Airplane Flying Handbook (FAA-H-8083-3C)

Chapter 7: Ground Reference Maneuvers

Introduction

During initial training, pilots learn how various flight control pressure inputs affect the airplane. After achieving a sufficient level of competence, the pilot is ready to apply this skill and maintain the airplane, not only at the correct attitude and power configuration, but also along an appropriate course relative to objects on the ground. This skill is the basis for traffic patterns, survey, photographic, sight-seeing, aerial application (crop dusting), and various other flight profiles requiring specific flightpaths referenced to points on the surface.

Ground reference maneuvers are the principal flight maneuvers that combine the four fundamentals (straight-and-level, turns, climbs, and descents) into a set of integrated skills that the pilot uses in everyday flight activity. From every takeoff to every landing, a pilot exercises these skills to control the airplane. Therefore, a pilot needs to develop the proper coordination, timing, and attention in order to accurately and safely maneuver the airplane with regard to the required attitudes and ground references.

The pilot should be introduced by their instructor to ground reference maneuvers as soon as the pilot shows proficiency in the four fundamentals. Ground reference maneuvers call for manipulation of the flight controls using necessary control pressures to affect the airplane's attitude and position by using the outside natural horizon and ground-based references with brief periods of scanning the flight instruments.

Maneuvering by Reference to Ground Objects

Ground reference maneuvers train the pilot to accurately place the airplane in relationship to specific references and maintain a desired ground track. While vision is the most utilized sense, other senses are actively involved at different levels. For example, the amount of pressure needed to overcome flight control surface forces provides tactile feedback as to the airplane's airspeed and aerodynamic load.

It is a common error for beginning pilots to fixate on a specific reference, such as a single location on the ground or a spot on the natural horizon. A pilot fixating on any one reference loses the ability to determine rate, which significantly degrades a pilot's performance. By visually scanning across several references, the pilot learns how to determine the rate of closure to a specific point. In addition, the pilot should scan between several visual references to determine relative motion and to determine if the airplane is maintaining, or drifting to or from, the desired ground track. Consider a skilled automobile driver in a simple intersection turn; the driver does not merely turn the steering wheel some degree and hope that it will work out. The driver picks out several references, such as an island to their side, a painted lane line, or the opposing curb, and uses those references to make almost imperceptible adjustments to the amount of deflection on the steering wheel. At the same time, the driver adjusts the pressure on the accelerator pedal to smoothly join the new lane. In the same manner, multiple references are required to precisely control the airplane in reference to the ground.

Not all ground-based references are visually equal. Awareness of typical visual illusions helps a pilot select appropriate references. For example, larger objects or references may appear closer than they actually are when compared to smaller objects or references. Prevailing visibility has a significant effect on the pilot's perception of the distance to a reference. Excellent visibility with clear skies tends to make an object or reference appear closer than when compared to a hazy day with poor visibility. Rain can alter the visual image in a manner creating an illusion of being at a higher than actual altitude, and brighter objects or references may appear closer than dimmer objects. However, if using references of similar size and proportion, pilots find ground reference maneuvers easier to execute.

Ground-based references can be numerous. Examples include breakwaters, canals, fence lines, field boundaries, highways, railroad tracks, roads, pipe lines, power lines, water tanks, and many other objects; however, choices can be limited by geography, population density, infrastructure, or structures. The pilot should consider the type of maneuver being performed, altitude at which the maneuver will be performed, emergency landing requirements, density of structures, wind direction, visibility, and the type of airspace when selecting a ground-based reference.

Ground reference maneuvers develop a pilot's division of attention skill. A pilot needs to control the airplane's attitude while tracking a specific path over the ground. In addition, the pilot should be able to scan for hazards such as other aircraft, prepare for an emergency landing should the need arise, and scan the flight and engine instruments at regular intervals to ensure that a pending situation, such as decreasing oil pressure, does not turn into an unexpected incident.

Ground reference maneuvers place the airplane in a low altitude environment with associated hazards. Pilots should look for other aircraft, including helicopters, and look for obstructions such as radio towers and wires. In addition, pilots should consider engine failure and have one or more locations available for an emergency landing. Pilots should always clear the area with two 90° clearing turns looking to the left and the right, as well as above and below the airplane. The maneuver area should not cause disturbances and be well away from any open air assembly of persons, congested areas of a city, town, or settlement, or herd of livestock. Before performing any maneuver, the pilot should complete the required checklist items, make any radio announcements (such as on a practice area frequency), and safety clearing turns. As a general note, a ground reference maneuver should not exceed a bank angle of 45° or an airspeed greater than the maneuvering speed. As part of preflight planning, the pilot should determine the predicted (POH/AFM) stall speed at 50° or at the highest bank angle expected during the maneuver to assure there will be a safety margin above the stall speed during the maneuver.

Drift and Ground Track Control

Wind direction and velocity variations create the need for flightpath corrections during a ground reference maneuver. In a similar way that water currents affect the progress of a boat or ship, wind directly influences the path that the airplane travels in reference to the ground. Whenever the airplane is in flight, the movement of the air directly affects the actual ground track of the airplane.

For example, an airplane is traveling at 90 knots (90 nautical miles per hour) and the wind is blowing from right to left at 10 knots. The airplane continues forward at 90 knots but also travels left 10 nautical miles for every hour of flight time. If the airplane, in this example doubles its speed to 180 knots, it still drifts laterally to the left 10 nautical miles every hour. Unless in still air, traveling to a point on the surface requires compensation for the movement of the air mass.

Ground reference maneuvers are generally flown at altitudes between 600 and 1,000 feet above ground level (AGL). The pilot should consider the following when selecting the maneuvering altitude:

- The lower the maneuvering altitude, the faster the airplane appears to travel in relation to the ground.
- Drift should be easily recognizable from both sides of the airplane.
- The altitude should provide obstruction clearance of no less than 500 feet vertically above the obstruction and 2,000 feet horizontally.
- In the event of an engine failure, lower altitudes equate to less time to configure the airplane and reduced gliding distance before a forced landing.
- What specific altitude or altitude range does the testing standard call for?

Correcting Drift During Straight-and-Level Flight

When flying straight and level and following a selected straight-line direct ground track, the preferred method of correcting for wind drift is to angle the airplane sufficiently into the wind to cancel the effect of the sideways drift caused by the wind. The wind's speed, the angle between the wind direction and the airplane's longitudinal axis, and the airspeed of the airplane determine the required wind correction angle. For example, an airplane with an airspeed of 100 knots in an air mass moving at 20 knots directly from the side, should turn 12° into the wind to cancel the airplane's drift. If the wind in the above example is only 10 knots, the wind correction angle required to cancel the drift is six degrees. When the drift has been neutralized by heading the airplane into the wind, the airplane will fly the direct straight ground track.

To further illustrate this point, if a boat is crossing a river and the river's current is completely still, the boat could head directly to a point on the opposite shore on a straight course without any drift. However, rivers tend to have a downstream current that needs to be considered if the captain wants the boat to arrive at the opposite shore using a direct straight path. Any downstream current pushes the boat sideways and downstream at the speed of the current. To counteract this downstream movement, the boat needs to move upstream at the same speed as the river is moving the boat downstream. This is accomplished by angling the boat upstream to counteract the downstream flow. If done correctly, the boat follows a direct straight track across the river to the intended destination point. A slower forward speed of the boat or a faster river current requires a greater angle to counteract the drift. *[Figure 7-1]*

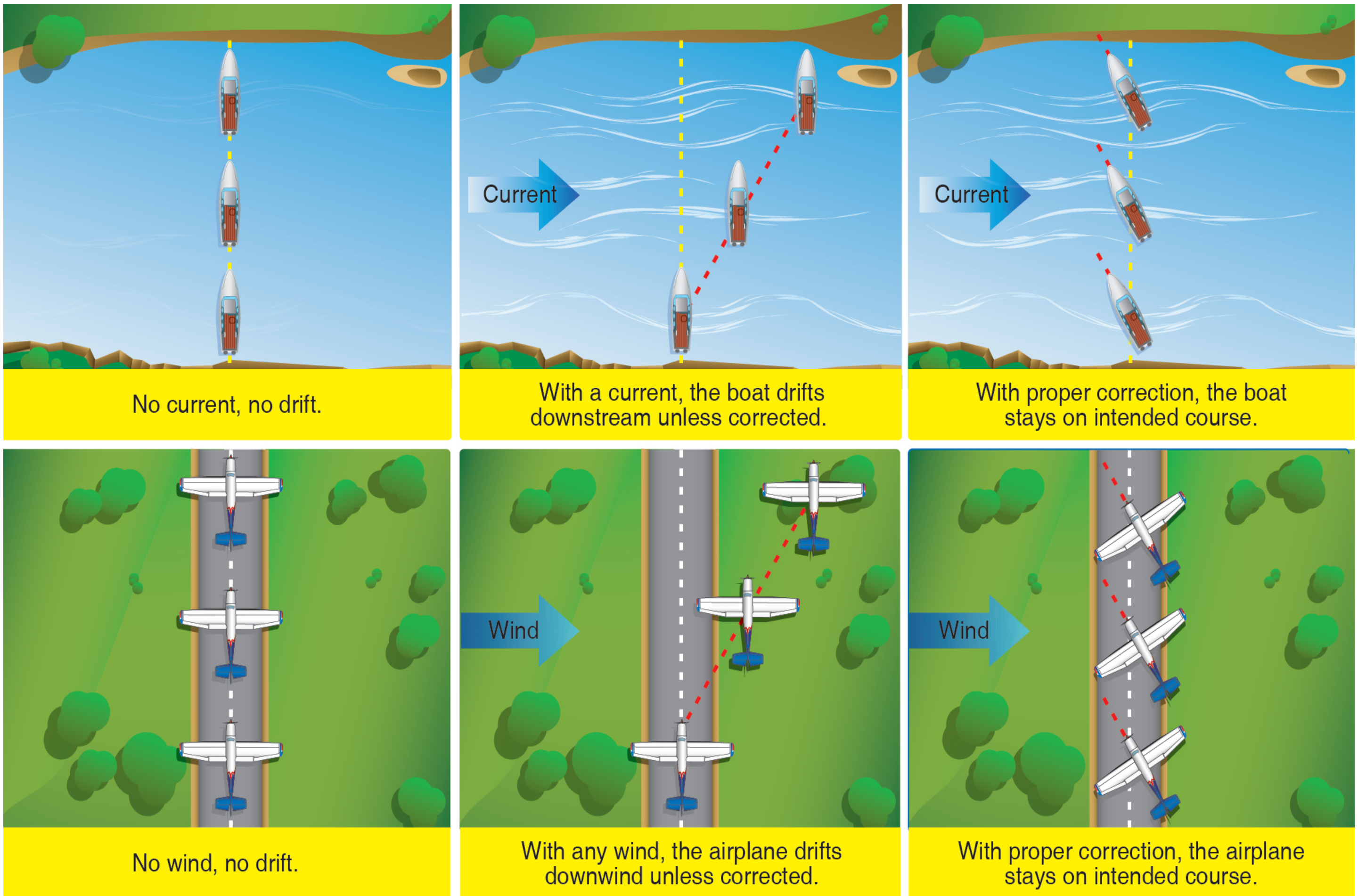

Figure 7-1. *Wind drift.*

As soon as the pilot lifts off the surface and levels the wings in a crosswind, the airplane begins tracking sideways. The force of the crosswind acts on the mass of the airplane, and the speed of drift increases up to the speed of the crosswind component. A wind that is directly to the right or the left (at a 90° angle) will cause the airplane to accelerate sideways at the same speed as the wind. When the wind is halfway between the side and the nose of the airplane (at a 45° angle), it causes a sideways drift up to just over 70 percent of the total speed of the wind. It should be understood that pilots do not calculate the required drift correction angles for ground reference maneuvers; they merely use the references and adjust the airplane's relationship to those references to cancel any drift. The groundspeed of the airplane is also affected by the wind. As the wind direction becomes parallel to the airplane's longitudinal axis, the magnitude of the wind's effect on the groundspeed is greater; as the wind becomes perpendicular to the longitudinal axis, the magnitude of the wind's effect on the groundspeed is less. In general, When the wind is blowing straight into the nose of the airplane, the groundspeed will be less than the airspeed. When the wind is blowing from directly behind the airplane, the groundspeed will be faster than the airspeed. In other words, when the airplane is headed upwind, the groundspeed is decreased; when headed downwind, the groundspeed is increased.

Constant Radius During Turning Flight

In a no-wind condition, a pilot may make a constant-radius turn over the ground using a fixed bank angle. If wind is present, however, a pilot will observe a change in the radius of a turn while maintaining that same constant bank angle. *[Figure 7-2]* As groundspeed increases, the observed radius of the turn increases. Conversely, as groundspeed decreases, the radius of the turn over the ground will decrease. For a ground-referenced constant-radius turn, the pilot compensates for changes in groundspeed by varying the bank angle throughout the turn. When groundspeed increases, the pilot banks more steeply to maintain a constant-radius turn over the ground. The converse is also true: when groundspeed decreases, the pilot uses a shallower bank.

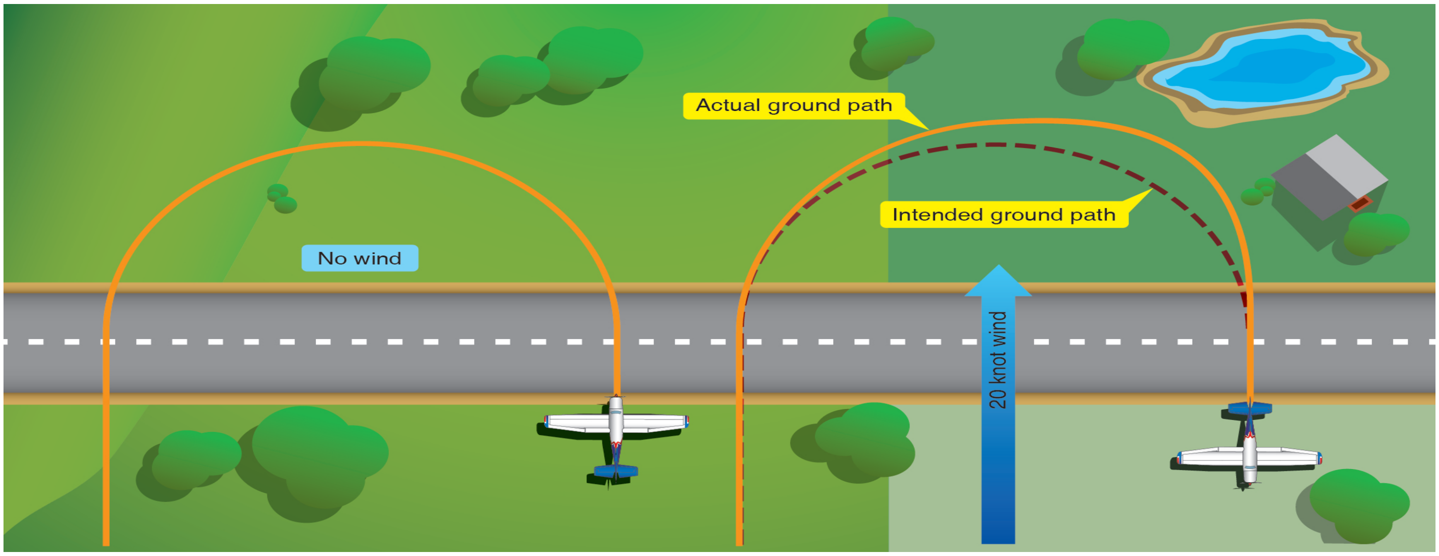

Figure 7-2. *Effect of wind during a turn.*

For a given true airspeed, the radius of turn in the air varies proportionally with the bank angle. To maintain a constant radius over the ground, the bank angle used is proportional to groundspeed. For example, an airplane is in the downwind position at 100 knots groundspeed. In this example, the wind is 10 knots, meaning that the airplane has an airspeed of 90 knots (for this discussion, assume true, calibrated, and indicated airspeed are all the same). If the pilot starts a turn using a 45° bank angle, the turn radius over the ground at that moment is approximately 890 feet. As the airplane turns, the groundspeed decreases and the bank angle needs to be reduced in order to maintain the same turn radius of 890 feet over the ground. At the upwind point of the turn, the bank angle should be approximately 33°. In another example, if the downwind is flown at an airspeed of 90 knots in a 10 knot tailwind with a desired turn radius of 2,000 feet, the bank angle would be approximately 24°. The bank angle flying upwind would be approximately 16°.

Put another way, at a higher groundspeed, there is less time to turn the airplane while trying to maintain a ground-referenced constant-radius turn. The pilot increases the bank angle in order to increase the rate of turn, and the increased rate of turn offsets the reduced time available to make the turn. Conversely, when flying at a lower groundspeed, the pilot reduces the angle of bank and rate of turn to compensate for the additional time taken while making the turn. With some experience, pilots may notice how wind direction affects the time needed for various segments of ground-referenced turns.

To demonstrate the effect that wind has on turns, the pilot should select a straight-line ground reference, such as a road or railroad track. *[Figure 7-3]* Choosing a straight-line ground reference that is parallel to the wind, the airplane would be flown into the wind and directly over the selected straight-line ground reference. Once a straight-line ground reference is established, the pilot makes a 360° constant medium-banked turn. As the airplane completes the 360° turn, it should return directly over the straight-line ground reference but downwind from the starting point. Choosing a straight-line ground reference that has a crosswind, and using the same 360° constant medium-banked turn, demonstrates how the airplane drifts away from the reference even as the pilot holds a constant bank angle. In both examples, the path over the ground is not circular, although in reference to the air, the airplane flew a perfect continuous radius.

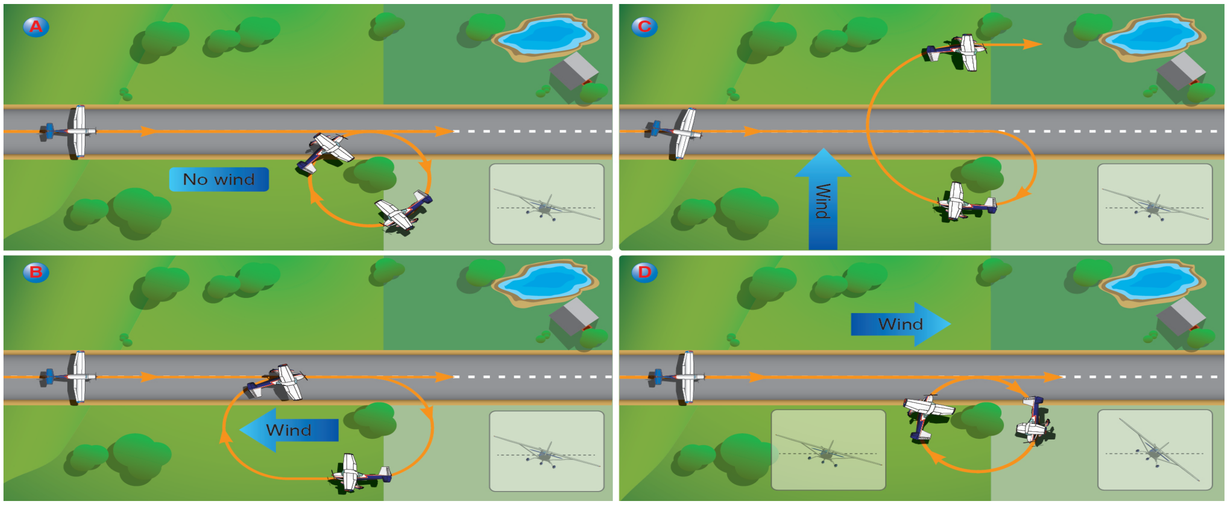

Figure 7-3. *Effect of wind during turn.*

In order to compensate for the effects of wind drift, the pilot adjusts the bank angle as the groundspeed changes throughout the turn. Where groundspeed is the fastest, such as when the airplane is headed downwind, the bank angle should be steepest. Where groundspeed is the slowest, such as when the airplane is headed upwind, the bank angle should be shallow. It is necessary to increase or decrease the angle of bank, which increases or decreases the rate of turn, to achieve the desired constant radius track over the ground.

Ground reference maneuvers should always be entered from a downwind position. This allows the pilot to establish the steepest bank angle required to maintain a constant radius ground track. If the bank is too steep, the pilot should immediately exit the maneuver and re-establish a lateral position that is further from the ground reference. The pilot should avoid bank angles in excess of 45°due to the increased stalling speed.

Tracking Over and Parallel to a Straight Line

The pilot should first be introduced to ground reference maneuvers by correcting for the effects of a crosswind over a straight-line ground reference, such as road or railroad tracks. If a straight road or railroad track is unavailable, the pilot should choose multiple references (three minimum) which line up along a straight path. The reference line should be suitably long so the pilot has sufficient time to understand the concepts of wind correction and practice the maneuver. Initially, the maneuver should be flown directly over the ground reference line with the pilot angling the airplane's longitudinal axis into the wind sufficiently such as to cancel the effect of drift. The pilot should scan between far ahead and close to the airplane to practice tracking multiple references.

When proficiency has been demonstrated by flying directly over the ground reference line, the pilot should then practice flying a straight parallel path that is offset from the ground reference. The offset parallel path should not be more than three-fourths of a mile from the reference line. The maneuver should be flown offset from the ground references with the pilot angling the airplane's longitudinal axis into the wind sufficiently to cancel the effect of drift while maintaining a parallel track.

Rectangular Course

A principal ground reference maneuver is the rectangular course. *[Figure 7-4]* The rectangular course is a training maneuver in which the airplane maintains an equal distance from all sides of the selected rectangular references. The maneuver is accomplished to replicate the airport traffic pattern that an airplane typically maneuvers while landing. While performing the rectangular course maneuver, the pilot should maintain a constant altitude, airspeed, and distance from the ground references. The maneuver assists the pilot in practicing the following:

- Maintaining a specific relationship between the airplane and the ground.
- Dividing attention between the flightpath, ground-based references, manipulating the flight controls, and scanning for outside hazards and instrument indications.
- Adjusting the bank angle during turns to correct for groundspeed changes in order to maintain constant-radius turns.
- Rolling out from a turn with the required wind correction angle to compensate for any drift caused by the wind.
- Establishing and correcting the wind correction angle in order to maintain the track over the ground.
- Preparing the pilot for the airport traffic pattern and subsequent landing pattern practice.

To fly the rectangular course, the pilot should first locate a square field, a rectangular field, or an area with suitable ground references on all four sides. Note that a square meets the definition of a rectangle. As previously mentioned, this area should be selected consistent with safe practices. The airplane should be flown parallel to and at an equal distance between one-half to three-fourths of a mile away from the field boundaries or selected ground references. The flightpath should be positioned outside the field boundaries or selected ground references so that the references may be easily observed from either pilot seat. It is not practical to fly directly above the field boundaries or selected ground references. The pilot should avoid flying close to the references, as this will require the pilot to turn using very steep bank angles, thereby increasing aerodynamic load factor and the airplane's stall speed, especially in the downwind to crosswind turn.

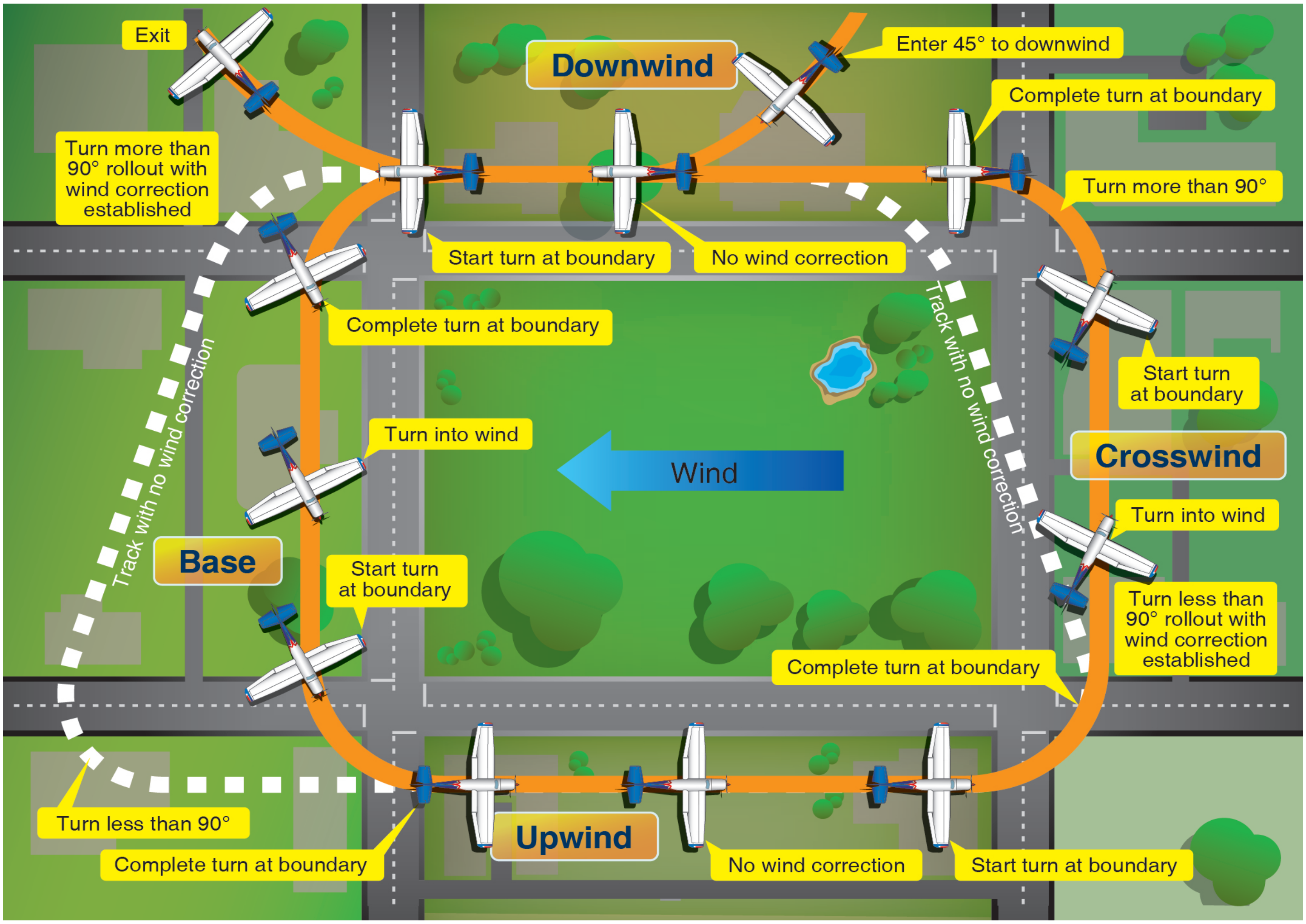

Figure 7-4. *Rectangular course.*

The entry into the maneuver should be accomplished downwind. This places the wind on the tail of the airplane and results in an increased groundspeed. There should be no wind correction angle if the wind is directly on the tail of the airplane; however, a real-world situation often results in some drift correction. The turn from the downwind leg onto the base leg is entered with a relatively steep bank angle. The pilot should roll the airplane into a steep bank with rapid, but not excessive, coordinated aileron and rudder pressures. As the airplane turns onto the following base leg, the tailwind lessens and becomes a crosswind; the bank angle is reduced gradually with coordinated aileron and rudder pressures. The pilot should be prepared for the lateral drift and compensate by turning more than 90° angling toward the inside of the rectangular course.

The next leg is where the airplane turns from a base leg position to the upwind leg. Ideally, on the upwind, the wind is directly on the nose of the airplane resulting in a direct headwind and decreased groundspeed; however, some drift correction may be necessary. The pilot should roll the airplane into a medium-banked turn with coordinated aileron and rudder pressures. As the airplane turns onto the upwind leg, the crosswind lessens and becomes a headwind, and the bank angle is gradually reduced with coordinated aileron and rudder pressures. Because the pilot was angled into the wind on the base leg, the turn to the upwind leg is less than 90°.

The next leg is where the airplane turns from an upwind leg position to the crosswind leg. The pilot should slowly roll the airplane into a shallow-banked turn, as the developing crosswind drifts the airplane into the inside of the rectangular course with coordinated aileron and rudder pressures. As the airplane turns onto the crosswind leg, the headwind lessens and becomes a crosswind. As the turn nears completion, the bank angle is reduced with coordinated aileron and rudder pressures. To compensate for the crosswind, the pilot maintains an angle into the wind, toward the outside of the rectangular course, which requires the turn to be less than 90°.

The final turn is back to the downwind leg, which requires a medium-banked angle and a turn greater than 90°. The groundspeed will be increasing as the turn progresses and the bank should be held and then rolled out in a rapid, but not excessive, manner using coordinated aileron and rudder pressures.

For the maneuver to be executed properly, the pilot should visually utilize the ground-based, nose, and wingtip references to properly position the airplane in attitude and in orientation to the rectangular course. In order to maintain a constant ground-based radius during the turns, each turn requires the bank angle to be adjusted to compensate for the changing groundspeed—the higher the groundspeed, the steeper the bank. If the groundspeed is initially higher and then decreases throughout the turn, the bank angle should progressively decrease throughout the turn. The converse is also true, if the groundspeed is initially slower and then increases throughout the turn, the bank angle should progressively increase throughout the turn until rollout is started. Also, the rate for rolling in and out of the turn should be adjusted to prevent drifting in or out of the course. When the wind is from a direction that could drift the airplane into the course, the banking roll rate should be slow. When the wind is from a direction that could drift the airplane to the outside of the course, the banking roll rate should be quick.

The following are the most common errors made while performing rectangular courses:

1. Failure to adequately clear the surrounding area for safety hazards, initially and throughout the maneuver.
2. Failure to establish a constant, level altitude prior to entering the maneuver.
3. Failure to maintain altitude during the maneuver.
4. Failure to properly assess wind direction.
5. Failure to establish the appropriate wind correction angle.
6. Failure to apply coordinated aileron and rudder pressure, resulting in slips and skids.
7. Failure to manipulate the flight controls in a smooth and continuous manner.
8. Failure to properly divide attention between airplane control and orientation with ground references.
9. Failure to execute turns with accurate timing.

Turns Around a Point

Turns around a point are a logical extension of both the rectangular course and S-turns across a road. The maneuver is a 360° constant radius turn around a single ground-based reference point. *[Figure 7-5]* The principles are the same in any turning ground reference maneuver—higher groundspeeds require steeper banks and slower ground speeds require shallower banks. The objectives of turns around a point are as follows:

- Maintaining a specific relationship between the airplane and the ground.
- Dividing attention between the flightpath, ground-based references, manipulating the flight controls, and scanning for outside hazards and instrument indications.
- Adjusting the bank angle during turns to correct for groundspeed changes in order to maintain a constant radius turn—steeper bank angles for higher ground speeds, shallow bank angles for slower groundspeeds.
- Improving competency in managing the quickly-changing bank angles.
- Establishing and adjusting the wind correction angle in order to maintain the track over the ground.
- Developing the ability to compensate for drift in quickly-changing orientations.
- Developing further awareness that the radius of a turn is correlated to the bank angle.

To perform a turn around a point, the pilot needs to complete at least one 360° turn; however, to properly assess wind direction, velocity, bank required, and other factors related to turns in wind, the pilot should complete two or more turns. As in other ground reference maneuvers, when wind is present, the pilot adjusts the airplane's bank and wind correction angle to maintain a constant radius turn around a point. In contrast to the ground reference maneuvers discussed previously, in which turns were approximately limited to either 90° or 180°, turns around a point are consecutive 360° turns, where pilot constantly adjusts the bank angle and the resulting rate of turn as the airplane sequences through the various wind directions. The pilot should make these adjustments by applying coordinated aileron and rudder pressure throughout the turn.

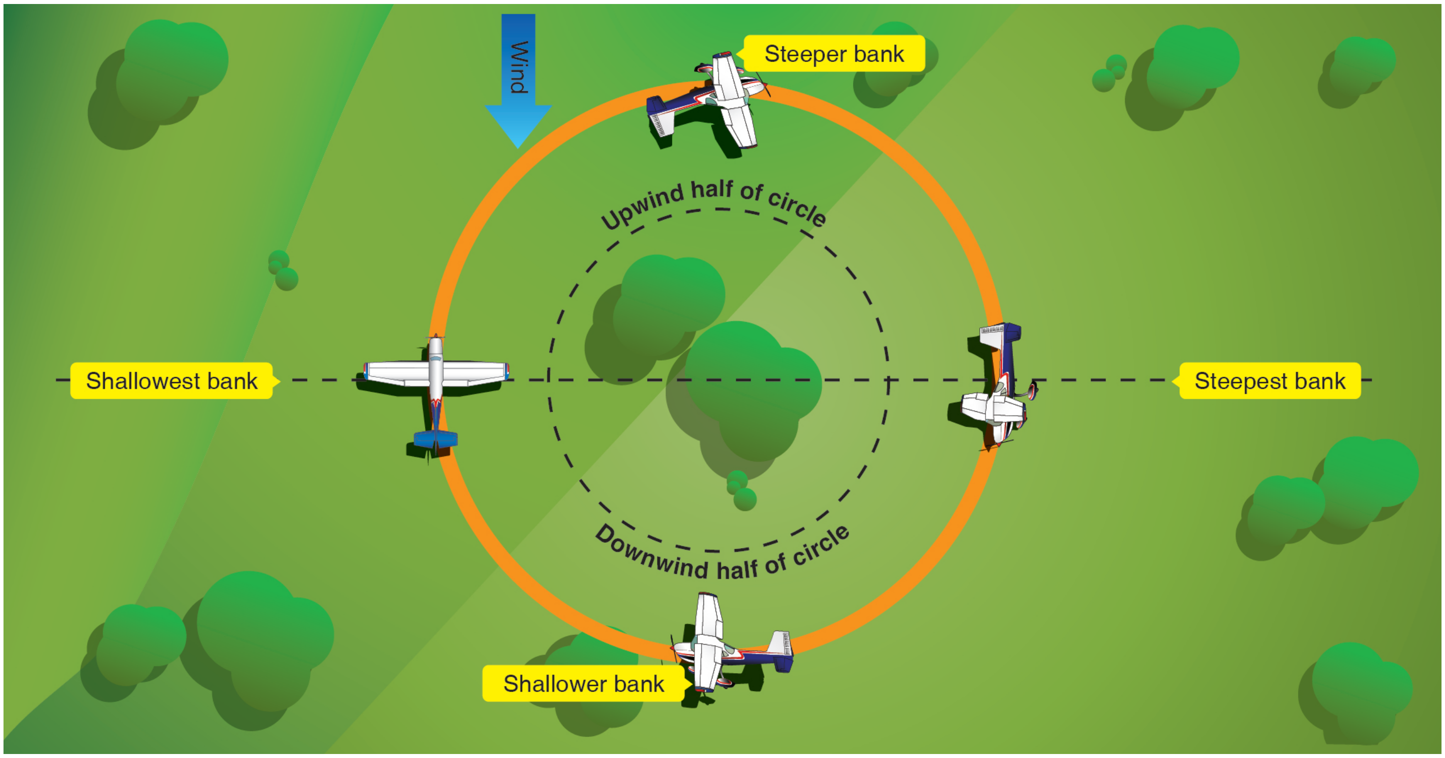

Figure 7-5. *Turns around a point.*

When performing a turn around a point, the pilot should select a prominent, ground-based reference that is easily distinguishable yet small enough to present a precise reference. The pilot should enter the maneuver downwind, where the groundspeed is at its fastest, at the appropriate radius of turn and distance from the selected ground-based reference point. In a high-wing airplane, the lowered wing may block the view of the ground reference point, especially in airplanes with side-by-side seating during a left turn (assuming that the pilot is flying from the left seat). To prevent this, the pilot may need to change the maneuvering altitude or the desired turn radius. The pilot should ensure that the reference point is visible at all times throughout the maneuver, even with the wing lowered in a bank.

Upon entering the maneuver, depending on the wind's speed, it may be necessary to roll into the initial bank at a rapid rate so that the steepest bank is set quickly to prevent the airplane from drifting outside of the desired turn radius. This is best accomplished by repeated practice and assessing the required roll in rate. Thereafter, the pilot should gradually decrease the angle of bank until the airplane is headed directly upwind. As the upwind becomes a crosswind and then a downwind, the pilot should gradually steepen the bank to the steepest angle upon reaching the initial point of entry.

During the downwind half of the turn, the pilot should progressively adjust the airplane's heading toward the inside of the turn. During the upwind half, the pilot should progressively adjust the airplane's heading toward the outside of the turn. Put another way, the airplane's heading should be ahead of its position over the ground during the downwind half of the turn and behind its position during the upwind half. Remember that the goal is to make a constant-radius turn over the ground and, because the airplane is flying through a moving air mass, the pilot should constantly adjust the bank angle to achieve this goal.

The following are the most common errors in the performance of turns around a point:

1. Failure to adequately clear the surrounding area for safety hazards, initially and throughout the maneuver.
2. Failure to establish a constant, level altitude prior to entering the maneuver.
3. Failure to maintain altitude during the maneuver.
4. Failure to properly assess wind direction.
5. Failure to properly execute constant-radius turns.
6. Failure to manipulate the flight controls in a smooth and continuous manner.
7. Failure to establish the appropriate wind correction angle.
8. Failure to apply coordinated aileron and rudder pressure, resulting in slips or skids.

S-Turns

An S-turn is a ground reference maneuver in which the airplane's ground track resembles two opposite but equal half-circles on each side of a selected ground-based straight-line reference. *[Figure 7-6]* This ground reference maneuver presents a practical application for the correction of wind during a turn. The objectives of S-turns across a road (or line) are as follows:

- Maintaining a specific relationship between the airplane and the ground.
- Dividing attention between the flightpath, ground-based references, manipulating the flight controls, and scanning for outside hazards and instrument indications.
- Adjusting the bank angle during turns to correct for groundspeed changes in order to maintain a constant-radius turn—steeper bank angles for higher groundspeeds, shallow bank angles for slower groundspeeds.
- Rolling out from a turn with the required wind correction angle to compensate for any drift cause by the wind.
- Establishing and correcting the wind correction angle in order to maintain the track over the ground.
- Developing the ability to compensate for drift in quickly-changing orientations.
- Arriving at specific points on required headings.

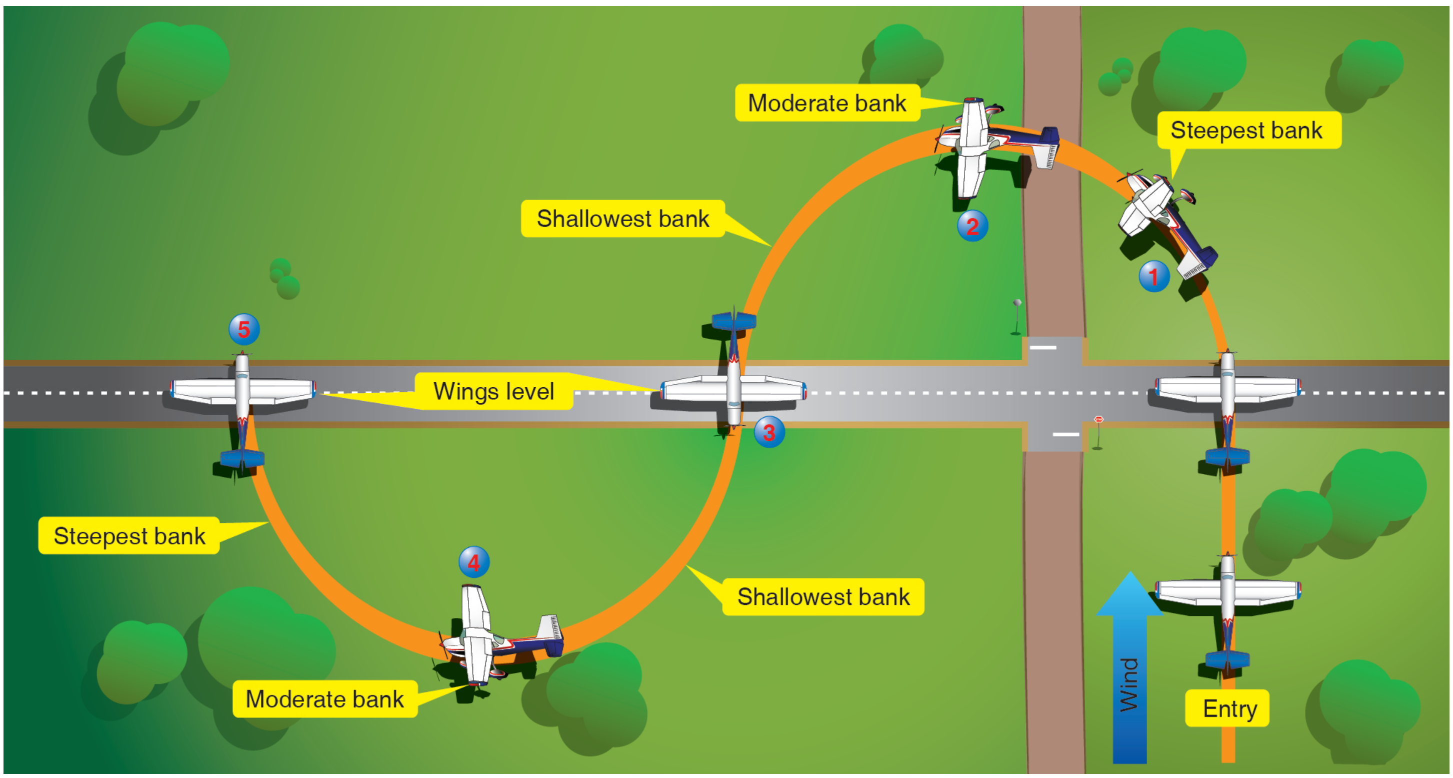

Figure 7-6. *S-turns.*

With the airplane in the downwind position, the maneuver consists of crossing a straight-line ground reference at a 90° angle and immediately beginning a 180° constant-radius turn. The pilot will then adjust the roll rate and bank angle for drift effects and changes in groundspeed, and re-cross the straight-line ground reference in the opposite direction just as the first 180° constant-radius turn is completed. The pilot will then immediately begin a second 180° constant-radius turn in the opposite direction, adjusting the roll rate and bank angle for drift effects and changes in groundspeed, again re-crossing the straight-line ground reference as the second 180° constant-radius turn is completed. If the straight-line ground reference is of sufficient length, the pilot may complete as many as can be safely accomplished.

In the same manner as the rectangular course, it is standard practice to enter ground-based maneuvers downwind where groundspeed is greatest. As such, the roll into the turn should be rapid, but not aggressive, and the angle of bank should be steepest when initiating the turn. As the turn progresses, the bank angle and the rate of rollout should be decreased as the groundspeed decreases to ensure that the turn's radius is constant. During the first turn, when the airplane is at the 90° point, it will be directly crosswind. In addition to the rate of rollout and bank angle, the pilot should control the wind correction angle throughout the turn.