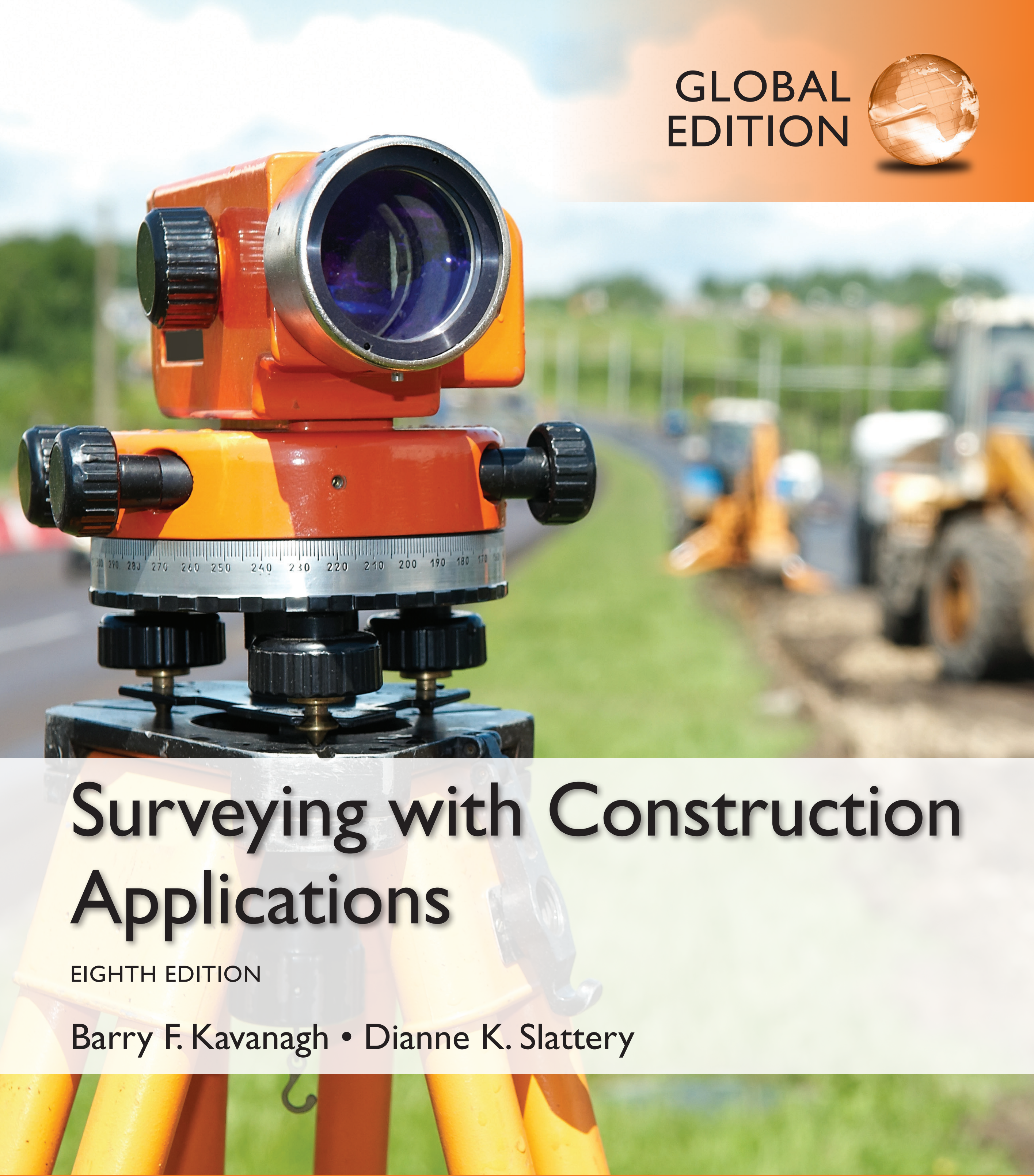


GLOBAL EDITION

Surveying with Construction Applications

EIGHTH EDITION

Barry F. Kavanagh • Dianne K. Slattery

ALWAYS LEARNING

PEARSON

EIGHTH EDITION

Surveying with Construction Applications

Global Edition

Barry F. Kavanagh, B.A., CET
Seneca College, Emeritus

Dianne K. Slattery, Ph.D., P.E.
Missouri State University

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

CHAPTER
EIGHT

TRAVERSE SURVEYS AND COMPUTATIONS

8.1 GENERAL BACKGROUND

A traverse is a form of control survey used in a wide variety of engineering and property surveys. Essentially, **traverses** are a series of established stations tied together by angle and distance. Angles are measured by theodolites or total stations; the distances can be measured by electronic distance measurement (EDM) instruments or by steel tapes. Traverses can be open, as in route surveys, or closed, as in closed geometric figures (Figures 8.1 and 8.2).

Traverse computations are used to do the following: balance field angles, compute latitudes and departures, compute traverse error, balance latitudes and departures, adjust original distances and directions, compute coordinates of the traverse stations, and compute the area enclosed by a closed traverse. In modern practice, these computations are routinely performed on computers and/or on some total stations—or their electronic field books/data collectors (Chapter 7). In this chapter, we will perform traverse computations manually (using calculators) to demonstrate and reinforce the mathematical concepts underlying each stage of these computations.

In engineering work, traverses are used as control surveys (1) to locate topographic detail for the preparation of plans, (2) to lay out (locate) engineering works, and (3) for the processing and ordering of earthwork and other engineering quantities. Traverses can also help provide horizontal control for aerial surveys in the preparation of photogrammetric mapping (Chapter 10).

8.1.1 Open Traverse

An open traverse (Figure 8.1) is particularly useful as a control for preliminary and construction surveys for roads, pipelines, electricity transmission lines, and the like. These surveys may be from a few hundred feet (meters) to many miles (kilometers) in length. The distances are normally measured by using EDM (sometimes, by using steel tapes). Each time the survey line changes direction, a deflection angle is measured with a theodolite or total station. **Deflection angles** are measured from the prolongation of the back line to the forward line (Figure 8.1); the angles are measured either to the right or to the left (L or R)—with the surveyor's back to 0 + 00, and the direction (L or R) is shown in the field notes, along with the numerical values. Angles are measured at least twice (See Section 6.6.1 for measuring angles by repetition) to eliminate mistakes and to improve accuracy. The distances are shown in the form of stations (chainages), which

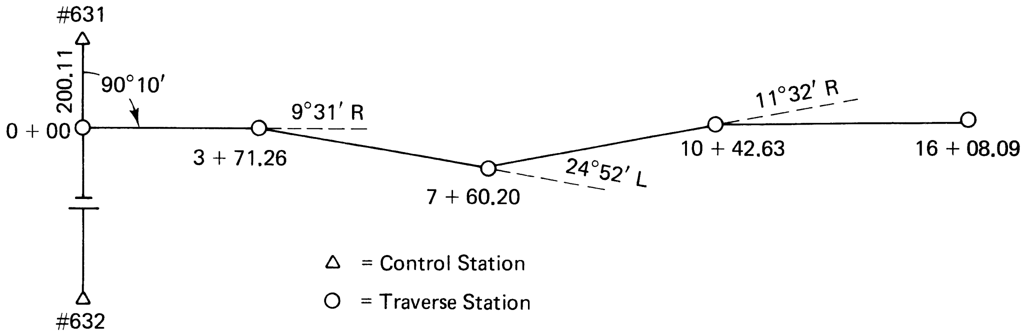


FIGURE 8.1 Open traverse.

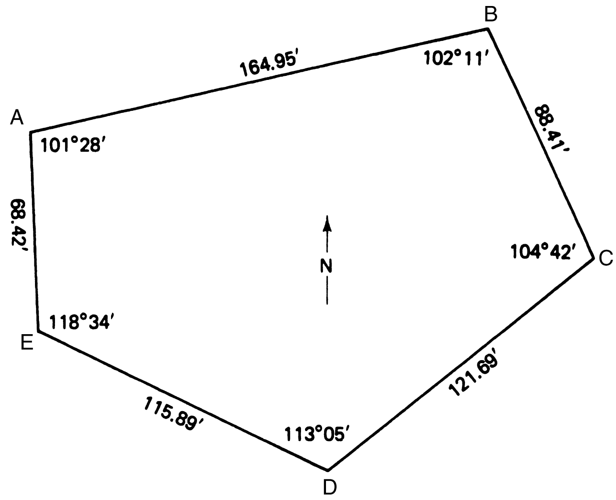


FIGURE 8.2 Closed traverse (loop).

are cumulative measurements referenced to the initial point of the survey, 0 + 00. See Figure 8.3 for typical field notes for a route survey.

Open traverses may extend for long distances without the opportunity for checking the accuracy of the ongoing work. Thus, all survey measurements are repeated carefully at the time of the work, and every opportunity for checking for position and direction is utilized (adjacent property surveys and intersecting road and railroad rights-of-way are checked when practical). Global Positioning System (GPS) surveying techniques are also used to determine and verify traverse station positioning.

Many states and provinces are now providing densely placed control monuments as an extension to their coordinate grid systems. It is now possible to tie in the initial and terminal survey stations of a route survey to coordinate control monuments. Because the *Y* and *X* (and *Z*) coordinates of these monuments have been precisely determined, the route survey changes from an open traverse to a closed traverse and is then subject to geometric verification and analysis (Sections 8.6 through 8.12).

PRELIMINARY SURVEY FOR CLEAR LAKE
ACCESS ROAD—TOMLIN TOWNSHIP

Job CLEAR 68° F
Date MAY 18, 2014 Page 14

STATION	DIRECT	DOUBLE	MEAN	L/R	
0+00	90° 11'	180° 20'	90° 10'	SEE SKETCH.	
	DEFLECTION ANGLES				
3+71.26	9° 31'	19° 02'	9° 31'	R	
7+60.20	24° 51'	49° 44'	24° 52'	L	
10+42.63	11° 32'	23° 04'	11° 32'	R	
		CHAINAGES			
	DIRECT	REVERSE	MEAN		CHAINAGES
					0+00.00
	371.24	371.28	371.26		3+71.26
	388.93	~~388.80~~			
		388.95	388.94		7+60.20
	282.43	282.43	282.43		10+42.63
	565.44	565.49	565.46		16+08.09
			1608.09		

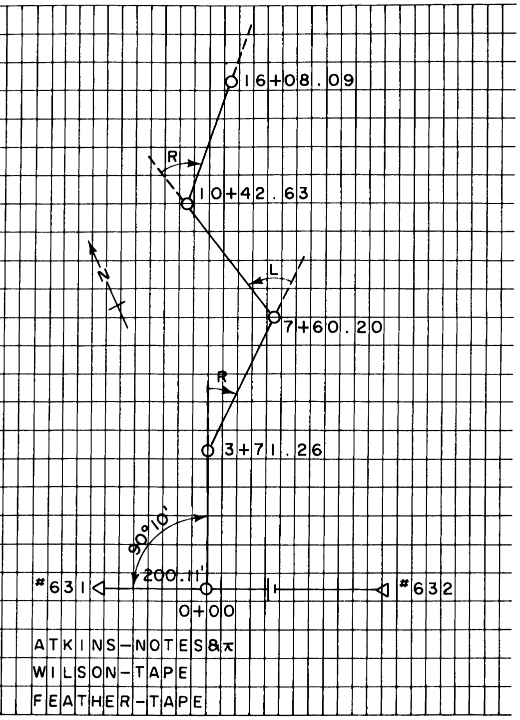


FIGURE 8.3 Field notes for open traverse. (*Note:* The terms *chainages* and *stations* are interchangeable.)

8.1.2 Closed Traverse

A closed traverse either begins and ends at the same point or begins and ends at points whose positions have been previously determined (as described above). In both cases, the angles can be closed geometrically, and the position closure can be determined mathematically. A closed traverse that begins and ends at the same point is called a loop traverse (Figure 8.2). In this case, the distances are measured from one station to the next and verified, using a steel tape or EDM instrument. The interior angle is measured at each station, and each angle is measured at least twice. Figure 8.4 illustrates typical field notes for a loop traverse survey. In this type of survey, distances are booked simply as dimensions, not as stations or chainages.

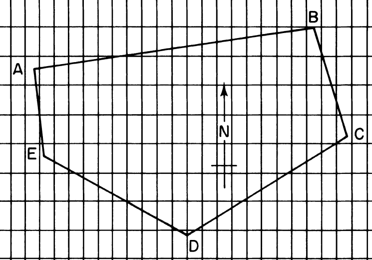
8.2 BALANCING FIELD ANGLES

For a closed polygon of n sides, the sum of the interior angles is $(n - 2)180°$. In Figure 8.2, the interior angles of a five-sided polygon have been measured as shown in the field notes in Figure 8.4. For a five-sided closed figure, the sum of the interior angles must be $(5 - 2)180° = 540°$. You can see in Figure 8.4 that the interior angles add to 540°01′—an excess of one minute.

Job NEWNHAM CAMPUS CONTROL SURVEY
Date .... Page ....

Job CLEAR 68° F
Date MAR 3 2014 Page 28

DISTANCES					
	COURSE	FORWARD	REVERSE	MEAN	
	AB	100.00	100.00		
		64.94	64.96		
		164.94	164.96	164.95	
	BC	88.41	88.41	88.41	
	CD	100.00	100.00		
		21.70	21.68		
		121.70	121.68	121.69	
	DE	100.00	100.00		
		15.88	15.90		
		115.88	115.90	115.89	
	EA	68.42	~~68.57~~		
			68.42	68.42	
ANGLES					
	STATION	DIRECT	DOUBLE	MEAN	
	A	101° 28'	202° 56'	101° 28'	
	B	102° 11'	204° 23'	102° 11'	30"
	C	104° 42'	209° 24'	104° 42'	
	D	113° 05'	226° 11'	113° 05'	30"
	E	118° 34'	237° 08'	118° 34'	
				538° 120'	60"
				= 540°	01'



L. CROCKER – NOTES, TAPE
K. SINGH – INSTRUMENT
D. JANCIE – TAPE

FIGURE 8.4 Field notes for closed traverse.

Before mathematical analysis can begin—that is, before the bearings or azimuths can be computed—the field angles must be adjusted so that their sum exactly equals the correct geometric total. The angles can be balanced by distributing the error evenly to each angle, or one or more angles can be arbitrarily adjusted to force the closure. The total allowable error of angular closure is quite small (Chapter 11); if the field results exceed the allowable error, the survey must be repeated.

The angles for the traverse in Figure 8.4 are shown in Table 8.1. Also shown are the results of equally balanced angles and arbitrarily balanced angles. The angles can be arbitrarily balanced if the required precision will not be affected or if one or two setups are suspect (e.g., due to unstable ground, or very short sightings).

8.3 MERIDIANS

A line on the surface of the Earth joining the north and south poles is called a geographic, astronomic, or "true" meridian. Figure 8.5 illustrates that **geographic meridian** is another term for a line of longitude. The figure also illustrates that all geographic meridians converge at the poles. **Grid meridians** are lines that are parallel to a grid reference meridian (a central meridian; see Figure 8.5). Rectangular coordinate grids are discussed further in Chapter 11. **Magnetic meridians** are lines parallel to the directions taken by freely moving

TABLE 8.1 Two methods of adjusting field angles

Station	Field Angle	Arbitrarily Balanced	Equally Balanced
A	101°28′	101°28′	101°27′48″
B	102°11′30″	102°11′	102°11′18″
C	104°42′	104°42′	104°41′48″
D	113°05′30″	113°05′	113°05′18″
E	118°34′	118°34′	118°33′48″
	= 538°120′60″	= 538°120′	= 538°117′180″
	= 540°01′00″	= 540°00′	= 540°00′00″

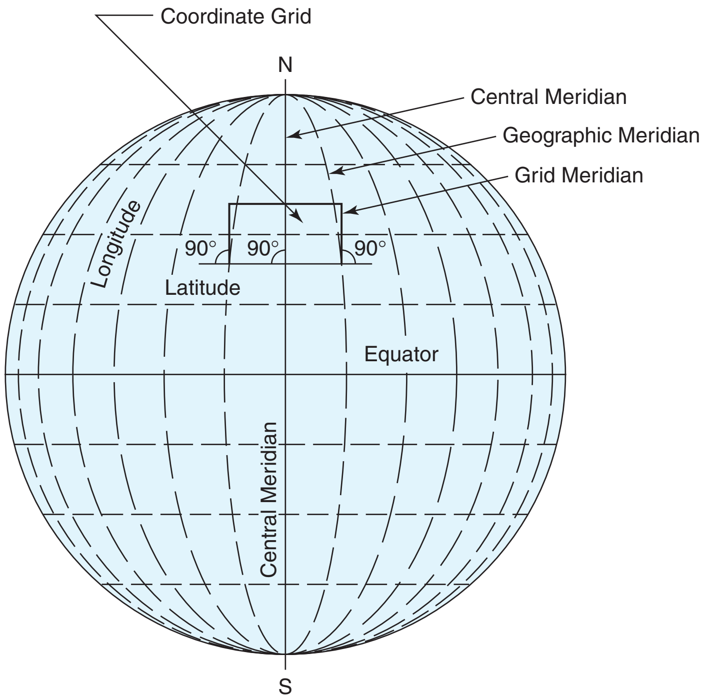


FIGURE 8.5 Relationship between "true" meridians and grid meridians. (a) Illustration of geographic ("true") meridians and grid meridians. (b) Illustration of geographic north and grid north.

magnetized needles, as in a compass. Whereas geographic and grid meridians are fixed, magnetic meridians can vary with time and location.

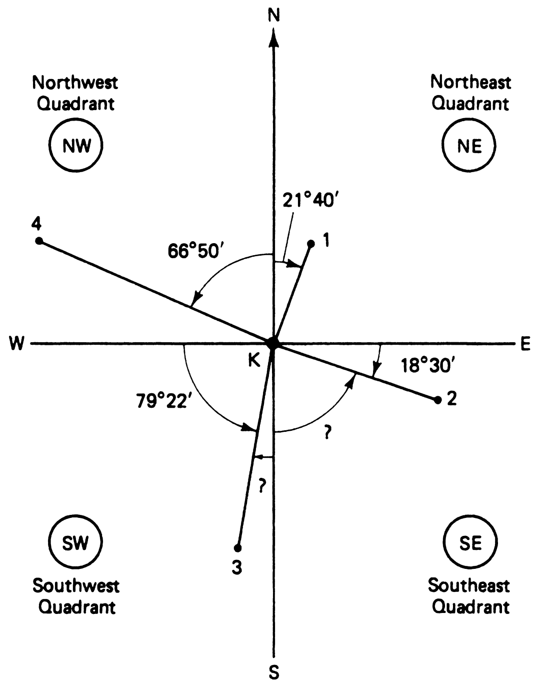
Geographic meridians can be established by tying into an existing survey line whose geographic direction is known or whose direction can be established by observations on the sun or on Polaris (the North Star) or through GPS surveys. Grid meridians can be established by tying into an existing survey line whose grid direction is known or whose direction can be established by tying into coordinate grid monuments whose rectangular coordinates are known. On small or isolated surveys of only limited importance, meridians are sometimes assumed (e.g., one of the survey lines is simply designated as being "due north"), and the whole survey is referenced to that assumed direction.

Meridians are important to the surveyor because they are used as reference directions for surveys. All survey lines can be related to each other and to the real world by angles measured from meridians. These angles are called bearings and azimuths.

8.4 BEARINGS

A **bearing** is the direction of a line given by the acute angle between the line and a meridian. The bearing angle, which can be measured clockwise or counterclockwise from the north or south end of a meridian, is always accompanied by the letters that describe the quadrant in which the line is located (NE, SE, SW, and NW). Figure 8.6 illustrates the concepts of bearings. The given angles for lines K1 and K4 are acute angles measured from the meridian and, as such, are bearing angles. The given angles for lines K2 and K3 are both measured from the E/W axis and therefore are not bearing angles; here, the given angles must be subtracted from 90° to determine the bearing angle.

All lines have two directions: forward and reverse. Figure 8.7 shows that to reverse a bearing, the directions are simply switched, for example, N to S and E to W. To illustrate, consider walking with a compass along a line in a northeasterly direction. If you were to stop and return along the same line, the compass would indicate that you were walking in a southwesterly direction. In Figure 8.7, when the meridian is drawn through point K, the line K1 is being considered, and the bearing is NE. If the meridian is drawn through



Line	Bearing
K-1	N.21°40′E
K-2	S.71°30′E
K-3	S.10°38′W
K-4	N.66°50′W

FIGURE 8.6 Bearings calculated from given data (answers in box).