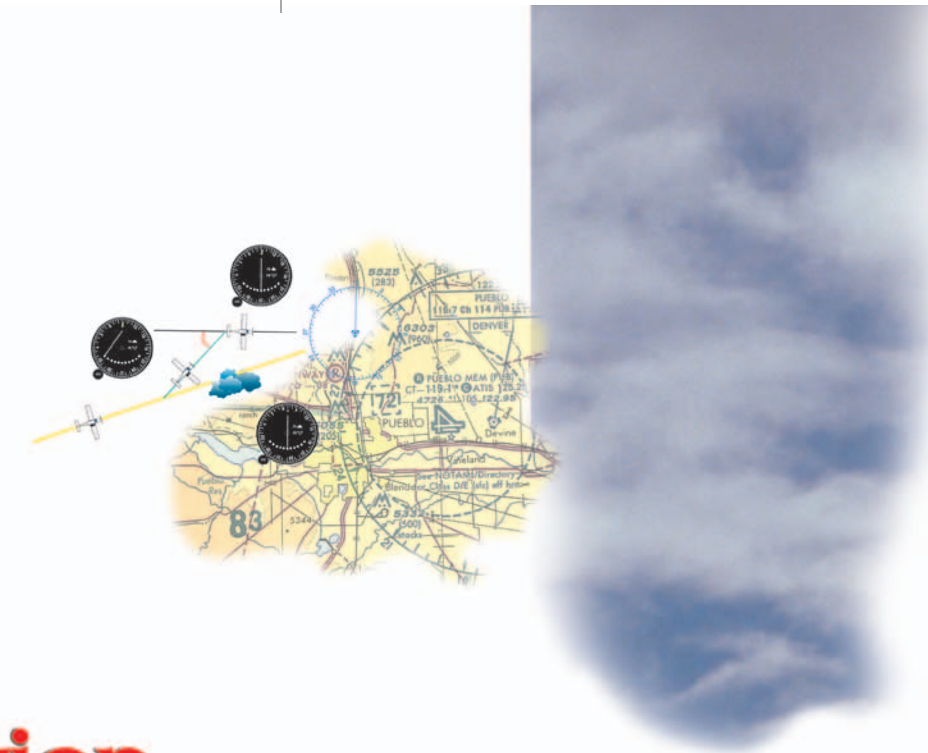
Chapter 14



Navigation

This chapter provides an introduction to cross-country flying under visual flight rules (VFR). It contains practical information for planning and executing cross-country flights for the beginning pilot.

Air navigation is the process of piloting an airplane from one geographic position to another while monitoring one's position as the flight progresses. It introduces the need for planning, which includes plotting the course on an aeronautical chart, selecting checkpoints, measuring distances, obtaining pertinent weather information, and computing flight time, headings, and fuel requirements. The methods used in this chapter include pilotage—navigating by reference to visible landmarks, dead reckoning—computations of direction and distance from a known position, and radio navigation—by use of radio aids.

AERONAUTICAL CHARTS

An aeronautical chart is the road map for a pilot flying under VFR. The chart provides information which allows pilots to track their position and provides available information which enhances safety. The three aeronautical charts used by VFR pilots are:

- Sectional Charts
- VFR Terminal Area Charts
- World Aeronautical Charts

A free catalog listing aeronautical charts and related publications including prices and instructions for ordering is available at the National Aeronautical Charting Office (NACO) Web site: www.naco.faa.gov.

SECTIONAL CHARTS

Sectional charts are the most common charts used by pilots today. The charts have a scale of 1:500,000 (1 inch = 6.86 nautical miles or approximately 8 statute miles) which allows for more detailed information to be included on the chart.

The charts provide an abundance of information, including airport data, navigational aids, airspace, and topography. Figure 14-1 on the next page is an excerpt from the legend of a sectional chart. By referring to the chart legend, a pilot can interpret most of the information on the chart. A pilot should also check the chart for other legend information, which includes air traffic control frequencies and information on airspace. These charts are revised semiannually except for some areas outside the conterminous United States where they are revised annually.

VISUAL FLIGHT RULE TERMINAL AREA CHARTS

Visual flight rule (VFR) terminal area charts are helpful when flying in or near Class B airspace. They have a scale of 1:250,000 (1 inch = 3.43 nautical miles or approximately 4 statute miles). These charts provide a more detailed display of topographical information and are revised semiannually, except for several Alaskan and Caribbean charts.

WORLD AERONAUTICAL CHARTS

World aeronautical charts are designed to provide a standard series of aeronautical charts, covering land areas of the world, at a size and scale convenient for navigation by moderate speed aircraft. They are produced at a scale of 1:1,000,000 (1 inch = 13.7 nautical miles or approximately 16 statute miles). These charts are similar to sectional charts and the symbols are the same except there is less detail due to the smaller scale. These charts are revised annually except several Alaskan charts and the Mexican/Caribbean charts which are revised every 2 years.

LATITUDE AND LONGITUDE (MERIDIANS AND PARALLELS)

The Equator is an imaginary circle equidistant from the poles of the Earth. Circles parallel to the Equator (lines running east and west) are parallels of latitude. They are used to measure degrees of latitude north or south of the Equator. The angular distance from the Equator

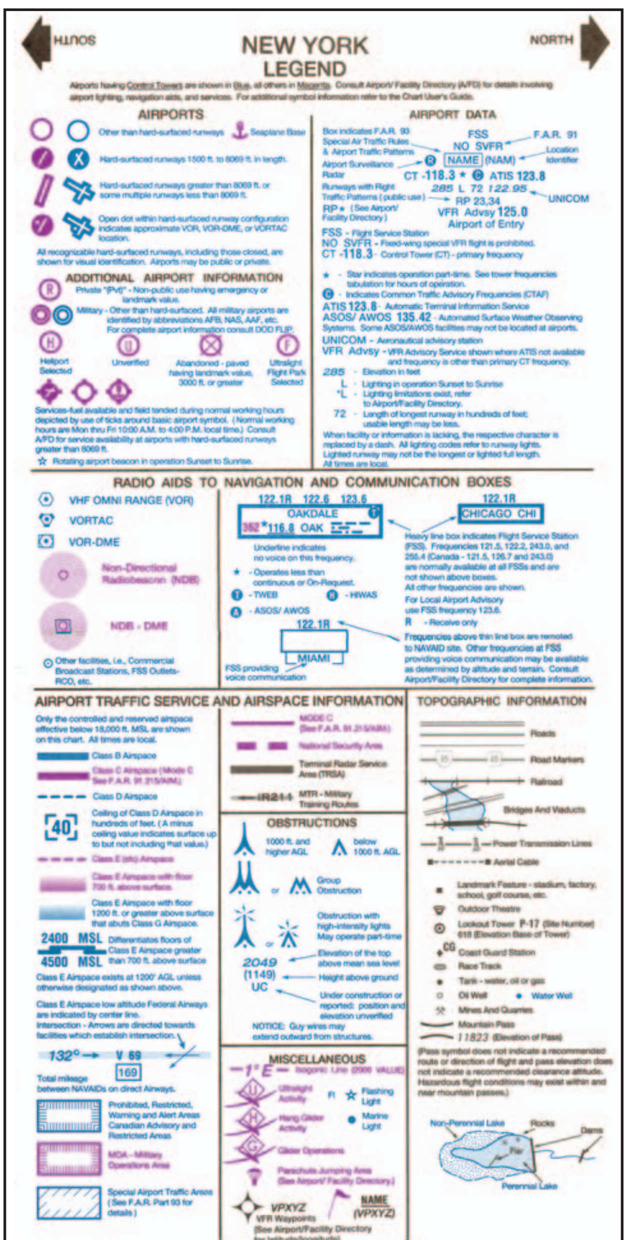


Figure 14-1. Sectional chart legend.

to the pole is one-fourth of a circle or 90°. The 48 conterminous states of the United States are located between 25° and 49° N. latitude. The arrows in figure 14-2 labeled "LATITUDE" point to lines of latitude.

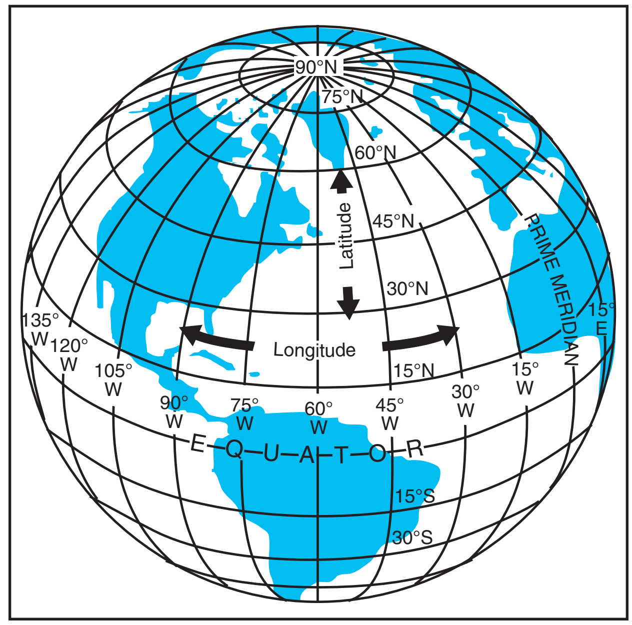


Figure 14-2. Meridians and parallels—the basis of measuring time, distance, and direction.

Meridians of longitude are drawn from the North Pole to the South Pole and are at right angles to the Equator. The "Prime Meridian" which passes through Greenwich, England, is used as the zero line from which measurements are made in degrees east and west to 180°. The 48 conterminous states of the United States are between 67° and 125° W. Longitude. The arrows in figure 14-2 labeled "LONGITUDE" point to lines of longitude.

Any specific geographical point can thus be located by reference to its longitude and latitude. Washington, DC for example, is approximately 39° N. latitude, 77° W. longitude. Chicago is approximately 42° N. latitude, 88° W. longitude.

TIME ZONES

The meridians are also useful for designating time zones. A day is defined as the time required for the Earth to make one complete rotation of 360°. Since the day is divided into 24 hours, the Earth revolves at the rate of 15° an hour. Noon is the time when the Sun is directly above a meridian; to the west of that meridian is morning, to the east is afternoon.

The standard practice is to establish a time zone for each 15° of longitude. This makes a difference of exactly 1 hour between each zone. In the United States, there are four time zones. The time zones are Eastern (75°), Central (90°), Mountain (105°), and Pacific (120°). The dividing lines are somewhat irregular because communities near the boundaries often find it more convenient to use time designations of neighboring communities or trade centers.

Figure 14-3 shows the time zones in the United States. When the Sun is directly above the 90th meridian, it is noon Central Standard Time. At the same time, it will be 1 p.m. Eastern Standard Time, 11 a.m. Mountain Standard Time, and 10 a.m. Pacific Standard Time. When "daylight saving" time is in effect, generally between the last Sunday in April and the last Sunday in October, the Sun is directly above the 75th meridian at noon, Central Daylight Time.

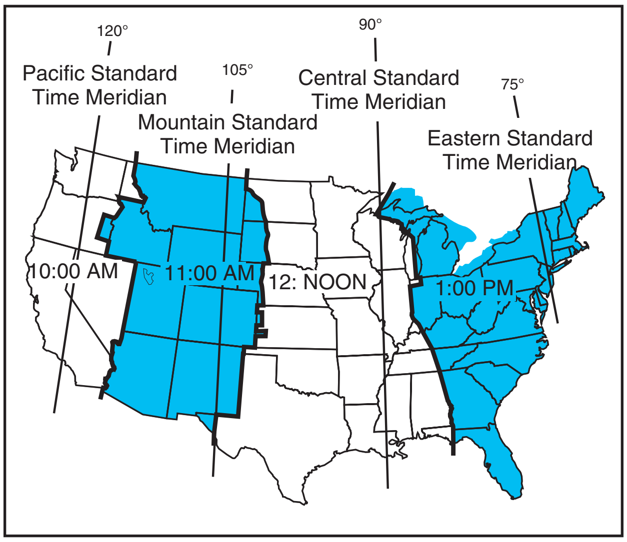


Figure 14-3. Time zones.

These time zone differences must be taken into account during long flights eastward—especially if the flight must be completed before dark. Remember, an hour is lost when flying eastward from one time zone to another, or perhaps even when flying from the western edge to the eastern edge of the same time zone. Determine the time of sunset at the destination by consulting the flight service stations (AFSS/FSS) or National Weather Service (NWS) and take this into account when planning an eastbound flight.

In most aviation operations, time is expressed in terms of the 24-hour clock. Air traffic control instructions, weather reports and broadcasts, and estimated times of arrival are all based on this system. For example: 9 a.m. is expressed as 0900, 1 p.m. is 1300, and 10 p.m. is 2200.

Because a pilot may cross several time zones during a flight, a standard time system has been adopted. It is called Universal Coordinated Time (UTC) and is often referred to as Zulu time. UTC is the time at the 0° line of longitude which passes through Greenwich, England. All of the time zones around the world are based on this reference. To convert to this time, a pilot should do the following:

Eastern Standard Time..........Add 5 hours

Central Standard Time..........Add 6 hours

Mountain Standard Time...... Add 7 hours

Pacific Standard Time.......... Add 8 hours

For daylight saving time, 1 hour should be subtracted from the calculated times.

MEASUREMENT OF DIRECTION

By using the meridians, direction from one point to another can be measured in degrees, in a clockwise direction from true north. To indicate a course to be followed in flight, draw a line on the chart from the point of departure to the destination and measure the angle which this line forms with a meridian. Direction is expressed in degrees, as shown by the compass rose in figure 14-4.

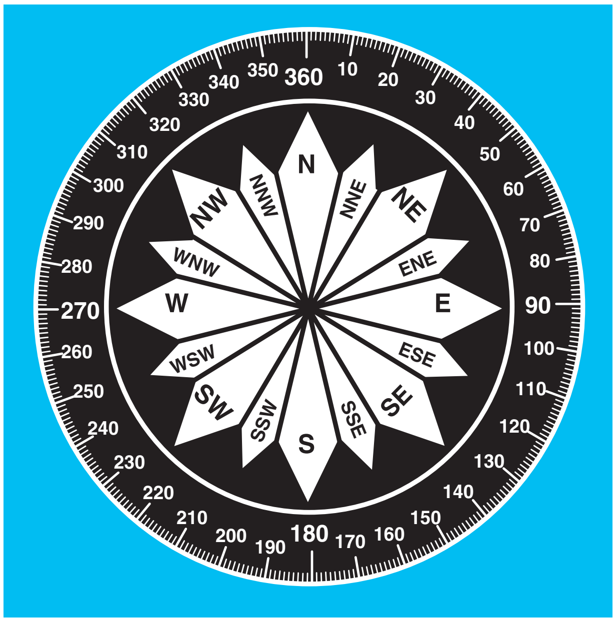


Figure 14-4. Compass rose.

Because meridians converge toward the poles, course measurement should be taken at a meridian near the midpoint of the course rather than at the point of departure. The course measured on the chart is known as the true course. This is the direction measured by reference to a meridian or true north. It is the direction of intended flight as measured in degrees clockwise from true north.

As shown in figure 14-5, the direction from A to B would be a true course of 065°, whereas the return trip (called the reciprocal) would be a true course of 245°.

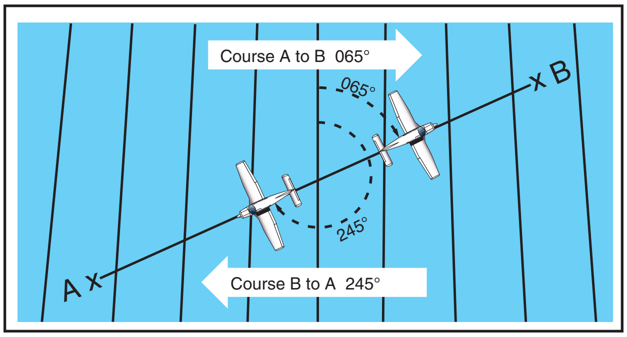


Figure 14-5. Courses are determined by reference to meridians on aeronautical charts.

The true heading is the direction in which the nose of the airplane points during a flight when measured in degrees clockwise from true north. Usually, it is necessary to head the airplane in a direction slightly different from the true course to offset the effect of wind. Consequently, numerical value of the true heading may not correspond with that of the true course. This will be discussed more fully in subsequent sections in this chapter. For the purpose of this discussion, assume a no-wind condition exists under which heading and course would coincide. Thus, for a true course of 065°, the true heading would be 065°. To use the compass accurately, however, corrections must be made for magnetic variation and compass deviation.

VARIATION

Variation is the angle between true north and magnetic north. It is expressed as east variation or west variation depending upon whether magnetic north (MN) is to the east or west of true north (TN).

The north magnetic pole is located close to 71° N. latitude, 96° W. longitude and is about 1,300 miles from the geographic or true north pole, as indicated in figure 14-6. If the Earth were uniformly magnetized, the compass needle would point toward the magnetic pole, in which case the variation between true north (as shown by the geographical meridians) and magnetic north (as shown by the magnetic meridians) could be measured at any intersection of the meridians.

Actually, the Earth is not uniformly magnetized. In the United States, the needle usually points in the general direction of the magnetic pole, but it may vary in certain geographical localities by many degrees. Consequently, the exact amount of variation at thousands of selected locations in the United States has been carefully determined. The amount and the direction of variation, which change slightly from time to time, are shown on most aeronautical charts as broken magenta lines, called isogonic lines, which connect points of equal magnetic

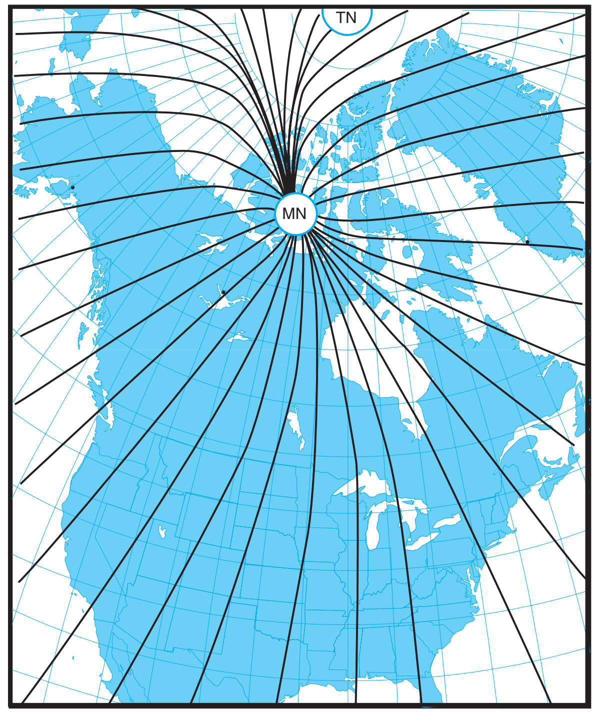


Figure 14-6. Isogonic chart. Magnetic meridians are in black; geographic meridians and parallels are in blue. Variation is the angle between a magnetic and geographic meridian.

variation. (The line connecting points at which there is no variation between true north and magnetic north is the agonic line.) An isogonic chart is shown in figure 14-6. Minor bends and turns in the isogonic and agonic lines are caused by unusual geological conditions affecting magnetic forces in these areas.

On the west coast of the United States, the compass needle points to the east of true north; on the east coast, the compass needle points to the west of true north. Zero degree variation exists on the agonic line, where magnetic north and true north coincide. This line runs roughly west of the Great Lakes, south through Wisconsin, Illinois, western Tennessee, and along the border of Mississippi and Alabama. [Compare figures 14-7 and 14-8.]

Because courses are measured in reference to geographical meridians which point toward true north, and these courses are maintained by reference to the compass which points along a magnetic meridian in the general direction of magnetic north, the true direction must be converted into magnetic direction for the purpose of flight. This conversion is made by adding or subtracting the variation which is indicated by the nearest isogonic line on the chart. The true heading, when corrected for variation, is known as magnetic heading.

If the variation is shown as "9°E," this means that magnetic north is 9° east of true north. If a true heading of 360° is to be flown, 9° must be subtracted from 360°, which results in a magnetic heading of 351°. To fly

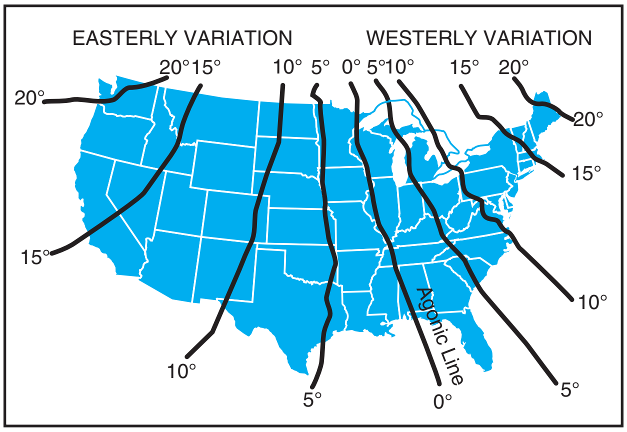


Figure 14-7. A typical isogonic chart. The black lines are isogonic lines which connect geographic points with identical magnetic variation.

east, a magnetic heading of 081° (090° – 9°) would be flown. To fly south, the magnetic heading would be 171° (180° – 9°). To fly west, it would be 261° (270° – 9°). To fly a true heading of 060°, a magnetic heading of 051° (060° – 9°) would be flown.

Remember, to convert true course or heading to magnetic course or heading, note the variation shown by the nearest isogonic line. If variation is west, add; if east, subtract. One method for remembering whether to add or subtract variation is the phrase "east is least (subtract) and west is best (add)."

DEVIATION

Determining the magnetic heading is an intermediate step necessary to obtain the correct compass heading for the flight. To determine compass heading, a correction for deviation must be made. Because of magnetic influences within the airplane such as electrical circuits, radio, lights, tools, engine, and magnetized metal parts, the compass needle is frequently deflected from its normal reading. This deflection is deviation. The deviation is different for each airplane, and it also may vary for different headings in the same airplane. For instance, if magnetism in the engine attracts the north end of the compass, there would be no effect when the plane is on a heading of magnetic north. On easterly or westerly headings, however, the compass indications would be in error, as shown in figure 14-9. Magnetic attraction can come from many other parts of the airplane; the assumption of attraction in the engine is merely used for the purpose of illustration.

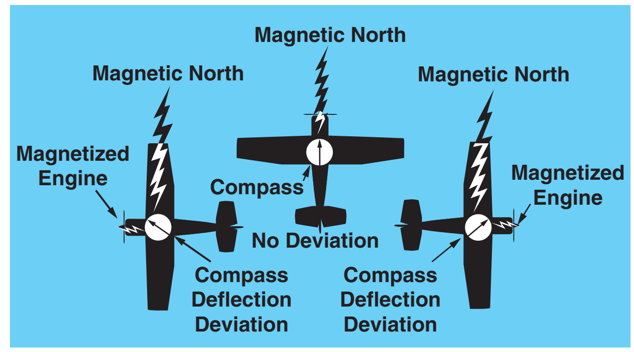


Figure 14-9. Magnetized portions of the airplane cause the compass to deviate from its normal indications.

Some adjustment of the compass, referred to as compensation, can be made to reduce this error, but the remaining correction must be applied by the pilot.

Proper compensation of the compass is best performed by a competent technician. Since the magnetic forces within the airplane change, because of landing shocks, vibration, mechanical work, or changes in equipment, the pilot should occasionally have the deviation of the compass checked. The procedure used to check the deviation (called "swinging the compass") is briefly outlined.

The airplane is placed on a magnetic compass rose, the engine started, and electrical devices normally used (such as radio) are turned on. Tailwheel-type airplanes should be jacked up into flying position. The airplane is aligned with magnetic north indicated on the compass

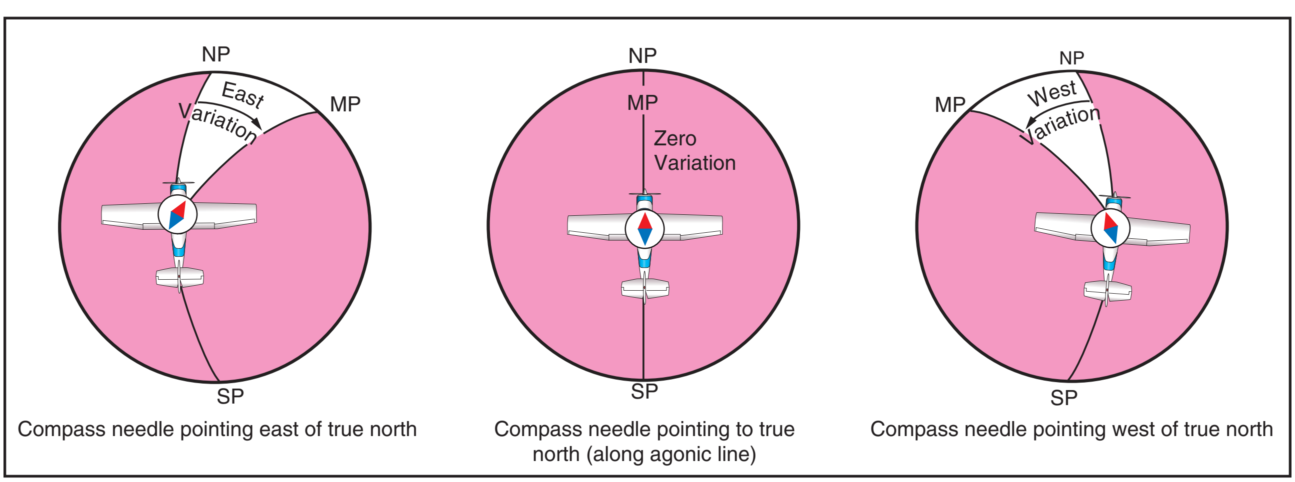


Figure 14-8. Effect of variation on the compass.

rose and the reading shown on the compass is recorded on a deviation card. The airplane is then aligned at 30° intervals and each reading is recorded. If the airplane is to be flown at night, the lights are turned on and any significant changes in the readings are noted. If so, additional entries are made for use at night.

The accuracy of the compass can also be checked by comparing the compass reading with the known runway headings.

A deviation card, similar to figure 14-10, is mounted near the compass, showing the addition or subtraction required to correct for deviation on various headings, usually at intervals of 30°. For intermediate readings, the pilot should be able to interpolate mentally with sufficient accuracy. For example, if the pilot needed the correction for 195° and noted the correction for 180° to be 0° and for 210° to be +2°, it could be assumed that the correction for 195° would be +1°. The magnetic heading, when corrected for deviation, is known as compass heading.

FOR (MAGNETIC)..........	N	30	60	E	120	150
STEER (COMPASS).......	0	28	57	86	117	148
FOR (MAGNETIC)..........	S	210	240	W	300	330
STEER (COMPASS).......	180	212	243	274	303	332

Figure 14-10. Compass deviation card.

The following method is used by many pilots to determine compass heading: After the true course (TC) is measured, and wind correction applied resulting in a true heading (TH), the sequence TH ± variation (V) = MH ± deviation (D) = compass heading (CH) is followed to arrive at compass heading. [Figure 14-11]

EFFECT OF WIND

The preceding discussion explained how to measure a true course on the aeronautical chart and how to make corrections for variation and deviation, but one important factor has not been considered—wind. As discussed in the study of the atmosphere, wind is a mass of air moving over the surface of the Earth in a definite direction. When the wind is blowing from the north at 25 knots, it simply means that air is moving southward over the Earth's surface at the rate of 25 nautical miles (NM) in 1 hour.

Under these conditions, any inert object free from contact with the Earth will be carried 25 NM southward in 1 hour. This effect becomes apparent when such things as clouds, dust, and toy balloons are observed being blown along by the wind. Obviously, an airplane flying within the moving mass of air will be similarly affected. Even though the airplane does not float freely

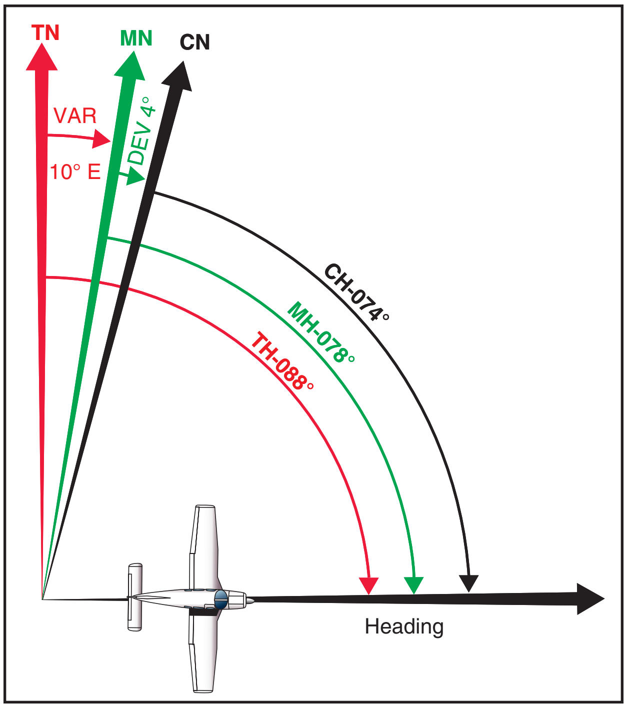


Figure 14-11. Relationship between true, magnetic, and compass headings for a particular instance.

with the wind, it moves through the air at the same time the air is moving over the ground, thus is affected by wind. Consequently, at the end of 1 hour of flight, the airplane will be in a position which results from a combination of these two motions:

- the movement of the air mass in reference to the ground, and
- the forward movement of the airplane through the air mass.

Actually, these two motions are independent. So far as the airplane's flight through the air is concerned, it makes no difference whether the mass of air through which the airplane is flying is moving or is stationary. A pilot flying in a 70-knot gale would be totally unaware of any wind (except for possible turbulence) unless the ground were observed. In reference to the ground, however, the airplane would appear to fly faster with a tailwind or slower with a headwind, or to drift right or left with a crosswind.

As shown in figure 14-12, an airplane flying eastward at an airspeed of 120 knots in still air, will have a groundspeed exactly the same—120 knots. If the mass of air is moving eastward at 20 knots, the airspeed of the airplane will not be affected, but the progress of the airplane over the ground will be 120 plus 20, or a groundspeed of 140 knots. On the other hand, if the mass of air is moving westward at 20 knots, the airspeed of the airplane still remains the same, but groundspeed becomes 120 minus 20 or 100 knots.

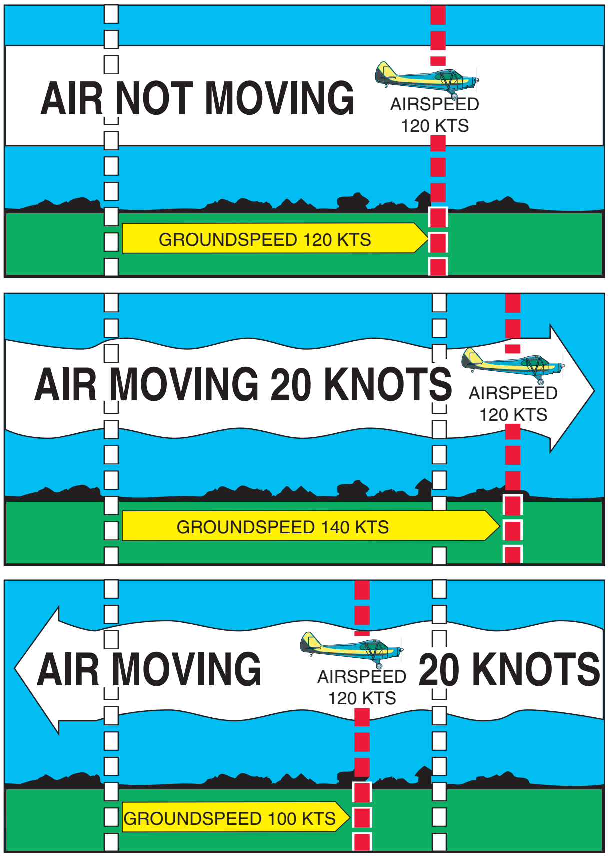


Figure 14-12. Motion of the air affects the speed with which airplanes move over the Earth's surface. Airspeed, the rate at which an airplane moves through the air, is not affected by air motion.

Assuming no correction is made for wind effect, if the airplane is heading eastward at 120 knots, and the air mass moving southward at 20 knots, the airplane at the end of 1 hour will be almost 120 miles east of its point of departure because of its progress through the air. It will be 20 miles south because of the motion of the air. Under these circumstances, the airspeed remains 120 knots, but the groundspeed is determined by combining the movement of the airplane with that of the air mass. Groundspeed can be measured as the distance from the point of departure to the position of the airplane at the end of 1 hour. The groundspeed can be computed by the time required to fly between two points a known distance apart. It also can be determined before flight by constructing a wind triangle, which will be explained later in this chapter. [Figure 14-13]

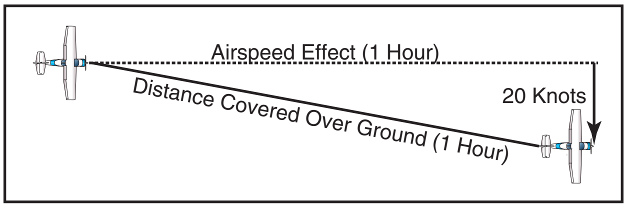


Figure 14-13. Airplane flightpath resulting from its airspeed and direction, and the windspeed and direction.

The direction in which the plane is pointing as it flies is heading. Its actual path over the ground, which is a combination of the motion of the airplane and the motion of the air, is track. The angle between the heading and the track is drift angle. If the airplane's heading coincides with the true course and the wind is blowing from the left, the track will not coincide with the true course. The wind will drift the airplane to the right, so the track will fall to the right of the desired course or true course. [Figure 14-14]

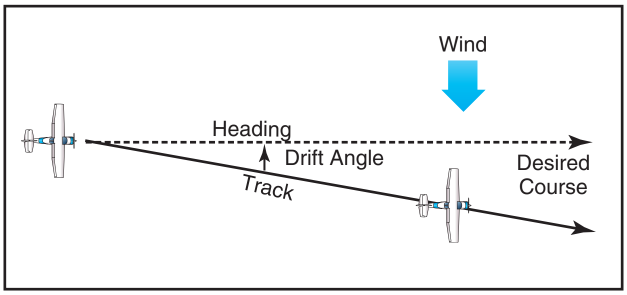


Figure 14-14. Effects of wind drift on maintaining desired course.

By determining the amount of drift, the pilot can counteract the effect of the wind and make the track of the airplane coincide with the desired course. If the mass of air is moving across the course from the left, the airplane will drift to the right, and a correction must be made by heading the airplane sufficiently to the left to offset this drift. To state in another way, if the wind is from the left, the correction will be made by pointing the airplane to the left a certain number of degrees, therefore correcting for wind drift. This is wind correction angle and is expressed in terms of degrees right or left of the true course. [Figure 14-15]

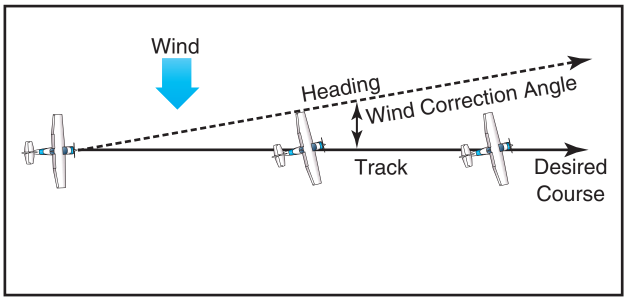


Figure 14-15. Establishing a wind correction angle that will counteract wind drift and maintain the desired course.

To summarize:

- **COURSE—**is the intended path of an airplane over the ground; or the direction of a line drawn on a chart representing the intended airplane path, expressed as the angle measured from a specific reference datum clockwise from 0° through 360° to the line.

- **HEADING—**is the direction in which the nose of the airplane points during flight.
- **TRACK—**is the actual path made over the ground in flight. (If proper correction has been made for the wind, track and course will be identical.)
- **DRIFT ANGLE—**is the angle between heading and track.
- **WIND CORRECTION ANGLE—**is correction applied to the course to establish a heading so that track will coincide with course.
- **AIRSPEED—**is the rate of the airplane's progress through the air.
- **GROUNDSPEED—**is the rate of the airplane's in-flight progress over the ground.

BASIC CALCULATIONS

Before a cross-country flight, a pilot should make common calculations for time, speed, and distance, and the amount of fuel required.

CONVERTING MINUTES TO EQUIVALENT HOURS

It frequently is necessary to convert minutes into equivalent hours when solving speed, time, and distance problems. To convert minutes to hours, divide by 60 (60 minutes = 1 hour). Thus, 30 minutes 30/60 = 0.5 hour. To convert hours to minutes, multiply by 60. Thus, 0.75 hour equals 0.75 x 60 = 45 minutes.

Time T = D/GS

To find the **time** (T) in flight, divide the **distance** (D) by the **groundspeed** (GS). The time to fly 210 nautical miles at a groundspeed of 140 knots is 210 divided by 140, or 1.5 hours. (The 0.5 hour multiplied by 60 minutes equals 30 minutes.) Answer: 1:30.

Distance D = GS X T

To find the distance flown in a given time, multiply groundspeed by time. The distance flown in 1 hour 45 minutes at a groundspeed of 120 knots is 120 x 1.75, or 210 nautical miles.

Groundspeed GS = D/T

To find the groundspeed, divide the distance flown by the time required. If an airplane flies 270 nautical miles in 3 hours, the groundspeed is 270 divided by 3 = 90 knots.

CONVERTING KNOTS TO MILES PER HOUR

Another conversion is that of changing knots to miles per hour. The aviation industry is using knots more frequently than miles per hour, but it might be well to discuss the conversion for those who do use miles per hour when working with speed problems. The National Weather Service reports both surface winds and winds aloft in knots. However, airspeed indicators in some airplanes are calibrated in miles per hour (although many are now calibrated in both miles per hour and knots). Pilots, therefore, should learn to convert windspeeds in knots to miles per hour.

A knot is 1 nautical mile per hour. Because there are 6,076.1 feet in a nautical mile and 5,280 feet in a statute mile, the conversion factor is 1.15. To convert knots to miles per hour, multiply knots by 1.15. For example: a windspeed of 20 knots is equivalent to 23 miles per hour.

Most flight computers or electronic calculators have a means of making this conversion. Another quick method of conversion is to use the scales of nautical miles and statute miles at the bottom of aeronautical charts.

FUEL CONSUMPTION

Airplane fuel consumption is computed in gallons per hour. Consequently, to determine the fuel required for a given flight, the time required for the flight must be known. Time in flight multiplied by rate of consumption gives the quantity of fuel required. For example, a flight of 400 NM at a groundspeed of 100 knots requires 4 hours. If the plane consumes 5 gallons an hour, the total consumption will be 4 x 5, or 20 gallons.

The rate of fuel consumption depends on many factors: condition of the engine, propeller pitch, propeller r.p.m., richness of the mixture, and particularly the percentage of horsepower used for flight at cruising speed. The pilot should know the approximate consumption rate from cruise performance charts, or from experience. In addition to the amount of fuel required for the flight, there should be sufficient fuel for reserve.

FLIGHT COMPUTERS

Up to this point, only mathematical formulas have been used to determine such items as time, distance, speed, and fuel consumption. In reality, most pilots will use a mechanical or electronic flight computer. These devices can compute numerous problems associated with flight planning and navigation. The mechanical or electronic computer will have an instruction book and most likely sample problems so the pilot can become familiar with its functions and operation. [Figure 14-16]

PLOTTER

Another aid in flight planning is a plotter, which is a protractor and ruler. The pilot can use this when determining true course and measuring distance. Most plotters have a ruler which measures in both

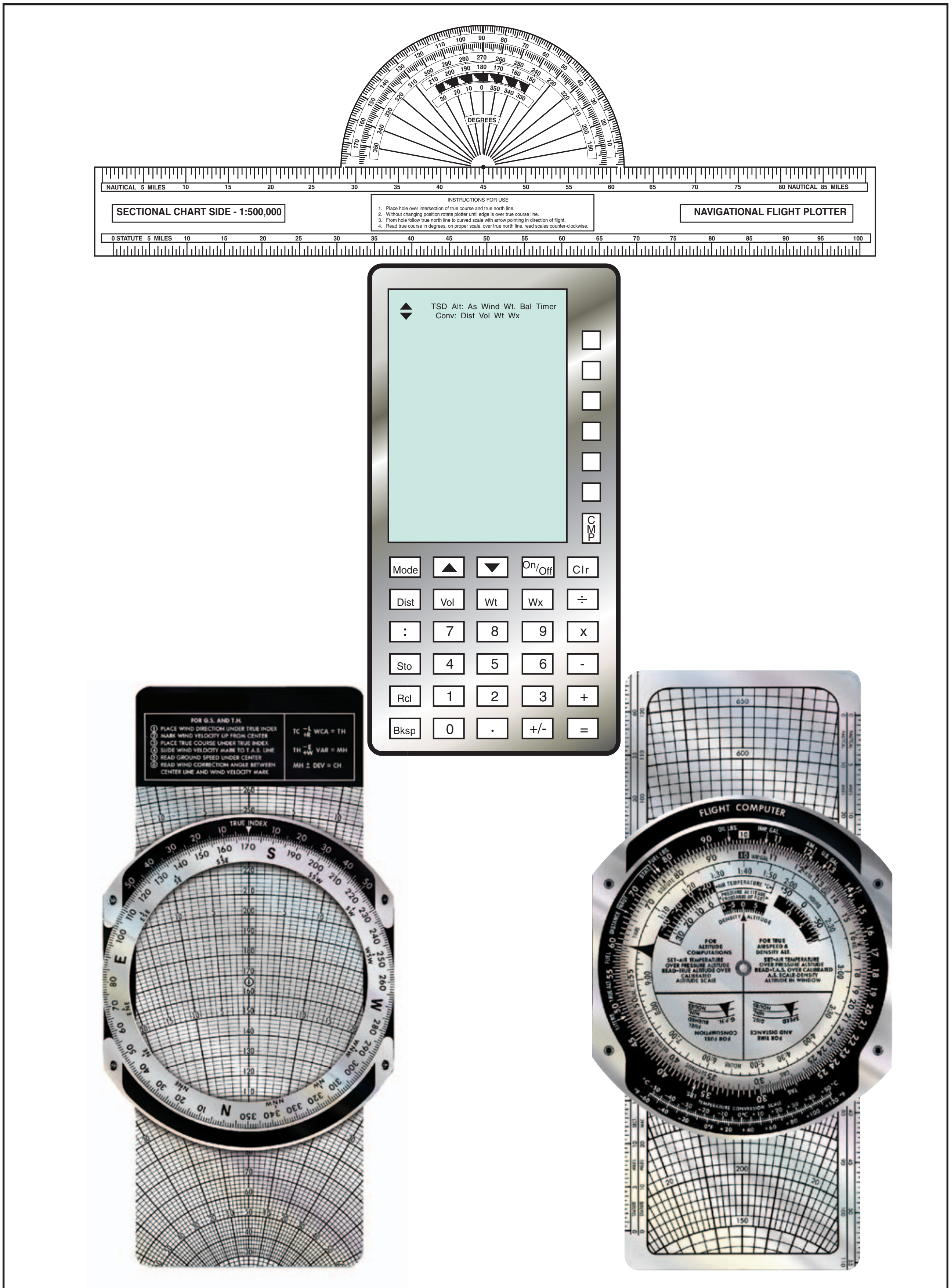


Figure 14-16. A picture of the computational and wind side of a common mechanical computer, an electronic computer, and plotter.

nautical and statute miles and has a scale for a sectional chart on one side and a world aeronautical chart on the other. [Figure 14-16]

PILOTAGE

Pilotage is navigation by reference to landmarks or checkpoints. It is a method of navigation that can be used on any course that has adequate checkpoints, but it is more commonly used in conjunction with dead reckoning and VFR radio navigation.

The checkpoints selected should be prominent features common to the area of the flight. Choose checkpoints that can be readily identified by other features such as roads, rivers, railroad tracks, lakes, and power lines. If possible, select features that will make useful boundaries or brackets on each side of the course, such as highways, rivers, railroads, and mountains. A pilot can keep from drifting too far off course by referring to and not crossing the selected brackets. Never place complete reliance on any single checkpoint. Choose ample checkpoints. If one is missed, look for the next one while maintaining the heading. When determining position from checkpoints, remember that the scale of a sectional chart is 1 inch = 8 statute miles or 6.86 nautical miles. For example, if a checkpoint selected was approximately one-half inch from the course line on the chart, it is 4 statue miles or 3.43 nautical miles from the course on the ground. In the more congested areas, some of the smaller features are not included on the chart. If confused, hold the heading. If a turn is made away from the heading, it will be easy to become lost.

Roads shown on the chart are primarily the well-traveled roads or those most apparent when viewed from the air. New roads and structures are constantly being built, and may not be shown on the chart until the next chart is issued. Some structures, such as antennas may be difficult to see. Sometimes TV antennas are grouped together in an area near a town. They are supported by almost invisible guy wires. Never approach an area of antennas less than 500 feet above the tallest one. Most of the taller structures are marked with strobe lights to make them more visible to a pilot. However, some weather conditions or background lighting may make them difficult to see. Aeronautical charts display the best information available at the time of printing, but a pilot should be cautious for new structures or changes that have occurred since the chart was printed.

DEAD RECKONING

Dead reckoning is navigation solely by means of computations based on time, airspeed, distance, and direction. The products derived from these variables, when adjusted by windspeed and velocity, are heading and groundspeed. The predicted heading will guide the airplane along the intended path and the groundspeed will establish the time to arrive at each checkpoint and the destination. Except for flights over water, dead reckoning is usually used with pilotage for cross-country flying. The heading and groundspeed as calculated is constantly monitored and corrected by pilotage as observed from checkpoints.

THE WIND TRIANGLE OR VECTOR ANALYSIS

If there is no wind, the airplane's ground track will be the same as the heading and the groundspeed will be the same as the true airspeed. This condition rarely exists. A wind triangle, the pilot's version of vector analysis, is the basis of dead reckoning.

The wind triangle is a graphic explanation of the effect of wind upon flight. Groundspeed, heading, and time for any flight can be determined by using the wind triangle. It can be applied to the simplest kind of cross-country flight as well as the most complicated instrument flight. The experienced pilot becomes so familiar with the fundamental principles that estimates can be made which are adequate for visual flight without actually drawing the diagrams. The beginning student, however, needs to develop skill in constructing these diagrams as an aid to the complete understanding of wind effect. Either consciously or unconsciously, every good pilot thinks of the flight in terms of wind triangle.

If a flight is to be made on a course to the east, with a wind blowing from northeast, the airplane must be headed somewhat to the north of east to counteract drift. This can be represented by a diagram as shown in figure 14-17. Each line represents direction and speed. The long dotted line shows the direction the plane is heading, and its length represents the airspeed for 1 hour. The short dotted line at the right shows the wind direction, and its length represents the wind velocity

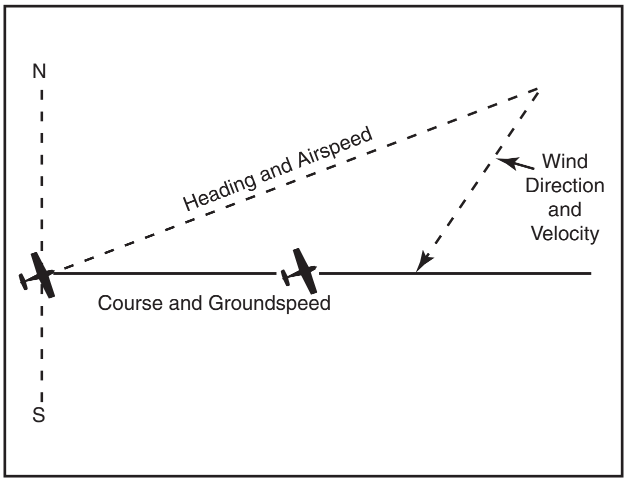


Figure 14-17. Principle of the wind triangle.

for 1 hour. The solid line shows the direction of the track, or the path of the airplane as measured over the Earth, and its length represents the distance traveled in 1 hour, or the groundspeed.

In actual practice, the triangle illustrated in figure 14-17 is not drawn; instead, construct a similar triangle as shown by the black lines in figure 14-18, which is explained in the following example.

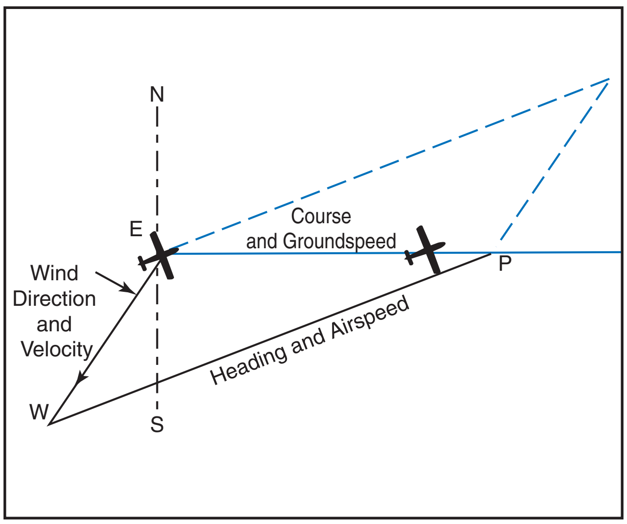


Figure 14-18. The wind triangle as is drawn in navigation practice. Dashed lines show the triangle as drawn in figure 14-17.

Suppose a flight is to be flown from E to P. Draw a line on the aeronautical chart connecting these two points; measure its direction with a protractor, or plotter, in reference to a meridian. This is the true course, which in this example is assumed to be 090° (east). From the National Weather Service, it is learned that the wind at the altitude of the intended flight is 40 knots from the northeast (045°). Since the National Weather Service reports the windspeed in knots, if the true airspeed of the airplane is 120 knots, there is no need to convert speeds from knots to miles per hour or vice versa.

Now on a plain sheet of paper draw a vertical line representing north and south. (The various steps are shown in figure 14-19.)

Place the protractor with the base resting on the vertical line and the curved edge facing east. At the center point of the base, make a dot labeled "E" (point of departure), and at the curved edge, make a dot at 90° (indicating the direction of the true course) and another at 45° (indicating wind direction).

With the ruler, draw the true course line from E, extending it somewhat beyond the dot by 90°, and labeling it "TC 090°."

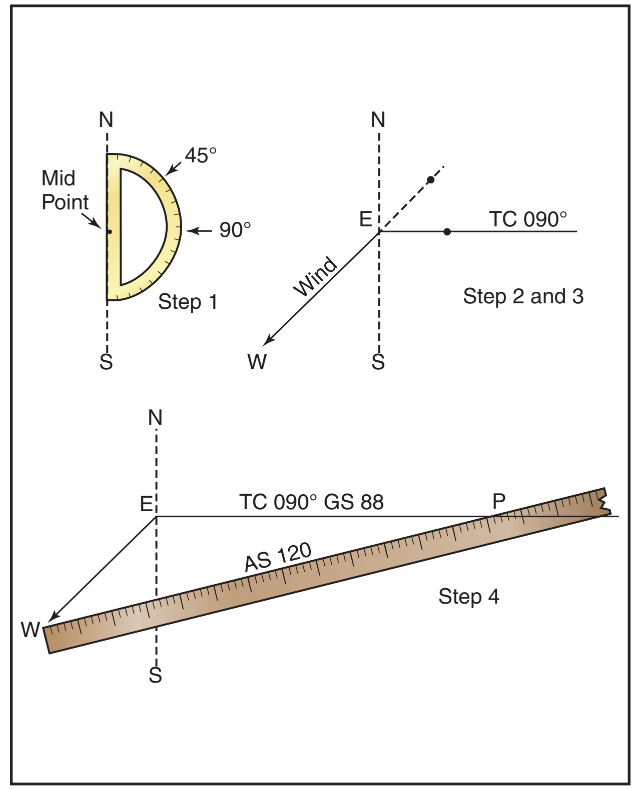


Figure 14-19. Steps in drawing the wind triangle.

Next, align the ruler with E and the dot at 45°, and draw the wind arrow from E, not toward 045°, but downwind in the direction the wind is blowing, making it 40 units long, to correspond with the wind velocity of 40 knots. Identify this line as the wind line by placing the letter "W" at the end to show the wind direction. Finally, measure 120 units on the ruler to represent the airspeed, making a dot on the ruler at this point. The units used may be of any convenient scale or value (such as $^1/_4$ inch = 10 knots), but once selected, the same scale must be used for each of the linear movements involved. Then place the ruler so that the end is on the arrowhead (W) and the 120-knot dot intercepts the true course line. Draw the line and label it "AS 120." The point "P" placed at the intersection represents the position of the airplane at the end of 1 hour. The diagram is now complete.

The distance flown in 1 hour (groundspeed) is measured as the numbers of units on the true course line (88 nautical miles per hour or 88 knots).

The true heading necessary to offset drift is indicated by the direction of the airspeed line, which can be determined in one of two ways:

- By placing the straight side of the protractor along the north-south line, with its center point at the intersection of the airspeed line and north-south line, read the true heading directly in degrees (076°). [Figure 14-20]

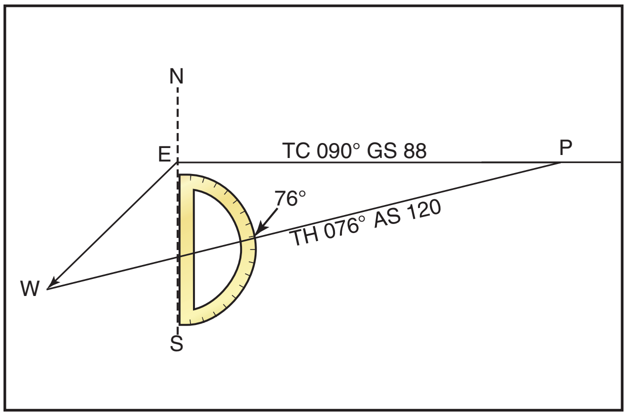


Figure 14-20. Finding true heading by direct measurement.

- By placing the straight side of the protractor along the true course line, with its center at P, read the angle between the true course and the airspeed line. This is the wind correction angle (WCA) which must be applied to the true course to obtain the true heading. If the wind blows from the right of true course, the angle will be added; if from the left, it will be subtracted. In the example given, the WCA is 14° and the wind is from the left; therefore, subtract 14° from true course of 090°, making the true heading 076°. [Figure 14-21]

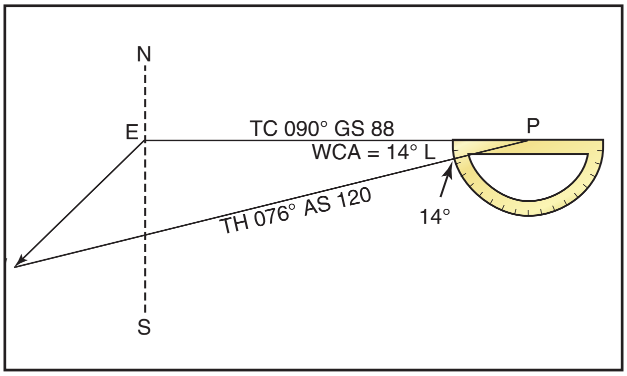


Figure 14-21. Finding true heading by the wind correction angle.

After obtaining the true heading, apply the correction for magnetic variation to obtain magnetic heading, and the correction for compass deviation to obtain a compass heading. The compass heading can be used to fly to the destination by dead reckoning.

To determine the time and fuel required for the flight, first find the distance to destination by measuring the length of the course line drawn on the aeronautical chart (using the appropriate scale at the bottom of the chart). If the distance measures 220 NM, divide by the groundspeed of 88 knots, which gives 2.5 hours or (2:30), as the time required. If fuel consumption is 8 gallons an hour, 8 x 2.5 or about 20 gallons will be used. Briefly summarized, the steps in obtaining flight information are as follows:

- **TRUE COURSE—**Direction of the line connecting two desired points, drawn on the chart and measured clockwise in degrees from true north on the mid-meridian.

- **WIND CORRECTION ANGLE—**Determined from the wind triangle. (Added to TC if the wind is from the right; subtract if wind is from the left.)

- **TRUE HEADING—**The direction measured in degrees clockwise from true north, in which the nose of the plane should point to make good the desired course.

- **VARIATION—**Obtained from the isogonic line on the chart. (Added to TH if west; subtract if east.)

- **MAGNETIC HEADING—**An intermediate step in the conversion. (Obtained by applying variation to true heading.)

- **DEVIATION—**Obtained from the deviation card on the airplane. (Added to MH or subtracted from, as indicated.)

- **COMPASS HEADING—**The reading on the compass (found by applying deviation to MH) which will be followed to make good the desired course.

- **TOTAL DISTANCE—**Obtained by measuring the length of the TC line on the chart (using the scale at the bottom of the chart).

- **GROUNDSPEED—**Obtained by measuring the length of the TC line on the wind triangle (using the scale employed for drawing the diagram).

- **ESTIMATED TIME EN ROUTE (ETE)—**Total distance divided by groundspeed.

- **FUEL RATE—**Predetermined gallons per hour used at cruising speed.

NOTE: Additional fuel for adequate reserve should be added as a safety measure.

FLIGHT PLANNING

Title 14 of the Code of Federal Regulations (14 CFR) part 91 states, in part, that before beginning a flight, the pilot in command of an aircraft shall become familiar with all available information concerning that flight. For flights not in the vicinity of an airport, this must include information on available current weather reports and forecasts, fuel requirements, alternatives available if the planned flight cannot be completed, and any known traffic delays of which the pilot in command has been advised by air traffic control (ATC).

ASSEMBLING NECESSARY MATERIAL

The pilot should collect the necessary material well before the flight. An appropriate current sectional chart and charts for areas adjoining the flight route should be among this material if the route of flight is near the border of a chart.

Additional equipment should include a flight computer or electronic calculator, plotter, and any other item appropriate to the particular flight—for example, if a night flight is to be undertaken, carry a flashlight; if a flight is over desert country, carry a supply of water and other necessities.

WEATHER CHECK

It may be wise to check the weather before continuing with other aspects of flight planning to see, first of all, if the flight is feasible and, if it is, which route is best. Chapter 11 on weather discusses obtaining a weather briefing.

USE OF THE AIRPORT/FACILITY DIRECTORY

Study available information about each airport at which a landing is intended. This should include a study of the *Notices to Airmen* (NOTAMs) and the *Airport/Facility Directory.* [Figure 14-22] This includes location, elevation, runway and lighting facilities, available services, availability of aeronautical advisory station frequency (UNICOM), types of fuel available (use to decide on refueling stops), AFSS/FSS located on the airport, control tower and ground control frequencies, traffic information, remarks, and other pertinent information. The NOTAMs, issued every 28 days, should be checked for additional information on hazardous conditions or changes that have been made since issuance of the *Airport/Facility Directory*.

The sectional chart bulletin subsection should be checked for major changes that have occurred since the last publication date of each sectional chart being used. Remember, the chart may be up to 6 months old. The effective date of the chart appears at the top of the front of the chart.

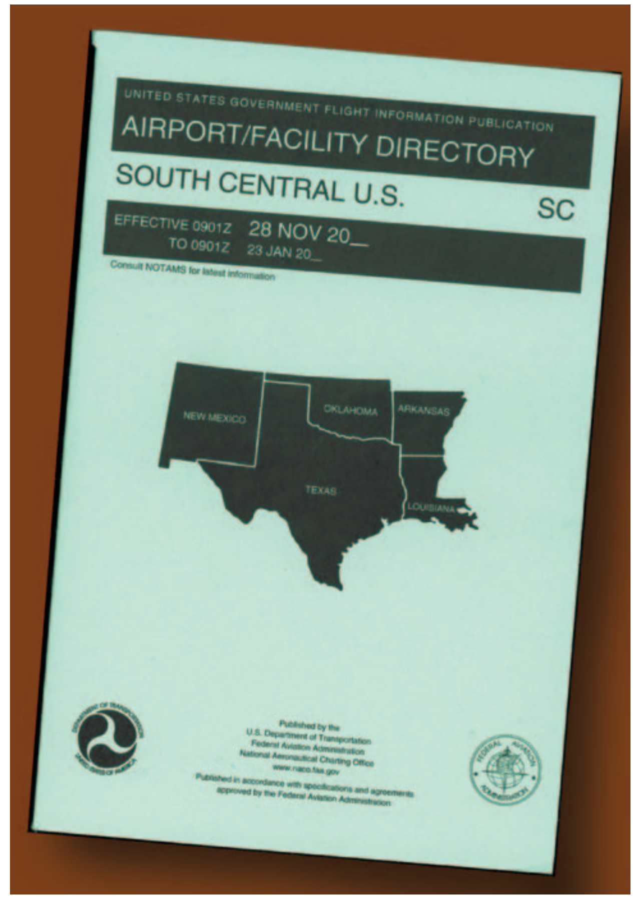


Figure 14-22. Airport Facility Directory.

The *Airport/Facility Directory* will generally have the latest information pertaining to such matters and should be used in preference to the information on the back of the chart, if there are differences.

AIRPLANE FLIGHT MANUAL OR PILOT'S OPERATING HANDBOOK

The Airplane Flight Manual or Pilot's Operating Handbook (AFM/POH) should be checked to determine the proper loading of the airplane (weight and balance data). The weight of the usable fuel and drainable oil aboard must be known. Also, check the weight of the passengers, the weight of all baggage to be carried, and the empty weight of the airplane to be sure that the total weight does not exceed the maximum allowable. The distribution of the load must be known to tell if the resulting center of gravity is within limits. Be sure to use the latest weight and balance information in the FAA-approved Airplane Flight Manual or other permanent airplane records, as appropriate, to obtain empty weight and empty weight center-of-gravity information.

Determine the takeoff and landing distances from the appropriate charts, based on the calculated load, elevation of the airport, and temperature; then compare these distances with the amount of runway available. Remember, the heavier the load and the higher the elevation, temperature, or humidity, the longer the takeoff roll and landing roll and the lower the rate of climb.

Check the fuel consumption charts to determine the rate of fuel consumption at the estimated flight altitude and power settings. Calculate the rate of fuel consumption, and then compare it with the estimated time for the flight so that refueling points along the route can be included in the plan.

CHARTING THE COURSE

Once the weather has been checked and some preliminary planning done, it is time to chart the course and determine the data needed to accomplish the flight. The following sections will provide a logical sequence to follow in charting the course, filling out a flight log, and filing a flight plan. In the following example, a trip is planned based on the following data and the sectional chart excerpt in figure 14-23.

Route of flight: Chickasha Airport direct to Guthrie Airport

- True Airspeed (TAS)..............................115 knots
- Winds Aloft....................................360° at 10 knots
- Usable fuel...38 gallons
- Fuel Rate..8 GPH
- Deviation..+2°

STEPS IN CHARTING THE COURSE

The following is a suggested sequence for arriving at the pertinent information for the trip. As information is determined, it may be noted as illustrated in the example of a flight log in figure 14-24. Where calculations are required, the pilot may use a mathematical formula or a manual or electronic flight computer. If unfamiliar with how to use a manual or electronic computer competently, it would be advantageous to read the operation manual and work several practice problems at this point.

First draw a line from Chickasha Airport (point A) directly to Guthrie Airport (point F). The course line should begin at the center of the airport of departure and end at the center of the destination airport. If the route is direct, the course line will consist of a single straight line. If the route is not direct, it will consist of two or more straight line segments—for example, a VOR station which is off the direct route, but which will make navigating easier, may be chosen (radio navigation is discussed later in this chapter).

Appropriate checkpoints should be selected along the route and noted in some way. These should be easy-to-locate points such as large towns, large lakes and rivers, or combinations of recognizable points such as towns with an airport, towns with a network of highways, and railroads entering and departing. Normally, choose only towns indicated by splashes of yellow on the chart. Do not choose towns represented by a small circle—these may turn out to be only a half-dozen houses. (In isolated areas, however, towns represented by a small circle can be prominent checkpoints.) For this trip, four checkpoints have been selected. Checkpoint 1 consists of a tower located east of the course and can be further identified by the highway and railroad track, which almost parallels the course at this point. Checkpoint 2 is the obstruction just to the west of the course and can be further identified by Will Rogers Airport which is directly to the east. Checkpoint 3 is Wiley Post Airport, which the airplane should fly directly over. Checkpoint 4 is a private non-surfaced airport to the west of the course and can be further identified by the railroad track and highway to the east of the course.

The course and areas on either side of the planned route should be checked to determine if there is any type of airspace with which the pilot should be concerned or which has special operational requirements. For this trip, it should be noted that the course will pass through a segment of the Class C airspace surrounding Will Rogers Airport where the floor of the airspace is 2,500 feet mean sea level (MSL) and the ceiling is 5,300 feet MSL (point B). Also, there is Class D airspace from the surface to 3,800 feet MSL surrounding Wiley Post Airport (point C) during the time the control tower is in operation.

Study the terrain and obstructions along the route. This is necessary to determine the highest and lowest elevations as well as the highest obstruction to be encountered so that an appropriate altitude which will conform to part 91 regulations can be selected. If the flight is to be flown at an altitude more than 3,000 feet above the terrain, conformance to the cruising altitude appropriate to the direction of flight is required. Check the route for particularly rugged terrain so it can be avoided. Areas where a takeoff or landing will be made should be carefully checked for tall obstructions. TV transmitting towers may extend to altitudes over 1,500 feet above the surrounding terrain. It is essential that pilots be aware of their presence and location. For this trip, it should be noted that the tallest obstruction is part of a series of antennas with a height of 2,749 feet MSL (point D). The highest elevation should be located in the northeast quadrant and is 2,900 feet MSL (point E).

Since the wind is no factor and it is desirable and within the airplane's capability to fly above the Class C and D airspace to be encountered, an altitude of 5,500 feet MSL will be chosen. This altitude also gives adequate clearance of all obstructions as well as conforms to the part 91 requirement to fly at an altitude of odd thousand plus 500 feet when on a magnetic course between 0 and 179°.

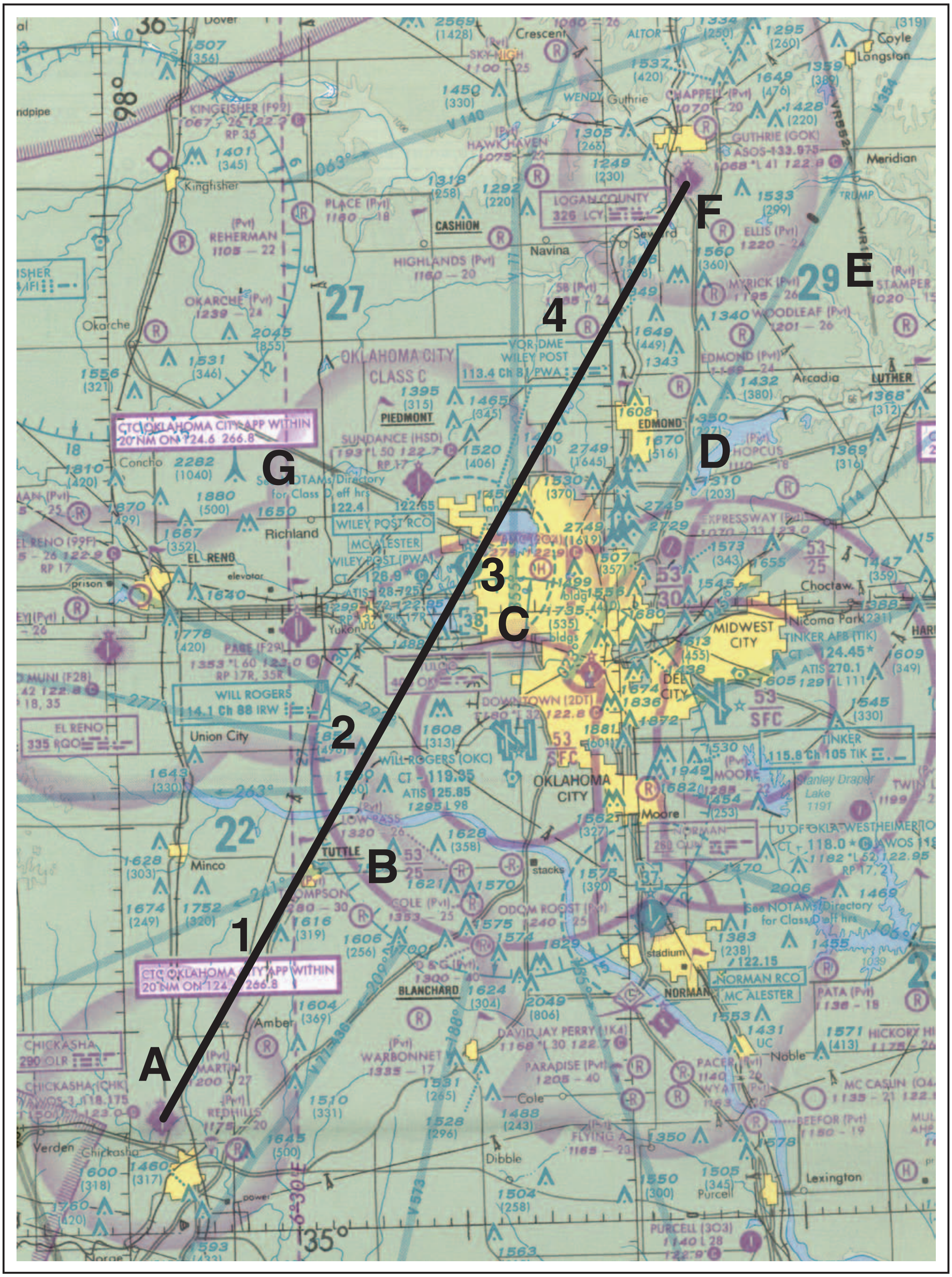


Figure 14-23. Sectional chart excerpt.

Next, the pilot should measure the total distance of the course as well as the distance between checkpoints. The total distance is 53 NM and the distance between checkpoints is as noted on the flight log in figure 14-24.

After determining the distance, the true course should be measured. If using a plotter, follow the directions on the plotter. The true course is 031°. Once the true heading is established, the pilot can determine the compass heading. This is done by following the formula given earlier in this chapter. The formula is:

TC ± WCA = TH ± VAR = MH ± DEV = CH

The wind correction angle can be determined by using a manual or electronic flight computer. Using a wind of 360° at 10 knots, it is determined the WCA is 3° left. This is subtracted from the TC making the TH 28°. Next, the pilot should locate the isogonic line closest to the route of the flight to determine variation. Point G in figure 14-23 shows the variation to be 6° 30′E (rounded to 7°E), which means it should be subtracted from the TH, giving an MH of 21°. Next, add 2° to the MH for the deviation correction. This gives the pilot the compass heading which is 23°.

Next, the groundspeed should be determined. This can be done using a manual or electronic calculator. It is determined the GS is 106 knots. Based on this information, the total trip time, as well as time between checkpoints, and the fuel burned can be determined. These calculations can be done mathematically or by using a manual or electronic calculator.

For this trip, the GS is 106 knots and the total time is 35 minutes (30 minutes plus 5 minutes for climb) with a fuel burn of 4.7 gallons. Refer to the flight log in figure 14-24 for the time between checkpoints.

As the trip progresses, the pilot can note headings and time and make adjustments in heading, groundspeed, and time.

FILING A VFR FLIGHT PLAN

Filing a flight plan is not required by regulations; however, it is a good operating practice, since the information contained in the flight plan can be used in search and rescue in the event of an emergency.

Flight plans can be filed in the air by radio, but it is best to file a flight plan either in person at the FSS or by phone just before departing. After takeoff, contact the FSS by radio and give them the takeoff time so the flight plan can be activated.

PILOT'S PLANNING SHEET

PLANE IDENTIFICATION N123DB DATE

COURSE	TC	WIND KNOTS	WIND FROM	WCA R+ L-	TH	VAR W+ E-	MH	DEV	CH	TOTAL MILES	GS	TOTAL TIME	FUEL RATE	TOTAL FUEL
From: Chickasha To: Guthrie	031°	10	360°	3° L	28	7° E	21°	+2°	23	53	106kts	35 min	8 GPH	38 gal
From: To:														

VISUAL FLIGHT LOG

TIME OF DEPARTURE	NAVIGATION AIDS	COURSE	DISTANCE	ELAPSED TIME	GS	CH	REMARKS
POINT OF DEPARTURE Chickasha Airport	NAVAID IDENT. FREQ.	TO / FROM	POINT TO POINT / CUMULATIVE	ESTIMATED / ACTUAL	ESTIMATED / ACTUAL	ESTIMATED / ACTUAL	WEATHER AIRSPACE ETC.
CHECKPOINTS #1			11 NM	6 MIN +5	106 kts	023°	
#2			10NM 21 NM	6 MIN	106 kts	023°	
#3			10.5 NM 31.5 NM	6 MIN	106 kts	023°	
#4			13 NM 44.5 NM	7 MIN	106 kts	023°	
DESTINATION Guthrie Airport			8.5 NM 53 NM	5 MIN			

Figure 14-24. Pilot's planning sheet and visual flight log.

When a VFR flight plan is filed, it will be held by the FSS until 1 hour after the proposed departure time and then canceled unless: the actual departure time is received; or a revised proposed departure time is received; or at the time of filing, the FSS is informed that the proposed departure time will be met, but actual time cannot be given because of inadequate communication. The FSS specialist who accepts the flight plan will not inform the pilot of this procedure, however.

Figure 14-25 shows the flight plan form a pilot files with the Flight Service Station. When filing a flight plan by telephone or radio, give the information in the order of the numbered spaces. This enables the FSS specialist to copy the information more efficiently. Most of the spaces are either self-explanatory or nonapplicable to the VFR flight plan (such as item 13). However, some spaces may need explanation.

Item 3 asks for the airplane type and special equipment. An example would be C-150/X, which means the airplane has no transponder. A listing of special equipment codes is listed in the *Aeronautical Information Manual* (AIM).

Item 6 asks for the proposed departure time in Universal Coordinated Time (indicated by the "Z").

Item 7 asks for the cruising altitude. Normally, "VFR" can be entered in this block, since the pilot will choose a cruising altitude to conform to FAA regulations.

Item 8 asks for the route of flight. If the flight is to be direct, enter the word "direct;" if not, enter the actual route to be followed such as via certain towns or navigation aids.

Item 10 asks for the estimated time en route. In the sample flight plan, 5 minutes was added to the total time to allow for the climb.

Item 12 asks for the fuel on board in hours and minutes. This is determined by dividing the total usable fuel aboard in gallons by the estimated rate of fuel consumption in gallons.

Remember, there is every advantage in filing a flight plan; but do not forget to close the flight plan on arrival. Do this by telephone with the nearest FSS, if possible, to avoid radio congestion.

RADIO NAVIGATION

Advances in navigational radio receivers installed in airplanes, the development of aeronautical charts which show the exact location of ground transmitting stations and their frequencies, along with refined cockpit instrumentation make it possible for pilots to navigate with precision to almost any point desired. Although precision in navigation is obtainable through the proper use of this equipment, beginning pilots should use this equipment to supplement navigation by visual reference to the ground (pilotage). This method provides the pilot with an effective safeguard against disorientation in the event of radio malfunction.

FLIGHT PLAN

1. TYPE	2. AIRCRAFT IDENTIFICATION	3. AIRCRAFT TYPE/ SPECIAL EQUIPMENT	4. TRUE AIRSPEED	5. DEPARTURE POINT	6. DEPARTURE TIME		7. CRUISING ALTITUDE
					PROPOSED (Z)	ACTUAL (Z)	
X VFR IFR DVFR	N123DB	C150/X	115 KTS	CHICKASHA AIRPORT	1400Z		5500

8. ROUTE OF FLIGHT
Chickasha direct Guthrie

9. DESTINATION (Name of airport and city)	10. EST. TIME ENROUTE		11. REMARKS
	HOURS	MINUTES	
Guthrie Airport Guthrie, OK		35	

12. FUEL ON BOARD		13. ALTERNATE AIRPORT(S)	14. PILOT'S NAME, ADDRESS & TELEPHONE NUMBER & AIRCRAFT HOME BASE	15. NUMBER ABOARD
HOURS	MINUTES			
4	45		Jane Smith Aero Air Oklahoma City, OK (405) 555-4149	1

16. COLOR OF AIRCRAFT	
Red/White	CLOSE VFR FLIGHT PLAN WITH McAlester FSS ON ARRIVAL

Figure 14-25. Flight plan form.

There are four radio navigation systems available for use for VFR navigation. These are:

VHF Omnidirectional Range (VOR)

Nondirectional Radiobeacon (NDB)

Long Range Navigation (LORAN-C)

Global Positioning System (GPS)

VERY HIGH FREQUENCY (VHF) OMNIDIRECTIONAL RANGE (VOR)

The VOR system is present in three slightly different navigation aids (NAVAIDs): VOR, VOR/DME, and VORTAC. By itself it is known as a VOR, and it provides magnetic bearing information to and from the station. When DME is also installed with a VOR, the NAVAID is referred to as a VOR/DME. When military tactical air navigation (TACAN) equipment is installed with a VOR, the NAVAID is known as a VORTAC. DME is always an integral part of a VORTAC. Regardless of the type of NAVAID utilized (VOR, VOR/DME or VORTAC), the VOR indicator behaves the same. Unless otherwise noted, in this section, VOR, VOR/DME and VORTAC NAVAIDs will all be referred to hereafter as VORs.

The word "omni" means all, and an omnidirectional range is a VHF radio transmitting ground station that projects straight line courses (radials) from the station in all directions. From a top view, it can be visualized as being similar to the spokes from the hub of a wheel. The distance VOR radials are projected depends upon the power output of the transmitter.

The course or radials projected from the station are referenced to magnetic north. Therefore, a radial is defined as a line of magnetic bearing extending outward from the VOR station. Radials are identified by numbers beginning with 001, which is 1° east of magnetic north, and progress in sequence through all the degrees of a circle until reaching 360. To aid in orientation, a compass rose reference to magnetic north is superimposed on aeronautical charts at the station location.

VOR ground stations transmit within a VHF frequency band of 108.0 – 117.95 MHz. Because the equipment is VHF, the signals transmitted are subject to line-of-sight restrictions. Therefore, its range varies in direct proportion to the altitude of receiving equipment. Generally, the reception range of the signals at an altitude of 1,000 feet above ground level (AGL) is about 40 to 45 miles. This distance increases with altitude. [Figure 14-26]

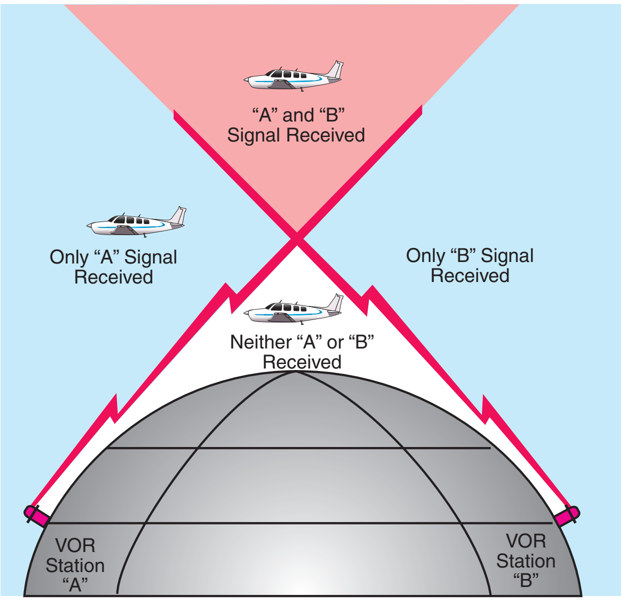


Figure 14-26. VHF transmissions follow a line-of-sight course.

VORs and VORTACs are classed according to operational use. There are three classes:

T (Terminal)

L (Low altitude)

H (High altitude)

The normal useful range for the various classes is shown in the following table:

VOR/VORTAC NAVAIDS

Normal Usable Altitudes and Radius Distances

Class	*Altitudes*	*Distance (Miles)*
T	12,000′ and below	25
L	Below 18,000′	40
H	Below 14,500′	40
H	Within the conterminous 48 states only, between 14,500 and 17,999′	100
H	18,000′ – FL 450	130
H	FL 450 – 60,000′	100

The useful range of certain facilities may be less than 50 miles. For further information concerning these restrictions, refer to the Comm/NAVAID Remarks in the *Airport/Facility Directory*.

The accuracy of course alignment of VOR radials is considered to be excellent. It is generally within plus or minus 1°. However, certain parts of the VOR receiver equipment deteriorate, and this affects its accuracy. This is particularly true at great distances from the VOR station. The best assurance of maintaining an accurate VOR receiver is periodic checks and calibrations. VOR accuracy checks are not a regulatory requirement for VFR flight. However, to assure accuracy of the equipment, these checks should be accomplished quite frequently along with a complete calibration each year. The following means are provided for pilots to check VOR accuracy:

- FAA VOR test facility (VOT);
- certified airborne checkpoints;
- certified ground checkpoints located on airport surfaces.

If dual VOR is installed in the airplane and tuned to the same VOR ground facility, the maximum permissible variation between the two indicated bearings is 4°.

A list of these checkpoints is published in the *Airport/Facility Directory*.

Basically, these checks consist of verifying that the VOR radials the airplane equipment receives are aligned with the radials the station transmits. There are not specific tolerances in VOR checks required for VFR flight. But as a guide to assure acceptable accuracy, the required IFR tolerances can be used which are ±4° for ground checks and ±6° for airborne checks. These checks can be performed by the pilot.

The VOR transmitting station can be positively identified by its Morse code identification or by a recorded voice identification which states the name of the station followed by the word "VOR." Many Flight Service Stations transmit voice messages on the same frequency that the VOR operates. Voice transmissions should not be relied upon to identify stations, because many FSSs remotely transmit over several omniranges, which have different names than the transmitting FSS. If the VOR is out of service for maintenance, the coded identification is removed and not transmitted. This serves to alert pilots that this station should not be used for navigation. VOR receivers are designed with an alarm flag to indicate when signal strength is inadequate to operate the navigational equipment. This happens if the airplane is too far from the VOR or the airplane is too low and therefore, is out of the line-of-sight of the transmitting signals.

USING THE VOR

In review, for VOR radio navigation, there are two components required: the ground transmitter and the airplane receiving equipment. The ground transmitter is located at a specific position on the ground and transmits on an assigned frequency. The airplane equipment includes a receiver with a tuning device and a VOR or omninavigation instrument. The navigation instrument consists of (1) an omnibearing selector (OBS) sometimes referred to as the course selector, (2) a course deviation indicator needle (Left-Right Needle), and (3) a TO-FROM indicator.

The course selector is an azimuth dial that can be rotated to select a desired radial or to determine the radial over which the airplane is flying. In addition, the magnetic course "TO" or "FROM" the station can be determined.

When the course selector is rotated, it moves the course deviation indicator (CDI) or needle to indicate the position of the radial relative to the airplane. If the course selector is rotated until the deviation needle is centered, the radial (magnetic course "FROM" the station) or its reciprocal (magnetic course "TO" the station) can be determined. The course deviation needle will also move to the right or left if the airplane is flown or drifting away from the radial which is set in the course selector.

By centering the needle, the course selector will indicate either the course "FROM" the station or the course "TO" the station. If the flag displays a "TO," the course shown on the course selector must be flown to the station.[Figure 14-27] If "FROM" is displayed and the course shown is followed, the airplane will be flown away from the station.

Figure 14-27. VOR indicator.

TRACKING WITH VOR

The following describes a step-by-step procedure to use when tracking to and from a VOR station. Figure 14-28 illustrates the discussion:

First, tune the VOR receiver to the frequency of the selected VOR station. For example: 115.0 to receive Bravo VOR. Next, check the identifiers to verify that the desired VOR is being received. As soon as the VOR is properly tuned, the course deviation needle will deflect either left or right; then rotate the azimuth dial to the course selector until the course deviation needle centers and the TO-FROM indicates "TO." If the needle centers with a "FROM" indication, the azimuth should be rotated 180° because, in this case, it is desired to fly "TO" the station. Now, turn the airplane to the heading indicated on the VOR azimuth dial or course selector. In this example 350°.

If a heading of 350° is maintained with a wind from the right as shown, the airplane will drift to the left of the intended track. As the airplane drifts off course, the VOR course deviation needle will gradually move to the right of center or indicate the direction of the desired radial or track.

To return to the desired radial, the airplane heading must be altered to the right. As the airplane returns to the desired track, the deviation needle will slowly return to center. When centered, the airplane will be on the desired radial and a left turn must be made toward, but not to the original heading of 350° because a wind drift correction must be established. The amount of correction depends upon the strength of the wind. If the wind velocity is unknown, a trial and error method can be used to find the correct heading. Assume, for this example, a 10° correction or a heading of 360° is maintained.

While maintaining a heading of 360°, assume that the course deviation begins to move to the left. This means that the wind correction of 10° is too great and the airplane is flying to the right of course. A slight turn to the left should be made to permit the airplane to return to the desired radial.

When the deviation needle centers, a small wind drift correction of 5° or a heading correction of 355° should be flown. If this correction is adequate, the airplane will remain on the radial. If not, small variation in heading should be made to keep the needle centered, and consequently keep the airplane on the radial.

As the VOR station is passed, the course deviation needle will fluctuate, then settle down, and the "TO" indication will change to "FROM." If the airplane passes to one side of the station, the needle will deflect in the direction of the station as the indicator changes to "FROM."

Generally, the same techniques apply when tracking outbound as those used for tracking inbound. If the intent is to fly over the station and track outbound on the reciprocal of the inbound radial, the course selector should not be changed. Corrections are made in the same manner to keep the needle centered. The only difference is that the omni will indicate "FROM."

If tracking outbound on a course other than the reciprocal of the inbound radial, this new course or radial must be set in the course selector and a turn made to intercept this course. After this course is reached, tracking procedures are the same as previously discussed.

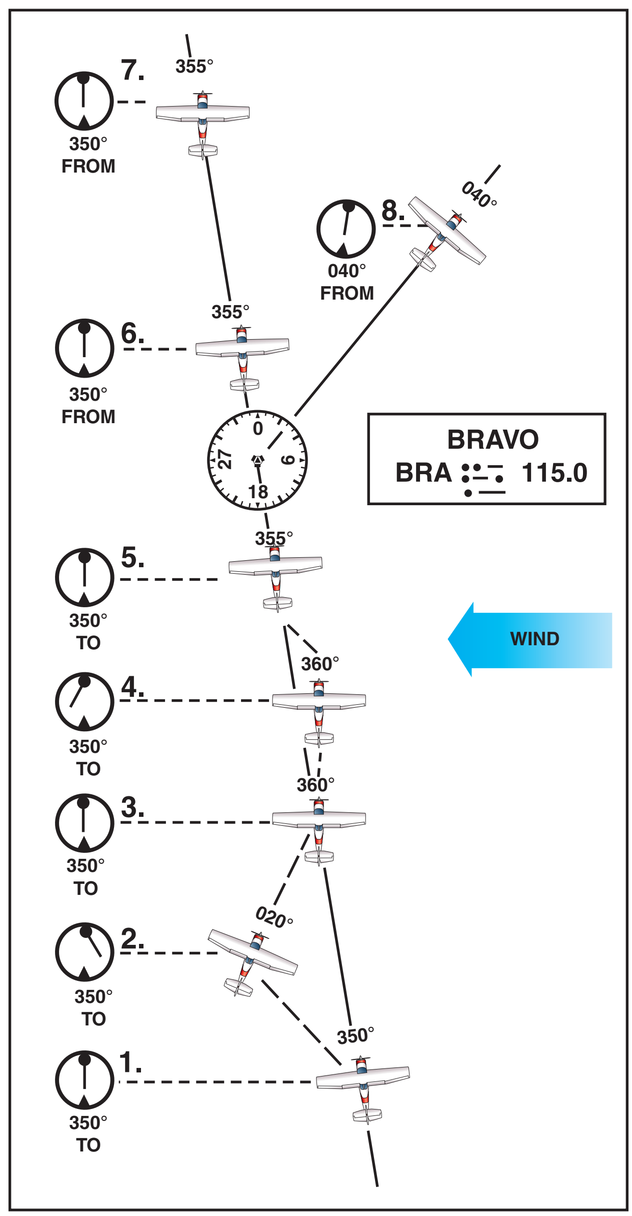


Figure 14-28. Tracking a radial in a crosswind.

TIPS ON USING THE VOR

- Positively identify the station by its code or voice identification.
- Keep in mind that VOR signals are "line-of-sight." A weak signal or no signal at all will be received if the airplane is too low or too far from the station.
- When navigating to a station, determine the inbound radial and use this radial. If the airplane drifts, do not reset the course selector, but correct for drift and fly a heading that will compensate for wind drift.
- If minor needle fluctuations occur, avoid changing headings immediately. Wait momentarily to see if the needle recenters; if it doesn't, then correct.
- When flying "TO" a station, always fly the selected course with a "TO" indication. When flying "FROM" a station, always fly the selected course with a "FROM" indication. If this is not done, the action of the course deviation needle will be reversed. To further explain this reverse action, if the airplane is flown toward a station with a "FROM" indication or away from a station with a "TO" indication, the course deviation needle will indicate in an opposite direction to that which it should. For example, if the airplane drifts to the right of a radial being flown, the needle will move to the right or point away from the radial. If the airplane drifts to the left of the radial being flown, the needle will move left or in the opposite direction of the radial.

DISTANCE MEASURING EQUIPMENT

Distance measuring equipment (DME) is an ultra high frequency (UHF) navigational aid present with VOR/DMEs and VORTACs. It measures, in nautical miles (NM), the slant range distance of an airplane from a VOR/DME or VORTAC (both hereafter referred to as a VORTAC). Although DME equipment is very popular, not all airplanes are DME equipped.

To utilize DME, the pilot should select, tune, and identify a VORTAC, as previously described. The DME receiver, utilizing what is called a "paired frequency" concept, automatically selects and tunes the UHF DME frequency associated with the VHF VORTAC frequency selected by the pilot. This process is entirely transparent to the pilot. After a brief pause, the DME display will show the slant range distance to or from the VORTAC. Slant range distance is the direct distance between the airplane and the VORTAC, and is therefore affected by airplane altitude. (Station passage directly over a VORTAC from an altitude of 6,076 feet above ground level (AGL) would show approximately 1.0 NM on the DME.) DME is a very useful adjunct to VOR navigation. A VOR radial alone merely gives line of position information. With DME, a pilot may precisely locate the airplane on that line (radial).

Most DME receivers also provide groundspeed and time-to-station modes of operation. The groundspeed is displayed in knots (NM per hour). The time-to-station mode displays the minutes remaining to VORTAC station passage, predicated upon the present groundspeed. Groundspeed and time-to-station information is only accurate when tracking directly to or from a VORTAC. DME receivers typically need a minute or two of stabilized flight directly to or from a VORTAC before displaying accurate groundspeed or time-to-station information.

Some DME installations have a hold feature that permits a DME signal to be retained from one VORTAC while the course indicator displays course deviation information from an ILS or another VORTAC.

VOR/DME RNAV

Area navigation (RNAV) permits electronic course guidance on any direct route between points established by the pilot. While RNAV is a generic term that applies to a variety of navigational aids, such as LORAN-C, GPS, and others, this section will deal with VOR/DME-based RNAV. VOR/DME RNAV is not a separate ground-based NAVAID, but a method of navigation using VOR/DME and VORTAC signals specially processed by the airplane's RNAV computer.

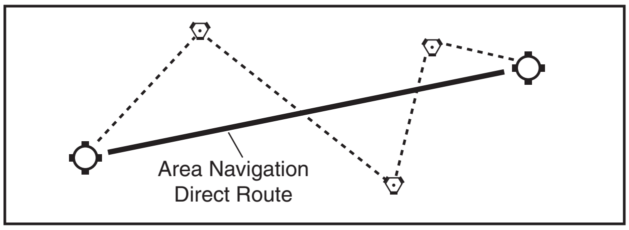


FIGURE 14-29. Flying an RNAV course.

[Figure 14-29] Note: In this section, the term "VORTAC" also includes VOR/DME NAVAIDs.

In its simplest form, VOR/DME RNAV allows the pilot to electronically move VORTACs around to more convenient locations. Once electronically relocated, they are referred to as waypoints. These waypoints are described as a combination of a selected radial and distance within the service volume of the VORTAC to be used. These waypoints allow a straight course to be flown between almost any origin and destination, without regard to the orientation of VORTACs or the existence of airways.

While the capabilities and methods of operation of VOR/DME RNAV units differ, there are basic principals of operation that are common to all. Pilots are urged to study the manufacturer's operating guide and receive instruction prior to the use of VOR/DME RNAV or any unfamiliar navigational system. Operational information and limitations should also be sought from placards and the supplement section of the Airplane Flight Manual and/or Pilot's Operating Handbook (AFM/POH).

VOR/DME-based RNAV units operate in at least three modes: VOR, En Route, and Approach. A fourth mode, VOR Parallel, may also be found on some models. The units need both VOR and DME signals to operate in any RNAV mode. If the NAVAID selected is a VOR without DME, RNAV mode will not function.

In the VOR (or non-RNAV) mode, the unit simply functions as a VOR receiver with DME capability. [Figure 14-30] The unit's display on the VOR indicator is conventional in all respects. For operation on established airways or any other ordinary VOR navigation, the VOR mode is used.

FIGURE 14-30. RNAV controls.

To utilize the unit's RNAV capability, the pilot selects and establishes a waypoint or a series of waypoints to define a course. To operate in any RNAV mode, the unit needs both radial and distance signals; therefore, a VORTAC (or VOR/DME) needs to be selected as a NAVAID. To establish a waypoint, a point somewhere within the service range of a VORTAC is defined on the basis of radial and distance. Once the waypoint is entered into the unit and the RNAV En Route mode is selected, the CDI will display course guidance to the waypoint, not the original VORTAC. DME will also display distance to the waypoint. Many units have the capability to store several waypoints, allowing them to be programmed prior to flight, if desired, and called up in flight.

RNAV waypoints are entered into the unit in magnetic bearings (radials) of degrees and tenths (i.e., 275.5°) and distances in nautical miles and tenths (i.e., 25.2 NM). When plotting RNAV waypoints on an aeronautical chart, pilots will find it difficult to measure to that level of accuracy, and in practical application, it is rarely necessary. A number of flight planning publications publish airport coordinates and waypoints with this precision and the unit will accept those figures. There is a subtle, but important difference in CDI operation and display in the RNAV modes.

In the RNAV modes, course deviation is displayed in terms of linear deviation. In the RNAV En Route mode, maximum deflection of the CDI typically represents 5 NM on either side of the selected course, without regard to distance from the waypoint. In the RNAV Approach mode, maximum deflection of the CDI typically represents $1\ ^{1}/_{4}$ NM on either side of the selected course. There is no increase in CDI sensitivity as the airplane approaches a waypoint in RNAV mode.

The RNAV Approach mode is used for instrument approaches. Its narrow scale width (one-quarter of the En Route mode) permits very precise tracking to or from the selected waypoint. In visual flight rules (VFR) cross-country navigation, tracking a course in the Approach mode is not desirable because it requires a great deal of attention and soon becomes tedious.

A fourth, lesser-used mode on some units is the VOR Parallel mode. This permits the CDI to display linear (not angular) deviation as the airplane tracks to and from VORTACs. It derives its name from permitting the pilot to offset (or parallel) a selected course or airway at a fixed distance of the pilot's choosing, if desired. The VOR Parallel mode has the same effect as placing a waypoint directly over an existing VORTAC. Some pilots select the VOR Parallel mode when utilizing the navigation (NAV) tracking function of their autopilot for smoother course following near the VORTAC.

Confusion is possible when navigating an airplane with VOR/DME-based RNAV, and it is essential that the pilot become familiar with the equipment installed. It is not unknown for pilots to operate inadvertently in one of the RNAV modes when the operation was not intended by overlooking switch positions or annunciators. The reverse has also occurred with a pilot neglecting to place the unit into one of the RNAV modes by overlooking switch positions or annunciators. As always, the prudent pilot is not only familiar with the equipment used, but never places complete reliance in just one method of navigation when others are available for cross-check.

AUTOMATIC DIRECTION FINDER

Many general aviation-type airplanes are equipped with automatic direction finder (ADF) radio receiving equipment. To navigate using the ADF, the pilot tunes the receiving equipment to a ground station known as a NONDIRECTIONAL RADIOBEACON (NDB). The NDB stations normally operate in a low or medium frequency band of 200 to 415 kHz. The frequencies are readily available on aeronautical charts or in the *Airport/Facility Directory*.

All radiobeacons except compass locators transmit a continuous three-letter identification in code except during voice transmissions. A compass locator, which is associated with an Instrument Landing System, transmits a two-letter identification.

Standard broadcast stations can also be used in conjunction with ADF. Positive identification of all radio stations is extremely important and this is particularly true when using standard broadcast stations for navigation.

Nondirectional radiobeacons have one advantage over the VOR. This advantage is that low or medium frequencies are not affected by line-of-sight. The signals follow the curvature of the Earth; therefore, if the airplane is within the range of the station, the signals can be received regardless of altitude.

The following table gives the class of NDB stations, their power, and usable range:

NONDIRECTIONAL RADIOBEACON (NDB)
(Usable Radius Distances for All Altitudes)

Class	*Power(Watts)*	*Distance (Miles)*
Compass Locator	Under 25	15
MH	Under 50	25
H	50 – 1999	*50
HH	2000 or more	75

*Service range of individual facilities may be less than 50 miles.

One of the disadvantages that should be considered when using low frequency for navigation is that low-frequency signals are very susceptible to electrical disturbances, such as lightning. These disturbances create excessive static, needle deviations, and signal fades. There may be interference from distant stations. Pilots should know the conditions under which these disturbances can occur so they can be more alert to possible interference when using the ADF.

Basically, the ADF airplane equipment consists of a tuner, which is used to set the desired station frequency, and the navigational display.

The navigational display consists of a dial upon which the azimuth is printed, and a needle which rotates around the dial and points to the station to which the receiver is tuned.

Some of the ADF dials can be rotated so as to align the azimuth with the airplane heading; others are fixed with 0° representing the nose of the airplane, and 180° representing the tail. Only the fixed azimuth dial will be discussed in this handbook. [Figure 14-31]

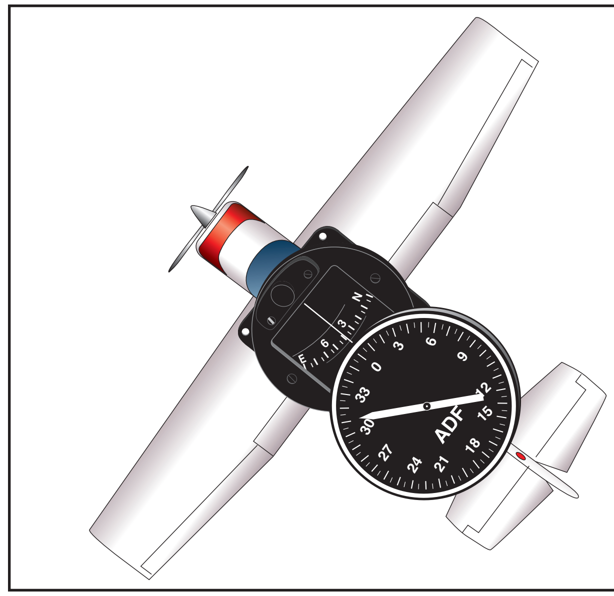


Figure 14-31. ADF with fixed azimuth and magnetic compass.

Figure 14-32 illustrates the following terms that are used with the ADF and should be understood by the pilot.

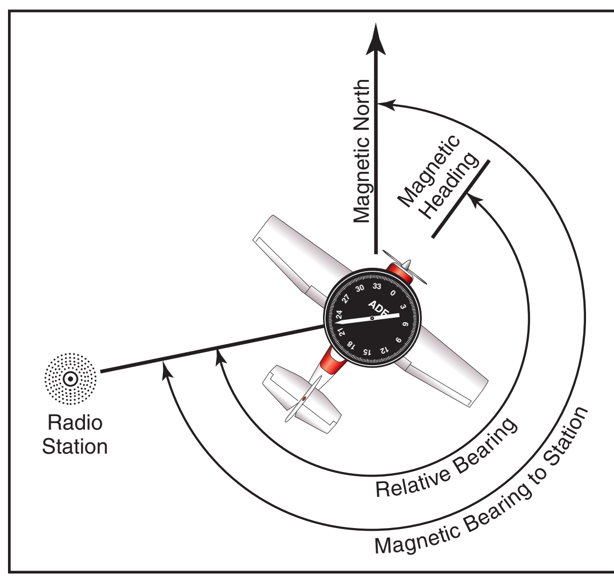


Figure 14-32. ADF terms.

Relative Bearing—is the value to which the indicator (needle) points on the azimuth dial. When using a fixed dial, this number is relative to the nose of the airplane and is the angle measured clockwise from the nose of the airplane to a line drawn from the airplane to the station.

Magnetic Bearing—"TO" the station is the angle formed by a line drawn from the airplane to the station and a line drawn from the airplane to magnetic north. The magnetic bearing to the station can be determined by adding the relative bearing to the magnetic heading of the airplane. For example, if the relative bearing is 060° and the magnetic heading is 130°, the magnetic bearing to the station is

060° plus 130° or 190°. This means that in still air a magnetic heading of approximately 190° would be flown to the station. If the total is greater than 360°, subtract 360° from the total to obtain the magnetic bearing to the station. For example, if the relative bearing is 270° and magnetic heading is 300°, 360° is subtracted from the total, or 570° – 360° = 210°, which is the magnetic bearing to the station.

To determine the magnetic bearing "FROM" the station, 180° is added to or subtracted from the magnetic bearing to the station. This is the reciprocal bearing and is used when plotting position fixes.

Keep in mind that the needle of fixed azimuth points to the station in relation to the nose of the airplane. If the needle is deflected 30° to the left or a relative bearing of 330°, this means that the station is located 30° left. If the airplane is turned left 30°, the needle will move to the right 30° and indicate a relative bearing of 0° or the airplane will be pointing toward the station. If the pilot continues flight toward the station keeping the needle on 0°, the procedure is called homing to the station. If a crosswind exists, the ADF needle will continue to drift away from zero. To keep the needle on zero, the airplane must be turned slightly resulting in a curved flightpath to the station. Homing to the station is a common procedure, but results in drifting downwind, thus lengthening the distance to the station.

Tracking to the station requires correcting for wind drift and results in maintaining flight along a straight track or bearing to the station. When the wind drift correction is established, the ADF needle will indicate the amount of correction to the right or left. For instance, if the magnetic bearing to the station is 340°, a correction for a left crosswind would result in a magnetic heading of 330°, and the ADF needle would indicate 10° to the right or a relative bearing of 010°. [Figure 14-33]

When tracking away from the station, wind corrections are made similar to tracking to the station, but the ADF needle points toward the tail of the airplane or the 180° position on the azimuth dial. Attempting to keep the ADF needle on the 180° position during winds results in the airplane flying a curved flight leading further and further from the desired track. To correct for wind when tracking outbound, correction should be made in the direction opposite of that in which the needle is pointing.

Although the ADF is not as popular as the VOR for radio navigation, with proper precautions and intelligent use, the ADF can be a valuable aid to navigation.

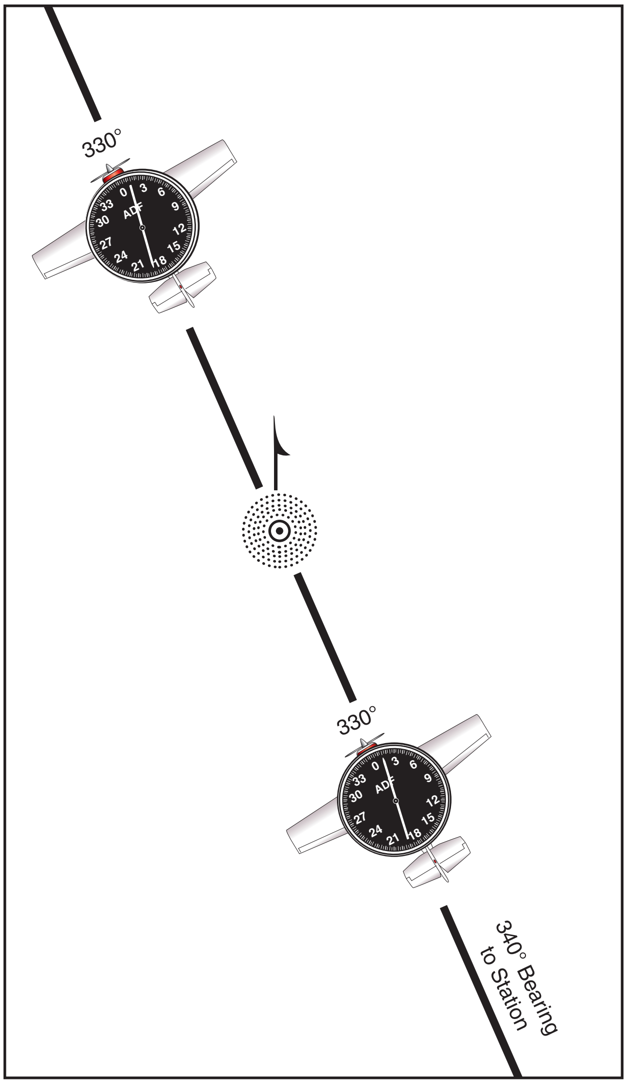


Figure 14-33. ADF tracking.

LORAN-C NAVIGATION

Long Range Navigation, version C (LORAN-C) is another form of RNAV, but one that operates from chains of transmitters broadcasting signals in the low frequency (LF) spectrum. World Aeronautical Chart (WAC), Sectional Charts, and VFR Terminal Area Charts do not show the presence of LORAN-C transmitters. Selection of a transmitter chain is either made automatically by the unit, or manually by the pilot using guidance information provided by the manufacturer. LORAN-C is a highly accurate, supplemental form of navigation typically installed as an adjunct to VOR and ADF equipment. Databases of airports, NAVAIDs, and air traffic control facilities are frequently features of LORAN-C receivers.

LORAN-C is an outgrowth of the original LORAN-A developed for navigation during World War II. The LORAN-C system is used extensively in maritime applications. It experienced a dramatic growth in popularity with pilots with the advent of the small, panel-mounted LORAN-C receivers available at relatively low cost. These units are frequently very sophisticated and capable, with a wide variety of navigational functions.

With high levels of LORAN-C sophistication and capability, a certain complexity in operation is an unfortunate necessity. Pilots are urged to read the operating handbooks and to consult the supplements section of the AFM/POH prior to utilizing LORAN-C for navigation. Many units offer so many features that the manufacturers often publish two different sets of instructions: (1) a brief operating guide and (2) in-depth operating manual.

While coverage is not global, LORAN-C signals are suitable for navigation in all of the conterminous United States, and parts of Canada and Alaska. Several foreign countries also operate their own LORAN-C systems. In the United States, the U.S. Coast Guard operates the LORAN-C system. LORAN-C system status is available from: USCG Navigation Center, Alexandria, VA (703) 313-5900.

LORAN-C absolute accuracy is excellent—position errors are typically less than .25 NM. Repeatable accuracy, or the ability to return to a waypoint previously visited, is even better. While LORAN-C is a form of RNAV, it differs significantly from VOR/DME-based RNAV. It operates in a 90 – 110 kHz frequency range and is based upon measurement of the difference in arrival times of pulses of radio frequency (RF) energy emitted by a chain of transmitters hundreds of miles apart.

Within any given chain of transmitters, there is a master station, and from three to five secondary stations. LORAN-C units must be able to receive at least a master and two secondary stations to provide navigational information. Unlike VOR/DME-based RNAV, where the pilot must select the appropriate VOR/DME or VORTAC frequency, there is not a frequency selection in LORAN-C. The most advanced units automatically select the optimum chain for navigation. Other units rely upon the pilot to select the appropriate chain with a manual entry.

After the LORAN-C receiver has been turned on, the unit must be initialized before it can be used for navigation. While this can be accomplished in flight, it is preferable to perform this task, which can take several minutes, on the ground. The methods for initialization are as varied as the number of different models of receivers. Some require pilot input during the process, such as verification or acknowledgment of the information displayed.

Most units contain databases of navigational information. Frequently, such databases contain not only airport and NAVAID locations, but also extensive airport, airspace, and ATC information. While the unit will operate with an expired database, the information should be current or verified to be correct prior to use. The pilot can update some databases, while others require removal from the airplane and the services of an avionics technician.

VFR navigation with LORAN-C can be as simple as telling the unit where the pilot wishes to go. The course guidance provided will be a great circle (shortest distance) route to the destination. Older units may need a destination entered in terms of latitude and longitude, but recent designs only need the identifier of the airport or NAVAID. The unit will also permit database storage and retrieval of pilot defined waypoints. LORAN-C signals follow the curvature of the Earth and are generally usable hundreds of miles from their transmitters.

The LORAN-C signal is subject to degradation from a variety of atmospheric disturbances. It is also susceptible to interference from static electricity buildup on the airframe and electrically "noisy" airframe equipment. Flight in precipitation or even dust clouds can cause occasional interference with navigational guidance from LORAN-C signals. To minimize these effects, static wicks and bonding straps should be installed and properly maintained.

LORAN-C navigation information is presented to the pilot in a variety of ways. All units have self-contained displays, and some elaborate units feature built-in moving map displays. Some installations can also drive an external moving map display, a conventional VOR indicator, or a horizontal situation indicator (HSI). Course deviation information is presented as a linear deviation from course—there is no increase in tracking sensitivity as the airplane approaches the waypoint or destination. Pilots must carefully observe placards, selector switch positions, and annunciator indications when utilizing LORAN-C because airplane installations can vary widely. The pilot's familiarity with unit operation through AFM/POH supplements and operating guides cannot be overemphasized.

LORAN-C *Notices To Airmen* (NOTAMs) should be reviewed prior to relying on LORAN-C for navigation. LORAN-C NOTAMs will be issued to announce outages for specific chains and transmitters. Pilots may obtain LORAN-C NOTAMs from FSS briefers only upon request.

The prudent pilot will never rely solely on one means of navigation when others are available for backup and cross-check. Pilots should never become so dependent upon the extensive capabilities of LORAN-C that other methods of navigation are neglected.

GLOBAL POSITIONING SYSTEM

The global positioning system (GPS) is a satellite-based radio navigation system. Its RNAV guidance is worldwide in scope. There are no symbols for GPS on aeronautical charts as it is a space-based system with global coverage. Development of the system is underway so that GPS will be capable of providing the primary means of electronic navigation. Portable and yoke mounted units are proving to be very popular in addition to those permanently installed in the airplane. Extensive navigation databases are common features in airplane GPS receivers.

The GPS is a satellite radio navigation and time dissemination system developed and operated by the U.S. Department of Defense (DOD). Civilian interface and GPS system status is available from the U.S. Coast Guard.

It is not necessary to understand the technical aspects of GPS operation to use it in VFR/instrument flight rules (IFR) navigation. It does differ significantly from conventional, ground-based electronic navigation, and awareness of those differences is important. Awareness of equipment approvals and limitations is critical to the safety of flight. The GPS system is composed of three major elements:

1. The space segment is composed of a constellation of 26 satellites orbiting approximately 10,900 NM above the Earth. The operational satellites are often referred to as the GPS constellation. The satellites are not geosynchronous but instead orbit the Earth in periods of approximately 12 hours. Each satellite is equipped with highly stable atomic clocks and transmits a unique code and navigation message. Transmitting in the UHF range means that the signals are virtually unaffected by weather although they are subject to line-of-sight limitations. The satellites must be above the horizon (as seen by the receiver's antenna) to be usable for navigation.

2. The control segment consists of a master control station at Falcon AFB, Colorado Springs, CO, five monitor stations, and three ground antennas. The monitor stations and ground antennas are distributed around the Earth to allow continual monitoring and communications with the satellites. Updates and corrections to the navigational message broadcast by each satellite are uplinked to the satellites as they pass over the ground antennas.

3. The user segment consists of all components associated with the GPS receiver, ranging from portable, hand-held receivers to receivers permanently installed in the airplane. The receiver matches the satellite's coded signal by shifting its own identical code in a matching process to precisely measure the time of arrival. Knowing the speed the signal traveled (approximately 186,000 miles per second) and the exact broadcast time, the distance traveled by the signal can be inferred from its arrival time.

To solve for its location, the GPS receiver utilizes the signals of at least four of the best-positioned satellites to yield a three-dimensional fix (latitude, longitude, and altitude). A two-dimensional fix (latitude and longitude only) can be determined with as few as three satellites. GPS receivers have extensive databases. Databases are provided initially by the receiver manufacturer and updated by the manufacturer or a designated data agency.

A wide variety of GPS receivers with extensive navigation capabilities are available. Panel mounted units permanently installed in the airplane may be used for VFR and may also have certain IFR approvals. Portable hand-held and yoke mounted GPS receivers are also popular, although these are limited to VFR use. Not all GPS receivers on the market are suited for air navigation. Marine, recreational, and surveying units, for example, are not suitable for airplane use. As with LORAN-C receivers, GPS unit features and operating procedures vary widely. The pilot must be familiar with the manufacturer's operating guide. Placards, switch positions, and annunciators should be carefully observed.

Initialization of the unit will require several minutes and should be accomplished prior to flight. If the unit has not been operated for several months or if it has been moved to a significantly different location (by several hundred miles) while off, this may require several additional minutes. During initialization, the unit will make internal integrity checks, acquire satellite signals, and display the database revision date. While the unit will operate with an expired database, the database should be current, or verified to be correct, prior to relying on it for navigation.

VFR navigation with GPS can be as simple as selecting a destination (an airport, VOR, NDB, intersection, or pilot defined waypoint) and placing the unit in the navigation mode. Course guidance provided will be a great circle route (shortest distance) direct to the destination. Many units provide advisory information about special use airspace and minimum safe altitudes, along with extensive airport data, and ATC services and frequencies. Users having prior experience with LORAN-C receivers will note many similarities in the wealth of navigation information available, although the technical principles of operation are quite different.

All GPS receivers have integral (built into the unit) navigation displays and some feature integral moving map displays. Some panel-mounted units will drive a VOR indicator, HSI, or even an external moving map display. GPS course deviation is linear—there is not an increase in tracking sensitivity as the airplane approaches a waypoint. Pilots must carefully observe placards, selector switch positions, and annunciator indications when utilizing GPS as installations and approvals can vary widely.

The integral GPS navigation display (like most LORAN-C units) uses several additional navigational terms beyond those used in NDB and VOR navigation. Some of these terms, whose abbreviations vary among manufacturers, are shown below. The pilot should consult the manufacturer's operating guide for specific definitions.

NOTAMs should be reviewed prior to relying on GPS for navigation. GPS NOTAMs will be issued to announce outages for specific GPS satellites by pseudorandom noise code (PRN) and satellite vehicle number (SVN). Pilots may obtain GPS NOTAMs from FSS briefers only upon request.

When using any sophisticated and highly capable navigation system, such as LORAN-C or GPS, there is a strong temptation to rely almost exclusively on that unit, to the detriment of using other techniques of position keeping. The prudent pilot will never rely on one means of navigation when others are available for cross-check and backup.

LOST PROCEDURES

Getting lost in an airplane is a potentially dangerous situation especially when low on fuel. If a pilot becomes lost, there are some good common sense procedures to follow. If a town or city cannot be seen, the first thing to do is climb, being mindful of traffic and weather conditions. An increase in altitude increases radio and navigation reception range, and also increases radar coverage. If flying near a town or city, it might be possible to read the name of the town on a water tower.

If the airplane has a navigational radio, such as a VOR or ADF receiver, it can be possible to determine position by plotting an azimuth from two or more navigational facilities. If GPS is installed, or a pilot has a portable aviation GPS on board, it can be used to determine the position and the location of the nearest airport.

Communicate with any available facility using frequencies shown on the sectional chart. If contact is made with a controller, radar vectors may be offered. Other facilities may offer direction finding (DF) assistance. To use this procedure, the controller will request the pilot to hold down the transmit button for a few seconds and then release it. The controller may ask the pilot to change directions a few times and repeat the transmit procedure. This gives the controller enough information to plot the airplane position and then give vectors to a suitable landing site. If the situation becomes threatening, transmit the situation on the emergency frequency 121.5 MHz and set the transponder to 7700. Most facilities, and even airliners, monitor the emergency frequency.

FLIGHT DIVERSION

There will probably come a time when a pilot will not be able to make it to the planned destination. This can be the result of unpredicted weather conditions, a system malfunction, or poor preflight planning. In any case, the pilot will need to be able to safely and efficiently divert to an alternate destination. Before any cross-country flight, check the charts for airports or suitable landing areas along or near the route of flight. Also, check for navigational aids that can be used during a diversion.

Computing course, time, speed, and distance information in flight requires the same computations used during preflight planning. However, because of the limited cockpit space, and because attention must be divided between flying the airplane, making calculations, and scanning for other airplanes, take advantage of all possible shortcuts and rule-of-thumb computations.

When in flight, it is rarely practical to actually plot a course on a sectional chart and mark checkpoints and distances. Furthermore, because an alternate airport is usually not very far from your original course, actual plotting is seldom necessary.

A course to an alternate can be measured accurately with a protractor or plotter, but can also be measured with reasonable accuracy using a straightedge and the compass rose depicted around VOR stations. This approximation can be made on the basis of a radial from a nearby VOR or an airway that closely parallels the course to your alternate. However, remember that the magnetic heading associated with a VOR radial or printed airway is outbound from the station. To find the course TO the station, it may be necessary to determine the reciprocal of that heading. It is typically easier to navigate to an alternate airport that has a VOR or NDB facility on the field.

After selecting the most appropriate alternate, approximate the magnetic course to the alternate using a compass rose or airway on the sectional chart. If time permits, try to start the diversion over a prominent ground feature. However, in an emergency, divert promptly toward your alternate. To complete all plotting, measuring, and computations involved before diverting to the alternate may only aggravate an actual emergency.

Once established on course, note the time, and then use the winds aloft nearest to your diversion point to calculate a heading and groundspeed. Once a groundspeed has been calculated, determine a new arrival time and fuel consumption. Give priority to flying the airplane while dividing attention between navigation and planning. When determining an altitude to use while diverting, consider cloud heights, winds, terrain, and radio reception.