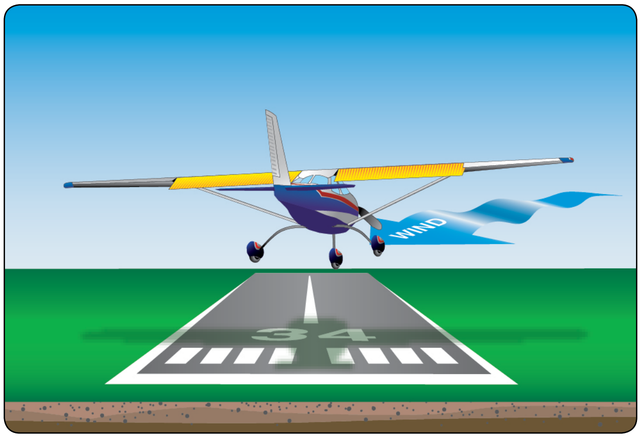

Figure 9-15. *Crabbed approach.*

While the wing-low (sideslip) method also compensates for a crosswind from any angle, it keeps the airplane's ground track and longitudinal axis aligned with the runway centerline throughout the final approach, round out, touchdown, and after-landing roll. This prevents the airplane from touching down in a sideward motion and imposing damaging side loads on the landing gear. When first experienced, it may seem odd to land while holding a bank angle. Although some pilots state that it appears the upwind wingtip will strike the ground, this is not the case. This method sets up the crosswind correction well before touchdown, does not require a heading change at the moment before touchdown, and allows the pilot to exercise smooth and continuous control. Pilots using this technique use precise airplane control as changes in control pressure occur near the ground, on short final, and while over the runway.

To use the wing-low method, the pilot first uses rudder to align and maintain the airplane's heading with the runway direction. Since the airplane is now exposed to an uncorrected crosswind, the airplane will begin to drift. Note the rate and direction of drift, and oppose it using ailerons resulting in just enough bank to cancel the drift. [*Figure 9-16*] Varying the amount of bank allows the pilot to drift either to the left or to the right, and the pilot adjusts control pressures as needed to intercept and maintain the runway centerline. If the crosswind changes, the sideslip is adjusted to keep the airplane in line with the center of the runway. [*Figure 9-17*]

Figure 9-16. *Sideslip approach.*

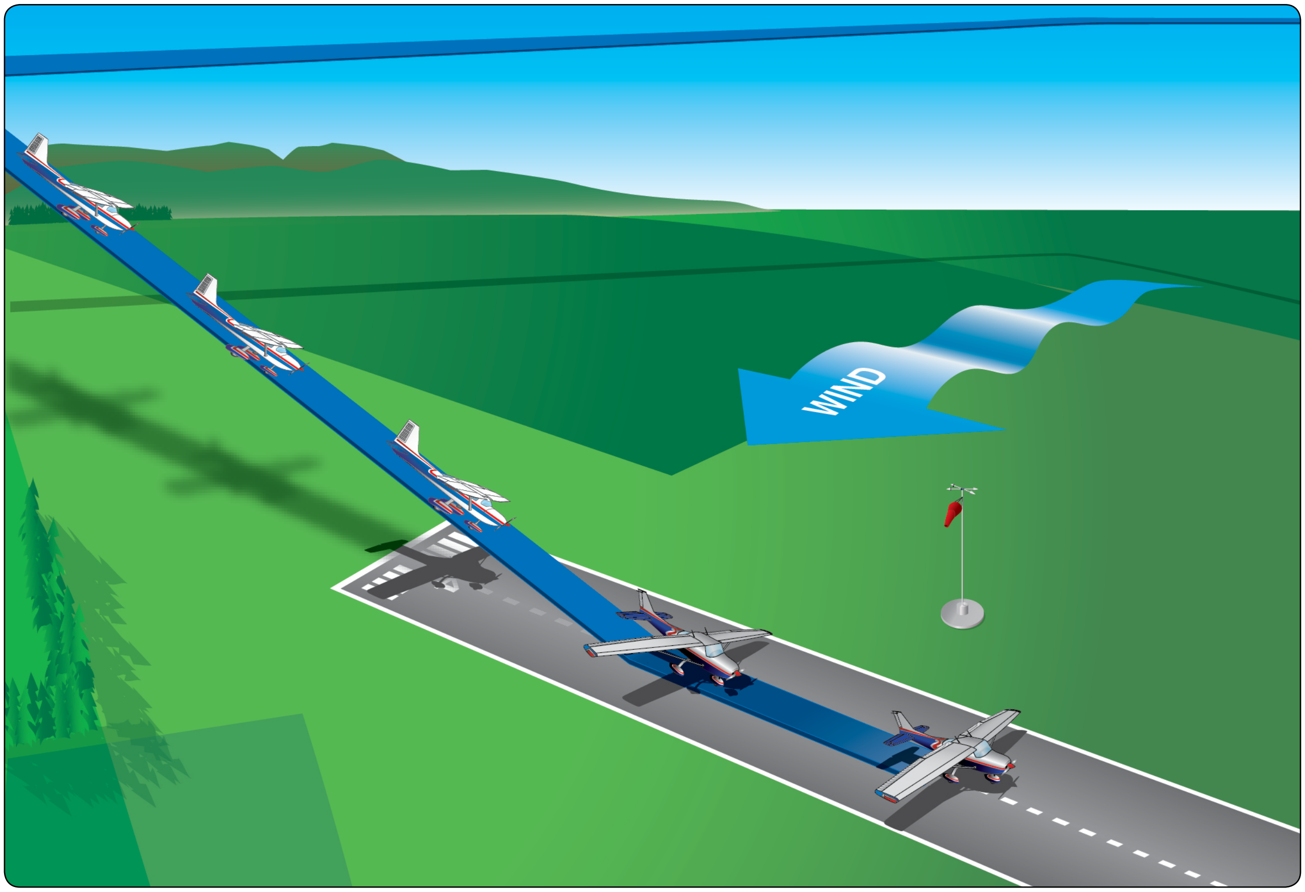

Figure 9-17. *Crosswind approach and landing.*

To correct for strong crosswind, the slip into the wind is increased by lowering the upwind wing as needed. As a consequence, this results in a greater tendency of the airplane to turn. Since turning is not desired, considerable opposite rudder is applied to keep the airplane's longitudinal axis aligned with the runway. In some airplanes, there may not be sufficient rudder travel available to compensate for the strong turning tendency caused by the steep bank. If the required bank is such that full opposite rudder does not prevent a turn, the wind is too strong to safely land the airplane on that particular runway with those wind conditions. Since the airplane's capability is exceeded, it is imperative that the landing be made on a more favorable runway either at that airport or at an alternate airport.

Flaps are used during most approaches since they tend to have a stabilizing effect on the airplane. The degree to which flaps are extended vary with the airplane's handling characteristics, as well as the wind velocity.

Crosswind Round Out (Flare)

Generally, the round out is made like a normal landing approach, but the application of a crosswind correction is continued as necessary to prevent drifting.

Since the airspeed decreases as the round out progresses, the flight controls gradually become less effective. As a result, the crosswind correction being held becomes inadequate. When using the wing-low method, it is necessary to gradually increase the deflection of the rudder and ailerons to maintain the proper amount of drift correction.

Keep the upwind wing down throughout the round out. If the wings are leveled, the airplane begins drifting and the touchdown occurs while drifting. Remember, the primary objective is to land the airplane without subjecting it to any side loads that result from touching down while drifting.

Crosswind Touchdown

If the crab method of drift correction is used throughout the final approach and round out, the crab needs to be removed the instant before touchdown by applying rudder to align the airplane's longitudinal axis with its direction of movement.

If the wing-low method is used, the crosswind correction is maintained throughout the round out, and the initial touchdown occurs on the upwind main wheel. During gusty or high wind conditions, prompt adjustments are made in the crosswind correction to assure that the airplane does not drift as the airplane touches down. As the forward momentum decreases after initial contact, the weight of the airplane causes the downwind main wheel to gradually settle onto the runway.

In those airplanes having nose-wheel steering interconnected with the rudder, the nose-wheel is not aligned with the runway as the main wheels touch down because opposite rudder is being held for the crosswind correction. To prevent swerving in the direction the nose-wheel is offset, the corrective rudder pressure needs to be relaxed as the nose-wheel touches down.

Crosswind After-Landing Roll

Particularly during the after-landing roll, special attention should be given to maintaining directional control by the use of rudder or nose-wheel steering, while keeping the upwind wing from rising by the use of aileron. When an airplane is airborne, it moves with the air mass in which it is flying regardless of the airplane's heading and speed. When an airplane is on the ground, it is unable to move with the air mass (crosswind) because of the resistance created by ground friction on the wheels.

Characteristically, an airplane has a greater profile or side area behind the main landing gear than forward of the gear. With the main wheels acting as a pivot point and the greater surface area exposed to the crosswind behind that pivot point, the airplane tends to turn or weathervane into the wind.

The relative wind acting on an airplane during the after-landing roll is the result of two factors. One is the natural wind, which acts in the direction the air mass is traveling. It has a headwind component acting along the airplane's ground track and a crosswind component acting 90° to its track. The other factor is the wind induced by the forward movement of the airplane, which acts parallel and opposite to the direction of movement. The relative wind is the resultant of these two factors and acts from a direction somewhere between the two components. The faster the airplane's groundspeed, the more the relative wind aligns towards the nose of the aircraft. As the airplane's forward speed decreases during the after-landing roll, the forward component of the relative wind decreases, causing the relative wind to act in a direction more aligned with the crosswind component. The greater the crosswind component, the more difficult it is to prevent weathervaning, especially with a conventional-gear airplane.

Maintaining control on the ground is a critical part of the after-landing roll because of the weathervaning effect of the wind on the airplane. Additionally, tire side load from runway contact while drifting may generate a "roll-over" in a tricycle-geared airplane. This occurs when one main wheel lifts up off the ground and the airplane tips forward along the axis between the nose-wheel and the main wheel still on the ground. A roll-over could cause one wingtip or the prop to contact the ground. The basic factors involved are cornering angle and side load.

Cornering angle is the angular difference between the heading of a tire and its path. Whenever a load-bearing tire's path and heading diverge, a side load is created. It is accompanied by tire distortion. Although side load differs in varying tires and air pressures, it is completely independent of speed, and through a considerable range, is directly proportional to the cornering angle and the weight supported by the tire. As little as 10° of cornering angle creates a side load equal to half the supported weight; after 20°, the side load does not increase with increasing cornering angle. For each high-wing, tricycle-geared airplane, there is a cornering angle at which roll-over is inevitable. At lesser angles, the roll-over may be avoided by use of ailerons, rudder, or steerable nose-wheel, but not brakes.

While the airplane is decelerating during the after-landing roll, more and more aileron is applied to keep the upwind wing from rising. Since the airplane is slowing down, there is less airflow around the ailerons and they become less effective. At the same time, the relative wind becomes more of a crosswind and exerts a greater lifting force on the upwind wing. When the airplane is coming to a stop, the aileron control should be held fully toward the wind.

Maximum Safe Crosswind Velocities

Takeoffs and landings in certain crosswind conditions are inadvisable or even dangerous. [*Figure 9-18*] If the crosswind is great enough to warrant an extreme drift correction, a hazardous landing condition may result. Therefore, the takeoff and landing capabilities with respect to the reported surface wind conditions and the available landing directions should be considered.

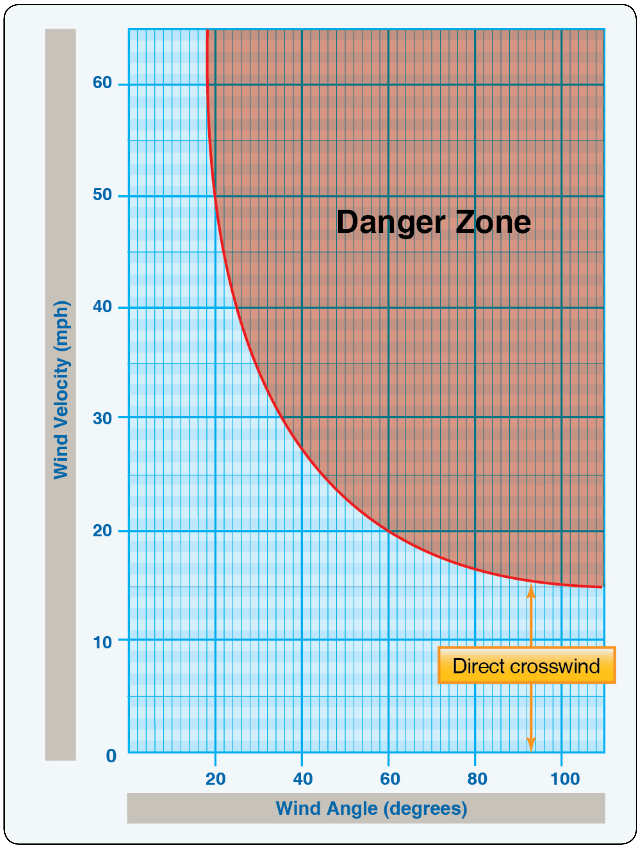

Figure 9-18. *Crosswind chart.*

Before an airplane is type certificated by the Federal Aviation Administration (FAA), it is flight tested to ensure it meets certain requirements. Among these is the demonstration of being satisfactorily controllable with no exceptional degree of skill or alertness on the part of the pilot in 90° crosswinds up to a velocity equal to 0.2 V_{SO}. This means a wind speed of two-tenths of the airplane's stalling speed with power off and in landing configuration. The demonstrated crosswind velocity is included on a placard in airplanes certificated after May 3, 1962.

The headwind component and the crosswind component for a given situation is determined by reference to a crosswind component chart. [*Figure 9-19*] It is imperative that pilots determine the maximum crosswind component of each airplane they fly and avoid operations in wind conditions that exceed the capability of the airplane.

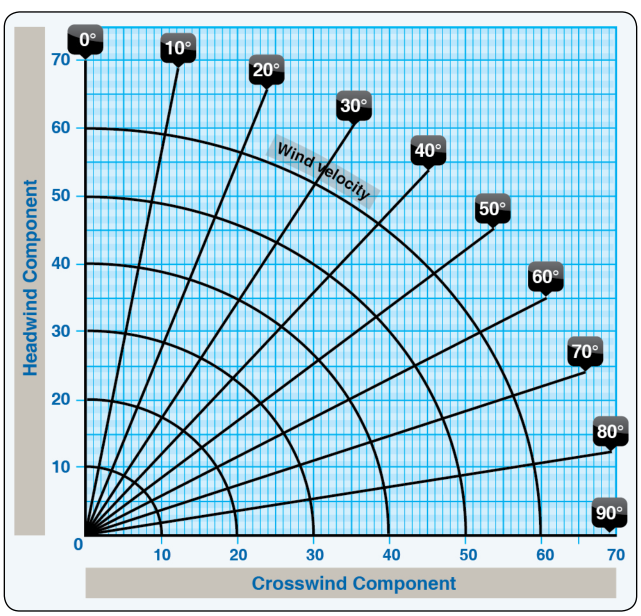

Figure 9-19. *Crosswind component chart.*

Common Errors

Common errors in the performance of crosswind approaches and landings are:

1. Attempted landing in crosswinds that exceed the airplane's maximum demonstrated crosswind component.
2. Undershooting or overshooting the turn from base leg to final approach.
3. Inadequate compensation for wind drift on final approach.
4. Unstable approach.
5. Excessive sink rate or too low an airspeed from increased drag and reduced vertical lift during sideslip.
6. Failure to touch down with the longitudinal axis aligned with the runway.
7. Touching down while drifting.
8. Excessive airspeed on touchdown.
9. Failure to apply appropriate flight control inputs during rollout.
10. Failure to maintain direction control on rollout.
11. Excessive braking.
12. Loss of aircraft control.

Turbulent Air Approach and Landing

For landing in turbulent conditions, the pilot should use a power-on approach at an airspeed slightly above the normal approach speed. This provides for more positive control of the airplane when strong horizontal wind gusts, or up and down drafts, are experienced. Like other power-on approaches, a coordinated combination of both pitch and power adjustments is usually required. The proper approach attitude and airspeed require a minimum round out and should result in little or no floating during the landing.

To maintain control during an approach in turbulent air with gusty crosswind, the pilot should use partial wing flaps. With less than full flaps, the airplane is in a higher pitch attitude. Thus, it requires less of a pitch change to establish the landing attitude and touchdown at a higher airspeed to ensure more positive control.

Pilots often use the normal approach speed plus one-half of the wind gust factors in turbulent conditions. If the normal speed is 70 knots, and the wind gusts are 15 knots, an increase of airspeed to 77 knots is appropriate. In any case, the airspeed and the flap setting should conform to airplane manufacturer's recommendations in the AFM/POH.

Use an adequate amount of power to maintain the proper airspeed and descent path throughout the approach, and retard the throttle to idling position only after the main wheels contact the landing surface. Care should be exercised in closing the throttle before the pilot is ready for touchdown. In turbulent conditions, the sudden or premature closing of the throttle may cause a sudden increase in the descent rate, resulting in a hard landing.

When landing from power approaches in turbulence, the touchdown is made with the airplane in approximately level flight attitude. The pitch attitude at touchdown would be only enough to prevent the nose-wheel from contacting the surface before the main wheels have touched the surface. After touchdown, the pilot should avoid the tendency to apply forward pressure on the yoke, as this may result in wheelbarrowing and possible loss of control. The pilot should allow the airplane to decelerate normally, assisted by careful use of wheel brakes and avoid heavy braking until the wings are devoid of lift and the airplane's full weight is resting on the landing gear.

Short-Field Approach and Landing

Short-field approaches and landings require the use of procedures for approaches and landings at fields with a relatively short landing area or where an approach is made over obstacles that limit the available landing area. [*Figure 9-20* and *Figure 9-21*] This low-speed type of power-on approach is closely related to the performance of flight near minimum controllable airspeeds.

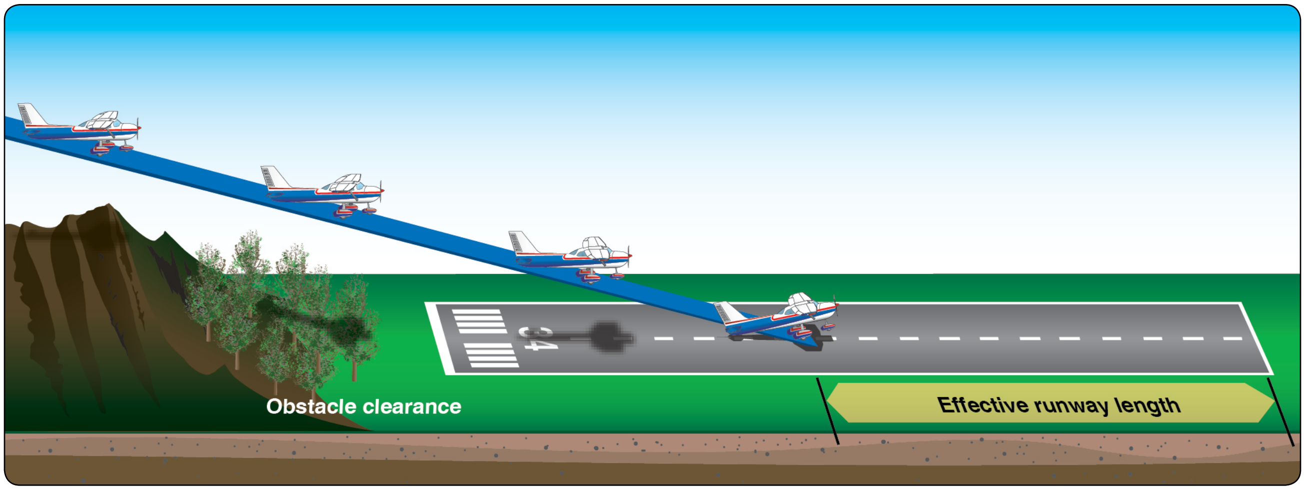

Figure 9-20. *Landing over an obstacle.*

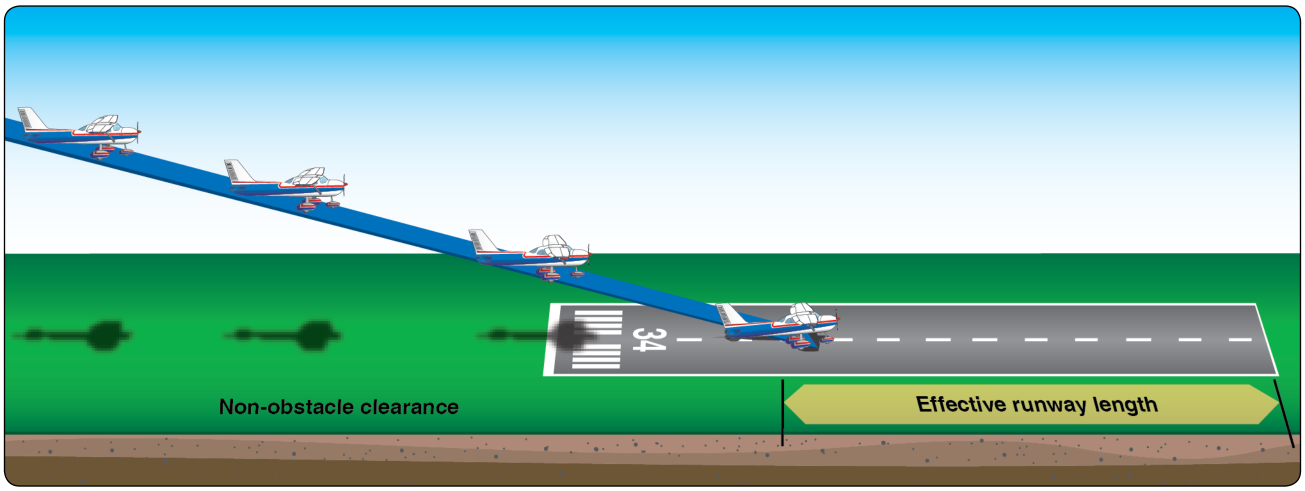

Figure 9-21. *Landing on a short field.*

To land within a short field or a confined area, the pilot needs to have precise, positive control of the rate of descent and airspeed, and fly an approach that clears any obstacles, results in little or no floating during the round out, and permits the airplane to be stopped in the shortest possible distance. When safety and conditions permit, a wider-than-normal pattern with a longer final approach may be used. This allows the pilot ample opportunity to adjust and stabilize the descent angle after the airplane is configured and trimmed. A stabilized approach is essential.

The procedures for landing on a short field or for landing approaches over obstacles as recommended in the AFM/POH should be used. [*Figure 9-22* and *Figure 9-23*] These procedures generally involve a final approach started from an altitude of at least 500 feet higher than the touchdown area and the use of full flaps at an appropriate point during the final approach. For many general aviation airplanes this means flying a stabilized final approach with the flap setting that precedes full flaps. When the field is made, the pilot should extend full flaps and lower the nose in order to maintain airspeed and keep the aiming point stationary in the windscreen. When over the obstacle, the pilot may reduce power slightly. Ideally, if full flaps are extended at the correct point, the pilot will be in a position to slowly reduce power. When no manufacturer's recommended approach speed is available, a speed of not more than 1.3 V_{SO} is used. In gusty air, no more than one-half the gust factor is added. An excessive amount of airspeed could result in a touchdown too far from the runway threshold or an after-landing roll that exceeds the available landing area. When obstacles are present, a slightly steeper approach angle places the touchdown closer to the obstacle, which gives the pilot more room to stop.

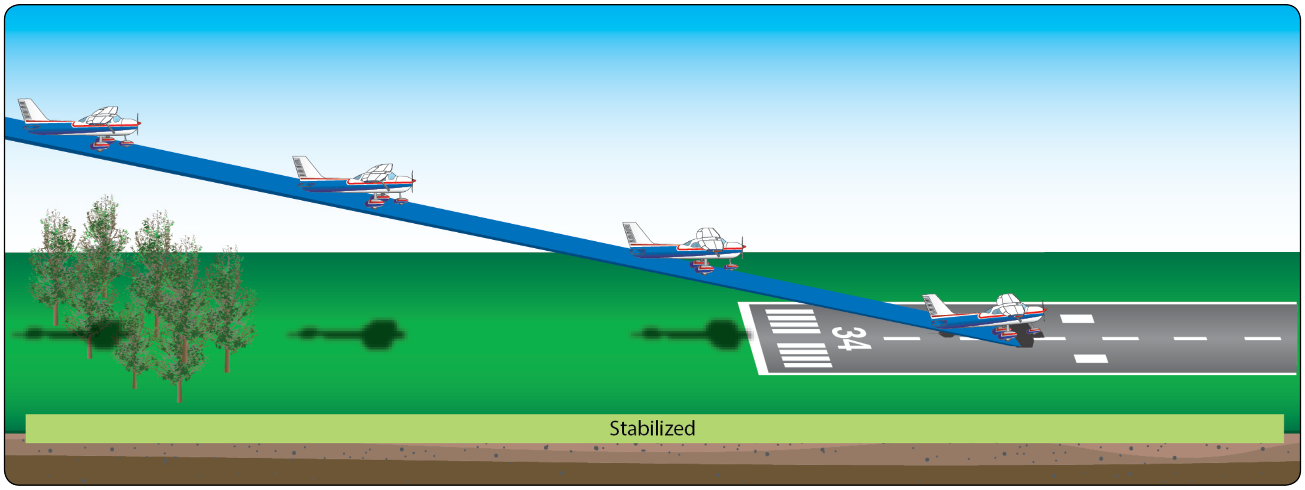

Figure 9-22. *Stabilized approach.*

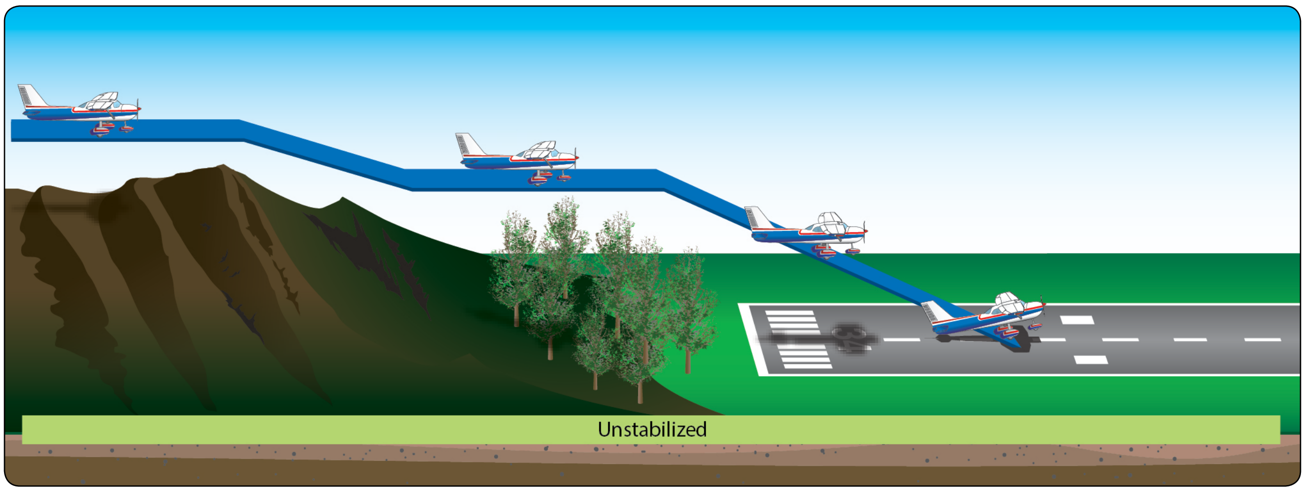

Figure 9-23. *Unstabilized approach.*

After the landing gear has been extended, if applicable, or when beginning a suitable final approach, the pilot simultaneously adjusts the power and the pitch attitude to establish and maintain the proper descent angle and airspeed. During a stabilized approach, small changes in the airplane's pitch attitude and power setting are needed when making corrections to the angle of descent and airspeed.

The short-field approach and landing is an accuracy approach to an aiming point. The procedures previously outlined in the section on the stabilized approach concept are used. If it appears that the obstacle clearance is excessive and touchdown occurs well beyond the desired aiming point, leaving insufficient room to stop, power is reduced while lowering the pitch attitude to steepen the descent path and increase the rate of descent. If it appears that the descent angle does not ensure safe clearance of obstacles, power is increased while simultaneously raising the pitch attitude to shallow the descent path and decrease the rate of descent. Care should be taken to avoid excessively low airspeeds. When operating at high AOAs and low airspeeds, an increase in pitch attitude increases the rate of descent. When there is doubt regarding the outcome of the approach, the pilot should execute a go-around, evaluate the situation, and decide whether to make another approach or divert to a more suitable landing area.

Because the final approach over obstacles is made at a relatively steep approach angle and close to the airplane's stalling speed, the initiation of the round out or flare needs to be judged accurately to avoid flying into the ground or stalling prematurely and sinking rapidly. A lack of floating during the flare with sufficient control to touch down properly is verification that the approach speed was correct.

Touchdown should occur at the minimum controllable airspeed with the airplane in approximately the pitch attitude that results in a power-off stall when the throttle is closed. Care should be exercised to avoid closing the throttle too rapidly, as closing the throttle may result in an immediate increase in the rate of descent and a hard landing. Note that a small amount of power provides more airflow over the elevator giving it more authority at low airspeeds to enable the pilot to flare. There is a risk that low airspeed and a windmilling propeller blocking airflow over the elevator may make it difficult to flare.

Upon touchdown, the airplane is held in this positive pitch attitude as long as the elevators remain effective and if recommended by the manufacturer. This provides aerodynamic braking to assist in deceleration. However, immediately upon touchdown of the nose-wheel, maximum braking is applied to minimize the after-landing roll. For most airplanes, aerodynamic drag is the single biggest factor in slowing the aircraft in the first quarter of its speed decay. Brakes become increasingly effective as airspeed and lift decrease. The pilot increases braking effectiveness by holding the wheel or stick full back while smoothly applying brakes. Back pressure is needed because the airplane tends to lean forward with heavy braking. Best braking results are always achieved with the wheels in an "incipient skid condition." That means a little more brake pressure would lock up the wheels entirely. In an incipient skid, the wheels are turning, but with great reluctance. If the wheels lock, braking effectiveness drops dramatically in a skid and the tires could be damaged. The airplane is normally stopped within the shortest possible distance consistent with safety and controllability. If the proper approach speed has been maintained, resulting in minimum float during the round out and the touchdown made at minimum control speed, excessive braking should not be needed.

Common Errors

Common errors in the performance of short-field approaches and landings are:

1. A final approach that necessitates an overly steep approach and high sink rate.
2. Unstable approach.
3. Undue delay in initiating glide path corrections.
4. Too low an airspeed on final resulting in inability to flare properly and landing hard.
5. Too high an airspeed resulting in floating on round out.
6. Prematurely reducing power to idle on round out resulting in hard landing.
7. Touchdown with excessive airspeed.
8. Excessive and/or unnecessary braking after touchdown.
9. Failure to maintain directional control.
10. Failure to recognize and abort a poor approach that cannot be completed safely.

Soft-Field Approach and Landing

Landing on fields that are rough or have soft surfaces, such as snow, sand, mud, or tall grass, requires unique procedures. When landing on such surfaces, the objective is to touch down as smoothly as possible and at the slowest possible landing speed. A pilot needs to control the airplane in a manner that the wings support the weight of the airplane as long as practical to minimize stresses imposed on the landing gear by a rough surface or to prevent sinking into a soft surface.

The approach for the soft-field landing is similar to the normal approach used for operating into long, firm landing areas. The major difference between the two is that a degree of power is used throughout the level-off and touchdown for the soft-field landing. This allows the airspeed to slowly dissipate while the airplane is flown 1 to 2 feet off the surface in ground effect. When the wheels first touch the ground, the wings continue to support much of the weight of the airplane. [*Figure 9-24*] This technique minimizes the nose-over forces that suddenly affect the airplane at the moment of touchdown.

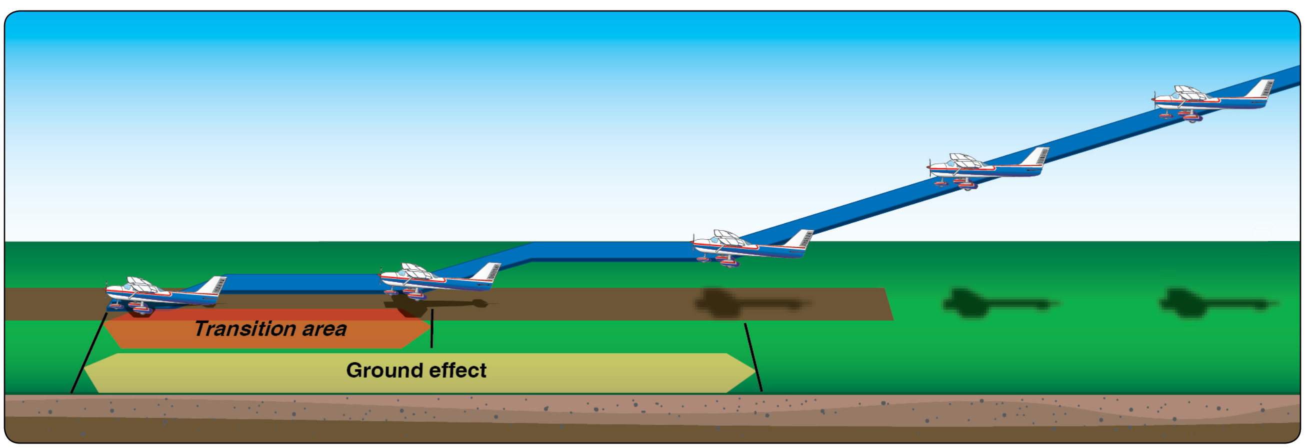

Figure 9-24. *Soft/rough field approach and landing.*

The use of flaps during soft-field landings aids in touching down at minimum speed and is recommended whenever practical. In low-wing airplanes, the flaps may suffer damage from mud, stones, or slush thrown up by the wheels. If flaps are used, it is generally inadvisable to retract them during the after-landing roll because the need for flap retraction is less important than the need for total concentration on maintaining full control of the airplane.

The final-approach airspeed used for short-field landings is equally appropriate to soft-field landings. The use of higher approach speeds may result in excessive float in ground effect, and floating makes a smooth, controlled touchdown even more difficult. There is no reason for a steep angle of descent unless obstacles are present in the approach path.

Touchdown on a soft or rough field is made at the lowest possible airspeed with the airplane in a nose-high pitch attitude. In nose-wheel type airplanes, after the main wheels touch the surface, the pilot should hold sufficient back-elevator pressure to keep the nose-wheel off the surface. Using back-elevator pressure and engine power, the pilot can control the rate at which the weight of the airplane is transferred from the wings to the wheels.

Field conditions may warrant that the pilot maintain a flight condition in which the main wheels are just touching the surface but the weight of the airplane is still being supported by the wings until a suitable taxi surface is reached. At any time during this transition phase, before the weight of the airplane is being supported by the wheels, and before the nose-wheel is on the surface, the ability is retained to apply full power and perform a safe takeoff (obstacle clearance and field length permitting) should the pilot elect to abandon the landing. Once committed to a landing, the pilot should gently lower the nose-wheel to the surface. A slight addition of power usually aids in easing the nose-wheel down.

The use of brakes on a soft field is not needed and should be avoided as this may tend to impose a heavy load on the nose-gear due to premature or hard contact with the landing surface, causing the nose-wheel to dig in. The soft or rough surface itself provides sufficient reduction in the airplane’s forward speed. Often upon landing on a very soft field, an increase in power may be needed to keep the airplane moving and from becoming stuck in the soft surface.

Common Errors

Common errors in the performance of soft-field approaches and landings are:

1. Excessive descent rate on final approach.
2. Excessive airspeed on final approach.
3. Unstable approach.
4. Round out too high above the runway surface.
5. Poor power management during round out and touchdown.
6. Hard touchdown.
7. Inadequate control of the airplane weight transfer from wings to wheels after touchdown.
8. Allowing the nose-wheel to “fall” to the runway after touchdown rather than controlling its descent.

Power-Off Accuracy Approaches

Power-off accuracy approaches and landings involve gliding to a touchdown at a given point (or within a specified distance beyond that point), while using a specific pattern and with the engine idling. The objective is to instill in the pilot the judgment and procedures necessary for accurately flying the airplane, without power, to a safe landing.

The ability to estimate the distance an airplane glides to a landing is the real basis of all power-off accuracy approaches and landings. The distance to be covered largely determines the amount of maneuvering needed to complete an approach from a given altitude. While developing the pilot's ability to estimate gliding distance, power-off accuracy approaches call upon the pilot to use a variety of techniques to set and maintain an appropriate glide angle and airspeed to the aiming point.

With experience and practice, altitudes up to approximately 1,000 feet can be estimated with fair accuracy; while above this level the accuracy in judgment of height above the ground decreases, since all features tend to merge. The best aid in perfecting the ability to judge height above this altitude is through the indications of the altimeter and associating them with the general appearance of the earth.

The judgment of altitude in feet, hundreds of feet, or thousands of feet is not as important as the ability to estimate gliding angle and its resultant distance. Regardless of altitude, a pilot who knows the normal glide angle of the airplane can estimate, with reasonable accuracy, the approximate spot along a given ground path at which the airplane will land. A pilot who has the ability to accurately estimate altitude, can also judge how much maneuvering is possible and safe during the glide, which is important to the choice of landing areas in an actual emergency.

The objective of a good final approach is to descend at an angle that permits the airplane to reach the desired aiming point at an airspeed that results in a predictable float where touchdown occurs on or within a specified distance beyond a designated point. To accomplish this, it is essential that both the descent angle and the airspeed be accurately controlled.

Unlike a normal approach when the power setting is variable, on a power-off approach the power is fixed at the idle setting. Pitch attitude is adjusted to control the airspeed. This also changes the glide or descent angle. If an airplane is on approach with an airspeed higher than best glide, pitching down will increase the airspeed and steepen the descent angle, while pitching up will reduce the airspeed and shallow the descent angle. Conversely, if the airspeed is below best glide, then pitching down will increase the airspeed and shallow the descent angle, while pitching up will reduce the airspeed and will greatly steepen the descent angle. If the airspeed is too high, the pilot should raise the nose; and when the airspeed is too low, lower the nose. If the pitch attitude is raised too high, the airplane settles rapidly due to a slow airspeed and insufficient lift. For this reason, the pilot should never try to stretch a glide to reach the desired landing spot.

Note that certain single-engine turboprop airplanes experience an excessive rate of descent if the power is set to flight idle. In some cases, if the powerplant failed, the manufacturer's checklist calls for feathering the propeller during a power-off glide. During flight training in these airplanes, the propeller is not feathered as would be the case in an emergency or true power-off glide. During training and pilot certification, where the manufacturer's checklist calls for propeller feathering in a power-off situation, the pilot should set sufficient power to provide the performance that would be expected with the propeller feathered.

Uniform approach patterns, such as the 90° or 180° power-off approaches, are described further in this chapter. Practicing these approaches provides a pilot with a basis on which to develop judgment in gliding distance and in planning an approach. While square patterns demonstrate good planning, they are not required and may not be appropriate for every approach. For example, when conditions are not as expected, pilots may need to dog-leg away from the runway on base or dog-leg toward the runway on base. Pilots may use S-turns, slips, early or late extension of flaps, reduce airspeed below best glide, or increase airspeed slightly above best glide in a headwind in order to stabilize the remaining approach, to reach the desired aiming point at an appropriate speed, and to touch down where planned. Note that selection of the runway numbers as the touchdown point does not provide a safety cushion in case of a mechanical problem or misjudgment. Selecting a point farther down the runway establishes an increased safety margin.

The basic procedure in these approaches involves closing the throttle at a given altitude and gliding to a key position. Starting with the same energy (airspeed and height) each time the throttle is closed, makes the maneuver more predictable. The key position, like the pattern itself, is not the primary objective; it is merely a convenient point in the air from which the pilot can judge what to do such that the landing occurs at or just beyond the desired point. The selected key position should be one that is appropriate for the available altitude and the wind condition. From the key position, the pilot should constantly evaluate the situation.

It should be emphasized that, although accurate spot touchdowns are important, safe and properly executed approaches and landings are vital. A pilot should never sacrifice a good approach or landing just to land on the desired spot.

90° Power-Off Approach

The 90° power-off approach is made from a base leg and requires an approximate 90° turn onto the final approach. The approach path may be varied by positioning the base leg closer to or farther out from the approach end of the runway according to wind conditions. [*Figure 9-25*] The glide from the key position on the base leg through the 90° turn to the final approach is the final part of all accuracy landing maneuvers. The 90° power-off approach usually begins from a rectangular pattern at approximately 1,000 feet above the ground or at normal traffic pattern altitude. The airplane is flown on a downwind leg at the same distance from the landing surface as in a normal traffic pattern. The before-landing checklist should be completed on the downwind leg, including extension of the landing gear if the airplane is equipped with retractable gear.

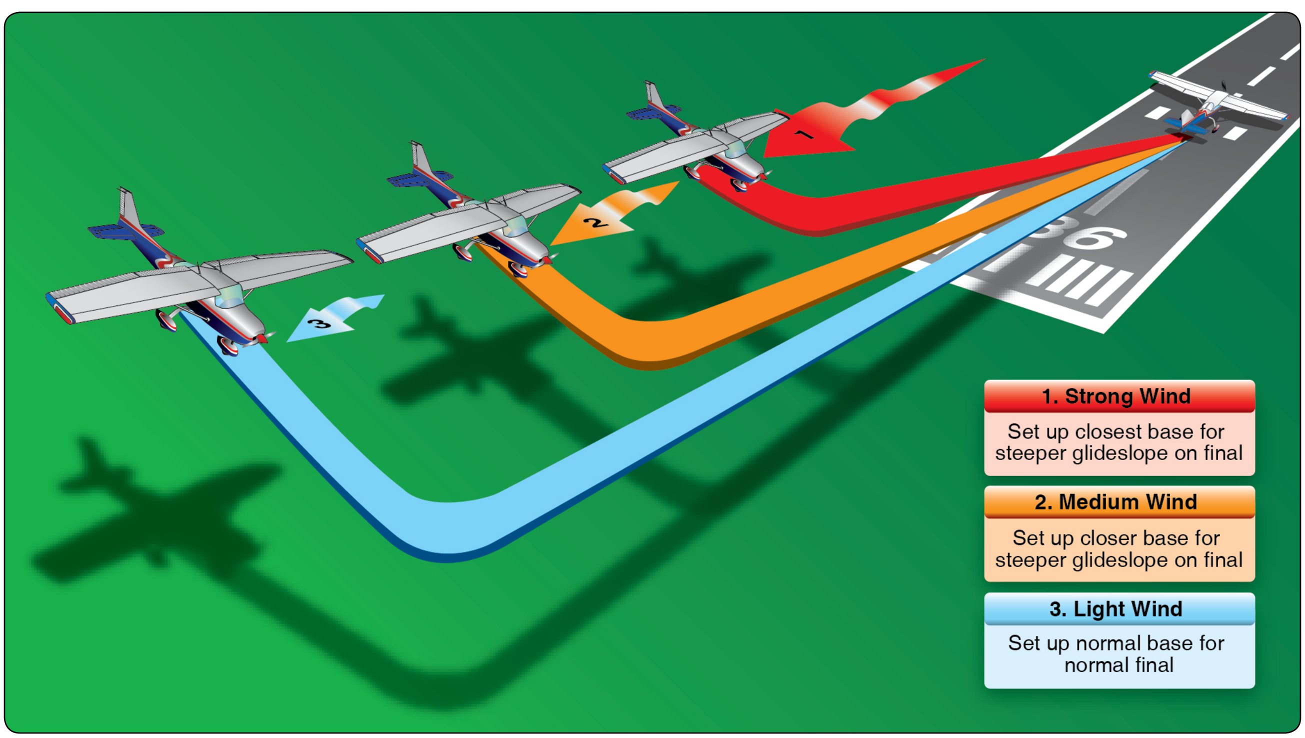

Figure 9-25. *Plan the base leg for wind conditions.*

After a medium-banked turn onto the base leg is completed, the throttle is retarded slightly and the airspeed allowed to decrease to the normal base-leg speed. [*Figure 9-26*] On the base leg, the airspeed, wind drift correction, and altitude are maintained while proceeding to the 45° key position. At this position, the intended landing spot appears to be on a 45° angle from the airplane's nose.

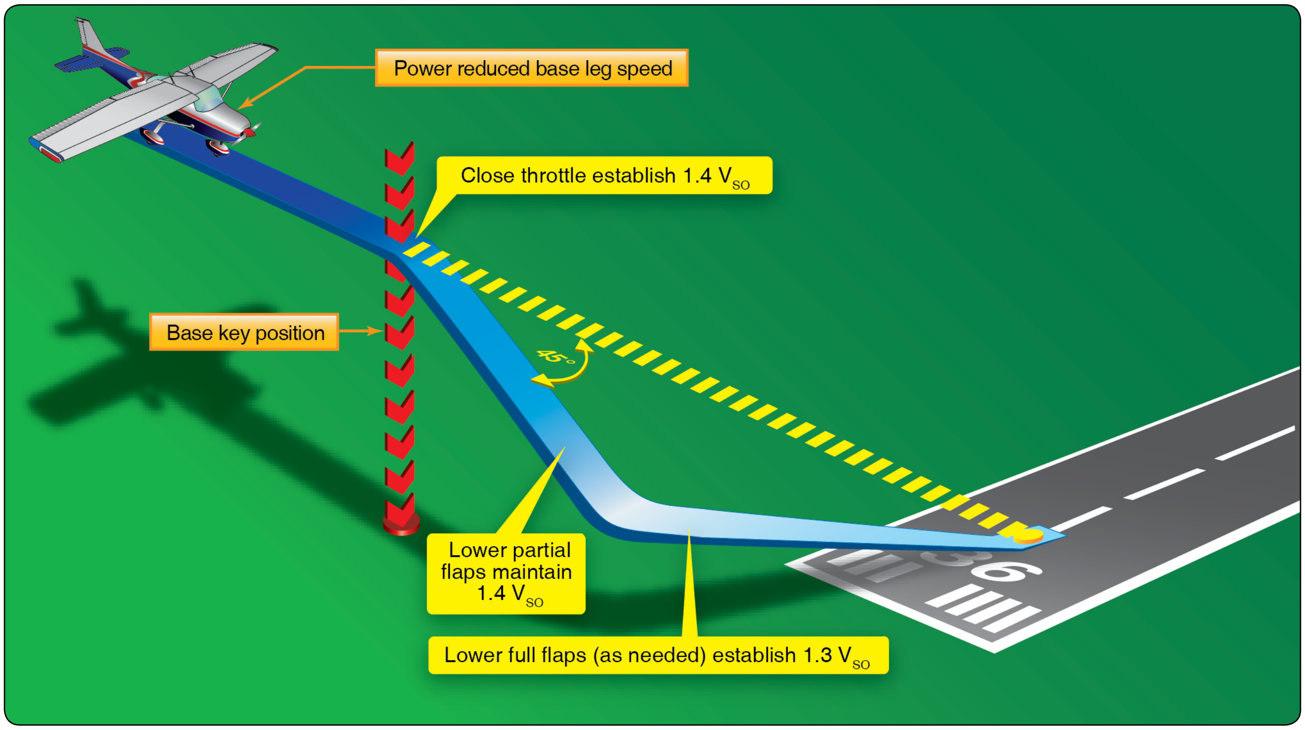

Figure 9-26. *90° power-off approach.*

The pilot can determine the strength and direction of the wind from the amount of crab necessary to hold the desired ground track on the base leg. This helps in planning the turn onto the final approach and provides some indication of when to lower the flaps.

At the 45° key position, the throttle is closed completely, the propeller control (if equipped) advanced to the full increase revolution per minute (rpm) position, and altitude maintained until the airspeed decreases to the manufacturer's recommended glide speed. In the absence of a recommended speed, the pilot should use 1.4 V_{SO}. When this airspeed is attained, the nose is lowered to maintain the gliding speed and the controls trimmed. The wing flaps may be gradually lowered and the pitch attitude adjusted, as needed, to establish the proper descent angle. The base-to-final turn is planned and accomplished so that upon rolling out of the turn, the airplane is aligned with the runway centerline. If the approach is planned to be slightly high in the current configuration, the pilot will be assured of making the aiming point. The wing flaps may be lowered, as needed, and the pitch attitude adjusted, as needed, to establish the proper descent angle and airspeed (1.3 V_{SO}), and the controls trimmed. Slight adjustments in pitch attitude and slips are used as necessary to control the glide angle and airspeed. A crab or side slip can be used to maintain the desired flight path. A forward slip may be used momentarily to steepen the descent without changing the airspeed. Full flaps should be delayed until it is clear that adding them will not cause the landing to be short of the point. The pilot should never try to stretch the glide or retract the flaps to reach the desired landing spot.

On short final, full attention is given to making a good, safe landing rather than concentrating on the selected landing spot. The approach angle used and final approach airspeed determine the probability of landing on the spot, and late adjustments to these parameters are not appropriate. It is always better to execute a good landing away from the spot than to make a poor landing precisely on or just past the spot.

180° Power-Off Approach

The 180° power-off approach is executed by gliding with idle power from a given point on a downwind leg to a preselected landing spot. [*Figure 9-27*] It is an extension of the principles involved in the 90° power-off approach just described. The objective is to further develop judgment in estimating distances and glide ratios, in that the airplane is flown without power from a higher altitude and through a 90° turn to reach the base-leg position at a proper altitude for executing the 90° approach.

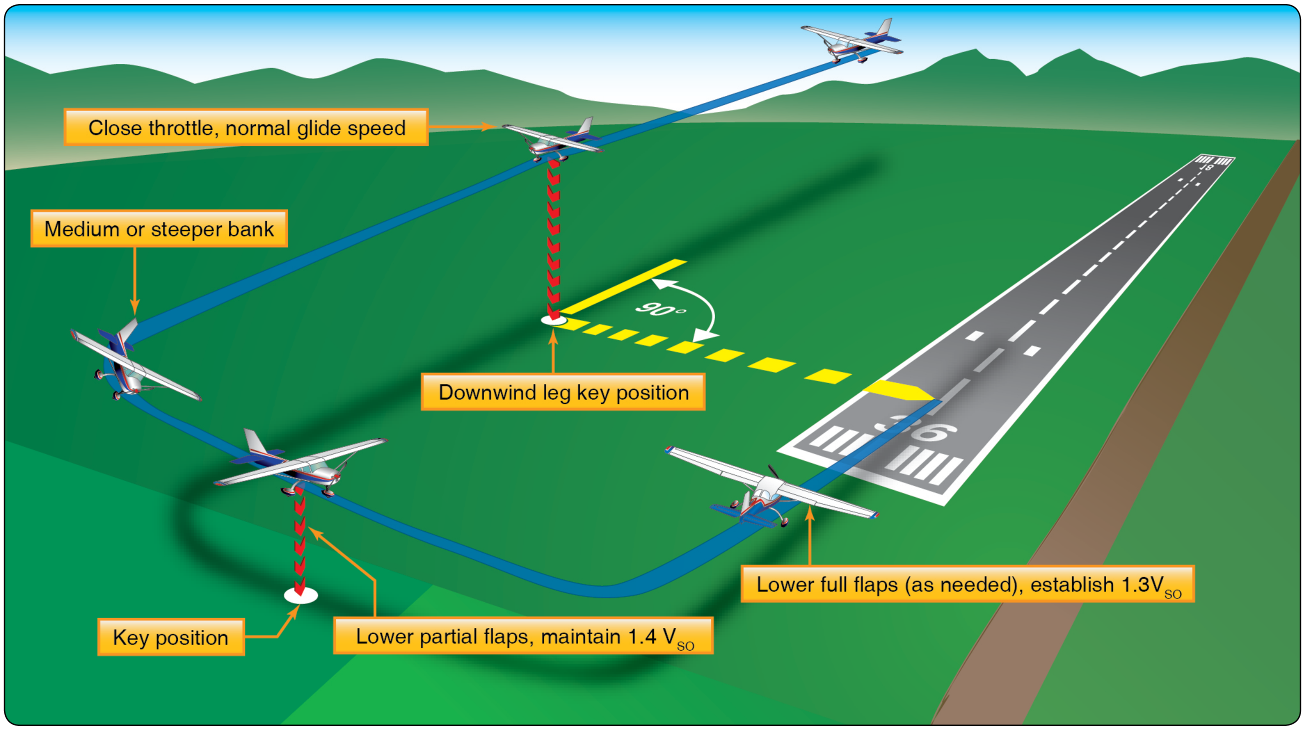

Figure 9-27. *180° power-off approach.*

The 180° power-off approach requires more planning and judgment than the 90° power-off approach. In the execution of 180° power-off approaches, the airplane is flown on a downwind heading parallel to the landing runway. The altitude from which this type of approach is started varies with the type of airplane, but should usually not exceed 1,000 feet above the ground, except with large airplanes. Greater accuracy in judgment and maneuvering is required at higher altitudes.

When abreast of or opposite the desired landing spot, the throttle is closed and altitude maintained while decelerating to the manufacturer's recommended glide speed or 1.4 V_{SO}. The point at which the throttle is closed is the downwind key position.

The turn from the downwind leg to the base leg is a uniform turn with a medium or slightly steeper bank. The degree of bank and amount of this initial turn depend upon the glide angle of the airplane and the velocity and direction of the wind. Again, the base leg is positioned as needed for the altitude or wind condition. Position the base leg to conserve or dissipate altitude so as to reach the desired landing spot.

The turn onto the base leg is made at an altitude high enough and close enough to permit the airplane to glide to what would normally be the base key position in a 90° power-off approach. Initial flaps may be extended prior to the base key position if needed.

Although the base key position is important, it should not be overemphasized nor considered as a fixed point on the ground. Many inexperienced pilots may gain a conception of it as a particular landmark, such as a tree, crossroad, or other visual reference, to be reached at a certain altitude. This misconception leaves the pilot at a total loss any time such objects are not present. Both altitude and geographical location should be varied as much as is practical to eliminate any such misconceptions. After reaching the base key position, the approach and landing are the same as in the 90° power-off approach.

Common Errors

Common errors in the performance of power-off accuracy approaches are:

1. Downwind leg is too far from the runway/landing area.
2. Overextension of downwind leg resulting from a tailwind.
3. Inadequate compensation for wind drift on base leg.
4. Skidding turns in an effort to increase gliding distance.
5. Failure to lower landing gear in retractable gear airplanes.
6. Attempting to "stretch" the glide during an undershoot.
7. Premature flap extension/landing gear extension.
8. Use of throttle to increase the glide instead of merely clearing the engine.
9. Forcing the airplane onto the runway in order to avoid overshooting the designated landing spot.

Emergency Approaches and Landings (Simulated)

During dual training flights, the instructor should give simulated emergency landings by retarding the throttle and calling "simulated emergency landing." The objective of these simulated emergency landings is to develop a pilot's accuracy, judgment, planning, procedures, and confidence when little or no power is available. A simulated emergency landing may be given with the airplane in any configuration. If the simulated power failure occurs while above best glide speed, the pilot allows the airplane to slow (or may even bleed off speed by climbing) until reaching best glide speed. When reaching that speed, the nose can be lowered and the airplane trimmed to maintain that speed. If the failure occurs at or below best glide speed, the nose should be lowered immediately to maintain or accelerate to best glide speed. The pilot should ensure that the flaps and landing gear are in the proper configuration for the existing situation.

A constant gliding speed is usually maintained because variations of gliding speed nullify all attempts at accuracy in judgment of gliding distance and the landing spot. The many variables, such as altitude, obstruction, wind direction, landing direction, landing surface and gradient, and landing distance requirements of the airplane, determine the pattern and approach procedures to use.

The pilot may use any combination of normal gliding maneuvers, from wings level to spirals to eventually arrive at the normal key position at a normal traffic pattern altitude for the selected landing area. From the key point on, the approach is a normal power-off approach. [*Figure 9-28*]

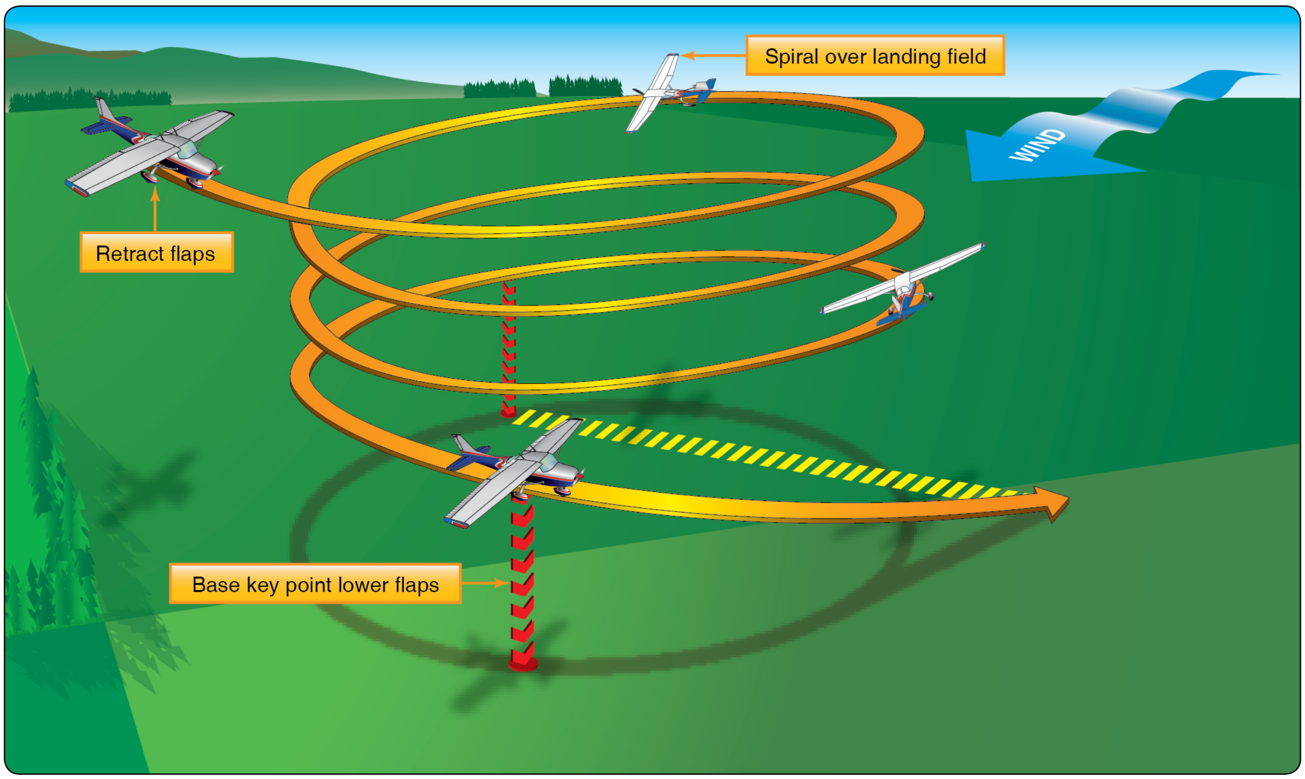

Figure 9-28. *Remain over intended landing area.*

With the greater choice of fields afforded by higher altitudes, the inexperienced pilot may be inclined to delay making a decision, and with considerable altitude in which to maneuver, errors in maneuvering and estimation of glide distance may develop.

All pilots should learn to determine the wind direction and estimate its speed from the windsock at the airport, smoke from factories or houses, dust, brush fires, wind farms, or patterns displayed on nearby bodies of water .

Once a field has been selected, a pilot should indicate the proposed landing area to the instructor. Normally, the pilot should plan and fly a pattern for landing on the field first elected until the instructor terminates the simulated emergency landing. This provides the instructor an opportunity to explain and correct any errors; it also gives the pilot an opportunity to see the results of the errors. However, if the pilot realizes during the approach that a poor field has been selected—one that would obviously result in disaster if a landing were to be made—and there is a more advantageous field within gliding distance, a change to the better field should be permitted. The instructor should thoroughly explain the hazards involved in these last-minute decisions, such as excessive maneuvering at very low altitudes.

Instructors should stress slipping the airplane, using flaps, varying the position of the base leg, and varying the turn onto final approach as ways of correcting for misjudgment of altitude and glide angle.

Eagerness to get down is one of the most common faults of inexperienced pilots during simulated emergency landings. They forget about speed and arrive at the edge of the field with too much speed to permit a safe landing. Too much speed is just as dangerous as too little;

it results in excessive floating and overshooting the desired landing spot. Instructors need to stress during their instruction that pilots cannot dive at a field and expect to land on it.

During all simulated emergency landings, keep the engine warm and cleared. During a simulated emergency landing, either the instructor or the pilot should have complete control of the throttle. There should be no doubt as to who has control since many near accidents have occurred from such misunderstandings.

Every simulated emergency landing approach is terminated as soon as it can be determined whether or not a safe landing is assured. In no case should it be continued to a point where it creates an undue hazard or an annoyance to persons or property on the ground.

In addition to flying the airplane from the point of simulated engine failure to where it is known that a reasonable safe landing could be made (or to where it is known that the approach cannot be salvaged), a pilot should also receive instruction on certain emergency flight deck procedures. The habit of performing these procedures should be developed to such an extent that, if an engine failure actually occurs, a pilot checks the critical items that might get the engine operating again while selecting a field and planning an approach. Combining the two operations—accomplishing emergency procedures and planning and flying the approach—is difficult during the early training in emergency landings.

There are steps and procedures pilots should follow in a simulated emergency landing. Although they may differ somewhat from the procedures used in an actual emergency, they should be learned thoroughly and each step called out to the instructor. The use of a checklist is strongly recommended. Most airplane manufacturers provide a checklist of the appropriate items. [*Figure 9-29*]

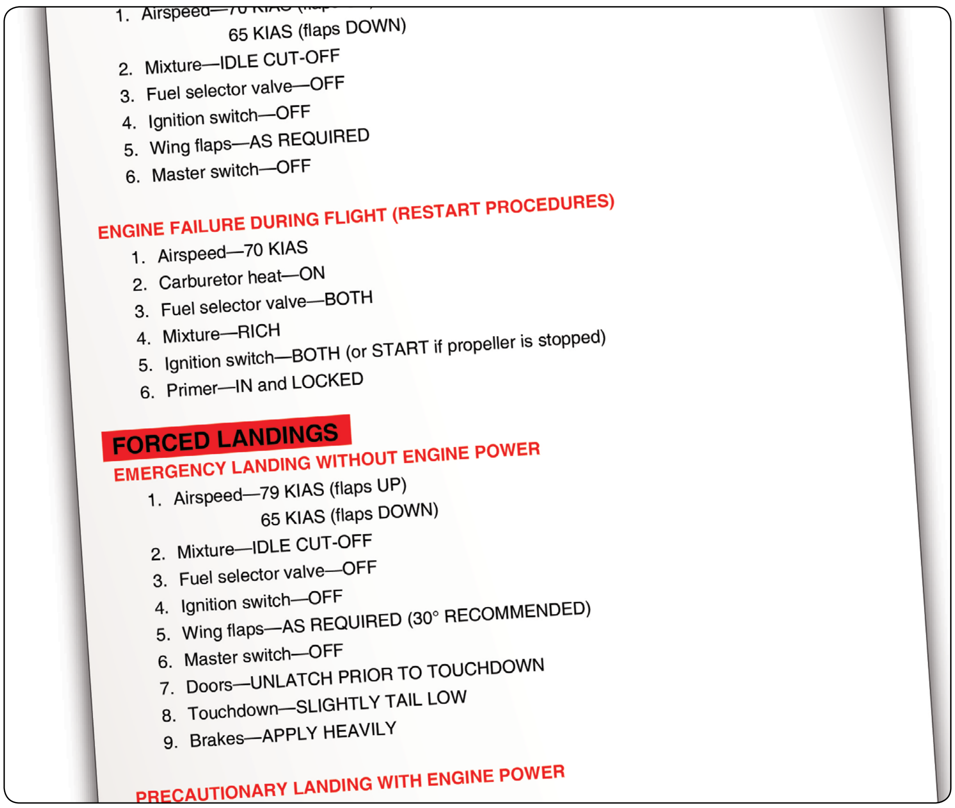

Figure 9-29. *Sample emergency checklist.*

Critical items to be checked include the position of the fuel tank selector, the quantity of fuel in the tank selected, the fuel pressure gauge to see if the electric fuel pump is needed, the position of the mixture control, the position of the magneto switch, and the use of carburetor heat. Many actual emergency landings have been made and later found to be the result of the fuel selector valve being positioned to an empty tank while the other tank had plenty of fuel. It may be wise to change the position of the fuel selector valve even though the fuel gauge indicates fuel in all tanks because fuel gauges can be inaccurate. Many actual emergency landings could have been prevented if the pilots had developed the habit of checking these critical items during flight training.

Instruction in emergency procedures is not limited to simulated emergency landings caused by power failures. Other emergencies associated with the operation of the airplane should be explained, demonstrated, and practiced if practicable. Among these emergencies are fire in flight, electrical or hydraulic system malfunctions, unexpected severe weather conditions, engine overheating, imminent fuel exhaustion, and the emergency operation of airplane systems and equipment.

Faulty Approaches and Landings

Landing involves many precise, time-sensitive, and sequential control inputs. When corrected early, small errors are often not noticeable. On the other hand, uncorrected errors may place the airplane and occupants in an undesirable state. Since pilot training normally includes exposure to landing deviations and their appropriate remedies, this section covers several common landing imperfections.

Low Final Approach

When the base leg is too low, insufficient power is used, landing flaps are extended prematurely, or the velocity of the wind is misjudged, the airplane may be well below the proper final approach path. In such a situation, the pilot would have to apply considerable power to fly the airplane (at an excessively low altitude) up to the runway threshold. When it is realized the runway cannot be reached unless appropriate action is taken, power should be applied immediately to maintain the airspeed while the pitch attitude is raised to increase lift and stop the descent. When the proper approach path has been intercepted, the correct approach attitude is reestablished and the power reduced and a stabilized approach maintained. [*Figure 9-30*] The pilot should not increase the pitch attitude without increasing the power because the airplane decelerates rapidly and may approach the critical AOA and stall. In addition, the pilot should not retract the flaps since this causes a sudden decrease in lift and causes the airplane to sink more rapidly. If there is any doubt about the approach being safely completed, it is advisable to execute an immediate go-around.

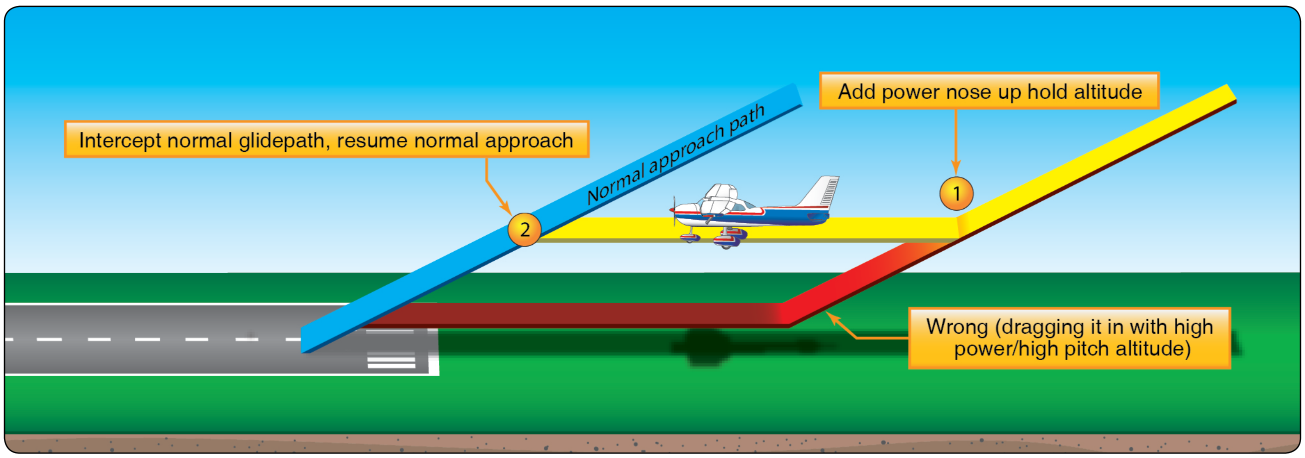

Figure 9-30. *Right and wrong methods of correction for low final approach.*

High Final Approach

When the final approach is too high, the pilot may lower the flaps as required. Further reduction in power may be necessary, while lowering the nose simultaneously to maintain approach airspeed and steepen the approach path. [*Figure 9-31*] Alternatively, the pilot could use a forward slip to increase the descent angle and rate of descent while maintaining proper approach speed. Since a sink rate in excess of 800–1,000 feet per minute (fpm) is considered excessive, either technique avoids the high sink rates that would occur if the pilot dives the airplane toward the aiming point. Since a high sink rate continued close to the surface makes it be difficult to slow to a proper rate prior to ground contact, it is not a good idea to dive toward the aiming point. Therefore, when intercepting the proper approach path from above, the pilot adjusts the power as required to maintain a stabilized approach. A go-around should be initiated if the sink rate becomes excessive.

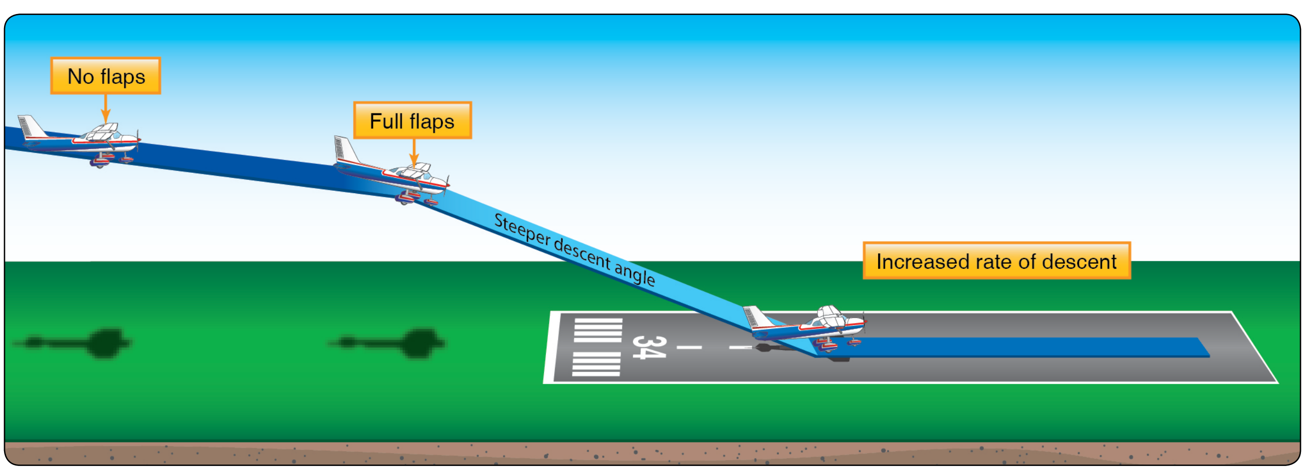

Figure 9-31. *Change in glidepath and increase in descent rate for high final approach.*

Slow Final Approach

On the final approach, when the airplane is flown at a slower than normal airspeed, the pilot's judgment of the rate of sink (descent) and the height of round out is difficult. During an excessively slow approach, the wing is operating near the critical AOA and, depending on the pitch attitude changes and control usage, the airplane may stall or sink rapidly, contacting the ground with a hard impact.

Whenever a slow speed approach is noted, the pilot should apply power to accelerate the airplane and increase the lift to reduce the sink rate and to prevent a stall. This is done while still at a high enough altitude to reestablish the correct approach airspeed and attitude. If too slow and too low, it is best to execute a go-around.

Use of Power

Power can be used effectively during the approach and round out to compensate for errors in judgment. Power may be added to accelerate the airplane, to increase lift without increasing the AOA, and to slow the descent to an acceptable rate. The increased propwash over the wing behind the propeller(s) also provides an immediate boost in lift that also helps slow the descent rate. If the proper landing attitude is attained and the airplane is only slightly high, the landing attitude is held constant and sufficient power applied to help ease the airplane onto the ground. After the airplane has touched down, the pilot closes the throttle so the additional thrust and lift are removed and the airplane remains on the ground.

High Round Out

Sometimes when the airplane appears to temporarily stop moving downward, the round out has been made too rapidly and the airplane is flying level, too high above the runway. Continuing the round out further reduces the airspeed and increases the AOA to the critical angle. This results in the airplane stalling and dropping hard onto the runway. To prevent this, the pitch attitude is held constant until the airplane decelerates enough to again start descending. Then the round out is continued to establish the proper landing attitude. This procedure is only used when there is adequate airspeed. It may be necessary to add a slight amount of power to keep the airspeed from decreasing excessively and to avoid losing lift too rapidly.

When the proper landing attitude is attained, the airplane is approaching a stall because the airspeed is decreasing and the critical AOA is being approached, even though the pitch attitude is no longer being increased. [*Figure 9-32*]

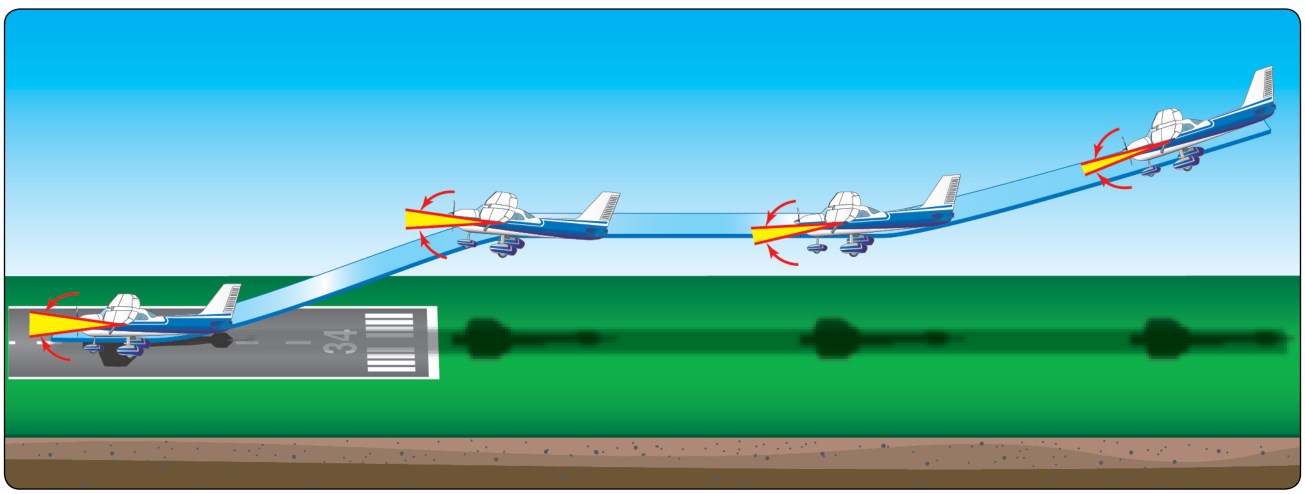

Figure 9-32. *Rounding out too high.*

Although back-elevator pressure may be relaxed slightly, the nose should not be lowered to make the airplane descend when fairly close to the runway unless some power is added momentarily. The momentary decrease in lift that results from lowering the nose and decreasing the AOA might cause the airplane to contact the ground with the nose-wheel first and may result in nose gear damage or collapse.

It is recommended that a go-around be executed any time it appears the nose needs to be lowered significantly or that the landing is in any other way uncertain.

Late or Rapid Round Out

Starting the round out too late or pulling the elevator control back too rapidly to prevent the airplane from touching down prematurely can impose a significant load on the wings and cause an accelerated stall.

Suddenly increasing the AOA and stalling the airplane during a round out is a dangerous situation since it may cause the airplane to land extremely hard on the main landing gear and then bounce back into the air. As the airplane contacts the ground, the tail is forced down very rapidly by the back-elevator pressure and by inertia acting downward on the tail.

Recovery from this situation requires prompt and positive application of power prior to occurrence of the stall. This may be followed by a normal landing if sufficient runway is available—otherwise the pilot should execute a go-around immediately.

If the round out is late and uncorrected, the nose-wheel may strike the runway first, causing the nose to bounce upward. Do not attempt to force the airplane back onto the ground; execute a go-around immediately.

Floating During Round Out

If the airspeed on final approach is excessive, it usually results in the airplane floating. [*Figure 9-33*] Before touchdown can be made, the airplane may be well past the desired landing point and the available runway may be insufficient. When diving the airplane on final approach to land at the proper point, there is an appreciable increase in airspeed. The proper touchdown attitude cannot be established without producing an excessive AOA and lift. This causes the airplane to gain altitude or balloon.

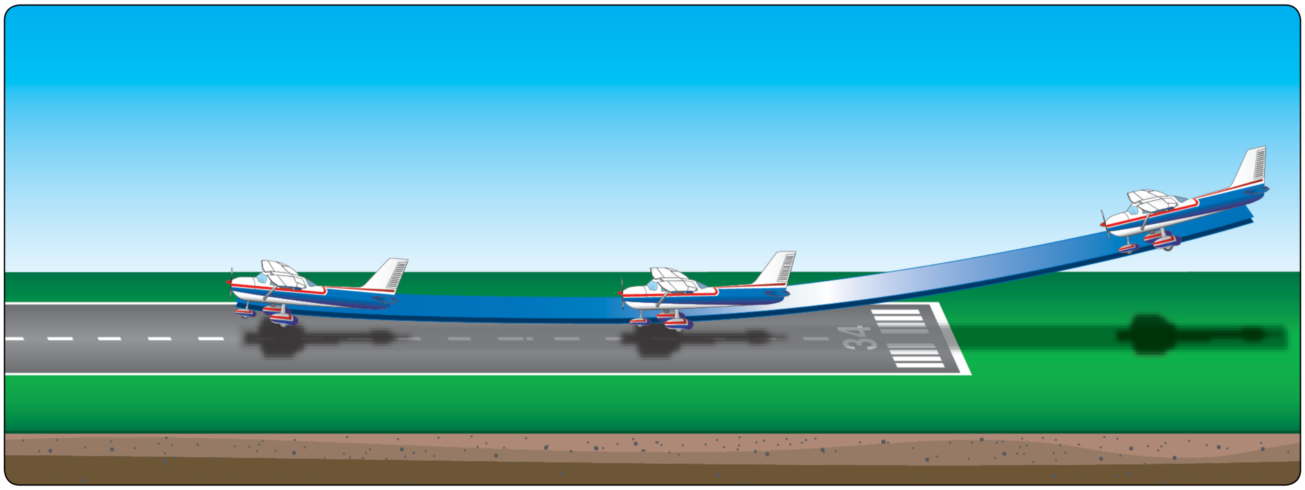

Figure 9-33. *Floating during round out.*

Any time the airplane floats, judgment of speed, height, and rate of sink needs to be especially acute. The pilot should smoothly and gradually adjust the pitch attitude as the airplane decelerates to touchdown speed and starts to settle, so the proper landing attitude is attained at the moment of touchdown. The slightest error in judgment and timing results in either ballooning or bouncing.

The recovery from floating is dependent upon the amount of floating and the effect of any crosswind, as well as the amount of runway remaining. Since prolonged floating utilizes considerable runway length, it should be avoided especially on short runways or in strong crosswinds. If a landing cannot be made on the first third of the runway, or the airplane drifts sideways, execute a go-around.

Ballooning During Round Out

If the pilot misjudges the rate of sink during a landing and thinks the airplane is descending faster than it should, there is a tendency to increase the pitch attitude and AOA too rapidly. This not only stops the descent, but actually starts the airplane climbing. This climbing during the round out is known as ballooning. [*Figure 9-34*] Ballooning is dangerous because the height above the ground is increasing and the airplane is rapidly approaching a stalled condition. The altitude gained in each instance depends on the airspeed or the speed with which the pitch attitude is increased.

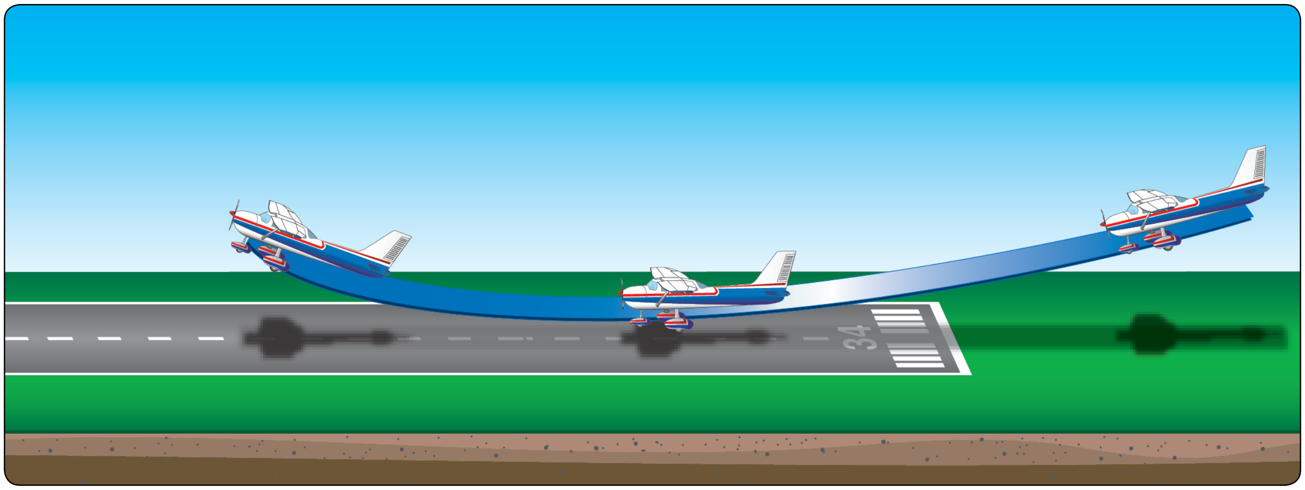

Figure 9-34. *Ballooning during roundout.*

Depending on the severity of ballooning, the use of throttle is helpful in cushioning the landing. By adding power, thrust is increased to keep the airspeed from decelerating too rapidly and the wings from suddenly losing lift, but throttle should be closed immediately after touchdown. Torque effects vary as power is changed, and it is necessary to use rudder pressure to keep the airplane straight as it settles onto the runway.

The pilot needs to be extremely cautious of ballooning when there is a crosswind present because the crosswind correction may be inadvertently released or it may become inadequate. Because of the lower airspeed after ballooning, the crosswind affects the airplane more. Consequently, the wing has to be lowered even further to compensate for the increased drift. It is imperative that the pilot makes certain that the appropriate wing is down and that directional control is maintained with opposite rudder. If there is any doubt, or the airplane starts to drift, the pilot should execute a go-around.

When ballooning is excessive, it is best to execute a go-around immediately and not attempt to salvage the landing. Power should be applied before the airplane enters a stalled condition.

Bouncing During Touchdown

When the airplane contacts the ground with a sharp impact as the result of an improper attitude or an excessive rate of sink, it tends to bounce back into the air. Though the airplane's tires and shock struts provide some springing action, the airplane does not bounce like a rubber ball. Instead, it rebounds into the air because the wing's AOA was abruptly increased, producing a sudden addition of lift. [*Figure 9-35*]

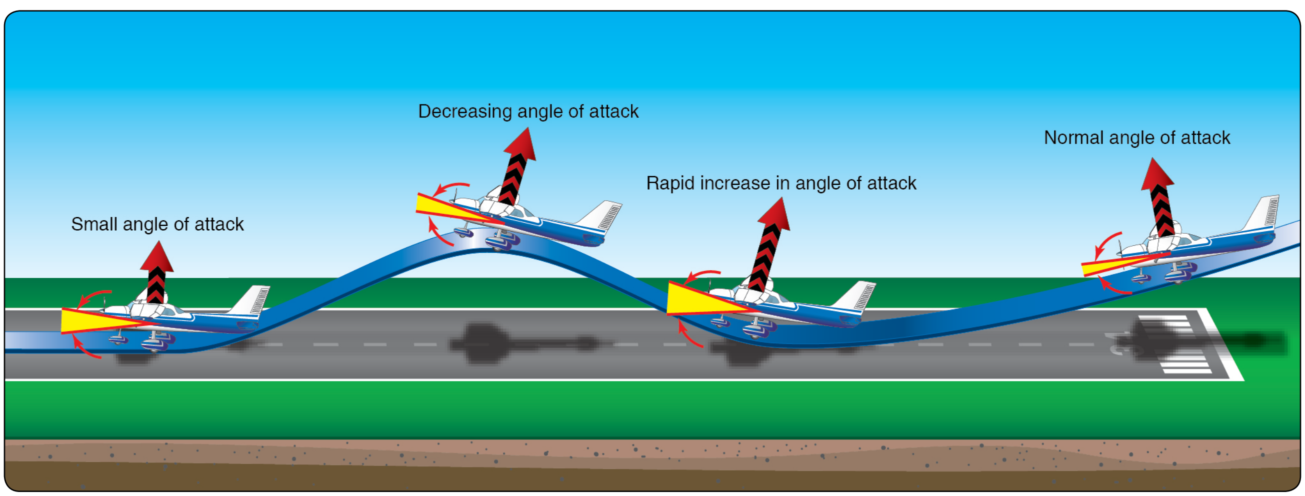

Figure 9-35. *Bouncing during touchdown.*

The abrupt change in AOA is the result of inertia instantly forcing the airplane's tail downward when the main wheels contact the ground sharply. The severity of the bounce depends on the airspeed at the moment of contact and the degree to which the AOA or pitch attitude was increased.

Since a bounce occurs when the airplane makes contact with the ground before the proper touchdown attitude is attained, it is almost invariably accompanied by the application of excessive back-elevator pressure. This is usually the result of the pilot realizing too late that the airplane is not in the proper attitude and attempting to establish it just as the second touchdown occurs.

The corrective action for a bounce is the same as for ballooning and similarly depends on its severity. When it is very slight and there is no extreme change in the airplane's pitch attitude, a follow-up landing may be executed by applying sufficient power to cushion the subsequent touchdown and smoothly adjusting the pitch to the proper touchdown attitude.

In the event a very slight bounce is encountered while landing with a crosswind, crosswind correction needs to be maintained while the next touchdown is made. Since the subsequent touchdown is made at a slower airspeed, the upwind wing has to be lowered even further to compensate for drift.

Extreme caution and alertness should be exercised any time a bounce occurs, but particularly when there is a crosswind. Pilots should not release the crosswind correction. When one main wheel of the airplane strikes the runway, the other wheel touches down immediately afterwards, and the wings become level. Then, with no crosswind correction as the airplane bounces, the wind causes the airplane to roll with the wind, thus exposing even more surface to the crosswind and increasing any drift.

When a bounce is severe, the safest procedure is to execute a go-around immediately. The pilot should not attempt to salvage the landing. Apply full power while simultaneously maintaining directional control and lowering the nose to a safe climb attitude. The go-around procedure should be continued even though the airplane may descend and another bounce may be encountered. Landing from a bad bounce should not be attempted, since airspeed diminishes very rapidly in the nose-high attitude, and a stall may occur before a subsequent touchdown can be made.

Porpoising

In a bounced landing that is improperly recovered, the airplane comes in nose first, initiating a series of motions imitating the jumps and dives of a porpoise. [*Figure 9-36*] The improper airplane attitude at touchdown may be caused by inattention, not knowing where the ground is, miss-trimming, or forcing the airplane onto the runway.

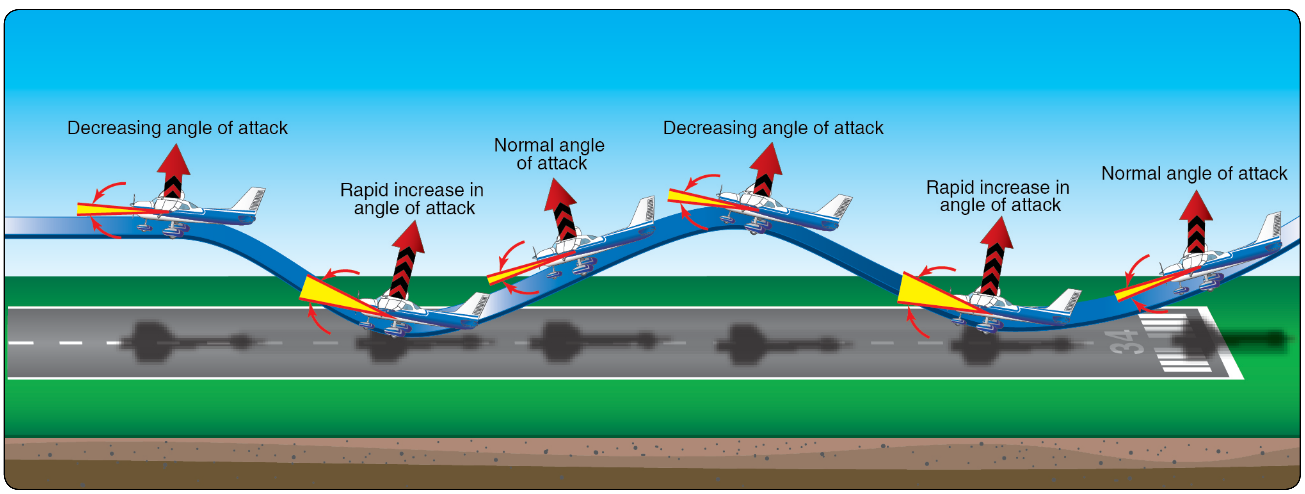

Figure 9-36. *Porpoising.*

Ground effect decreases elevator control effectiveness and increases the effort required to raise the nose. Not enough elevator or stabilator trim can result in a nose low contact with the runway and a porpoise develops.

Porpoising can also be caused by improper airspeed control. Usually, if an approach is too fast, the airplane floats and the pilot tries to force it on the runway when the airplane still wants to fly. A gust of wind, a bump in the runway, or even a slight tug on the control wheel sends the airplane aloft again.

The corrective action for a porpoise is the same as for a bounce and similarly depends on its severity. When it is very slight and there is no extreme change in the airplane's pitch attitude, a follow-up landing may be executed by applying sufficient power to cushion the subsequent touchdown and smoothly adjusting the pitch to the proper touchdown attitude.

When pilots attempt to correct a severe porpoise with flight control and power inputs, the inputs are often untimely may increase the severity of each successive contact with the surface. These unintentional and increasing pilot-induced oscillations may lead to damage or collapse of the nose gear. When porpoising is severe or seems to be getting worse, the safest procedure is to execute a go-around immediately by applying full power while simultaneously maintaining directional control and lowering the nose to a safe climb attitude.

Wheelbarrowing

When a pilot permits the airplane weight to become concentrated about the nose-wheel during the takeoff or landing roll, a condition known as wheelbarrowing occurs. Wheelbarrowing may cause loss of directional control during the landing roll because braking action is ineffective, and the airplane tends to swerve or pivot on the nose-wheel, particularly in crosswind conditions. One of the most common causes of wheelbarrowing during the landing roll is a simultaneous touchdown of the main and nose-wheel with excessive speed, followed by application of forward pressure on the elevator control. Usually, the situation can be corrected by smoothly applying back-elevator pressure.

Wheelbarrowing does not occur if the pilot achieves and maintains the correct landing attitude, touches down at the proper speed, and gently lowers the nose-wheel while losing speed on rollout. However, if wheelbarrowing is encountered and runway and other conditions permit, it is advisable to promptly initiate a go-around. If the pilot decides it's safer to stay on the ground rather than attempt a go-around when directional control is lost, close the throttle and adjust the pitch attitude smoothly but firmly to the proper landing attitude.

Hard Landing

When the airplane contacts the ground during landings, its vertical speed is instantly reduced to zero. Unless provisions are made to slow this vertical speed and cushion the impact of touchdown, the force of contact with the ground could cause structural damage to the airplane.

The purpose of pneumatic tires, shock absorbing landing gear, and other devices is to cushion the impact and to increase the time in which the airplane's vertical descent is stopped. The importance of this cushion may be understood from the computation that a 6-inch free fall on landing is roughly equal to a 340 fpm descent. Within a fraction of a second, the airplane gets slowed from this rate of vertical descent to zero without damage.

During this time, the landing gear, together with some aid from the lift of the wings, supplies whatever force is needed to counteract the force of the airplane's inertia and weight. However, the lift decreases rapidly as the airplane's forward speed is decreased, and the force on the landing gear increases by the impact of touchdown. When the descent stops, the lift is practically zero, leaving the landing gear alone to carry both the airplane's weight and inertia force. The load imposed at the instant of touchdown may easily be three or four times the actual weight of the airplane depending on the severity of contact.

Touchdown in a Drift or Crab

At times, it is necessary to correct for wind drift by crabbing on the final approach. If the round out and touchdown are made while the airplane is drifting or in a crab, it contacts the ground while moving sideways. This imposes extreme side loads on the landing gear and, if severe enough, may cause structural failure.

The most effective method to prevent drift is the wing-low method. This technique keeps the longitudinal axis of the airplane aligned with both the runway and the direction of motion throughout the approach and touchdown. There are three factors that cause the longitudinal axis and the direction of motion to be misaligned during touchdown: drifting, crabbing, or a combination of both.

If the pilot does not take adequate corrective action to avoid drift during a crosswind landing, the main wheels' tire tread offers resistance to the airplane's sideward movement with respect to the ground. Consequently, any sideward velocity of the airplane is abruptly decelerated, as shown in *Figure 9-37*. This creates a moment around the main wheel when it contacts the ground, tending to overturn or tip the airplane. If the upwind wingtip is raised by the action of this moment, all the weight and shock of landing is borne by one main wheel. This concentration of forces may cause tire failure or structural damage.

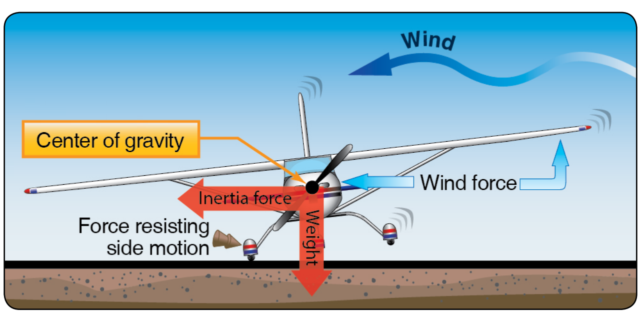

Figure 9-37. *Drifting during touchdown.*

Not only are the same factors present that are attempting to raise a wing, but the crosswind is also acting on the fuselage surface behind the main wheels, tending to yaw (weathervane) the airplane into the wind. This often results in a ground loop.

Ground Loop

A ground loop is an uncontrolled turn during ground operation that may occur while taxiing or taking off. However, an airplane is especially vulnerable to this occurrence during the after-landing roll. A ground loop may result if the pilot fails to control an initial swerve. Drift or weathervaning may cause the initial swerve. Careless use of the rudder, an uneven ground surface, or a soft spot that retards one main wheel of the airplane may also cause a swerve. In any case, the initial swerve tends to make the airplane ground loop, whether it is a tailwheel-type or nose-wheel type. [*Figure 9-38*]

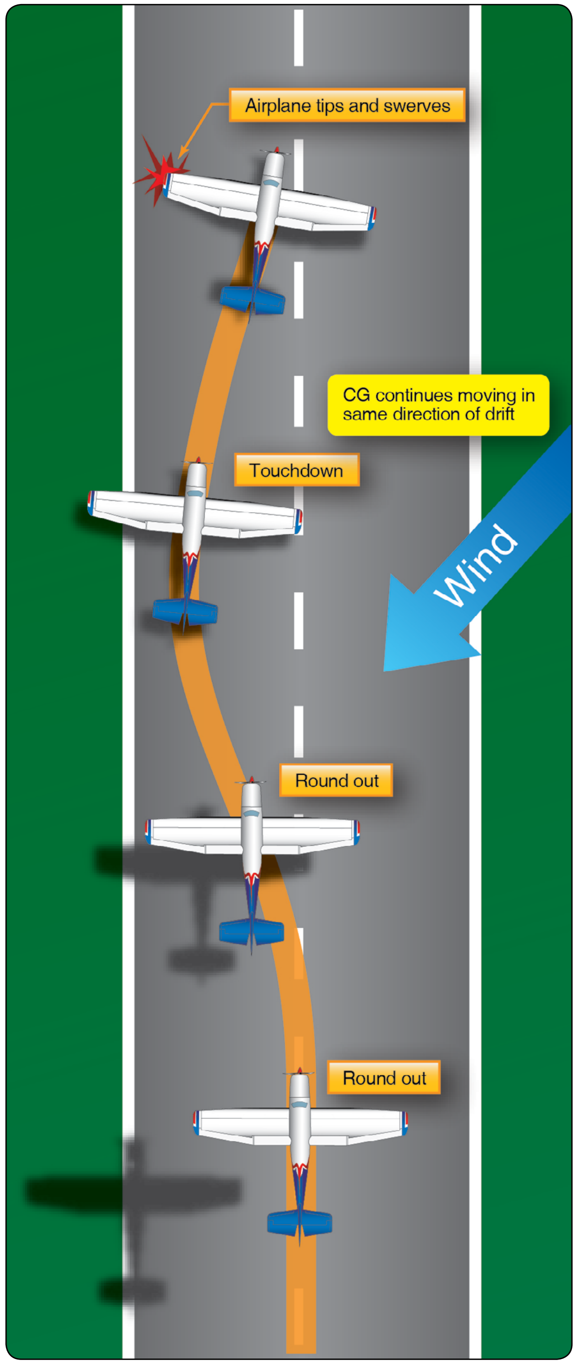

Figure 9-38. *Start of a ground loop.*

Nose-wheel type airplanes are somewhat less prone to ground loop than tailwheel-type airplanes. Since the center of gravity (CG) is located forward of the main landing gear on these airplanes, any time a swerve develops, centrifugal force acting on the CG tends to stop the swerving action.

If the airplane touches down while drifting or in a crab, apply aileron toward the high wing and stop the swerve with the rudder. Brakes are used to correct for turns or swerves only when the rudder is inadequate. Exercise caution when applying corrective brake action because it is very easy to over control and aggravate the situation.

If brakes are used, sufficient brake is applied on the low-wing wheel (outside of the turn) to stop the swerve. When the wings are approximately level, the new direction should be maintained until the airplane has slowed to taxi speed or has stopped.

In nose-wheel airplanes, a ground loop is almost always a result of wheelbarrowing. A pilot should be aware that even though the nose-wheel type airplane is less prone than the tailwheel-type airplane, virtually every type of airplane, including large multiengine airplanes, can be made to ground loop when sufficiently mishandled.

Wing Rising After Touchdown

When landing in a crosswind, there may be instances when a wing rises during the after-landing roll. This may occur whether or not there is a loss of directional control, depending on the amount of crosswind and the degree of corrective action.

Any time an airplane is rolling on the ground in a crosswind condition, the upwind wing is receiving a greater force from the wind than the downwind wing. This causes a lift differential. Also, as the upwind wing rises, there is an increase in the AOA, which increases lift on the upwind wing, rolling the airplane downwind.

When the effects of these two factors are great enough, the upwind wing may rise even though directional control is maintained. If no correction is applied, it is possible that the upwind wing rises sufficiently to cause the downwind wing to strike the ground.

In the event a wing starts to rise during the landing roll, the pilot should immediately apply more aileron pressure toward the high wing and continue to maintain direction. The sooner the aileron control is applied, the more effective it is. The further a wing is allowed to rise before taking corrective action, the more airplane surface is exposed to the force of the crosswind. This diminishes the effectiveness of the aileron.

Hydroplaning

Hydroplaning is a condition that can exist when an airplane has landed on a runway surface contaminated with standing water, slush, or wet snow. Hydroplaning can have serious adverse effects on ground controllability and braking efficiency. The three basic types of hydroplaning are dynamic hydroplaning, reverted rubber hydroplaning, and viscous hydroplaning. Any one of the three can render an airplane partially or totally uncontrollable anytime during the landing roll.

Dynamic Hydroplaning

Dynamic hydroplaning is a relatively high-speed phenomenon that occurs when there is a film of water on the runway that is at least one-tenth of an inch deep. As the speed of the airplane and the depth of the water increase, the water layer builds up an increasing resistance to displacement, resulting in the formation of a wedge of water beneath the tire. At some speed, termed the hydroplaning speed (V_p), the water pressure equals the weight of the airplane, and the tire is lifted off the runway surface. In this condition, the tires no longer contribute to directional control and braking action is nil.

Dynamic hydroplaning is related to tire inflation pressure. Data obtained during hydroplaning tests have shown the minimum dynamic hydroplaning speed (V_p) of a tire to be 8.6 times the square root of the tire pressure in pounds per square inch (PSI). For an airplane with a main tire pressure of 24 PSI, the calculated hydroplaning speed would be approximately 42 knots. It is important to note that the calculated speed referred to above is for the start of dynamic hydroplaning. Once hydroplaning has started, it may persist to a significantly slower speed depending on the type being experienced.

Reverted Rubber Hydroplaning

Reverted rubber (steam) hydroplaning occurs during heavy braking that results in a prolonged locked-wheel skid. Only a thin film of water on the runway is required to facilitate this type of hydroplaning. The tire skidding generates enough heat to cause the rubber in contact with the runway to revert to its original uncured state. The reverted rubber acts as a seal between the tire and the runway and delays water exit from the tire footprint area. The water heats and is converted to steam, which supports the tire off the runway.

Reverted rubber hydroplaning frequently follows an encounter with dynamic hydroplaning, during which time the pilot may have the brakes locked in an attempt to slow the airplane. Eventually the airplane slows enough to where the tires make contact with the runway surface and the airplane begins to skid. The remedy for this type of hydroplaning is to release the brakes and allow the wheels to spin up and apply moderate braking. Reverted rubber hydroplaning is insidious in that the pilot may not know when it begins, and it can persist to very slow groundspeeds (20 knots or less).

Viscous Hydroplaning

Viscous hydroplaning is due to the viscous properties of water. A thin film of fluid no more than one-thousandth of an inch in depth is all that is needed. The tire cannot penetrate the fluid and the tire rolls on top of the film. This can occur at a much lower speed than dynamic hydroplaning, but requires a smooth or smooth acting surface, such as asphalt or a touchdown area coated with the accumulated rubber from previous landings. Such a surface can have the same friction coefficient as wet ice.

When confronted with the possibility of hydroplaning, it is best to land on a grooved runway (if available). Touchdown speed should be as slow as possible consistent with safety. After the nose-wheel is lowered to the runway, moderate braking is applied. If deceleration is not detected and hydroplaning is suspected, raise the nose and use aerodynamic drag to decelerate to a point where the brakes become effective.

Proper braking technique is essential. The brakes are applied firmly until reaching a point just short of a skid. At the first sign of a skid, release brake pressure and allow the wheels to spin up. Directional control is maintained as far as possible with the rudder. Remember that in a crosswind, if hydroplaning occurs, the crosswind causes the airplane to simultaneously weathervane into the wind, as well as slide downwind.

Chapter Summary

Accident statistics show that a pilot is more at risk during the approach and landing than during any other phase of a flight. There are many factors that contribute to accidents in this phase, but an overwhelming percentage of these accidents result from a lack of pilot proficiency. This chapter presents procedures that, when learned and practiced correctly, are key to attaining proficiency. Additional information on aerodynamics, aircraft performance, and other aspects affecting approaches and landings can be found in the Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-25, as revised). For information concerning risk assessment as a means of preventing accidents, refer to the Risk Management Handbook (FAA-H-8083-2, as revised). Both of these publications are available at www.faa.gov/regulations_policies/handbooks_manuals/aviation/.