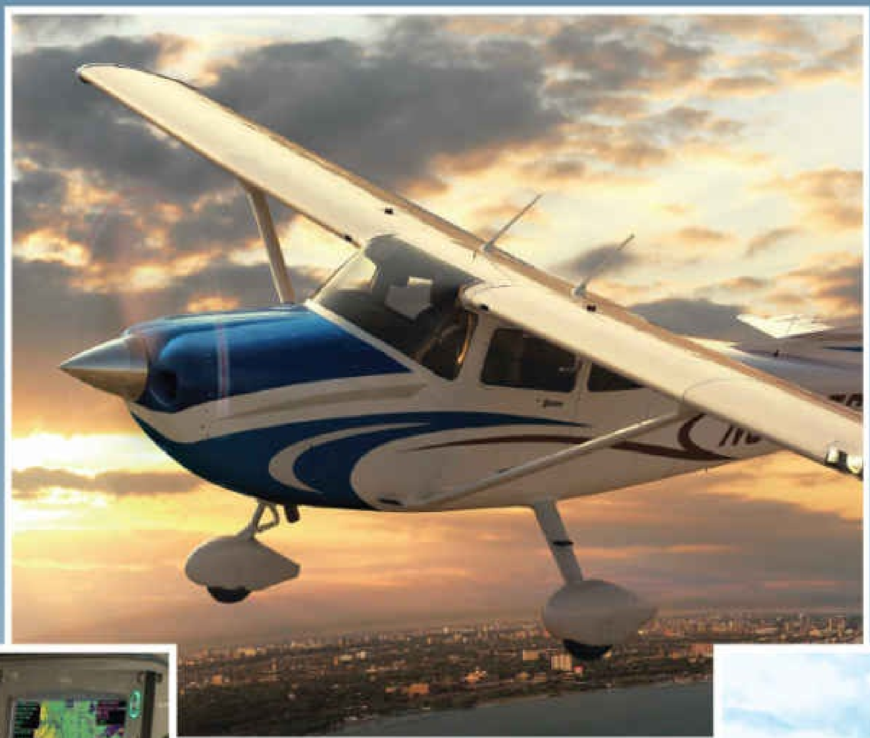
The Pilot's Manual

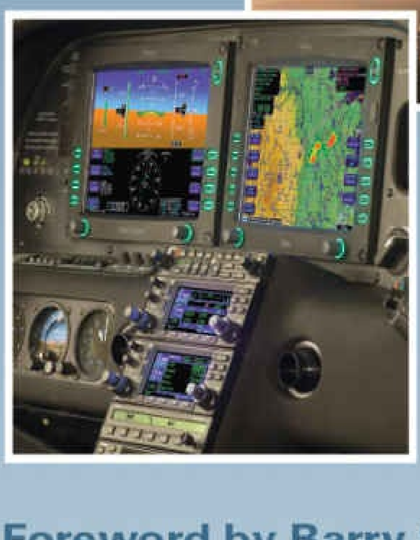
PM 3

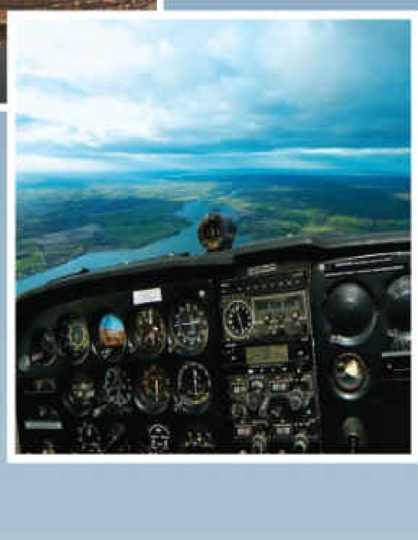
# Instrument Flying

All the aeronautical knowledge required to pass the FAA exams, IFR checkride, and operate as an Instrument-Rated pilot

*Seventh Edition*







**Foreword by Barry Schiff**

**CLICK HERE TO DOWNLOAD THE COMPLETE MANUAL**

- Thank you very much for reading the preview of the manual.
- You can download the complete manual from: www.heydownloads.com by clicking the link below


- Please note: If there is no response to CLICKING the link, please download this PDF first and then click on it.


**CLICK HERE TO DOWNLOAD THE COMPLETE MANUAL**

# 1
# Introduction to Instrument Flight

Air travel becomes much more reliable when airplane operations are not restricted by poor weather or by darkness. Greater reliability can be achieved with a suitably equipped airplane and a pilot skilled in instrument flying.

The instrument-qualified pilot and the instrument-equipped airplane must be able to cope with flying in restricted visibility, such as in cloud, mist, smog, rain, snow, or at night, all of which may make the natural horizon and ground features difficult, or even impossible, to see.

**Figure 1-1** Control and performance.

As an instrument pilot, you must learn to trust what you see on the instruments. We generally use vision to orient ourselves with our surroundings, supported by other gravity-perceiving bodily senses, such as feel and balance. Even with the eyes closed, however, we can usually manage to sit, stand and walk on steady ground without losing control. This becomes much more difficult standing on the tray of an accelerating or turning truck, or even in an accelerating elevator.

In an airplane, which can accelerate in three dimensions, the task becomes almost impossible unless you have the use of your eyes.

The eyes must gather information from the external ground features, including the horizon; or, in poor visibility, they gather substitute information from the instruments.

and lean down to look for it in one motion — take it carefully step by step to avoid any feeling of vertigo.

Because an airplane moves in three dimensions, there is the possibility to accelerate and decelerate in three dimensions, and this can lead to more complicated illusions. Pulling up into a steep climb, for example, will hold you tightly in your seat, which is exactly the same feeling as in a steep turn. Banking the airplane and pulling it into a turn will increase the pressure on "the seat of your pants," which is a similar sensation to suddenly entering a climb. As well as your muscles, the balance organs of your inner ear may be sending false signals to your brain. Rolling into and out of a turn may be interpreted as a climb or descent (or vice versa) by your bodily feel. With your eyes closed, it is sometimes difficult to say which maneuver it is.

A sudden change from a climb to straight-and-level flight or a descent may cause an illusion of tumbling backward. A sudden acceleration in straight-and-level flight, or during the takeoff roll, may cause an illusion of being in a nose-up attitude.

Decelerating while in a turn to the left may give a false impression of a turn to the right. Be aware that your sense of balance and bodily feel can lead you astray in an airplane, especially with rapidly changing g-forces in maneuvers such as this.

The one sense that can resolve most of these illusions is sight. If the automobile passenger could see out, or if the pilot had reference to the natural horizon and landmarks, then the confusion, and the risk of not knowing your attitude in space (i.e., the risk of *spatial disorientation*), would be easily dispelled. A false horizon seen by the eyes, however, can be misleading — such as what a pilot might see flying above a sloping cloud formation, or on a dark night with ground lights and stars spread in certain patterns, or when the natural horizon is obscured. Trust the flight instruments!

*Believe only what your eyes tell you when flying on instruments.*

Unfortunately, in instrument flight you do not have reference to ground features, but you can still use your sense of sight to scan the instruments and obtain substitute information. Therefore, an important instruction to the budding instrument pilot is: "believe your eyes and what the instruments tell you."

It is good airmanship to avoid any situation in flight, or prior to flight, that will affect your vision. While in clouds at night, for instance, turn off the strobe light if it is bothering you. If enough flashing light is reflected into the cockpit, the strobe can induce vertigo, or a sense of dizziness or whirling around. It is good practice to avoid strong white light, such as a flashlight, in the cockpit when night flying, so that the night adaptation of your eyes is not impaired. However, if flying in dark conditions with thunderstorms in the vicinity, turn the cockpit lights up to a bright setting to minimize the effects of nearby lightning flashes. If expecting to fly out of cloud tops and into bright sunlight, have your sunglasses handy. Protect your sight!

While sight is the most important sense, and must be protected at all costs, also make sure that you avoid anything that will affect your balance or position sensing systems.

Avoid alcohol, drugs (including smoking in the cockpit) and medication. Do not fly when ill or suffering with an upper respiratory infection (a cold). Do not fly when tired or fatigued. Do not fly with a cabin altitude higher than 10,000 feet MSL without using oxygen (or above 5,000 feet MSL at night). Avoid sudden head movements, and avoid lowering your head or turning around in the cockpit.

Despite all these don'ts, there is one very important do — *do* trust what your eyes tell you from the instruments.

## The Instrument Rating Test

Detailed information of the standards required for you to obtain an instrument rating is included in 14 CFR (Part 61) and in a small publication entitled Airman Certification Standards (ACS), published by the FAA, reprinted by ASA in book form and available electronically. These standards change from time to time, so be sure that you are working from a current set of regulations and a current issue of the ACS book.

## Review 1

## Introduction to Instrument Flight

1. How can you avoid spatial disorientation when flying in IMC?
2. Flying visually in a clear, blue sky above a sloping cloud layer may not be as easy as it sounds. Why?
3. You are flying over a well-lit town situated on sloping ground. What sort of visual illusion could you

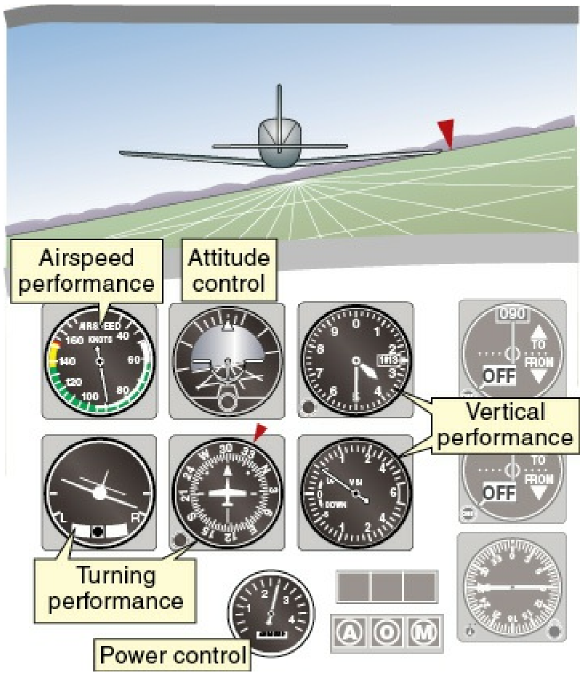



**Figure 2-17** Performance is displayed on the performance instruments.


**Figure 2-18** The bank instruments.

## The Selective Radial Scan

*The attitude indicator is the master flight instrument.*

Of the six main flight instruments, the *attitude indicator* is the master instrument. It gives you a direct and immediate picture of pitch attitude and bank angle. It will be the one most frequently referred to (at least once every few seconds in most stages of flight). The eyes can be directed selectively toward the other instruments to derive relevant information from them as required, before being returned to the AI. This eye movement radiating out and back to selected instruments is commonly known as the *selective radial scan*.

For instance, when climbing with full power selected, the estimated climb pitch attitude is held on the attitude indicator, with subsequent reference to the airspeed indicator to confirm that the selected pitch attitude is indeed correct. If the ASI indicates an airspeed that is too low, then lower the pitch attitude on the AI (say by a half bar width or by one bar width), allow a few seconds for the airspeed to settle, and then check the ASI again.

The miniature airplane attached to the case of the AI usually consists of a wing-bar on either side of a central dot that represents the nose of the airplane. In normal cruise flight, the miniature airplane is on the horizon bar. In normal climb, it appears above the horizon bar, and in normal descent, it appears slightly below the horizon bar. Occasionally, the miniature airplane may require repositioning in flight. If so, it should be aligned with the horizon line when the airplane is flying straight-and-level at a steady speed.

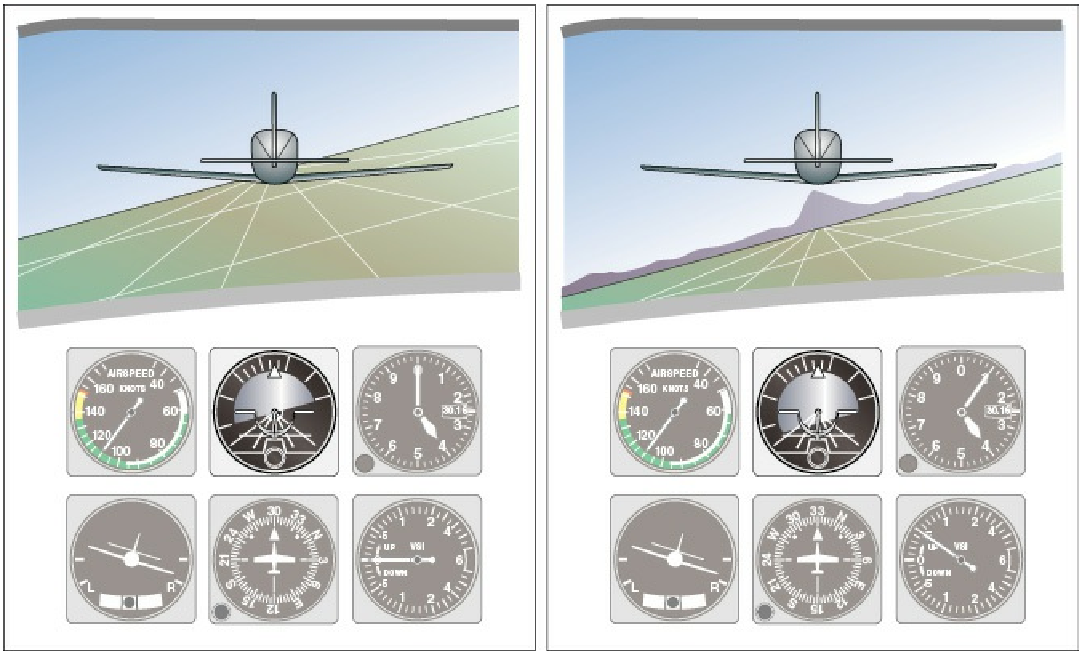



**Figure 3-7** The AI provides pitch and bank information only.

## Errors of the Attitude Indicator

The attitude indicator is an exceptionally useful and important instrument, but it is not perfect and is subject to power failures and precession errors.

*The attitude indicator is subject to power failures and precession errors.*

### *Power Source Failure*

If the AI experiences a failure of the power source, it will become unusable. An electrically driven AI usually incorporates a red warning flag to alert the pilot to a power failure, but a vacuum-driven AI may not include this feature — the gyroscope may just wind down gradually, and the AI will provide false indications without any specific warning to the unwary pilot. So, if your airplane is fitted with a vacuum-driven AI, you should conscientiously check the suction gauge at regular intervals to ensure that an adequate vacuum of approximately 3–5 in. Hg is being provided. If not, treat the attitude indicator with caution (as well as the heading indicator which, most likely, will also be vacuum-driven). It is useful to cover a failed instrument in order to avoid the distraction of false information.

*It is useful to cover a failed instrument in order to avoid the distraction of false information.*

### *Precession Errors*

The AI suffers from gyroscopic precession errors during rapid speed changes and turns, which can cause false indications of pitch attitude and bank angle. These errors are usually small, and are easily identified and corrected for. For instance, maneuvering to follow a slightly incorrect horizon bar results in changes to the other instrument indications. Scanning them enables you to take appropriate corrective action to maintain the desired pitch attitude and direction until the AI indications normalize.

Any acceleration (such as a rapid speed change or a turn) will exert additional g-forces on the airplane. Everything within it, including the pilot and the AI's self-erecting mechanism, will sense a false "gravity" force. This may cause the gyroscope's spin axis to move off the vertical briefly, thereby moving the horizon line to a slightly incorrect position.

*A small bank error in the AI from precession is greatest following a turn of 180° (possibly up to 5° of bank error in the direction opposite the turn), with a slight climb falsely indicated.*

During a rapid acceleration, the horizon line will move down, and so the AI will indicate a false climb. If you follow the AI without reference to the other instruments and lower the nose, the airplane will have a lower pitch attitude than desired. Conversely, during a deceleration, the horizon line

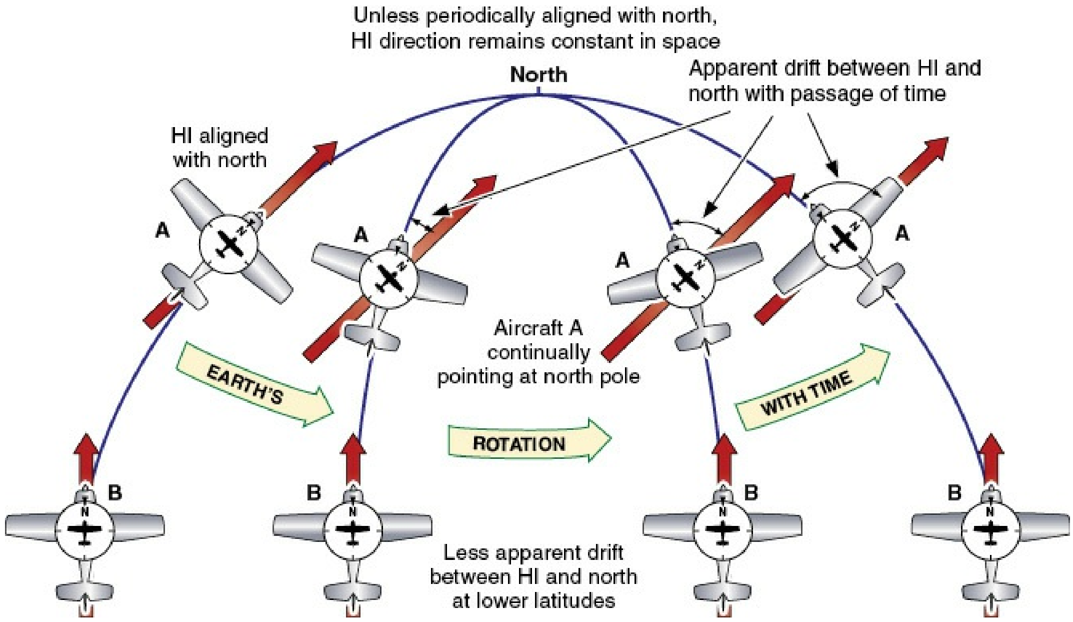



**Figure 3-16** The HI will gradually drift off heading.

The heading indicator should be checked at least every 15 minutes, and reset to the correct magnetic heading by reference to the magnetic compass (and compass correction card) during steady straight-and-level flight. For the heading indicator to be acceptable in normal operations, this correction should not exceed 3° in 15 minutes.

*Check HI alignment with the magnetic compass at least every 15 minutes.*

Complete failure of the heading indicator makes heading control more difficult because the pilot must include the magnetic compass in the scan, and must also allow for its turning and acceleration errors. Because the attitude indicator and heading indicator often share the same power source, loss of one may mean the loss of the other.

## Preflight Checks of the Heading Indicator

After start-up, the electrical or vacuum power source should be checked to ensure that the gyroscope will get up to speed. Once up to speed, which may take up to 5 minutes for a vacuum-driven gyroscope, the heading indicator should be aligned with the magnetic compass using the manual adjustment knob. The heading indicator can then help in orientation on the ground — e.g., in determining which direction the takeoff will be.

While taxiing, the heading indicator should be checked for correct functioning: "turning right, heading increases — turning left, heading decreases."

At the holding point, just prior to takeoff, the heading indicator should again be checked against the magnetic compass (but not while turning or accelerating), and it can be used to verify that the correct runway is about to be used.

## The Remote Indicating Compass

The remote indicating compass is a logical extension of the heading indicator. It combines the functions of the magnetic compass and the heading indicator. The remote indicating compass employs a magnetic sensor, called the *magnetic flux detector* (or fluxvalve), which is positioned well away from other magnetic influences in the airframe, usually in a wingtip. This sensor detects magnetic direction and sends electrical signals to the heading indicator to automatically align it with the current magnetic heading of the airplane. This process is known as *slaving* of the compass card and it eliminates the need for the pilot to manually align the heading indicator, which now becomes known as a remote indicating compass.

On a climb, the pressure in the capsule changes instantaneously to the now lower static pressure. The case that surrounds the capsule, however, contains the original higher pressure which takes some time to change. The effect is to compress the capsule, driving a pointer around the dial to indicate a rate of climb.

The changed pressure gradually leaks into the instrument case. If the airplane continues to climb, the pressure within the instrument case never quite catches up with the external static pressure within the capsule, and so the VSI continues to indicate a rate of climb. Once the airplane levels off, however, the two pressures do gradually equalize, and the VSI reads zero.

The VSI is good as a trend instrument ("Am I going up?" or "Am I going down?"), as well as a rate instrument ("How fast am I going up or down?"). Whereas the trend is obvious almost immediately in smooth air, the precise rate will take a few seconds to settle down. In rough air, it may take longer.

Some advanced VSIs have accelerometers to reduce the lag and to give instantaneous indications of climb and descent rates. Such an instrument is known as an *instantaneous vertical speed indicator* and is labeled IVSI.

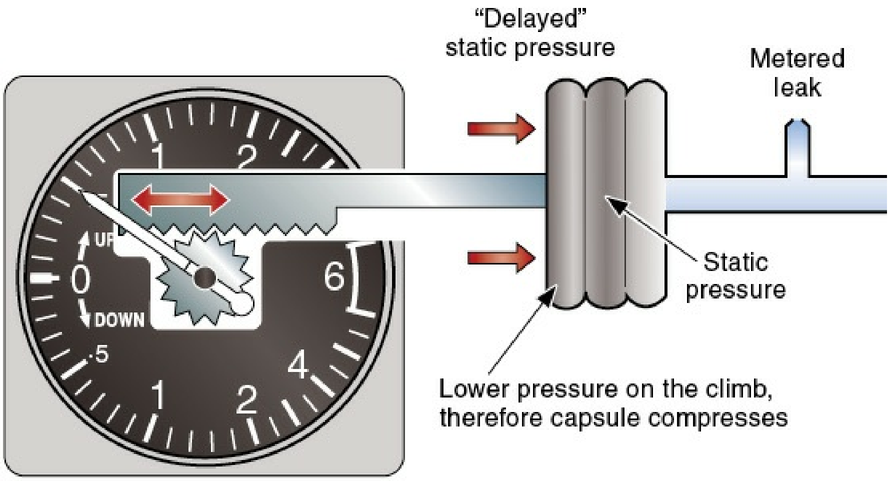



**Figure 3-28** The VSI compares static pressure in the capsule with delayed static pressure in the case.

## Preflight Checks of the VSI

Like all static pressure instruments, the VSI requires a static vent and line that is not blocked. The VSI should also indicate approximately zero while the airplane is on the ground. Indication errors may exist in some VSIs, for which allowance will have to be made in flight. For instance, if the VSI indicates 100 fpm UP while on the ground, then this 100 fpm UP must be the "zero" position in flight, verified, of course, against the altimeter when cruising. Keep in mind that wind blowing directly towards the static port on the ground can lead to a false indication of a descent due to the increased pressure.

# The Turn Coordinator and Turn Indicator

The turn coordinator is a significant development of an earlier instrument, the turn indicator. They are both *rate gyroscopes*, where the rotating mass has freedom to move about two of its three axes and is designed to show movement of the aircraft about the third axis. The gyroscope in the turn indicator or turn coordinator will not tumble in extreme attitudes, making for a very reliable instrument. The gyroscope of the turn coordinator or turn indicator may be driven electrically or by suction.

The *inclinometer*, a small ball which is displaced from its central position in coordinated flight (slips or skids), is usually incorporated into the instrument case of the turn indicator or turn coordinator, even though it is not part of the gyroscopic system. The turn indicator is sometimes called the turn-and-slip indicator.

## Turn Indicator

The turn indicator is the older of the two instruments and has a lateral horizontal spin axis (with a vertical spinning gyro) attached to a gimbal. The gimbal axis is fixed and aligned with the airplane's longitudinal axis. The turn indicator is designed to show motion about a vertical axis, and therefore show the rate of turn.

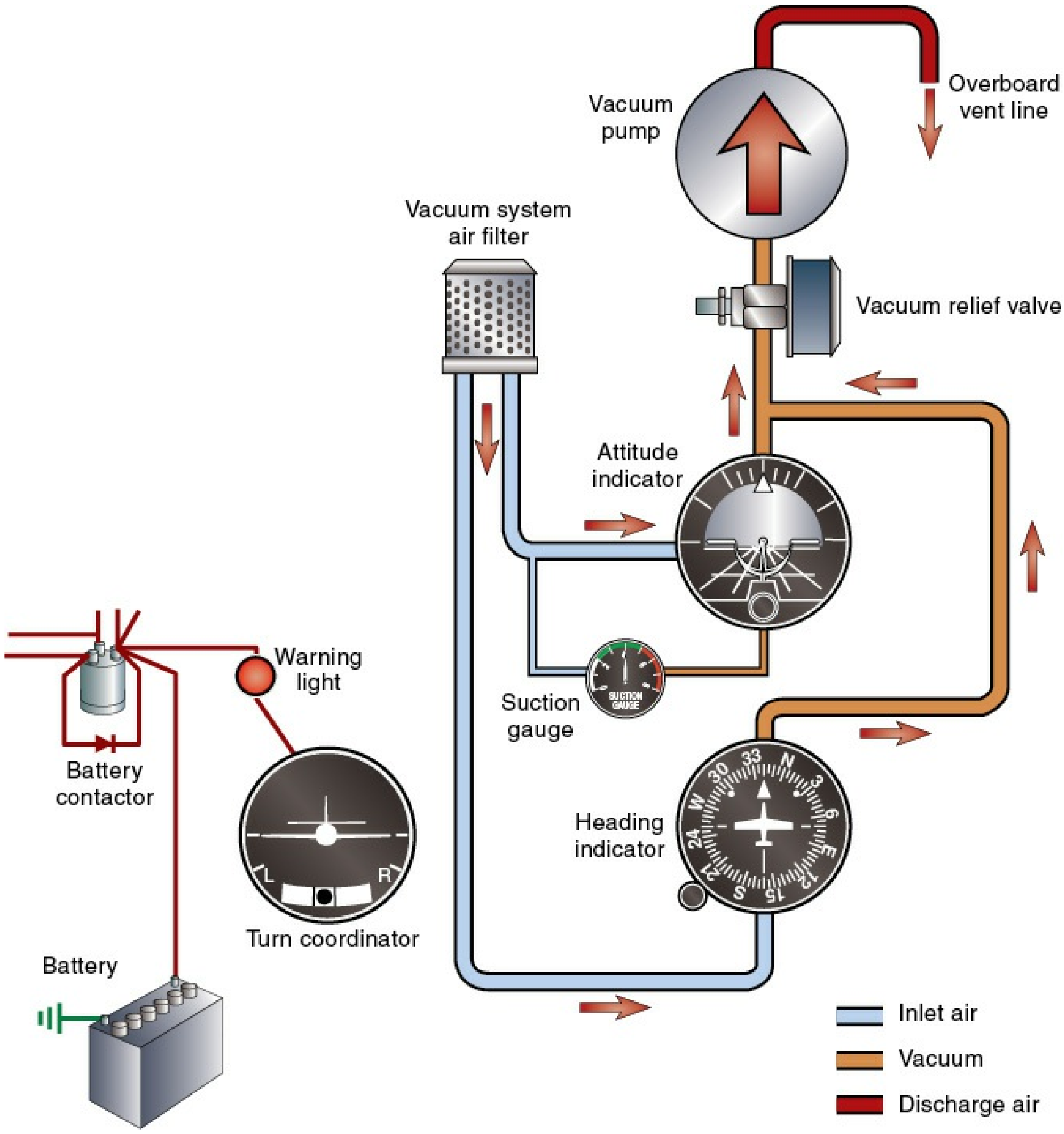


**Figure 3-43** A typical vacuum system and electrically driven turn coordinator.

A common arrangement has the attitude indicator and the heading indicator driven by suction, but the turn coordinator driven electrically. This guards against all three failing simultaneously. With a loss of electrical power, the turn coordinator may be inoperative, but the attitude indicator and heading indicator remain.

With a loss of suction, the attitude indicator and heading indicator may gradually become erratic as they spin down and then become unusable, but the turn coordinator will remain. It is possible also that an individual instrument will fail from an internal fault.

The suction (vacuum) gauge should be checked periodically to ensure that sufficient high-speed air is available to drive the gyroscopes. Power failure to an electrically driven gyroscope is usually indicated by a red warning flag on the affected instrument.

When first switching electrical power on to the electric gyro instruments, you should listen for any unusual or irregular mechanical noise as the gyro spins up, which could indicate a faulty instrument.

# Preflight Checks of the Flight Instruments

## External Inspection

During the preflight external inspection, check that the pitot cover is removed, and that the pitot tube and the static ports are not obstructed in any way.

## In the Cockpit

airplane, not fiddling with the instruments. Glass instruments can be very helpful and pleasant, but there is a limit to how much help you need, and how much you really want.

Finally, the industry is developing even more realistic and powerful flight instruments. Already, companies are advertising "artificial vision" PFDs that depict a clear sky, and the actual terrain and horizon outside the aircraft. The airplane symbol may give way to a miniature re-creation of the actual aircraft being flown. Imagine landing on a cloudy, foggy day, and looking into the PFD at the same runway on a clear, sunny day — you get the picture. Synthetic vision technology is amazing, but as pilots we must place *piloting* first — never "gadgets."

## EFIS — What's Behind the Glass

The Primary Flight Display (PFD) combines the information of all the flight instruments onto one computer screen, but the information supplied to the computer must still come from standard sources. This is especially true with the pitot-static system.

In order for the information to be presented on the PFD it must be processed and interpreted electronically. The computerized PFD still has a pitot-static system as described earlier in this chapter. The pitot tube still collects ram air and the static ports still collect static air pressure just as they do with round dials. Yet the air in the pitot and static lines do not go to the back of the instrument, instead they go to an air data computer. The *air data computer* calculates the speed of the air from the pitot line and the pressure of the air from the static line and presents that information electronically on the PFD. The air data computer also calculates the change in pressure as the airplane climbs or descends and presents that information as an electronic vertical speed indicator, complete with the same lag time that a round mechanical VSI would have.

The air data computer also collects outside air temperature data and uses that to calculate true airspeed. True airspeed is displayed with navigation information. Glass cockpit aircraft still use indicated airspeed in the flight instruments area. Finally the air data computer passes on the altitude information to the Mode C transponder so ATC can also see the airplane's altitude on their RADAR screens. FAA certification of glass cockpits also requires the installation of several round mechanical instruments as back-ups. The traditional airspeed indicator and altimeter, run through the standard pitot-static system, is still required.


**Figure 3-59** Conventional steam gauge flight instruments.


**Figure 4-2** The vertical performance instruments showing a gradual loss of altitude and airspeed increase.

The altimeter indicates altitude directly. The VSI indicates any trend away from that altitude. The ASI indicates airspeed, but can also provide information indirectly regarding pitch attitude and altitude. For instance, an increasing airspeed at a constant power setting may mean that the pitch attitude is too low for straight-and-level flight, and that a loss of altitude is occurring.

For the altimeter reading to be meaningful, the pilot must have the appropriate pressure setting in the pressure window, since this will be the pressure level from which the altimeter measures height. The setting should be:

- the current local altimeter setting for operations below 18,000 feet; and
- standard pressure 29.92 in. Hg for operations at or above 18,000 feet.

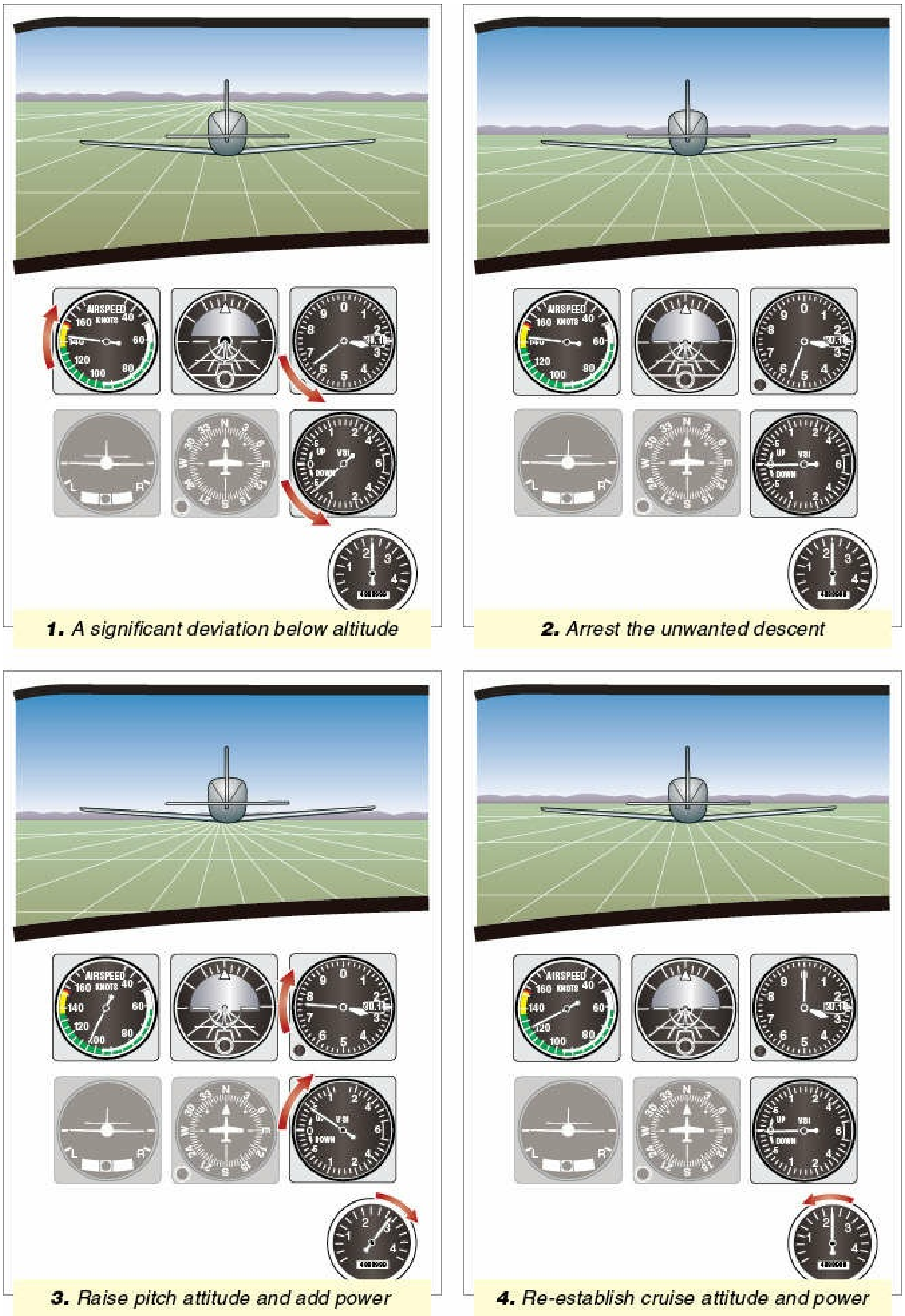


**Figure 4-16** Attitude and power corrections for a significant deviation below altitude.

Following a large deviation below altitude, a significant climb back to the desired altitude of 100 feet or more will probably require increased power for the period of the climb if airspeed is to be maintained. Once back on altitude at the desired airspeed, cruise power can be reset to maintain that airspeed.

*The rate of climb or descent to return to altitude should not exceed the number of feet off altitude.*

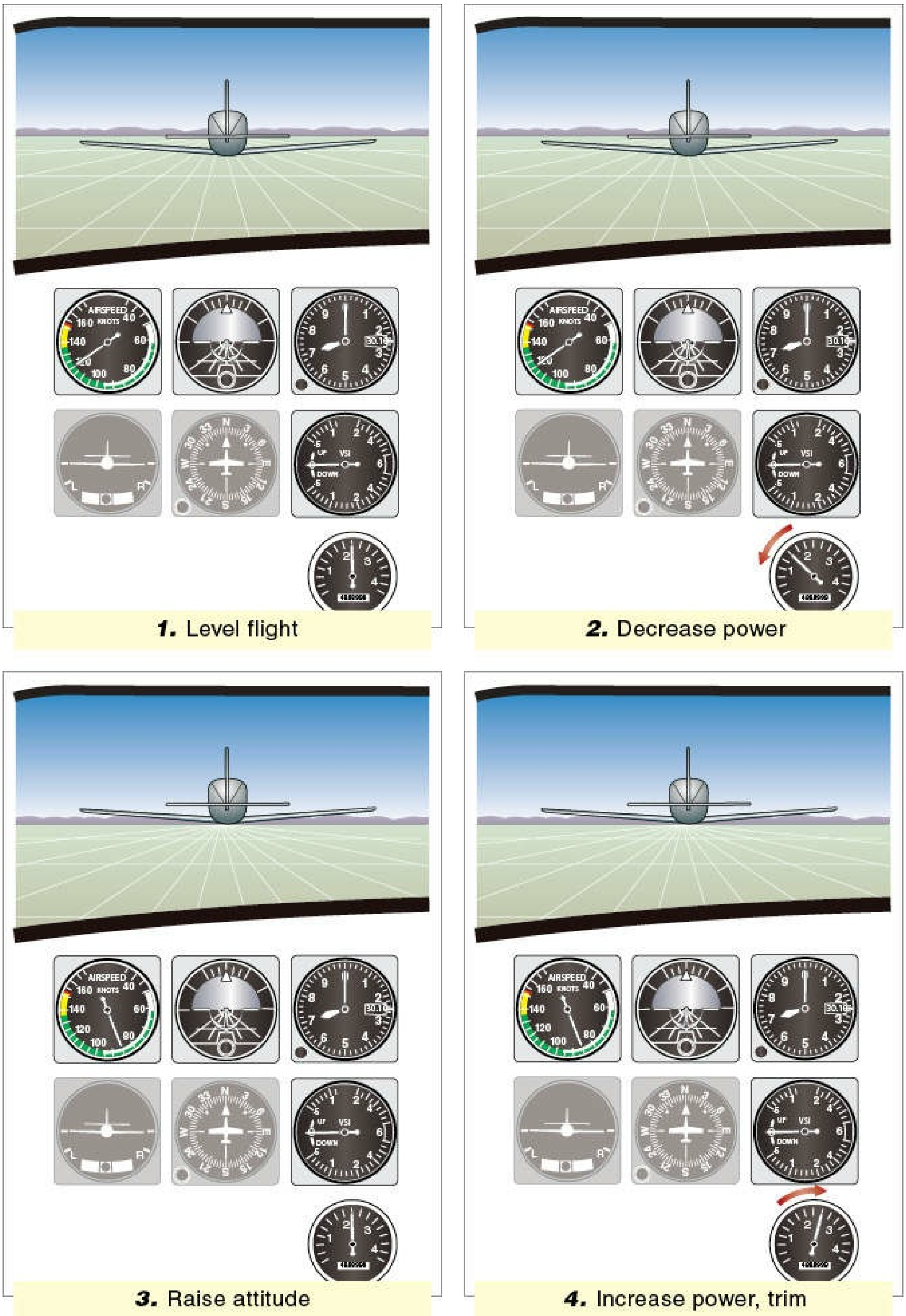



**Figure 4-27** Decreasing speed in level flight.

## Changing Configuration in Level Flight

On occasion, it is necessary to change the configuration of the airplane while maintaining level flight, for instance when extending flaps or lowering the landing gear while maneuvering prior to landing. Before making any configuration changes, however, you must ensure that airframe limitations are satisfied. For minor pitch adjustments to maintain the desired climb speed (the usual P-A-T). This is the normal technique.

In general, A-P-T is acceptable, but most instructors prefer P-A-T. When using the P-A-T method, be careful you do not exceed engine RPM limitations with a fixed-pitch propeller. The initial pitch attitude selected on the AI should be that appropriate to the desired climb speed.

## Climbing at a Particular Rate

Limiting the rate of climb to a specific value is not generally required in most light aircraft because of their relatively modest performance capabilities, even at full power. High-powered airplanes, however, may occasionally be required to climb at a particular rate.

The airspeed in a climb is controlled by small alterations in pitch attitude using elevator, with the airspeed indicator as the primary performance instrument for climb speed. The pilot has a measure of rate of climb from either:

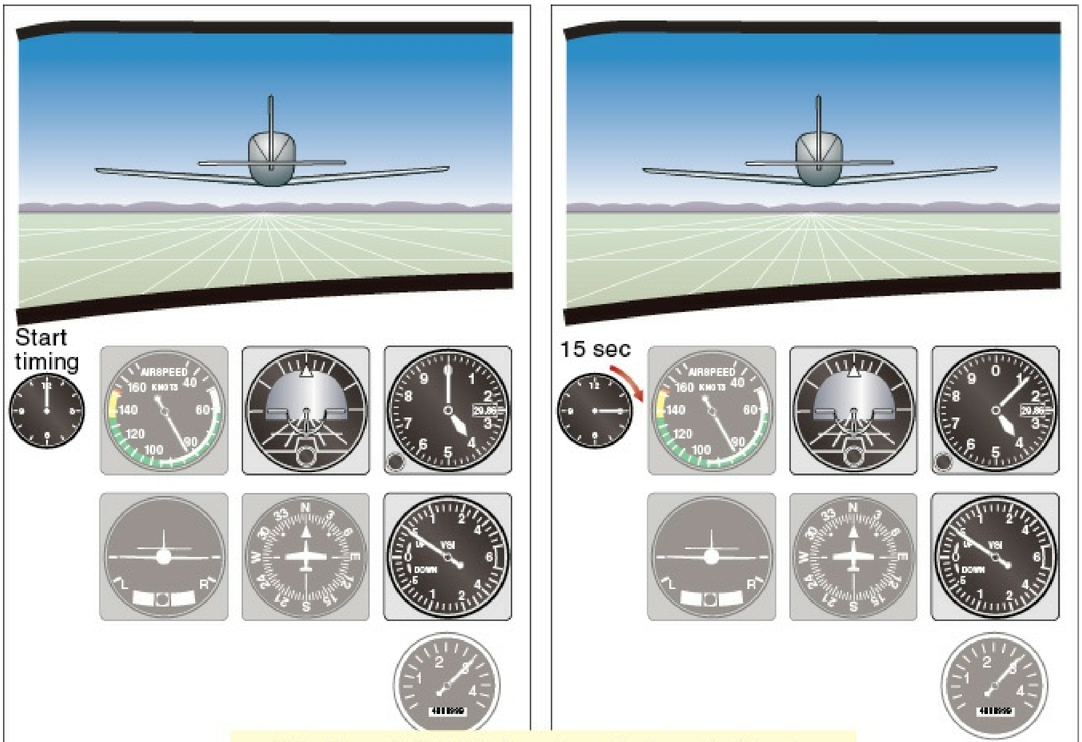
- the vertical speed indicator (VSI); or
- the clock and the altimeter combined.

The VSI, after it has stabilized, is normally the primary performance instrument for rate of climb but, if turbulence causes the VSI to fluctuate, then the pilot can either estimate the average reading of the VSI or use the clock and altimeter to time the climb. In figure 5-7, the airplane has climbed 125 feet in 15 seconds (¼ minute), a rate of 500 fpm.

Power can be adjusted until the desired rate of climb is achieved, accompanied by minor adjustments of pitch attitude on the AI to hold airspeed. For instance, as illustrated in figure 5-8, a decrease in power to reduce the rate of climb from 900 fpm to 500 fpm will require a slight lowering of the pitch attitude to maintain a constant airspeed of 80 knots.

Conversely, the rate of climb can be increased at a constant airspeed by adding power and raising the pitch attitude. If maximum power is already being used (often the case in light aircraft), the only way of improving rate of climb is to fly closer to $V_Y$, the best rate of climb airspeed.

Be warned that raising the pitch attitude too high and reducing the airspeed to below $V_Y$ will lead to a poorer rate of climb. In an extreme case, the airplane may simply stagger along in a nose-high attitude with a poor rate of climb (if any), facing the possibility of a stall, and with the risk of poor engine cooling because of the high power and reduced cooling airflow.




*Climbing at 500 ft/min using clock and altimeter*

# 6
# Turning

The aim of a turn is to change heading. This is achieved by banking the airplane and tilting the lift force produced by the wings. The horizontal component of the tilted lift force (known as the *centripetal force*) pulls the airplane into the turn.

If altitude is to be maintained, the magnitude of the tilted lift force must be increased so that its vertical component will equal the weight. This is achieved with back pressure on the control column to increase the angle of attack (raising the pitch attitude), thereby increasing the lift generated by the wings.

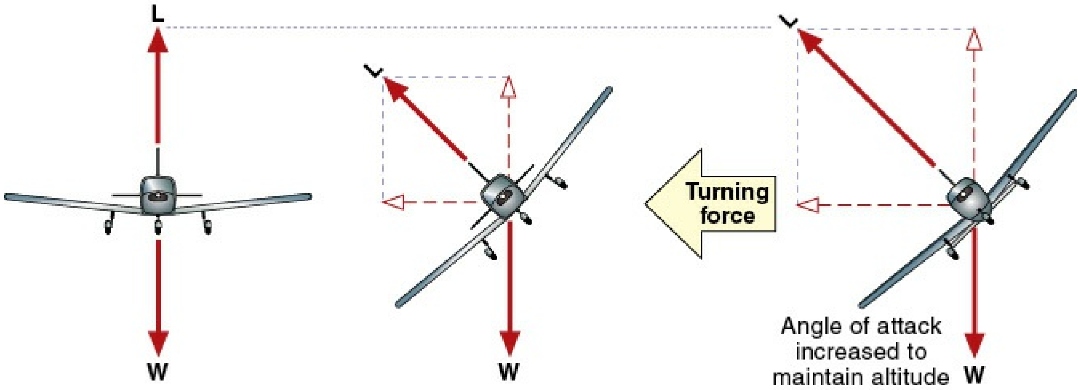



**Figure 6-1** Lift must be increased to maintain altitude in a level turn.

A consequence of the increased lift is increased induced drag. The airplane will therefore slow down unless power is applied. In a medium turn, the loss of a few knots is usually acceptable, and so additional power is not normally applied. The airspeed loss is regained fairly quickly once the airplane is returned to straight-and-level flight.

## Bank Angle and Rate of Turn

*On an electronic flight display, the rate of turn is shown using the heading trend indicator.*

The *standard-rate* of turn in instrument flying is 3° change of heading per second. At standard-rate, it will therefore take 30 seconds to turn through a heading change of 90°, one minute to turn through 180°, and two minutes to turn through 360°. The standard-rate of turn is marked on most turn coordinators, which may also be labeled "2 MIN." A half standard-rate turn would be at 1.5° per second, and a complete 360° turn would take four minutes at this rate.

The rate of turn is a function of airspeed and bank angle — a higher airspeed requiring a greater bank angle to achieve the same rate of turn. A quick method of estimating the bank angle required for a standard-rate turn is: *Divide airspeed by 10, then add one-half the answer.* For example, at an airspeed of 100 KIAS, the approximate bank angle for a standard-rate turn is: airspeed ÷ 10 + ½ the answer:

$$\frac{100}{10} + \left(\frac{1}{2} \times \frac{100}{10}\right) = 15° \text{ bank angle}$$

At 140 KIAS airspeed, the required bank angle is approximately airspeed ÷ 10 + ½ the answer:

$$\frac{140}{10} + \left(\frac{1}{2} \times \frac{140}{10}\right) = 21° \text{ bank angle}$$

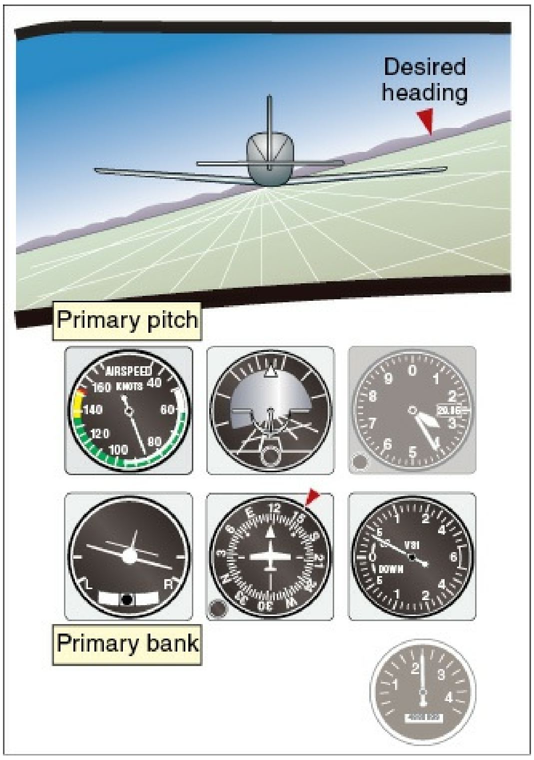



**Figure 6-13** Maintaining a climbing turn.

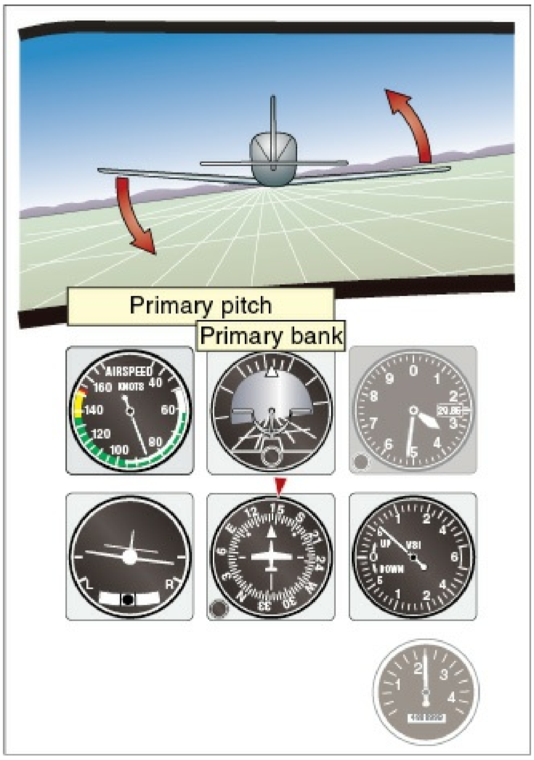



**Figure 6-14** Rolling out of a climbing turn.

## Descending Turns

*Maintain airspeed in a descending turn.*

The technique for a descending turn is the same as for a level turn, except that airspeed (rather than altitude) is maintained. This makes the ASI the primary performance guide to the correct pitch attitude.

# 7
# Unusual Attitudes

An *unusual attitude* in instrument flying is any attitude not normally used during flight solely on instruments, including:

- bank angles in excess of 30°;
- nose-high attitudes with a decreasing airspeed; and
- nose-low attitudes with an increasing airspeed.

Unusual attitudes are potentially hazardous, so you should learn to recognize and recover from them before they develop into hazardous situations.

*To recover from an unusual attitude you must recognize exactly what the airplane is doing and return it safely to normal acceptable flight.*

*Increase your scan rate. Cross-check instruments to determine if any has malfunctioned.*

An unusual attitude may result from some external influence such as turbulence, or it can be induced by pilot error. For instance, you might become disoriented or confused (Where am I? Which way is up?). You could become preoccupied with other cockpit duties such as radio calls, or chart study, at the expense of an adequate scan. You might overreact on the controls, interpret the instruments incorrectly, or unknowingly follow an instrument that has failed. Such loss in control may allow the airplane to enter an unusual attitude.

Whatever the cause of the unusual attitude, the immediate problem is to recognize exactly what the airplane is actually doing, and to return it safely to normal acceptable flight (generally straight-and-level flight). Advanced avionics and glass cockpits can aid in situational awareness and recovery from unusual attitudes. After the recovery, you should try to determine the cause of the event, to prevent any recurrence.

In unusual attitudes, the physiological sensations may be disconcerting, but do not allow these to influence either the recognition of the attitude, or the subsequent recovery action.

## Recognizing an Unusual Attitude

If you notice any unusual indications on flight instruments, experience unexpected g-forces or hear unusual air noise, assume that the airplane could be in (or is about to enter) an unusual attitude.

Increase your scan rate. Cross-check all instruments to determine if any instrument has malfunctioned.

If all instruments are functioning normally, then an *excessive bank angle* will be indicated directly on the AI, supported by an excessive rate of turn on the turn coordinator, and a rapidly turning heading indicator. Which way the wings are banked can be determined from the attitude indicator, supported by the turn coordinator. (Be aware that some attitude indicator gyroscopes can tumble and become unusable when the airplane is in an extreme attitude. This is discussed shortly.)

**Figure 7-12** Question 6.

**Figure 7-13** Question 7.

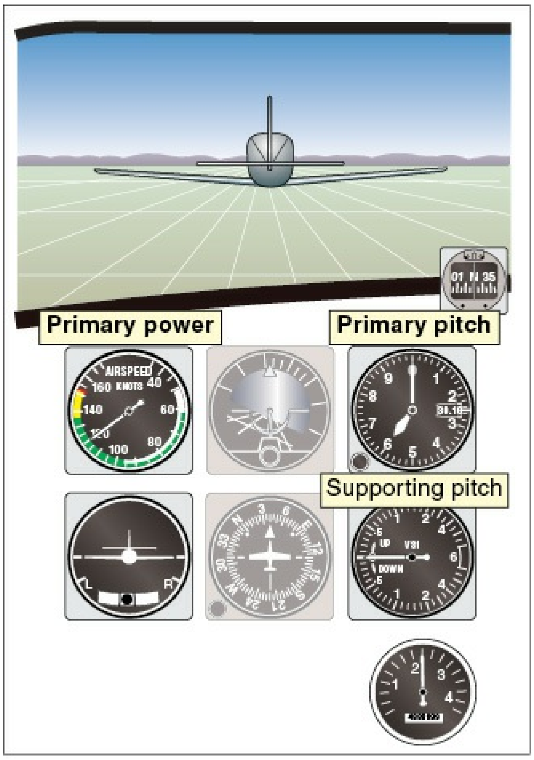



**Figure 8-11** Changing airspeed on a partial panel.

*Lower Airspeed*

Reducing the airspeed requires less power and a higher pitch attitude. The power reduction will cause a *pitch down/yaw right* tendency, which the pilot should be ready to counteract. The VSI can be used to anticipate any tendency to lose altitude, prevented by use of the elevator, and the turn coordinator and ball can be used to prevent any tendency to drift off heading. Once the desired lower airspeed is achieved, minor power adjustments with the throttle may be required. The airplane should then be retrimmed.

# Climbing on a Partial Panel

## Entering a Climb

*Use P-A-T, power — attitude — trim to climb on partial panel.*

The procedure to enter a climb using only a partial instrument panel is the same as with a full panel: P-A-T, power-attitude-trim. Smoothly apply climb power (mixture RICH if necessary); remember: there will be a pitch-up tendency as power is applied. Keep the wings level on the turn coordinator and the ball centered to stay coordinated. Raise the nose to the climb attitude with back pressure on the control column.

Even if your aircraft is not a glass cockpit in a TAA, having a GPS can offer much assistance to the pilot flying on partial panel. Advantages are:

- NRST airport function — for easy diversion to an alternate.
- General situational awareness.
- VNAV for a standard descent attitude.
- Autopilot relieves workload for the pilot faced with an unexpected diversion to an alternate.
- Some autopilots have their own separate turn coordinator.
- Depending on the type of autopilot, HDG mode may work as a wing-leveler; the NAV and ALT functions may also serve to keep the aircraft stabilized.

Dealing with a partial panel situation takes practice and an understanding of what has failed. Recognizing which sources can provide replacement information is an important skill. A large part of a pilot's training involves training for failures, but by using the correct redundant information the pilot can maintain control of the airplane and fly safely through the loss of an instrument.

## Encountering Partial Panel — What to Do

Standby Vac Equipped

1. Confirm your assessment of functioning instruments.
2. Activate standby vac.
3. Re-affirm your assessment of working instruments after standby vac activated.
4. Engage autopilot, if available and not already engaged.
5. Evaluate your current flight/weather/safety situation: IMC or VMC.
6. Make a plan to divert to nearest practical airport.
7. Advise ATC of situation and intentions.
8. Comply with standby-vac operational limitations.
9. Use all available resources.
10. Land as soon as practical.

Standby Vac Not Equipped

1. Confirm your assessment of functioning instruments.
2. Engage autopilot, if available and not already engaged.
3. Evaluate your current flight/weather/safety situation: IMC or VMC.
4. Make a plan to divert to nearest practical airport.
5. Declare emergency. Advise ATC of situation and intentions.
6. Use all available resources.
7. Plan to do the one IAP that will get you safely on the ground the first time.
8. Land as soon as practical.

## Attitude Instrument Flying and Emergency Instrument Procedures in the ACS

In the Airman Certification Standards, the FAA has stressed the imperative that instrument pilots acquire and maintain adequate instrument skills and that they be capable of performing instrument flight with the backup systems installed in the aircraft. However, some technically advanced aircraft may be equipped with backup flight instruments or an additional electronic flight display that is not located directly in front of the pilot. Additionally, some light airplanes are not equipped with dual, independent, gyroscopic heading and/or attitude indicators and in many cases have only a single vacuum source.

Regardless of what your aircraft has, in your practical test as required by Airman Certification Standards (FAA-ACS-8), your basic instrument flight maneuvers will be evaluated by the examiner under full- and partial-panel, with reference to backup primary flight instruments and/or electronic flight displays.

The instrument rating Airman Certification Standards place emphasis on and require the demonstration of a nonprecision instrument approach without the use of the primary flight instruments or electronic flight instrument display, which is considered one of the most demanding situations a pilot can encounter. In other

Figure 9-4 Pattern B.

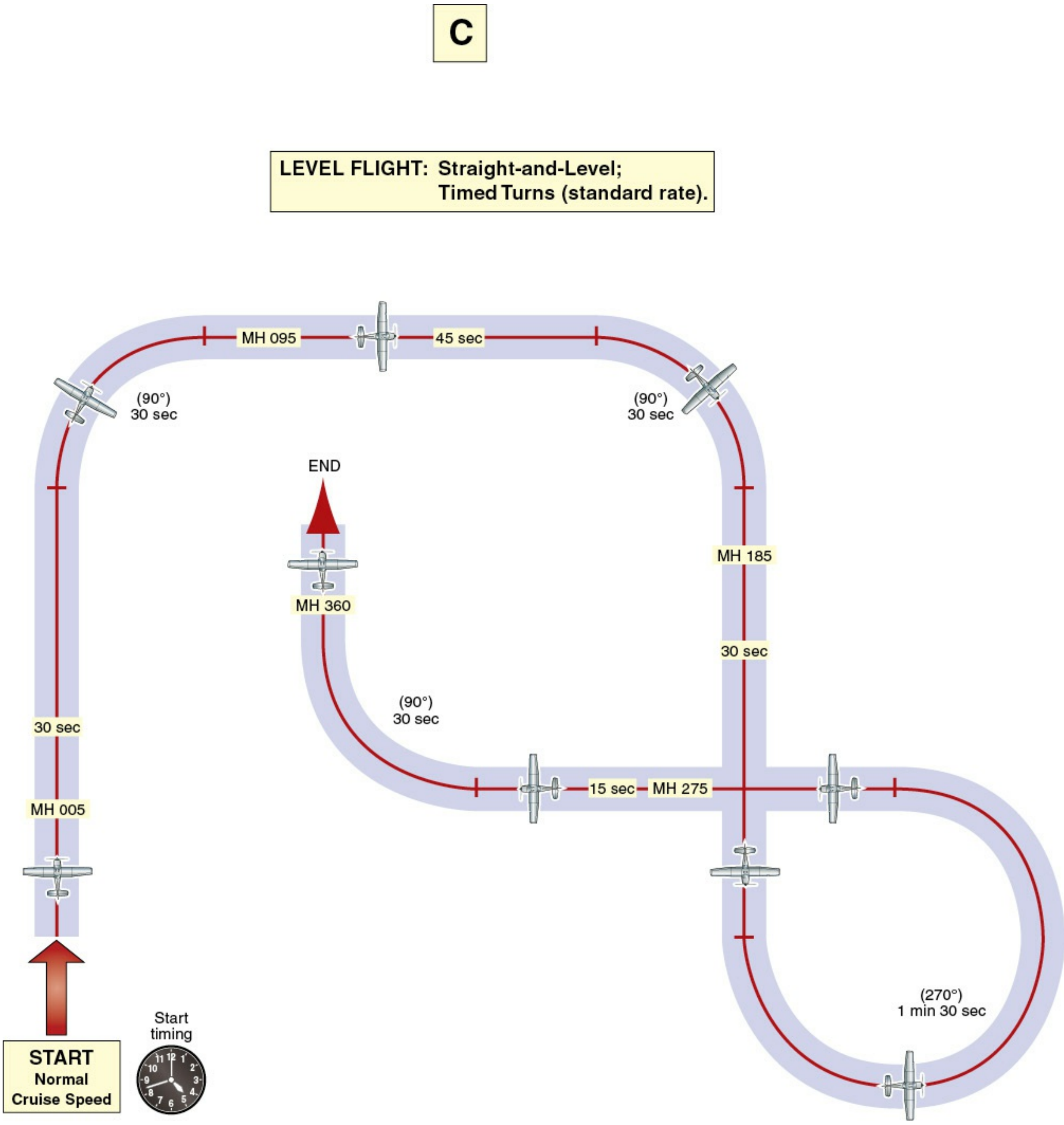



Figure 9-5 Pattern C.

Even if you are receiving this service, you are still responsible, in suitable conditions, for continual vigilance to "see and avoid" other traffic. The radar controller will pass what he or she considers relevant information using the clock system to specify the position of the other traffic relative to your course. The controller sees your course on a screen rather than your heading, so you will have to allow for the drift angle when you look out the window for other traffic.

An important component of the surveillance radar systems used in the U.S. is the *air traffic control radar beacon system* (ATCRBS), sometimes referred to as *secondary surveillance radar*, or SSR. The operating principles of this system, and its advantages over primary radar, will be explained later in this chapter.

An essential component of the SSR system is the *transponder*, a piece of equipment common in most aircraft. A transponder transmits a unique reply signal in response to radar signals received from the ground, allowing a radar controller to identify and track individual aircraft with greater accuracy and safety. The term *transponder* is a contraction of *transmitter/responder*.

At some airports, ATC may use SSR information to provide course guidance down a final approach path for what is known as an *airport surveillance radar* (ASR) approach, usually referred to simply as a *surveillance approach*. This procedure is normally only considered if equipment failure has ruled out all other types of instrument approach. It is a back-up procedure only.

A very small number of airports are equipped with a special type of approach radar equipment, known as *precision approach radar* (PAR), which enables ATC to provide extremely accurate guidance, along both a specific final approach course and a descent slope, to land on a particular runway. The PAR approach is rarely used by civilian pilots.

We will consider radar vectoring and then look at radar approaches to land. We will reserve consideration of the principles of radar until the end of the chapter.

The availability of radar at a particular airport is indicated on FAA instrument approach charts by the letters ASR in the notes portion of the "pilot briefing and procedures" section. On *Jeppesen* instrument approach charts it is indicated by the letter "R" in brackets following the particular communications frequency. There are many airports and much airspace in the world that is in a nonradar environment. Without the protection of radar, you should comply with any published departure and approach procedures, and expect ATC to request additional reports to enable them to monitor the progress of your flight.


**Figure 10-2** Typical SSR transponder.

# Radar Vectoring

Radar vectoring is a procedure in which a radar controller passes a *heading* to steer to a pilot, with an instruction like:

*Cessna seven zero four charlie delta,*

*turn left heading two five zero*

The aim of the controller when issuing these headings is to get the aircraft to follow a particular *course* over the ground. Because the radar controller will not know precisely the actual wind at your level, or the amount of drift it is causing, he or she will occasionally issue modified vectors to achieve the desired course.

*ATC's initial assignment of vectors will include the purpose of those vectors, for example: "Vectors to final approach" or "Vectors for spacing"*

Radio communication and maintaining an accurate heading is essential when being radar vectored by ATC. The pilot concentrates on attitude flying (maintaining the desired heading, altitude and airspeed), while the radar controller concentrates on getting the aircraft to follow the desired course. This does not, however, relieve the pilot of the responsibility to be aware of the aircraft's approximate

Both the bearing and the range of an object can therefore be determined by radar, so that its position can be precisely pinpointed, and the *returns* displayed as *blips* (echoes or sometimes called skin paints) on a suitable screen.

## Primary Surveillance Radar

Radar that makes use of reflected radio energy is known as *primary radar,* and it is used for a number of purposes in aviation including:

- *surveillance radar,* to provide an overview of a wide area, and used in *air route surveillance radar* (ARSR) and *airport surveillance radar* (ASR), and also used for ASR instrument approaches; and
- *precision approach radar* (PAR), used for extremely accurate azimuth and slope guidance on final approach to land.

Surveillance radar is designed to give a radar controller an overview of the area of responsibility. It does not transmit pulses in all directions simultaneously, but rather as a beam, which is slowly rotated. For an aircraft to be detected, the beam must be directed roughly toward it.

If the radar controller has the radar tilted up, then it may miss lower aircraft at a distance; conversely, nearby high aircraft may not be detected if the tilt is down.

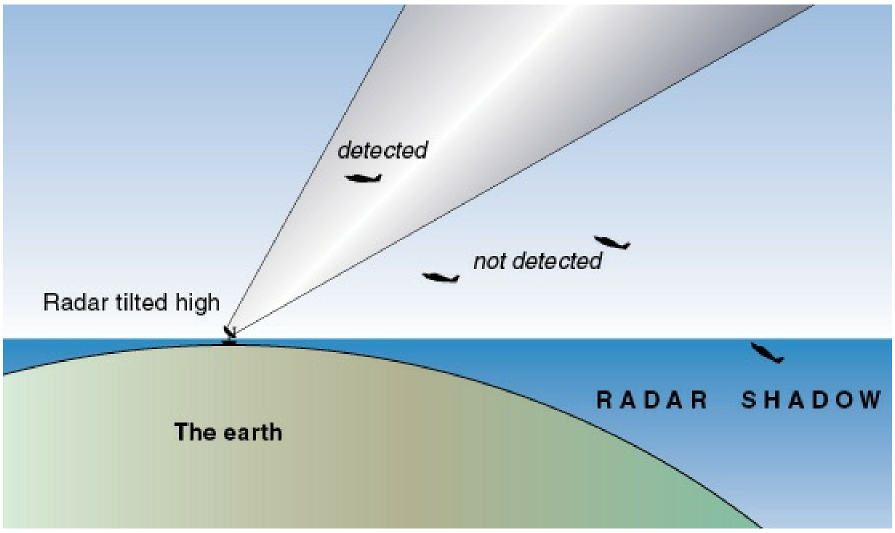



**Figure 10-11** To be detected, aircraft must be within the radar transmitter's beam.

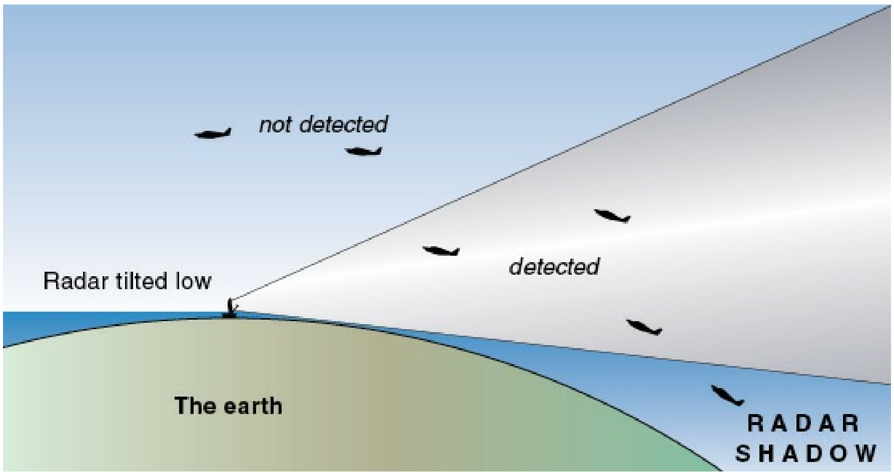



**Figure 10-12** Radar tilted low cannot detect high targets.

## The Radar Screen

For decades, radar screens were simply cathode ray tubes (CRTs) that resembled an old circular television screen. In a CRT, using the same principle as television, a beam of electrons was directed at the fluorescent coating of the tube, providing a radar picture. Radar controllers generally had circular displays showing the

- control panel; and
- display unit.

The radar returns are displayed separately or superimposed on a *multi function display* (MFD) over the navigation and waypoint information. Thus the pilot receives a total picture of position track and possible heavy weather. Color coding is used to classify the seriousness of the weather (the size of the droplets and particles). The more active the cell, the larger the droplets. Also, a storm is most violent just before releasing the suspended rain and hail, perhaps before there is visible lightning; however, there are likely to be internal electrical discharges which will show on a stormscope.

Airborne weather radar systems operate in the C and X bands. With power outputs from 12 kWatts for older designs, to only 30 Watts for fully digital radar systems, the maximum range of modern radars is about 300 NM. The antenna is normally stabilized using attitude signals from one of the vertical gyros or inertial references (to avoid clutter from ground returns during turns).

The antenna sweeps (scans) the pencil-shaped radar beam about 60° either side of the nose and can be tilted up and down to about ±15°. Radar returns, or *echoes*, are processed to provide range and azimuth data, which is then displayed in the cockpit.

*Airborne weather radar provides real-time weather that can be used for tactical decisions on navigation around weather.*

Airborne weather radar installed in sophisticated aircraft is a type of primary radar that can detect water drops. Most models cannot detect air currents, turbulence, windshear, hail, or the fact that instrument-flying conditions exist, but can warn you of the possibility of these phenomena since they are associated with cumulonimbus clouds, which do contain large water drops — a case of guilt by association.

*Some models of airborne weather radar can also detect turbulence.*

Large water drops reflect the radar beam transmitted from the airplane, and this reflected signal is shown on the display in the cockpit as a radar echo. Color weather radar displays are extremely effective in portraying the weather, with a number of strong colors representing the intensity of the returns — usually graded from *green* for light rain, through *yellow* and *red*, to *magenta* for severe rain showers.

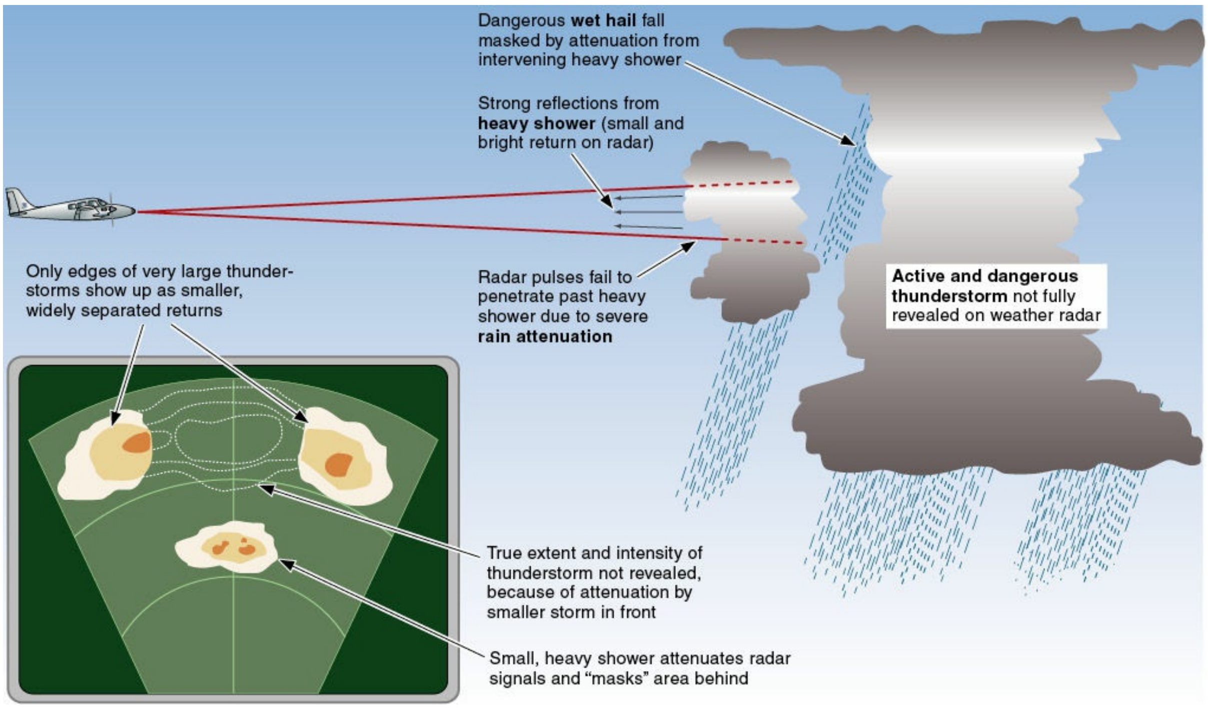



**Figure 10-25** Storm cells appearing as echoes on a weather radarscope.

Not all storm cells containing large drops of water will be detected initially, since nearer cells may mask the presence of more distant cells. An extremely strong storm may also show up as a "hole" in the radar picture.

Any storm cells strong enough to cause a radar echo should be avoided by at least 20 miles. To achieve this separation between two storm cells, they must be at least 40 miles apart. If not you should consider flying to one side of the pair of cells.

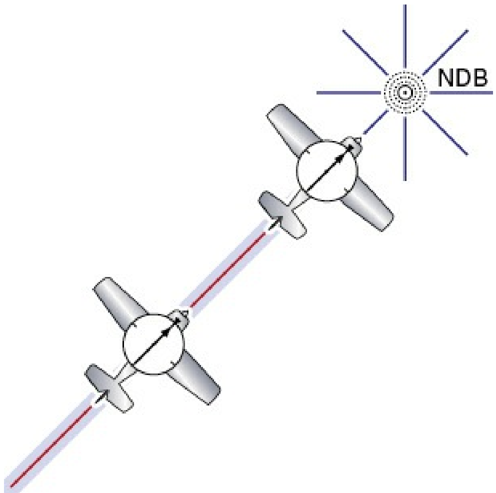



**Figure 11-2** Flying to a station is straightforward.

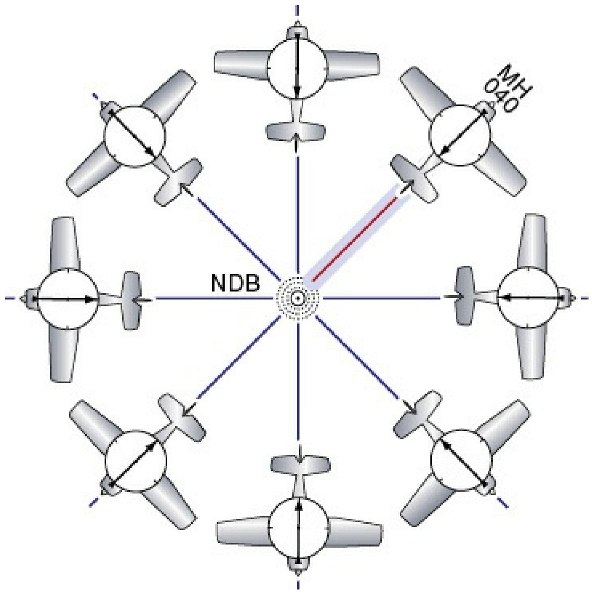



**Figure 11-3** Flying away from a station requires more navigation information than just the needle on the tail.

# ADF and the HI

The extra information required by the pilot, in addition to that supplied by the ADF needle, comes from the magnetic compass or, more commonly, from the heading indicator (which is kept manually aligned with the compass by the pilot, and is easier to use). Accurate navigation can be carried out using these two references:

- *an ADF needle* that points at an NDB ground station; plus
- *a heading indicator* that indicates the airplane's magnetic heading (MH).

**Note.** Since a heading indicator will slowly drift out of alignment, it is vital that you periodically realign it with the magnetic compass in straight-and-level flight at a steady speed, say every 10 minutes or so.

A drift out of alignment of 3° in 15 minutes is the maximum acceptable for the HI to be considered serviceable.

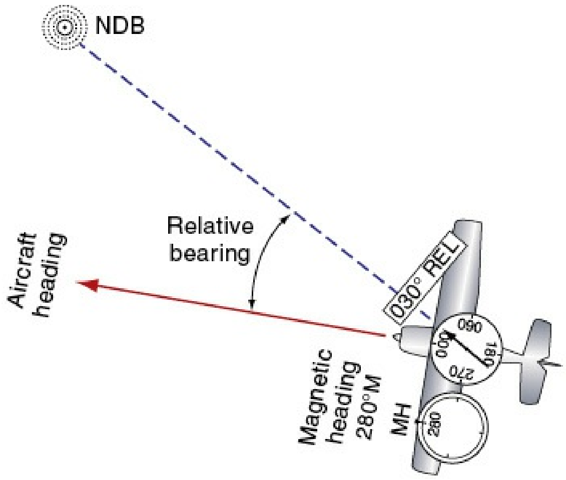



**Figure 11-16** A fixed-card ADF is a relative bearing indicator (RBI).

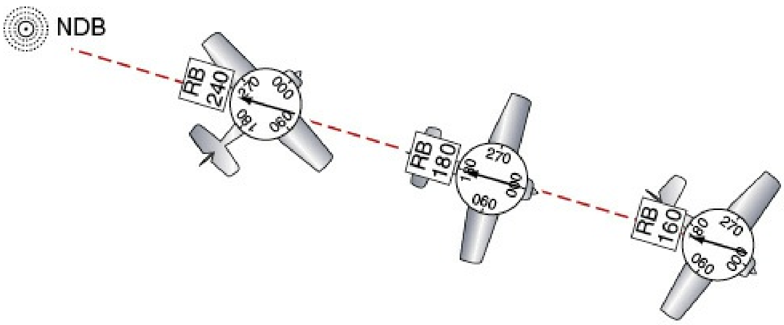



**Figure 11-17** Each time heading is changed,the relative bearing also changes.

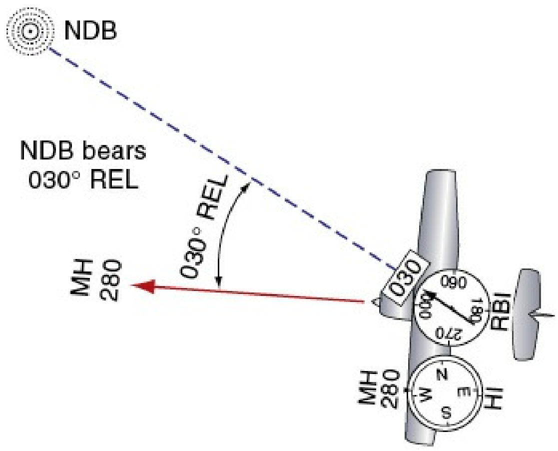



**Figure 11-18** Orientation (Where am I?) using an RBI.

*Visualizing Magnetic Bearing From the NDB*

The magnetic bearing of the aircraft from the NDB is the reciprocal of the magnetic bearing to the NDB. In figure 11-19, this is MB 130 from the NDB. MB from can be visualized as the tail of the pencil (or needle) when it is transferred from the RBI on the ADF onto the HI.

**Note.** An easier method of finding reciprocals than adding or subtracting 180°, is to either add 200 and subtract 20 or subtract 200 and add 20.

*Example 11-2*

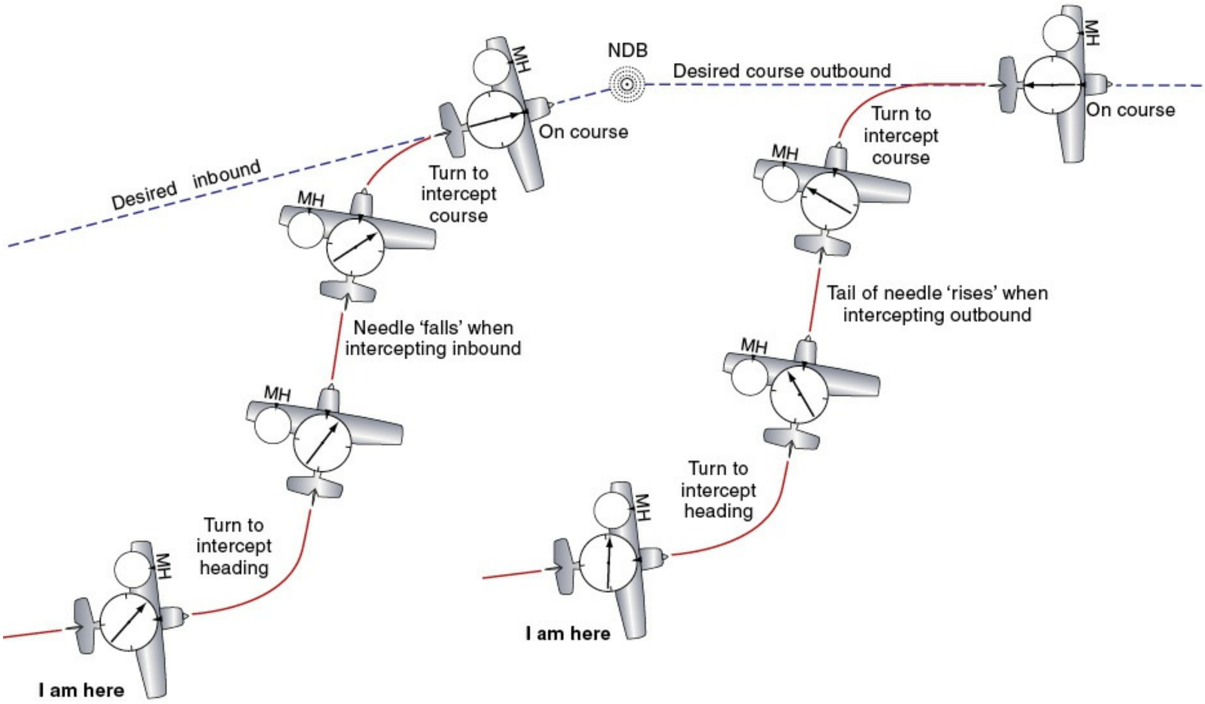



**Figure 11-35** Where am I? Where do I want to go? How do I get there?

*Visualizing Where You Are and Where You Want To Go*

The heading indicator (HI) helps you visualize the situation. In the previous example, the situation MH 070 and RB 260 was visualized, with MB 330 to the NDB. What if the pilot wishes to intercept a magnetic course (MC) 270 to the NDB?

All the pilot needs to do is visualize the desired course on the heading indicator. With a model airplane on the tail of the needle tracking as desired, it becomes clear what turns are necessary to intercept the desired course. First turn left to a suitable intercept heading, say MH 360 for a 90° intercept of MC 270 to the NDB.

**Note.** If you become disoriented, a simple procedure is to take up the heading of the desired course. Even though not on course, the airplane will at least be parallel to it, and the ADF needle will indicate which way to turn to intercept it.

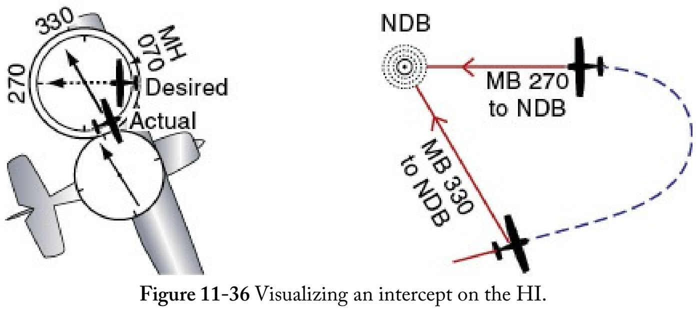



**Figure 11-36** Visualizing an intercept on the HI.

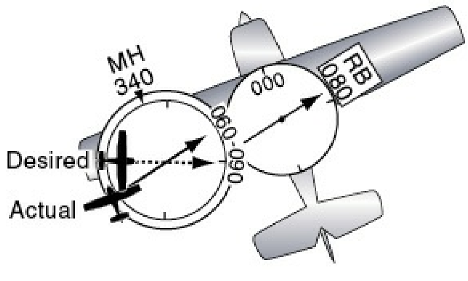



**Figure 11-37** Visualizing the intercept.

Attempting to maintain the desired course (remaining on a constant MB to the NDB) is the normal navigational technique when more than just a mile or two from the NDB. If, when steering a steady magnetic heading, the ADF needle indicates a constant relative bearing near the top of the dial, then the airplane is tracking directly to the NDB, and no correction to heading is necessary.

Just how great each correcting turn should be depends on the deviation from course. A simple method is to *double the error*. If the airplane has deviated 10° left indicated by the RBI moving 10° right, then alter heading by 20° to the right. (If you alter heading by only 10° to the right, the result will probably be a further deviation to the left, a further correction to the right, with this being repeated again and again, resulting in a curved homing to the NDB.)

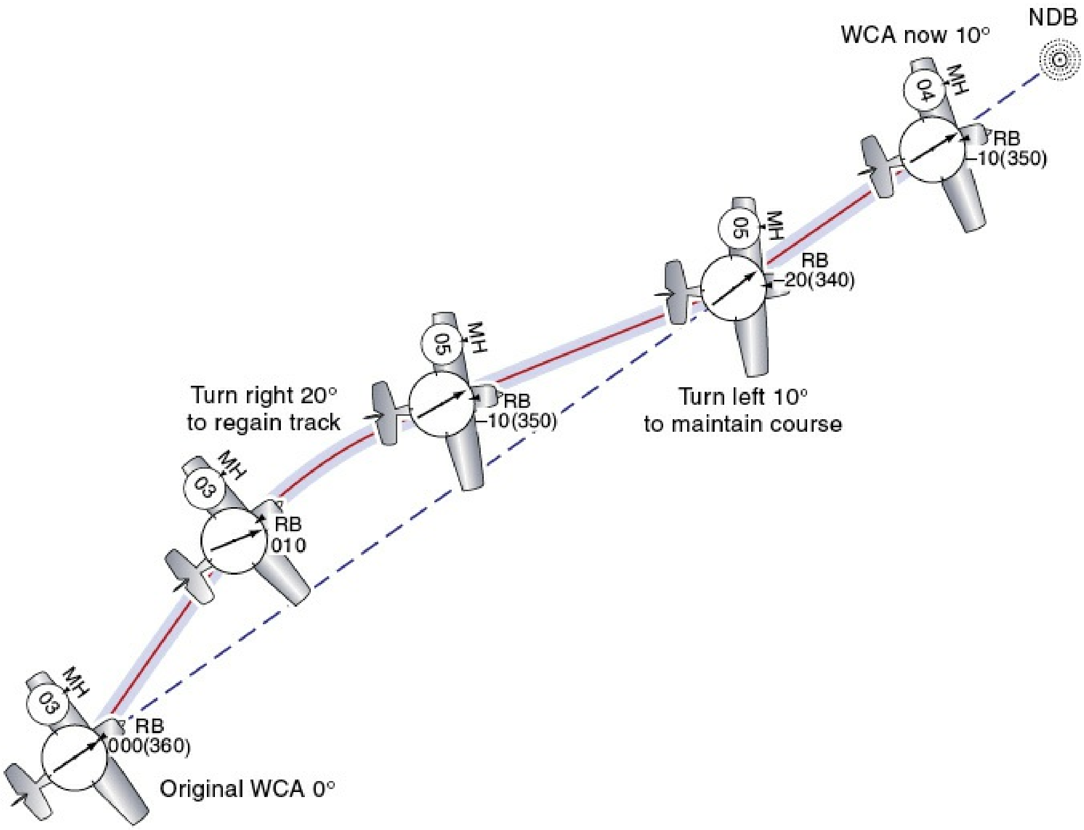



**Figure 11-53** Regain course by "doubling the error" and maintain course thereafter.

Having regained course, turn left by only half the correcting turn of 20°, that is, turn left 10° to intercept and maintain course. This leaves you with a WCA different to the original one (remembering that the original WCA caused you to deviate from course).

The new WCA should provide reasonable tracking. If not, make further minor corrections to heading.

## "Bracketing" Course

In practice, an absolutely perfect direct course is difficult to achieve. The actual ground track by the pilot will probably consist of a series of short segments either side of the desired course, which corresponds to minor corrections similar to those described above. This technique is known as bracketing the course, and involves making suitable heading corrections, left or right as required, to regain and maintain the desired course.

The aim of bracketing is to find the precise WCA needed to maintain course. If, for instance, a WCA of 10° right is found to be too great and the airplane diverges to the right of course, and a WCA of only 5° right is too little and the wind blows the airplane to the left of course, then try something in between, such as WCA 8° right.

*Bracketing is a technique used to get you to a point where you can begin tracking.*

Monitor the tracking of the airplane on a regular basis, and make corrections earlier rather than later, the result being a number of small corrections rather than just one big correction. However, if a big correction is required, as may be the case in strong winds, make it.

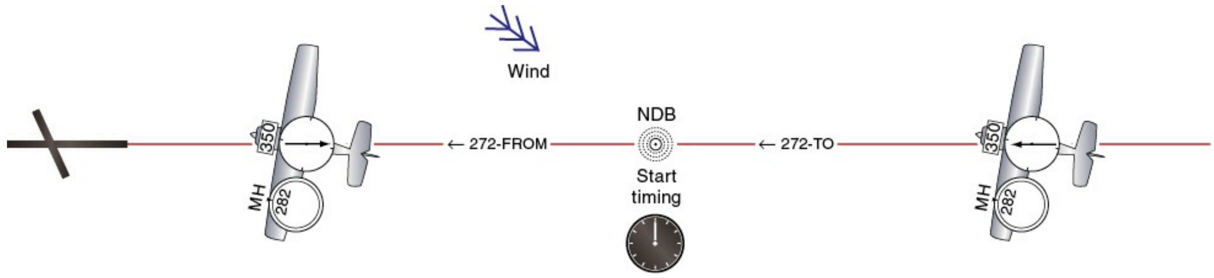



**Figure 11-65** Tracking on the Valparaiso NDB Rwy 27 approach.

# The RMI and Rotatable-Card ADF

The *radio magnetic indicator* combines the *relative bearing indicator* and the heading indicator into the one instrument, where the ADF card is aligned automatically with magnetic north. This considerably reduces your workload by reducing the amount of visualization and mental arithmetic required. Even the manually rotatable-card (the "poor man's RMI" which allows you to align the ADF card manually with magnetic north) lightens the workload, since it also reduces the amount of visualization and mental arithmetic required. The following discussion applies to both the RMI and the manually rotatable-card ADF, except that:

- the RMI is continuously and automatically aligned with magnetic north; while
- the manually rotatable-card must be realigned with the heading indicator by hand following every heading change (and of course the HI must be realigned with the magnetic compass by hand every 10 minutes or so).


**Figure 11-66** The manually rotatable ADF card.

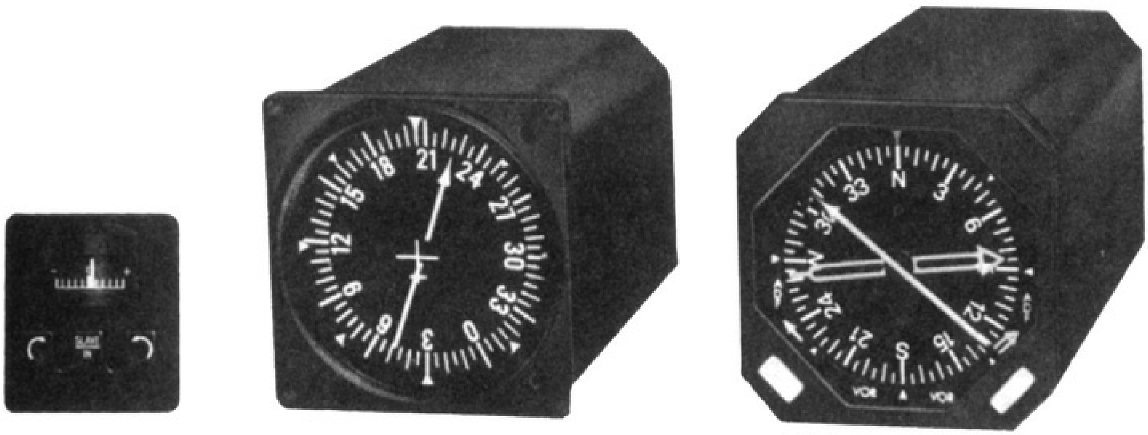


**Figure 11-67** Single and double ADF pointer RMIs.

## Orientation

An RMI gives a graphic picture of where the airplane is:

- the *head* of the RMI needle displays magnetic bearing *to* the ground station; and
- the *tail* of the RMI needle displays magnetic bearing *from* the ground station.

One significant advantage of the RMI over the RBI is that you can select it to either an NDB or a VOR ground station. The method of use is the same in each case. If the head of the RMI needle indicates 030, then achieved, you must be prepared to increase your scan rate and respond more frequently.

Close to the station and just prior to passing over the NDB, however, the RMI needle can become agitated, and the pilot should relax a little and steer a steady heading until the RMI needle moves toward the bottom of the dial and settles down, at which time tracking from the NDB should be checked and suitable adjustments made to heading.

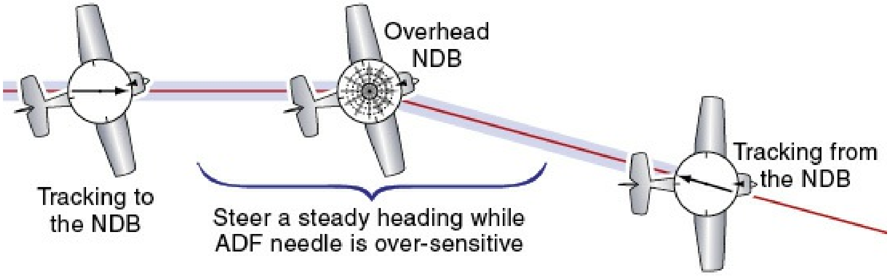



**Figure 11-81** Do not overcorrect when close to the station.

If the course outbound is different from that inbound, then a suitable heading change estimate could be made as soon as the RMI needle falls past the mid-position on its way to the bottom of the dial.

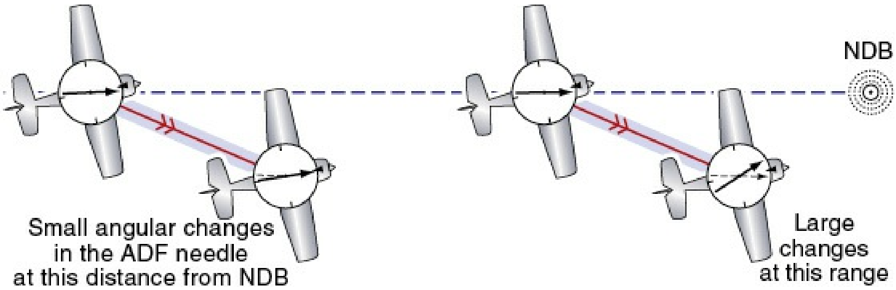



**Figure 11-82** Approaching the NDB, the RMI needle becomes more sensitive.

The RMI needle becoming extremely active and then falling rapidly past the abeam position to the bottom of the dial indicates that the airplane has passed directly over the NDB.

The RMI needle moving gradually to one side and slowly falling to the bottom of the dial indicates that the airplane is passing to one side of the beacon — the rate at which the needle falls being an indication of the airplane's proximity to the NDB. If it falls very slowly, then possibly the tracking by the pilot could have been better. Time over (or abeam) the NDB can be taken as the needle falls through the approximate mid-position.

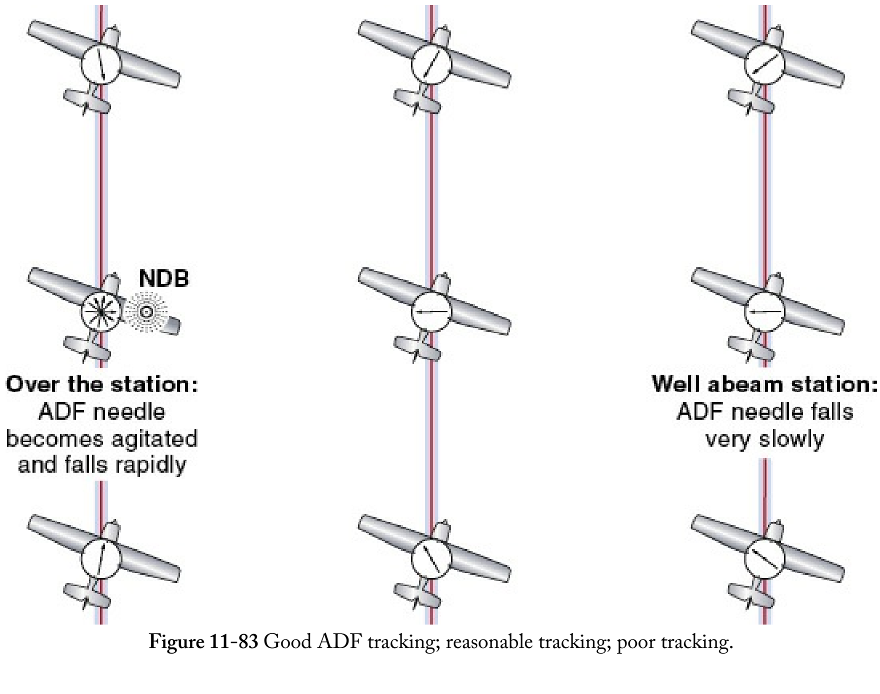



**Figure 11-83** Good ADF tracking; reasonable tracking; poor tracking.

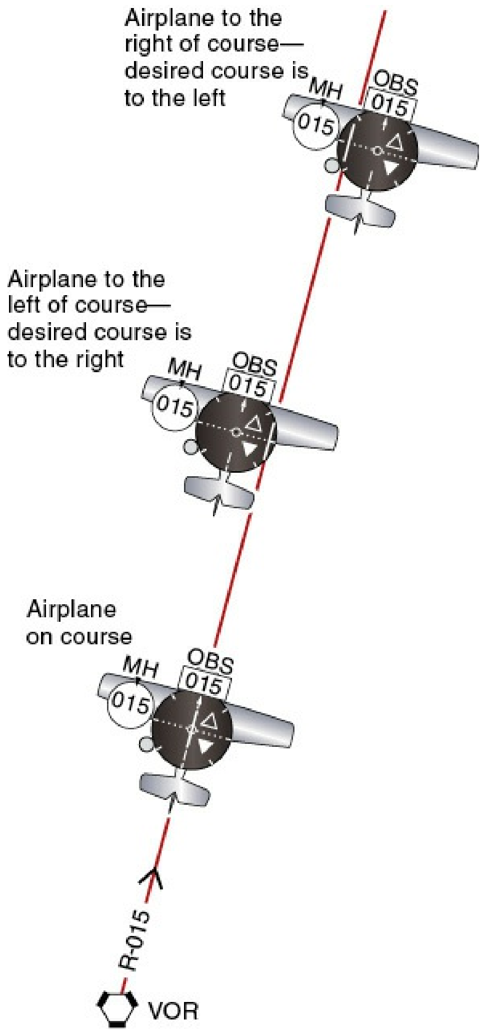



**Figure 12-2** The VOR is used to indicate course (track).

The 090 radial, which is a magnetic bearing of 090 away *from* the station, is the same position line as 270 *to* the station. If an airplane is on this position line, then the CDI will be centered when either 090 or 270 is selected with the OBS. Any ambiguity in the pilot's mind regarding the position of the airplane relative to the VOR ground station is resolved with the TO/FROM indicator.

The TO or FROM flags or arrows indicate to the pilot whether the selected omni bearing will take the airplane *to* the VOR ground station, or away *from* it. In the case shown in figure 12-16, the pilot can center the CDI by selecting either 090 or 270 (which are reciprocals) with the OBS. A course of 090 would take the airplane *from* the VOR, whereas a course of 270 would lead it *to* the VOR.

**Note.** In this manual, the active direction is indicated by the white arrow, triangle.

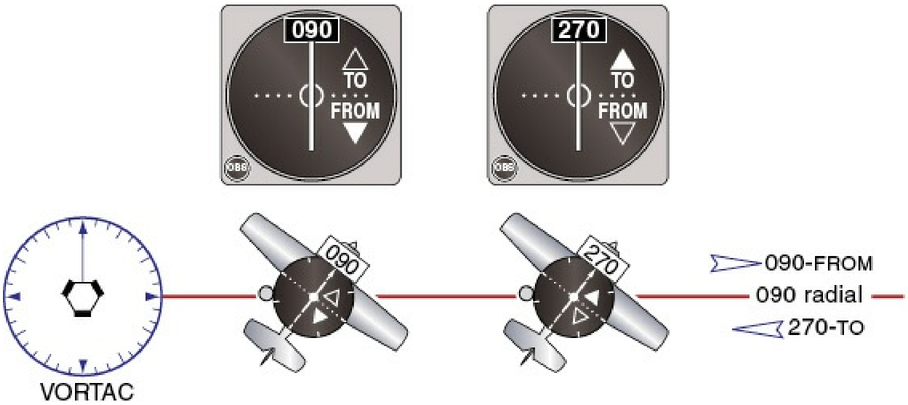



**Figure 12-16** Using the TO/FROM flag.

*Example 12-2*

Figure 12-17 illustrates two indications on the VOR cockpit display informing the pilot that the airplane is on the 235 radial. The 235 radial is either:

- 235-FROM the VOR; or
- 055-TO the VOR.

So, with the CDI centered, the VOR cockpit display could indicate either 235-FROM or 055-TO.

At all times, the reference when using the VOR indicator is the course selected under the course index. The selected course determines CDI deflection and whether the TO or the FROM flag shows.

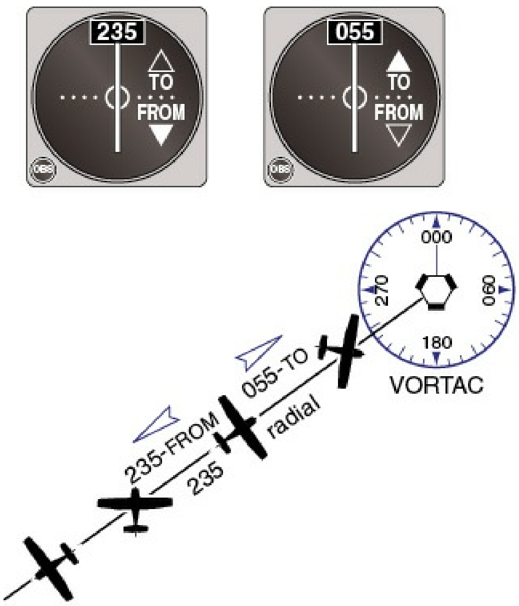



**Figure 12-17** Indications that the airplane is on the 235 radial.

## The VOR Display Is Not Heading Sensitive

*The CDI position will not change as*

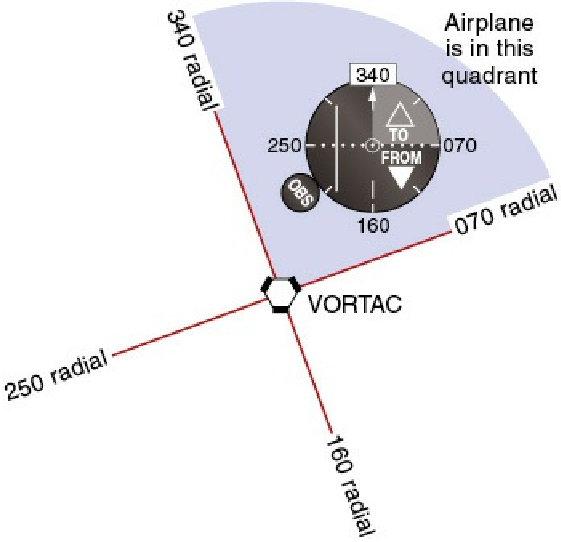


**Figure 12-30** The airplane is in the quadrant away from the CDI and TO/FROM flag.

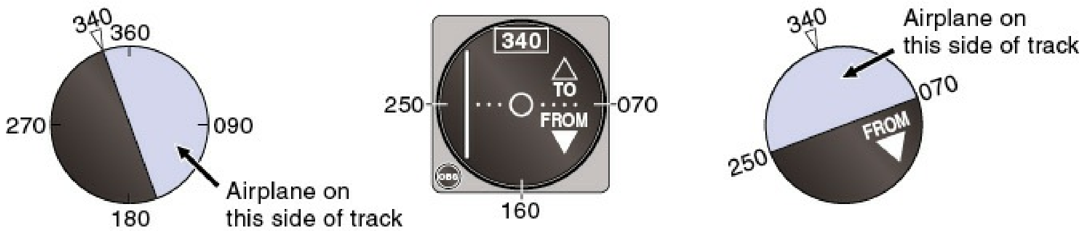


**Figure 12-31** Using the CDI and the TO/FROM flag for orientation without moving the omni bearing selector.

**Note.** Remember, no information is available from the VOR cockpit display regarding airplane heading. Heading information in degrees magnetic must be obtained from the heading indicator.

*Example 12-9*

With 085 under the course index, the VOR indicator shows CDI deflected right with the TO flag showing. Position the airplane with respect to the VOR. This method is just a quick means of determining the approximate position of the airplane with respect to the VOR ground station.

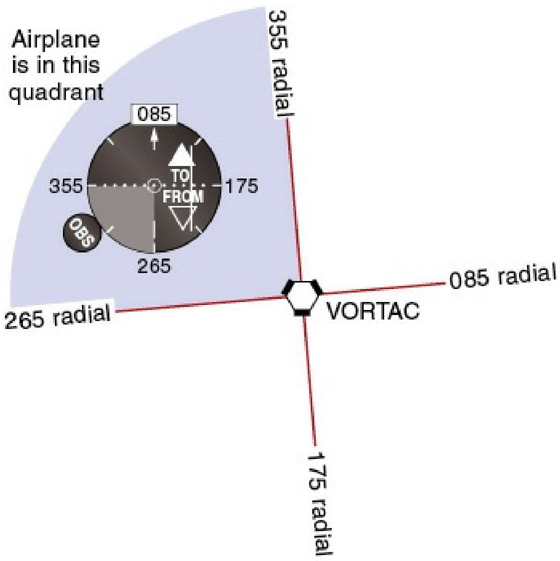


**Figure 12-32** The airplane is between the 355 and 265 radials.

## Tracking Using the VOR

The VOR is just as useful tracking away from a VOR ground station as tracking toward it, and it is much easier to use than the NDB/ADF combination.

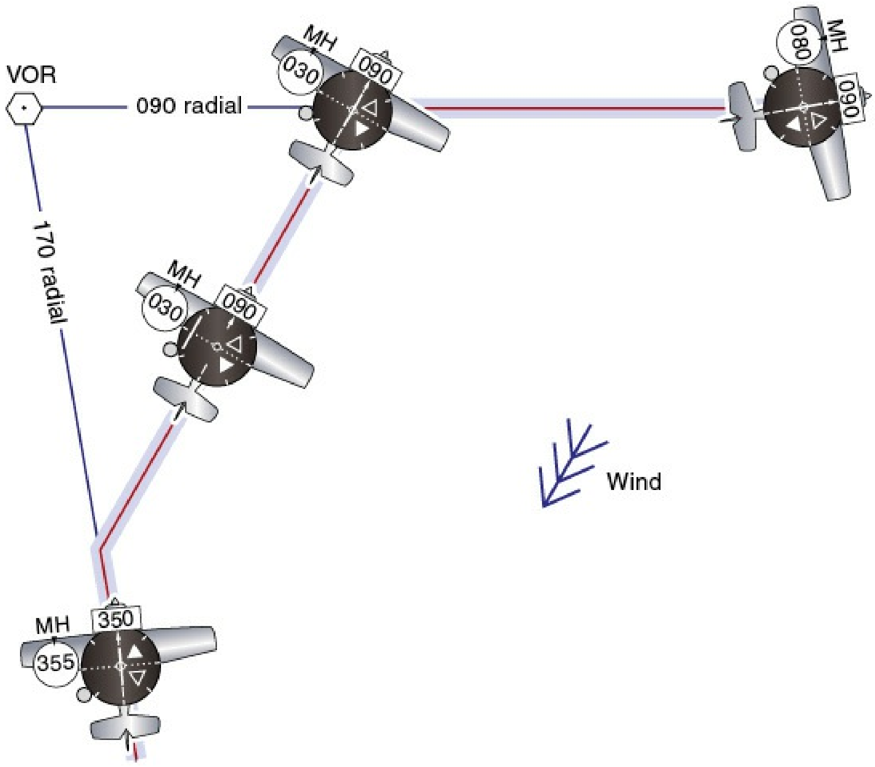



**Figure 12-40** Intercepting a course outbound from a VOR.

*Example 12-13*

An airplane is tracking inbound on the 170 radial to a VOR (350-TO). ATC instructs the pilot to take up a heading to intercept the 090 radial outbound (090-FROM).

Orientation is not a problem in this example since the pilot already knows where he or she is (the usual situation). The better method tracking inbound on the 170 radial is to have 350 set under the course index, since the airplane is tracking 350-TO the VOR. This ensures that the VOR indicator is a command instrument (fly toward the CDI needle to regain course). The pilot visualizes the situation:

- tracking northward toward the VOR;
- the course, 090-FROM, lying ahead to the right.

To intercept the 090-FROM course, the pilot:

- sets 090 under the course index;
- takes up a suitable intercept heading (MH 030 for a 60° intercept); and
- maintains MH 030 until the CDI moves from full-scale deflection toward the center. Depending on your distance from the station, the needle will move at different rates. With experience, you will "lead" the needle by reducing the intercept angle as the needle closes to center.

## Intercepting an Inbound Course

*Example 12-14*

ATC instructs a pilot to track inbound on the 010 radial to a particular VOR. The pilot:

- selects and identifies the VOR; then
- orients himself with respect to the VOR (perhaps by centering the CDI suitably);
- sets the desired course under the course index; inbound on the 010 radial, 190-TO; and determines the relative position of this course;
- takes up a suitable intercept heading, and waits for the CDI to center.

In figure 12-41:

- the CDI centers on 050-FROM (it would also center on 230-TO);

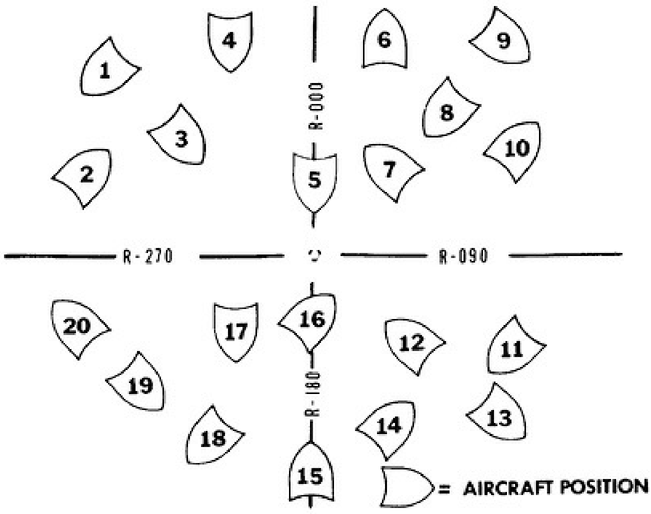



**Figure 12-53** Aircraft position.

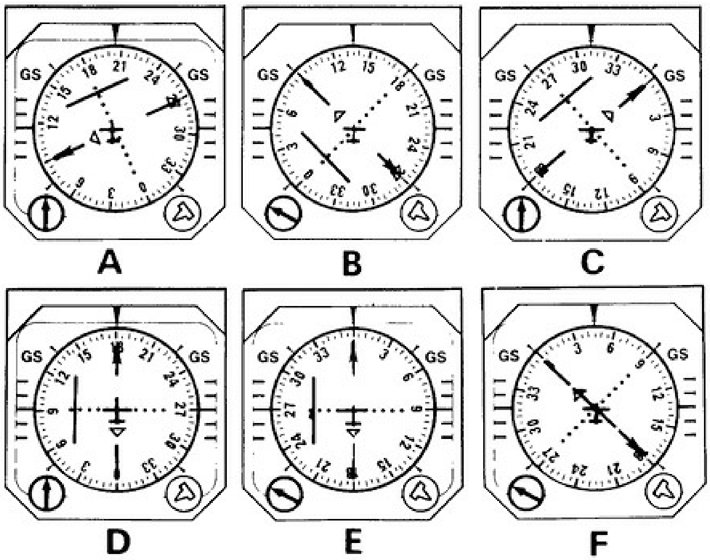



**Figure 12-54** HSI presentations.

52. HSI presentation D corresponds to aircraft position:
   a. 4.
   b. 5.
   c. 15.
   d. 17.
53. HSI presentation E corresponds to aircraft position:
   a. 5.
   b. 6.
   c. 15.
   d. 17.
54. HSI presentation F corresponds to aircraft position:
   a. 2.
   b. 10.
   c. 14.
   d. 16.
55. HSI presentation A corresponds to aircraft position:
   a. 1.

The aim is to fly a heading that will maintain the airplane on centerline. If a crosswind exists, a wind correction angle will be required, and the airplane heading will differ slightly from the published inbound course of the localizer. The wind will probably weaken in strength as the airplane descends, and there will also be gusts and lulls, so periodic adjustments to heading can be expected.

For an airplane on approach, the localizer needle indicates which way the airplane should move to regain the centerline. If the localizer needle is to the left, then the airplane should be flown left. On approach, the CDI acts as a command instrument; to regain centerline, fly toward the needle.

*On approach the CDI is a command instrument fly toward the needle.*

You should aim to capture the localizer as soon as possible on the approach, and ensure that small deviations are corrected before they can become large deviations. An ILS approach normally requires many such heading corrections to regain and maintain the localizer centerline. This is only to be expected, because wind effect will almost certainly vary along the glide path.

The CDI needle displays angular displacement from the centerline and, because the localizer beam width narrows as the runway is approached (a bit like a funnel), it will become more and more sensitive during the descent. Heading corrections should become finer and finer, ±5° at the start of the approach, ±2° toward the end.

A typical *heading bug* on a heading indicator has an angular width of about 12°, or 6° either side of center. If such a heading bug is used as a heading datum on the HI, then most heading changes necessary to maintain the localizer can be contained within its angular width.

You should initially steer a heading that stops the needle moving, even if it is not perfectly centered, and hold that heading for a few seconds as a reference heading using the HI. Glance at the CDI to observe its position and any movement, then make gentle turns using the flight instruments to return the airplane to the localizer centerline and keep it there. Employ normal attitude instrument flying techniques using the flight instruments, with just an occasional glance at the CDI. You should aim to have the correct heading determined by the time you reach the outer marker, with the CDI centered and steady. Any tendency for the CDI to move after you have passed the outer marker can be remedied with small changes of heading, about ±2°.

*Use the rudder to fly the localizer with precision, avoid over-corrections, and maintain the LOC corrections within 2 degrees.*

Tracking over the runway and outbound on the back course, the CDI remains a command instrument, so fly toward the needle to regain course centerline. If you reverse heading, however, the CDI becomes a non-command instrument (or has reverse sensing). When tracking outbound on a localizer front course, which is sometimes necessary when positioning the airplane for an ILS, the CDI will still indicate which sector the airplane is in (left or right of course), and will display the angular displacement from centerline as if the airplane were on approach. To regain centerline the airplane must be turned away from the CDI needle because it is acting as a non-command instrument when the airplane is flying outbound. When "flying" a non-command instrument, you must fly away from the CDI to pull it back into the center.

*When tracking inbound on the "back course," the CDI is a non-command instrument — it has reverse sensing.*

The situation is the same tracking inbound on a localizer back course, when the basic CDI becomes a non-command instrument. Some runways have a LOC BC nonprecision approach, based on tracking inbound on the back course of the ILS serving the opposite runway.

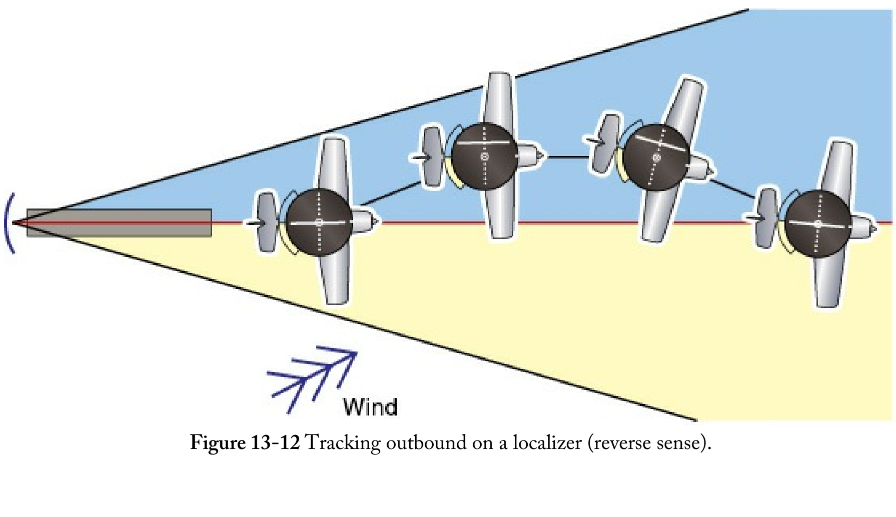



**Figure 13-12** Tracking outbound on a localizer (reverse sense).

CLICK HERE TO **DOWNLOAD** THE COMPLETE MANUAL

- Thank you very much for reading the preview of the manual.
- You can download the complete manual from: www.heydownloads.com by clicking the link below


- Please note: If there is no response to CLICKING the link, please download this PDF first and then click on it.

CLICK HERE TO **DOWNLOAD** THE COMPLETE MANUAL

second (*-dah-dit-dah-dit-dah-dit-dah-dit-*); and

- a flashing amber light synchronized with the aural *dah-dits.*

Some ILS's have an *inner marker* (IM) between the middle marker and the landing threshold that has an aural *"-dit-dit-dit-dit-"* signal at 3,000 Hz (high-pitched) and 95 dot/dash combinations per minute, and a synchronized flashing white light.

Some localizer back courses have a *back course marker* (BCM) that has an aural *"dit-dit dit-dit dit-dit"* signal, and a synchronized flashing white light. The BC marker is used to indicate the LOC BC final approach fix (FAF).

The marker beacon signals increase in strength fairly quickly as the airplane nears the marker beacon, remain very strong for a number of seconds, and then quickly fade away as the airplane moves further along the approach. Many airborne receivers have a HIGH/LOW sensitivity switch, LOW sensitivity giving a much narrower vertical pattern. For instrument approaches, the sensitivity switch is normally set to HIGH, because the airplane will be at a low level during the instrument approach, and the marker beacon signal will only be heard and seen for a few seconds.

## Other Means of Checking Glide Slope

Not all ILS installations have an outer marker and/or middle marker. For example, the Hayden, Colorado, ILS/DME Rwy 10 has neither. The glide slope, however, can be checked at the FAF at 7.8 DME from the *I-HDN* DME (automatically selected along with the ILS on the NAV/COM). If you are exactly on glide slope at 7.8 DME, the altimeter should read close to 8,608 feet MSL.

The DME can be helpful in providing approximate slope guidance, or protection from underlying obstructions, if the electronic glide slope is not working or is not part of the approach. For example, the localizer back course approach at Tucson International, Arizona, LOC/DME BC Rwy 29R, has a number of DME/altitude restrictions.

Descent from 8,000 feet MSL may be commenced at 20 DME using the *I-TUS* localizer back course and DME, followed by an approach slope:

- not below 7,200 feet until 13.5 DME;
- not below 6,100 feet until 9.5 DME;
- not below 4,800 feet until 5 DME, the final approach fix (FAF);
- not below 3,600 feet until 2 DME; and
- not below MDA 3,120 feet until visual, otherwise a missed approach at 0.3 DME.

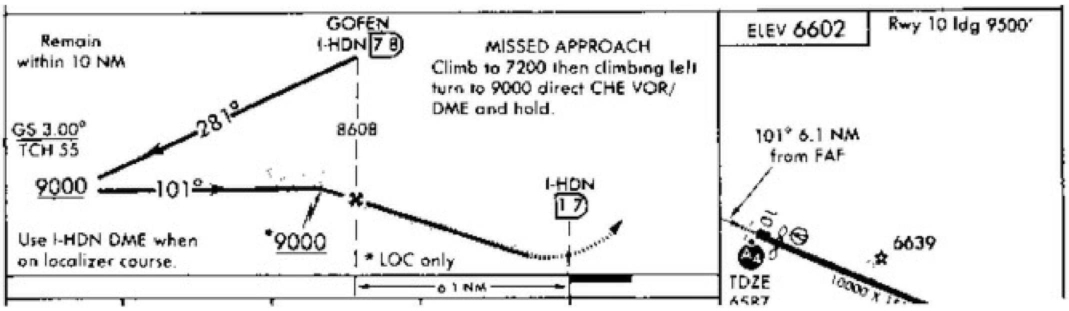


**Figure 13-26** A typical ILS/DME Rwy 10 profile diagram.

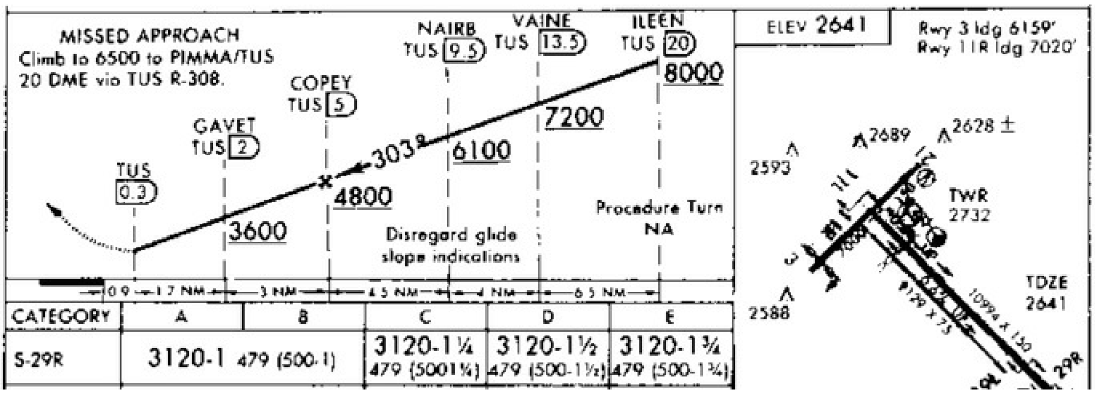


**Figure 13-27** Tucson International, AZ, LOC/DME BC Rwy 29R profile diagram.

ILS glide slope inoperative (or "GS out") minimums are published on FAA instrument approach charts as localizer (LOC) minimums.

(1) ILS, MLS, and PAR

| Inoperative Component or Aid | Approach Category | Increase Visibility |
|---|---|---|
| ALSF 1 & 2, MALSR, & SSALR | ABCD | ¼ mile |

(2) ILS with visibility minimum of 1800 RVR

| | | |
|---|---|---|
| ALSF 1 & 2, MALSR, & SSALR | ABCD | To 4000 RVR |
| TDZI RCLS | ABCD | To 2400 RVR |
| RVR | ABCD | ½ mile |

(3) VOR, VOR/DME, VORTAC, VOR (TAC), VOR/DME (TAC, LOC, LOC/DME, LDA, LDA/DME, SDF, SDF/DME, RNAV, and ASR

| Inoperative Component or Aid | Approach Category | Increase Visibility |
|---|---|---|
| ALSF 1 & 2, MALSR, & SSALR | ABCD | ½ mile |
| SSALS, MALS, & ODALS | ABC | ¼ mile |

(4) NDB

| | | |
|---|---|---|
| ALSF 1 & 2, MALSR, | C | ½ mile |
| & SSALR | ABD | ¼ mile |
| MALS, SSALS, ODALS | ABC | ¼ mile |

**Figure 13-43** FAA Inoperative Components and Visual Aids tables. Note: the tables may be amended by notes on the particular approach plate.

# Flying a Typical ILS

The relevant instrument approach procedure (IAP) chart should be checked for currency, and thoroughly studied before commencing the approach. Briefing an approach is the process of identifying the key elements of the procedure, such as missed approach, minimums, and inbound course. A standard practice for professional pilots, the approach briefing can enhance the safety of any instrument landing procedure. Even though the chart can be referred to during the actual approach, it is helpful to build up an overall view of where the airplane is and what path it will follow. As an example, the published FAA Burbank-Glendale-Pasadena ILS RWY 8 chart (plan and profile) follows, with a sketch (figure 13-45) of how the approach will be flown.

(approximate feet) is indicated by a 1 dot deviation of the ILS localizer needle?

12. At 100 feet HAT, approximately 1,300 feet horizontally from the runway, what deviation left or right of the localizer is indicated by a 1 dot deviation of the ILS localizer needle?
13. At 1.9 NM, the glide-slope needle is 2 dots below its central position, and the localizer needle is 2 dots left of its central position. What is the lateral and vertical deviation from the desired flight path?
14. What does RVR stand for?
15. Having become visual on an ILS approach, what typical landing minimum is required?

## HSI and ILS

16. What is the preferable technique when using an HSI to fly a localizer?
17. What will be the result if you accidentally set the reciprocal of the inbound localizer course on the HSI?

*Refer to figures 13-54 and 13-55 for questions 18 to 23.*

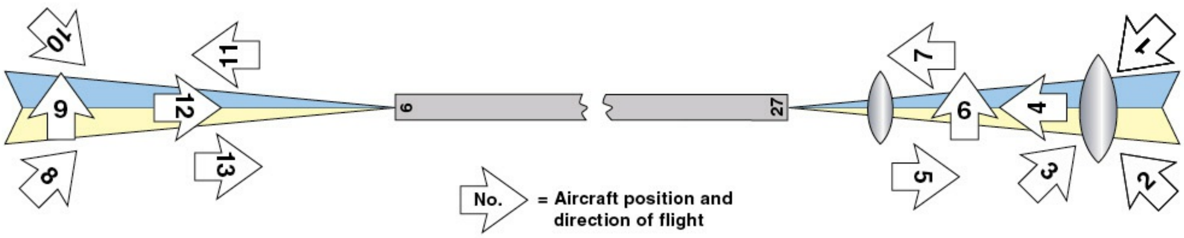



**Figure 13-54** 27 Localizer with back course — questions 18 to 23.

18. Will HSI presentation G cause the HSI to act as a command instrument?
19. Presentation G indicates that the aircraft could be at position:
    a. 1.
    b. 2.
    c. 3.
    d. 4.
    e. 7.
20. At position 4 with the HSI set correctly, the indication will be presentation:
    a. F.
    b. G.
    c. H.
    d. A.
21. At position 6 with the HSI set correctly, the indication will be presentation:
    a. F.
    b. G.
    c. H.
    d. A.
22. At position 11 with the HSI set correctly, the indication will be presentation:
    a. F.
    b. G.
    c. H.
    d. A.
23. The following HSI presentations correspond to which position(s)?
    a. Presentation A.
    b. Presentation B.
    c. Presentation C.
    d. Presentation D.
    e. Presentation E.

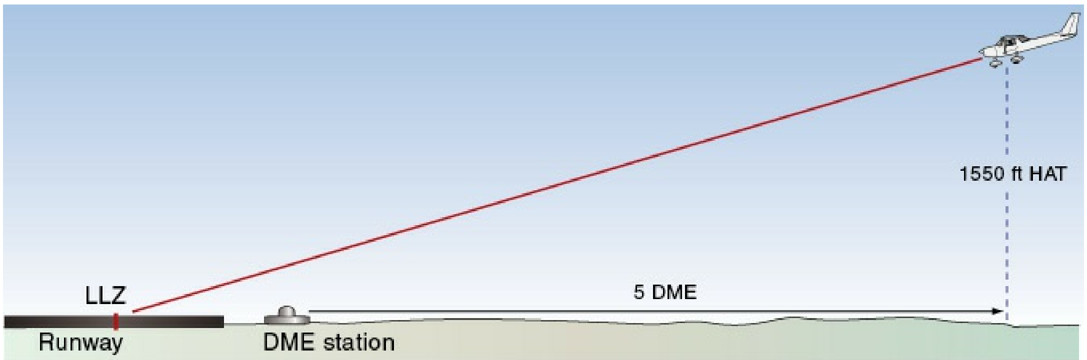



**Figure 14-8** Using a paired localizer/DME.

## DME Arcs

Many instrument approach procedures use a DME arc along which the airplane should track to intercept the final approach course. DME arcs are sometimes used in Departure Procedures (DPs) as well.

The DME arc is a circular path centered on the DME ground facility. The airplane is flown to stay, at least approximately, at a fixed DME distance. Another aid, such as an RMI, is normally used to assist in tracking.

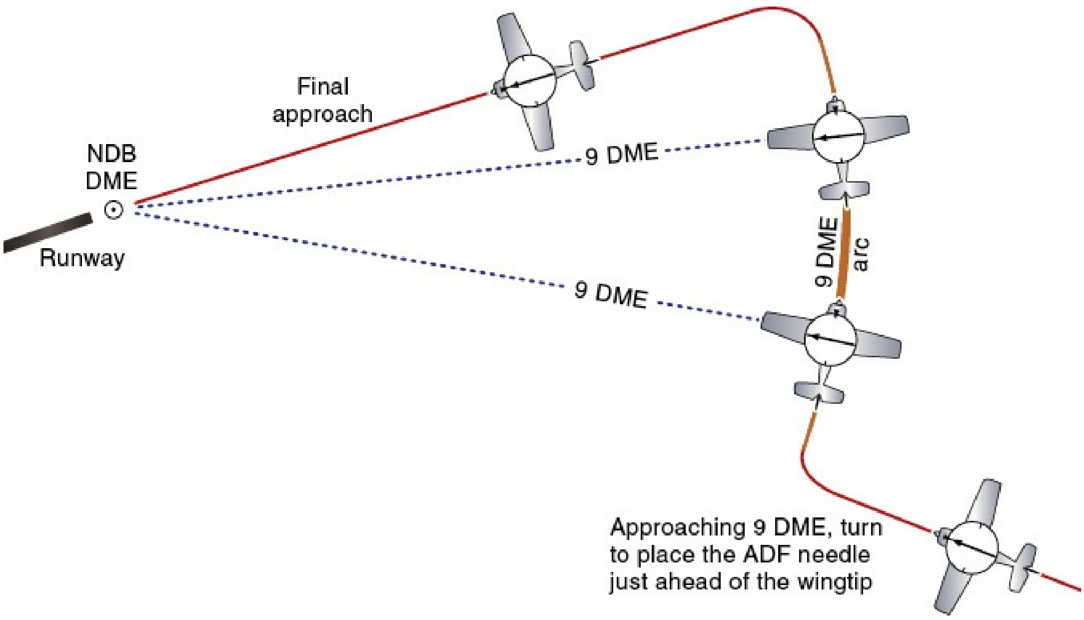



**Figure 14-9** Example of a DME arc maneuver.

# Review 14

## Distance Measuring Equipment (DME)

1. What is DME the abbreviation for?
2. What does DME measure?
3. How is the DME selected?
4. How often is the coded identifier of the DME transmitted? What frequency is it modulated to?
5. How often is the coded identifier of the VOR transmitted? What frequency is it modulated to?
6. DME readings are accurate if the airplane is what altitude above the elevation of the DME ground station?
7. An airplane, cruising at 12,000 ft MSL, approaches a VORTAC situated on an airport with 2,000 feet MSL elevation. What is the minimum distance the plane should be from the VORTAC for the DME

**Note.** In early 2000, the U.S. Department of Defense turned SA off.

The control segment includes monitoring stations at various locations around the world, ground antennas and up-links, and a master station. The stations track all satellites in view, passing information to a master control station, which controls the satellites' clock and orbit states and the currency of the navigation messages.

Satellites are frequently updated with new data for the compilation of the navigation messages transmitted to system users. Assuming the current level of space vehicle technology, the planned life span of a GPS satellite is around seven to eight years.

# User Segment (the Receiver)

*GPS receiver computes navigation values (distance and bearing to a waypoint, groundspeed, etc.) by using the aircraft's known latitude/longitude with reference to the receiver's database.*

As previously mentioned, the receiver identifies each satellite being received by its unique pseudo-random code, i.e., the C/A code for civilian operations. It then starts to receive and process navigation information. Ephemeris data takes about 6 seconds to transmit, but almanac data takes about 13 seconds. For this reason, almanac data is stored in the receiver's memory. During operation, almanac data in the receiver is changed on a continuous basis. On start-up, the receiver recalls the data that was last in memory on the preceding shutdown. From this information and the stored almanac data, the receiver determines which satellites should be in view and then searches for their respective C/A codes. It then establishes ranges to the satellites, and by knowing their position, computes aircraft position, velocity, and time. This process is known as *pseudoranging.*

Range determination is a simple matter of measuring the period between the time of transmission and the time of reception of each satellite's C/A code and multiplying that time interval by the speed of light in free space. The GPS receiver, in fact, does this by emitting its own code at the same time as the satellite's and uses it and the time the signal from the satellite is received to establish the time interval. Timing is critical. This is the reason why the time reference is provided by synchronized, high-precision atomic clocks in the satellites.

## Fixing Position

A three-dimensional position in space (position and altitude) is accomplished by the receiver determining where it must be located to satisfy the ranges to four or more appropriately positioned satellites. A two-dimensional fix requires only three satellites in view if altitude is known. The synchronization of the receiver's time reference with that of the satellite is important in this process.

Timing errors are detected and eliminated by the receiver's computer. Figure 16-5 shows a two-dimensional position established, assuming the respective clocks are synchronized perfectly.

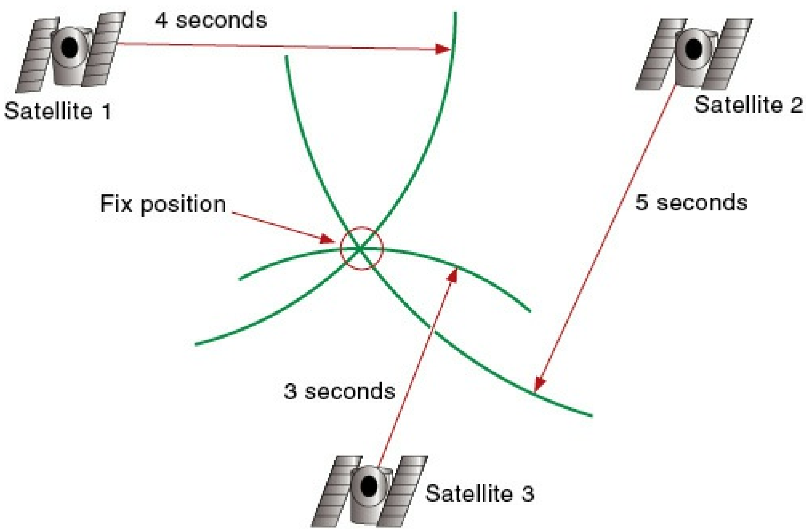



**Figure 16-5** Two-dimensional fix established with perfect timing.

However, if the receiver's clock is, say, one second fast, as is the case in figure 16-6, the period between transmission and reception with respect to each of the three satellites interrogated will be sensed initially as taking one second longer. This will be represented as a gross error in all three ranges and thus, rather than

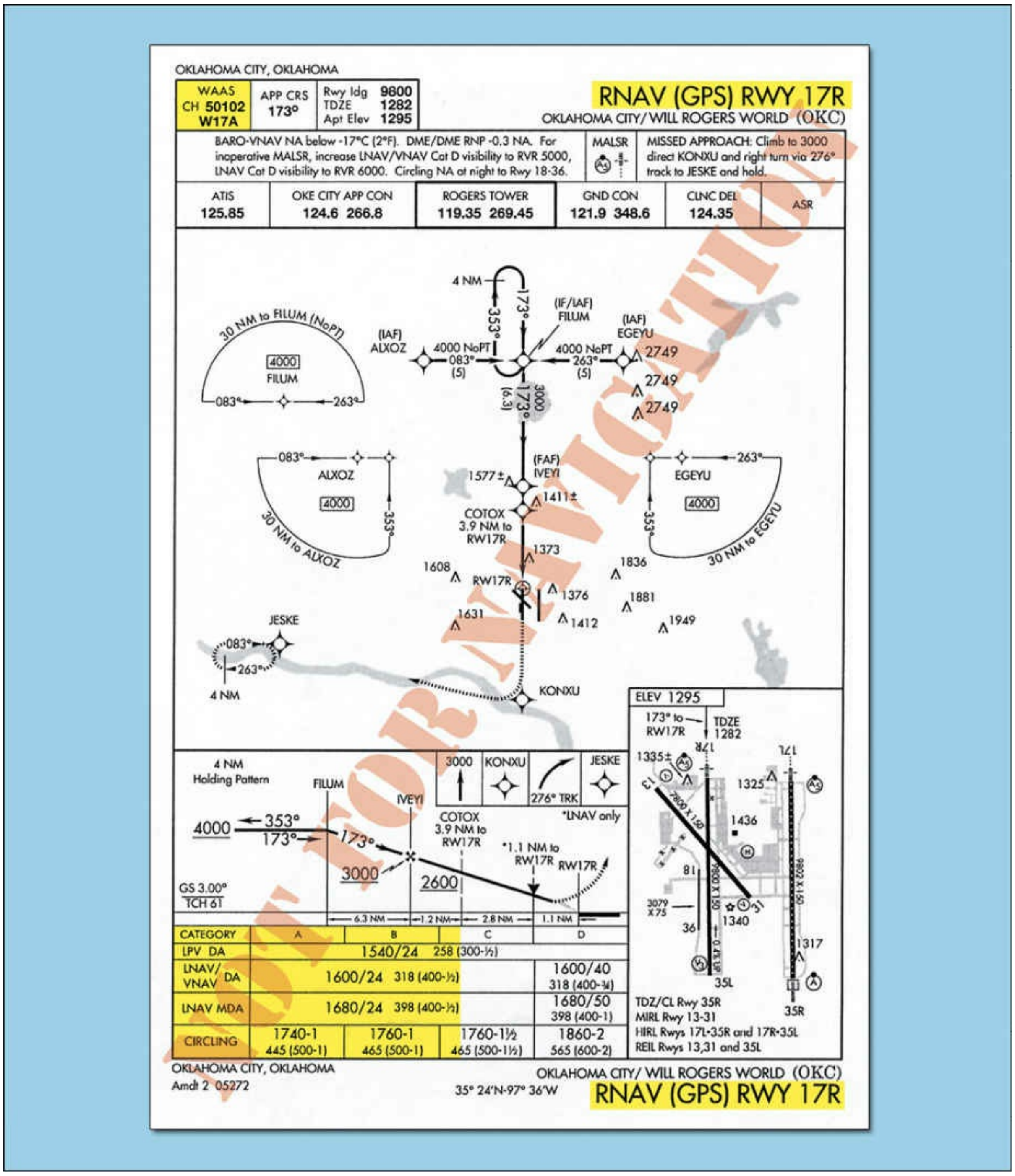



Figure 16-15 RNAV (GPS) electronic vertical guidance approach minima.

## Multiple Approaches to the Same Runway

GPS has made it necessary to change the way instrument approaches are named. Traditionally, one NAVAID would provide one instrument approach to a single runway or to a circle-to-land. Now there can be more than one GPS instrument approach to the same runway. To eliminate confusion, instrument approaches with the same guidance are annotated with an alphabetical suffix beginning at the end of the alphabet and working backwards for subsequent procedures. Figure 16-16 depicts two GPS instrument approaches to the same runway which are designated as the "Z" and "Y" approach.

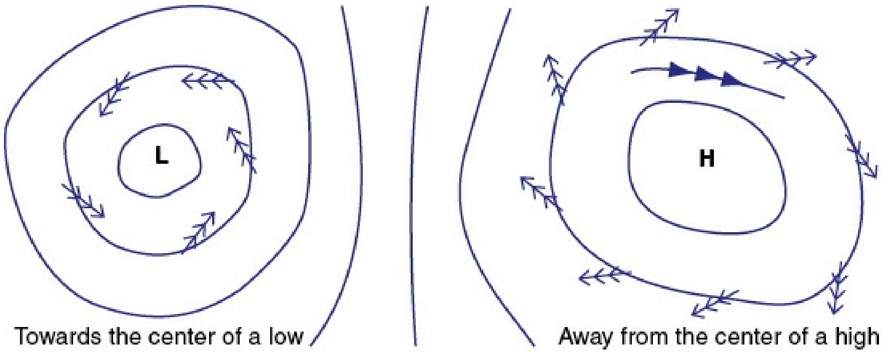


**Figure 17-5** Friction causes the surface winds to weaken in strength and flow across the isobars.

# Windshear

*Windshear is the variation of wind speed and/or direction from place to place or from one altitude to another, and is often present around cold or warm fronts, or near convective activity.*

Windshear is the variation of wind speed and/or direction from place to place. It affects the flight path and airspeed of an airplane and can be a hazard to aviation.

Windshear is generally present to some extent as an airplane approaches the ground for a landing, because of the different speed and direction of the surface wind compared to the wind at altitude. Low-level windshear can be quite marked at night or in the early morning when there is little mixing of the layers, or when a temperature inversion exists.

Windshear can also be expected when a sea breeze or a land breeze is blowing, or when in the vicinity of a thunderstorm. Cumulonimbus clouds have enormous updrafts and downdrafts associated with them, and the effects can be felt up to 10 or 20 NM away from the actual cloud. Windshear and turbulence associated with a thunderstorm can destroy an airplane.

Windshear often is present in the wind changes that occur around fronts, usually prior to the passage of a warm front, and during or just after the passage of a cold front. It is also likely to be present in the air surrounding a fast moving jet stream.

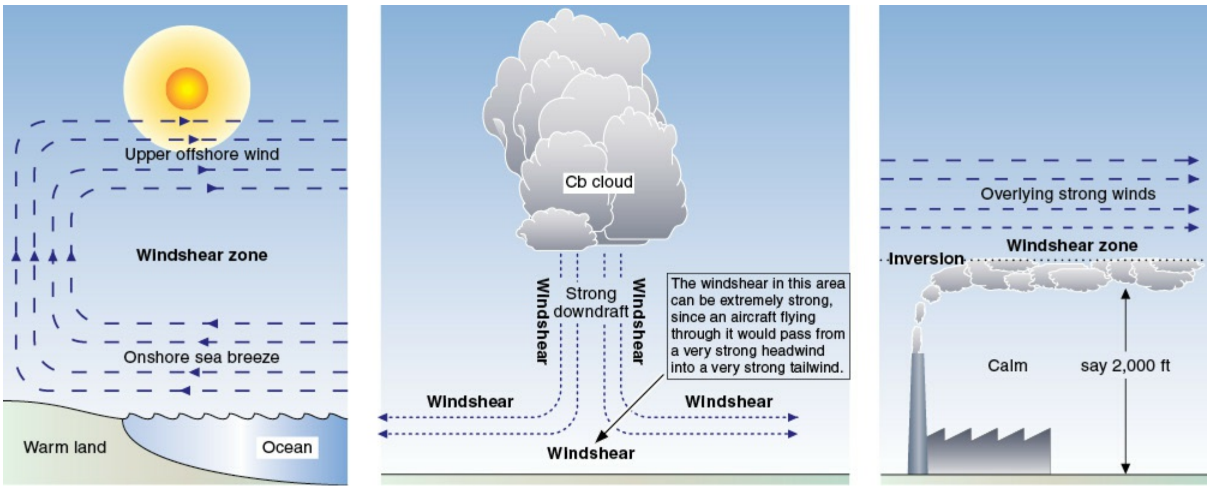


**Figure 17-6** Windshear is a change of wind speed and/or direction between various places and altitudes.

## Windshear on the Approach

An understanding of windshear helps explain why alterations of pitch attitude and/or power are continually required to maintain a desired flight path, just as changes in heading are required to maintain a steady course.

The study of windshear and its effect on airplanes, and what protective measures can be taken to avoid potentially dangerous results, is still in its infancy and much remains to be learned.

What is certain is that every airplane and every pilot will be affected by windshear — usually the light windshear that occurs in everyday flying, but occasionally a moderate windshear that requires positive recovery action from the pilot. On rare occasions, severe windshears can occur from which a recovery may even be

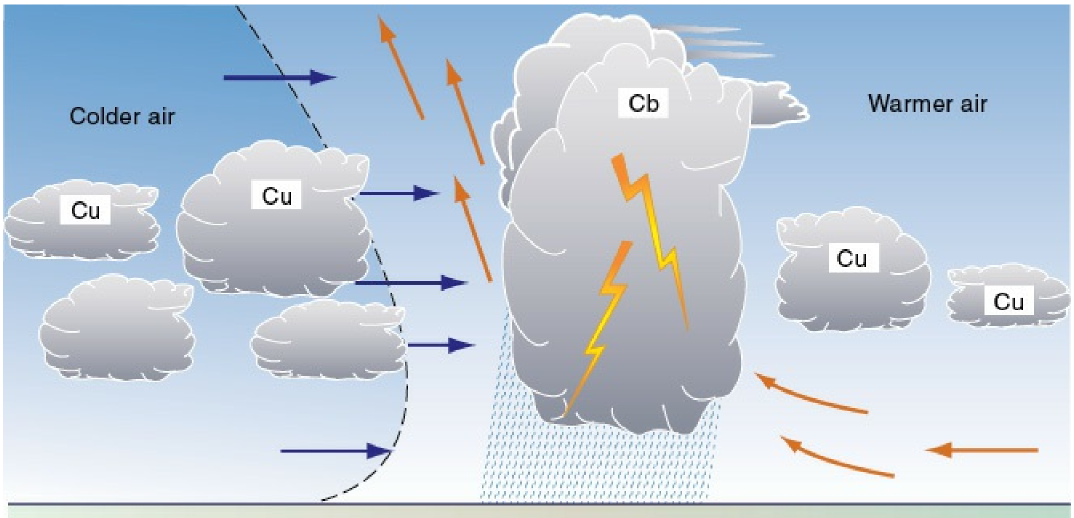


**Figure 17-20** Cross-section of a cold front.

*The Cold Front from the Ground*

The atmospheric pressure will fall as a cold front approaches and the change in weather with its passage may be quite pronounced. There may be cumulus and possibly cumulonimbus clouds with heavy rain showers, thunderstorm activity and squalls, with a sudden drop in temperature and change in wind direction as the front passes (the direction shifting clockwise in the Northern Hemisphere, and counterclockwise in the Southern Hemisphere).

The cooler air mass contains less moisture than the warm air, and so the dewpoint temperature after the cold front has passed is lower. Once the cold front has passed, the pressure may rise rapidly. The general characteristics of a cold front are:

- cumuliform clouds — cumulus, cumulonimbus;
- a sudden drop in temperature, and a lower dewpoint temperature;
- possible low-level windshear as or just after the front passes;
- a veering of the wind direction; and
- a falling atmospheric pressure that rises once the front is past.

*The Cold Front from the Air*

Flying through a cold front may require diversions to avoid weather. There may be thunderstorm activity, violent winds (both horizontal and vertical) from cumulonimbus clouds, squall lines, windshear, heavy showers of rain or hail, and severe turbulence. In some instances, icing could be a problem. Visibility away from the showers and the clouds may be quite good, but it is still a good idea for a pilot to consider avoiding the strong weather activity that accompanies many cold fronts. A squall line may form ahead of the front.

**Figure 17-21** Thickening low cloud preceding a cold front.

## The Occluded Front

Because cold fronts usually travel much faster than warm fronts, it often happens that a cold front overtakes a warm front, creating an *occlusion* (or occluded front). This may happen in the final stages of a frontal

## Radiation Fog

Radiation fog forms when air is cooled to below its dewpoint temperature by losing heat energy as a result of radiation. Conditions suitable for the formation of radiation fog are:

- a cloudless night, allowing the land to lose heat by radiation to the atmosphere and thereby cool, also causing the air in contact with the ground to lose heat (possibly leading to a temperature inversion);
- moist air and a small temperature/dewpoint spread (i.e., a high relative humidity) that only requires a little cooling for the air to reach its dewpoint temperature, causing the water vapor to condense onto small condensation nuclei in the air and form visible water; and
- light winds (5-7 knots) to promote mixing of the air at low level, thereby thickening the fog layer.

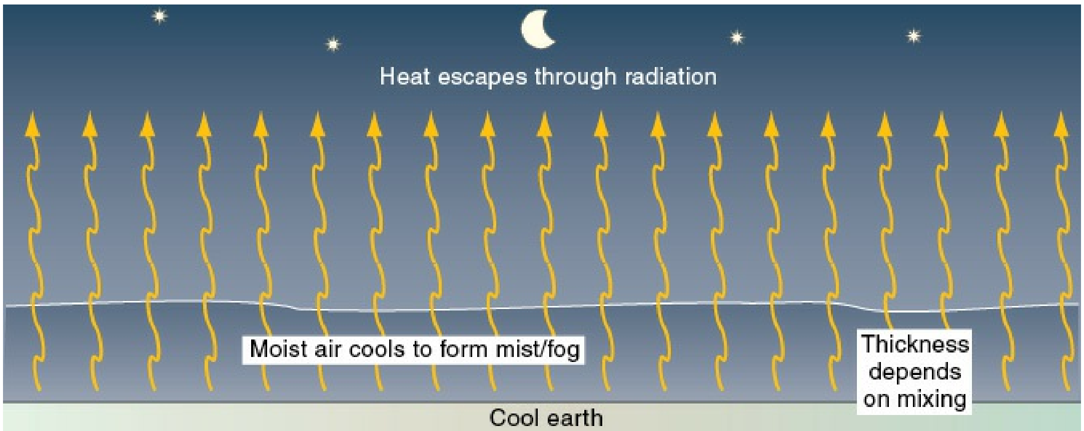



**Figure 18-3** Radiation fog.

These conditions are commonly found with an anticyclone (or high-pressure system).

Air is a poor conductor of heat. If the wind is absolutely calm only the very thin layer of air 1 to 2 inches thick actually comes in contact with the surface will lose heat to it. This will cause dew or frost to form on the surface itself, instead of fog forming in the air above it. Dew will form at temperatures above freezing, and frost will form at and below freezing point. Dew may inhibit the formation of radiation fog by removing moisture from the air. After dawn, however, the dew may evaporate and fog may form.

If the wind is stronger than about 7 knots, the extra turbulence may cause too much mixing and, instead of radiation fog right down to the ground, a layer of *stratus* clouds may form above the surface.

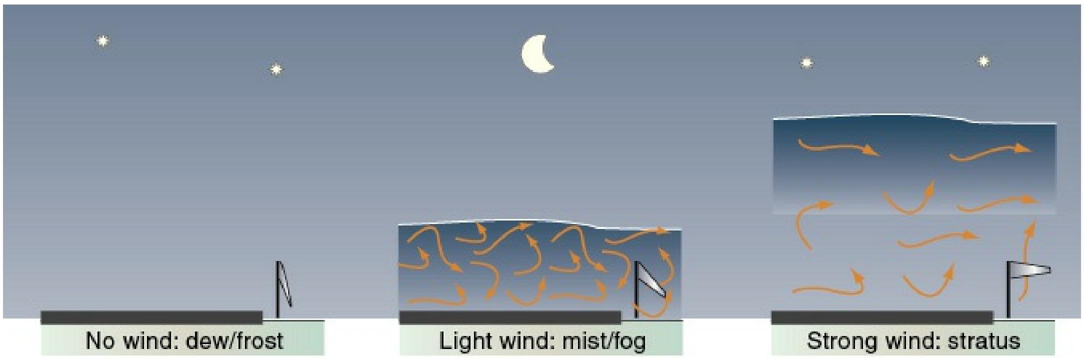



**Figure 18-4** Wind strength will affect the formation of dew/frost, mist/fog or stratus clouds.

The temperature of the sea remains fairly constant throughout the year, unlike that of the land which warms and cools quite quickly on a diurnal (daily) basis. Radiation fog is therefore much more likely to form over land, which cools more quickly at night, than over the sea.

As the earth's surface begins to warm up again some time after sunrise, the air in contact with it will also warm, causing the fog to gradually dissipate. It is common for this to occur by early or mid-morning. Possibly the fog may rise to form a low layer of stratus before the sky fully clears.

*The dispersal of radiation fog depends on heating of the air.*

If the fog that has formed overnight is thick, however, it may act as a blanket, shutting out the sun and impeding the heating of the earth's surface after the sun has risen. As a consequence, the air in which the fog exists will not be

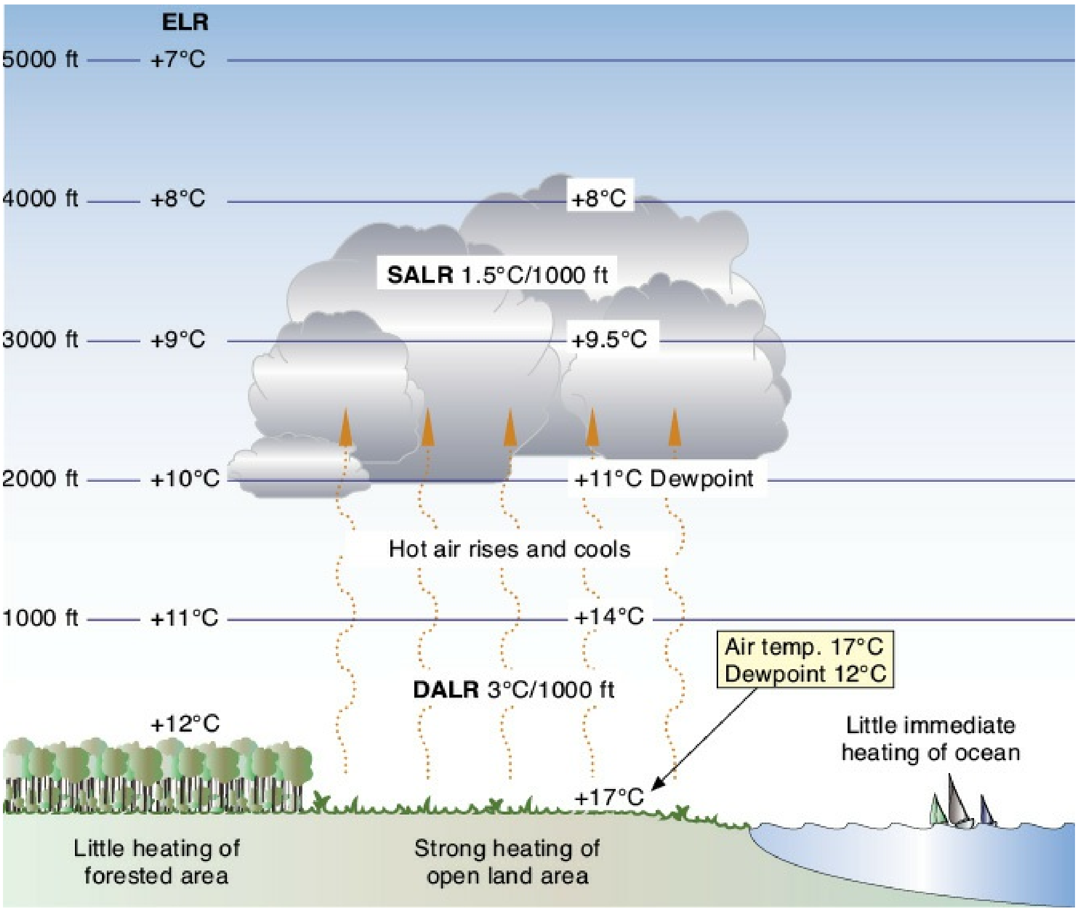



**Figure 19-5** The temperature processes involved in the formation of a cumulus cloud.

The ascending unsaturated air will cool at the dry adiabatic lapse rate of 3°C/1,000 feet. The closer the air temperature is to the dewpoint, the lesser altitude it has to rise before condensing to form clouds. The dewpoint decreases at about 0.5°C/1,000 feet, which means that the *air temperature/dewpoint* spread will decrease at approximately 2.5°C/1,000 feet in rising unstable air.

For working in degrees Fahrenheit, DALR for unsaturated air is 5.4°F and dewpoint lapse rate is approximately 1°F, so they converge at approximately *4.4°F/1,000 feet* (which is the same as 2.5°C/1,000 feet).

*Example 19-1*

If the temperature at a given level is 17°C and the dewpoint is 12°C, (a temperature/dewpoint spread of 5°C), then as the air rises this spread will decrease by approximately 2.5°C/1,000 feet. The temperature and dewpoint will have the same value at an altitude approximately 2,000 feet higher (5 ÷ 2.5 = 2).

The cloud base will form at a level 2,000 feet higher and the air, if it is still unstable, will continue to rise and form a heaped cumuliform cloud. Because it is now saturated, latent heat will be given off as more and more water vapor condenses into liquid water droplets. This reduces the rate at which the rising saturated air cools to the saturated adiabatic lapse rate of approximately 1.5°C/1,000 feet.

*Example 19-2*

What is the appropriate base MSL of clouds if the temperature at 3,000 feet MSL is 68°F and the dewpoint is 46°F?

$$\text{Cloud base in thousands of feet} = \frac{68 - 46}{4.4} = \frac{22}{4.4} = 5$$

$$\text{Therefore cloud base MSL} = 3{,}000 \text{ feet MSL} + 5{,}000 \text{ feet}$$

$$= 8{,}000 \text{ feet MSL}$$

Frost on the wings during takeoff may disturb the airflow sufficiently to prevent the airplane from becoming airborne at its normal takeoff speed, or prevent it from becoming airborne at all.

## Cold Soaking

Another phenomenon pilots need to be wary of is "cold soaking." The wings of aircraft are said to be "cold-soaked" when they contain very cold fuel as a result of having just landed after a flight at high altitude or from having been refueled with very cold fuel. Whenever precipitation falls on a cold-soaked aircraft when on the ground, clear icing may occur. Even in ambient temperatures between -2°C and +15°C, ice or frost can form in the presence of visible moisture or high humidity if the aircraft structure remains at 0°C or below. Clear ice is very difficult to detect visually and may break loose during or after takeoff. The following factors contribute to cold-soaking: temperature and quantity of fuel in fuel cells, type and location of fuel cells, length of time at high altitude flights, the temperature of the new fuel added when refueling, and time lapsed since refueling.

When obtaining or making icing reports, take into consideration the aircraft associated with the report. Aircraft that cruise at speeds higher than 250 knots will have less of a problem than slower aircraft, due to aerodynamic heating.

*Evaluate icing PIREPs in an intelligent way to determine how conditions might affect the aircraft you are flying.*

## Structural Icing and Cloud Type

### *Cumulus-Type Clouds*

Cumulus-type clouds nearly always consist predominantly of liquid water droplets at temperatures down to about -20°C, below which either liquid-drops or ice-crystals may predominate. Newly formed parts of the clouds will tend to contain more liquid drops than in mature parts. The risk of airframe icing is high in these clouds in the range 0°C to -20°C, and medium to high in the range -20° to -40°C, with only a small chance of structural icing below -40°C.

Since there is a lot of vertical motion in convective clouds, the composition of the clouds may vary considerably at the one level, and the risk of icing may exist throughout a wide altitude band in (and under) the clouds. Updrafts will tend to carry the water droplets higher and increase their size. If significant structural icing does occur, it may be necessary to descend into warmer air. If descent to warmer air is not possible, turn around and return the way you came, leaving the icing conditions. If aircraft power is sufficient and the aircraft is equipped with either anti- or deicing equipment, climbing into warmer air in a winter warm front inversion or into very cold air where the cloud is glaciated is also an option.

### *Stratiform Clouds*

Stratiform clouds can consist entirely or predominantly of liquid water drops down to about -15°C, with a risk of structural icing. If significant icing is a possibility, it may be advisable to fly at a lower level where the temperature is above 0°C, or at a higher level where the temperature is colder than -15°C. In certain conditions, such as stratiform clouds associated with an active front or with orographic uplift, the risk of icing is increased at temperatures lower than usual; continuous upward motion of air generally means a greater retention of liquid water in the clouds. The most serious icing in stratiform clouds is generally found near the cloud tops, where the creation of liquid water by adiabatic lifting is at its maximum.

### *Raindrops and Drizzle*

Raindrops and drizzle from any type of clouds will freeze if they meet an airplane whose surface is below 0°C, with a higher risk of clear ice forming the bigger the water droplets are. You need to be cautious when flying in rain at freezing temperatures. This could occur for instance when flying in the cool sector underlying the warmer air of a warm front from which rain is falling.

### *High-Level Clouds*

High-level clouds, such as cirrus, with their bases above 20,000 feet, are usually composed of ice crystals which will not freeze onto the airplane, and so the risk of structural icing is only slight in these clouds.

Structural icing is most likely to accumulate rapidly on an airplane in conditions of freezing rain, for instance when flying in below-freezing air underneath the surface of a warm front from which rain is falling.

*Structural icing is most likely to accumulate rapidly on an airplane in conditions of freezing rain, for instance when flying in below-freezing air underneath the surface of a warm front from which rain is falling.*

## Icing

The most critical icing levels for airplanes inside a cumulonimbus cloud is from the freezing level (0°C) up to an altitude where the temperature is -15°C, the range where it is most likely to encounter supercooled water drops (freezing rain). If possible, avoid this temperature band inside clouds.

## Hailstones

*With lifting and super-cooled droplets, ice can occur in a much wider temperature range. Avoid flight into any known icing conditions, regardless of the temperature!*

Large hailstones often form inside cumulonimbus clouds as water adheres to already formed hailstones and then freezes, leading to even larger hailstones. In certain conditions hailstones can grow to the size of an orange. Heavy hail can damage the skin of an airplane and damage its windshield.

Almost all cumulonimbus clouds contain hail, with most of it melting before reaching the ground where it falls as rain. Strong air currents can sometimes throw hailstones out of the storm for a distance of several miles. For this reason, pilots try to avoid severe thunderstorms by 20 NM. On cold days, with freezing level at or near ground level, hail will fall from the cloud and reach the ground before melting.

## Lightning Strikes

Lightning strikes can cause damage to electrical equipment in the airplane and to the airplane skin and antennas. It can also temporarily blind the pilot, especially if flying at night in a darkened cockpit with the eyes adjusted to the darkness. A good precaution against this is to turn up the cockpit lights when in the vicinity of thunderstorms.

Lightning strikes seem to be most likely when flying in or near to cumulonimbus clouds at altitudes near the freezing level (±5°C, within about ±2,500 feet of the freezing level).

## Turbulence

*When receiving the turbulence information given by another pilot in flight, consider the type of equipment being flown. Heavy, large aircraft might call turbulence light to moderate, whereas in the same situation a Cessna 172 would refer to it as severe.*

So that pilots and FSS can communicate efficiently regarding turbulence, certain classifications are used and should be generally understood.

- *Light turbulence* causes slight, erratic changes in attitude and/or altitude. Pilots may feel a slight pull from the seatbelt.
- *Moderate turbulence* causes some changes in attitude and/or altitude, and possibly in airspeed, but the aircraft stays in positive control at all times. Pilots will feel more pronounced pulls from the seatbelt.
- *Severe turbulence* causes large changes in attitude and/or altitude, probably with large changes in airspeed, and the aircraft may occasionally be momentarily out of control. Pilots will experience severe pulling from the seatbelt.
- *Extreme turbulence* causes violent changes in attitude and/or altitude and airspeed, with possible structural damage.

The duration of the turbulence can be described by:

- *occasional* — less than N of the time;
- *intermittent* — ⅓ to ⅔ of the time;
- *continuous* — more than ⅔ of the time.

Turbulence in the vicinity of a thunderstorm that causes large changes in attitude, altitude and airspeed, with the aircraft occasionally out of control for a moment, and causing you to experience severe pulling from the seatbelt for about three quarters of the time, would be described as *continuous severe turbulence.*

# Downbursts and Microbursts

Strong downdrafts that spread out near the ground are known as *downbursts*. A very strong downburst not exceeding 2 NM in diameter is called a *microburst*.

Airplanes may not have the performance capability or the structural strength to combat the extremely strong downdrafts, turbulence and windshear in downbursts and microbursts, and can be destroyed. You should carefully avoid such weather phenomena.

Downbursts and microbursts are mainly associated with cumulonimbus clouds, but they may also occur with smaller clouds, such as cumulus, or with clouds from which virga is falling. As rain falls from high clouds and

Once the wind starts to flow, the Coriolis force turns it to the right in the Northern Hemisphere. In the situation in figure 22-4, the wind will flow out of the page (from west to east as a westerly wind), and will be stronger at higher altitudes in the troposphere. If you look at weather charts and winds-aloft forecasts, you will often see westerlies that increase with altitude.

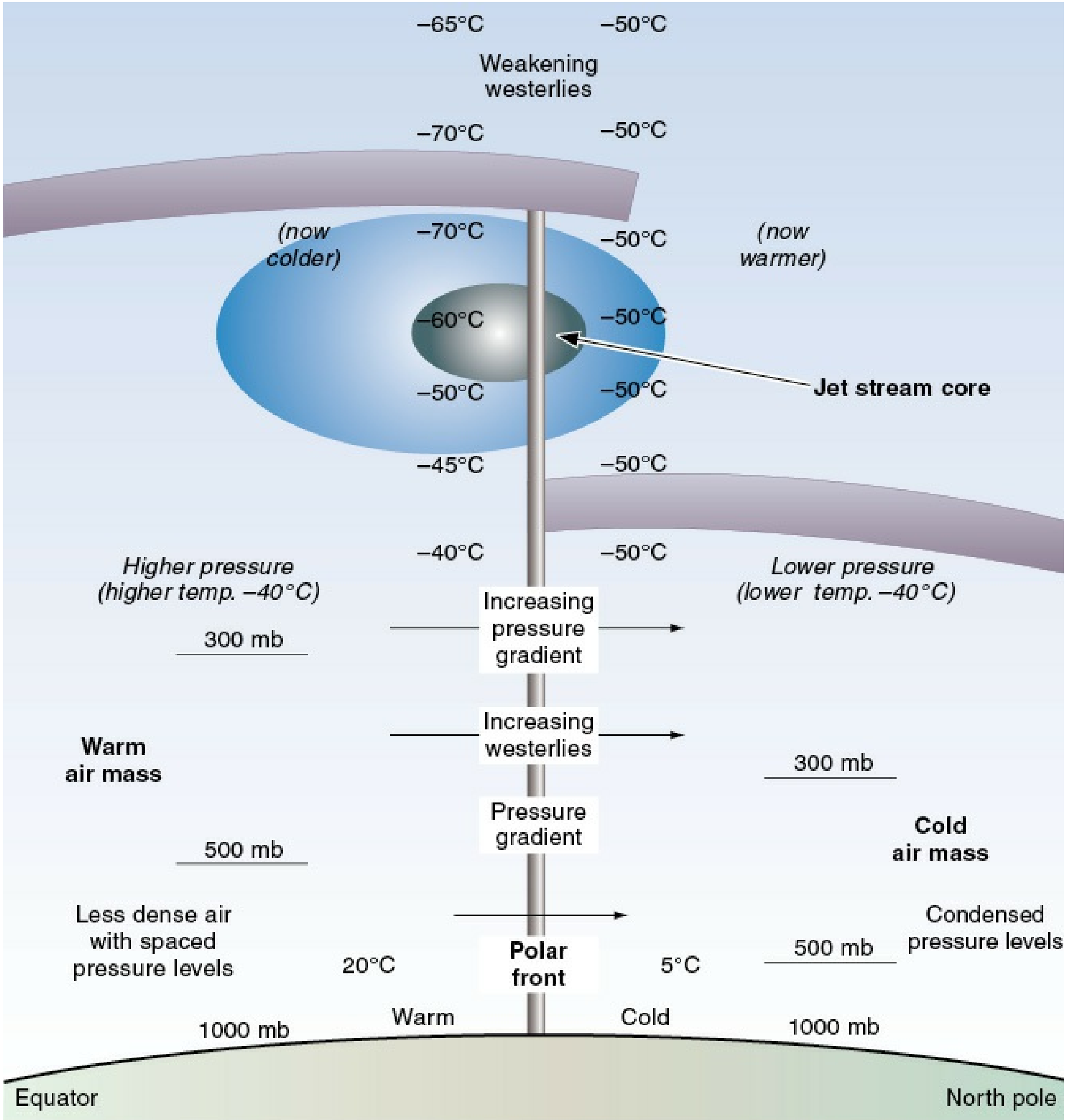



**Figure 22-4** The polar front bringing cold air down from polar regions.

At the tropopause, temperature stops decreasing. Since the polar tropopause is lower than the mid-latitude tropopause, temperature above it will stop decreasing with altitude.

As well as the temperature gradient reversing with altitude, the pressure gradient will also start to reverse, and so the westerlies will start to weaken with increasing altitude above the tropopause, and may even become easterlies at great altitudes. The westerly winds reach their maximum intensity in the break between the two tropopause sheets, often blowing in a narrow jet stream tube at speeds well in excess of 100 knots.

## Clouds at High Levels

High-altitude cirriform clouds which form in the cold air at high levels usually consist of ice crystals, and so generally do not create a significant icing hazard, although you may experience continuous turbulence. Streaks of cirrus clouds may be associated with a jet stream. It is also possible for strong thunderstorms to punch their way up to high levels, even above the tropopause, creating the usual cumulonimbus problems for high-flying pilots.

*Cloud cover:*
*SKC: Sky Clear.*
*FEW: 0–2/8.*
*SCT: 3/8–4/8.*
*BKN: 5/8–7/8.*
*OVC: 8/8.*

1. The report is from Orlando International Airport, Florida.
2. The day is the 14th, the time is 16:53Z.
3. The wind is from 230 degrees, at 6 knots.
4. The visibility is 10 statute miles or better.
5. There are a few clouds (0-2/8 coverage) at 4,000 feet.
6. The temperature is 27°C and the dewpoint 14°C, not close enough for you to have to worry about fog at the present time.
7. The altimeter is 30.04 in. Hg.
8. The remarks tell us that an automated observation (AWOS) that can determine precipitation (AO2) was used. We also see that the sea level pressure is 1,017.0 hPa (SLP170 is decoded by placing the decimal point between last two numbers and include a 9 or 10 in front of coded number, whichever is closest to 1,000) and the temperature/dewpoint spread is a + 27.2°C and 14.4°C, respectively.

Another typical METAR/SPECI weather report is:

SPECI KTPA 141056Z 35003KT 6SM BR SCT250 21/18 A2998 RMK AO2 SLP152 TO2060183

This decodes to: "Special weather observation for Tampa International Airport at the 14th day of the month, 10:56Z. The wind is 350 at 3 knots. There is 6 miles visibility with mist. There are scattered clouds (3/8-4/8 coverage) at 25,000 feet. The temperature is 21°C and the dewpoint is 18°C. The weather was taken by an automated observer capable of noting precipitation. The sea level pressure is 1,015.2, and the precise temperature/dewpoint spread is +20.6°C/+18.3°C."

## Pilot Weather Reports (PIREPs)

Pilot reports can be your best source — sometimes the only source — of information about what is going on between weather stations. Since the reports are voluntary, PIREPs may not be available to you on every flight, but you should still ask for them.

Pilot reports (PIREPs), identified by UA or by UUA if urgent, are often appended to METARs. The form of a PIREP is UA followed by the mandatory items:

- /OV (over location);
- /TM (time);
- /FL (altitude or flight level);
- /TP (aircraft type); and then by the optional items /SK (sky cover);
- /WX (flight visibility and weather);
- /TA (temperature in degrees Celsius);
- /WV (wind velocity °M/kt);
- /TB (turbulence);
- /IC (icing); and
- /RM (remarks).

A typical PIREP, decoded below, is:

UA/OV 12 NW MDB/TM 1540/FL 120/TP BE55/SK 026 BKN 034/044 BKN-OVC/TA -11/IC MDT RIME 060-080/RM R TURBC INCRS WWD MH 270 TAS 185

"PIREP, 12 NM northwest of MDB, at time 1540 UTC, altitude 12,000 feet MSL, type Beech Baron, sky cover is first cloud layer base 2,600 feet MSL broken with tops at 3,400 feet MSL and second cloud layer base 4,400 feet MSL broken occasionally overcast with no reported tops, temperature minus 11 degrees Celsius, icing moderate rime between 6,000 and 8,000 feet MSL, remarks are turbulence increasing westward, magnetic heading 270, true airspeed 185 knots."

You can generally interpret the abbreviations without too much trouble. For example: FL080/SK INTMTLY BL means an airplane at 8,000 feet MSL is flying intermittently between layers; /TB MDT means turbulence moderate; /TP B727 means type Boeing 727; /SK OVC 075/085 OVC 150 means sky cover is an overcast layer with tops 7,500 feet MSL and no reported base, with a second overcast layer base 8,500 feet MSL and tops 15,000 feet MSL.

If the METAR at the place where the UA PIREP contained those last cloud details above also contained OVC009, then it is possible to calculate the thickness of the lower cloud layer. If the station elevation is say 2,300 feet MSL, then the cloud base is 3,200 feet MSL (elevation 2,300 feet MSL + ceiling 900 feet AGL).

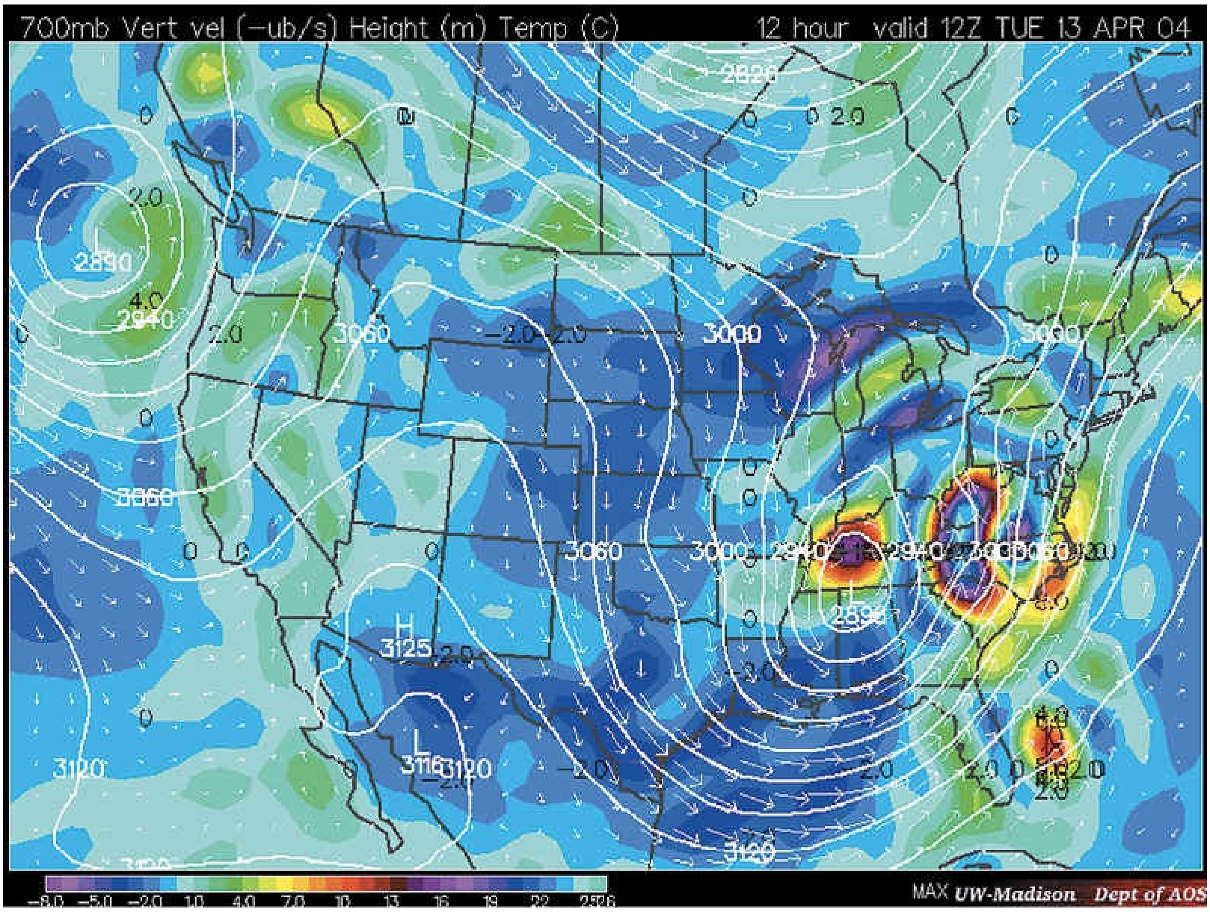



**Figure 23-14** Part of a 700 mb constant pressure analysis chart (pressure alt. 10,000 feet).

If you plan on cruising at 10,000 feet MSL, you should look at the 700 mb/hPa chart especially. The 700 mb/hPa pressure level, which is equivalent to about 10,000 feet pressure altitude in the standard atmosphere, will vary in its height MSL in any real atmosphere. By plotting contour lines showing the altitudes MSL (in meters) at which the specified pressure level is found, 700 mb in this case, an upper air picture of pressure distribution is formed, in exactly the same way that variations in height are shown by contours on an ordinary survey map.

Plotted at each reporting station, at the level of the specified pressure, are:

- *height of that pressure surface* (in meters);
- *changes in this height over the past 12 hours;*
- *temperature;*
- *temperature/dewpoint spread* (useful in determining the possibility of cloud or fog formation); and
- *wind direction and speed.*

*Height contours* join places where the pressure level is at equal heights MSL, and these height pattern contours depict highs, lows, troughs and ridges in the upper atmosphere in a similar way to isobars on the surface charts. A *high height center* on a 700 mb/hPa constant pressure chart is analogous to a *high pressure center* at about 10,000 feet. Winds will parallel the contours, flowing clockwise around a *high* height center in the northern hemisphere and counterclockwise around a *low* above the friction layer. Fronts, if they reach as high as the specified pressure level, are depicted in the normal manner.

*Isotherms* are dashed lines joining places of equal temperatures, and these allow you to determine if you are flying toward warmer or cooler air. Temperatures near to and below freezing and a temperature/dewpoint spread of 5°C or less indicate a risk of structural icing.

*Isotachs* are short dashed lines joining places of equal wind strength. Strong wind areas are indicated by hatching. Areas with winds of 70-110 knots will be hatched, and these areas may include a clear area of stronger winds of 110-150 knots, and perhaps contain another hatched area of even stronger winds.

If the constant pressure level is high, then it has warm air beneath it. A consequence of this is that a parcel of warm air will not tend to rise through the already warm air, and so the weather in the vicinity of a *warm upper high* is likely to be typical of a high pressure system, good, although with a possibility of restricted

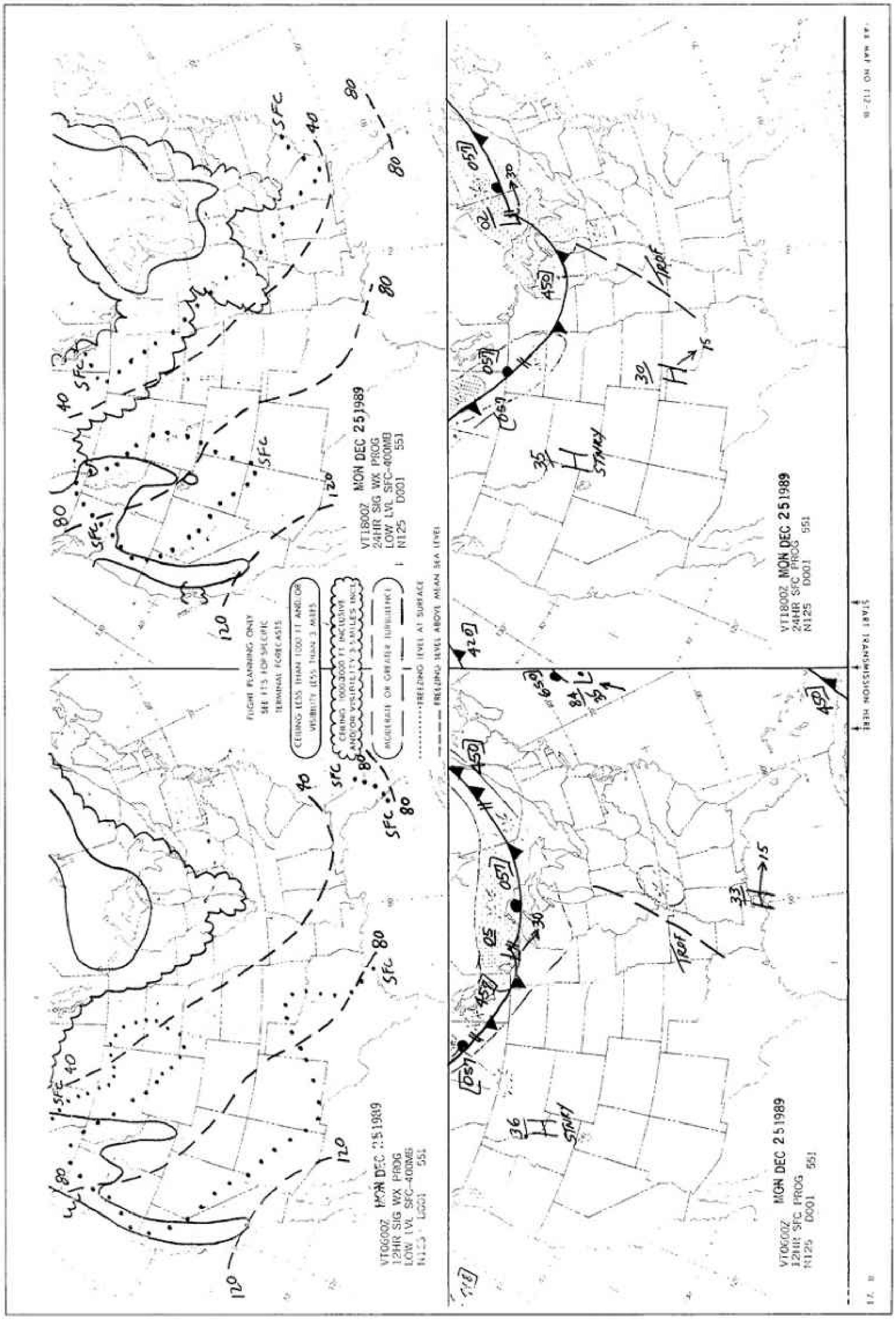



**Figure 23-19** Questions 66 to 68.

66. In the forecast for 1800 UTC for Dec. 25, is the weather over the state of Michigan expected to be VFR,

and the District of Columbia for which VOR is required — these altitudes are, of course, within Class A airspace, and IFR operations are therefore required at all times).
- A gyroscopic rate-of-turn indicator (turn coordinator or turn-and-balance indicator).
- A slip-skid indicator (balance ball).
- A sensitive altimeter, adjustable for barometric pressure.
- A clock displaying hours, minutes, and seconds with a sweep second pointer or digital presentation.
- Gyroscopic bank and pitch indicator (attitude indicator or artificial horizon).
- Gyroscopic direction indicator (heading indicator).

## Part 91: Operations in Class B Airspace

To operate in Class B airspace, you require the following communications and navigation equipment:

- An operable VOR receiver (for IFR operations, but not required for VFR operations).
- An operable two-way radio capable of communications with ATC.
- A Mode C (altitude-reporting) 4096 transponder. A new Mode S transponder is, of course, also acceptable.

Having satisfied the equipment requirements, you also require prior authorization from ATC to operate in Class B airspace (an ATC clearance).

## Part 91: ATC Transponder and Altitude Reporting Equipment and Use

A Mode C (or better) transponder is required to be carried by all aircraft operating:

- in Class A, Class B and Class C airspace, and, within the lateral boundaries of Class B and C airspace areas designated for an airport, up to 10,000 feet MSL;
- within 30 NM of an airport listed in section 1 of Appendix D of 14 CFR Part 91 (this list contains most major U.S. airports, for example Atlanta, Denver, Los Angeles, Miami, Minneapolis, both New York airports, St. Louis and both Washington airports), from the surface up to 10,000 feet MSL;
- in all airspace of the 48 contiguous states and the District of Columbia at and above 10,000 feet MSL (except at and below 2,500 feet AGL); and
- from the surface to 10,000 feet MSL within a 10 NM radius of any airport in 14 CFR 91 Appendix D, section 2 (none currently listed), except the airspace below 1,200 feet outside the lateral boundaries of the surface area of the airspace designated for that airport.

If your transponder fails in flight, and you are, or will be, operating in airspace where it is required equipment, you should notify ATC immediately. ATC may authorize deviation from the requirement to have an operating transponder to allow you to continue to the airport of your ultimate destination, including any intermediate stops, or to proceed to a place where suitable repairs can be made, or both. For a continuing waiver you should make a request to ATC at least one hour before the proposed flight.

## Part 91: ATC Transponder Tests and Inspections

To be used, the transponder must have been tested and inspected satisfactorily within the preceding 24 calendar months.

## Part 91: Altimeter System and Altitude Reporting Equipment Tests and Inspections

To operate under IFR each static pressure system, each altimeter instrument, and each automatic pressure altitude reporting system must have been tested and inspected satisfactorily within the preceding 24 calendar months. You may not operate under IFR at an altitude above the maximum at which the systems were tested.

## Part 91: VOR Equipment Check for IFR Operations

To use the VOR under IFR, the aircraft's VOR receiving equipment must either:

- be maintained, checked and inspected under an approved procedure; or
- have been operationally checked within the preceding 30 days, and found to be within the permissible limits. The accuracy for the VOR equipment is covered in Chapter 12 and is specified in this regulation.

## Special VFR Weather Minimums

12. In what airspace may a special VFR clearance be issued by ATC?
13. Name the visibility and distance from clouds requirements for a special VFR clearance.
14. May a non-instrument-rated pilot fly special VFR at night?

## Requirements for Certificates, Ratings, and Authorizations

15. Do you require an instrument rating to be pilot-in-command of an IFR flight?
16. Do you require an instrument rating to be pilot-in-command of an IFR flight in VFR conditions?
17. Do you require an instrument rating to be pilot-in-command of a flight in weather conditions less than the minimums prescribed for VFR flight?
18. Do you require an instrument rating to operate in Class A airspace?

## Pilot Logbooks

19. Must you be flying in actual IFR conditions to log the time as instrument time?
20. Can the total flight time of a flight on an IFR flight plan be logged as instrument flight time?
21. Which part of the total flight time under an IFR flight plan can be logged as instrument flight time?
22. If you enter some flight time as being simulated instrument conditions, what additional qualifying information must also be entered?
23. Can an instrument flight instructor log the total flight time for an instrument training flight as instrument time?
24. Can an instrument flight instructor log the flight time during an instrument training flight that the student is under the hood in simulated instrument conditions as instrument time?
25. Can an instrument flight instructor log the flight time during an instrument training flight that the student is actually in instrument weather conditions as instrument time?

## Recent Flight Experience — Pilot-in-Command

26. What is the minimum instrument time required within the last 6 months for you to be current for IFR?
27. How much flight time in actual IFR conditions is required to remain instrument current?
28. How many instrument approaches must have been flown in the previous 6 months for you to be current for IFR operations? How many of these instrument approaches have to have been in an aircraft?
29. What must you have accomplished in the last 6 months in order to remain current for IFR operations? If these conditions cannot be met, what other options are available to you?
30. After your recent IFR experience lapses, how much time do you have before you must pass an instrument proficiency check to act as pilot-in-command under IFR?
31. How long do you remain current for IFR flight after successfully completing an instrument proficiency check, even if no further IFR flights are made?
32. Do you require any recent IFR experience to submit yourself to an instrument proficiency check with an FAA inspector, a designated examiner, or a certificated instrument flight instructor?
33. Your recent IFR experience expires on June 1 of this year. What is the latest date that you can meet the IFR recent experience requirement without having to take an instrument proficiency check?
34. Your present instrument experience within the last 6 months is:
    - in a simulator: 3 hours and 1 instrument approach; and
    - in an airplane: 3 hours and 1 instrument approach.

What additional IFR experience do you require to meet the recent IFR requirements to act as pilot-in-command under IFR?

## Flight Instruction — Simulated Instrument Flight and Certain Flight Tests

35. For you to practice simulated IFR flight under the hood in VFR conditions, what minimum requirements must be met?
36. Define the qualifications that your safety pilot must possess.

routes are depicted on en route high altitude charts and are available for use by RNAV-equipped aircraft between 18,000 feet MSL and FL 450 inclusive. These relatively new types of airways can be defined by GPS waypoints and require an IFR-capable GPS receiver.

Breaks in airways are shown at intersections (published fixes) by a triangle, and at mileage break points not coincident with an intersection by a small cross. DME distance to the relevant VORTAC is shown at intersections, if appropriate.

*A mileage break is a point on a route where the leg segment mileage ends and a new leg segment mileage begins, often at a route turning point.*

A segment of an airway common to more than one route carries the numbers of each of these routes, "V107-301," but you only need to indicate the number of the route you are using on your flight plan, "V301." Alternate airways are identified by their location with respect to the associated main airway, "V12W" is to the west of "V12."

From 18,000 feet MSL up to and including FL 600, the airspace is Class A. Flight in Class A airspace is IFR only, and the airways from 18,000 feet MSL up to and including FL 450, are known as *jet routes*. These are labeled with a "J" and their designated number, "J84." The low altitude en route charts are not designed for flights above 18,000 feet MSL.

### *Minimum En Route IFR Altitude (MEA)*

The MEA appears as a number, such as 9,500, along the airway and is the lowest published altitude between fixes that assures:

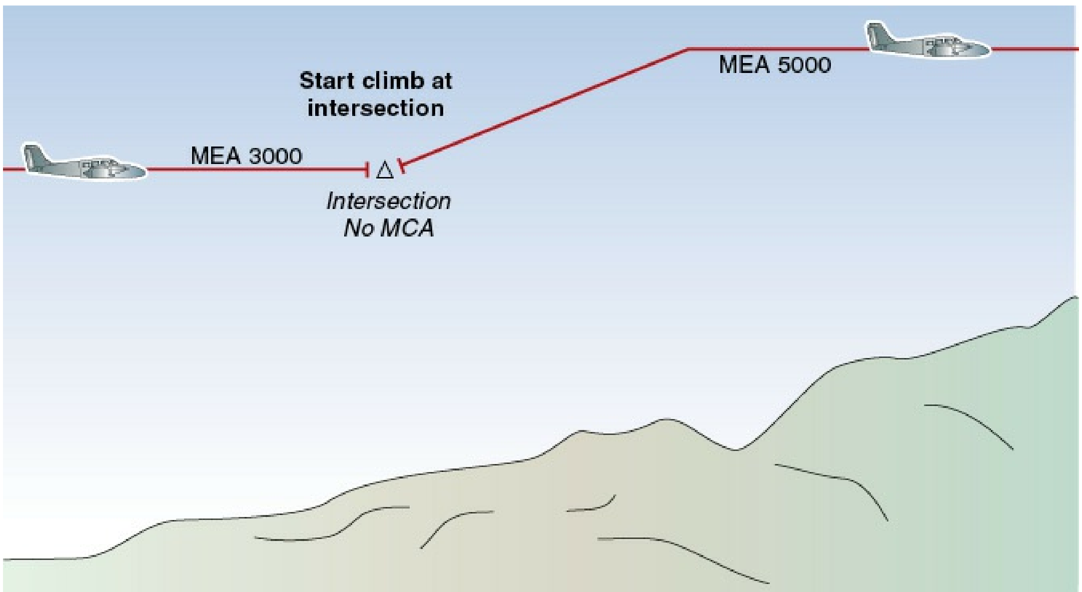
- *acceptable navigation signal coverage* (but not necessarily 2-way communications coverage); and
- *meets obstacle clearance requirements between those fixes* (1,000 feet normally, 2,000 feet in designated mountainous areas) within ±4 NM of the route to be flown.

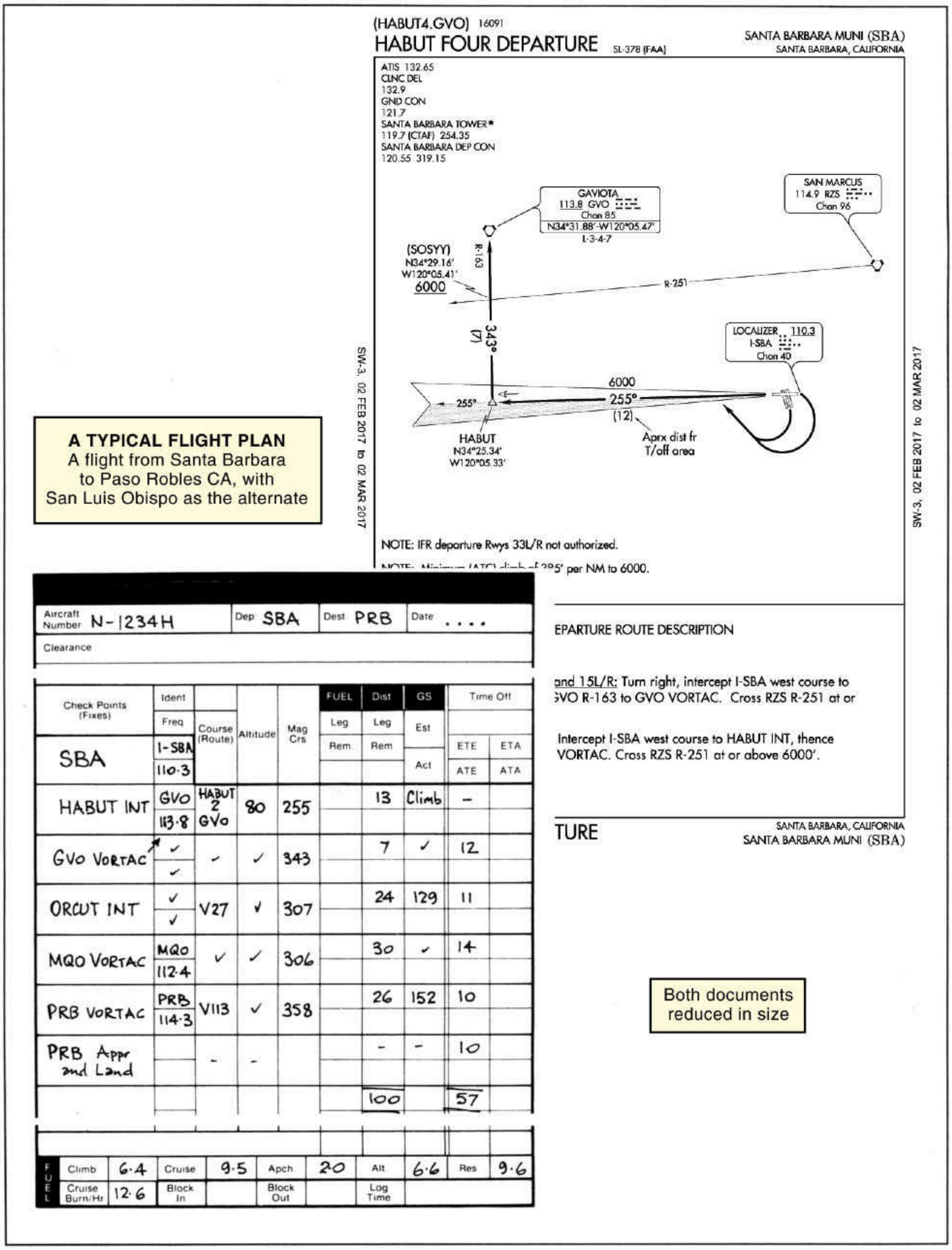
It is usual to maintain an IFR altitude at or above the MEA that is in accordance with the hemispherical rule (WEEO: West-evens, East-odds), determined by your magnetic course (not heading). Occasionally, an MEA may be approved with a *gap* in navigation signal coverage, and this will be depicted on FAA charts with the words "MEA GAP," and on *Jeppesen* charts by a broken bar. Some routes have *directional MEAs*, the MEA depending on which direction you are traveling — the MEA flying toward high ground being higher than when flying in the opposite direction away from high ground.

A bar crossing an airway at an intersection indicates that there is a change of MEA. You do not have to commence a climb to a higher MEA until reaching the intersection where the MEA change occurs, unless a minimum crossing altitude (MCA) is specified.

### *Minimum Crossing Altitude (MCA)*

The MCA is the lowest altitude at certain fixes at which an aircraft may cross when proceeding in the direction of a higher MEA. The MCA is usually specified for obstacle clearance requirements, but it may also be specified to assure adequate reception of navigation signals so that you can identify the intersection. MCA is indicated by a "flagged X" on FAA charts, and as an airway number and altitude alongside the intersection on *Jeppesen* charts ("V-25 11000S" means MCA 11,000 feet MSL flying south on V-25).






| Aircraft Number | Dep | Dest | Date |
|---|---|---|---|
| N-1234H | SBA | PRB | . . . . |

Clearance

| Check Points (Fixes) | Ident / Freq | Course (Route) | Altitude | Mag Crs | FUEL Leg / Rem. | Dist Leg / Rem | GS Est / Act | Time Off ETE / ATE | ETA / ATA |
|---|---|---|---|---|---|---|---|---|---|
| SBA | I-SBA / 110.3 | | | | | | | | |
| HABUT INT | GVO / 113.8 | HABUT 2 GVO | 80 | 255 | | 13 | Climb | – | |
| GVO VORTAC | ✓ / ✓ | ✓ | ✓ | 343 | | 7 | ✓ | 12 | |
| ORCUT INT | ✓ / ✓ | V27 | ✓ | 307 | | 24 | 129 | 11 | |
| MQO VORTAC | MQO / 112.4 | ✓ | ✓ | 306 | | 30 | ✓ | 14 | |
| PRB VORTAC | PRB / 114.3 | V113 | ✓ | 358 | | 26 | 152 | 10 | |
| PRB Appr and Land | | - | - | | | - | - | 10 | |
| | | | | | | 100 | | 57 | |

| FUEL | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Climb | 6.4 | Cruise | 9.5 | Apch | 2.0 | Alt | 6.6 | Res | 9.6 |
| Cruise Burn/Hr | 12.6 | Block In | | Block Out | | Log Time | | | |

**Figure 25-9** The Santa Barbara Habut 2 (DP) and a pilot's navigation log.

The tower controller will normally inform you of the departure control frequency and, if appropriate, the transponder code, prior to takeoff. The transponder should not be operated until ready to start the takeoff roll, and you should not change to departure control until requested. Ensure that the current local altimeter setting is set in the pressure window for takeoff and departure so that the altimeter indicates vertical distance above mean sea level, and ensure that your heading indicator is aligned with the magnetic compass.

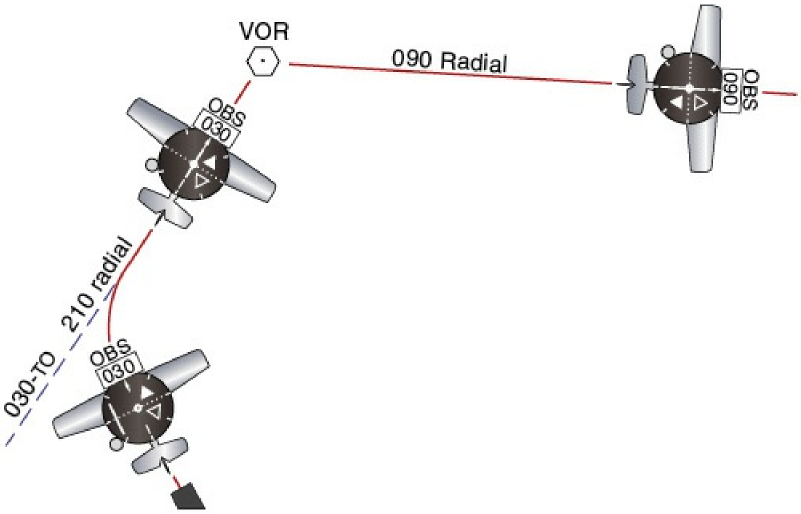



**Figure 26-5** Intercepting departure course using a VOR.

Standard takeoff and departure procedure is to climb straight ahead to at least 400 feet HAA before making any turns, and then to climb to the en route MEA at best rate of climb. Change from the tower frequency to departure control when requested. Any IFR departure procedure, standard departure procedure or other clearance specified by ATC, and accepted by you, should be followed. ATC should be notified if your rate of climb to cruising altitude is less than 500 fpm. For the last 1,000 feet of the climb to the cleared cruising altitude, the rate of climb should be reduced to between 500 and 1,500 fpm.

Figure 26-4 shows an airplane taking off and intercepting the 270 magnetic course outbound from an NDB positioned near the airport.

Figure 26-5 shows an airplane intercepting the 030-TO course to a VOR (the 210 radial), and then tracking outbound on the 090 radial.

**Note.** Many instrument departures are made in visual meteorological conditions (VMC). Remember that it is the pilot's responsibility to see and avoid other aircraft when operating in VMC conditions while on an IFR flight plan. Climb on the centerline of the airway and systematically focus on different segments of the sky for short intervals, occasionally making gentle banks left and right to clear the area under the nose.

# Instrument Departure Procedures (DPs)

At many busy controlled airports, specific *instrument departure procedures* (DPs) are published for the use of instrument-rated pilots. DPs consist of either a standard instrument departure (SID) or an obstacle departure procedure (ODP). A DP is a published IFR departure procedure providing a standard route from the terminal to the appropriate en route structure. In some cases a DP may have an associated *transition*, which is a published procedure connecting the end of the DP to one of several en route structures.

DPs considerably simplify the issuance of departure clearances, allowing ATC to simply specify the DP by name without having to describe any further tracking details, since these are provided in diagrammatic and textual form on the pilot's DP charts. The clearance may include the basic DP name and number, plus a transition to the desired route. The departure control frequency, normally passed to a pilot with IFR departure clearance, may be omitted by ATC since it is published on the DP page.

*A DP is a published IFR departure procedure providing a standard route from the terminal to the appropriate en route structure. To accept a DP, you must have at least have it written down in the cockpit.*

To accept a DP, you must have at least a textual description of it available in the cockpit. An example of a DP, the STAAV-2 DP for Las Vegas, is shown in figure 26-6 on page 544. ATC may issue DPs without a specific pilot request. If you do not wish to accept a DP or operating limitations exist, then you should advise ATC, preferably by inserting "No DP" in the remarks section of the filed flight plan, otherwise verbally. (The same applies to STARs — Standard

- ETA and name of next reporting point;
- name only of the following reporting point; and
- pertinent remarks.

*Example 27-1*

*Sacramento, Cessna 238 Sierra Sacramento at two eight Niner thousand Manteca four seven Following-point Panoche Moderate turbulence.*

Compulsory reporting points are shown on en route charts by solid triangles; on-request reporting points are shown by open triangles, requiring reports only when requested by ATC. When flying on a direct route and when requested, reports shall also be made over each fix defining the route.

*In a radar environment, after having been informed of being in radar contact by ATC, you may discontinue position reports.*

In a radar environment, after having been informed of being in radar contact by ATC, you may discontinue position reports. The words "radar contact" signify that you have been identified on the radar controller's display, and that radar flight-following will be provided until radar service is terminated or radar contact lost. You should use transponder Mode C (altitude reporting capability) at all times, unless ATC requests you not to. If ATC advise "radar contact lost" or "radar service terminated," you should resume normal position reporting.

Even in a radar environment, you should maintain a flight log, so that, in the event of loss of radar contact, you are able to continue with full position reporting.

# Additional Compulsory Radio Reports

You should initiate the following radio reports without any specific request from ATC:

- at all times:
  - when vacating a previously assigned altitude for a newly assigned altitude;
  - when an altitude change will be made while operating VFR-on-top;
  - when unable to climb or descend at a rate of at least 500 fpm;
  - after initiating a missed approach;
  - if you change the TAS at cruising altitude by 5% or 10 knots (whichever is greater) from that filed in the flight plan;
  - the time and altitude upon reaching a holding fix or clearance limit;
  - when leaving any assigned holding fix or point;
  - any loss of navigation or communications capability in controlled airspace;
  - any information relating to the safety of flight; and
  - any unforecast weather, or any hazardous conditions encountered (forecast or not).
- when not in radar contact:
  - when leaving the final approach fix (FAF) inbound on a nonprecision approach (VOR/NDB/LOC/LDA/SDF/GPS);
  - when leaving the outer marker (OM), or fix used in lieu of the outer marker, inbound on a precision approach (ILS/MLS/PAR);
  - when an estimate previously submitted is in error by in excess of 3 minutes, and a revised estimate is required.

# Flying the Airways

*An airway corridor is 8 NM wide. Strive to fly in this protected airspace.*

You should fly along the centerline of airways, except to pass well clear of other traffic in VFR conditions, keeping in mind that the protected airspace of an airway is at least ±4 NM, making a corridor 8 NM wide. Maintain calculated IFR safe altitudes when flying IFR routes and procedures, since this is your only protection from obstacles and terrain that you may not see.

If climbing, cruising or descending outside of clouds, you should keep a good lookout, and make gentle banks periodically to assist you in detecting other traffic. When weather conditions permit, you are responsible to see-and-avoid, even if you are under radar control. The radar controller may advise you of second inbound leg, with the airplane arriving overhead the fix inbound at 1446. In windy conditions, some timing adjustment outbound will be required.

## Tracking in Holding Patterns

The main tracking leg of a holding pattern is the inbound leg toward the holding fix. Normal tracking procedures are followed using the tracking aid (which may be a VOR, NDB or localizer) by applying a wind correction angle so that the desired inbound course is maintained.

Monitor the tracking periodically on the VOR cockpit indicator, or the ADF if the hold is based on an NDB. The tracking aid will act as your navigation performance instrument. Most of your attention should be on the attitude flying instruments (monitoring altitude, airspeed and heading), with an occasional scan of the navigation instruments (VOR, DME, ADF). Any adjustments to heading called for by deviations on the navigation instruments should be made with reference to the attitude indicator and the heading indicator.

The outbound turns after crossing the fix, and the inbound turn at the end of outbound leg, should be standard-rate turns, and should never exceed 30° bank angle (25° if a flight director system is used).

During the turn outbound, and on the outbound leg, there is no direct tracking aid, so you have to estimate a suitable heading. Both the turns and the outbound leg of the holding pattern are modified according to the estimated wind effect, so that the standard-rate turn to rejoin the inbound leg will bring the airplane out right on course. You should check the tracking instrument during this inbound turn to determine if you will overshoot or undershoot the inbound course, in which case you can take early corrective action.

## Corrections for Wind in Holding Patterns

*Aim for a neat pattern with a one-minute inbound leg.*

The aim when flying a normal holding pattern is to fly a neat pattern and intercept an inbound leg that takes 1 minute exactly to the fix.

The initial outbound leg should be flown for 1 minute, so that the wind effect can be established on the subsequent inbound leg. The initial pattern is, more or less, a trial run so you can make timing and tracking adjustments to later patterns. It may take several patterns before you get the tracking and timing perfect.

In no-wind conditions, the ground track of the holding pattern will be a straightforward racetrack pattern with the outbound timing starting as the airplane passes abeam the fix, and with the outbound leg (where there is no tracking aid) simply being the reciprocal of the inbound leg and flown for one minute.

### *Headwinds and Tailwinds*

If there is a strong tailwind outbound, then 1 minute outbound will carry the airplane much further than in no-wind conditions and will carry the plane even further downwind during the turn inbound. With an airspeed of 90 knots, for instance, the groundspeed will be 110 knots outbound with a 20-knot tailwind and only 70 knots inbound. The 20-knot wind acting for the 3 minutes from overhead the fix to rejoining the inbound leg will have carried the airplane an extra 1 NM downwind compared with the no-wind situation. It will be a long haul at the slower groundspeed back to the fix (well in excess of one minute), unless some correction to the outbound timing is made.

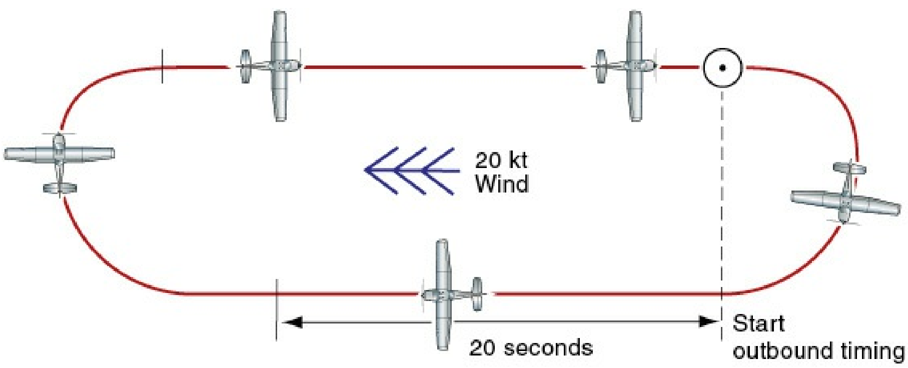



**Figure 28-4** Adjust outbound timing to allow for head/tail wind.

A reasonable correction is to reduce the timing of the next "1-minute" outbound leg by 2 seconds per knot of the estimated tailwind. For instance, with a 20-knot tailwind outbound, reduce the timing by 40 seconds to only 20 seconds outbound before starting the standard-rate turn inbound. Conversely, in a strong headwind outbound, add 2 seconds per knot. The timing is started when abeam the fix, or when the wings are level.

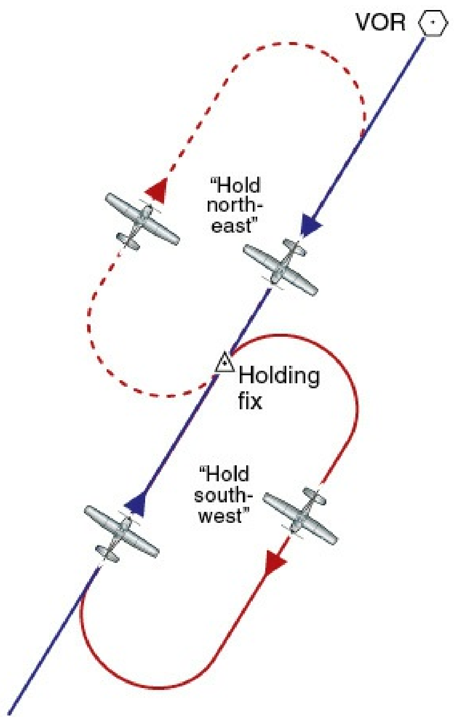


**Figure 28-17** Holding toward, and away from, a VOR at an intersection.

### *Holding at a VOR/DME Fix*

A holding fix can also be specified using a DME distance along a particular VOR radial. Many intersections are determined in this manner.

In a DME hold, the controller will specify the length of the outbound leg that you should fly, rather than specifying an inbound time. If the fix distance is 15 DME, and the specified leg length is 5 NM, then you would turn outbound at the 15 DME holding fix, and start your turn inbound at:

- 20 DME if the inbound holding course is toward the VOR; or
- 10 DME if the inbound holding course is away from the VOR).

*Use the seven T's at each turn to ensure that all appropriate tasks are completed. Time-turn-twist-tracking-throttle-transmit-think. While you should consider all of the T's, some aren't needed in a holding pattern, such as twist, because the OBS will remain the same right around the pattern.*

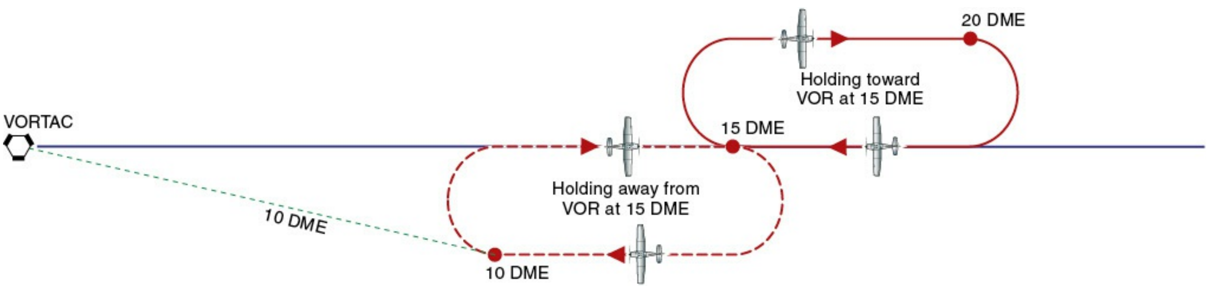


**Figure 28-18** Holding at a VOR/DME fix.

### *Holding at an ILS Outer Marker*

This method of holding is often shown on ILS approach charts. The inbound course to the holding fix is the localizer (supported by the locator NDB if needed), with the fix being defined by passage over the outer marker or locator. (See figure 28-19.)

Because the localizer CDI is four times as sensitive as the VOR CDI, the locator NDB can prove useful when intercepting the inbound course, since close in to the airport the CDI may move from the full-scale position with a rush, whereas the ADF needle will move progressively and continually show position.

### *Timed Approaches from a Holding Fix*

At busy airports, ATC may use timed approaches by assigning each pilot in an approach sequence a time to depart the holding fix inbound. For nonprecision approaches (VOR, NDB), the holding fix may be the final


**Figure 28-31** Questions 24 to 27.

24. A pilot receives this ATC clearance: *"hold east of the Dingo VOR on the zero niner zero radial, left turns."*
   a. Will the pattern be left or right turns?
   b. What is the MC for the inbound leg of the holding pattern?
   c. What is the recommended procedure to enter the holding pattern?
   d. In which direction is the first turn after crossing the VOR?
   e. What will be your approximate MH?
25. A pilot receives this ATC clearance: *"hold south of the Dingo VOR on the one eight zero radial."*
   a. Will the pattern be left or right turns?
   b. What is the MC for the inbound leg of the holding pattern?
   c. What is the recommended procedure to enter the holding pattern?
   d. In which direction is the first turn after crossing the VOR?
   e. What will be your approximate MH?
26. A pilot receives this ATC clearance: *"hold north of the Dingo VOR on the three six zero radial, left turns."*
   a. Will the pattern be left or right turns?
   b. What is the MC for the inbound leg of the holding pattern?
   c. What is the recommended procedure to enter the holding pattern?
   d. In which direction is the first turn after crossing the VOR?
   e. What will be your approximate MH?
27. A pilot receives this ATC clearance: *"cleared to the Dingo VOR, hold west on the two seven zero radial."*
   a. Will the pattern be left or right turns?
   b. What is the MC for the inbound leg of the holding pattern?
   c. What is the recommended procedure to enter the holding pattern?
   d. In which direction is the first turn after crossing the VOR?
   e. What will be your approximate MH?

*Refer to figure 28-32 for questions 28 to 30.*

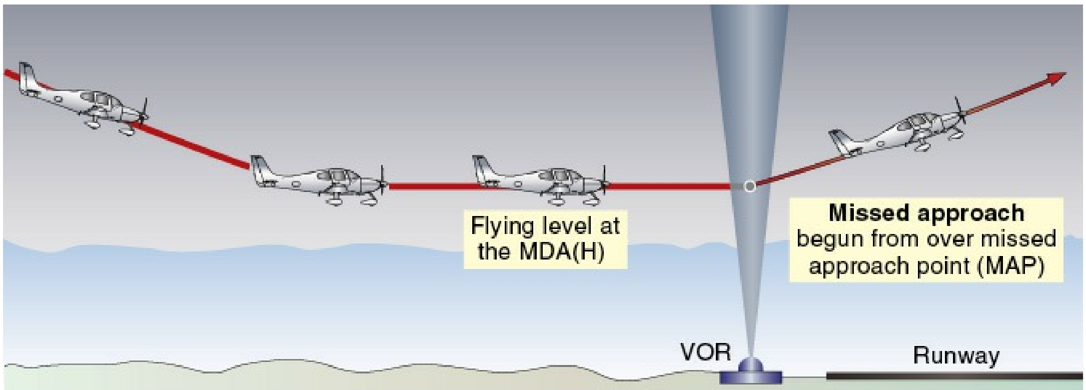



**Figure 29-8** If not visual on a nonprecision approach, track in to the MAP at MDA.

# Instrument Approach Charts

Instrument approach procedure (IAP) charts provide a graphic presentation to the pilot of:

- *holding procedures* (if required prior to commencing the instrument approach);
- *the instrument approach procedure*; and
- *the missed approach procedure*.

Instrument approach charts are designed to be readable in the cockpit, although some difficulty may be experienced in turbulence and/or poor light. A good approach briefing in cruise will minimize these problems once you've begun the approach. The actual instrument approach is shown in both plan and profile on the chart.

IAP charts are available for all airports where instrument approach procedures have been established and approved by the FAA. Charts acceptable to the FAA are those published by Aeronautical Information Services (AIS) and *Jeppesen*.

You must study carefully the actual instrument approach charts that you will be using, since presentation of the same instrument approach by the various publishers is not identical. The symbols and abbreviations used will also differ. We have used both FAA and *Jeppesen* charts as examples.

*Update your approach charts at the designated intervals.*

Only current instrument approach charts must be used! They are regularly revised, and amendments are made available every 56 days. Changes to the actual procedure, the appearance of significant new obstacles, such as buildings or masts in the approach or missed approach areas, changes to frequencies or the addition of new NAVAIDs relevant to that approach will require a current chart. Urgent amendments of a timely nature may be advised to pilots by NOTAM. Check currency of chart, and check the NOTAMs for any amendments.

## The Elements of an Instrument Approach Chart

The information provided on an instrument approach chart includes:

- identification of the particular approach;
- a *plan* view of the approach and the missed approach;
- a *profile* view of the approach and the missed approach;
- holding procedures associated with the approach;
- full details of facilities associated with the instrument approach, missed approach and holding;
- necessary airport and topographical information (coastlines, lakes and rivers, relief, built-up areas, etc.) pertinent to the safe execution of the approach; and
- a landing chart, showing the runway layout.

## Identification of an Instrument Approach Chart

An instrument approach chart is normally identified at the top by:

- the name of the airport;
- an abbreviation of the type of radio facility (further identified by the runway served in the case of a runway approach as opposed to airport approach); and
- additional information to distinguish between separate charts for the same airport.

## Visual Illusions on Approach

Be prepared for visual illusions. A narrower-than-usual or upsloping runway will give the impression that you are high on slope, leading some pilots to make a lower-than-normal approach. Haze creates the illusion that the runway is further away, and can lead some pilots into making a lower-than-normal approach.

Most runways are of standard width and on flat ground. On every approach, you should try to achieve the same flight path angle to the horizontal, and your eyes will become accustomed to this, allowing you to make consistently good approaches along an acceptable glide slope merely by keeping your view of the runway through the windshield in standard perspective.


**Visual**


**Not visual**

**Figure 29-14** Visual, or not visual.

# 30
# Visual Maneuvering

As you near your destination airport in IFR conditions, there are three types of approaches possible:

- a *standard instrument approach* as published by FAA, followed by a straight-in or circle-to-land maneuver;
- a *contact approach* if visibility is at least 1 SM (special VFR conditions); or
- a *visual approach* (if VFR weather conditions exist).

Contact and visual approaches allow a pilot to avoid flying what may be a time-consuming instrument approach if VFR or special VFR conditions exist. They expedite the flow of air traffic and reduce pilot/controller workload by shortening the flight path to the landing.

To assist maneuvering pilots to locate the airport in conditions of visibility less than 3 miles and/or ceiling below 1,000 feet, the airport rotating beacon may be operated.

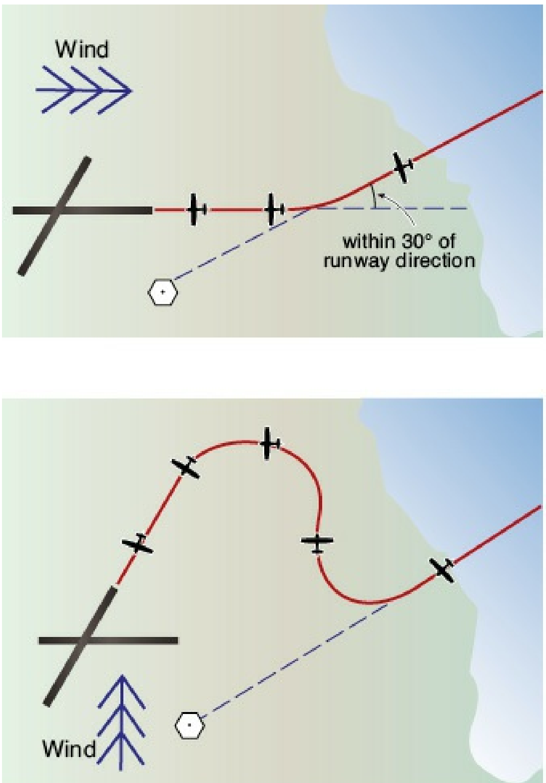



**Figure 30-1** A straight-in approach (top)and a circling approach (bottom).

## Circling to Land

If the final approach direction of an instrument approach procedure does not align the airplane within ±30° of the landing runway, then it is technically no longer a *straight-in* procedure, and significant visual maneuvering (probably involving at least part of a traffic pattern) will be required to align the airplane with the landing runway.

Visual maneuvering is also known as *circling*, or *circle-to-land*. These terms are used to describe the *visual* phase of flight after completing an instrument approach, with the aim of maneuvering an aircraft into position for a landing on a runway to which a straight-in approach is not possible.

Circling to land is most commonly used when it is necessary to make an instrument approach to one runway, but you wish to land on another runway. After becoming visual, you must then maneuver the airplane for a landing on the favored runway — for instance, using a Runway 27 ILS to become visual, followed by a circling approach and landing on the into-wind Runway 9, which is not served by an instrument approach.

19. Can ATC issue a visual approach without pilot request?

20. Can ATC issue a contact approach without pilot request?

21. The weather minimums for a visual approach are:
   a. higher than those for a contact approach.
   b. lower than those for a contact approach.
   c. the same as those for a contact approach.

22. What weather minimums must exist for a visual approach?

23. What weather minimums must exist for a contact approach?

24. Must a pilot request a contact approach?

25. If the reported visibility is less than 1 mile and you request a contact approach, would you expect ATC to issue one?

26. On visual approaches, radar service automatically terminated when:
   a. ATC so advises.
   b. the pilot is instructed to contact the tower.
   c. after landing.

27. What causes wake turbulence?

28. When is wake turbulence greatest?

29. Can a light crosswind carry the upwind wingtip vortex of a preceding airplane over the runway?

30. The wind condition which prolongs wake turbulence of a preceding aircraft on the runway for the longest period of time is a:
   a. a strong headwind.
   b. a strong tailwind.
   c. a strong crosswind.
   d. a light crosswind.
   e. a light quartering tailwind.

31. If possible, where should you try to land in relation to a preceding heavy jet airliner?

32. When can hydroplaning occur?

33. Where is the tire in relation to the runway surface during hydroplaning?

34. How does hydroplaning affect a pilot's ability to achieve directional control and good braking on the runway?

35. If an airport rotating beacon is operating during daylight hours in Class B, C, or D airspace, what does this indicate?

36. What action could a tower controller take during daylight hours to assist maneuvering pilots to locate the airport in poor conditions with visibility less than 3 miles and/or ceiling less than 1,000 feet?

**W:** weight
**WA:** AIRMET
**WAAS:** Wide Area Augmentation System
**WAC:** World Aeronautical Charts
**WCA:** wind correction angle
**WS:** SIGMET
**WSFO:** National Weather Service Forecast Office
**WSO:** National Weather Service Office
**W/V:** wind velocity
**WX:** weather
**Z:** Zulu (ATC reference to UTC)
**ZFW:** zero fuel weight

31. MC 060.
32. The desired MC is MC 060 inbound to the NDB. The airplane is right of this.
33. Steer MH 345. Expect the RBI to indicate RB 355.
34. Steer MH 128. Expect the RBI to indicate RB 172.
35. Steer MH 360. The RBI would indicate RB 090.
36. Steer MH 010. The RBI would indicate RB 080.
37. Steer MH 030. The RBI would indicate RB 090.
38. Steer MH 030. The RBI would indicate RB 270.
39. Steer MH 037. The RBI would indicate RB 263.
40. RB 084.
41. RB 264.
42. RB 275.

***The RMI and Rotatable-Card ADF***

43. MB 070 to ground station.
44. MB 250 from ground station (the reciprocal of 070).
45. a. MB 075 to the NDB.
    b. MB 255 from the NDB.
46. a. MB 330 to the NDB.
    b. MB 150 from the NDB.
47. RMI 040.
48. RMI 230.
49. RMI 300.
50. Right turn to MH 130. The RMI would indicate RMI 040.
51. Right turn to MH 100. The RMI would indicate RMI 040.
52. Turn right. The RMI would indicate RMI 075.
53. Turn left. The RMI would indicate RMI 320. The RMI tail would indicate 140.
54. Turn left. The RMI would indicate RMI 270. The RMI tail would indicate 090.
55. MC 060.
56. To the right.
57. Steer MH 345. Expect the RMI to indicate RMI 340.
58. Steer MH 128. Expect the RMI to indicate RMI 300 and RMI tail 120.
59. Steer MH 360. The RMI indicates RMI 090.
60. Steer MH 010. The RMI indicates RMI 090.
61. Steer MH 030. The RMI indicates RMI 120.
62. Steer MH 030. The RMI indicates RMI 300.
63. Steer MH 037. The RMI indicates RMI 300.
64. RMI 149.
65. The tail of the RMI.
66. The 190 radial.
67. The 089 radial.

## Review 12: VOR

1. VHF omni-directional range.
2. VHF.

35. Stratiform cloud.
36. Cumuliform cloud.
37. The growth rate is enhanced by updrafts. This is most likely in cumulonimbus clouds.
38. Virga.
39. There is a great risk. This is the case because clouds of extensive vertical development may contain large supercooled water drops.
40. There is little risk. This is the case because high-level cirriform clouds consist mainly of ice crystals.
41. Answer c.
42. Evaporating rain will cause the temperature to decrease.
43. Yes.
44. Microburst.

## Review 20: Icing

*Structural Icing*

1. Visible moisture and a temperature at or below freezing.
2. Clear ice.
3. Rime ice.
4. Approximately 4,500 feet MSL.
5. Approximately 7,500 feet MSL.
6. When flying through freezing rain.
7. Supercooled water drops.
8. When rain falls into a layer of air that is below 0°C.
9. These can form freezing rain. They may freeze to form ice pellets.
10. They will spread out on impact, join together and freeze to form clear ice (clear ice is very dangerous).
11. By ice pellets.
12. Freezing rain at a higher level.
13. This indicates that temperatures at some higher altitude are above the freezing temperature of 0°C.
14. Flying through wet snow indicates that temperatures at some higher altitude are below the freezing temperature of 0°C. This also indicates that the temperature at your altitude is above 0°C.
15. Yes.
16. Yes. Frost can cause a loss of lift by causing early airflow separation from the wing.
17. Yes.
18. Cumuliform cloud.
19. High-level cloud.
20. In freezing rain.
21. PIREPs, SIGMETs, and AIRMETs.

*Induction Icing*

22. No.
23. Yes.
24. It cools.
25. Carburetor heat control.
26. Yes.

*Instrument Icing*

27. The ASI only.

111. Answer a.

112. An airport without an authorized instrument approach procedure may be included on an IFR flight plan as an alternate if the current weather forecast indicates that the ceiling and visibility at the ETA will allow descent from the MEA followed by an approach and landing, all under basic VFR.

113. You are restricted to the landing minimums for the approach to be used.

*ATC Clearance and Flight Plan Required*

114. Yes.

115. Yes.

116. Yes.

117. No.

118. Yes.

119. No.

120. No.

121. No.

122. Yes.

123. Answer c.

*Operations in Class A Airspace*

124. Yes.

125. The Class A airspace area begins at 18,000 feet MSL.

126. Yes.

127. Yes.

128. No person may operate an aircraft in controlled airspace under IFR unless a flight plan has been filed and a clearance has been received prior to entering controlled airspace.

*Compliance with ATC Clearances and Instructions*

129. Notify ATC of the deviation as soon as possible.

130. You should declare an emergency and obtain an amended clearance, time permitting.

131. When ATC has given you priority.

*Altimeter Settings*

132. When below 18,000 feet MSL.

133. Within 100 NM of the aircraft.

*VFR and IFR Cruising Level*

134. 5,500 feet MSL.

135. 7,000 feet MSL.

136. 6,000 feet MSL.

137. 6,500 feet MSL.

138. FL200.

139. 9,500 feet MSL (don't forget VFR vertical separation from clouds).

*Minimum Altitudes for IFR Operations*

140. Minimum en route altitude.

141. Yes.

142. Yes.

143. Minimum obstruction clearance altitude.

144. Yes.

32. The holding maneuver must be executed within the one minute time limitation or the published leg length. The maneuver is considered complete when established inbound.

33. Yes.

34. Yes.

35. No.

36. The pilot should leave the final approach fix inbound at the assigned time. Yes, the holding pattern can be adjusted to achieve this.

37. No — the pilot must be in contact with ATC, which may be center or approach control, before switching to the tower.

38. For a timed approach from a holding fix with only one missed approach procedure available, the reported ceiling and visibility minimums must be equal to or greater than the prescribed circling minimums for the instrument approach procedure.

39. A procedure turn is a common maneuver used for course reversal.

40. Yes.

41. A procedure turn should normally be completed within 10 NM of the procedure turn fix, or as otherwise published on the instrument approach chart.

42. The bearing pointer should be on the right wingtip.

43. The bearing pointer should be ahead of the right wingtip.

44. The bearing pointer should be behind of the right wingtip.

45. For each ½ NM you have drifted outside a DME arc, a suitable heading change is approximately 10° to 20° toward the arc.

46. Yes, course reversal or positioning to commence an instrument approach can sometimes be achieved by entering an appropriate holding pattern.

47. Squawk 7600 with the transponder. You should depart the holding fix at 1245. Yes, in IFR conditions, you should continue on the cleared route.

## Review 29: Instrument Approaches

*Arrivals*

1. This means you may delay the commencement of the descent.
2. You should remain VFR and advise ATC.
3. 160 ±10 knots, but exactly 160 is better.
4. You should look approximately 60° right.
5. You should look approximately 40° right.
6. Radar flight-following will be provided. You are not required to give position reports.
7. Standard Terminal Arrival Route.
8. STARs are established to simplify clearance delivery procedures.
9. To accept a STAR, you need at least a textual description of it in the cockpit.
10. Yes.
11. "No STAR. "
12. a. The actual arrival begins at DINGO.
    b. The Stanfield transition begins at TFD.
    c. The Phoenix transition begins at PXR VORTAC.
    d. No (see top of chart).
    e. ATIS frequency 123. 8.
13. No, you need an approach clearance.

*Instrument Approach Charts*

convective outlook forecasts
convective SIGMETs
coordinated universal time (UTC)
coordination
  instrument scan for
coordination ball
  preflight check of
COP. See changeover point
course deviation indicator (CDI)
CRAFT
crosswind effect
cruise-climb airspeed
cruise speed
cruising altitude
  IFR
  VFR
CTAF. See common traffic advisory frequency
cylinder head temperature (CHT)
cylinder head temperature gauge

# D

DALR. See dry adiabatic lapse rate
data latency
datalink weather
  advantages of
  limitations of
  NEXRAD
data resolution
decision altitude (DA)
decision height (DH)
de-icing
density error
departure
  ATC clearance on
  instrument departure procedures
  obstacle clearance
  radar vectoring on
  setting course on
  takeoff minimums
depression (low)
descent
  climb entry from on partial panel
  climbing away from
  effect of static line blockage on
  entering
  entering on partial panel
  and final approach
  leveling off from
  leveling off from on partial panel
  maintaining airspeed in
  maintaining on partial panel
  and missed approach
  precision approach on
  rate of descent control in

**CLICK HERE TO DOWNLOAD THE COMPLETE MANUAL**

- Thank you very much for reading the preview of the manual.
- You can download the complete manual from: www.heydownloads.com by clicking the link below


- Please note: If there is no response to CLICKING the link, please download this PDF first and then click on it.

**CLICK HERE TO DOWNLOAD THE COMPLETE MANUAL**