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
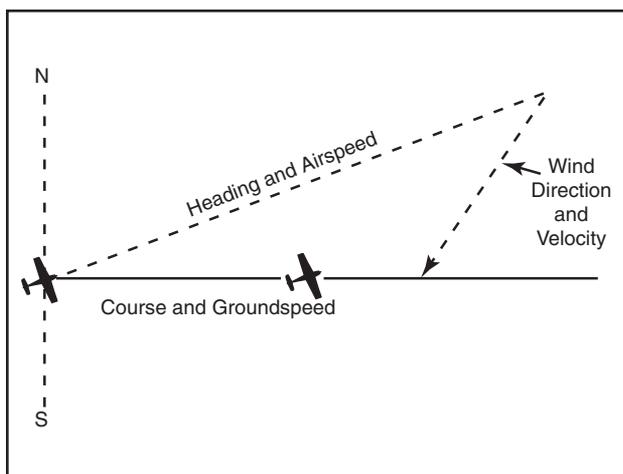

Figure 14-17. Principle of the wind triangle.

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.
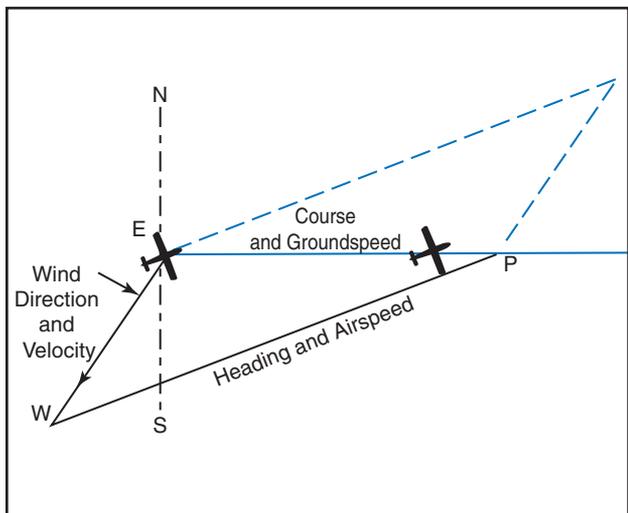

Figure 14-18. The wind triangle as is drawn in navigation practice. Dashed lines show the triangle as drawn in figure 14-17.

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°."
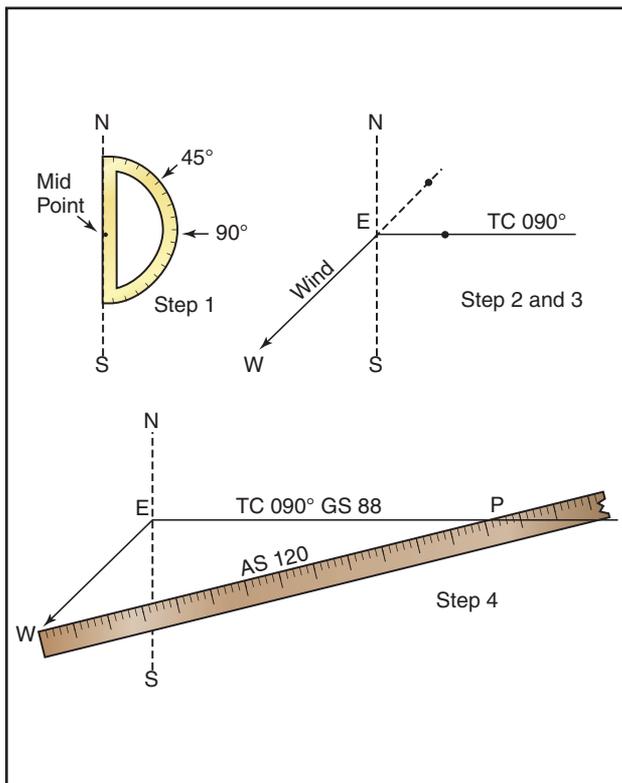

Figure 14-19. Steps in drawing the wind triangle.

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

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the intersection of the airspeed line and north-south line, read the true heading directly in degrees (076°). [Figure 14-20]
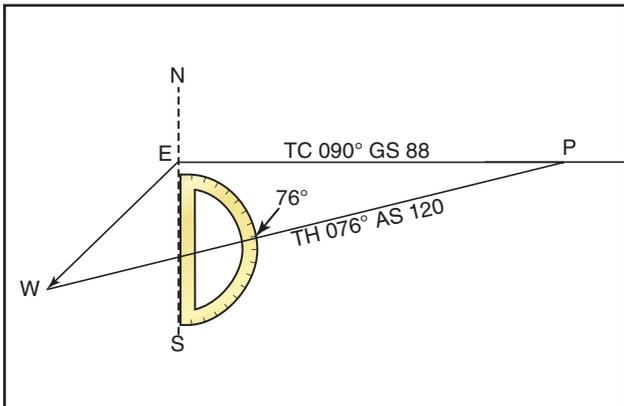

Figure 14-20. Finding true heading by direct measurement.

• 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]
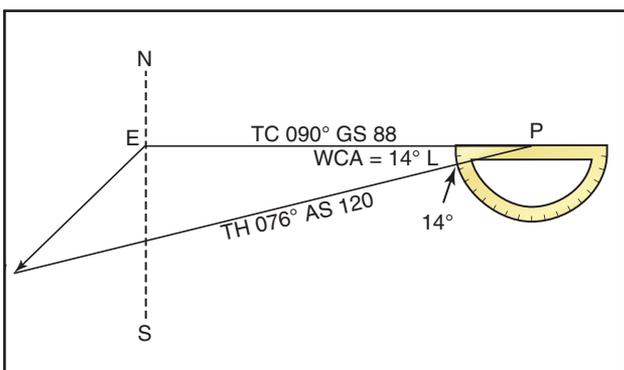

Figure 14-21. Finding true heading by the wind correction angle.

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.