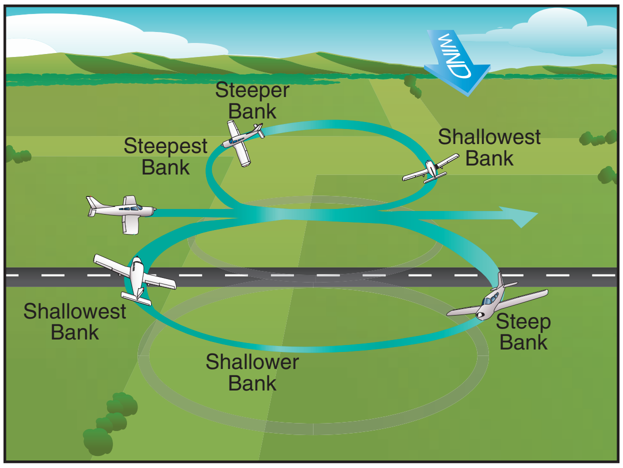

Figure 6-7. Eights along a road.

compensating for drift, maintaining orientation with ground references, and maintaining a constant altitude.

Although eights along a road may be performed with the wind blowing parallel to the road or directly across the road, for simplification purposes, only the latter situation is explained since the principles involved in either case are common.

A reference line or road which is perpendicular to the wind should be selected and the airplane flown parallel to and directly above the road. Since the wind is blowing across the flightpath, the airplane will require some wind correction angle to stay directly above the road during the initial straight and level portion. Before starting the maneuver, the area should be checked to ensure clearance of obstructions and avoidance of other aircraft.

Usually, the first turn should be made toward a downwind heading starting with a medium bank. Since the airplane will be turning more and more directly downwind, the groundspeed will be gradually increasing and the rate of departing the road will tend to become faster. Thus, the bank and rate of turn is increased to establish a wind correction angle to keep the airplane from exceeding the desired distance from the road when 180° of change in direction is completed. The steepest bank is attained when the airplane is headed directly downwind.

As the airplane completes 180° of change in direction, it will be flying parallel to and using a wind correction angle toward the road with the wind acting directly perpendicular to the ground track. At this point, the pilot should visualize the remaining 180° of ground track required to return to the same place over the road from which the maneuver started.

While the turn is continued toward an upwind heading, the wind will tend to keep the airplane from reaching the road, with a decrease in groundspeed and rate of closure. The rate of turn and wind correction angle are decreased proportionately so that the road will be reached just as the 360° turn is completed. To accomplish this, the bank is decreased so that when headed directly upwind, it will be at the shallowest angle. In the last 90° of the turn, the bank may be varied to correct any previous errors in judging the returning rate and closure rate. The rollout should be timed so that the airplane will be straight and level over the starting point, with enough drift correction to hold it over the road.

After momentarily flying straight and level along the road, the airplane is then rolled into a medium bank turn in the opposite direction to begin the circle on the upwind side of the road. The wind will still be decreasing the groundspeed and trying to drift the airplane back toward the road; therefore, the bank must be decreased slowly during the first 90° change in direction in order to reach the desired distance from the road and attain the proper wind correction angle when 180° change in direction has been completed.

As the remaining 180° of turn continues, the wind becomes more of a tailwind and increases the airplane's groundspeed. This causes the rate of closure to become faster; consequently, the angle of bank and rate of turn must be increased further to attain sufficient wind correction angle to keep the airplane from approaching the road too rapidly. The bank will be at its steepest angle when the airplane is headed directly downwind.

In the last 90° of the turn, the rate of turn should be reduced to bring the airplane over the starting point on the road. The rollout must be timed so the airplane will be straight and level, turned into the wind, and flying parallel to and over the road.

The measure of a student's progress in the performance of eights along a road is the smoothness and accuracy of the change in bank used to counteract drift. The sooner the drift is detected and correction applied, the smaller will be the required changes. The more quickly the student can anticipate the corrections needed, the less obvious the changes will be and the more attention can be diverted to the maintenance of altitude and operation of the airplane.

Errors in coordination must be eliminated and a constant altitude maintained. Flying technique must not be allowed to suffer from the fact that the student's attention is diverted. This technique should improve as the student becomes able to divide attention between the operation of the airplane controls and following a designated flightpath.

EIGHTS ACROSS A ROAD

This maneuver is a variation of eights along a road and involves the same principles and techniques. The primary difference is that at the completion of each loop of the figure eight, the airplane should cross an intersection of roads or a specific point on a straight road. [Figure 6-8]

The loops should be across the road and the wind should be perpendicular to the road. Each time the road is crossed, the crossing angle should be the same and the wings of the airplane should be level. The eights also may be performed by rolling from one bank immediately to the other, directly over the road.

EIGHTS AROUND PYLONS

This training maneuver is an application of the same principles and techniques of correcting for wind drift as used in turns around a point and the same objectives as other ground track maneuvers. In this case, two points or pylons on the ground are used as references, and turns around each pylon are made in opposite directions to follow a ground track in the form of a figure 8. [Figure 6-9]

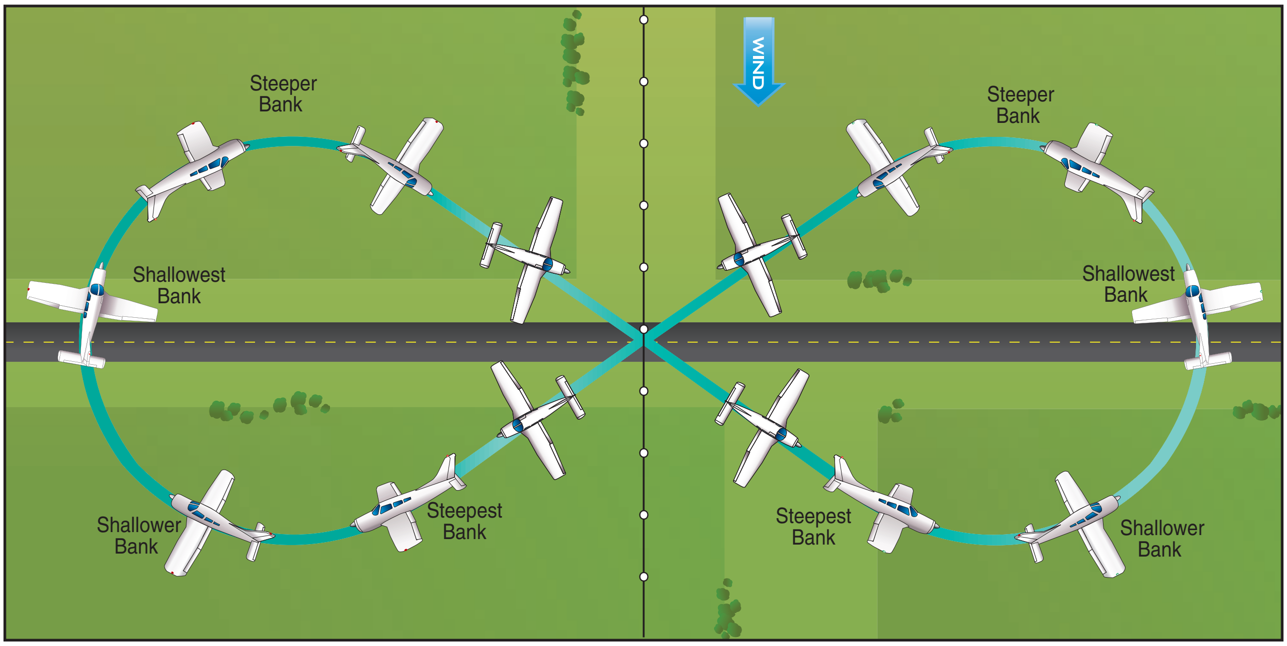

Figure 6-8. Eights across a road.

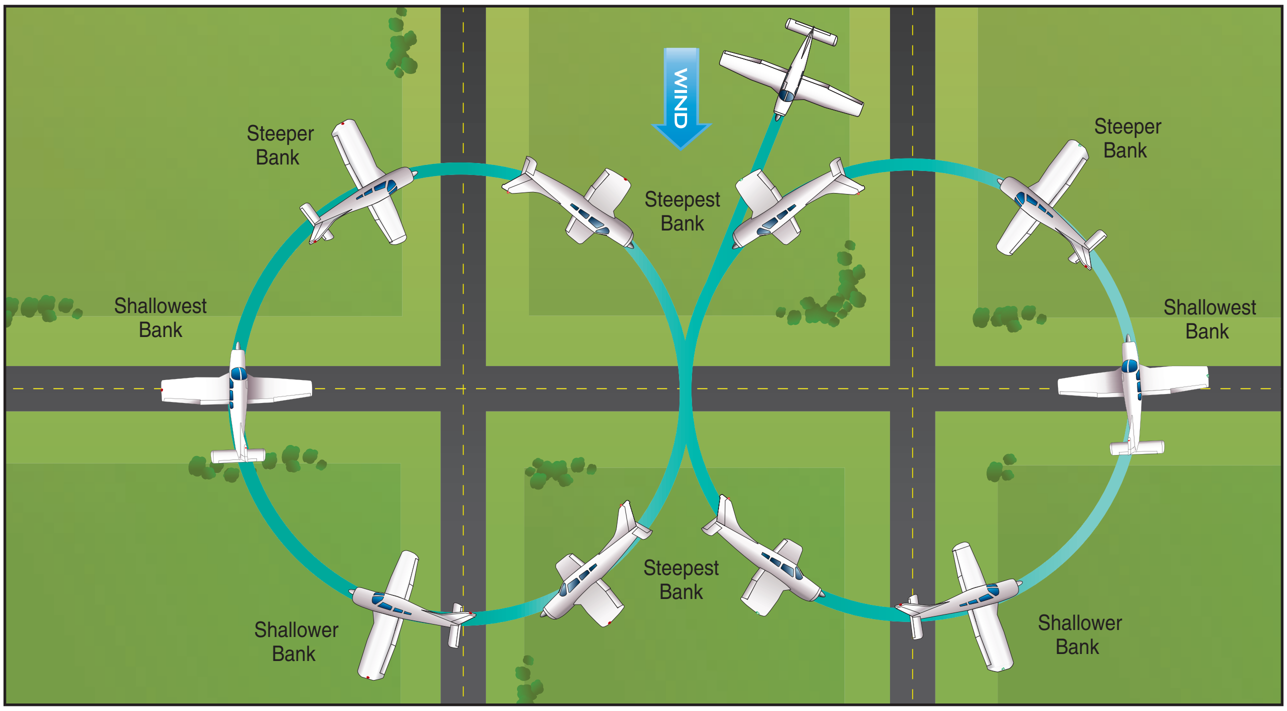

Figure 6-9. Eights around pylons.

The pattern involves flying downwind between the pylons and upwind outside of the pylons. It may include a short period of straight-and-level flight while proceeding diagonally from one pylon to the other.

The pylons selected should be on a line 90° to the direction of the wind and should be in an area away from communities, livestock, or groups of people, to avoid possible annoyance or hazards to others. The area selected should be clear of hazardous obstructions and other air traffic. Throughout the maneuver a constant altitude of at least 500 feet above the ground should be maintained.

The eight should be started with the airplane on a downwind heading when passing between the pylons. The distance between the pylons and the wind velocity will determine the initial angle of bank required to maintain a constant radius from the pylons during each turn. The steepest banks will be necessary just after each turn entry and just before the rollout from each turn where the airplane is headed downwind and the groundspeed is greatest; the shallowest banks will be when the airplane is headed directly upwind and the groundspeed is least.

The rate of bank change will depend on the wind velocity, the same as it does in S-turns and turns around a point, and the bank will be changing continuously during the turns. The adjustment of the bank angle should be gradual from the steepest bank to the shallowest bank as the airplane progressively heads into the wind, followed by a gradual increase until the steepest bank is again reached just prior to rollout. If the airplane is to proceed diagonally from one turn to the other, the rollout from each turn must be completed on the proper heading with sufficient wind correction angle to ensure that after brief straight-and-level flight, the airplane will arrive at the point where a turn of the same radius can be made around the other pylon. The straight-and-level flight segments must be tangent to both circular patterns.

Common errors in the performance of elementary eights are:

- Failure to adequately clear the area.
- Poor choice of ground reference points.
- Improper maneuver entry considering wind direction and ground reference points.
- Incorrect initial bank.
- Poor coordination during turns.
- Gaining or losing altitude.
- Loss of orientation.
- Abrupt rather than smooth changes in bank angle to counteract wind drift in turns.
- Failure to anticipate needed drift correction.
- Failure to apply needed drift correction in a timely manner.
- Failure to roll out of turns on proper heading.
- Inability to divide attention between reference points on the ground, airplane control, and scanning for other aircraft.

EIGHTS-ON-PYLONS (PYLON EIGHTS)

The pylon eight is the most advanced and most difficult of the low altitude flight training maneuvers. Because of the various techniques involved, the pylon eight is unsurpassed for teaching, developing, and testing subconscious control of the airplane.

As the pylon eight is essentially an advanced maneuver in which the pilot's attention is directed at maintaining a pivotal position on a selected pylon, with a minimum of attention within the cockpit, it should not be introduced until the instructor is assured that the student has a complete grasp of the fundamentals. Thus, the prerequisites are the ability to make a coordinated turn without gain or loss of altitude, excellent feel of the airplane, stall recognition, relaxation with low altitude maneuvering, and an absence of the error of over concentration.

Like eights around pylons, this training maneuver also involves flying the airplane in circular paths, alternately left and right, in the form of a figure 8 around two selected points or pylons on the ground. Unlike eights around pylons, however, no attempt is made to maintain a uniform distance from the pylon. In eights-on-pylons, the distance from the pylons varies if there is any wind. Instead, the airplane is flown at such a precise altitude and airspeed that a line parallel to the airplane's lateral axis, and extending from the pilot's eye, appears to pivot on each of the pylons. [Figure 6-10] Also, unlike eights around pylons, in the performance of eights-on-pylons the degree of bank increases as the distance from the pylon decreases.

The altitude that is appropriate for the airplane being flown is called the pivotal altitude and is governed by the groundspeed. While not truly a ground track maneuver as were the preceding maneuvers, the objective is similar—to develop the ability to maneuver the airplane accurately while dividing one's attention between the flightpath and the selected points on the ground.

In explaining the performance of eights-on-pylons, the term "wingtip" is frequently considered as being synonymous with the proper reference line, or pivot point on the airplane. This interpretation is not

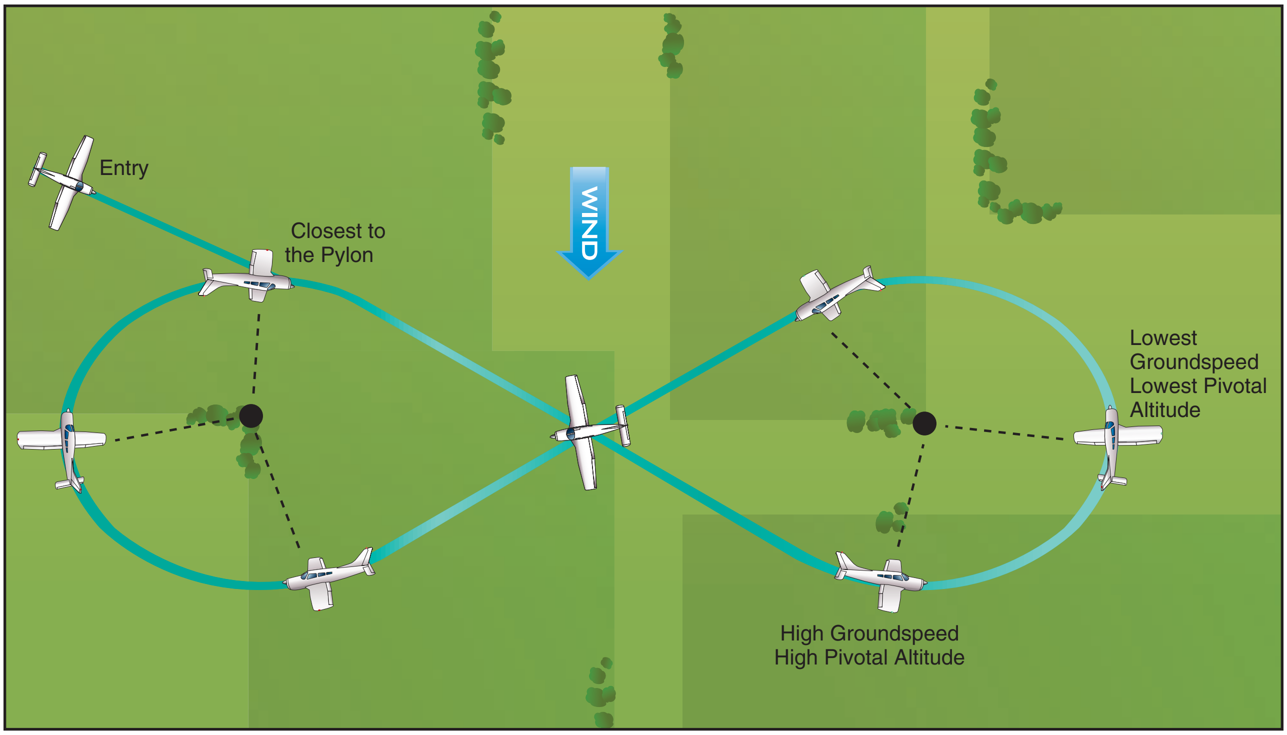

Figure 6-10. Eights-on-pylons.

always correct. High-wing, low-wing, sweptwing, and tapered wing airplanes, as well as those with tandem or side-by-side seating, will all present different angles from the pilot's eye to the wingtip. [Figure 6-11] Therefore, in the correct performance of eights-on-pylons, as in other maneuvers requiring a lateral reference, the pilot should use a sighting reference line that, from eye level, parallels the lateral axis of the airplane.

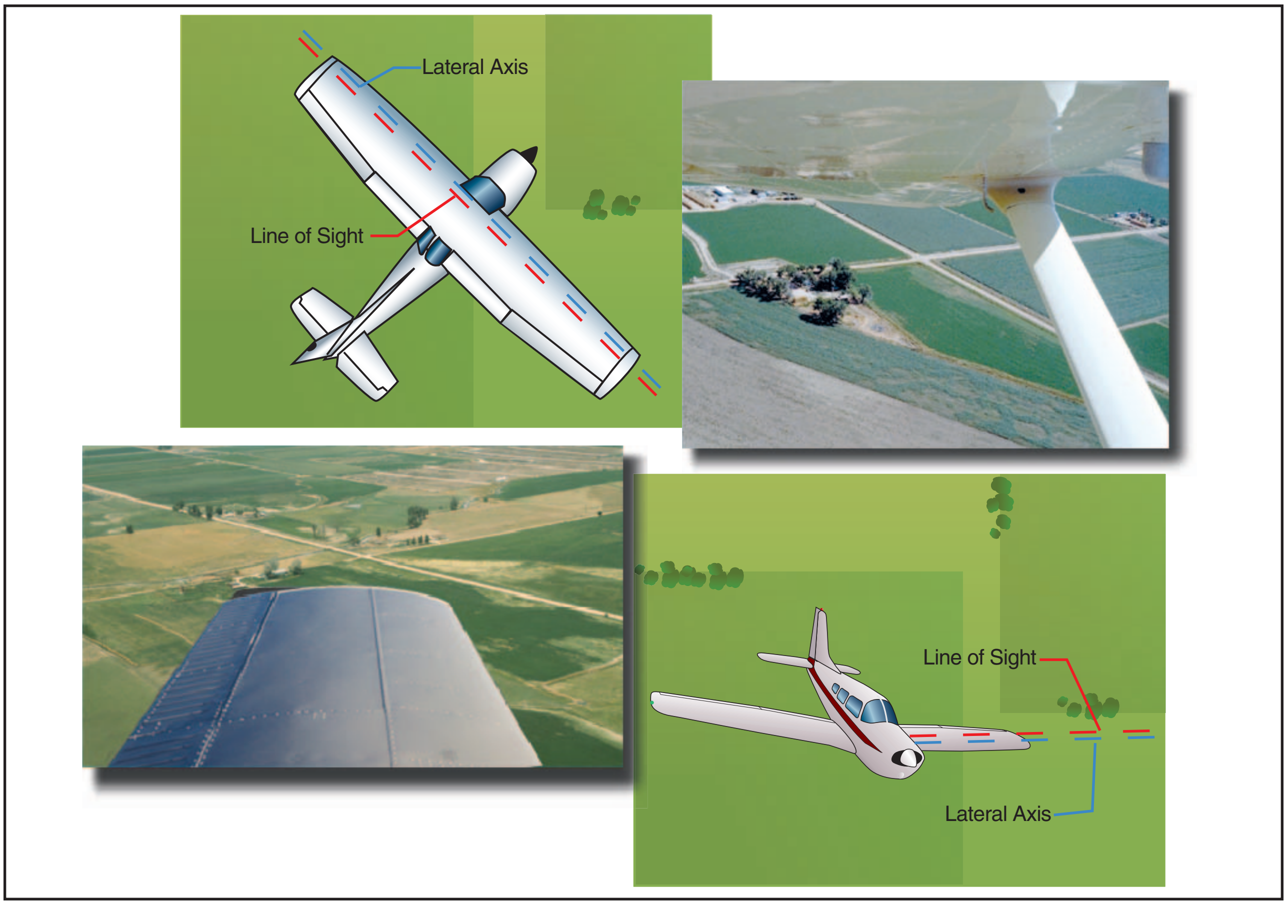

Figure 6-11. Line of sight.

The sighting point or line, while not necessarily on the wingtip itself, may be positioned in relation to the wingtip (ahead, behind, above, or below), but even then it will differ for each pilot, and from each seat in the airplane. This is especially true in tandem (fore and aft) seat airplanes. In side-by-side type airplanes, there will be very little variation in the sighting lines for different persons if those persons are seated so that the eyes of each are at approximately the same level.

An explanation of the pivotal altitude is also essential. There is a specific altitude at which, when the airplane turns at a given groundspeed, a projection of the sighting reference line to the selected point on the ground will appear to pivot on that point. Since different airplanes fly at different airspeeds, the groundspeed will be different. Therefore, each airplane will have its own pivotal altitude. [Figure 6-12] The pivotal altitude does not vary with the angle of bank being used unless the bank is steep enough to affect the groundspeed. A rule of thumb for estimating pivotal altitude in calm wind is to square the true airspeed and divide by 15 for miles per hour (m.p.h.) or 11.3 for knots.

AIRSPEED		APPROXIMATE PIVOTAL ALTITUDE
KNOTS	MPH	
87	100	670
91	105	735
96	110	810
100	115	885
104	120	960
109	125	1050
113	130	1130

Figure 6-12. Speed vs. pivotal altitude.

Distance from the pylon affects the angle of bank. At any altitude above that pivotal altitude, the projected reference line will appear to move rearward in a circular path in relation to the pylon. Conversely, when the airplane is below the pivotal altitude, the projected reference line will appear to move forward in a circular path. [Figure 6-13]

To demonstrate this, the airplane is flown at normal cruising speed, and at an altitude estimated to be below the proper pivotal altitude, and then placed in a medium-banked turn. It will be seen that the projected reference line of sight appears to move forward along the ground (pylon moves back) as the airplane turns.

A climb is then made to an altitude well above the pivotal altitude, and when the airplane is again at normal cruising speed, it is placed in a medium-banked turn. At this higher altitude, the projected reference line of sight now appears to move backward across the ground (pylon moves forward) in a direction opposite that of flight.

After the high altitude extreme has been demonstrated, the power is reduced, and a descent at cruising speed begun in a continuing medium bank around the pylon. The apparent backward travel of the projected reference line with respect to the pylon will slow down as altitude is lost, stop for an instant, then start to reverse itself, and would move forward if the descent were allowed to continue below the pivotal altitude.

The altitude at which the line of sight apparently ceased to move across the ground was the pivotal altitude. If the airplane descended below the pivotal altitude, power should be added to maintain airspeed while altitude is regained to the point at which the projected reference line moves neither backward nor forward but actually pivots on the pylon. In this way the pilot can determine the pivotal altitude of the airplane.

The pivotal altitude is critical and will change with variations in groundspeed. Since the headings throughout the turns continually vary from directly downwind to directly upwind, the groundspeed will constantly change. This will result in the proper pivotal altitude varying slightly throughout the eight. Therefore, adjustment is made for this by climbing or descending, as necessary, to hold the reference line or point on the pylons. This change in altitude will be dependent on how much the wind affects the groundspeed.

The instructor should emphasize that the elevators are the primary control for holding the pylons. Even a very slight variation in altitude effects a double correction, since in losing altitude, speed is gained, and even a slight climb reduces the airspeed. This variation in altitude, although important in holding the pylon, in most cases will be so slight as to be barely perceptible on a sensitive altimeter.

Before beginning the maneuver, the pilot should select two points on the ground along a line which lies 90° to the direction of the wind. The area in which the maneuver is to be performed should be checked for obstructions and any other air traffic, and it should be located where a disturbance to groups of people, livestock, or communities will not result.

The selection of proper pylons is of importance to good eights-on-pylons. They should be sufficiently prominent to be readily seen by the pilot when completing the turn around one pylon and heading for the next, and should be adequately spaced to provide time

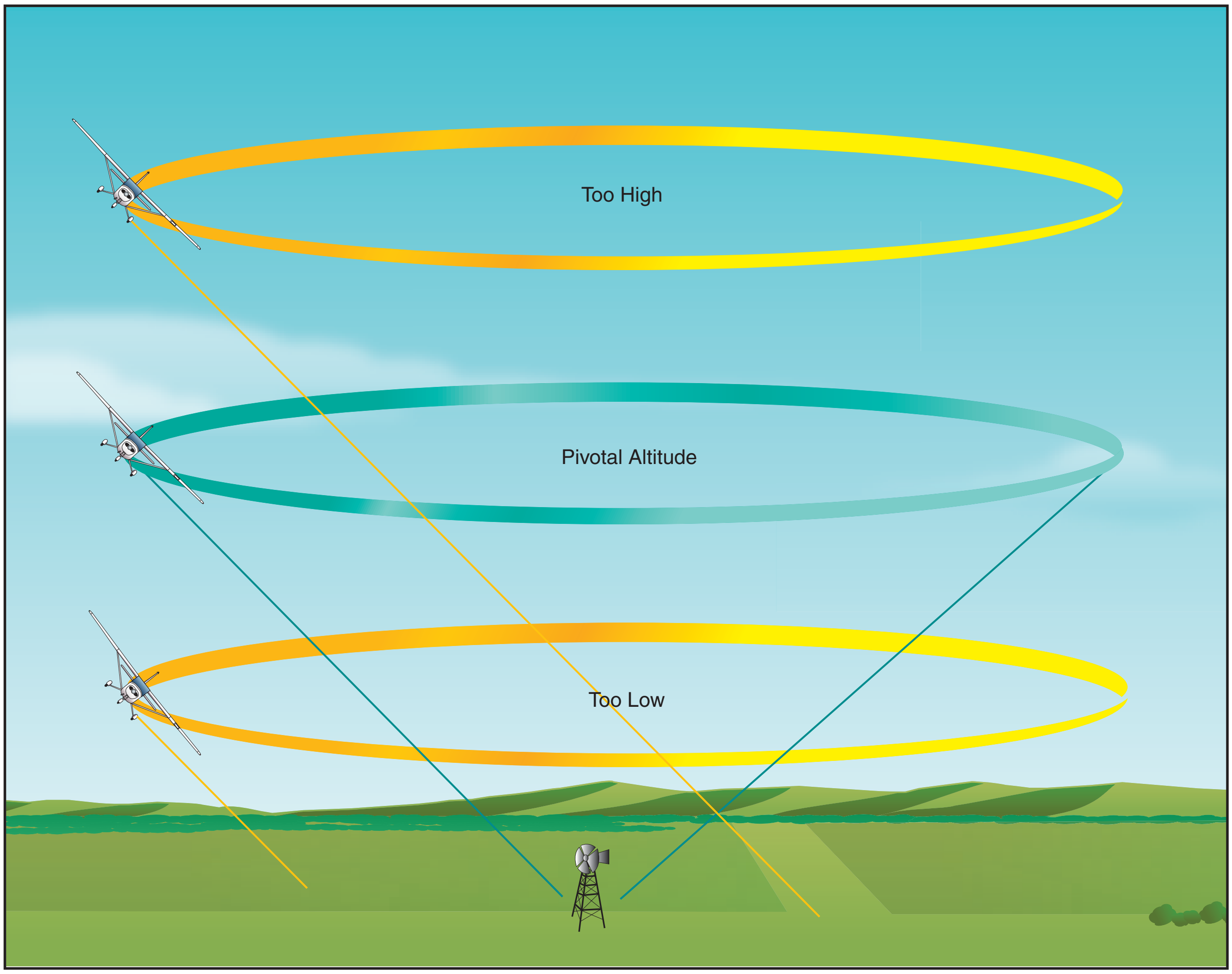

Figure 6-13. Effect of different altitudes on pivotal altitude.

for planning the turns and yet not cause unnecessary straight-and-level flight between the pylons. The selected pylons should also be at the same elevation, since differences of over a very few feet will necessitate climbing or descending between each turn.

For uniformity, the eight is usually begun by flying diagonally crosswind between the pylons to a point downwind from the first pylon so that the first turn can be made into the wind. As the airplane approaches a position where the pylon appears to be just ahead of the wingtip, the turn should be started by lowering the upwind wing to place the pilot's line of sight reference on the pylon. As the turn is continued, the line of sight reference can be held on the pylon by gradually increasing the bank. The reference line should appear to pivot on the pylon. As the airplane heads into the wind, the groundspeed decreases; consequently, the pivotal altitude is lower and the airplane must descend to hold the reference line on the pylon. As the turn progresses on the upwind side of the pylon, the wind becomes more of a crosswind. Since a constant distance from the pylon is not required on this maneuver, no correction to counteract drifting should be applied during the turns.

If the reference line appears to move ahead of the pylon, the pilot should increase altitude. If the reference line appears to move behind the pylon, the pilot should decrease altitude. Varying rudder pressure to yaw the airplane and force the wing and reference line forward or backward to the pylon is a dangerous technique and must not be attempted.

As the airplane turns toward a downwind heading, the rollout from the turn should be started to allow the airplane to proceed diagonally to a point on the downwind side of the second pylon. The rollout must be completed in the proper wind correction angle to correct for wind drift, so that the airplane will arrive at a point downwind from the second pylon the same distance it was from the first pylon at the beginning of the maneuver.

Upon reaching that point, a turn is started in the opposite direction by lowering the upwind wing to again place the pilot's line of sight reference on the pylon. The turn is then continued just as in the turn around the first pylon but in the opposite direction.

With prompt correction, and a very fine control touch, it should be possible to hold the projection of the reference line directly on the pylon even in a stiff wind. Corrections for temporary variations, such as those caused by gusts or inattention, may be made by shallowing the bank to fly relatively straight to bring forward a lagging wing, or by steepening the bank temporarily to turn back a wing which has crept ahead. With practice, these corrections will become so slight as to be barely noticeable. These variations are apparent from the movement of the wingtips long before they are discernable on the altimeter.

Pylon eights are performed at bank angles ranging from shallow to steep. [Figure 6-14] The student should understand that the bank chosen will not alter the pivotal altitude. As proficiency is gained, the instructor should increase the complexity of the maneuver by directing the student to enter at a distance from the pylon that will result in a specific bank angle at the steepest point in the pylon turn.

The most common error in attempting to hold a pylon is incorrect use of the rudder. When the projection of the reference line moves forward with respect to the pylon, many pilots will tend to press the inside rudder to yaw the wing backward. When the reference line moves behind the pylon, they will press the outside rudder to yaw the wing forward. The rudder is to be used only as a coordination control.

Other common errors in the performance of eights-on-pylons (pylon eights) are:

- Failure to adequately clear the area.
- Skidding or slipping in turns (whether trying to hold the pylon with rudder or not).
- Excessive gain or loss of altitude.
- Over concentration on the pylon and failure to observe traffic.
- Poor choice of pylons.
- Not entering the pylon turns into the wind.
- Failure to assume a heading when flying between pylons that will compensate sufficiently for drift.
- Failure to time the bank so that the turn entry is completed with the pylon in position.
- Abrupt control usage.
- Inability to select pivotal altitude.

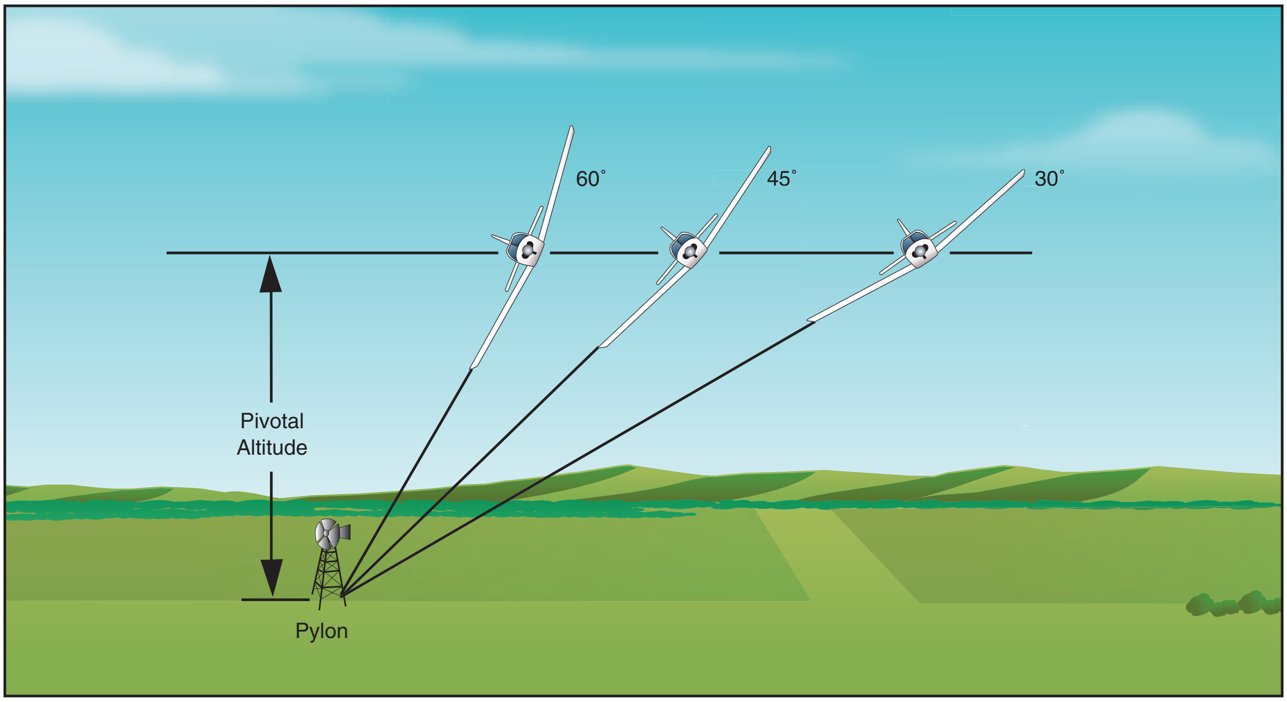

Figure 6-14. Bank angle vs. pivotal altitude.