

### Introduction

There is an old saying that while takeoff is optional, landing is mandatory. In consideration of that adage, this chapter focuses on the approach to landing, factors that affect landings, types of landings, and aspects of faulty landings. A careful pilot knows that the safe outcome of a landing should never be in doubt. Pilots who respect their own limitations are able to approach each landing with confidence and achieve the satisfaction that comes from successful aircraft control. After any landing, a pilot performs a self-evaluation. If there is a question, a read of the relevant section in this chapter may help. When needed, additional flight instruction enhances safety.

The manufacturer's recommended procedures, including airplane configuration and airspeeds, and other information relevant to approaches and landings in a specific make and model airplane are contained in the Federal Aviation Administration (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.

### Use of Flaps

The following general discussion applies to airplanes equipped with flaps. The pilot may use landing flaps during the descent to adjust lift and drag. Flap settings help determine the landing spot and the descent angle to that spot. [Figure 9-1 and Figure 9-2] Flap extension during approaches and landings provides several advantages by:

1. Producing greater lift and permitting lower approach and landing speeds,
2. Producing greater drag and permitting a steeper descent angle,
3. Increasing forward visibility by allowing a lower pitch, and
4. Reducing the length of the landing roll.

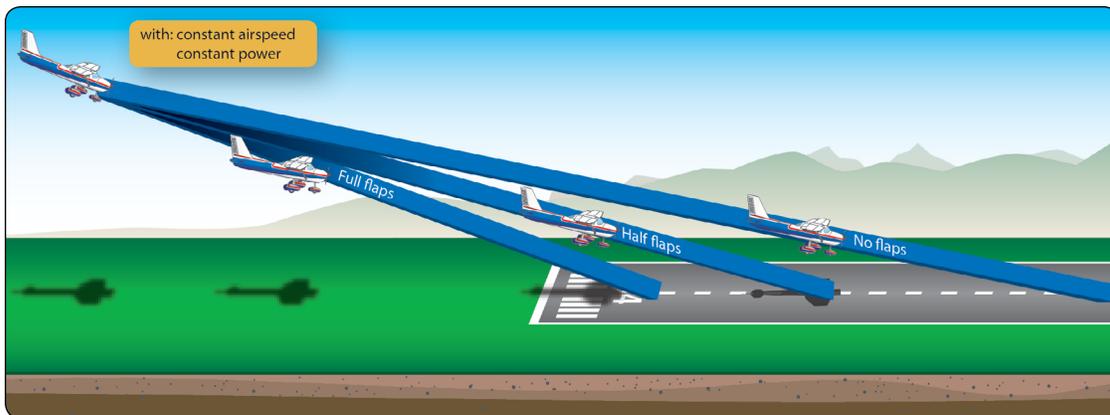


Figure 9-1. Effect of flaps on the landing point.

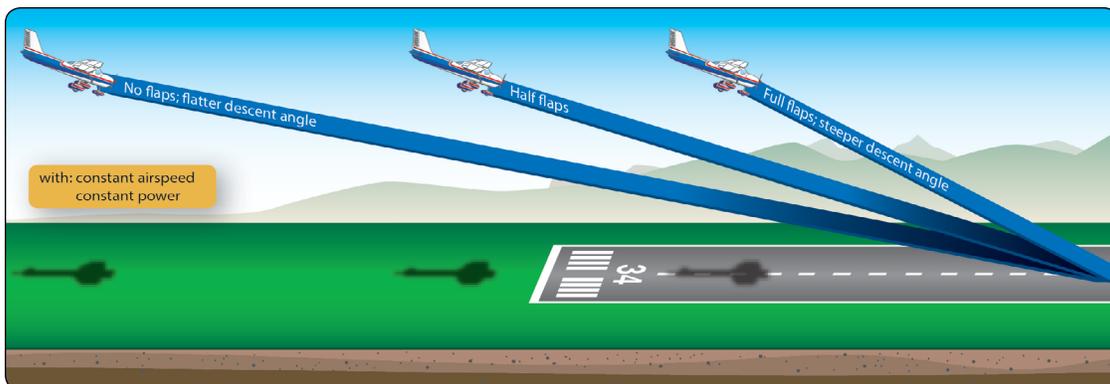


Figure 9-2. Effect of flaps on the approach angle.

The increased camber from flap deflection increases lift, primarily on the rear portion of the wing. This produces a nose-down pitching moment which may cause the airplane to pitch down. Flap deployment may also affect wing downwash on the horizontal tail and alter the tail-down force. Consequently, pitch behavior from flap extension depends on the design of the particular airplane.

Flap deflection of up to 15° primarily produces lift with minimal drag. The airplane has a tendency to balloon up with initial flap deflection because of the lift increase. The nose-down pitching moment, however, tends to offset the balloon. Flap deflection beyond 15° produces a large increase in drag. Deflection beyond 15° also produces a significant nose-up pitching moment in certain high-wing airplanes because the resulting downwash changes the airflow over the horizontal tail.

The time of flap extension and the degree of deflection are related. Large changes in flap deflection at one single point in the landing pattern can produce large lift changes that require significant pitch and power changes in order to maintain airspeed and descent angle. Consequently, there is an advantage to extending flaps in increments while in the landing pattern. Incremental deflection of flaps on downwind, base leg, and final approach allow smaller adjustments of pitch and power and support a stabilized approach.

Whenever the flap setting is changed, the pilot should be prepared to re-trim the airplane as needed to compensate for the change in aerodynamic forces. Throughout this chapter, more detail is provided on the use of flaps during specific approach and landing situations, as appropriate.

## Normal Approach and Landing

Normal approach and landing procedures are used when the engine power is available, the wind is light or the final approach is made directly into the wind, the final approach path has no obstacles, and the landing surface is firm and of ample length to gradually bring the airplane to a stop. The selected landing point is normally beyond the runway approach threshold but within the first 1/3 of the runway.

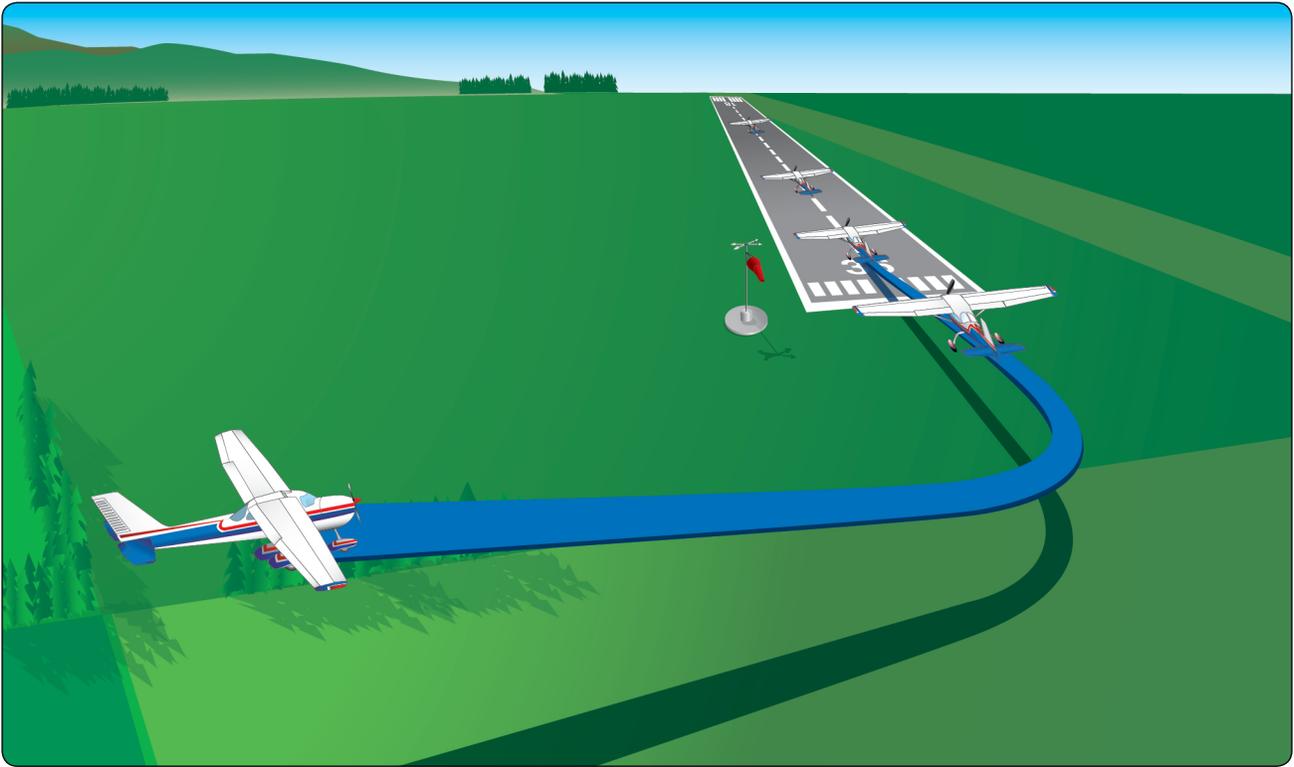
The factors involved and the procedures described for the normal approach and landing also have applications to the other-than-normal approaches and landings discussed later in this chapter. The principles of normal operations are explained first and need to be understood before proceeding to the more complex operations. To better understand the factors that influence judgment and procedures, the last part of the approach pattern and the actual landing are divided into five phases:

1. the base leg
2. the final approach
3. the round out (flare)
4. the touchdown
5. the after-landing roll

### Base Leg

The placement of the base leg is one of the important judgments made by the pilot to set up for a good landing. [Figure 9-3] The pilot accurately judges the height, distance from the approach end of the runway, and rate of descent to allow a stabilized approach, round out, and touchdown at the desired spot. The distance depends on the altitude of the base leg, the current winds, and the amount of wing flaps used. When there is a strong wind on final approach or the flaps are used to produce a steep angle of descent, the base leg should be positioned closer to the approach end of the runway than would be required with normal winds or flap settings. Normally, the landing gear is extended and the before-landing check completed prior to reaching the base leg.

After turning onto the base leg, the pilot starts or continues the descent with reduced power and a target airspeed of approximately 1.4  $V_{SO}$ —the stalling speed in the landing configuration. For example, if  $V_{SO}$  is 60 knots, 1.4  $V_{SO}$  is 84 knots ( $84 = 1.4 \times 60$ ). Landing flaps should be deployed as recommended. Full flaps are not recommended until the final approach is established. Since the final approach and landing are normally made into the wind, there is usually a crosswind during the base leg. A drift correction is established and maintained to follow a ground track perpendicular to the extension of the landing runway centerline. This requires that the airplane be angled sufficiently into the wind to prevent drifting farther away from the intended landing spot.



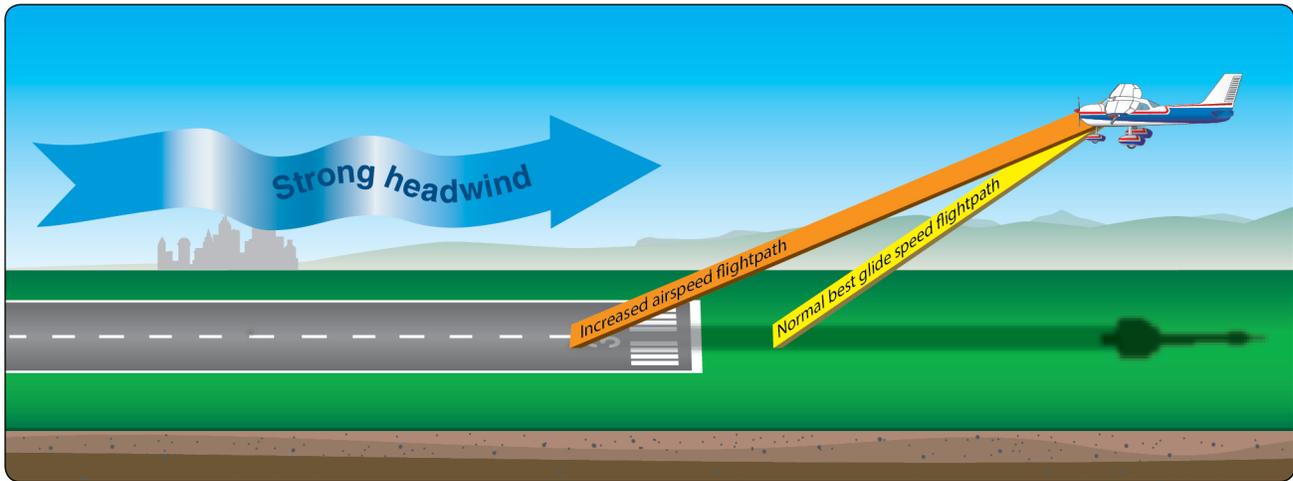
**Figure 9-3.** Base leg and final approach.

## Final Approach

After the base-to-final approach turn is completed, the pilot aligns the longitudinal axis of the airplane with the centerline of the runway or landing surface. On a final approach, with no crosswind, the longitudinal axis is kept aligned with the runway centerline throughout the final approach and landing. (Methods to correct for a crosswind are explained in the “Crosswind Approach and Landing” section of this chapter. For now, only approaches and landings where the wind is straight down the runway are discussed.)

After aligning the airplane with the runway centerline, the final flap setting is completed and the pitch attitude adjusted as required. Some adjustment of pitch and power may be necessary to maintain the desired rate of descent and approach airspeed. The pilot should use the manufacturer's recommended airspeed or  $1.3 V_{SO}$  if there is no manufacturer's recommendation. As the pitch attitude and airspeed stabilize, the airplane is re-trimmed to relieve any control pressure.

The descent angle is controlled throughout the approach so that the airplane lands in the center of the first third of the runway. The descent angle is affected by all four fundamental forces that act on an airplane (lift, drag, thrust, and weight). If all the forces are balanced out such that the net force on the airplane is zero, the descent angle remains constant in a steady state wind condition. The pilot controls these forces by adjusting the airspeed, attitude, power, and drag (flaps or forward slip). However, wind may affect the gliding distance over the ground [Figure 9-4]; the pilot does not have control over the wind, but corrects for its effect on the airplane's descent by adjusting pitch and power appropriately.



**Figure 9-4.** *Effect of headwind on final approach.*

A well-executed final approach includes reaching the desired touchdown point at an airspeed that results in minimum floating just before touchdown. To accomplish this, both the descent angle and the airspeed need to be controlled. This is one reason for performing approaches with partial power; if the approach is too high, the pilot can lower the nose and reduce the power to maintain the correct airspeed. When the approach is too low, the pilot can add power and raise the nose.

While the proper angle of descent and airspeed are maintained by integrating pitch and power changes, an untrained or inexperienced pilot may try to reach a landing spot by applying back-elevator pressure without adding power. However, attempting to stretch the final approach by raising the pitch attitude alone is almost always a bad idea. Using pitch alone causes a significant increase in AOA and decay in airspeed that leads to an excessive rate of descent or a low altitude stall. It is possible for either or both to occur.

### ***Wrong Surface Landing Avoidance***

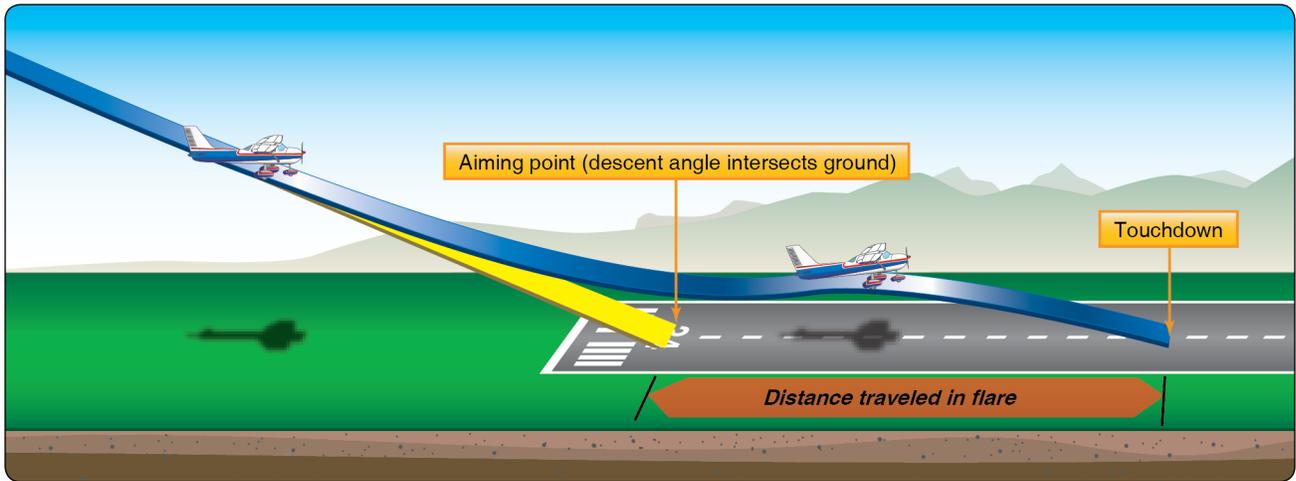
A wrong surface landing occurs when an aircraft lands or tries to land on the wrong runway, on a taxiway in error, or at the wrong airport. The pilot should take a moment on every final approach to verify the correctness of the landing zone ahead.

Lack of familiarity with a particular airport, complacency, or fatigue may lead to pilot confusion, and occasionally a pilot will line up with the wrong surface while perceiving the situation as normal. A pilot may compensate for any lack of destination airport familiarity by studying an airport diagram and lighting ahead of time and noting key features and geometry. On final approach, the pilot should verify correct runway alignment and runway number. Pilots often refer to moving map displays driven by GPS, and these devices should increase situational awareness and safety. If there is a doubt over the landing surface, the pilot should go around and consider the situation further.

### ***Stabilized Approach Concept***

A stabilized approach is one in which the pilot establishes and maintains a constant-angle glide path towards a predetermined point on the landing runway. It is based on the pilot's judgment of certain visual clues and depends on maintaining a constant final descent airspeed and configuration.

An airplane descending on final approach at a constant rate and airspeed travels in a straight line towards a spot on the ground ahead, commonly called the aiming point. If the airplane maintains a constant glide path without a round out for landing, it will strike the ground at the aiming point. [Figure 9-5]



**Figure 9-5.** *Stabilized approach.*

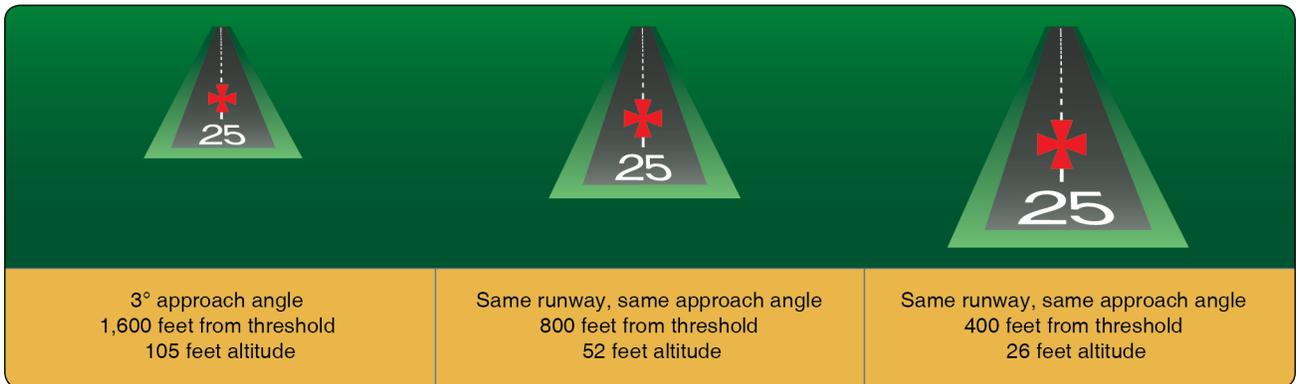
To the pilot, the aiming point appears to be stationary. It does not appear to move under the nose of the aircraft and does not appear to move forward away from the aircraft. This feature identifies the aiming point—it does not move. However, objects in front of and beyond the aiming point do appear to move as the distance is closed, and they appear to move in opposite directions! For a constant angle glide path, the distance between the horizon and the aiming point remains constant. If descending at a constant angle and the distance between the perceived aiming point and the horizon appears to increase (aiming point moving down away from the horizon), then the true aiming point is farther down the runway. If the distance between the perceived aiming point and the horizon decreases, meaning that the aiming point is moving up toward the horizon, the true aiming point is closer than perceived.

During instruction in landings, one of the important skills a pilot acquires is how to use visual cues to discern the true aiming point from any distance out on final approach. From this, the pilot determines if the current glide path will result in either an under or overshoot. Note that the aiming point is not where the airplane actually touches down. Since the pilot reduces the rate of descent during the round out (flare), the actual touchdown occurs farther down the runway. Considering float during round out, the pilot is also able to predict the point of touchdown with some accuracy.

When the airplane is established on final approach, the shape of the runway image also presents clues as to what should be done to maintain a stabilized approach to a safe landing.

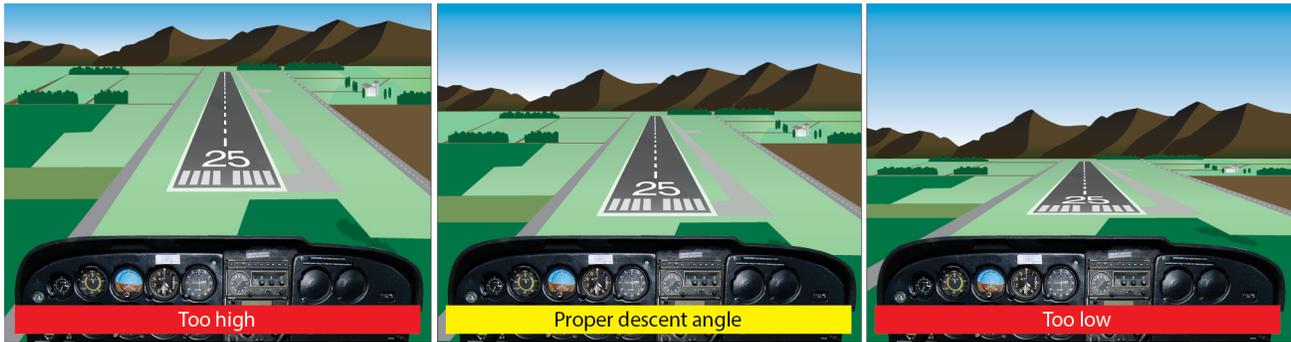
Obviously, a runway is normally shaped in the form of an elongated rectangle. When viewed from the air during the approach, the phenomenon, known as perspective, causes the runway to assume the shape of a trapezoid with the far end looking narrower than the approach end and the edge lines converging ahead.

As an airplane continues down the glide path at a constant angle (stabilized), the image the pilot sees is still trapezoidal, but of proportionately larger dimensions. In other words, during a stabilized approach, the runway shape does not change. [Figure 9-6]



**Figure 9-6.** *Runway shape during stabilized approach.*

If the approach becomes shallow, the runway appears to shorten and become wider. Conversely, if the approach is steepened, the runway appears to become longer and narrower. [Figure 9-7]



**Figure 9-7.** Change in runway shape if approach becomes narrow or steep.

Immediately after rolling out on final approach, the pilot adjusts the pitch attitude, power, and trim so that the airplane is descending directly toward the aiming point at the appropriate airspeed in the landing configuration. If it appears that the airplane is going to overshoot the desired landing spot, a steeper approach results by reducing power and lowering the pitch attitude to maintain airspeed. If available and not fully extended, the pilot may further extend the flaps. If the desired landing spot is being undershot and a shallower approach is needed, the pilot increases both power and pitch attitude to reduce the descent angle. Once the approach is set up and control pressures removed with trim, the pilot is free to devote significant attention toward outside references and use the available visual cues to fine tune the approach. The pilot should not stare at any one place, but rather scan from one point to another, such as from the aiming point to the horizon, to any objects along the runway, to an area well short of the runway, and back to the aiming point. This makes it easier to perceive any deviation from the desired glide path and determine if the airplane is proceeding directly toward the aiming point. The pilot should also glance at the airspeed indicator periodically and correct for any airspeed deviation.

Pilots normally establish a stabilized approach before short final. The round out, touchdown, and landing roll are much easier to accomplish when preceded by a stabilized final approach, which reduces the chance of a landing mishap. Therefore, deviations from the desired glide path should be detected and corrected early so that the magnitude of corrections during the later portion of the approach is small. If the approach is very high or very low, it may not be possible to establish a stabilized approach, and the pilot normally executes a go-around. If the airplane is initially low and undershooting the aiming point, the pilot may intercept the desired glide path by increasing pitch attitude and adding power to level off while maintaining the correct airspeed. This may necessitate a substantial increase in power if the aircraft is operating on the backside of the power curve. As the airplane intercepts the desired glide path, the pilot reduces power and pitches down to remain on the glide path. Retracting the flaps to correct for an undershoot creates an unnecessary risk. It may cause a sudden decrease in lift, an excessive sink rate, and an aggravated unstable condition.

If the approach is too high or too low, it may not be possible to establish a stabilized approach, and the pilot should execute a go-around. Typically, pilots go-around if unable to establish a stabilized approach by 500 ft above airport elevation in visual meteorological conditions (VMC) or 1,000 ft above airport elevation in instrument conditions (IMC). For a typical GA piston aircraft in a traffic pattern, an immediate go-around should be initiated if the approach becomes unstabilized below 300 ft AGL.

Pilots may consider the following elements when attempting to set up and fly a stabilized approach to landing. The pilot should focus on the elements that lead to a stabilized approach rather than the order of the elements or the insistence on meeting all of the approach criteria. For a typical piston aircraft, an approach is stabilized when the following criteria are met:

1. **Glide path.** Typically a constant 3 degrees to the touchdown zone on the runway (obstructions permitting).
2. **Heading.** The aircraft tracks the centerline to the runway with only minor heading/pitch changes necessary to correct for wind or turbulence to maintain alignment. Bank angle normally limited to 15 degrees once established on final.
3. **Airspeed.** The aircraft speed is within +10 /-5 KIAS of the recommended landing speed specified in the AFM,  $1.3V_{SO}$ , or on approved placards/markings. If the pilot applies a gust factor, indicated airspeed should not decay below the recommended landing speed.
4. **Configuration.** The aircraft is in the correct landing configuration with flaps as required; landing gear extended, and is in trim.
5. **Descent rate.** A descent rate (generally 500-1000 fpm for light general aviation aircraft) makes for a safe approach. Minimal adjustments to the descent rate as the airplane approaches the runway provide an additional indication of a stabilized and safe approach. If using a descent rate in excess of 500 fpm due to approach considerations, the pilot should reduce the descent rate prior to 300 ft AGL.
6. **Power setting.** The pilot should use a power setting appropriate for the aircraft configuration and not below the minimum power for approach as defined by the AFM.
7. **Briefings and checklists.** Completing all briefings and checklists prior to initiating the approach (except the landing checklist), ensures the pilot can focus on the elements listed above.

### ***Estimating Airplane Movement and Height***

During short final, round out, and touchdown, vision is of prime importance. To provide a wide scope of vision and to foster good judgment of height and movement, the pilot's head should assume a natural, straight-ahead position. Visual focus is not fixed on any one side or any one spot ahead of the airplane. Instead, it is changed slowly from a point just over the airplane's nose to the desired touchdown zone and back again. This is done while maintaining a deliberate awareness of distance from either side of the runway using peripheral vision.

Accurate estimation of distance, besides being a matter of practice, depends upon how clearly objects are seen. It requires that vision be focused properly so that the important objects stand out as clearly as possible.

Speed blurs objects at close range. For example, most everyone has noted this in an automobile moving at high speed. Nearby objects seem to merge together in a blur, while objects farther away stand out clearly. The driver subconsciously focuses the eyes sufficiently far ahead of the automobile to see objects distinctly.

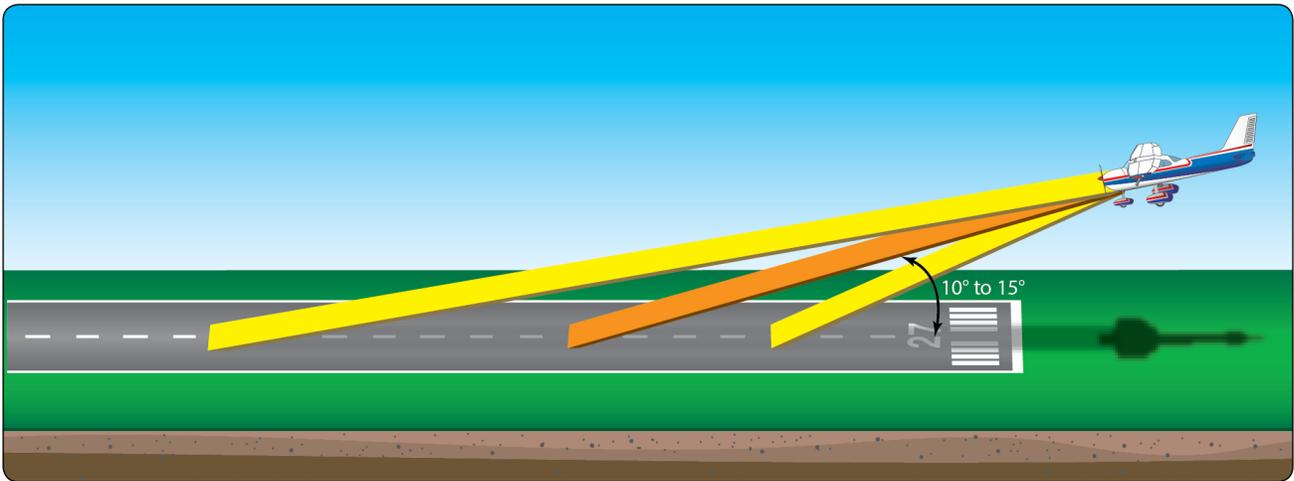
The distance at which the pilot's vision is focused should be proportional to the speed at which the airplane is traveling over the ground. Thus, as speed is reduced during the round out, the distance ahead of the airplane at which it is possible to focus is brought closer accordingly.

If the pilot attempts to focus on a reference that is too close or looks directly down, the reference becomes blurred, [Figure 9-8] and the reaction is either too abrupt or too late. In this case, the pilot's tendency is to over-control, round out high, and make full-stall, drop-in landings. If the pilot focuses too far ahead, accuracy in judging the closeness of the ground is lost and the consequent reaction is too slow, since there does not appear to be a necessity for action. This sometimes results in the airplane flying into the ground nose first. The change of visual focus from a long distance to a short distance requires a definite time interval, and even though the time is brief, the airplane's speed during this interval is such that the airplane travels an appreciable distance, both forward and downward toward the ground.



**Figure 9-8.** *Focusing too close blurs vision.*

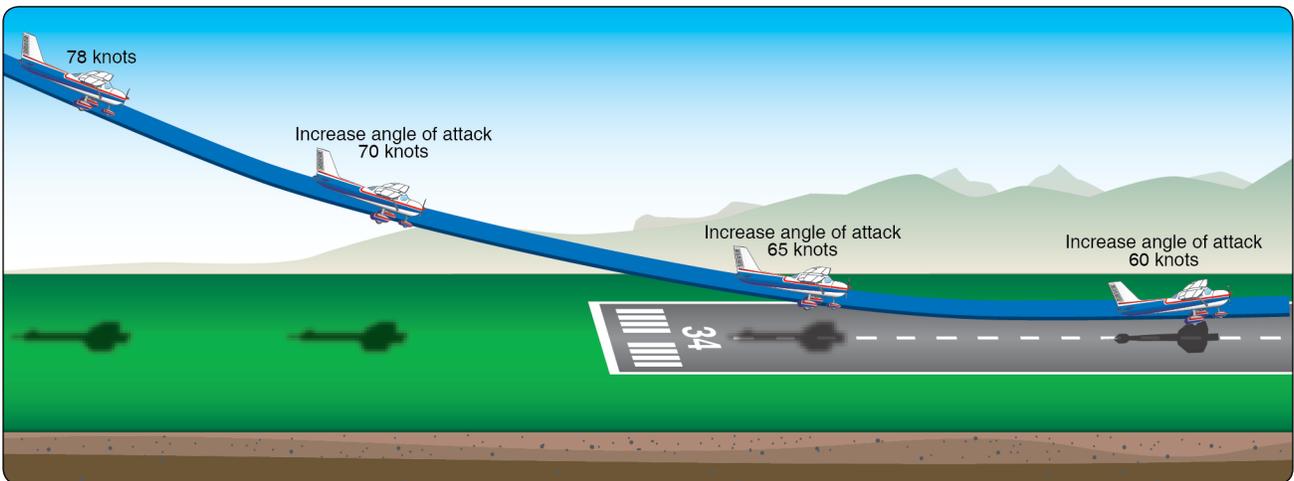
Visual cues are important in flaring at the proper height and maintaining the wheels a few inches above the runway until eventual touchdown. Flare cues are primarily dependent on the angle at which the pilot's central vision intersects the ground (or runway) ahead and slightly to the side. Proper depth perception is a factor in a successful flare, but the visual cues used most are those related to changes in runway or terrain perspective and to changes in the size and texture of familiar objects near the landing area. The pilot should focus direct central vision at a shallow downward angle from 10° to 15° relative to the runway as the round out/flare is initiated. [Figure 9-9] When using this steady viewing angle, the point of visual interception with the runway appears progressively closer as the airplane loses altitude. This rate of closure is an important visual cue in assessing the rate of altitude loss. Conversely, movement of the visual interception point further down the runway indicates an increase in altitude and means that the pitch angle was increased too rapidly during the flare. Location of the visual interception point in conjunction with assessment of flow velocity of nearby off-runway terrain, as well as the similarity of appearance of height above the runway ahead of the airplane (in comparison to the way it looked when the airplane was taxied prior to takeoff), is also used to judge when the wheels are just a few inches above the runway.



**Figure 9-9.** To obtain necessary visual cues, the pilot should look toward the runway at a shallow angle.

### Round Out (Flare)

The round out is a slow, smooth transition from a normal approach attitude to a landing attitude, gradually rounding out the flightpath to one that is parallel to and a few inches above the runway. When the airplane approaches 10 to 20 feet above the ground in a normal descent, the round out or flare is started. Back-elevator pressure is gradually applied to slowly increase the pitch attitude and AOA. [Figure 9-10] The AOA is increased at a rate that allows the airplane to continue settling slowly as forward speed decreases. This is a continuous process until the airplane touches down on the ground.



**Figure 9-10.** Changing angle of attack during round out.

When the AOA is increased, the lift is momentarily increased and this decreases the rate of descent. Since power normally is reduced to idle during the round out, the airspeed also gradually decreases. This causes lift to decrease again and necessitates raising the nose and further increasing the AOA. During the round out, the airspeed is decreased to touchdown speed while the lift is controlled so the airplane settles gently onto the landing surface. The round out is executed at a rate such that the proper landing attitude and the proper touchdown airspeed are attained simultaneously just as the wheels contact the landing surface.

The rate at which the round out is executed depends on the airplane's height above the ground, the rate of descent, and the pitch attitude. A round out started excessively high needs to be executed more slowly than one started from a lower height. The round out rate should also be proportional to the rate of closure with the ground. When the airplane appears to be descending very slowly, the increase in pitch attitude should be made at a correspondingly slow rate.

The pitch attitude of the airplane in a full-flap approach is considerably lower than in a no-flap approach. To attain the proper landing attitude before touching down, the nose needs to travel through a greater pitch change when flaps are fully extended. Since the round out is usually started at approximately the same height above the ground regardless of the degree of flaps used, the pitch attitude should be increased at a faster rate when full flaps are used. However, the round out should still be executed at a rate that takes the airplane's downward motion into account.

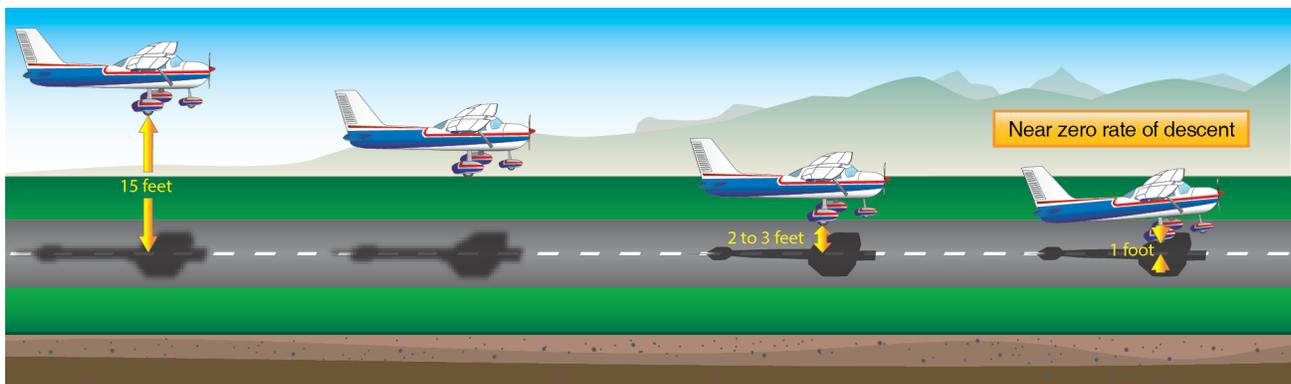
Once the actual process of rounding out is started, the pilot should not push the elevator control forward. If too much back-elevator pressure was exerted, this pressure is either slightly relaxed or held constant, depending on the degree of the error. In some cases, it may be necessary to advance the throttle slightly to prevent an excessive rate of sink or a stall, either of which results in a hard, drop-in type landing.

It is recommended that a pilot form the habit of keeping one hand on the throttle throughout the approach and landing should a sudden and unexpected hazardous situation require an immediate application of power.

## Touchdown

The touchdown is the gentle settling of the airplane onto the landing surface. The round out and touchdown are normally made with the engine idling. During the round out, the airspeed decays such that the airplane touches down on the main gear at or just above the approximate stalling speed. As the airplane settles, proper landing attitude is attained by application of whatever back-elevator pressure is necessary.

Some pilots try to force or fly the airplane onto the ground without establishing proper landing attitude. The airplane should never be flown onto the runway with excessive speed. A common technique to making a smooth touchdown is to actually focus on holding the wheels of the aircraft a few inches off the ground as long as possible using the elevators while the power is smoothly reduced to idle. In most cases, when the wheels are within 2 or 3 feet of the ground, the airplane is still settling too fast for a gentle touchdown. Therefore, this descent is retarded by increasing back-elevator pressure. Since the airplane is already close to its stalling speed and is settling, this added back-elevator pressure only slows the settling instead of stopping it. At the same time, it results in the airplane touching the ground in the proper landing attitude and the main wheels touching down first so that little or no weight is on the nose-wheel. [Figure 9-11]



**Figure 9-11.** *A well-executed round out results in attaining the proper landing attitude.*

After the main wheels make initial contact with the ground, back-elevator pressure is held to maintain a positive AOA for aerodynamic braking and to hold the nose-wheel off the ground as the airplane decelerates. The pilot should be certain not to inadvertently have brake pressure engaged as touchdown occurs. Early use of brakes can result in a sudden drop in the nose and a loss of aerodynamic braking. As the airplane's momentum decreases, back-elevator pressure is gradually relaxed to allow the nose-wheel to gently settle onto the runway. This permits steering if the airplane has a steerable nose-wheel. At the same time, it decreases the AOA and reduces lift on the wings to prevent floating or skipping and allows the full weight of the airplane to rest on the wheels for better mechanical braking action. As the airplane slows, the mechanical braking becomes more effective.

It is extremely important that the touchdown occur with the airplane's longitudinal axis exactly parallel to the direction in which the airplane is moving along the runway. Failure to accomplish this imposes severe side loads on the landing gear. To avoid these side stresses, the pilot should not allow the airplane to touch down while turned into the wind or drifting.

## After-Landing Roll

The landing process should never be considered complete until the airplane decelerates to the normal taxi speed during the landing roll or has been brought to a complete stop when clear of the landing area. Accidents may occur as a result of pilots abandoning their vigilance and failing to maintain positive control after getting the airplane on the ground.

A pilot should be alert for directional control difficulties immediately upon and after touchdown due to the ground friction on the wheels. Loss of directional control may lead to an aggravated, uncontrolled, tight turn on the ground, or a ground loop. The combination of centrifugal force acting on the center of gravity (CG) and ground friction of the main wheels resisting it during the ground loop may cause the airplane to tip or lean enough for the outside wingtip to contact the ground. This imposes a sideward force that could collapse the landing gear.

The rudder serves the same purpose on the ground as it does in the air—it controls the yawing of the airplane. The effectiveness of the rudder is dependent on the airflow, which depends on the speed of the airplane. As the speed decreases and the nose-wheel has been lowered to the ground, the steerable nose provides more positive directional control.

The brakes of an airplane serve the same primary purpose as the brakes of an automobile—to reduce speed on the ground. In airplanes, they are also used as an aid in directional control when more positive control is required than could be obtained with rudder or nose-wheel steering alone.

To use brakes, on an airplane equipped with toe brakes, the pilot slides the toes or feet up from the rudder pedals to the brake pedals. If rudder pressure is being held at the time braking action is needed, the pilot should not release that pressure as the feet or toes are being slid up to the brake pedals because control may be lost before brakes can be applied.

Putting maximum weight on the wheels after touchdown is an important factor in obtaining optimum braking performance. During the early part of rollout, some lift continues to be generated by the wing. After touchdown, the nose-wheel is lowered to the runway to maintain directional control. During deceleration, applying brakes may cause the nose to pitch down and some weight to transfer to the nose-wheel from the main wheels. This does not aid in braking action, so back pressure is applied to the controls without lifting the nose-wheel off the runway. This enables directional control while keeping weight on the main wheels.

Careful application of the brakes is initiated after the nose-wheel is on the ground and directional control is established. Maximum brake effectiveness is just short of the point where skidding occurs. If the brakes are applied so hard that skidding takes place, braking becomes ineffective. Skidding is stopped by releasing the brake pressure. Braking effectiveness is not enhanced by alternately applying, releasing, and reapplying brake pressure. The brakes are applied firmly and smoothly as necessary.

During the ground roll, the airplane's direction of movement can be changed by carefully applying pressure on one brake or uneven pressures on each brake in the desired direction. Caution must be exercised when applying brakes to avoid over-controlling.

The ailerons serve the same purpose on the ground as they do in the air—they change the lift and drag components of the wings. During the after-landing roll, they are used to keep the wings level in much the same way they are used in flight. If a wing starts to rise, aileron control is applied toward that wing to lower it. The amount required depends on speed because as the forward speed of the airplane decreases, the ailerons become less effective. Procedures for using ailerons in crosswind conditions are explained in the “Crosswind Approach and Landing” section of this chapter.

Once the airplane has slowed sufficiently and has turned onto the taxiway and stopped, the pilot performs the after-landing checklist. Many accidents have occurred as a result of the pilot unintentionally operating the landing gear control and retracting the gear instead of the flap control when the airplane was still rolling. The habit of positively identifying both of these controls, before actuating them, should be formed from the very beginning of flight training and continued in all future flying activities. If available runway permits, the speed of the airplane is allowed to dissipate in a normal manner.

## Common Errors

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

1. Failure to complete the landing checklist in a timely manner.
2. Inadequate wind drift correction on the base leg.
3. An overshooting, undershooting, too steep, or too shallow a turn onto final approach.
4. A skidding turn from base leg to final approach as a result of overshooting/inadequate wind drift correction.
5. Poor coordination during turn from base to final approach.
6. Unstable approach.
7. Failure to adequately compensate for flap extension.
8. Poor trim technique on final approach.
9. Attempting to maintain altitude or reach the runway using elevator alone.
10. Focusing too close to the airplane resulting in a too high round out.
11. Focusing too far from the airplane resulting in a too low round out.
12. Touching down prior to attaining proper landing attitude.
13. Failure to hold sufficient back-elevator pressure after touchdown.
14. Excessive braking after touchdown.
15. Loss of aircraft control during touchdown and rollout.

## Go-Arounds (Rejected Landings)

A go-around is a normal maneuver that is used when approach and landing parameters deviate from expectations or when it is hazardous to continue. Situations such as air traffic control (ATC) requirements, unexpected appearance of hazards on the runway, overtaking another airplane, wind shear, wake turbulence, mechanical failure, or an unstable approach are all reasons to discontinue a landing approach. Like any other normal maneuver, the go-around should be practiced and perfected. The flight instructor should emphasize

early on, and the pilot should understand, that any approach or landing may result in a go-around. The assumption that an aborted landing is invariably the consequence of a poor approach, which in turn is due to insufficient experience or skill, is a fallacy.

Although the need to discontinue a landing may arise at any point in the landing process, the most critical go-around is one started when very close to the ground. The go-around maneuver is not inherently dangerous in itself. It becomes dangerous only when delayed unduly or executed improperly. Delay in initiating the go-around normally stems from two sources:

1. Landing expectancy or set—the anticipatory belief that conditions are not as threatening as they are and that the approach is sure to terminate with a safe landing.
2. Pride—the mistaken belief that the act of going around is an admission of failure—failure to execute the approach properly.

The proper execution of a go-around maneuver includes three cardinal principles:

1. Power
2. Attitude
3. Configuration

## Power

Power is the pilot's first concern. The instant a pilot decides to go around, full or maximum allowable takeoff power should be applied smoothly, without hesitation, and held until flying speed and controllability are restored. An airplane that is settling toward the ground has inertia that needs to be overcome, and sufficient power is needed to stop the descent. The application of power is smooth, as well as positive. Abrupt movements of the throttle in some airplanes cause the engine to falter. Carburetor heat is turned off to obtain maximum power, as applicable.

## Attitude

A pilot executing a go-around needs to accept the fact that an airplane cannot fly below stall speed, and it cannot climb below minimum power required speed. The pilot should resist any impulse to pitch-up for a climb if airspeed is insufficient. In some circumstances, it may be desirable to lower the nose briefly to gain airspeed and not be on the backside of the power curve.

At the time a pilot decides to go around, a trim setting for low airspeed is in place. The sudden addition of power tends to raise the airplane's nose and causes left yaw. Allowing the nose to rise too early could result in an unrecoverable stall when the go-around occurs at a low altitude. The pilot should anticipate the need for considerable forward elevator pressure to hold the nose level or in a safe climb attitude. The pilot applies sufficient right rudder pressure to counteract torque and P-factor. Trim helps to relieve adverse control pressures and assists in maintaining a proper pitch attitude. After attaining the appropriate airspeed and adjusting pitch attitude for a climb, the pilot should "rough trim" the airplane to relieve any adverse control pressures. More precise trim adjustments can be made when flight conditions have stabilized. On airplanes that produce high control pressures when using maximum power on go-arounds, the pilot should use caution when reaching for the flap handle. Airplane control is the first consideration during this high-workload phase.

## Configuration

After establishing the proper climb attitude and power settings, the pilot's next concern is flap retraction. After the descent has been stopped, the landing flaps are partially retracted or placed in the takeoff position as recommended by the manufacturer. Depending on the airplane's altitude and airspeed, it is wise to retract the flaps intermittently in small increments to allow time for the airplane to accelerate progressively as they are being raised. A sudden and complete retraction of the flaps could cause a loss of lift resulting in the airplane settling into the ground. [Figure 9-12]

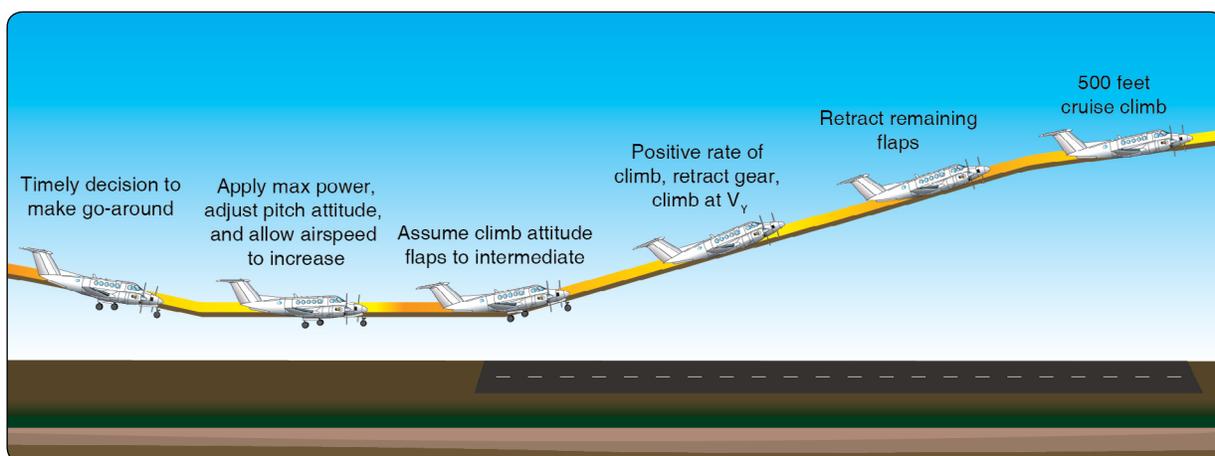


Figure 9-12. Go-around procedure.

Unless otherwise specified in the AFM/POH, it is generally recommended that the flaps be retracted (at least partially) before retracting the landing gear for two reasons. First, on most airplanes full flaps produce more drag than the landing gear; and second, in case the airplane inadvertently touches down as the go-around is initiated, it is desirable to have the landing gear in the down-and-locked position. After a positive rate of climb is established, the landing gear is retracted.

The landing gear is retracted only after the initial or rough trim is accomplished and when it is certain the airplane will remain airborne. During the initial part of an extremely low go-around, it is possible for the airplane to settle onto the runway and bounce. This situation is not particularly dangerous provided the airplane is kept straight and a constant, safe pitch attitude is maintained. With the application of power, the airplane attains a safe flying speed rapidly and the advanced power cushions any secondary touchdown.

## Ground Effect

Ground effect is a factor in every landing and every takeoff in fixed-wing airplanes. Ground effect can also be an important factor in go-arounds. If the go-around is made close to the ground, the airplane may be in the ground effect area. Pilots are often lulled into a sense of false security by the apparent “cushion of air” under the wings that initially assists in the transition from an approach descent to a climb. This “cushion of air,” however, is imaginary. The apparent increase in airplane performance is, in fact, due to a reduction in induced drag in the ground effect area. It is “borrowed” performance that is repaid when the airplane climbs out of the ground effect area. The pilot needs to factor in ground effect when initiating a go-around close to the ground. An attempt to climb prematurely may result in the airplane not being able to climb or even maintain altitude at full power.

## Common Errors

Common errors in the performance of go-arounds (rejected landings) are:

1. Failure to recognize a condition that warrants a rejected landing.
2. Indecision.
3. Delay in initiating a go-around.
4. Failure to apply maximum allowable power in a timely manner.
5. Abrupt power application.
6. Improper pitch attitude.
7. Failure to configure the airplane appropriately.
8. Attempting to climb out of ground effect prematurely.
9. Failure to adequately compensate for torque/P factor.
10. Loss of aircraft control.

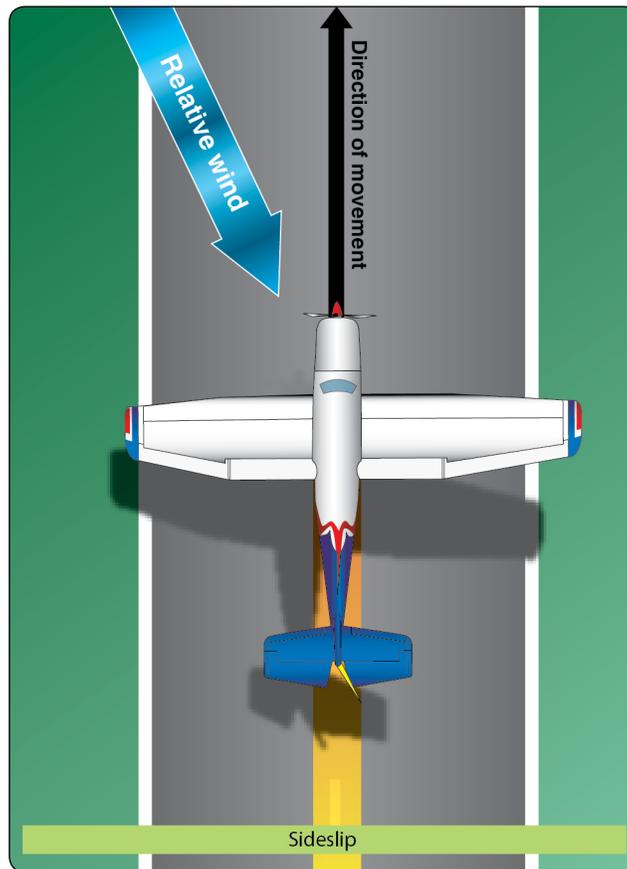
## Intentional Slips

A slip occurs when the bank angle of an airplane is too steep for the existing rate of turn. Unintentional slips are most often the result of uncoordinated rudder/aileron application. Intentional slips, however, are used to dissipate altitude without increasing airspeed and/or to adjust airplane ground track during a crosswind. Intentional slips are especially useful in forced landings and in situations where obstacles need to be cleared during approaches to confined areas. A slip can also be used as a means of rapidly reducing airspeed in situations where wing flaps are inoperative or not installed.

A slip is a combination of forward movement and sideward (with respect to the longitudinal axis of the airplane) movement, the lateral axis being inclined and the sideward movement being toward the low end of this axis (low wing). An airplane in a slip is in fact flying sideways through the air even though it may appear to be going straight over the ground. This results in a change in the direction that the relative wind strikes the airplane. Slips are characterized by a marked increase in drag and corresponding decrease in airplane climb, cruise, and glide performance. Because the airplane is banked, the vertical component of lift is reduced allowing for an airplane in a slip to descend rapidly without an increase in airspeed.

Most airplanes exhibit the characteristic of positive static directional stability and, therefore, have a natural tendency to compensate for slipping. An intentional slip usually requires deliberate cross-controlling of ailerons and rudder throughout the maneuver.

There are two types of intentional slips: sideslip and forward slips. Sideslips are frequently used when landing with a crosswind to keep the aircraft aligned with the runway centerline. A sideslip is entered by lowering a wing and applying just enough opposite rudder to prevent a turn. In a sideslip, the airplane’s longitudinal axis remains parallel to the original flightpath, but the airplane no longer flies straight ahead. Instead, the horizontal component of lift forces the airplane also to move somewhat sideways toward the low wing. [Figure 9-13] The amount of slip, and therefore the rate of sideward movement, is determined by the bank angle. The steeper the bank, the greater the degree of slip. As bank angle is increased, additional opposite rudder is required to prevent turning.



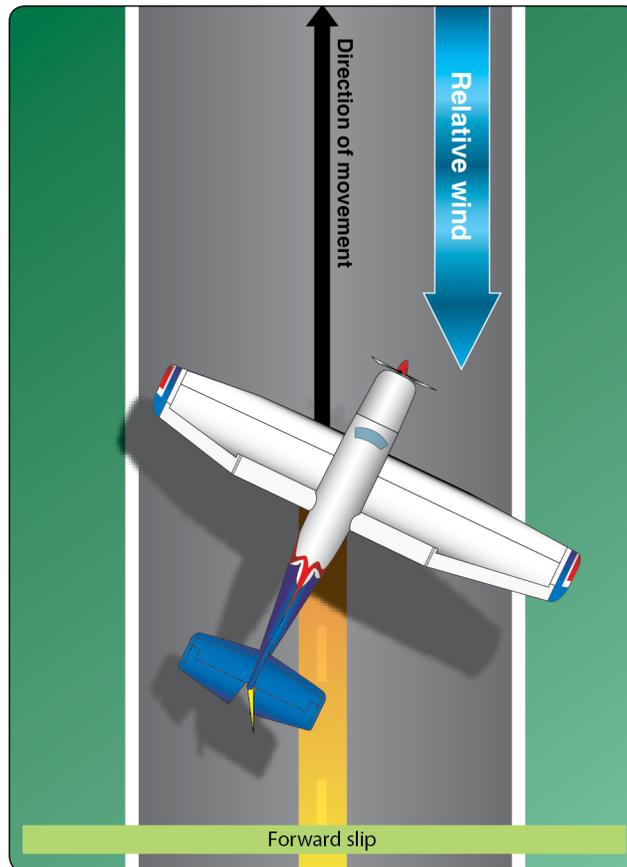
**Figure 9-13.** *Sideslip.*

A forward slip is used to dissipate altitude and increase descent rate without increasing airspeed. In a forward slip, the airplane's direction of motion continues the same as before the slip was begun. Assuming the airplane is originally in straight coordinated flight, the wing on one side is lowered by use of the ailerons. Simultaneously, sufficient opposite rudder is used to yaw the airplane's nose in the opposite direction such that the airplane remains on its original flightpath. However, the nose of the airplane will no longer point in the direction of flightpath. [Figure 9-14] In a forward slip, the amount of slip, and therefore the sink rate, is determined by the bank angle. The steeper the bank, the steeper the descent. In order to use the maneuver to lose altitude, power is normally reduced to idle. The pilot controls airspeed using elevator control. When a crosswind is present, the pilot should lower the upwind wing such that the airplane is banked into the crosswind since slipping into the wind makes it easier to remain on the original flightpath.

In most light airplanes, the steepness of a slip is limited by the amount of rudder travel available. In both sideslips and forward slips, the point may be reached where full rudder is required to maintain heading even though the ailerons are capable of further steepening the bank angle. This is the practical slip limit because any additional bank would cause the airplane to turn even though full opposite rudder is being applied. If there is a need to descend more rapidly, even though the practical slip limit has been reached, lowering the nose not only increases the sink rate but also increases airspeed. The increase in airspeed increases rudder effectiveness permitting a steeper slip. Conversely, when the nose is raised, rudder effectiveness decreases and the bank angle should be reduced.

Discontinuing a slip is accomplished by leveling the wings and simultaneously releasing the rudder pressure while readjusting the pitch attitude to the normal glide attitude. If the pressure on the rudder is released abruptly, the nose swings too quickly into line and the airplane tends to acquire excess speed. Because of the location of the pitot tube and static vents, airspeed indicators in some airplanes may have considerable error when the airplane is in a slip. The pilot needs to be aware of this possibility and recognize a properly performed slip by the attitude of the airplane, the sound of the airflow, and the feel of the flight controls. Unlike skids, however, if an airplane in a slip is made to stall, it displays very little of the yawing tendency that causes a skidding stall to develop into a spin. The airplane in a slip may do little more than tend to roll into a wings-level attitude.

Note that some airplanes have limitations regarding slips. In some cases slips are limited in duration or by fuel quantity. These limitations are meant to preclude fuel starvation caused when fuel is forced to one side of a tank in uncoordinated flight. If a forward slip is being used to reach a landing area in an actual engine-out emergency, the time limitation or fuel limitation is irrelevant (unless a prolonged slip caused the engine issue). For aerodynamic reasons, there may also be recommendations or limitations related to slips with flaps extended. Consult the manufacturer's AFM/POH for specific airplane information.



**Figure 9-14.** *Forward slip.*

Some pilots try to avoid using forward slips. An approach with flaps allows for coordinated and more familiar flight orientation, while the sideways force on the occupants of the aircraft during a forward slip may seem uncomfortable. However, in a real emergency that involves engine failure, the ability to use a forward slip provides a pilot with a technique contributing to a better outcome. In that situation, a pilot may initiate a descent using a forward slip much more quickly than by deploying flaps. To reduce the descent, the pilot can remove the slip without penalty. On the other hand, retracting flaps on an approach could lead to an unwanted loss of altitude. Even with full rudder displacement during a forward slip, the pilot can adjust to the left and right of the intended ground track by increasing and decreasing aileron deflection. The value of the maneuver explains its inclusion as a task in the Private Pilot Airman Certification Standards (ACS).

## Forward Slip to a Landing

When demonstrating a forward slip to a landing in an airport traffic pattern, the pilot plans the descent such that a forward slip may be used on final approach. Flaps usually remain retracted, and using a forward slip on downwind or base may be a necessary part of the maneuver. When abeam the landing point on the downwind leg, the pilot initiates a descent by reducing power to idle. If an insufficient rate of descent occurs on downwind, the pilot uses a forward slip to increase the rate of descent. The pilot should make a coordinated turn to base. At this point, ongoing evaluation of height takes place. If the airplane is high on base, continued forward slip should occur. However, the pilot should make a coordinated turn to line up with the final approach course. Once established on a final approach, the height above ground should be sufficient to allow the pilot to use a forward slip and establish a suitable approach path to the runway aiming point. At the appropriate time, when the round out begins, the pilot removes the forward slip and transitions to a normal landing.

## Common Errors

Common errors with forward slips to a landing:

1. Incorrect pitch adjustments that result in poor airspeed control.
2. Reacting to erroneous airspeed indications.
3. Using excess power while trying to lose altitude.
4. A slip in the same direction as any crosswind.
5. Poor glidepath control.
6. Late transition to a sideslip during landing with crosswinds.
7. Landing without the longitudinal axis parallel to runway.
8. Landing off the centerline.

## Crosswind Approach and Landing

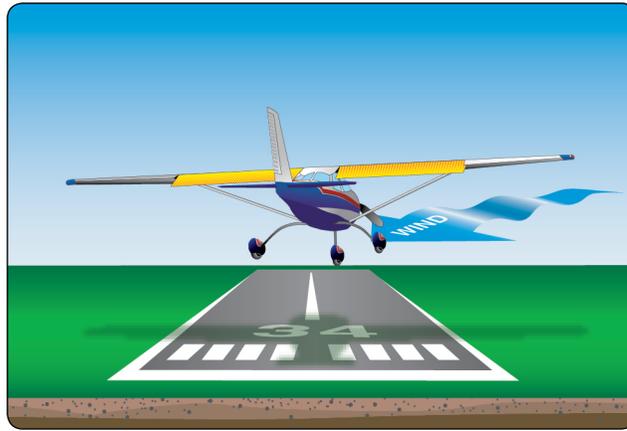
Most runways or landing areas are such that landings need to be made while the wind is blowing at an angle to the runway rather than parallel to the landing direction. All pilots should be prepared to manage a crosswind situation when it arises. Many of the same basic principles and factors involved in a normal approach and landing apply to a crosswind approach and landing; therefore, only the additional procedures required for correcting for wind drift are discussed here.

Crosswind landings are a little more difficult to perform than crosswind takeoffs, mainly due to different inputs involved in maintaining accurate control of the airplane while its speed is decreasing rather than increasing as on takeoff.

There are two usual methods of accomplishing a crosswind approach and landing—the crab method and the wing-low (sideslip) method. Although the crab method may be easier for the pilot to maintain during final approach, it requires judgment and precise timing when removing the crab immediately prior to touchdown. The wing-low method is recommended in most cases, although a combination of both methods may be used. While current testing standards allow for either method, pilots should learn to do both.

## Crosswind Final Approach

When using the crab method, the pilot makes a coordinated turn to establish a heading (crab) toward the wind. The selected heading should align the airplane's wings-level ground track with the centerline of the runway. The pilot makes small heading corrections, if needed, to maintain alignment with the runway. [Figure 9-15] The appropriate crab angle is maintained until just prior to touchdown, when the pilot uses rudder control to align the longitudinal axis of the airplane with the runway to avoid sideward contact of the wheels with the runway. A change in alignment made too early or too late results in a side load. If a long final approach is being flown, one option is to use the crab method initially and smoothly transition to the wing-low method before the round out is started.



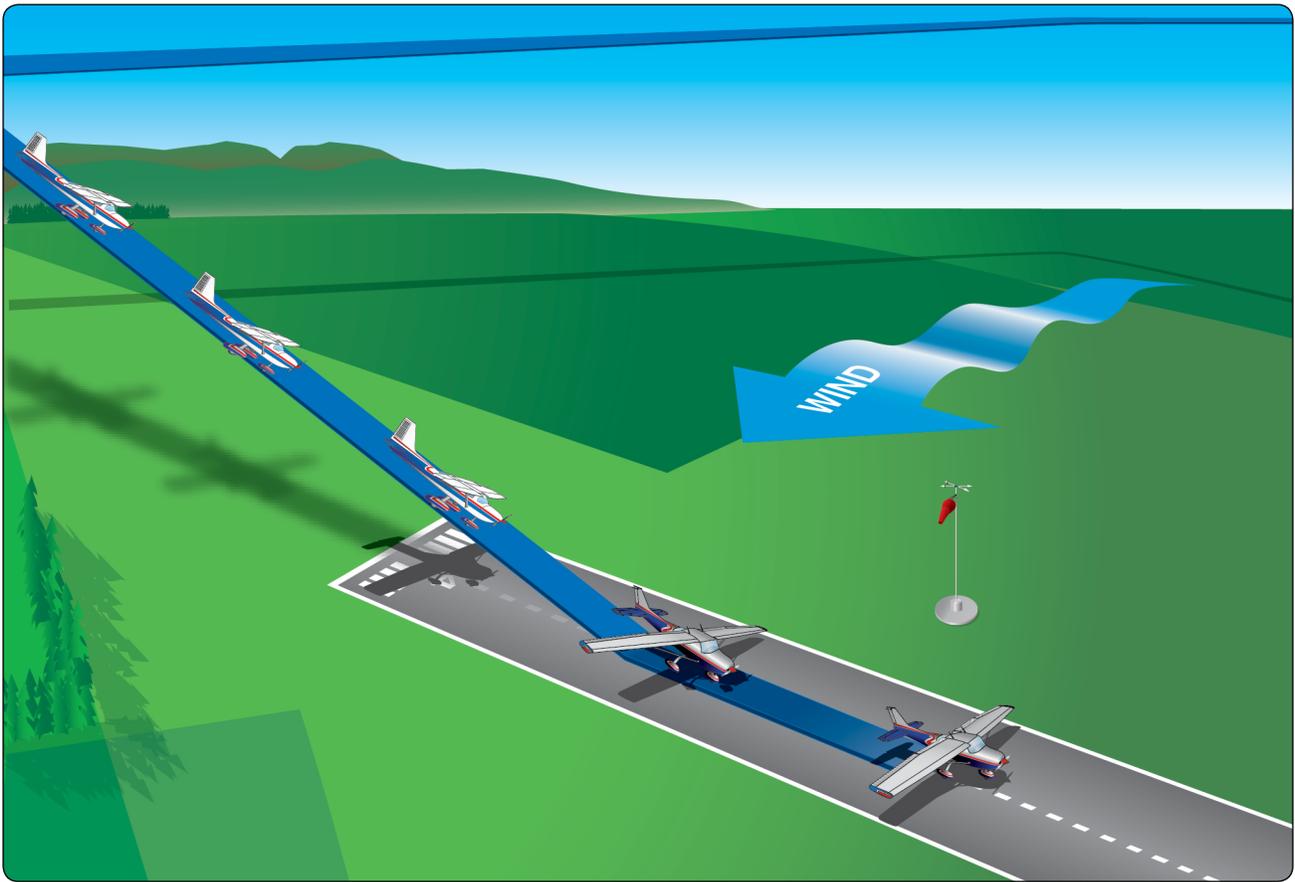
**Figure 9-15.** *Crabbed approach.*

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-gear 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-gear 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.

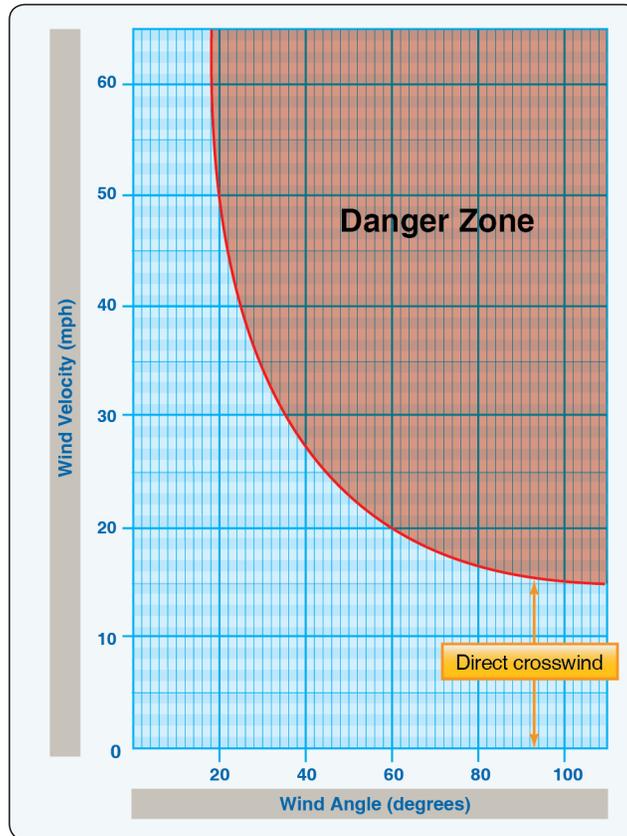


Figure 9-18. Crosswind chart.

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.

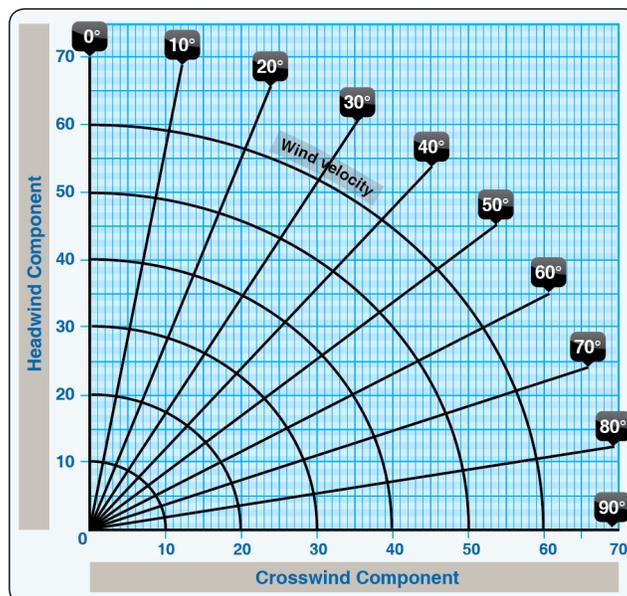


Figure 9-19. Crosswind component chart.

## 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.

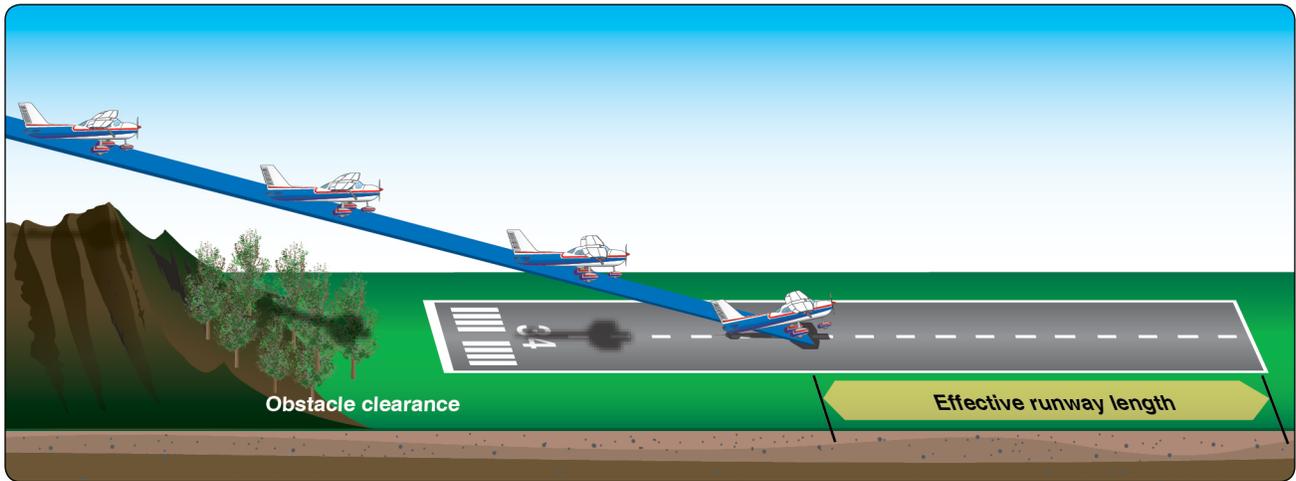
Pilots often use the normal approach speed plus one-half of the wind gust factors in turbulent conditions. If the normal speed is 70 knots, and the wind gusts are 15 knots, an increase of airspeed to 77 knots is appropriate. In any case, the airspeed and the flap setting should conform to airplane manufacturer's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

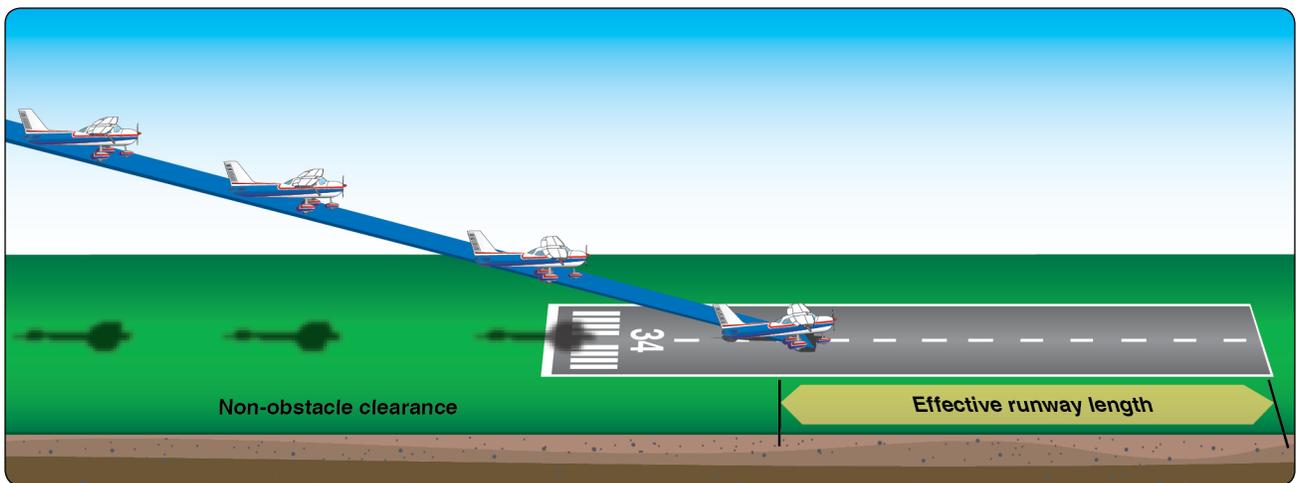
When landing from power approaches in turbulence, the touchdown is made with the airplane in approximately level flight attitude. The pitch attitude at touchdown would be only enough to prevent the nose-wheel from contacting the surface before the main wheels have touched the surface. After touchdown, 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.



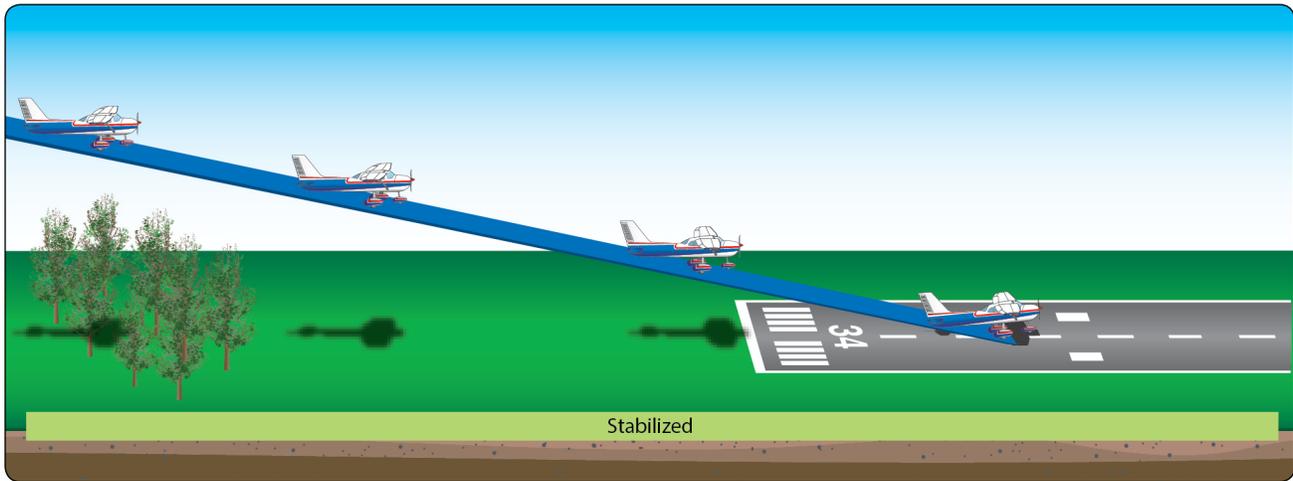
**Figure 9-20.** *Landing over an obstacle.*



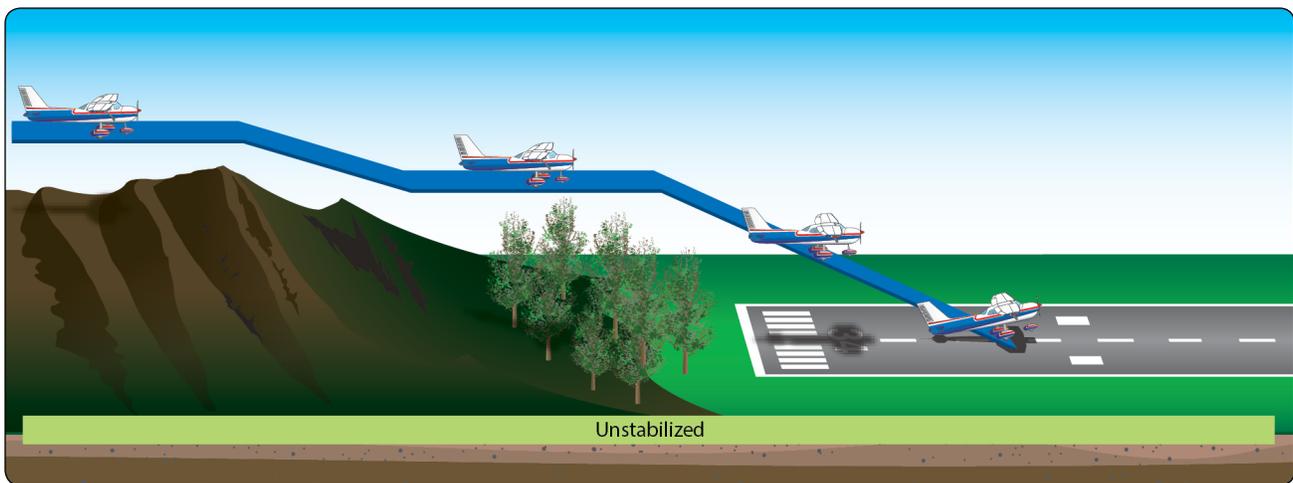
**Figure 9-21.** *Landing on a short field.*

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 AOA's 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

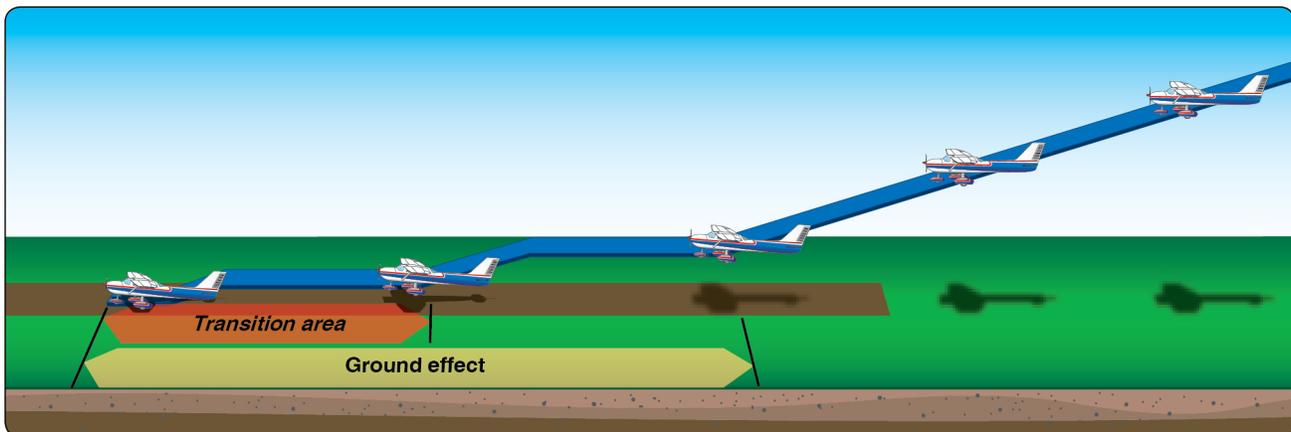
Common errors in the performance of short-field approaches and landings are:

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.

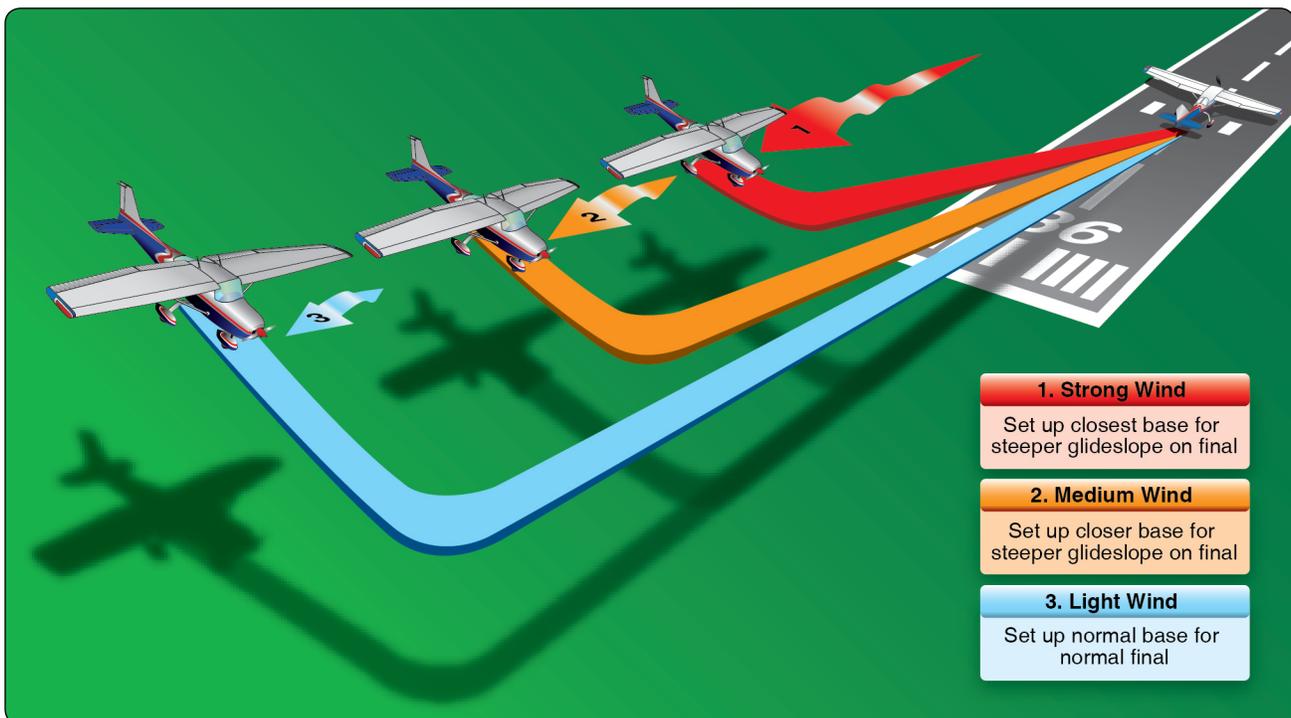
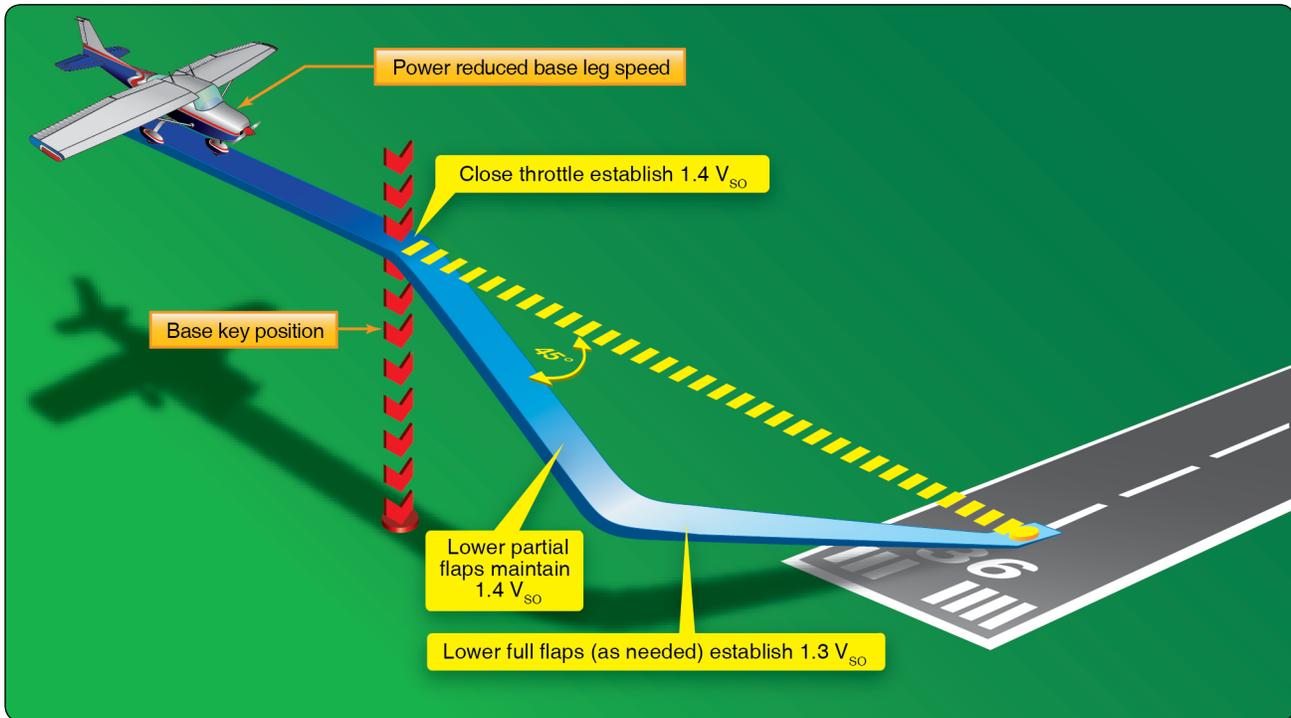


Figure 9-25. Plan the base leg for wind conditions.

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.

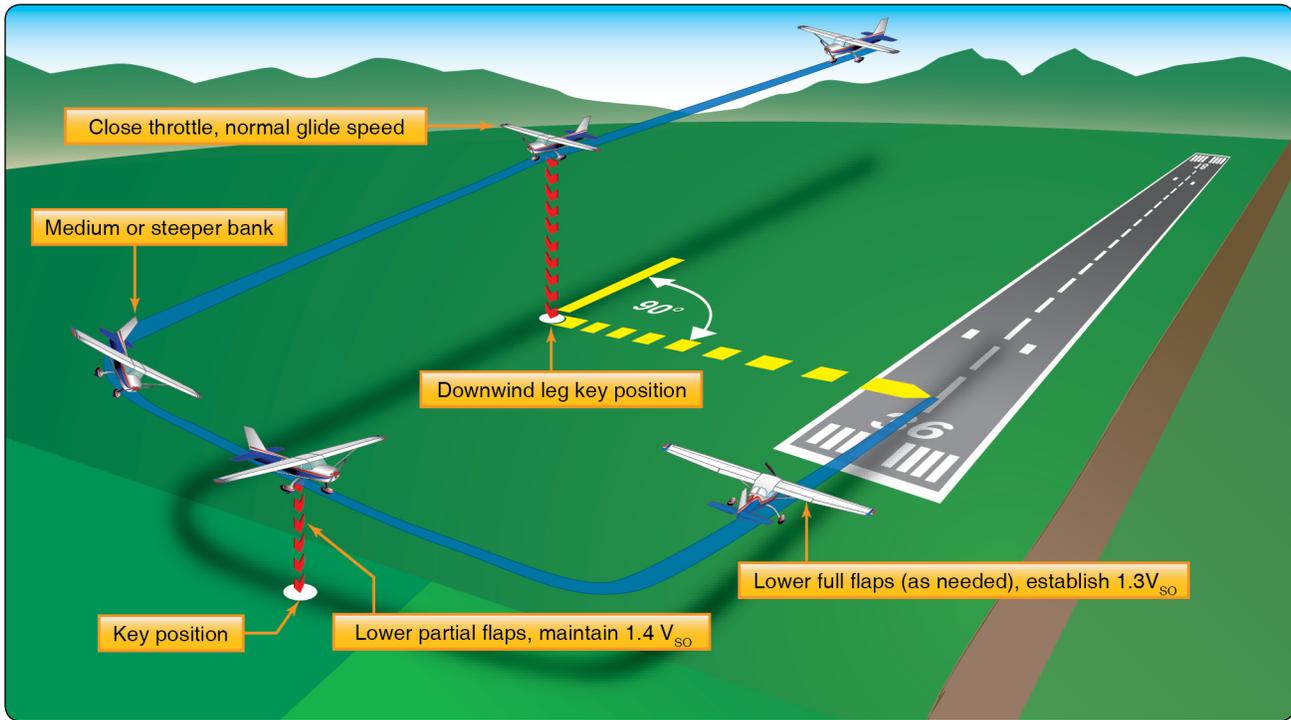
The pilot can determine the strength and direction of the wind from the amount of crab necessary to hold the desired ground track on the base leg. This helps in planning the turn onto the final approach and provides some indication of when to lower the flaps.

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:

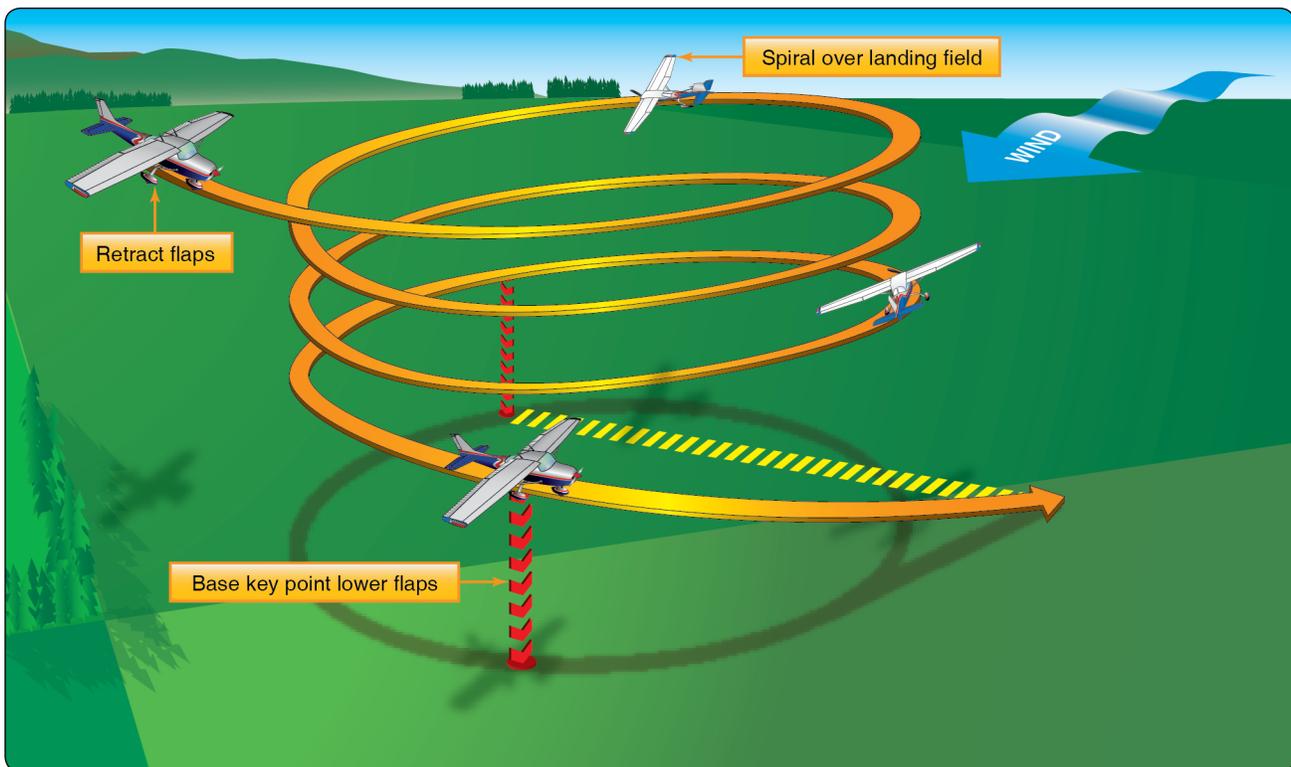
1. Downwind leg is too far from the runway/landing area.
2. Overextension of downwind leg resulting from a tailwind.
3. Inadequate compensation for wind drift on base leg.
4. Skidding turns in an effort to increase gliding distance.
5. Failure to lower landing gear in retractable gear airplanes.
6. Attempting 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]

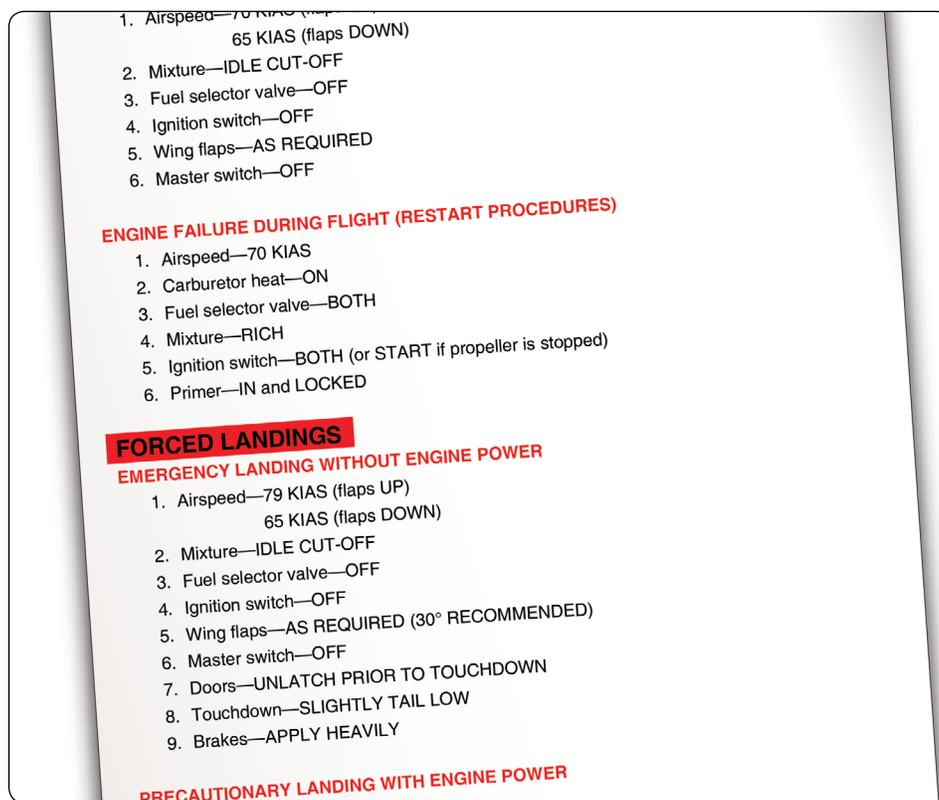


Figure 9-29. Sample emergency checklist.

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.

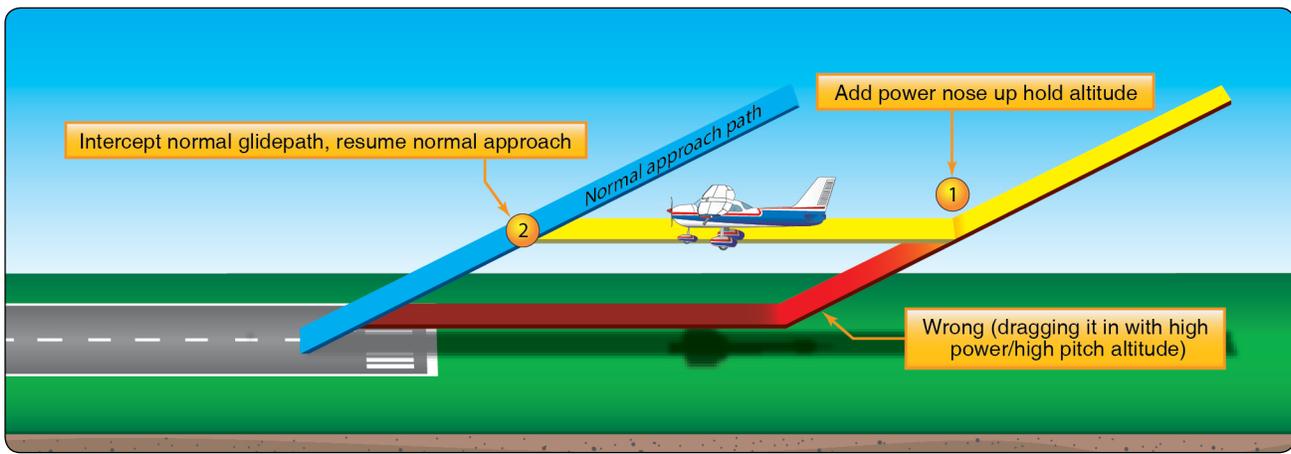


Figure 9-30. Right and wrong methods of correction for low final approach.

### 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.

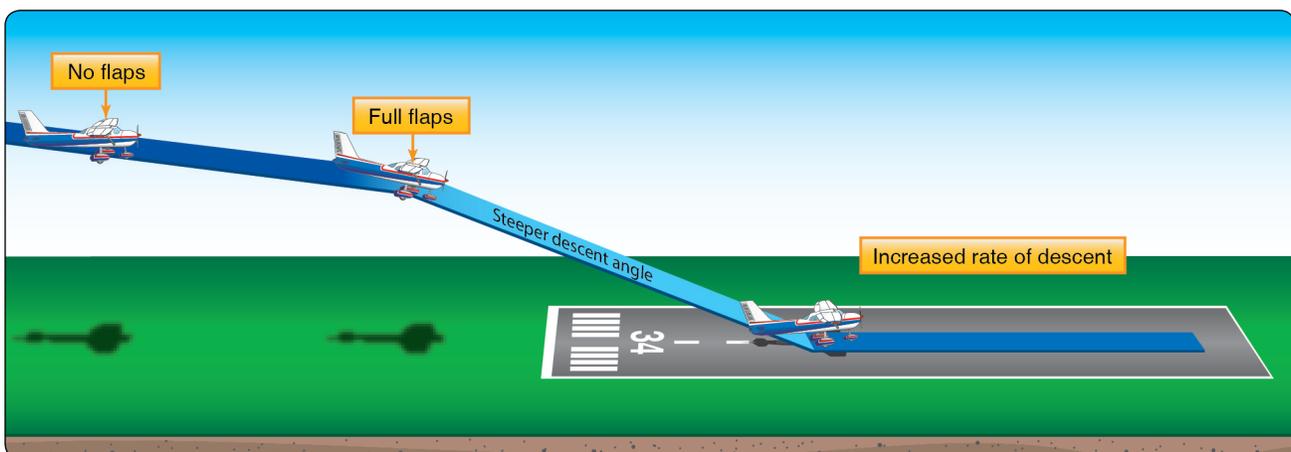


Figure 9-31. Change in glidepath and increase in descent rate for high final approach.

## 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]

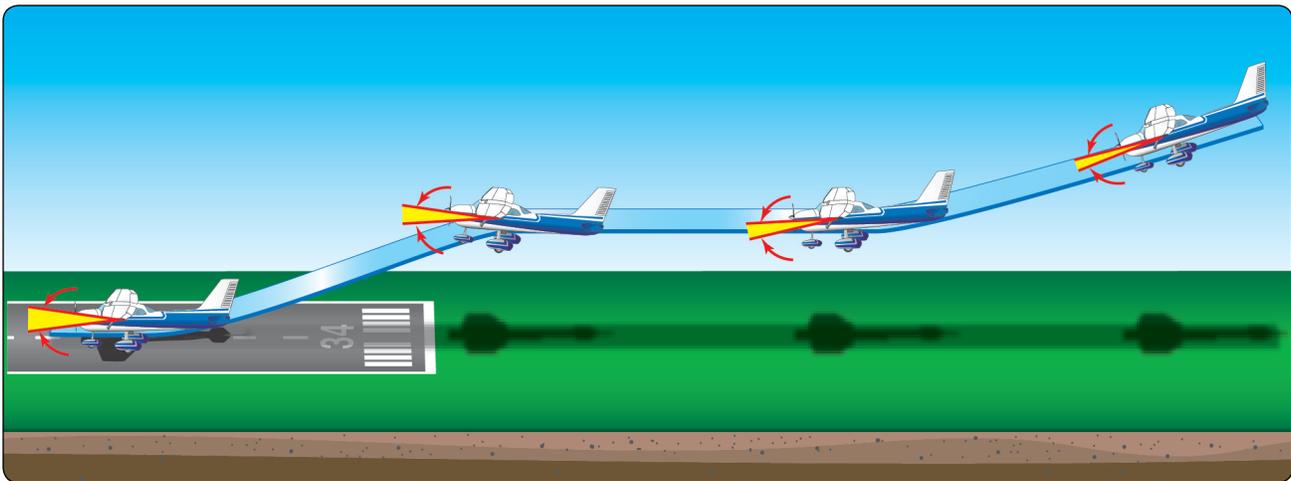


Figure 9-32. Rounding out too high.

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.

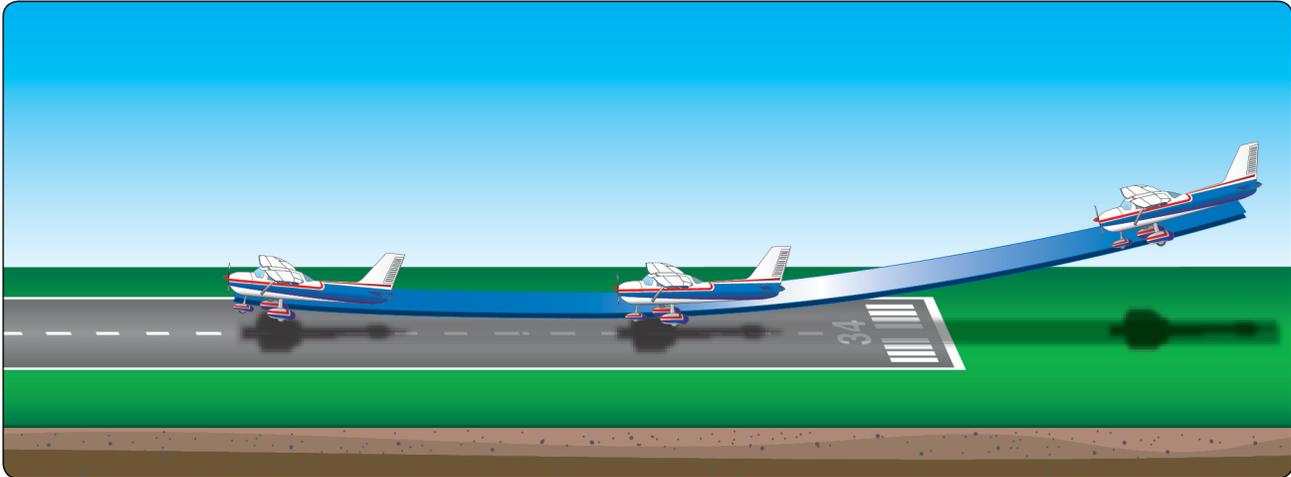
Suddenly increasing the AOA and stalling the airplane during a round out is a dangerous situation since it may cause the airplane to land extremely hard on the main landing gear and then bounce back into the air. As the airplane contacts the ground, the tail is forced down very rapidly by the back-elevator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



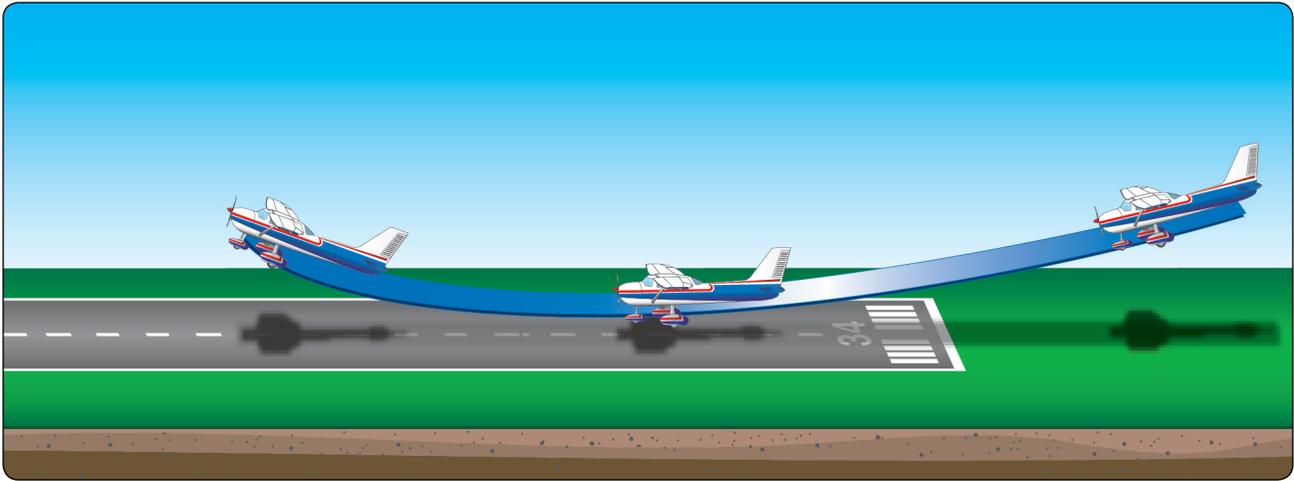
**Figure 9-33.** *Floating during round out.*

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.*

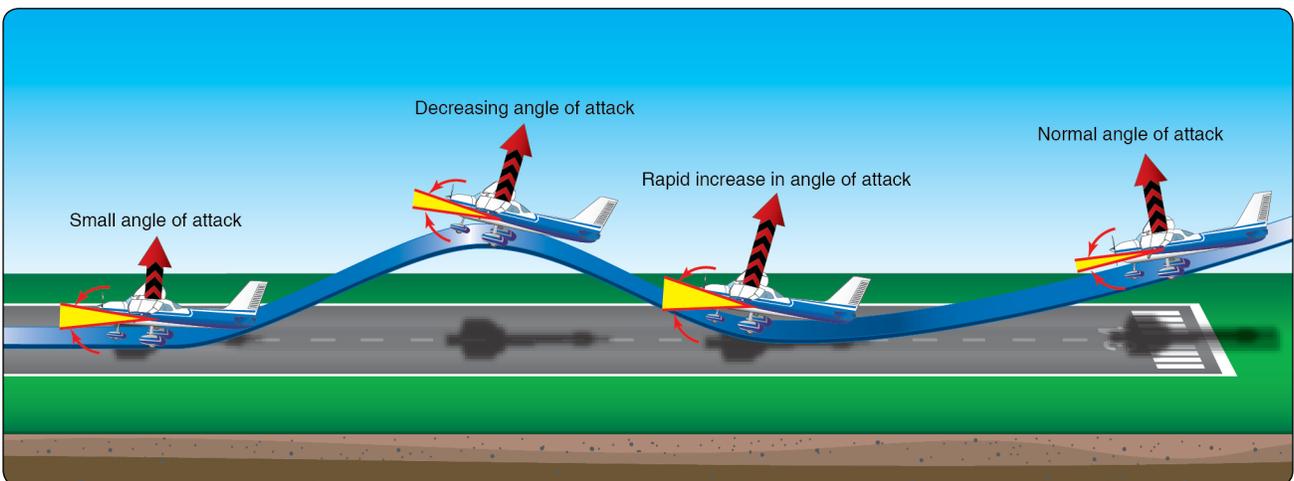
Depending on the severity of ballooning, the use of throttle is helpful in cushioning the landing. By adding power, thrust is increased to keep the airspeed from decelerating too rapidly and the wings from suddenly losing lift, but throttle should be closed immediately after touchdown. Torque effects 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.

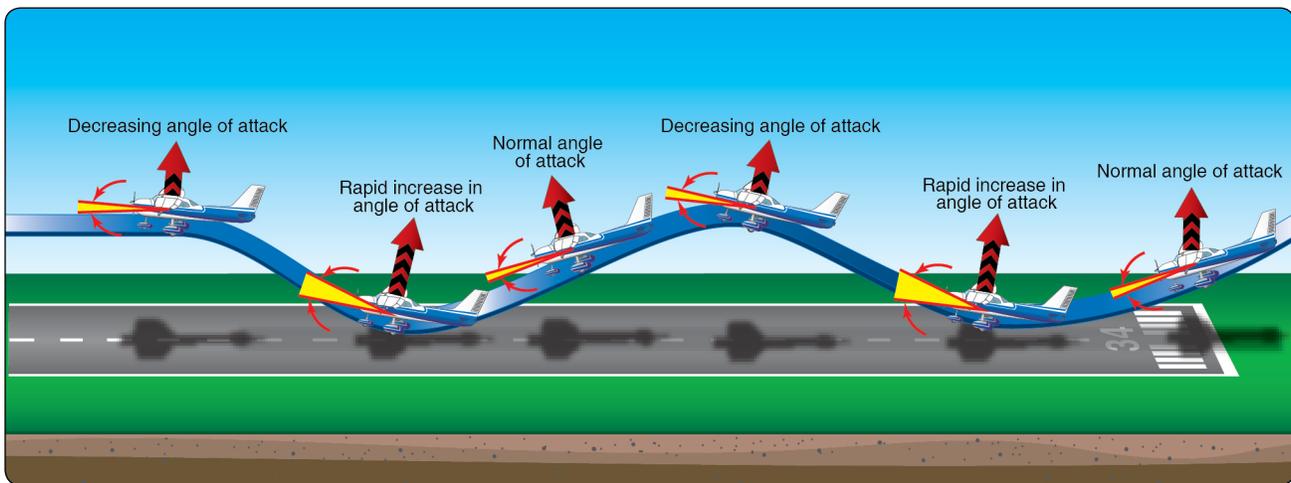


Figure 9-36. Porpoising.

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.

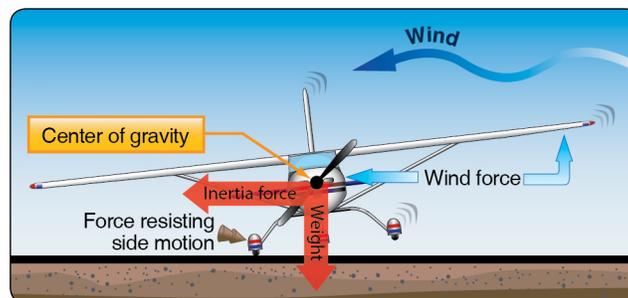
During this time, the landing gear, together with some aid from the lift of the wings, supplies whatever force is needed to counteract the force of the airplane's inertia and weight. However, the lift decreases rapidly as the airplane's forward speed is decreased, and the force on the landing gear increases 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.

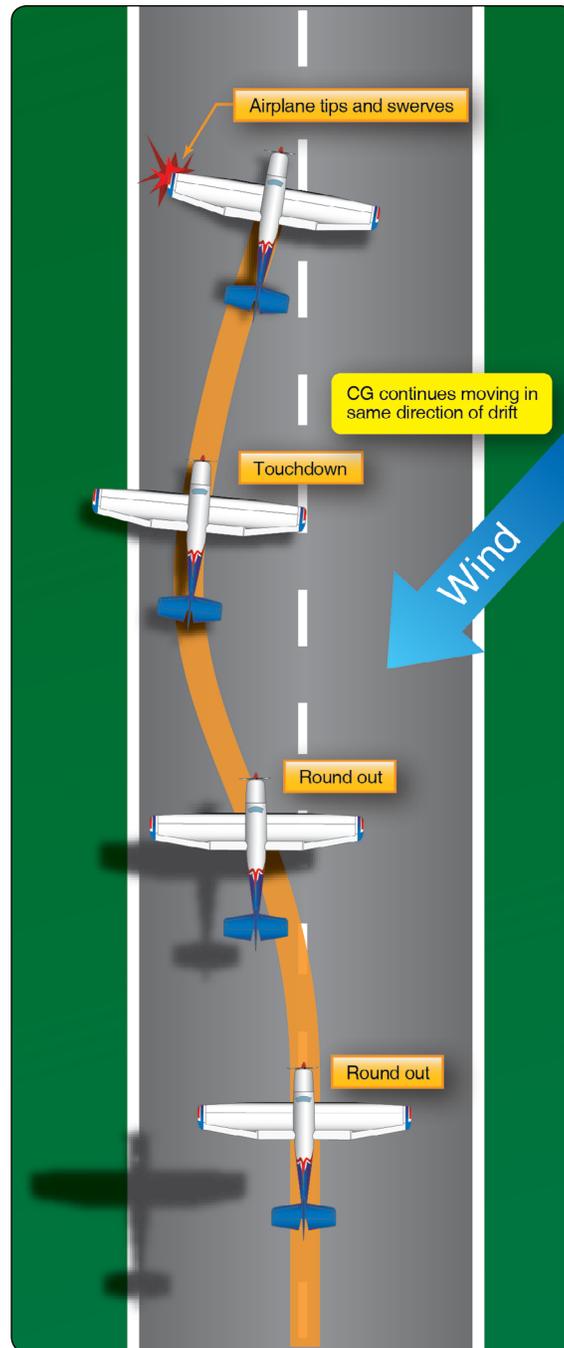


**Figure 9-37.** *Drifting during touchdown.*

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/](http://www.faa.gov/regulations_policies/handbooks_manuals/aviation/).