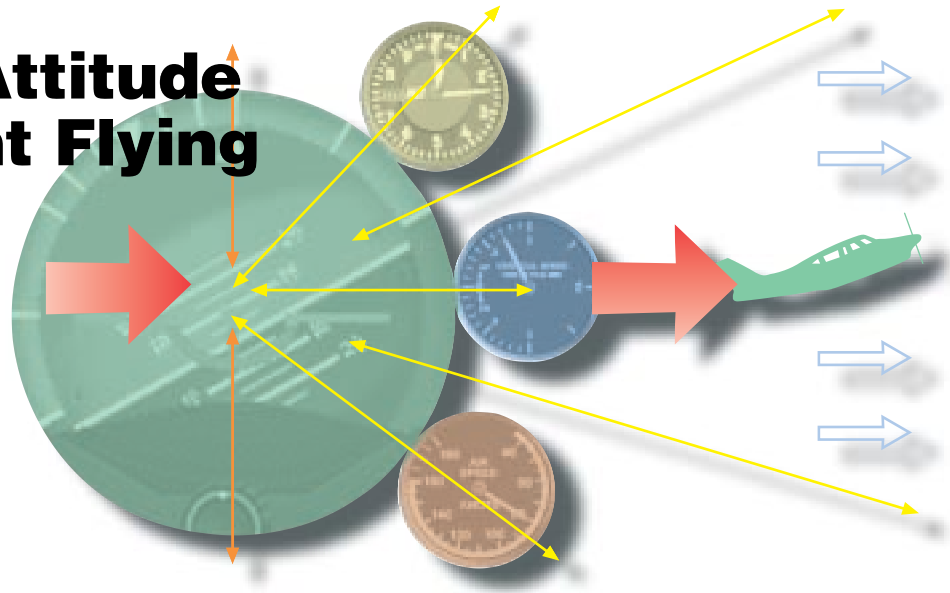
Chapter 4

Airplane Attitude Instrument Flying



Introduction

Attitude instrument flying may be defined as the control of an aircraft's spatial position by using instruments rather than outside visual references.

Any flight, regardless of the aircraft used or route flown, consists of basic maneuvers. In visual flight, you control aircraft attitude with relation to the natural horizon by using certain reference points on the aircraft. In instrument flight, you control aircraft attitude by reference to the flight instruments. A proper interpretation of the flight instruments will give you essentially the same information that outside references do in visual flight. Once you learn the role of all the instruments in establishing and maintaining a desired aircraft attitude, you will be better equipped to control the aircraft in emergency situations involving failure of one or more key instruments.

Two basic methods used for learning attitude instrument flying are "control and performance" and "primary and supporting." Both methods involve the use of the same instruments, and both use the same responses for attitude control. They differ in their reliance on the attitude indicator and interpretation of other instruments.

Attitude instrument flying:
Controlling the aircraft by reference to the instruments rather than outside visual cues.

Control and Performance Method

Aircraft performance is achieved by controlling the aircraft attitude and power (angle of attack and thrust to drag relationship). Aircraft attitude is the relationship of its longitudinal and lateral axes to the Earth's horizon. An aircraft is flown in instrument flight by controlling the attitude and power, as necessary, to produce the desired performance. This is known as the control and performance method of attitude instrument flying and can be applied to any basic instrument maneuver. [Figure 4-1] The three general categories of instruments are control, performance, and navigation instruments.

Control Instruments

The control instruments display immediate attitude and power indications and are calibrated to permit attitude and power adjustments in precise amounts. In this discussion, the term "power" is used in place of the more technically correct term "thrust or drag relationship." Control is determined by reference to the attitude indicator and power indicators. These power indicators vary with aircraft and may include tachometers, manifold pressure, engine pressure ratio, fuel flow, etc.

Instrument flight fundamental:
Attitude + Power = Performance

Figure 4-1. *Control/Performance cross-check method.*

Performance Instruments

The performance instruments indicate the aircraft's actual performance. Performance is determined by reference to the altimeter, airspeed or Mach indicator, vertical speed indicator, heading indicator, angle-of-attack indicator, and turn-and-slip indicator.

Navigation Instruments

The navigation instruments indicate the position of the aircraft in relation to a selected navigation facility or fix. This group of instruments includes various types of course indicators, range indicators, glide-slope indicators, and bearing pointers.

Procedural Steps

1. Establish—Establish an attitude and power setting on the control instruments that will result in the desired performance. Known or computed attitude changes and approximate power settings will help to reduce the pilot's workload.

2. **Trim**—Trim until control pressures are neutralized. Trimming for hands-off flight is essential for smooth, precise aircraft control. It allows pilots to divert their attention to other cockpit duties with minimum deviation from the desired attitude.

Trim: Adjusting the aerodynamic forces on the control surfaces so that the aircraft maintains the set attitude without any control input.

3. Cross-check— Cross-check the performance instruments to determine if the established attitude or power setting is providing the desired performance. The cross-check involves both seeing and interpreting. If a deviation is noted, determine the magnitude and direction of adjustment required to achieve the desired performance.
4. Adjust—Adjust the attitude or power setting on the control instruments as necessary.

Attitude Control

Proper control of aircraft attitude is the result of maintaining a constant attitude, knowing when and how much to change the attitude, and smoothly changing the attitude a precise amount. Aircraft attitude control is accomplished by properly using the attitude indicator. The attitude reference provides an immediate, direct, and corresponding indication of any change in aircraft pitch or bank attitude.

Pitch Control

Pitch changes are made by changing the "pitch attitude" of the miniature aircraft or fuselage dot by precise amounts in relation to the horizon. These changes are measured in degrees or fractions thereof, or bar widths depending upon the type of attitude reference. The amount of deviation from the desired performance will determine the magnitude of the correction.

Bank Control

Bank changes are made by changing the "bank attitude" or bank pointers by precise amounts in relation to the bank scale. The bank scale is normally graduated at 0°, 10°, 20°, 30°, 60°, and 90° and may be located at the top or bottom of the attitude reference. Normally, use a bank angle that approximates the degrees to turn, not to exceed 30°.

Power Control

Proper power control results from the ability to smoothly establish or maintain desired airspeeds in coordination with attitude changes. Power changes are made by throttle adjustments and reference to the power indicators. Power indicators are not affected by such factors as turbulence, improper trim, or inadvertent control pressures. Therefore, in most aircraft little attention is required to ensure the power setting remains constant.

From experience in an aircraft, you know approximately how far to move the throttles to change the power a given amount. Therefore, you can make power changes primarily by throttle movement and then cross-check the indicators to establish a more precise setting. The key is to avoid **fixating** on the indicators while setting the power. A knowledge of approximate power settings for various **flight configurations** will help you avoid overcontrolling power.

Primary and Supporting Method

Another basic method for presenting attitude instrument flying classifies the instruments as they relate to control function as well as aircraft performance. All maneuvers involve some degree of motion about the lateral (pitch), longitudinal (bank/roll), and vertical (yaw) axes. Attitude control is stressed in this handbook in terms of pitch control, bank control, power control, and trim control. [Figure 4-2] Instruments are grouped as they relate to control function and aircraft performance as follows:

Pitch Instruments

Attitude Indicator
Altimeter
Airspeed Indicator
Vertical Speed Indicator

Bank Instruments

Attitude Indicator
Heading Indicator
Magnetic Compass
Turn Coordinator

Power Instruments

Airspeed Indicator
Engine Instruments
- Manifold Pressure Gauge (MP)
- Tachometer/RPM
- Engine Pressure Ratio (EPR)—Jet

For any maneuver or condition of flight, the pitch, bank, and power control requirements are most clearly indicated by certain key instruments. The instruments that provide the most pertinent and essential information will be referred to as primary instruments. Supporting instruments back up and supplement the information shown on the primary

Fixating: Staring at a single instrument, thereby interrupting the cross-check process.

Flight configurations: Adjusting the aircraft controls surfaces (including flaps and landing gear) in a manner that will achieve a specified attitude.

Figure 4-2. *Primary/Supporting cross-check method.*

instruments. Straight-and-level flight at a constant airspeed, for example, means that an exact altitude is to be maintained with zero bank (constant heading) at a constant airspeed. The pitch, bank, and power instruments that tell you whether you are maintaining this flight condition are the:

1. Altimeter—supplies the most pertinent altitude information and is therefore primary for pitch.
2. Heading Indicator—supplies the most pertinent bank or heading information, and is primary for bank.
3. Airspeed Indicator—supplies the most pertinent information concerning performance in level flight in terms of power output, and is primary for power.

Although the attitude indicator is the basic attitude reference, this concept of primary and supporting instruments does not devalue any particular flight instrument. It is the only instrument that portrays instantly and directly the actual flight attitude. It should always be used, when available, in establishing and maintaining pitch-and-bank attitudes. You will better understand the specific use of primary and supporting instruments when the basic instrument maneuvers are presented in detail in Chapter 5, "Airplane Basic Flight Maneuvers."

You will find the terms "direct indicating instrument" and "indirect indicating instrument" used in the following pages. A "direct" indication is the true and instantaneous reflection of airplane pitch-and-bank attitude by the miniature aircraft relative to the horizon bar of the attitude indicator. The altimeter, airspeed indicator, and vertical speed indicator give supporting ("indirect") indications of pitch attitude at a given power setting. The heading indicator and turn needle give supporting indications for bank attitude.

Fundamental Skills

During attitude instrument training, you must develop three fundamental skills involved in all instrument flight maneuvers: instrument cross-check, instrument interpretation, and aircraft control. Although you learn these skills separately and in deliberate sequence, a measure of your proficiency in precision flying will be your ability to integrate these skills into unified, smooth, positive control responses to maintain any prescribed flight path.

Cross-Check

The first fundamental skill is cross-checking (also called "scanning" or "instrument coverage"). Cross-checking is the continuous and logical observation of instruments for attitude and performance information. In attitude instrument flying, the pilot maintains an attitude by reference to instruments that will produce the desired result in performance. Due to human error, instrument error, and airplane performance differences in various atmospheric and loading conditions, it is impossible to establish an attitude and have performance remain constant for a long period of time. These variables make it necessary for the pilot to constantly check the instruments and make appropriate changes in airplane attitude.

Selected Radial Cross-Check

When you use the selected radial cross-check, your eyes spend 80 to 90 percent of the time looking at the attitude indicator, leaving it only to take a quick glance at one of the flight instruments (for this discussion, the five instruments surrounding the attitude indicator will be called the flight instruments). With this method, your eyes never travel directly between the flight instruments but move by way of the attitude indicator. The maneuver being performed determines which instruments to look at in the pattern. [Figure 4-3]

Figure 4-3. *Selected radial cross-check pattern.*

Inverted-V Cross-Check

Moving your eyes from the attitude indicator down to the turn instrument, up to the attitude indicator, down to the vertical speed indicator, and back up to the attitude indicator is called the inverted-V cross-check. [Figure 4-4]

Figure 4-4. *Inverted-V cross-check.*

The Rectangular Cross-Check

If you move your eyes across the top three instruments (airspeed indicator, attitude indicator, and altimeter) and drop them down to scan the bottom three instruments (vertical speed indicator, heading indicator, and turn instrument), their path will describe a rectangle (clockwise or counterclockwise rotation is a personal choice). [Figure 4-5]

This cross-checking method gives equal weight to the information from each instrument, regardless of its importance to the maneuver being performed. However, this method lengthens the time it takes for your eyes to return to an instrument critical to the successful completion of the maneuver.

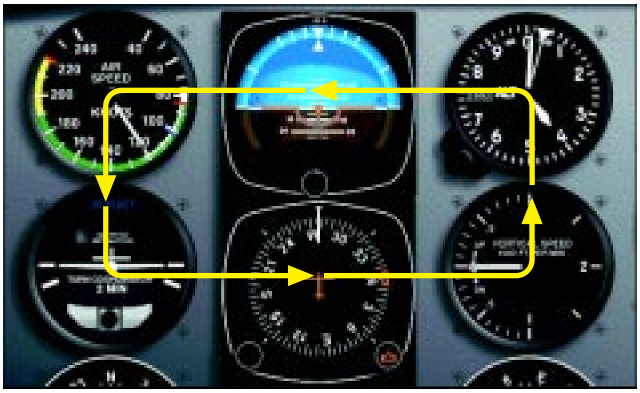


Figure 4-5. *Rectangular cross-check pattern.*

Common Cross-Check Errors

As a beginner, you might cross-check rapidly, looking at the instruments without knowing exactly what you are looking for. With increasing experience in basic instrument maneuvers and familiarity with the instrument indications associated with them, you will learn what to look for, when to look for it, and what response to make. As proficiency increases, you cross-check primarily from habit, suiting your scanning rate and sequence to the demands of the flight situation.

You can expect to make many of the following common scanning errors, both during training and at any subsequent time, if you fail to maintain basic instrument proficiency through practice:

1. Fixation, or staring at a single instrument, usually occurs for a good reason, but has poor results. For instance, you may find yourself staring at your altimeter, which reads 200 feet below the assigned altitude, wondering how the needle got there. While you gaze at the instrument, perhaps with increasing **tension** on the controls, a heading change occurs unnoticed, and more errors accumulate.

   Another common fixation is likely when you initiate an attitude change. For example, you establish a shallow bank for a 90° turn and stare at the heading indicator throughout the turn, instead of maintaining your cross-check of other pertinent instruments. You know the aircraft is turning and you do not need to recheck the heading indicator for approximately 25 seconds after turn entry, yet you cannot take your eyes off the instrument. The problem here may not be entirely due to cross-check error. It may be related to difficulties with one or both of the other fundamental skills. You may be fixating because of uncertainty about reading the heading indicator (interpretation), or because of inconsistency in rolling out of turns (control).
2. Omission of an instrument from your cross-check is another likely fault. It may be caused by failure to anticipate significant instrument indications following attitude changes. For example, on your roll-out from a 180° steep turn, you establish straight-and-level flight with reference to the attitude indicator alone, neglecting to check the heading indicator for constant heading information. Because of precession error, the attitude indicator will temporarily show a slight error, correctable by quick reference to the other flight instruments.
3. Emphasis on a single instrument, instead of on the combination of instruments necessary for attitude information, is an understandable fault during the initial stages of training. You naturally tend to rely on the instrument that you understand most readily, even when it provides erroneous or inadequate information. Reliance on a single instrument is poor technique. For example, you can maintain reasonably close altitude control with the attitude indicator, but you cannot hold altitude with precision without including the altimeter in your cross-check.

Tension: Maintaining an excessively strong grip on the control column; usually results in an overcontrolled situation.

Instrument Interpretation

The second fundamental skill, instrument interpretation, requires the most thorough study and analysis. It begins as you understand each instrument's construction and operating principles. Then you must apply this knowledge to the performance of the aircraft that you are flying, the particular maneuvers to be executed, the cross-check and control techniques applicable to that aircraft, and the flight conditions in which you are operating.

For example, a pilot uses full power in a small airplane for a 5-minute climb from near sea level, and the attitude indicator shows the miniature aircraft two bar widths (twice the thickness of the miniature aircraft wings) above the artificial horizon. [Figure 4-6] The airplane is climbing at 500 feet per minute (fpm) as shown on the vertical speed indicator, and at an airspeed of 90 knots, as shown on the airspeed indicator. With the power available in this particular airplane and the attitude selected by the pilot, the performance is shown on the instruments.

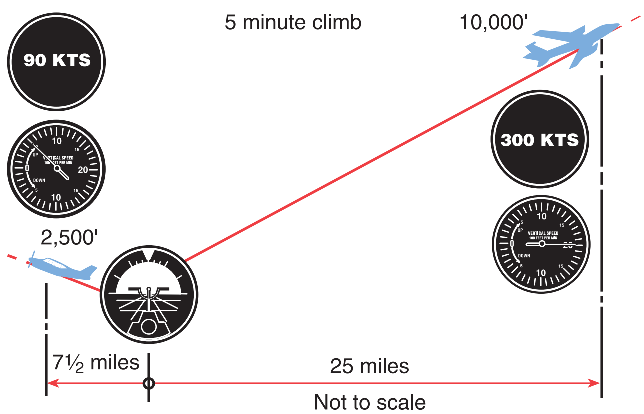


Figure 4-6. *Power and attitude equal performance.*

Now set up the identical picture on the attitude indicator in a jet airplane. With the same airplane attitude as shown in the first example, the vertical speed indicator in the jet reads 2,000 fpm, and the airspeed indicates 300 knots. As you learn the performance capabilities of the aircraft in which you are training, you will interpret the instrument indications appropriately in terms of the attitude of the aircraft. If the pitch attitude is to be determined, the airspeed indicator, altimeter, vertical speed indicator, and attitude indicator provide the necessary information. If the bank attitude is to be determined, the heading indicator, turn coordinator, and attitude indicator must be interpreted.

For each maneuver, you will learn what performance to expect and the combination of instruments you must interpret in order to control aircraft attitude during the maneuver.

Aircraft Control

The third fundamental instrument flying skill is aircraft control. When you use instruments as substitutes for outside references, the necessary control responses and thought processes are the same as those for controlling aircraft performance by means of outside references. Knowing the desired attitude of the aircraft with respect to the natural and artificial horizon, you maintain the attitude or change it by moving the appropriate controls.

Aircraft control is composed of four components: pitch control, bank control, power control, and trim.

1. Pitch control is controlling the rotation of the aircraft about the lateral axis by movement of the elevators. After interpreting the pitch attitude from the proper flight instruments, you exert control pressures to effect the desired pitch attitude with reference to the horizon.

2. Bank control is controlling the angle made by the wing and the horizon. After interpreting the bank attitude from the appropriate instruments, you exert the necessary pressures to move the ailerons and roll the aircraft about the longitudinal axis.

3. Power control is used when interpretation of the flight instruments indicates a need for a change in thrust.

4. Trim is used to relieve all control pressures held after a desired attitude has been attained. An improperly trimmed aircraft requires constant control pressures, produces tension, distracts your attention from cross-checking, and contributes to abrupt and erratic attitude control. The pressures you feel on the controls must be those you apply while controlling a planned change in aircraft attitude, not pressures held because you let the aircraft control you.

Chapter 5

Airplane Basic Flight Maneuvers

Introduction

Instrument flying **techniques** differ according to aircraft type, class, performance capability, and instrumentation. Therefore, the procedures and techniques that follow will need to be modified for application to different types of aircraft. Recommended procedures, performance data, operating limitations, and flight characteristics of a particular aircraft are available in your Pilot's Operating Handbook/Airplane Flight Manual (POH/AFM) for study before practicing the flight maneuvers.

The flight maneuvers discussed here assume the use of a single-engine, propeller-driven **small airplane** with retractable gear and flaps and a panel with instruments representative of those discussed earlier in Chapter 3, "Flight Instruments." With the exception of the instrument takeoff, all of the maneuvers can be performed on "partial panel," with the attitude gyro and heading indicator covered or inoperative.

Straight-and-Level Flight

Pitch Control

The pitch attitude of an airplane is the angle between the longitudinal axis of the airplane and the actual horizon. In level flight, the pitch attitude varies with airspeed and load. For training purposes, the latter factor can normally be disregarded in small airplanes. At a constant airspeed, there is only one specific pitch attitude for level flight. At slow cruise speeds, the level-flight attitude is nose-high; at fast cruise speeds, the level-flight attitude is nose-low. [Figures 5-1 and 5-2] Figure 5-3 shows the attitude at normal cruise speeds.

The pitch instruments are the attitude indicator, the altimeter, the vertical speed indicator, and the airspeed indicator.

Attitude Indicator

The attitude indicator gives you a **direct indication** of pitch attitude. You attain the desired pitch attitude by using the elevator control to raise or lower the miniature aircraft in relation to the horizon bar. This corresponds to the way you adjust pitch attitude in visual flight by raising or lowering the nose of the airplane in relation to the natural horizon. However, unless the airspeed is constant, and until you have established and identified the level-flight attitude for that airspeed, you have no way of knowing whether level flight, as indicated on the attitude indicator, is resulting in level flight as shown on the altimeter, vertical speed indicator, and airspeed indicator. If the miniature aircraft of the attitude indicator is properly adjusted on the ground before takeoff, it will show approximately level flight at normal cruise speed when you complete your level-off from a climb. If further adjustment of the miniature aircraft is necessary, the other pitch instruments must be used to maintain level flight while the adjustment is made.

Technique: The manner or style in which the procedures are executed.

Small airplane: An airplane of 12,500 pounds or less maximum certificated takeoff weight.

Direct indication: The true and instantaneous reflection of aircraft pitch-and-bank attitude by the miniature aircraft, relative to the horizon bar of the attitude indicator.

Figure 5-1. *Pitch attitude and airspeed in level flight, slow cruise speed.*

Figure 5-2. *Pitch attitude and airspeed in level flight, fast cruise speed.*

Figure 5-3. *Pitch attitude and airspeed in level flight, normal cruise speed.*

In practicing pitch control for level flight using only the attitude indicator, restrict the displacement of the horizon bar to a bar width up or down, a half-bar width, then a one-and-one-half bar width. Half-, two-, and three-bar-width nose-high attitudes are shown in figures 5-4, 5-5, and 5-6.

Your instructor pilot may demonstrate these normal pitch corrections while you compare the indications on the attitude indicator with the airplane's position to the natural horizon.

Figure 5-4. *Pitch correction for level flight, half-bar width.*

Pitch attitude changes for corrections to level flight by reference to instruments are much smaller than those commonly used for visual flight. With the airplane correctly trimmed for level flight, the elevator displacement and the **control pressures** necessary to effect these standard pitch changes are usually very slight. Following are a few helpful hints to help you determine how much elevator control pressure is required.

Figure 5-5. *Pitch correction for level flight, two-bar width.*

Control pressures: The amount of physical exertion on the control column necessary to achieve the desired aircraft attitude.

Figure 5-6. *Pitch correction for level flight, three-bar width.*

Figure 5-7. *Using the altimeter for pitch interpretation, a high altitude means a nose-high pitch attitude.*

Figure 5-8. *Pitch correction following altitude increase—lower nose to correct altitude error.*

First, a tight grip on the controls makes it difficult to feel control pressure changes. Relaxing and learning to control "with your eyes and your head" instead of your muscles usually takes considerable conscious effort during the early stages of instrument training.

Second, make smooth and small pitch changes with a positive pressure. Practice these small corrections until you can make pitch corrections up or down, "freezing" (holding constant) the one-half, full, and one-and-one-half bar widths on the attitude indicator.

Third, with the airplane properly trimmed for level flight, momentarily release all of your pressure on the elevator control when you become aware of tenseness. This will remind you that the airplane is stable; except under turbulent conditions, it will maintain level flight if you leave it alone. Even when your eyes tell you that no control change is called for, it will be difficult to resist the impulse to move the controls. This may prove to be one of your most difficult initial training problems.

Altimeter

At constant power, any deviation from level flight (except in turbulent air) must be the result of a pitch change. Therefore, the altimeter gives an **indirect indication** of the pitch attitude in level flight, assuming constant power. Since the altitude should remain constant when the airplane is in level flight, any deviation from the desired altitude signals the need for a pitch change. If you are gaining altitude, the nose must be lowered. [Figures 5-7 and 5-8]

The rate of movement of the altimeter needle is as important as its direction of movement for maintaining level flight without the use of the attitude indicator. An excessive pitch deviation from level flight results in a relatively rapid change of altitude; a slight pitch deviation causes a slow change. Thus, if the altimeter needle moves rapidly clockwise, assume a considerable nose-high deviation from level-flight attitude. Conversely, if the needle moves slowly counterclockwise to indicate a slightly nose-low attitude, assume that the pitch correction necessary to regain the desired altitude is small. As you add the altimeter to the attitude indicator in your cross-check, you will learn to recognize the rate of movement of the altimeter needle for a given pitch change as shown on the attitude indicator.

If you are practicing precision control of pitch in an airplane without an attitude indicator, make small pitch changes by visual reference to the natural horizon, and note the rate of movement of the altimeter. Note what amount of pitch change gives the slowest steady rate of change on the altimeter. Then

Indirect indication: A reflection of aircraft pitch-and-bank attitude by the instruments other than the attitude indicator.

practice small pitch corrections by accurately interpreting and controlling the rate of needle movement.

Your instructor pilot may demonstrate an excessive nose-down deviation (indicated by rapid movement of the altimeter needle) and then, as an example, show you the result of improper corrective technique. The normal impulse is to make a large pitch correction in a hurry, but this inevitably leads to **overcontrolling**. The needle slows down, then reverses direction, and finally indicates an excessive nose-high deviation. The result is tension on the controls, erratic control response, and increasingly extreme control movements. The correct technique, which is slower and smoother, will return the airplane to the desired attitude more quickly, with positive control and no confusion.

When a pitch error is detected, corrective action should be taken promptly, but with light control pressures and two distinct changes of attitude: (1) a change of attitude to stop the needle movement, and (2) a change of attitude to return to the desired altitude.

When you observe that the needle movement indicates an altitude deviation, apply just enough elevator pressure to slow down the rate of needle movement. If it slows down abruptly, ease off some of the pressure until the needle continues to move, but slowly. Slow needle movement means your airplane attitude is close to level flight. Add a little more corrective pressure to stop the direction of needle movement. At this point you are in level flight; a reversal of needle movement means you have passed through it. Relax your control pressures carefully as you continue to cross-check, since changing airspeed will cause changes in the effectiveness of a given control pressure. Next, adjust the pitch attitude with elevator pressure for the rate of change of altimeter needle movement that you have correlated with normal pitch corrections, and return to the desired altitude.

As a rule of thumb, for errors of less than 100 feet, use a half-bar-width correction. [Figures 5-9 and 5-10] For errors in excess of 100 feet, use an initial full-bar-width correction. [Figures 5-11 and 5-12]

Practice predetermined altitude changes using the altimeter alone, then in combination with the attitude indicator.

Overcontrolling: Using more movement in the control column than is necessary to achieve the desired pitch-and-bank condition.

Figure 5-9. *Altitude error, less than 100 feet.*

Figure 5-10. *Pitch correction, less than 100 feet—1/2 bar low to correct altitude error.*

Figure 5-11. *Altitude error, greater than 100 feet.*

Figure 5-12. *Pitch correction, greater than 100 feet—1 bar correction initially.*

Vertical Speed Indicator

The vertical speed indicator gives an indirect indication of pitch attitude and is both a **trend** and a rate instrument. As a trend instrument, it shows immediately the initial vertical movement of the airplane, which, disregarding turbulence, can be considered a reflection of pitch change. To maintain level flight, use the vertical speed indicator in conjunction with the altimeter and attitude indicator. Note any "up" or "down" trend of the needle from zero and apply a very light corrective elevator pressure. As the needle returns to zero, relax the corrective pressure. If your control pressures have been smooth and light, the needle will react immediately and slowly, and the altimeter will show little or no change of altitude.

Used as a rate instrument, the **lag** characteristics of the vertical speed indicator must be considered.

Lag refers to the delay involved before the needle attains a stable indication following a pitch change. Lag is directly proportional to the speed and magnitude of a pitch change. If a slow, smooth pitch change is initiated, the needle will move with minimum lag to a point of deflection corresponding to the extent of the pitch change, and then stabilize as the aerodynamic forces are balanced in the climb or descent. A large and abrupt pitch change will produce erratic needle movement, a reverse indication, and introduce greater time delay (lag) before the needle stabilizes. Pilots are cautioned not to chase the needle when flight through turbulent conditions produces erratic needle movements.

When using the vertical speed indicator as a rate instrument and combining it with the altimeter and attitude indicator to maintain level flight, keep this in mind: the amount the altimeter has moved from the desired altitude governs the rate at which you should return to that altitude. A rule of thumb is to make an attitude change that will result in a vertical-speed rate approximately double your error in altitude. For example, if altitude is off by 100 feet, your rate of return should be approximately 200 feet per minute (fpm). If it is off more than 100 feet, the correction should be correspondingly greater, but should never exceed the optimum rate of climb or descent for your airplane at a given airspeed and configuration.

A deviation more than 200 fpm from the desired rate of return is considered overcontrolling. For example, if you are attempting to return to an altitude at a rate of 200 fpm, a rate in excess of 400 fpm indicates overcontrolling.

When you are returning to an altitude, the vertical speed indicator is the primary pitch instrument. Occasionally, the vertical speed indicator is slightly out of calibration and may indicate a climb or descent when the airplane is in level flight. If you cannot adjust the instrument, you must take the error into consideration when using it for pitch control. For example, if the needle indicates a descent of 200 fpm while in level flight, use this indication as the zero position.

Airspeed Indicator

The airspeed indicator presents an indirect indication of the pitch attitude. At a constant power setting and pitch attitude, airspeed remains constant. [Figure 5-13] As the pitch attitude lowers, airspeed increases, and the nose should be raised. [Figure 5-14] As the pitch attitude rises, airspeed decreases,

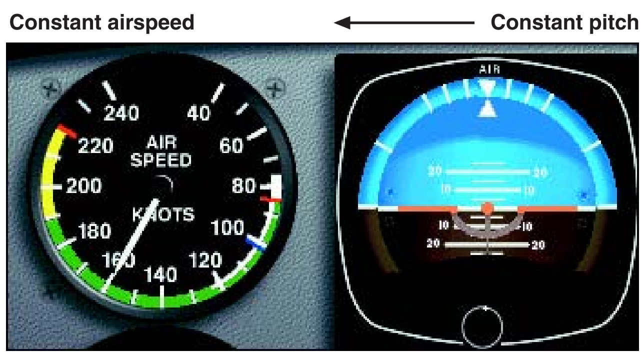


Figure 5-13. *Constant power plus constant pitch equals constant airspeed.*

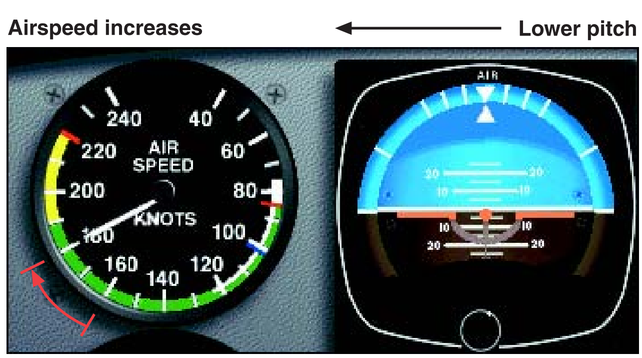


Figure 5-14. *Constant power plus decreased pitch equals increased airspeed.*

Trend: Instruments showing an immediate indication of the direction of aircraft movement.

Lag: The delay that occurs before an instrument needle attains a stable indication.

and the nose should be lowered. [Figure 5-15] A rapid change in airspeed indicates a large pitch change, and a slow change of airspeed indicates a small pitch change.

Figure 5-15. *Constant power plus increased pitch equals decreased airspeed.*

The apparent lag in airspeed indications with pitch changes varies greatly among different airplanes and is due to the time required for the airplane to accelerate or decelerate when the pitch attitude is changed. There is no appreciable lag due to the construction or operation of the instrument. Small pitch changes, smoothly executed, result in an immediate change of airspeed.

Pitch control in level flight is a question of cross-check and interpretation of the instrument panel for the instrument information that will enable you to visualize and control pitch attitude. Regardless of individual differences in cross-check technique, all pilots should use the instruments that give the best information for controlling the airplane in any given maneuver. Pilots should also check the other instruments to aid in maintaining the important, or primary, instruments at the desired indication.

As noted previously, the primary instrument is the one that gives the most pertinent information for any particular maneuver. It is usually the one you should hold at a constant indication. Which instrument is primary for pitch control in level flight, for example? This question should be considered in the context of specific airplane, weather conditions, pilot experience, operational conditions, and other factors. Attitude changes must be detected and interpreted instantly for immediate control action in high-performance airplanes. On the other hand, a reasonably proficient instrument pilot in a slower airplane may rely more on the altimeter for primary pitch information, especially if it is determined that too much reliance on the attitude indicator fails to provide the necessary precise attitude information. Whether the pilot decides to regard the altimeter or the attitude indicator as primary depends on which approach will best help control the attitude.

In this handbook, the altimeter is normally considered as the primary pitch instrument during level flight.

Bank Control

The bank attitude of an airplane is the angle between the lateral axis of the airplane and the natural horizon. To maintain a straight-and-level flight path, you must keep the wings of the airplane level with the horizon (assuming the airplane is in **coordinated** flight). Any deviation from straight flight resulting from bank error should be corrected by coordinated aileron and rudder pressure.

The instruments used for bank control are the attitude indicator, the heading indicator, and the turn coordinator. [Figure 5-16]

Attitude Indicator

The attitude indicator shows any change in bank attitude directly and instantly. On the standard attitude indicator, the angle of bank is shown pictorially by the relationship of the miniature aircraft to the artificial horizon bar, and by the alignment of the pointer with the banking scale at the top of the instrument. On the face of the standard 3-inch instrument, small angles of bank can be difficult to detect by reference to the miniature aircraft, especially if you lean to one side or move your seating position slightly. The position of the scale pointer is a good check against the apparent miniature aircraft position. Disregarding **precession error**, small deviations from straight coordinated flight can be readily detected on the scale pointer. The banking index may be graduated as shown in figure 5-17, or it may lack the 10° and 20° indexes.

Coordinated: Using the controls to maintain or establish various conditions of flight with (1) a minimum disturbance of the forces maintaining equilibrium, or (2) the control action necessary to effect the smoothest changes in equilibrium.

Precession error: The result of the force applied to a spinning gyroscope felt not at the point the force is applied, but at a point 90° in the direction of rotation from that point.

Figure 5-16. *Instruments used for bank control.*

The instrument depicted in figure 5-17 has a scale pointer that moves in the same direction of bank shown by the miniature aircraft. On some attitude indicators, the scale pointer moves in a direction opposite to the direction of bank shown by the miniature aircraft. A bank indication of 30° to the right of the zero, or nose position, indicates a 30° left banking attitude. Errors due to the construction of this instrument are common and predictable, but the obvious advantage of the attitude indicator is that you get an immediate indication of both pitch attitude and bank attitude in a single glance. Even with the precession errors associated with many attitude indicators, the quick attitude presentation requires less visual effort and time for positive control than other flight instruments.

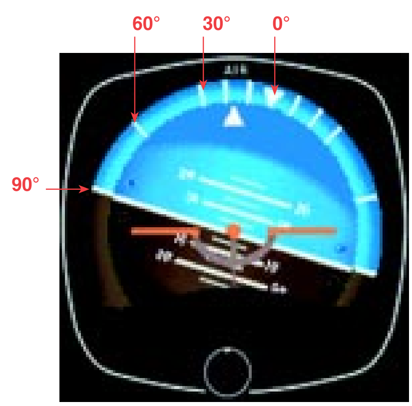


Figure 5-17. *Bank interpretation with the attitude indicator.*

Heading Indicator

The bank attitude of an aircraft in coordinated flight is shown indirectly on the heading indicator, since banking results in a turn and change in heading. Assuming the same airspeed in both instances, a rapid movement of the heading indicator needle (or azimuth card in a directional gyro) indicates a large angle of bank, whereas a slow movement of the needle or card reflects a small angle of bank. If you note the rate of movement of the heading indicator and compare it to the attitude indicator's degrees of bank, you will learn to look for important bank information on the heading indicator. This is especially the case when the attitude indicator's precession error makes a precise check of heading information necessary in order to maintain straight flight.

When you note deviations from straight flight on the heading indicator, make your correction to the desired heading using a bank angle no greater than the number of degrees to be turned. In any case, limit your bank corrections to a bank angle no greater than that required for a standard-rate turn. Use of larger bank angles requires a very high level of proficiency, and normally results in overcontrolling and erratic bank control.

Turn Coordinator

The miniature aircraft of the turn coordinator gives you an indirect indication of the bank attitude of the airplane. When the miniature aircraft is level, the airplane is in straight flight. If the ball is centered, a left deflection of the miniature aircraft means the left wing is low and the airplane is in a left turn. Thus, when the miniature aircraft is in a stabilized deflection, the airplane is turning in the direction indicated. Return to straight flight is accomplished by coordinated aileron and rudder pressure to level the miniature aircraft. Include the miniature aircraft in your cross-check and correct for even the smallest deviations from the desired position. When the instrument is used to maintain straight flight, control pressures must be applied very lightly and smoothly.

The ball of the turn coordinator is actually a separate instrument, conveniently located under the miniature aircraft because the two instruments are used together. The ball instrument indicates the quality of the turn. If the ball is off center, the airplane is slipping or skidding, and the miniature aircraft under these conditions shows an error in bank attitude. Figures 5-18 and 5-19 show the instrument indications for slips and skids, respectively. If the wings are level and the airplane is properly trimmed, the ball will remain in the center, and the airplane will be in straight flight. If the ball is not centered, the airplane is improperly trimmed (or you are holding rudder pressure against proper trim).

Figure 5-18. *Slip indication.*

Figure 5-19. *Skid indication.*

To maintain straight-and-level flight with proper trim, note the direction of ball displacement. If the ball is to the left of center and the left wing is low, apply left rudder pressure (or release right rudder pressure if you are holding it) to center the ball and correct the slip. At the same time apply right aileron pressure as necessary to level the wings, cross-checking the heading indicator and attitude indicator as you center the ball. If the wings are level and the ball is displaced from the center, the airplane is skidding. Note the direction of ball displacement, and use the same corrective technique as for an indicated slip. Center the ball (left ball/left rudder, right ball/right rudder), use aileron as necessary for bank control, and retrim.

To trim the airplane using only the turn coordinator, use aileron pressure to level the miniature aircraft and rudder pressure to center the ball. Hold these indications with control pressures, gradually releasing them as you apply rudder trim sufficient to relieve all rudder pressure. Apply aileron trim, if available, to relieve aileron pressure. With a full instrument panel, maintain a wings-level attitude by reference to all available instruments while you trim the airplane.

Power Control

Power produces thrust which, with the appropriate angle of attack of the wing, overcomes the forces of gravity, drag, and inertia to determine airplane performance.

Power control must be related to its effect on altitude and airspeed, since any change in power setting results in a change in the airspeed or the altitude of the airplane. At any given airspeed, the power setting determines whether the airplane is in level flight, in a climb, or in a descent. If you increase the power while in straight-and-level flight and hold the airspeed constant, the airplane will climb; and if you decrease the power while holding the airspeed constant, the airplane will descend. On the other hand, if you hold altitude constant, the power applied will determine the airspeed.

The relationship between altitude and airspeed determines the need for a change in pitch or power. If the airspeed is off the desired value, always check the altimeter before deciding that a power change is necessary. If you think of altitude and airspeed as interchangeable, you can trade altitude for airspeed by lowering the nose, or convert airspeed to altitude by raising the nose. If your altitude is higher than desired and your airspeed is low, or vice versa, a change in pitch alone may return the airplane to the desired altitude and airspeed. [Figure 5-20] If both airspeed and altitude are high or if both are low, then a change in both pitch and power is necessary in order to return to the desired airspeed and altitude. [Figure 5-21]

For changes in airspeed in straight-and-level flight, pitch, bank, and power must be coordinated in order to maintain constant altitude and heading. When power is changed to vary airspeed in straight-and-level flight, a single-engine, propeller-driven airplane tends to change attitude around all axes of movement. Therefore, to maintain constant altitude and heading, you will need to apply various control pressures in proportion to the change in power. When you add power to increase airspeed, the pitch instruments will show a climb unless you apply forward-elevator control pressure as the airspeed changes. When you increase power, the airplane tends to yaw and roll to the left unless you apply counteracting aileron and rudder pressures. Keeping ahead of these changes requires an increase in your cross-check speed, which varies with the type of airplane and its torque characteristics, the extent of power and speed change involved, and your technique in making the power change.

Figure 5-20. *Airspeed low and altitude high (lower pitch).*

Figure 5-21. *Airspeed and altitude high (lower pitch and reduce power).*

Power Settings

Power control and airspeed changes are much easier when you know in advance the approximate power settings necessary to maintain various airspeeds in straight-and-level flight. However, to change airspeed any appreciable amount, the common procedure is to **underpower** or **overpower** on initial power changes to accelerate the rate of airspeed change. (For small speed changes, or in airplanes that decelerate or accelerate rapidly, overpowering or underpowering is not necessary.)

Consider the example of an airplane that requires 23 inches of manifold pressure to maintain a normal cruising airspeed of 140 knots, and 18 inches of manifold pressure to maintain an airspeed of 100 knots. The reduction in airspeed from 140 knots to 100 knots while maintaining straight-and-level flight is discussed below and illustrated in figures 5-22, 5-23, and 5-24.

Instrument indications, prior to the power reduction, are shown in figure 5-22. The basic attitude is established and maintained on the attitude indicator, and the specific pitch, bank, and power control requirements are detected on these primary instruments:

Altimeter—Primary Pitch
Heading Indicator—Primary Bank
Airspeed Indicator—Primary Power

Supporting pitch-and-bank instruments are shown in the illustrations. The supporting power instrument is the manifold pressure gauge (or tachometer if the propeller is fixed-pitch).

As you make a smooth power reduction to approximately 15" Hg (underpower), the manifold pressure gauge becomes the primary power instrument. [Figure 5-23] With practice, you will be able to change a power setting with only a brief glance at the power instrument, by sensing the movement of the throttle, the change in sound, and the changes in the feel of control pressures.

Figure 5-22. *Straight-and-level flight (normal cruising speed).*

Underpower: Using less power than required for the purpose of achieving a faster rate of airspeed change.

Overpower: Using more power than required for the purpose of achieving a faster rate of airspeed change.

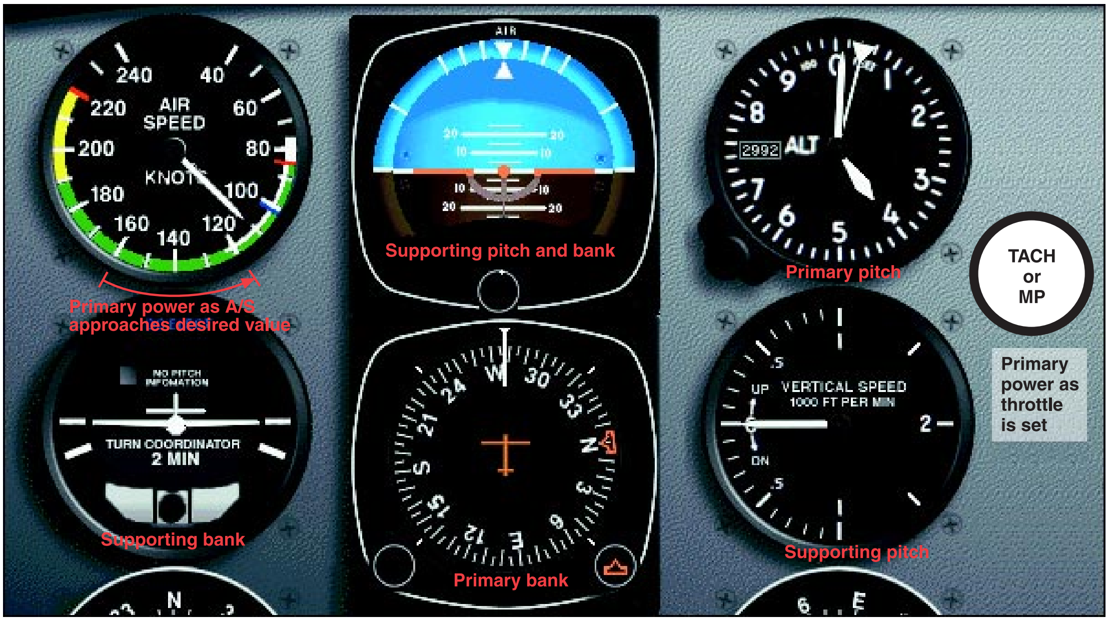


Figure 5-23. *Straight-and-level flight (airspeed decreasing).*

As the thrust decreases, increase the speed of your cross-check and be ready to apply left rudder, back-elevator, and aileron control pressure the instant the pitch-and-bank instruments show a deviation from altitude and heading. As you become proficient, you will learn to cross-check, interpret, and control the changes with no deviation of heading and altitude. Assuming smooth air and ideal control technique, as airspeed decreases, a proportionate increase in airplane pitch attitude is required to maintain altitude. Similarly, effective torque control means counteracting yaw with rudder pressure.

As the power is reduced, the altimeter is primary for pitch, the heading indicator is primary for bank, and the manifold pressure gauge is momentarily primary for power (at 15" Hg in this example). Control pressures should be trimmed off as the airplane decelerates. As the airspeed approaches the desired airspeed of 100 knots, the manifold pressure is adjusted to approximately 18" Hg and becomes the supporting power instrument. The airspeed indicator again becomes primary for power. [Figure 5-24]

Airspeed Changes in Straight-and-Level Flight

Practice of airspeed changes in straight-and-level flight provides an excellent means of developing increased proficiency in all three basic instrument skills, and brings out some common errors to be expected during training in straight-and-level flight. Having learned to control the airplane in a **clean configuration** (minimum drag conditions), you can increase your proficiency in cross-check and control by practicing speed changes while extending or retracting the flaps and landing gear. While practicing, be sure you comply with the airspeed limitations specified in your POH/AFM for gear and flap operation.

Sudden and exaggerated attitude changes may be necessary in order to maintain straight-and-level flight as the landing gear is extended and the flaps are lowered in some airplanes. The nose tends to pitch down with gear extension, and when flaps are lowered, lift increases momentarily (at partial flap settings) followed by a marked increase in drag as the flaps near maximum extension.

Clean configuration: Placing all flight control surfaces in order to create minimum drag; in most aircraft this means flaps and gear retracted.

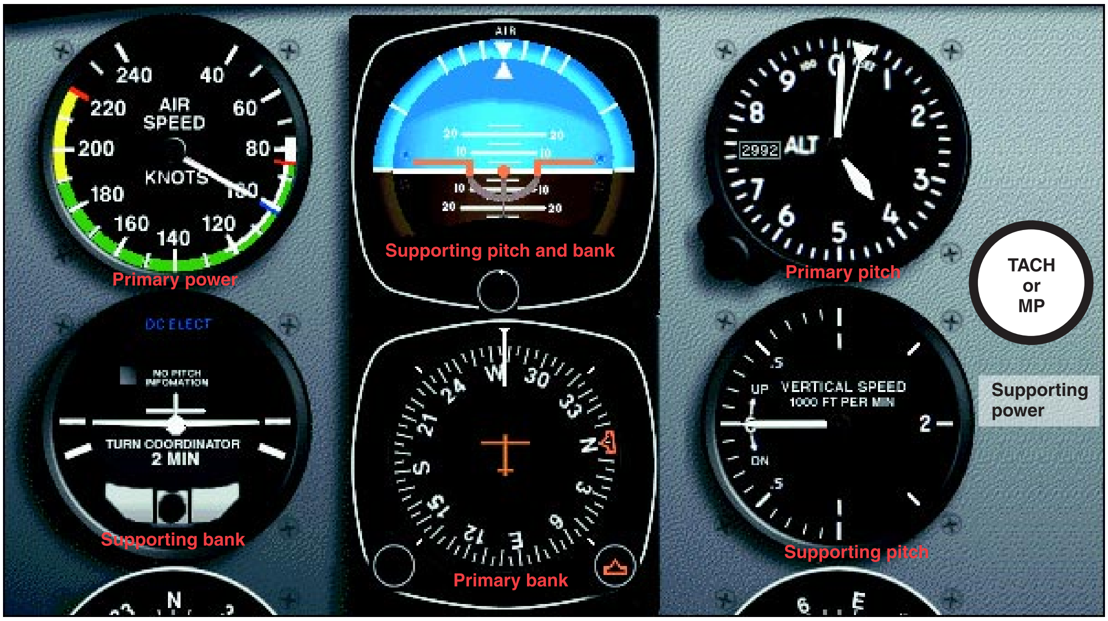


Figure 5-24. *Straight-and-level flight (reduced airspeed stabilized).*

Control technique varies according to the lift and drag characteristics of each airplane. Accordingly, knowledge of the power settings and trim changes associated with different combinations of airspeed, gear and flap configurations will reduce your instrument cross-check and interpretation problems.

For example, assume that in straight-and-level flight, an airplane indicates 145 knots with power at 22" Hg manifold pressure/2,300 RPM, gear and flaps up. After reduction in airspeed, with gear and flaps fully extended, straight-and-level flight at the same altitude requires 25" Hg manifold pressure/2,500 RPM. Maximum gear extension speed is 125 knots; maximum flap extension speed is 105 knots. Airspeed reduction to 95 knots, gear and flaps down, can be made in the following manner:

1. Increase RPM to 2,500, since a high power setting will be used in full drag configuration.

2. Reduce manifold pressure to 10" Hg. As the airspeed decreases, increase cross-check speed.

3. Make trim adjustments for an increased angle of attack and decrease in torque.

4. As you lower the gear at 125 knots, the nose may tend to pitch down and the rate of deceleration increases. Increase pitch attitude to maintain constant altitude, and trim off some of the back-elevator pressures. If you lower full flaps at this point, your cross-check, interpretation, and control must be very rapid. A less difficult technique is to stabilize the airspeed and attitude with gear down before lowering the flaps.

5. Since 18" Hg manifold pressure will hold level flight at 95 knots with the gear down, increase power smoothly to that setting as the airspeed indicator shows approximately 100 knots, and retrim. The attitude indicator now shows approximately two-and-a-half bar width nose-high in straight-and-level flight.

6. Actuate the flap control and simultaneously increase power to the predetermined setting (25" Hg) for the desired airspeed, and trim off the pressures necessary to hold constant altitude and heading. The attitude indicator now shows a bar-width nose-low in straight-and-level flight at 95 knots.

You will have developed a high level of proficiency in the basic skills involved in straight-and-level flight when you can consistently maintain constant altitude and heading with smooth pitch, bank, power, and trim control during these pronounced changes in trim.

Trim Technique

Proper **trim** technique is essential for smooth and precise aircraft control during all phases of flight. By relieving all control pressures, it is much easier to hold a given attitude constant, and you can devote more attention to other cockpit duties.

An aircraft is trimmed by applying control pressures to establish a desired attitude, then adjusting the trim so the aircraft will maintain that attitude when the flight controls are released. Trim the aircraft for coordinated flight by centering the ball of the turn-and-slip indicator. This is done by using rudder trim in the direction the ball is displaced from the center. Differential power control on multiengine aircraft is an additional factor affecting coordinated flight. Use balanced power or thrust, when possible, to aid in maintaining coordinated flight.

Changes in attitude, power, or configuration will require a trim adjustment, in most cases. Using trim alone to establish a change in aircraft attitude invariably leads to erratic aircraft control. Smooth and precise attitude changes are best attained by a combination of control pressures and trim adjustments. Therefore, when used correctly, trim adjustment is an aid to smooth aircraft control.

Common Errors in Straight-and-Level Flight

Pitch

Pitch errors usually result from the following faults:

1. Improper adjustment of the attitude indicator's miniature aircraft to the wings-level attitude. Following your initial level-off from a climb, check the attitude indicator and make any necessary adjustment in the miniature aircraft for level flight indication at normal cruise airspeed.

2. Insufficient cross-check and interpretation of pitch instruments. For example, the airspeed indication is low. Believing you are in a nose-high attitude, you react with forward pressure without noting that a low power setting is the cause of the airspeed discrepancy. Increase your cross-check speed to include all relevant instrument indications before you make a control response.

3. **Uncaging** the attitude indicator (if it has a caging feature) when the airplane is not in level flight. The altimeter and heading indicator must be stabilized with airspeed indication at normal cruise when you pull out the caging knob, if you expect the instrument to read straight-and-level at normal cruise airspeed.

4. Failure to interpret the attitude indicator in terms of the existing airspeed.

5. Late pitch corrections. Pilots commonly like to leave well enough alone. When the altimeter shows a 20-foot error, there is a reluctance to correct it, perhaps because of fear of overcontrolling. If overcontrolling is the error, the more you practice small corrections and find out the cause of overcontrolling, the closer you will be able to hold your altitude. If you tolerate a deviation, your errors will increase.

6. Chasing the vertical-speed indications. This tendency can be corrected by proper cross-check of other pitch instruments, as well as by increasing your understanding of the instrument characteristics.

7. Using excessive pitch corrections for the altimeter evaluation. Rushing a pitch correction by making a large pitch change usually aggravates the existing error and saves neither time nor effort.

8. Failure to maintain established pitch corrections. This is a common error associated with cross-check and trim errors. For example, having established a pitch change to correct an altitude error, you tend to slow down your cross-check, waiting for the airplane to stabilize in the new pitch attitude. To maintain the attitude, you must continue to cross-check and trim off the pressures you are holding.

Trim: Adjusting the aerodynamic forces on the control surfaces so that the aircraft maintains the set attitude without any control input.

Uncaging: Unlocking the gimbals of a gyroscopic instrument, making it susceptible to damage by abrupt flight maneuvers or rough handling.

9. Fixations during cross-check. After initiating a heading correction, for example, you become preoccupied with bank control and neglect to notice a pitch error. Likewise, during an airspeed change, unnecessary gazing at the power instrument is common. Bear in mind that a small error in power setting is of less consequence than large altitude and heading errors. The airplane will not decelerate any faster if you stare at the manifold pressure gauge than if you continue your cross-check.

Heading

Heading errors usually result from the following faults:

1. Failure to cross-check the heading indicator, especially during changes in power or pitch attitude.

2. Misinterpretation of changes in heading, with resulting corrections in the wrong direction.

3. Failure to note, and remember, a preselected heading.

4. Failure to observe the rate of heading change and its relation to bank attitude.

5. Overcontrolling in response to heading changes, especially during changes in power settings.

6. Anticipating heading changes with premature application of rudder control.

7. Failure to correct small heading deviations. Unless zero error in heading is your goal, you will find yourself tolerating larger and larger deviations. Correction of a 1° error takes a lot less time and concentration than correction of a 20° error.

8. Correcting with improper bank attitude. If you correct a 10° heading error with a 20° bank correction, you can roll past the desired heading before you have the bank established, requiring another correction in the opposite direction. Do not multiply existing errors with errors in corrective technique.

9. Failure to note the cause of a previous heading error and thus repeating the same error. For example, your airplane is out of trim, with a left wing low tendency. You repeatedly correct for a slight left turn, yet do nothing about trim.

10. Failure to set the heading indicator properly, or failure to uncage it.

Power

Power errors usually result from the following faults:

1. Failure to know the power settings and pitch attitudes appropriate to various airspeeds and airplane configurations.

2. Abrupt use of throttle.

3. Failure to lead the airspeed when making power changes. For example, during an airspeed reduction in level flight, especially with gear and flaps extended, adjust the throttle to maintain the slower speed before the airspeed reaches the desired speed. Otherwise, the airplane will decelerate to a speed lower than that desired, resulting in further power adjustments. How much you lead the airspeed depends upon how fast the airplane responds to power changes.

4. Fixation on airspeed or manifold pressure instruments during airspeed changes, resulting in erratic control of both airspeed and power.

Trim

Trim errors usually result from the following faults:

1. Improper adjustment of seat or rudder pedals for comfortable position of legs and feet. Tension in the ankles makes it difficult to relax rudder pressures.

2. Confusion as to the operation of trim devices, which differ among various airplane types. Some trim wheels are aligned appropriately with the airplane's axes; others are not. Some rotate in a direction contrary to what you expect.

3. Faulty sequence in trim technique. Trim should be used, not as a substitute for control with the wheel (stick) and rudders, but to relieve pressures already held to stabilize attitude. As you gain proficiency, you become familiar with trim settings, just as you do with power settings. With little conscious effort, you trim off pressures continually as they occur.

4. Excessive trim control. This induces control pressures that must be held until you retrim properly. Use trim frequently and in small amounts.

5. Failure to understand the cause of trim changes. If you do not understand the basic aerodynamics related to the basic instrument skills, you will continually lag behind the airplane.

Straight Climbs and Descents

Climbs

For a given power setting and load condition, there is only one attitude that will give the most efficient rate of climb. The airspeed and the climb power setting that will determine this climb attitude are given in the performance data found in your POH/AFM. Details of the technique for entering a climb vary according to airspeed on entry and the type of climb (constant airspeed or constant rate) desired. (Heading and trim control are maintained as discussed under straight-and-level flight.)

Entry

To enter a constant-airspeed climb from cruising airspeed, raise the miniature aircraft to the approximate nose-high indication for the predetermined climb speed. The attitude will vary according to the type of airplane you are flying. Apply light back-elevator pressure to initiate and maintain the climb attitude. The pressures will vary as the airplane decelerates. Power may be advanced to the climb power setting simultaneously with the pitch change, or after the pitch change is established and the airspeed approaches climb speed. If the transition from level flight to climb is smooth, the vertical speed indicator will show an immediate trend upward, continue to move slowly, then stop at a rate appropriate to the stabilized airspeed and attitude. (Primary and supporting instruments for the climb entry are shown in figure 5-25.)

Figure 5-25. *Climb entry for constant-airspeed climb.*

Figure 5-26. *Stabilized climb at constant airspeed.*

Once the airplane stabilizes at a constant airspeed and attitude, the airspeed indicator is primary for pitch and the heading indicator remains primary for bank. [Figure 5-26] You will monitor the tachometer or manifold pressure gauge as the primary power instrument to ensure the proper climb power setting is being maintained. If the climb attitude is correct for the power setting selected, the airspeed will stabilize at the desired speed. If the airspeed is low or high, make an appropriate small pitch correction.

To enter a constant-airspeed climb, first complete the airspeed reduction from cruise airspeed to climb speed in straight-and-level flight. The climb entry is then identical to entry from cruising airspeed, except that power must be increased simultaneously to the climb setting as the pitch attitude is increased. Climb entries on partial panel are more easily and accurately controlled if you enter the maneuver from climbing speed.

The technique for entering a constant-rate climb is very similar to that used for entry to a constant-airspeed climb from climb airspeed. As the power is increased to the approximate setting for the desired rate, simultaneously raise the miniature aircraft to the climbing attitude for the desired airspeed and rate of climb. As the power is increased, the airspeed indicator is primary for pitch control until the vertical speed approaches the desired value. As the vertical-speed needle stabilizes, it becomes primary for pitch control and the airspeed indicator becomes primary for power control. [Figure 5-27]

Pitch and power corrections must be promptly and closely coordinated. For example, if the vertical speed is correct, but the airspeed is low, add power. As the power is increased, the miniature aircraft must be lowered slightly to maintain constant vertical speed. If the vertical speed is high and the airspeed is low, lower the miniature aircraft slightly and note the increase in airspeed to determine whether or not a power change is also necessary. [Figure 5-28] Familiarity with the approximate power settings helps to keep your pitch and power corrections at a minimum.

Figure 5-27. *Stabilized climb at constant rate.*

Figure 5-28. *Airspeed low and vertical speed high—reduce pitch.*

Leveling Off

To level-off from a climb and maintain an altitude, it is necessary to start the level-off before reaching the desired altitude. The amount of lead varies with rate of climb and pilot technique. If your airplane is climbing at 1,000 fpm, it will continue to climb at a decreasing rate throughout the transition to level flight. An effective practice is to lead the altitude by 10 percent of the vertical speed shown (500 fpm/ 50-foot lead, 1,000 fpm/100-foot lead).

To level-off at cruising airspeed, apply smooth, steady forward-elevator pressure toward level-flight attitude for the speed desired. As the attitude indicator shows the pitch change, the vertical-speed needle will move slowly toward zero, the altimeter needle will move more slowly, and the airspeed will show acceleration. [Figure 5-29] Once the altimeter, attitude indicator, and vertical speed indicator show level flight, constant changes in pitch and torque control will have to be made as the airspeed increases. As the airspeed approaches cruising speed, reduce power to the cruise setting. The amount of lead depends upon the rate of acceleration of your airplane.

To level-off at climbing airspeed, lower the nose to the pitch attitude appropriate to that airspeed in level flight. Power is simultaneously reduced to the setting for that airspeed as the pitch attitude is lowered. If your power reduction is at a rate proportionate to the pitch change, the airspeed will remain constant.

Descents

A descent can be made at a variety of airspeeds and attitudes by reducing power, adding drag, and lowering the nose to a predetermined attitude. Sooner or later the airspeed will stabilize at a constant value. Meanwhile, the only flight instrument providing a positive attitude reference, by itself, is the attitude indicator. Without the attitude indicator (such as during a partial-panel descent) the airspeed indicator, the altimeter, and the vertical speed indicator will be showing varying rates of change until the airplane decelerates to a constant airspeed at a constant attitude. During the transition, changes in control pressure and trim, as well as cross-check and interpretation, must be very accurate if you expect to maintain positive control.

Figure 5-29. *Level-off at cruising speed.*

Entry

The following method for entering descents is effective either with or without an attitude indicator. First, reduce airspeed to your selected descent airspeed while maintaining straight-and-level flight, then make a further reduction in power (to a predetermined setting). As the power is adjusted, simultaneously lower the nose to maintain constant airspeed, and trim off control pressures.

During a constant-airspeed descent, any deviation from the desired airspeed calls for a pitch adjustment. For a constant-rate descent, the entry is the same, but the vertical-speed indicator is primary for pitch control (after it stabilizes near the desired rate), and the airspeed indicator is primary for power control. Pitch and power must be closely coordinated when corrections are made, as they are in climbs. [Figure 5-30]

Leveling Off

The level-off from a descent must be started before you reach the desired altitude. The amount of lead depends upon the rate of descent and control technique. With too little lead, you will tend to overshoot the selected altitude unless your technique is rapid. Assuming a 500-fpm rate of descent, lead the altitude by 100–150 feet for a level-off at an airspeed higher than descending speed. At the lead point, add power to the appropriate level-flight cruise setting. [Figure 5-31] Since the nose will tend to rise as the airspeed increases, hold forward-elevator pressure to maintain the vertical speed at the descending rate until approximately 50 feet above the altitude, then smoothly adjust the pitch attitude to the level-flight attitude for the airspeed selected.

To level-off from a descent at descent airspeed, lead the desired altitude by approximately 50 feet, simultaneously adjusting the pitch attitude to level flight and adding power to a setting that will hold the airspeed constant. [Figure 5-32] Trim off the control pressures and continue with the normal straight-and-level flight cross-check.

Figure 5-30. *Constant airspeed descent, airspeed high—reduce power.*

Figure 5-31. *Level-off airspeed higher than descent airspeed.*

Figure 5-32. *Level-off at descent airspeed.*

Common Errors in Straight Climbs and Descents

Common errors result from the following faults:

1. Overcontrolling pitch on climb entry. Until you know the pitch attitudes related to specific power settings used in climbs and descents, you will tend to make larger than necessary pitch adjustments. One of the most difficult habits to acquire during instrument training is to restrain the impulse to disturb a flight attitude until you know what the result will be. Overcome your inclination to make a large control movement for a pitch change, and learn to apply small control pressures smoothly, cross-checking rapidly for the results of the change, and continuing with the pressures as your instruments show the desired results at a rate you can interpret. Small pitch changes can be easily controlled, stopped, and corrected; large changes are more difficult to control.

2. Failure to vary the rate of cross-check during speed, power, or attitude changes or climb or descent entries.

3. Failure to maintain a new pitch attitude. For example, you raise the nose to the correct climb attitude, and as the airspeed decreases, you either overcontrol and further increase the pitch attitude, or allow the nose to lower. As control pressures change with airspeed changes, cross-check must be increased and pressures readjusted.

4. Failure to trim off pressures. Unless you trim, you will have difficulty determining whether control pressure changes are induced by aerodynamic changes or by your own movements.

5. Failure to learn and use proper power settings.

6. Failure to cross-check both airspeed and vertical speed before making pitch or power adjustments.

7. Improper pitch and power coordination on slow-speed level-offs, due to slow cross-check of airspeed and altimeter indications.

8. Failure to cross-check the vertical speed indicator against the other pitch control instruments, resulting in chasing the vertical speed.

9. Failure to note the rate of climb or descent to determine the lead for level-offs, resulting in overshooting or undershooting the desired altitude.

10. Ballooning (allowing the nose to pitch up) on level-offs from descents, resulting from failure to maintain descending attitude with forward-elevator pressure as power is increased to the level flight cruise setting.

11. Failure to recognize the approaching straight-and-level flight indications as you level-off. Until you have positively established straight-and-level flight, maintain an accelerated cross-check.

Turns

Standard-Rate Turns

To enter a standard-rate level turn, apply coordinated aileron and rudder pressures in the desired direction of turn. Pilots commonly roll into turns at a much too rapid rate. During initial training in turns, base your control pressures on your rate of cross-check and interpretation. There is nothing to be gained by maneuvering an airplane faster than your capacity to keep up with the changes in instrument indications.

On the roll-in, use the attitude indicator to establish the approximate angle of bank, then check the turn coordinator's miniature aircraft for a standard-rate turn indication. Maintain the bank for this rate of turn, using the turn coordinator's miniature aircraft as the primary bank reference and the attitude indicator as the supporting bank instrument. [Figure 5-33] Note the exact angle of bank shown on the banking scale of the attitude indicator when the turn coordinator indicates a standard-rate turn.

During the roll-in, check the altimeter, vertical speed indicator, and attitude indicator for the necessary pitch adjustments as the vertical lift component decreases with an increase in bank. If constant airspeed is to be maintained, the airspeed indicator becomes primary for power, and the throttle must be adjusted as drag increases. As the bank is established, trim off the pressures applied during pitch and power changes.

Figure 5-33. *Standard-rate turn, constant airspeed.*

To recover to straight-and-level flight, apply coordinated aileron and rudder pressures opposite the direction of turn. If you strive for the same rate of roll-out you used to roll into the turn, you will encounter fewer problems in estimating the lead necessary for roll-out on exact headings, especially on partial-panel maneuvers. As you initiate the turn recovery, the attitude indicator becomes the primary bank instrument. When the airplane is approximately level, the heading indicator is the primary bank instrument as in straight-and-level flight. Pitch, power, and trim adjustments are made as changes in vertical lift component and airspeed occur. The ball should be checked throughout the turn, especially if control pressures are held rather than trimmed off.

Some airplanes are very stable during turns, and slight trim adjustments permit hands-off flight while the airplane remains in the established attitude. Other airplanes require constant, rapid cross-check and control during turns to correct overbanking tendencies. Due to the interrelationship of pitch, bank, and airspeed deviations during turns, your cross-check must be fast in order to prevent an accumulation of errors.

Turns to Predetermined Headings

As long as an airplane is in a coordinated bank, it continues to turn. Thus, the roll-out to a desired heading must be started before the heading is reached. The amount of lead varies with the relationship between the rate of turn, angle of bank, and rate of recovery. For small heading changes, use a bank angle that does not exceed the number of degrees to be turned. Lead the desired heading by one-half the number of degrees of bank used. For example, if you maintain a 10° bank during a change in heading, start the roll-out 5° before you reach the desired heading. For larger changes in heading, the amount of lead will vary since the angle of bank for a standard-rate turn varies with the true airspeed.

Practice with a lead of one-half the angle of bank until you have determined the precise lead suitable to your technique. If your rates of roll-in and roll-out are consistent, you can readily determine the precise amount of lead suitable to your particular roll-out technique by noting the amount that you consistently undershoot or overshoot the headings.

Figure 5-34. *Turn coordinator calibration.*

Timed Turns

A timed turn is a turn in which the clock and the turn coordinator are used to change heading a definite number of degrees in a given time. For example, in a standard-rate turn (3° per second), an airplane turns 45° in 15 seconds; in a half-standard-rate turn, the airplane turns 45° in 30 seconds.

Prior to performing timed turns, the turn coordinator should be **calibrated** to determine the accuracy of its indications. [Figure 5-34] Establish a standard-rate turn as indicated by the turn coordinator, and as the sweep-second hand of the clock passes a cardinal point (12, 3, 6, 9), check the heading on the heading indicator. While holding the indicated rate of turn constant, note the indicated heading changes at 10-second intervals. If the airplane turns more or less than 30° in that interval, a larger or smaller deflection of the miniature aircraft of the turn coordinator is necessary to produce a standard-rate turn. When you have calibrated the turn coordinator during turns in each direction, note the corrected deflections, if any, and apply them during all timed turns.

The same cross-check and control technique is used in making timed turns that you use to execute turns to predetermined headings, except that you substitute the clock for the heading indicator. The miniature aircraft of the turn coordinator is primary for bank control, the altimeter is primary for pitch control, and the airspeed indicator is primary for power control. Start the roll-in when the clock's second hand passes a cardinal point, hold the turn at the calibrated standard rate indication (or half-standard rate for small heading changes), and begin the roll-out when the computed number of seconds has elapsed. If the rates of roll-in and roll-out are the same, the time taken during entry and recovery does not need to be considered in the time computation.

If you practice timed turns with a full instrument panel, check the heading indicator for the accuracy of your turns. If you execute the turns without the gyro heading indicator, use the magnetic compass at the completion of the turn to check turn accuracy, taking compass deviation errors into consideration.

Calibrated: The instrument indication was compared with a standard value to determine the accuracy of the instrument.

Compass Turns

In most small airplanes, the magnetic compass is the only direction-indicating instrument independent of other airplane instruments and power sources. Because of its operating characteristics, called compass errors, pilots are prone to use it only as a reference for setting the heading indicator, but a knowledge of magnetic compass characteristics will enable you to use the instrument to turn your airplane to correct headings and maintain them.

Bear in mind the following points when making turns to magnetic compass headings or when using the magnetic compass as a reference for setting the heading indicator:

1. If you are on a northerly heading and you start a turn to the east or west, the compass indication lags, or shows a turn in the opposite direction.

2. If you are on a southerly heading and you start a turn toward the east or west, the compass indication precedes the turn, showing a greater amount of turn than is actually occurring.

3. When you are on an east or west heading, the compass indicates correctly as you start a turn in either direction.

4. If you are on an easterly or westerly heading, acceleration results in a northerly turn indication; deceleration results in a southerly turn indication.

5. If you maintain a north or south heading, no error results from diving, climbing, or changing airspeed.

With an angle of bank between 15° and 18°, the amount of lead or lag to be used when turning to northerly or southerly headings varies with, and is approximately equal to, the latitude of the locality over which the turn is being made. When turning to a heading of north, the lead for roll-out must include the number of degrees of your latitude, plus the lead you normally use in recovery from turns. During a turn to a south heading, maintain the turn until the compass passes south the number of degrees of your latitude, minus your normal roll-out lead. [Figure 5-35]

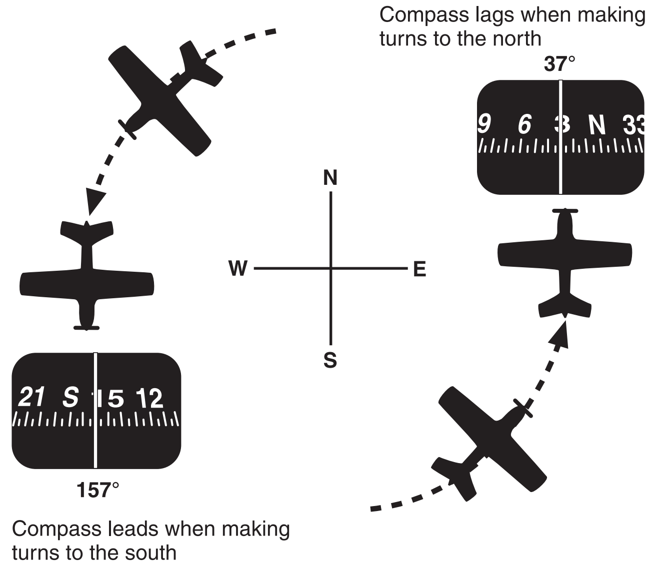


Figure 5-35. *Northerly and southerly turn error.*

For example, when turning from an easterly direction to north, where the latitude is 30°, start the roll-out when the compass reads 37° (30° plus one-half the 15° angle of bank, or whatever amount is appropriate for your rate of roll-out). When turning from an easterly direction to south, start the roll-out when the magnetic compass reads 203° (180° plus 30° minus one-half the angle of bank). When making similar turns from a westerly direction, the appropriate points at which to begin your roll-out would be 323° for a turn to north, and 157° for a turn to south.

When turning to a heading of east or west from a northerly direction, start the roll-out approximately 10° to 12° before the east or west indication is reached. When turning to an east or west heading from a southerly direction, start the roll-out approximately 5° before the east or west indication is reached. When turning to other headings, the lead or lag must be interpolated.

Abrupt changes in attitude or airspeed and the resulting erratic movements of the compass card make accurate interpretations of the instrument very difficult. Proficiency in compass turns depends on knowledge of the compass characteristics, smooth control technique, and accurate bank-and-pitch control.

Figure 5-36. *Steep left turn.*

Steep Turns

For purposes of instrument flight training in conventional airplanes, any turn greater than a standard rate may be considered steep. [Figure 5-36] The exact angle of bank at which a normal turn becomes steep is unimportant. What is important is that you learn to control the airplane with bank attitudes in excess of those you normally use on instruments. Practice in **steep turns** will not only increase your proficiency in the basic instrument flying skills, but also enable you to react smoothly, quickly, and confidently to unexpected abnormal flight attitudes under instrument flight conditions.

Pronounced changes occur in the effects of aerodynamic forces on aircraft control at progressively steepening bank attitudes. Skill in cross-check, interpretation, and control is increasingly necessary in proportion to the amount of these changes, though the techniques for entering, maintaining, and recovering from the turn are the same in principle for steep turns as for shallower turns.

Enter a steep turn exactly as you do a shallower turn, but prepare to cross-check rapidly as the turn steepens. Because of the greatly reduced vertical lift component, pitch control is usually the most difficult aspect of this maneuver. Unless immediately noted and corrected with a pitch increase, the loss of vertical lift results in rapid movement of the altimeter, vertical speed, and airspeed needles. The faster the rate of bank change, the more suddenly the lift changes occur. If your cross-check is fast enough to note the immediate need for pitch changes, smooth, steady back-elevator pressure will maintain constant altitude. However, if you overbank to excessively steep angles without adjusting pitch as the bank changes occur, pitch corrections require increasingly stronger

Steep turns: In instrument flight, anything greater than standard rate; in visual flight, anything greater than a 45° bank.

elevator pressure. The loss of vertical lift and increase in wing loading finally reach a point where further application of back-elevator pressure tightens the turn without raising the nose.

How do you recognize overbanking and a low pitch attitude? What should you do to correct it? If you observe a rapid downward movement of the altimeter needle or vertical-speed needle, together with an increase in airspeed, despite your application of back-elevator pressure, you are in a diving spiral. [Figure 5-37] Immediately shallow the bank with smooth and coordinated aileron and rudder pressures, hold or slightly relax elevator pressure, and increase your cross-check of the attitude indicator, altimeter, and vertical speed indicator. Reduce power if the airspeed increase is rapid. When the vertical speed trends upward, the altimeter needle will move slower as the vertical lift increases. When you note that the elevator is effective in raising the nose, hold the bank attitude shown on the attitude indicator and adjust elevator control pressures smoothly for the nose-high attitude appropriate to the bank maintained. If your pitch control is consistently late on your entries to steep turns, roll-out immediately to straight-and-level flight and analyze your errors. Practice shallower turns until you can keep up with the attitude changes and control responses required, then steepen the banks as you develop quicker and more accurate control technique.

The power necessary to maintain constant airspeed increases as the bank and drag increase. With practice, you quickly learn the power settings appropriate to specific bank attitudes, and can make adjustments without undue attention to airspeed and power instruments. During training in steep turns, as in any other maneuver, attend to first things first. If you keep the pitch attitude relatively constant, you have more time to cross-check, interpret, and control for accurate airspeed and bank control.

During recovery from steep turns to straight-and-level flight, elevator and power control must be coordinated with bank control in proportion to the changes in aerodynamic forces. Back-elevator pressures must be released and power decreased. The common errors associated with steep turns are the same as those discussed later in this section; however, remember, errors are more exaggerated, more difficult to correct, and more difficult to analyze unless your rates of entry and recovery are consistent with your level of proficiency in the three basic instrument flying skills.

Figure 5-37. *Diving spiral.*

Climbing and Descending Turns

To execute climbing and descending turns, combine the technique used in straight climbs and descents with the various turn techniques. The aerodynamic factors affecting lift and power control must be considered in determining power settings, and the rate of cross-check and interpretation must be increased to enable you to control bank as well as pitch changes.

Change of Airspeed in Turns

Changing airspeed in turns is an effective maneuver for increasing your proficiency in all three basic instrument skills. Since the maneuver involves simultaneous changes in all components of control, proper execution requires rapid cross-check and interpretation as well as smooth control. Proficiency in the maneuver will also contribute to your confidence in the instruments during attitude and power changes involved in more complex maneuvers. Pitch and power control techniques are the same as those used during changes in airspeed in straight-and-level flight.

The angle of bank necessary for a given rate of turn is proportional to the true airspeed. Since the turns are executed at a standard rate, the angle of bank must be varied in direct proportion to the airspeed change in order to maintain a constant rate of turn. During a reduction of airspeed, you must decrease the angle of bank and increase the pitch attitude to maintain altitude and a standard-rate turn.

The altimeter and turn coordinator indications should remain constant throughout the turn. The altimeter is primary for pitch control and the miniature aircraft of the turn coordinator is primary for bank control. The manifold pressure gauge (or tachometer) is primary for power control while the airspeed is changing. As the airspeed approaches the new indication, the airspeed indicator becomes primary for power control.

Two methods of changing airspeed in turns may be used. In the first method, airspeed is changed after the turn is established [Figure 5-38]; in the second method, the airspeed change is initiated simultaneously with the turn entry. The first method is easier, but regardless of the method used, the rate of cross-check must be increased as you reduce power. As the airplane decelerates, check the altimeter and vertical speed indicator for needed pitch changes and the bank instruments for needed bank changes. If the miniature aircraft of the turn coordinator shows a deviation from the desired deflection, change the bank. Adjust pitch attitude to maintain altitude. When approaching the desired airspeed, it becomes primary for power control and the manifold pressure gauge (or tachometer) is adjusted to maintain the desired airspeed. Trim is important throughout the maneuver to relieve control pressures.

Figure 5-38. *Change of airspeed in turn.*

Until your control technique is very smooth, frequent cross-check of the attitude indicator is essential to keep from overcontrolling and to provide approximate bank angles appropriate to the changing airspeeds.

Common Errors in Turns

Pitch

Pitch errors result from the following faults:

1. Preoccupation with bank control during turn entry and recovery. If it takes 5 seconds to roll into a turn, check the pitch instruments as you initiate bank pressures. If your bank control pressure and rate of bank change are consistent, you will soon develop a sense of timing that tells you how long an attitude change will take. During the interval, you check pitch, power, and trim—as well as bank—controlling the total attitude instead of one factor at a time.

2. Failure to understand or remember the need for changing the pitch attitude as the vertical lift component changes, resulting in consistent loss of altitude during entries.

3. Changing the pitch attitude before it is necessary. This fault is very likely if your cross-check is slow and your rate of entry too rapid. The error occurs during the turn entry due to a mechanical and premature application of back-elevator control pressure.

4. Overcontrolling the pitch changes. This fault commonly occurs with the previous error.

5. Failure to properly adjust the pitch attitude as the vertical lift component increases during the roll-out, resulting in consistent gain in altitude on recovery to headings.

6. Failure to trim during turn entry and following turn recovery (if turn is prolonged).

7. Failure to maintain straight-and-level cross-check after roll-out. This error commonly follows a perfectly executed turn.

8. Erratic rates of bank change on entry and recovery, resulting from failure to cross-check the pitch instruments with a consistent technique appropriate to the changes in lift.

Bank

Bank and heading errors result from the following faults:

1. Overcontrolling, resulting in overbanking upon turn entry, overshooting and undershooting headings, as well as aggravated pitch, airspeed, and trim errors.

2. Fixation on a single bank instrument. On a 90° change of heading, for example, leave the heading indicator out of your cross-check for approximately 20 seconds after establishing a standard-rate turn, since at 3° per second you will not approach the lead point until that time has elapsed. Make your cross-check selective; check what needs to be checked at the appropriate time.

3. Failure to check for precession of the horizon bar following recovery from a turn. If the heading indicator shows a change in heading when the attitude indicator shows level flight, the airplane is turning. If the ball is centered, the attitude gyro has precessed; if the ball is not centered, the airplane may be in a slipping or skidding turn. Center the ball with rudder pressure, check the attitude indicator and heading indicator, stop the heading change if it continues, and retrim.

4. Failure to use the proper degree of bank for the amount of heading change desired. Rolling into a 20° bank for a heading change of 10° will normally overshoot the heading. Use the bank attitude appropriate to the amount of heading change desired.

5. Failure to remember the heading you are turning to. This fault is likely when you rush the maneuver.

6. Turning in the wrong direction, due either to misreading or misinterpreting the heading indicator, or to confusion as to the location of points on the compass. Turn in the shortest direction to reach a given heading, unless you

have a specific reason to turn the long way around. Study the compass rose until you can visualize at least the positions of the eight major points around the azimuth. A number of methods can be used to make quick computations for heading changes. For example, to turn from a heading of 305° to a heading of 110°, do you turn right or left for the shortest way around? Subtracting 200 from 305 and adding 20, you get 125° as the reciprocal of 305°; therefore, execute the turn to the right. Likewise, to figure the reciprocal of a heading less than 180°, add 200 and subtract 20. If you can compute more quickly using multiples of 100s and 10s than by adding or subtracting 180° from the actual heading, the method suggested above may save you time and confusion.

7. Failure to check the ball of the turn coordinator when interpreting the instrument for bank information. If the roll rate is reduced to zero, the miniature aircraft of the turn coordinator indicates only direction and rate of turn. Unless the ball is centered, you cannot assume the turn is resulting from a banked attitude.

Power

Power and airspeed errors result from the following faults:

1. Failure to cross-check the airspeed indicator as you make pitch changes.

2. Erratic use of power control. This may be due to improper throttle friction control, inaccurate throttle settings, chasing the airspeed readings, abrupt or overcontrolled pitch-and-bank changes, or failure to recheck the airspeed to note the effect of a power adjustment.

3. Poor coordination of throttle control with pitch-and-bank changes, associated with slow cross-check or failure to understand the aerodynamic factors related to turns.

Trim

Trim errors result from the following faults:

1. Failure to recognize the need for a trim change may be due to slow cross-check and interpretation. For example, a turn entry at a rate too rapid for your cross-check leads to confusion in cross-check and interpretation, with resulting tension on the controls.

2. Failure to understand the relationship between trim and attitude/power changes.

3. Chasing the vertical-speed needle. Overcontrolling leads to tension and prevents you from sensing the pressures to be trimmed off.

4. Failure to trim following power changes.

Errors During Compass Turns

In addition to the faults discussed above, the following errors connected with compass turns should be noted:

1. Faulty understanding or computation of lead and lag.

2. Fixation on the compass during the roll-out. Until the airplane is in straight-and-level, unaccelerated flight, there is no point in reading the indicated heading. Accordingly, after you initiate the roll-out, cross-check for straight-and-level flight before checking the accuracy of your turn.

Approach to Stall

Practicing approach to stall recoveries in various airplane configurations should build confidence in your ability to control the airplane in unexpected situations. Approach to stall should be practiced from straight flight and from shallow banks. The objective is to practice recognition and recovery from the approach to a stall.

Prior to stall recovery practice, select a safe altitude above the terrain, an area free of conflicting air traffic, adequate weather, and the use of radar traffic advisory service should be among the items considered.

Approach to stalls are accomplished in the following configurations:

1. Takeoff configuration—should begin from level flight near liftoff speed. Power should be applied while simultaneously increasing the angle of attack to induce an indication of a stall.

2. Clean configuration—should begin from a reduced airspeed, such as pattern airspeed, in level flight. Power should be applied while simultaneously increasing the angle of attack to induce an indication of a stall.

3. Approach or landing configuration—should be initiated at the appropriate approach or landing airspeed. The angle of attack should be smoothly increased to induce an indication of a stall.

Recoveries should be prompt in response to a stall warning device or an aerodynamic indication, by smoothly reducing the angle of attack and applying maximum power, or as recommended by the POH/AFM. The recovery should be completed without an excessive loss of altitude, and on a predetermined heading, altitude, and airspeed.

Unusual Attitudes and Recoveries

An unusual attitude is an airplane attitude not normally required for instrument flight. Unusual attitudes may result from a number of conditions, such as turbulence, disorientation, instrument failure, confusion, preoccupation with cockpit duties, carelessness in cross-checking, errors in instrument interpretation, or lack of proficiency in aircraft control. Since unusual attitudes are not intentional maneuvers during instrument flight, except in training, they are often unexpected, and the reaction of an inexperienced or inadequately trained pilot to an unexpected abnormal flight attitude is usually instinctive rather than intelligent and deliberate. This individual reacts with abrupt muscular effort, which is purposeless and even hazardous in turbulent conditions, at excessive speeds, or at low altitudes. However, with practice, the techniques for rapid and safe recovery from unusual attitudes can be learned.

When an unusual attitude is noted on your cross-check, the immediate problem is not how the airplane got there, but what it is doing and how to get it back to straight-and-level flight as quickly as possible.

Recognizing Unusual Attitudes

As a general rule, any time you note an instrument rate of movement or indication other than those you associate with the basic instrument flight maneuvers already learned, assume an unusual attitude and increase the speed of cross-check to confirm the attitude, instrument error, or instrument malfunction.

Nose-high attitudes are shown by the rate and direction of movement of the altimeter needle, vertical-speed needle, and airspeed needle, as well as the immediately recognizable indication of the attitude indicator (except in extreme attitudes). [Figure 5-39] Nose-low attitudes are shown by the same instruments, but in the opposite direction. [Figure 5-40]

Figure 5-39. *Unusual attitude—nose high.*

Figure 5-40. *Unusual attitude—nose-low.*

Recovery From Unusual Attitudes

In moderate unusual attitudes, the pilot can normally reorient him/herself by establishing a level flight indication on the attitude indicator. However, the pilot should not depend on this instrument for the following reasons: If the attitude indicator is the spillable type, its upset limits may have been exceeded; it may have become inoperative due to mechanical malfunction; even if it is the nonspillable-type instrument and is operating properly, errors up to 5° of pitch-and-bank may result and its indications are very difficult to interpret in extreme attitudes. As soon as the unusual attitude is detected, the recommended recovery procedures stated in the POH/AFM should be initiated. If there are no recommended procedures stated in the POH/AFM, the recovery should be initiated by reference to the airspeed indicator, altimeter, vertical speed indicator, and turn coordinator.

Nose-High Attitudes

If the airspeed is decreasing, or below the desired airspeed, increase power (as necessary in proportion to the observed deceleration), apply forward-elevator pressure to lower the nose and prevent a stall, and correct the bank by applying coordinated aileron and rudder pressure to level the miniature aircraft and center the ball of the turn coordinator. The corrective control applications are made almost simultaneously, but in the sequence given above. A level pitch attitude is indicated by the reversal and stabilization of the airspeed indicator and altimeter needles. Straight coordinated flight is indicated by the level miniature aircraft and centered ball of the turn coordinator.

Nose-Low Attitudes

If the airspeed is increasing, or is above the desired airspeed, reduce power to prevent excessive airspeed and loss of altitude. Correct the bank attitude with coordinated aileron and rudder pressure to straight flight by referring to the turn coordinator. Raise the nose to level flight attitude by applying smooth back-elevator pressure. All components of control should be changed simultaneously for a smooth, proficient recovery. However, during initial training a positive, confident recovery should be made by the numbers, in the sequence given above. A very important point to remember is that the instinctive reaction to a nose-down attitude is to pull back on the elevator control.

After initial control has been applied, continue with a fast cross-check for possible overcontrolling, since the necessary initial control pressures may be large. As the rate of movement of altimeter and airspeed indicator needles decreases, the attitude is approaching level flight. When the needles stop and reverse direction, the aircraft is passing through level flight. As the indications of the airspeed indicator, altimeter, and turn coordinator stabilize, incorporate the attitude indicator into the cross-check.

The attitude indicator and turn coordinator should be checked to determine bank attitude, and then corrective aileron and rudder pressures should be applied. The ball should be centered. If it is not, skidding and slipping sensations can easily aggravate disorientation and retard recovery. If you enter the unusual attitude from an assigned altitude (either by your instructor or by air traffic control (ATC) if operating under instrument flight rules (IFR)), return to the original altitude after stabilizing in straight-and-level flight.

Common Errors in Unusual Attitudes

Common errors associated with unusual attitudes include the following faults:

1. Failure to keep the airplane properly trimmed. A cockpit interruption when you are holding pressures can easily lead to inadvertent entry into unusual attitudes.

2. Disorganized cockpit. Hunting for charts, logs, computers, etc., can seriously detract your attention from the instruments.

3. Slow cross-check and fixations. Your impulse is to stop and stare when you note an instrument discrepancy unless you have trained enough to develop the skill required for immediate recognition.

4. Attempting to recover by sensory sensations other than sight. The discussion of disorientation in Chapter 1 ("Human Factors") indicates the importance of trusting your instruments.

5. Failure to practice basic instrument skills once you have learned them. All of the errors noted in connection with basic instrument skills are aggravated during unusual attitude recoveries until the elementary skills have been mastered.

Instrument Takeoff

Your competency in **instrument takeoffs** will provide the proficiency and confidence necessary for use of flight instruments during departures under conditions of low visibility, rain, low ceilings, or disorientation at night. A sudden rapid transition from "visual" to "instrument" flight can result in serious disorientation and control problems.

Instrument takeoff techniques vary with different types of airplanes, but the method described below is applicable whether the airplane is single- or multiengine; tricycle-gear or conventional-gear.

Align the airplane with the centerline of the runway with the nosewheel or tailwheel straight. (Your instructor pilot may align the airplane if he/she has been taxiing while you perform the instrument check under a hood or visor.) Lock the tailwheel, if so equipped, and hold the brakes firmly to avoid creeping while you prepare for takeoff. Set the heading indicator with the nose index on the 5° mark nearest the published runway heading, so you can instantly detect slight changes in heading during the takeoff. Make certain that the instrument is uncaged (if it has a caging feature) by rotating the knob after uncaging and checking for constant heading indication. If you use an electric heading indicator with a rotatable needle, rotate the needle so that it points to the nose position, under the top index. Advance the throttle to an RPM that will provide partial rudder control. Release the brakes, advancing the power smoothly to takeoff setting.

During the takeoff roll, hold the heading constant on the heading indicator by using the rudder. In multiengine, propeller-driven airplanes, also use differential throttle to maintain direction. The use of brakes should be avoided,

Instrument takeoff: Using the instruments rather than outside visual cues to maintain runway heading and execute a safe takeoff.

except as a last resort, as it usually results in overcontrolling and extending the takeoff roll. Once you release the brakes, any deviation in heading must be corrected instantly.

As the airplane accelerates, cross-check both heading indicator and airspeed indicator rapidly. The attitude indicator may precess to a slight nose-up attitude. As flying speed is approached (approximately 15-25 knots below takeoff speed), smoothly apply elevator control for the desired takeoff attitude on the attitude indicator. This is approximately a 2-bar-width climb indication for most small airplanes.

Continue with a rapid cross-check of heading indicator and attitude indicator as the airplane leaves the ground. Do not pull it off; let it fly off while you hold the selected attitude constant. Maintain pitch-and-bank control by referencing the attitude indicator, and make coordinated corrections in heading when indicated on the heading indicator. Cross-check the altimeter and vertical speed indicator for a positive rate of climb (steady clockwise rotation of the altimeter needle at a rate that you can interpret with experience, and the vertical speed indicator showing a stable rate of climb appropriate to the airplane).

When the altimeter shows a safe altitude (approximately 100 feet), raise the landing gear and flaps, maintaining attitude by referencing the attitude indicator. Because of control pressure changes during gear and flap operation, overcontrolling is likely unless you note pitch indications accurately and quickly. Trim off control pressures necessary to hold the stable climb attitude. Check the altimeter, vertical speed indicator, and airspeed for a smooth acceleration to the predetermined climb speed (altimeter and airspeed increasing, vertical speed stable). At climb speed, reduce power to climb setting (unless full power is recommended for climb by your POH/AFM and trim).

Throughout the instrument takeoff, cross-check and interpretation must be rapid, and control positive and smooth. During liftoff, gear and flap retraction, and power reduction, the changing control reactions demand rapid cross-check, adjustment of control pressures, and accurate trim changes.

Common Errors in Instrument Takeoffs

Common errors during the instrument takeoff include the following:

1. Failure to perform an adequate cockpit check before the takeoff. Pilots have attempted instrument takeoffs with inoperative airspeed indicators (pitot tube obstructed), gyros caged, controls locked, and numerous other oversights due to haste or carelessness.

2. Improper alignment on the runway. This may result from improper brake application, allowing the airplane to creep after alignment, or from alignment with the nosewheel or tailwheel cocked. In any case, the result is a built-in directional control problem as the takeoff starts.

3. Improper application of power. Abrupt application of power complicates directional control. Add power with a smooth, uninterrupted motion.

4. Improper use of brakes. Incorrect seat or rudder pedal adjustment, with your feet in an uncomfortable position, frequently causes inadvertent application of brakes and excessive heading changes.

5. Overcontrolling rudder pedals. This fault may be caused by late recognition of heading changes, tension on the controls, misinterpretation of the heading indicator (and correcting in the wrong direction), failure to appreciate changing effectiveness of rudder control as the aircraft accelerates, and other factors. If heading changes are observed and corrected instantly with small movement of the rudder pedals, swerving tendencies can be reduced.

6. Failure to maintain attitude after becoming airborne. If you react to seat-of-the-pants sensations when the airplane lifts off, your pitch control is guesswork. You may either allow excessive pitch or apply excessive forward-elevator pressure, depending on your reaction to trim changes.

7. Inadequate cross-check. Fixations are likely during trim changes, attitude changes, gear and flap retractions, and power changes. Once you check an instrument or apply a control, continue the cross-check and note the effect of your control during the next cross-check sequence.

8. Inadequate interpretation of instruments. Failure to understand instrument indications immediately indicates that further study of the maneuver is necessary.

Basic Instrument Flight Patterns

After you have attained a reasonable degree of proficiency in basic maneuvers, you can apply your skills to the various combinations of individual maneuvers. The following practice **flight patterns** are directly applicable to operational instrument flying.

Racetrack Pattern

Steps:

1. Time 3 minutes straight-and-level flight from A to B. [Figure 5-41] During this interval, reduce airspeed to the holding speed appropriate for your aircraft.
2. Start 180° standard-rate turn at B. Roll-out at C on the reciprocal of your heading at A.
3. Time 1 minute straight-and-level flight from C to D.
4. Start 180° standard rate level turn at D, rolling-out on original heading.

Note: This pattern is an exercise combining use of the clock with basic maneuvers.

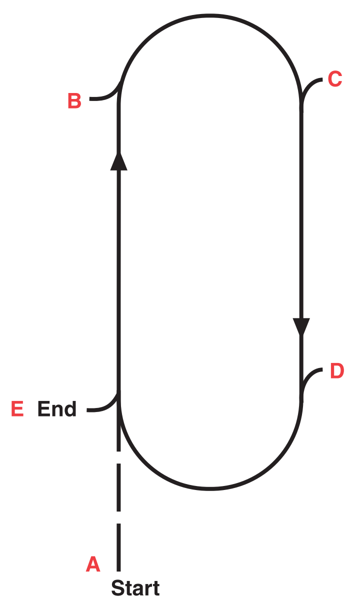


Figure 5-41. *Racetrack pattern (entire pattern in level flight).*

Flight patterns: Basic maneuvers, flown by sole reference to the instruments rather than outside visual cues, for the purpose of practicing basic attitude flying. The patterns simulate maneuvers encountered on instrument flights such as holding patterns, procedure turns, and approaches.

Standard Procedure Turn

Steps:

1. Start timing at A for 2 minutes from A to B. [Figure 5-42]
2. At B, turn 45° (standard rate). After roll-out, fly 1 minute to C.
3. At C, turn 180°.
4. At completion of turn, time 45 seconds from D to E.
5. Start turn at E for 45° change of heading to reciprocal of heading at beginning of maneuver.

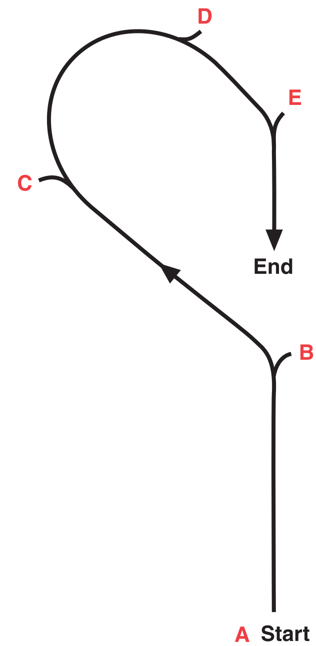


Figure 5-42. *Standard procedure turn (entire pattern in level flight).*

80/260 Procedure Turn

Steps:

1. Start timing at A for 2 minutes from A to B. [Figure 5-43]
2. At B, enter a left standard-rate turn for a heading change of 80°.
3. At the completion of the 80° turn at C, immediately turn right for a heading change of 260°, rolling-out on the reciprocal of the entry heading.

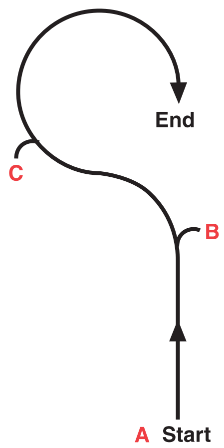


Figure 5-43. *80/260 procedure turn (entire pattern in level flight).*

Teardrop Pattern

Steps:

1. Start timing at A for 2 minutes from A to B. [Figure 5-44] Reduce airspeed to holding speed in this interval.
2. At B, enter standard-rate turn for 30° change of heading. Time 1 minute from B to C.
3. At C, enter standard-rate turn for a 210° change of heading, rolling-out on the reciprocal of the original entry heading.

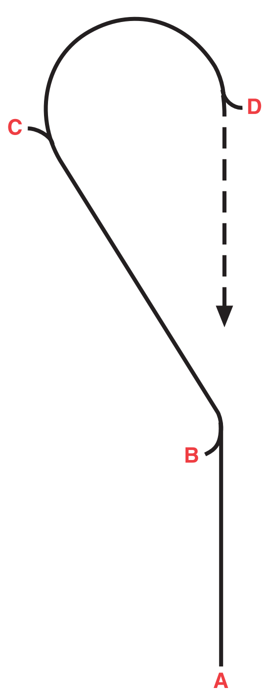


Figure 5-44. *Teardrop pattern (entire pattern in level flight).*

Circling Approaches Pattern

Pattern I

Steps:

1. At A, start timing for 2 minutes from A to B; reduce airspeed to approach speed. [Figure 5-45, I]
2. At B, make a standard-rate turn to the left for 45°.
3. At the completion of the turn, time for 45 seconds to C.
4. At C, turn to the original heading; fly 1 minute to D, lowering the landing gear and flaps.
5. At D, turn right 180°, rolling-out at E on the reciprocal of the entry heading.
6. At E, enter a 500 fpm rate descent. At the end of a 500-foot descent, enter a straight constant-airspeed climb, retracting gear and flaps.

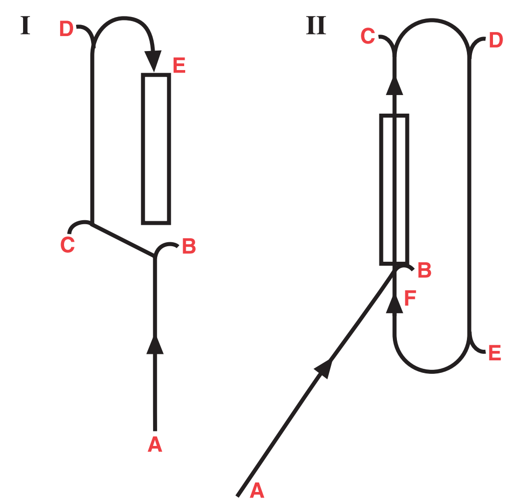


Figure 5-45. *Patterns applicable to circling approaches (runways are imaginary).*

Pattern II

Steps:

1. At A, start timing for 2 minutes from A to B; reduce airspeed to approach speed. [Figure 5-45, II]
2. At B, make a standard-rate turn to the left for 45°.
3. At the completion of the turn, time for 1 minute to C.
4. At C, turn right for 180°; fly for 1-1/2 minutes to E, lowering the landing gear and flaps.
5. At E, turn right for 180°, rolling-out at F.
6. At F, enter a 500 fpm rate descent. At the end of a 500-foot descent, enter a straight constant-airspeed climb, retracting gear and flaps.