Fuel Consumption

Aircraft 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 GS of 100 knots requires 4 hours. If an aircraft consumes 5 gallons an hour, the total consumption is 4 x 5, or 20 gallons.

The rate of fuel consumption depends on many factors: condition of the engine, propeller/rotor pitch, propeller/rotor revolutions per minute (rpm), 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 use a mechanical or electronic flight computer. These devices can compute numerous problems associated with flight planning and navigation. The mechanical or electronic computer has an instruction book that probably includes sample problems so the pilot can become familiar with its functions and operation. *[Figure 15-18]*

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 NM and SM and has a scale for a sectional chart on one side and a world aeronautical chart on the other. *[Figure 15-18]*

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 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 SM or 6.86 NM. For example, if a checkpoint selected was approximately one-half inch from the course line on the chart, it is 4 SM or 3.43 NM 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 is 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 wind speed and velocity, are heading and GS. The predicted heading takes the aircraft along the intended path and the GS establishes 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 GS 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 aircraft's ground track is the same as the heading and the GS is 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. GS, 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
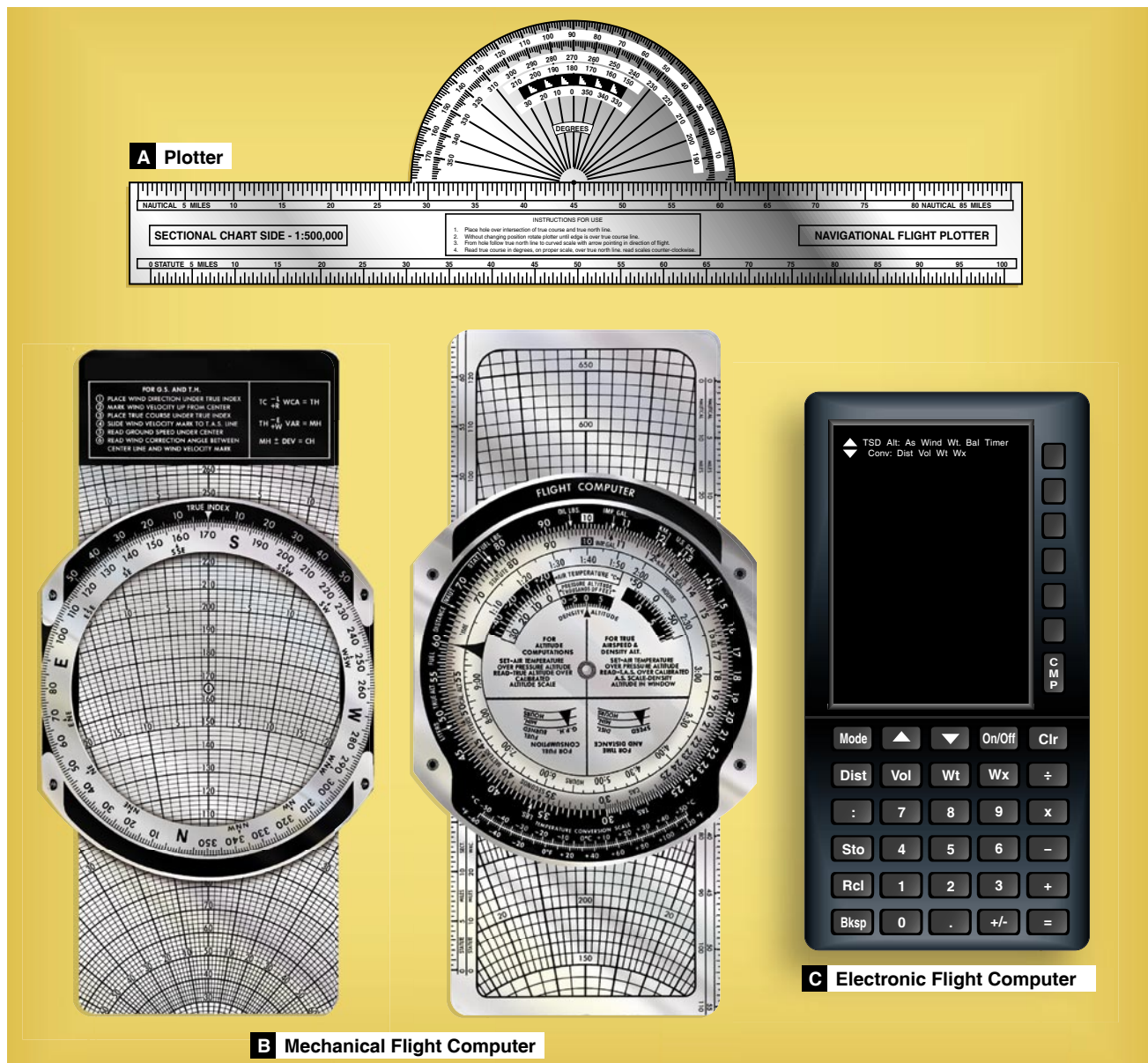
Figure 15-18. *A plotter (A), the computational and wind side of a mechanical flight computer (B), and an electronic flight computer (C).*

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 flight is to be made on a course to the east, with a wind blowing from the northeast, the aircraft must be headed somewhat to the north of east to counteract drift. This can be represented by a diagram as shown in *Figure 15-19.* Each line represents direction and speed. The long blue and white hashed line shows the direction the aircraft is heading, and its length represents the distance the airspeed for 1 hour. The short blue arrow at the right shows the wind direction, and its length represents the wind velocity for 1 hour. The solid

yellow line shows the direction of the track or the path of the aircraft as measured over the earth, and its length represents the distance traveled in 1 hour, or the GS.

In actual practice, the triangle illustrated in *Figure 15-19* is not drawn; instead, construct a similar triangle as shown by the blue, yellow, and black lines in *Figure 15-20,* which is explained in the following example.

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 NWS, it is learned that
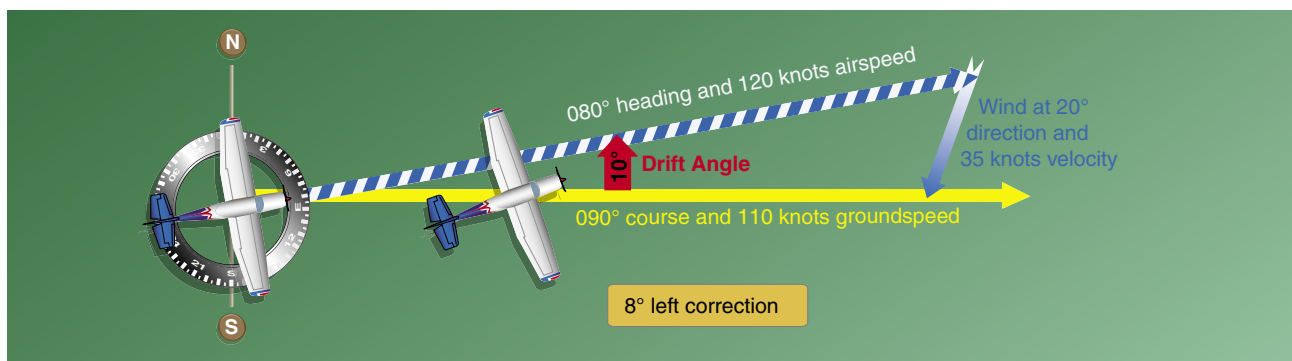
Figure 15-19. *Principle of the wind triangle.*
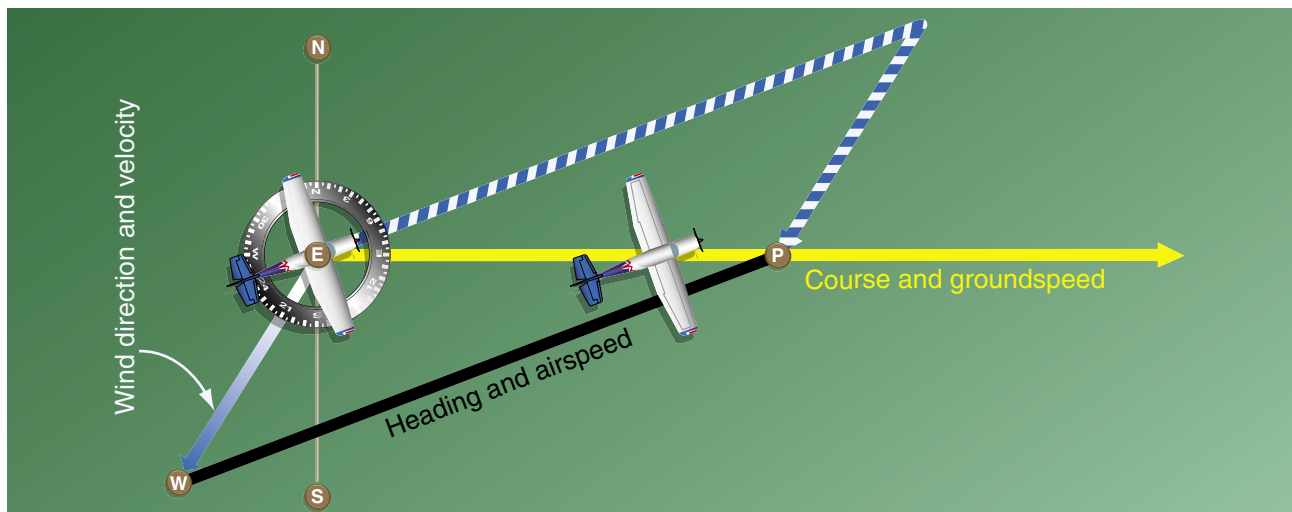
Figure 15-20. *The wind triangle as is drawn in navigation practice.*

the wind at the altitude of the intended flight is 40 knots from the northeast (045°). Since the NWS reports the wind speed in knots, if the true airspeed of the aircraft is 120 knots, there is no need to convert speeds from knots to mph or vice versa.

Now, on a plain sheet of paper draw a vertical line representing north to south. (The various steps are shown in *Figure 15-21*.)

Step 1

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).

Step 2

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

Step 3

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.

Step 4

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 ¼ 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 aircraft at the end of 1 hour. The diagram is now complete.
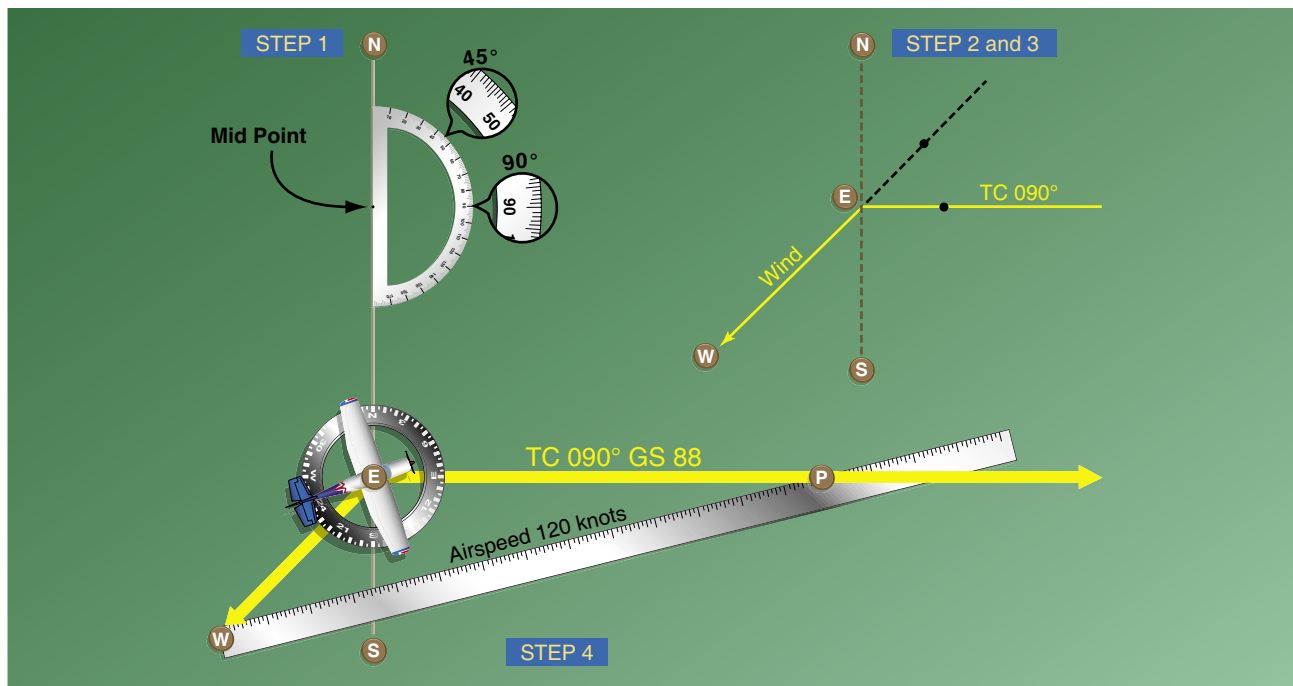
Figure 15-21. *Steps in drawing the wind triangle.*

The distance flown in 1 hour (GS) is measured as the numbers of units on the true course line (88 NMPH, 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 15-22]*

• 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 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 is added; if from the left, it is 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 15-23]*
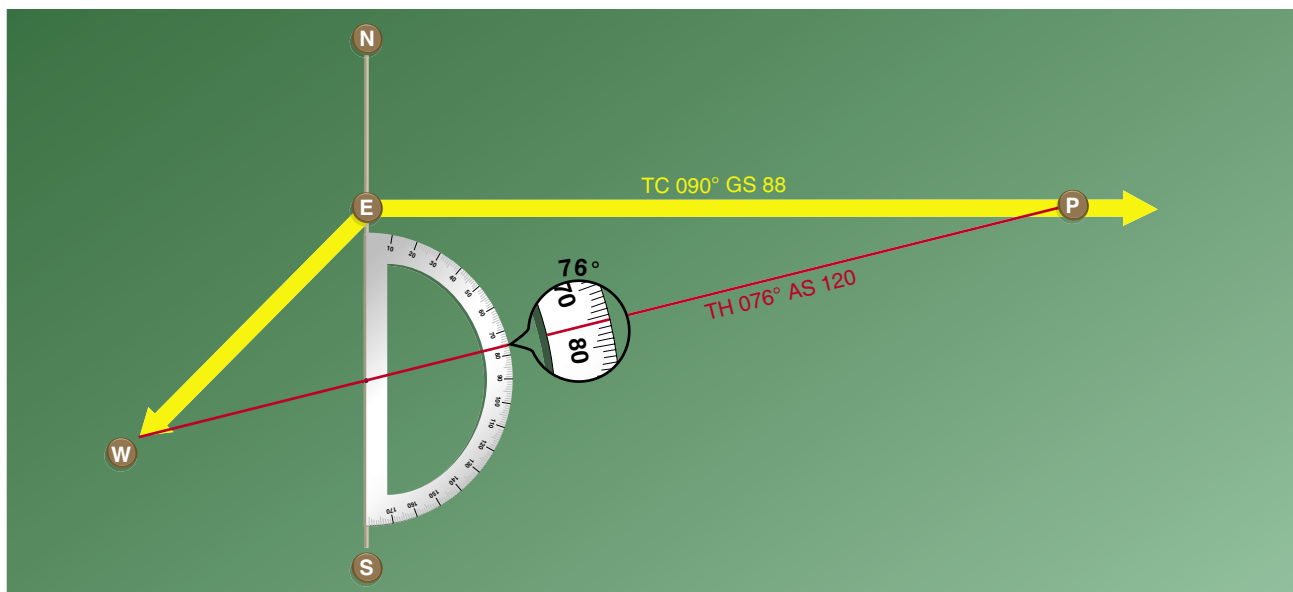
Figure 15-22. *Finding true heading by the wind correction angle.*
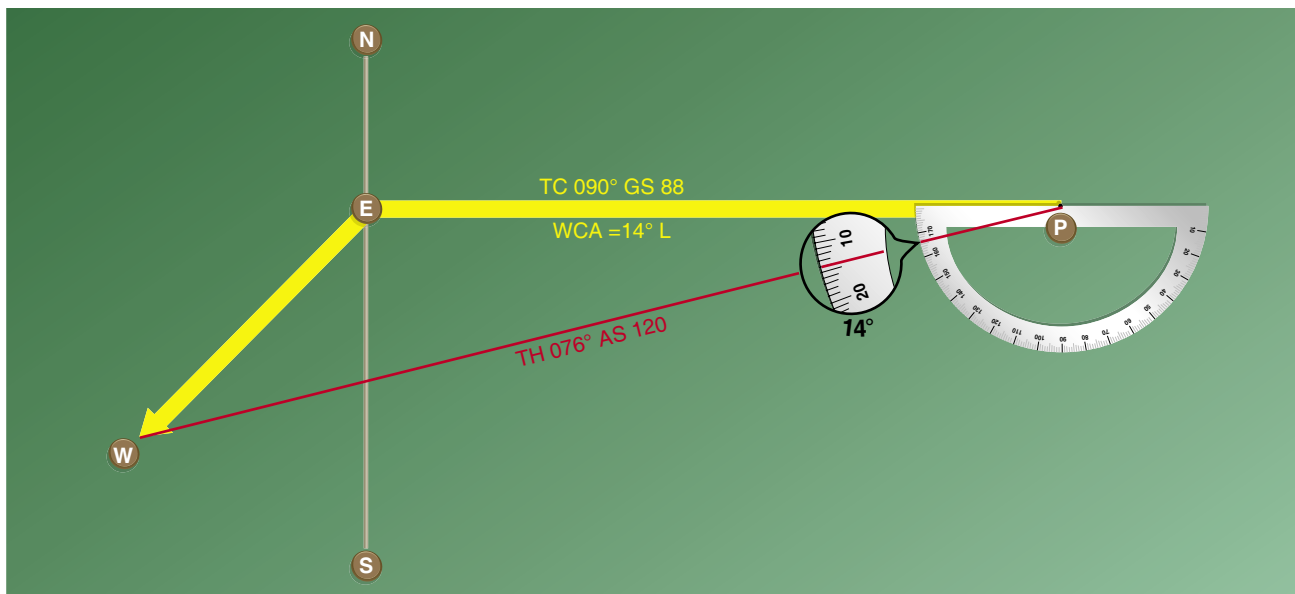
Figure 15-23. *Finding true heading by direct measurement.*

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 GS 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 is used. Briefly summarized, the steps in obtaining flight information are as follows:

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

- WCA—determined from the wind triangle. (Added to TC if the wind is from the right; subtracted if wind is from the left).

- TH—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; subtracted if east).

- MH—an intermediate step in the conversion (obtained by applying variation to true heading).

- Deviation—obtained from the deviation card on the aircraft (added to MH or subtracted from, as indicated).

- Compass heading—reading on the compass (found by applying deviation to MH) which is 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).

- GS—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 GS.

- 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 (PIC) 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 ATC.

Assembling Necessary Material

The pilot should collect the necessary material well before the flight. An appropriate current sectional chart and charts for