

Northern Technical University Technical Engineering Collage/ Kirkuk Surveying Engineering Department



Tacheometry

Prepared by Ass. Prof. Dr. Muntadher Aidi Shareef Muntadher.a.shareef@ntu.edu.iq

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Tacheometry

The word Tacheometry means "Speed measurement". It is derived from the Greek "tacheos" (fast) and "metron" (measurement) and is, in fact, a method of measuring distances without the use of a tape.

The distances, both horizontal and vertical, are measured by using the optical properties of the telescope.

The accuracy attainable by tacheometric methods varies from about 1:500 to 1:10000. It has the advantage that poor surface measuring conditions do not affect it and in many instances the accuracy in higher than that obtained by normal ground taping.

Tacheometry field operation us used to establish positions of points (horizontal and vertical) using x - hairs in a theodolite.

1- Uses or Purpose of Tacheometry

The following are the main uses or purposes or objectives of Tacheometric surveying:

- 1- For location surveys of roads or railways, canals etc.
- 2- For preparing contour maps of uneven country.
- 3- For filling the details on topographic surveys.
- 4- For conducting hydrographic surveying.
- 5- For conducting land surveying.
- 6- For Traversing in difficult terrain.
- 7- For measuring vertical distances by angular measurements.
- 8- For determination of elevation of staff station.

DIFFERENT SYSTEMS OF TACHEOMETRIC MEASUREMENT

The various systems of tacheometric survey may be classified lows: (1)

The stadia system

- (a) Fixed Hair method
- (b) Movable Hair method, or Sub-tense method.
- (2) The tangential system.

1. The Stadia System

A figure below illustrates for principle upon which the stadia method is based.

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FIG 1.1: The principle of stadia

In the figure, the line of sight of the telescope is horizontal and the stadia rod is vertical. The stadia hairs are indicated by points a & b. The distance between the stadia is (i).

The apparent locations of the stadia hairs on the rod are points A & B and the stadia interval is (s).

a b = a' b'The triangles a' b' F, ABF are similar f d

$$\frac{J}{i}=\frac{u}{AB}$$

$$\therefore \quad d = (\frac{f}{i}) \ s = Ks$$

 $K = \frac{f}{i}$ is a coefficient called the stadia interval factor, which for a particular instruments is a constant as long as conditions remain unchanged

1.1 Horizontal sight

For a **horizontal sight** the distance from principal focus to rod is obtained by multiplying the stadia interval factor by the stadia interval.

The horizontal distance from center of instrument to rod is then:

D = Ks + (f + c) = Ks + C

Usually, the value of $\mathbf{C} = \mathbf{f} + \mathbf{c}$ is determined by the manufacturer and is stated on the inside of the instrument box.

In the internal – focusing telescopes are so constructed that C is zero or

nearly so and the ratio $\frac{f}{ab}$ which is represent **K** is made as equal 100.

1.2 DISTANCE AND ELEVATION FORMULAE FOR STAFF VERTICAL : INCLINED SIGHT CK - 199

- P = Instrument station
- Q = Staff station Position of instruments axis
- O = Optical center of the objective
- A, C, B = Points corresponding to the readings of the three hairs
- s = AB = Staff intercept
- i = Stadia interval



FIG. 1.2: ELEVATED SIGHT: VERTICAL HOLDING. Θ = Inclination of the line of sight from the horizontal L = Length MC measured along the line of sight D = MQ' = Horizontal distance between the instrument and the staff V = Vertical intercept, at Q, between the line of sight and the horizontal

line.

h = Height of the instrument

r = Central hair reading

 β = Angle between the two extreme rays corresponding to stadia hairs.

 $L = K \cdot A'B' + C = Ks\cos\theta + C$

$$D = L \times \cos \theta = (Ks \cos \theta + C) \cos \theta$$

 $D = Ks \cos^2\theta + C \cos\theta$



(a) Elevation of the staff station for angle of elevation. If the line of sight has an angle of elevation 6, as shown in Fig. 1.2, we have

Elev. of staff station= Elev. of instrument station + h +V - r

(b) Elevation of the staff station for the angle of depression From Fig. 1.3,



FIG. 1.3 : DEPRESSUED SIGHT: VERTICAL HOLDING.

DISTANCE AND ELEVATION FORMULAE FOR STAFF NORMAL

Fig. 1.4 shows the case when the staff is held normal to the line of sight.







Case (b) Line of sight at an angle of depression Θ

FIG. 1.5: DEPRESSED SIGHT: NORMAL HOLDING.

Same equation of D and V in case (a) , the difference is in elevation equation

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Elevation of Q = E levation of $P + h - V - r \cos \theta$

2. THE TANGENTIAL METHOD

In the tangential method, the horizontal and vertical distances from the instrument to the staff station are computed from the observed vertical angles to the vanes fixed at a constant distance apart upon the staff. The stadia hairs are, therefore, not used and the vane is bisected every time with the axial hair. Thus, two vertical angles are to be measured—one corresponding to each vane. There may be three cases of the vertical angles:

- (i) Both angles are angles of elevation.
- (ii) Both angles are angles of depression.
- (iii) One angle of elevation and the other of depression.

Case I. Both Angles are Angles of Elevation:

- Let **P** = Position of the instrument
- Q = Staff station
- M = Position of instrument axis
- A, B = Position of vanes
- s = Distance between the vanes—staff intercept
- \propto l = Angle of elevation corresponding to A
- $\propto 2 =$ Angle of elevation corresponding to B
- D = Horizontal distance between P and Q = MQ'
- V = Vertical intercept between the lower vane and the horizontal line of sight
- h = Height of the instrument= MP
- r = Height of the lower vane above the foot of the staff
- = Staff reading at lower vane= BQ











3. HORIZONTAL BASE SUBTENSE MEASUREMENTS

In this method, the base AB is kept in a horizontal plane and the angle AOB is measured with the help of the horizontal circle of the theodolite .

Thus, in Fig. 1.9, let

AB be the horizontal base of a length s and let

O is the position of the instrument meant for measuring the horizontal angle AOB. If the line AB is perpendicular to the line OC, where C is midway between A and B, we have from ΔOAC ,



9: HORIZONTAL BASE SUBTENSE METHOD.

The equation above is the standard expression for the horizontal distance between O and C.



If β is small, we get

 $an rac{eta}{2} = rac{eta}{2}$, where eta in radian

$$=rac{eta}{2} imesrac{1}{206265}$$
 , where eta in seconds

(Since 1 radian= 206265 seconds)

Substituting in Equation, we get

 $D = \frac{s \times 206265}{\beta}$

Where β is in seconds.

The accuracy of the expression above depends upon the size of angle.

Traversing

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Bearing – Compass: 1- Magnetic Meridian:

The magnetic meridian is the direction which is indicated by a freely suspend Magnetic needle. The earth is a big magnet. A magnetic needle always point in one direction, this direction is called the magnetic meridian Due to certain reasons direction does not remain constant but varies from time to time.

2-True Meridian:

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The ends of the axis of the earth around which it rotates in its Diurnal motion are called north and south poles, this direction is called the true meridians is also called the geographic meridian. The true meridian and magnetic meridian do not coincide with each other , The angle between two is called declination , the magnetic meridian does not indirection but swings ,the amount of declination also varies from time to time ,some time it is east of the true meridian and some year it may be west of the true Meridian.



3-Arbitrary Meridian:

Any direction is assumed to be the reference meridian to carry out small surveys which have no link with other works. The magnetic the horizontal between the true meridian and the declination, Meridian at a place called Declination The position of true meridian remains unaffected but the magnetic meridian always changes its position, so that the direction is never constant and keeps chaining from time to time and place to place, if the magnetic meridian is west of the meridian it is called westerly declination is called easterly declination.

Bearing:

The direction of a line with respect to the magnetic north, this may be represented from 0° to 360° from the magnetic north in the clockwise direction or may represent with respect to the quadrant in which it lies.

Whole Circular Bearing (W.C.B.):

The angle is measured from the magnetic north in the clock wise direction, this varies 0° to 360° .

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Bearing AB - N 45°

Bearing AC - 120

Bearing AD - 260°

Quadrant Bearing (Q.B.):

The direction is represented with respect to nearest north or south line.

Bearing AB - N 45° E

Bearing AB - S 70° E

0°W Bearing AD - S 3



Conversion of (W.C.B.) and (Q.B.) and vice versa: -

1) Conversion of (W.C.B.) to (Q.B.):

LINE	W .C .B	Q.B
OA	$0^{\circ} \longrightarrow 90^{\circ}$	Q.B=W.C.B
OB C	90° - 180°	Q.B=180°- W.C.B
OC	$180^{\circ} \longrightarrow 270^{\circ}$	Q.B=W.C.B - 180°
OD	270° → 360°	Q.B= 360° - W.C.B

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2) Conversion of (Q.B.) to (W.C.B.):

LINE	W .С .В	Q.B
OA	NQE	W.C.B = Q.W
OB	SQE	W.C.B = $180^{\circ} - Q.W$
OC	SQW	W.C.B = $180^{\circ} + Q.W$
OD	NQW	W.C.B = $360^{\circ} - Q.W$

Angles

Finding the locations of points and orientations of lines depends on measurements of angles and directions. In surveying, directions are given by azimuths and bearing .

Angels measured in surveying are classified as

- Horizontal angels
- Vertical angles

Kinds of Horizontal Angles

The most commonly measured horizontal angles in surveying:

- Interior angles,
- Angles to the right, and
- Deflection angles

Because they differ considerably, the kind used must be clearly identified in field notes.

Deflection Angles

- Measured from an extension of the back line, to the forward station. Used principally on the long linear alignments of route surveys.
- Deflection angles may be measured to the right (clockwise) or to the left (counterclockwise) depending upon the direction of the route.

Angle to the right

Azimuths

Azimuths are horizontal angles measured clockwise from any reference meridian. In plane surveying, azimuths are generally measured from north. Azimuths are used advantageously in boundary, topographic, control, and other kinds of surveys, as well as in computations.



Traverse:

Traverse is a method in the field of surveying to establish control networks. It is also used in geodetic work. Traverse networks involved placing the survey stations along a line or path of travel, and then using the previously surveyed points as a base for observing the next point.

The traverse is more accurate than triangulation and trilateration



Types of traverses

There are many different types of traverse:

- **1.** An open traverse starts on a known point and finishes on an unknown point. (Doesn't need correction).
- **2.** A closed link traverse joins two known points . (Needs Coordinates correction).
- **3.** A closed polygonal traverse starts and finishes on the same known point. (Needs Departure and Latitude correction).

1. An open traverse

- It doesn't need correction because we cannot check neither department and latitude nor coordinates of last point
- From coordinates of first point, angles of traverse, direction of first line and lengths of all lines of travers we can calculate all coordinates of rest point

 $E_{2} = E_{1} + L_{12} \times \sin A_{z_{1}}$

> N 2 = N1 + L12 × cos Azi. 12

2. A close link traverse

The coordinates of start and end points (B and C) are known

The direction of AB and CD are also known



> Sides and angles of traverse are known

1. Angles Adjustment

Known Azimuth of final line = measured Azimuth

Computed Azimuth of final line can be computed from the first Azimuth and the angles of traverse

Total correction = Final Azimuth – Initial Azimuth + n. 180°

Then,

Correction for each angle = \pm Total correction / n

2. The corrected angles

Corrected $\Theta 1$ = measured $\Theta 1$ ± Correction for each angle Corrected $\Theta 2$ = measured $\Theta 2$ ± Correction for each angle Corrected $\Theta 3$ = measured $\Theta 3$ ± Correction for each angle Corrected $\Theta 4$ = measured $\Theta 4$ ± Correction for each angle Corrected $\Theta 5$ = measured $\Theta 5$ ± Correction for each angle

3. Compute the partial coordinates of points

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3T1	Length of BT1	Bearing BT1	L BT1× sin Azi. BT1	L BT1× cos Azi. BT1	E known $ET1 = EB \pm \Delta E$	N known $NT1 = NB$ $\pm \Delta N$
3T1	Length of BT1	Bearing BT1	L BT1× sin Azi. BT1	L BT1× cos Azi. BT1	known ET1 = EB $\pm \Delta E$	known NT1 = NB $\pm \Delta N$
BT1	Length of BT1	Bearing BT1	L BT1× sin Azi. BT1	L BT1× cos Azi. BT1	$\mathbf{ET1} = \mathbf{EB} \pm \Delta \mathbf{E}$	$NT1 = NB \\ \pm \Delta N$
		1				
T1T2						
			<u> </u>			
2T3						
C2C						
			Same Proced	ures		
2	2T3 2C	2C	2C	2C Same Proced	2C Same Procedures	2C Same Procedures

4. Correction the coordinates

<u> Total Correction for E – coordinate</u>

T.C. = E Known - E Computed

Correction of E for any point = $(T.C. / \sum L) \times L$ from start to a point

For example: in the previous figure of close link traverse

Correction of E T1 = (T.C. $/ \sum L$) × L BT1

Correction of E T2 = $(T.C. / \Sigma L) \times (L BT1 + L T1T2)$

Correction of E T3 = $(T.C. / \Sigma L) \times (L BT1 + L T1T2 + L T2T3)$

Correction of E C= $(T.C. / \Sigma L) \times (L BT1 + L T1T2 + L T2T3 + LT3C)$

And the same procedure apply for coordinate N of all points

After that,

5. E corrected for any point = E correction for same point \pm E partial for it

6. Finally, we organize the table to compute the final corrected coordinates

POINT	PARTIAL				CORRE	CCTION	CORRI	ECTED
	E		N	I	E	Ν	E	Ν
B	Known Kr		Kno	own				
T1								
T2		From Table 2						
T3								
С								

3. A closed polygonal traverse

• We should have Bearing of the first Line (AB)

• The traverse starts from point A and ends at the same point.

1. Angles Adjustment

Total correction = \sum theor. - \sum meas.

 \sum theor. = (n - 2) × 180° For interior angles

 $= (n + 2) \times 180^{\circ} \dots$ For external angles

 \sum meas. = the sum. of measured angles.

Correction for each angle = Total correction / n

Where (n) is the number of angles.

2- The corrected angles:

Corrected $< A = Measured < A \pm correction for each angle$



Corrected < B = Measured $< B \pm$ correction for each angle Corrected < C = Measured $< C \pm$ correction for each angle Corrected < D = Measured $< D \pm$ correction for each angle Corrected < F = Measured $< F \pm$ correction for each angle Corrected < G = Measured $< G \pm$ correction for each angle

3- Bearings Computations.

In a traverse ABCDFGA figure(1) the bearing of AB should be known, then F.B of BC = B.B of AB - $\langle B |$ (corrected) F.B of CD = B.B of BC - $\langle C |$ (corrected) F.B of DF = B.B of CD - $\langle D |$ (corrected) F.B of FG = B.B of DF - $\langle F |$ (corrected) F.B of GA = B.B of FG - $\langle G |$ (corrected) And Finally to check

F.B of AB = B.B of $GA - \langle A |$ (corrected)

4- Department (ΔE), Latitude (ΔN) correction ,and determine the final coordinates

A - by Compass (or Bowditch rule)

 ΔE Partial = L of side \times sin bearing of side

 ΔN Partial = L of side \times cos bearing of side



 $\sum \Delta E$ and $\sum \Delta N$ should be zero, if not we have to make correction

 ΔE correction = $(\sum \Delta E / \sum L) \times L$ of side

 ΔN correction = $(\sum \Delta N / \sum L) \times L$ of side

 ΔE corrected = ΔE Partial $\pm \Delta E$ correction

 ΔN corrected = ΔN Partial $\pm \Delta N$ correction

And $E2 = E1 \pm \Delta E$ corrected

 $N2 = N1 \pm \Delta N$ corrected

Note: the coordinates of point A are known or can be assumed

Point	Side	Length	Bearing	Pa	rtial	Correction		Corrected		Final Co	ordinates
				ΔE	ΔN	ΔE	ΔN	ΔE	ΔN	E	N
Α										Known	Known
	AB	L AB	Bearing AB	L AB × sin	L AB × cos	(∑ ∆E / ∑L)	(ΣΔN / ΣL)	∆E Partial ±	∆E Partial		
				bearing AB	bearing AB	× LAB	× LAB	ΔE	± ΔE		
								correction	correction		
В										EA ± ΔE	NA ± ∆N
										corrected of	corrected of
										AB	AB
	BC	L BC	Bearing BC		L,						
С					U						e l
	CD	L CD	Bearing CD		5						5
D					2						eq
	DF	L DF	Bearing DF		3						8
F					-						Pr
	FG	L FG	Bearing FG		U						e l
G										J	<u> </u>
	GA	L GA	Bearing GA	5	20						Sa
Α										Must be	Must be
										checked	checked
		ΣL		ΣΔΕ	ΣΔΝ						

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Now $\Sigma \Delta E$ and $\Sigma \Delta N$ must be zero

B - by Transit rule

We use this method if we don't have lengths of Travers's sides

 ΔE correction = ($\pm \sum \Delta E / (\sum |\Delta E|) * \sum |\Delta E$ of side |

 ΔN correction = ($\pm \sum \Delta N / (\sum |\Delta N|) * \sum |\Delta N|$ of side |

 ΔE corrected = $\Delta E \pm \Delta E$ correction

 ΔN corrected = $\Delta N \pm \Delta N$ correction

and $E2 = E1 \pm \Delta E$ corrected

 $N2 = N1 \pm \Delta N$ corrected

Linear misclosure and accuracy of traverse

These discrepancies represent the difference on the ground between the position of the point computed from the observations and the known position of the point. The easting and northing misclosures are combined to give the linear misclosure of the traverse, where

Linear misclosure error = $\sqrt{\sum \Delta E^2 + \sum \Delta N^2}$

Angular misclosure error = K \sqrt{n}

Accuracy = linear misclosure / \sum L