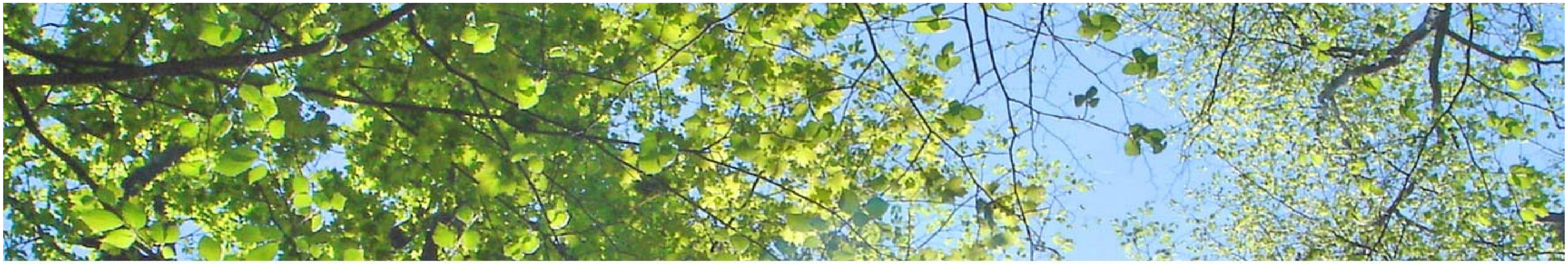
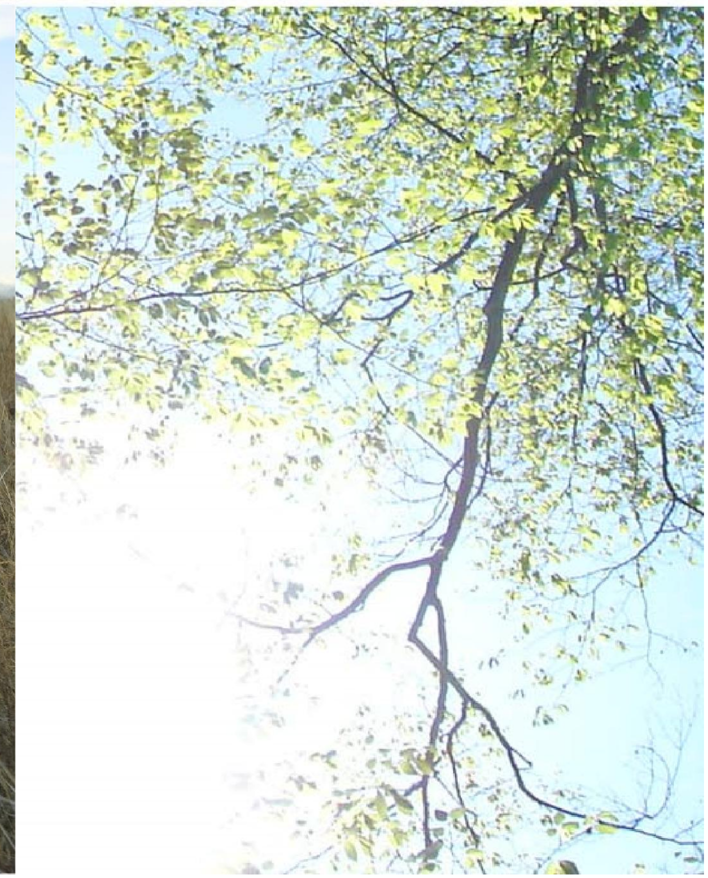


Higher Surveying

Tacheometry



Tacheometry

Tacheometry is defined as a procedure of obtaining horizontal distances and differences in elevation based on the optical geometry of the instrument deployed.

Tacheometry

The Stadia Method

The word stadia is the plural of stadium. It comes from the Greek word for a unit of length originally applied in measuring distances for athletic contests. A stadia denoted 600 Greek units, or 184m 93 cm(606 ft 9 in) by present-day international standards.

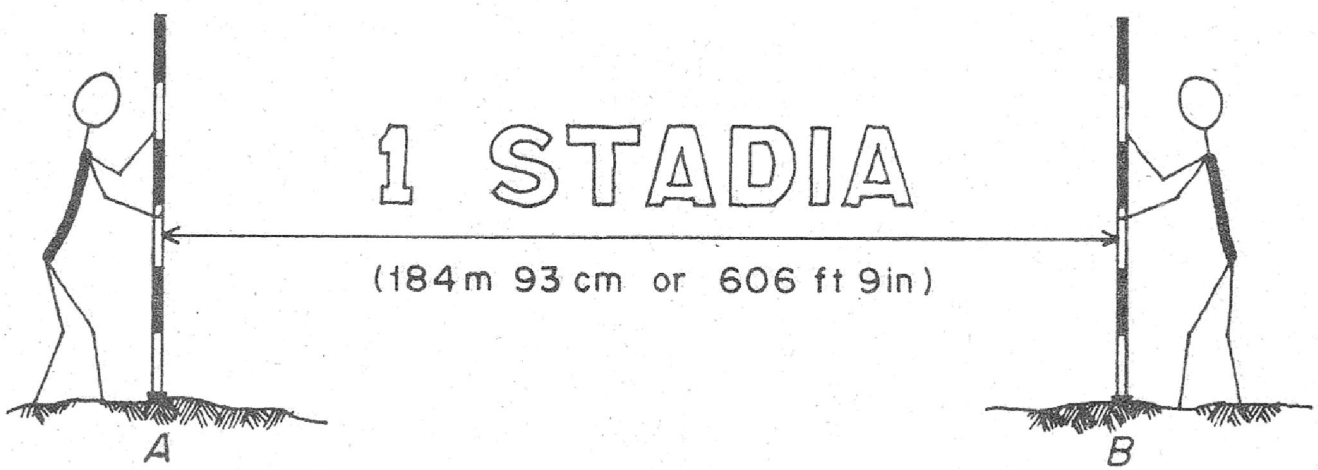
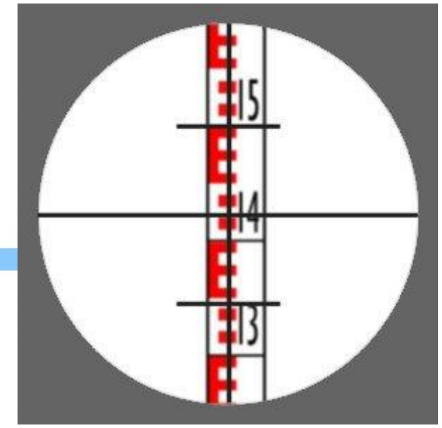


Fig. 1-1. Present-day equivalent of a stadia unit.

Tacheometry

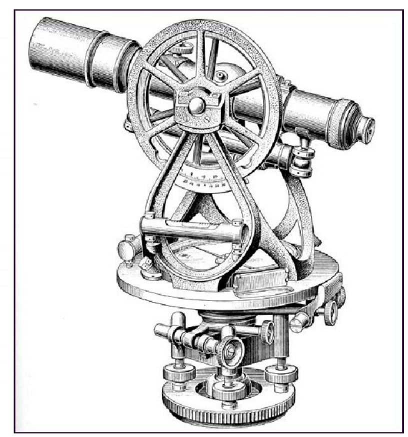


The Stadia Method

The term now applied to the cross hairs and rod used in making measurements, as well as to the method itself.

Stadia readings can be taken with most surveying instruments such as the engineer’s level, alidade, theodolite, and the engineer‘s transit.



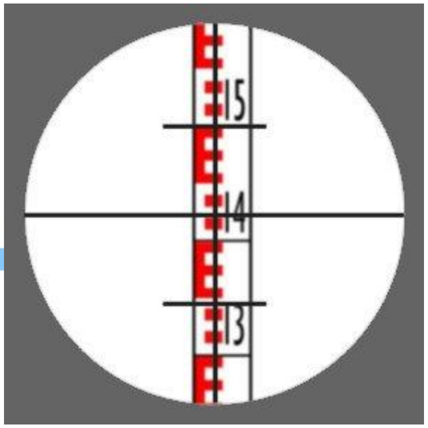


Tacheometry

<u>The Stadia Method</u>

The equipment for stadia measurements consists of a telescope with two horizontal hairs called **stadia hairs** and a graduated rod called a **stadia rod**.

Tacheometry



<u>Stadia Hairs</u>

The telescopes of most surveying instruments are equipped with stadia hairs in addition to the regular vertical and horizontal hairs (Fig. 1-2).

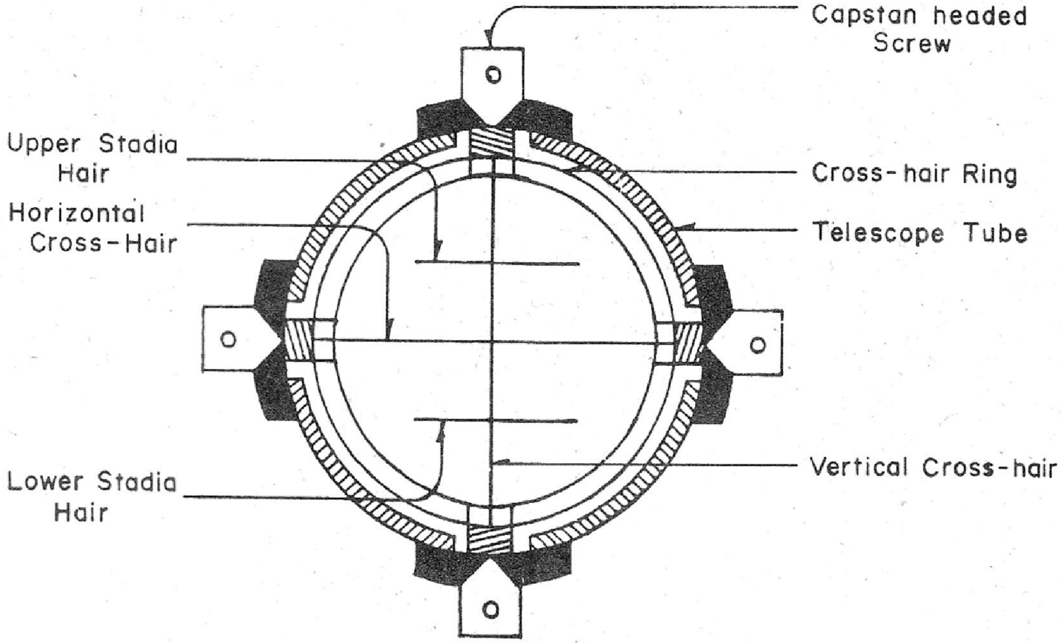
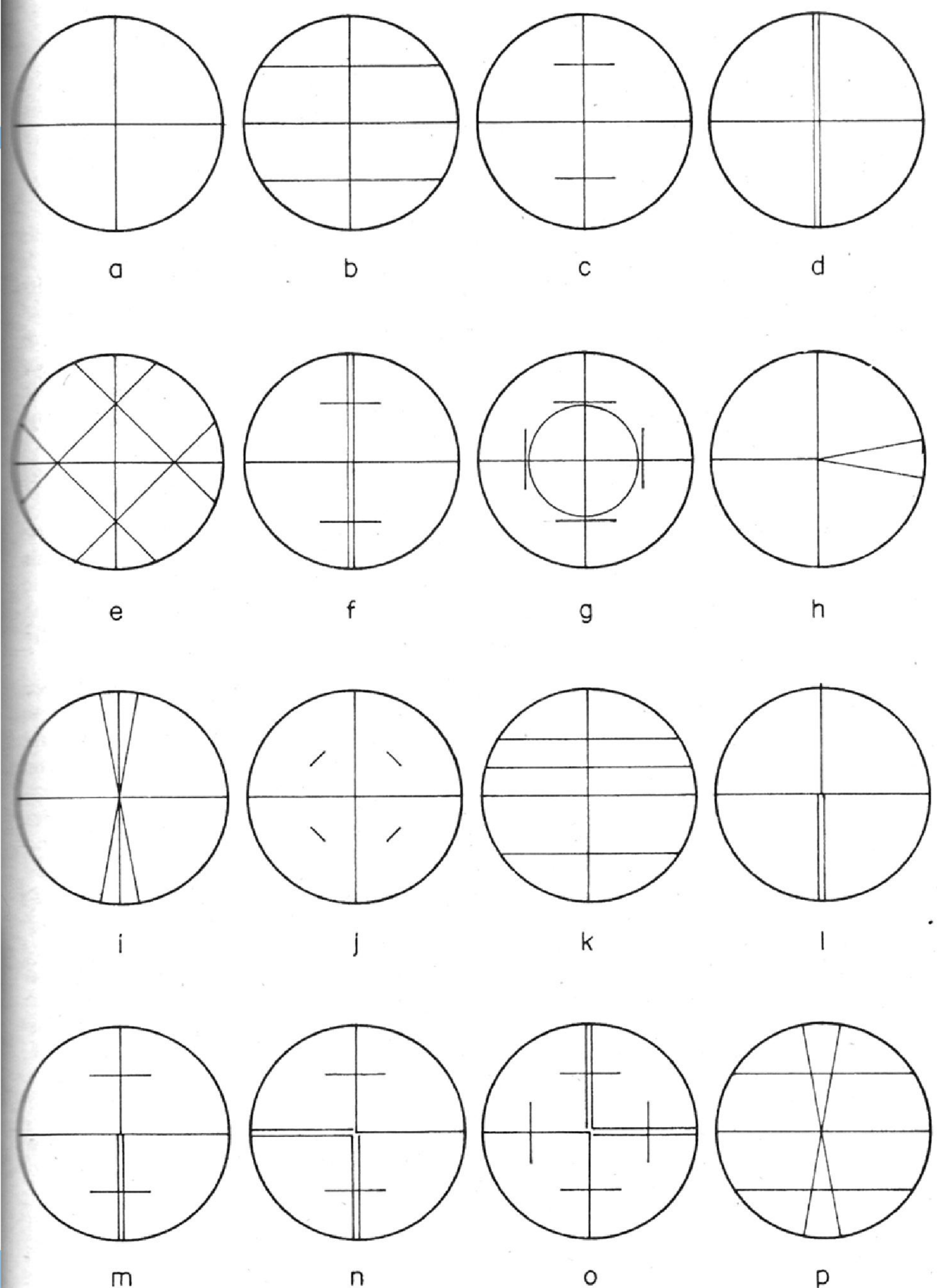


Fig. 1-2. Typical cross hair ring (or reticule).

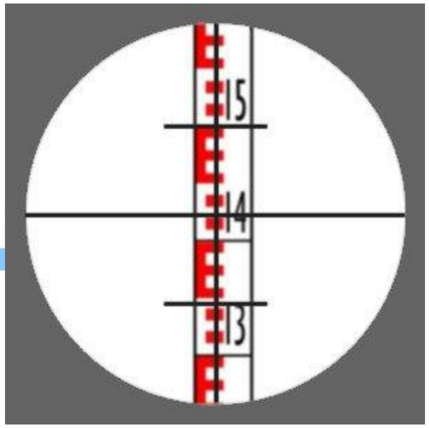
Stadia Hairs

(Fig. 1-4)

PATTERNS FOR CROSS HAIRS AND STADIA HAIRS

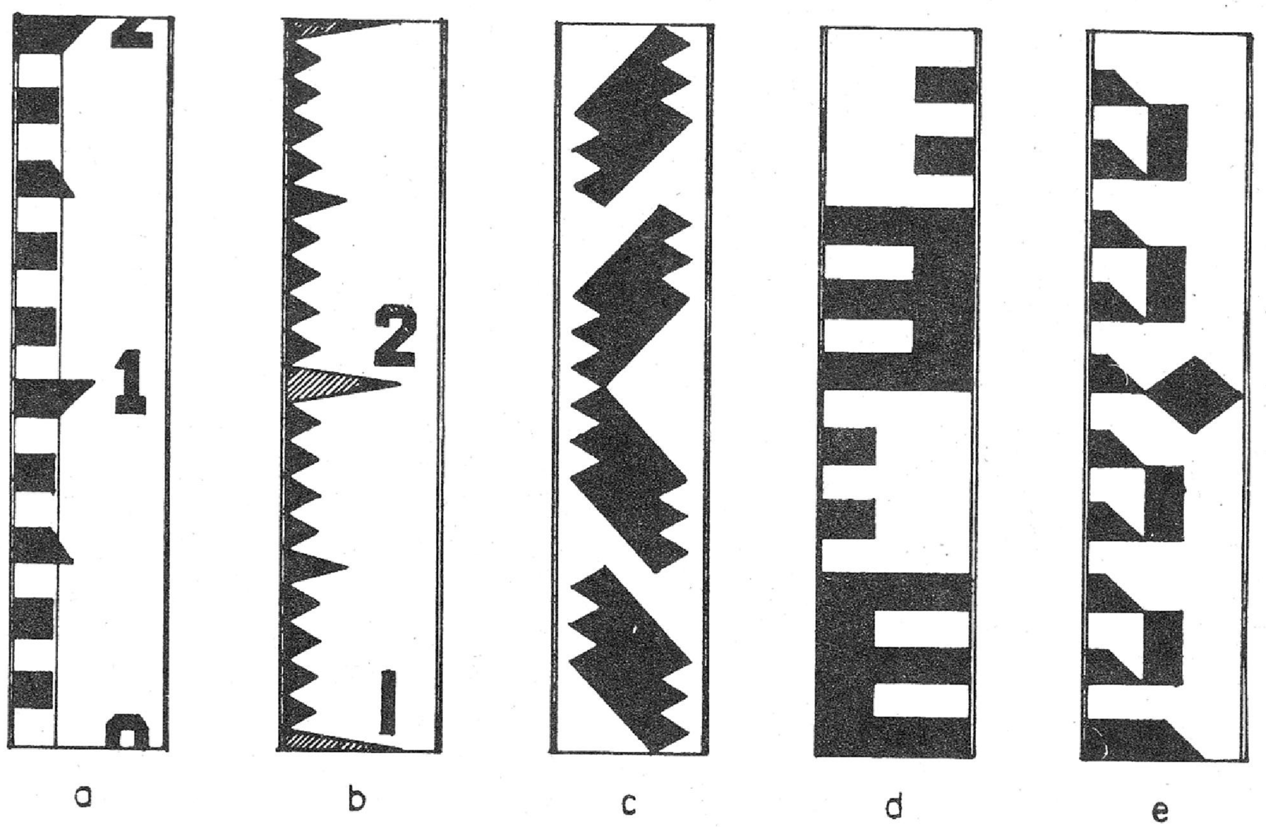


Tacheometry



Stadia Rods

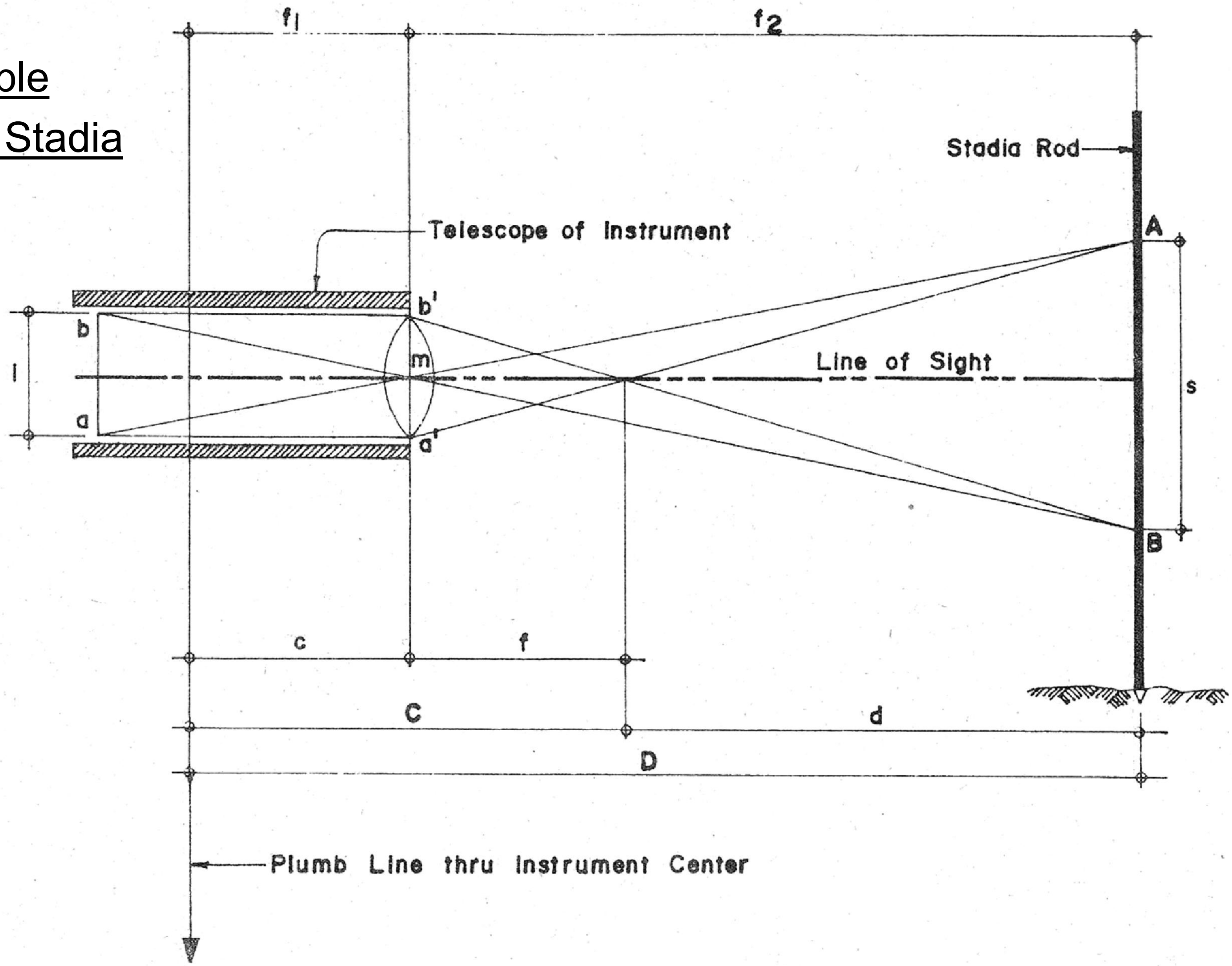
Markings and Graduations on Stadia Rods



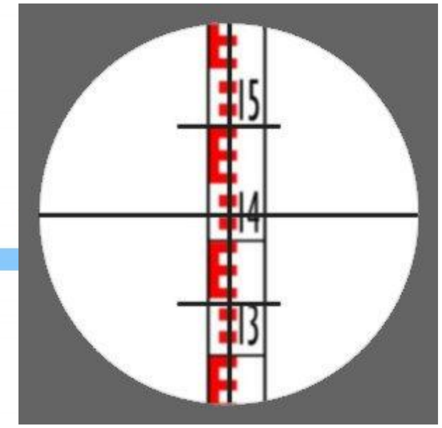
Principle of the Stadia

(Fig. 1-5)

STANDARD SYMBOLS USED IN STADIA MEASUREMENTS



Tacheometry



Principle of the Stadia

By similar triangles:

f:i = d:s and $d = \left(\frac{f}{i}\right)s$

Also

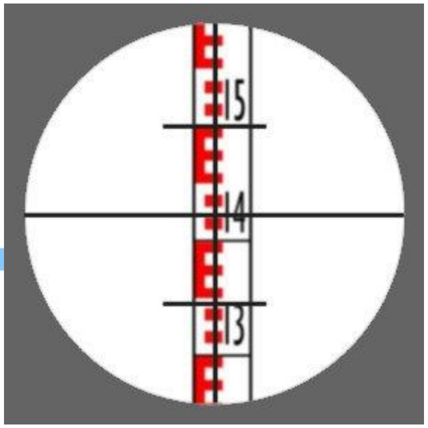
D = d + (f+c)
= (f/i)s + C
D = Ks + C

where: C = stadia constant, the distance from the center of the instrument to the principal focus, (f+c)

f = focal length of the lens

c = distance from the center of the instrument to the center of the objective lens

Tacheometry



Principle of the Stadia

$$D = Ks + C$$

where: C = stadia constant, the distance from the center of the instrument to the principal focus, (f+c)

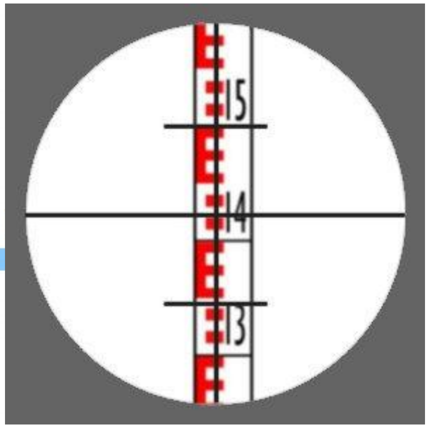
f = focal length of the lens

c = distance from the center of the instrument to the center of the objective lens

K = stadia interval factor, (f/i)

s = stadia intercept (or interval), the difference between the upper stadia hair reading and the lower stadia hair reading

Tacheometry

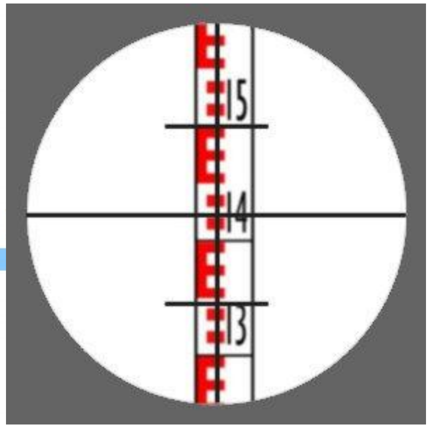


Stadia Constant, C

It is the distance from the center of the instrument to the principal focus. This quantity is composed of the focal length (f), which remains constant, and the distance (c) from the center of the instrument to the center of the objective lens. The distance, c, varies such a small amount that essentially it may be considered a constant.

The important advantage of internal-focusing telescope used in stadia work is that they are so constructed that C is either zero or small enough to be neglected.

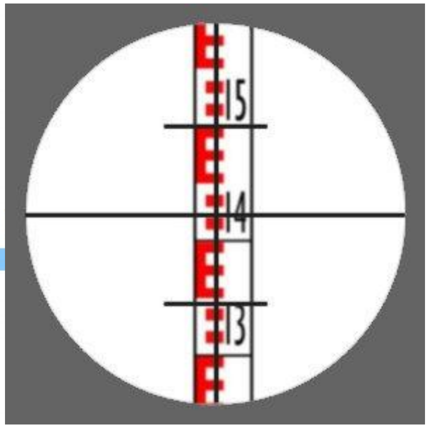
Tacheometry



Stadia Constant, C

There should be no problem in determining the value of C for a newly purchased instrument since this value is usually determined by the manufacturer before the instrument is sold. It is usually indicated on the inside of the instrument box.

Tacheometry



Stadia interval factor, K

The ratio f/i is called the stadia interval factor, K. For any given instrument, this value remains constant and depends only on the spacing between the stadia hairs.

The most common value of K is 100.

The stadia hairs are so adjusted such that the horizontal cross hair lies exactly equidistant from the upper and lower stadia hairs.

Tacheometry

Determination of Stadia interval factor, K

The stadia interval factor of surveying instruments is usually 100.

Tacheometry

<u>Observation of stadia interval, s</u>

On transit-stadia surveys the stadia interval (or intercept) is more conveniently determined by setting the lower stadia hair on the nearest whole centimeter mark then reading the location of the upper stadia hair.

The stadia interval is easily computed mentally by subtracting the whole centimeter value from the reading at the upper stadia hair.

The slight increase (or decrease) in the vertical angle introduced by this procedure does not cause a significant error when stadia distances are computed.

Tacheometry

Observation of stadia interval, s

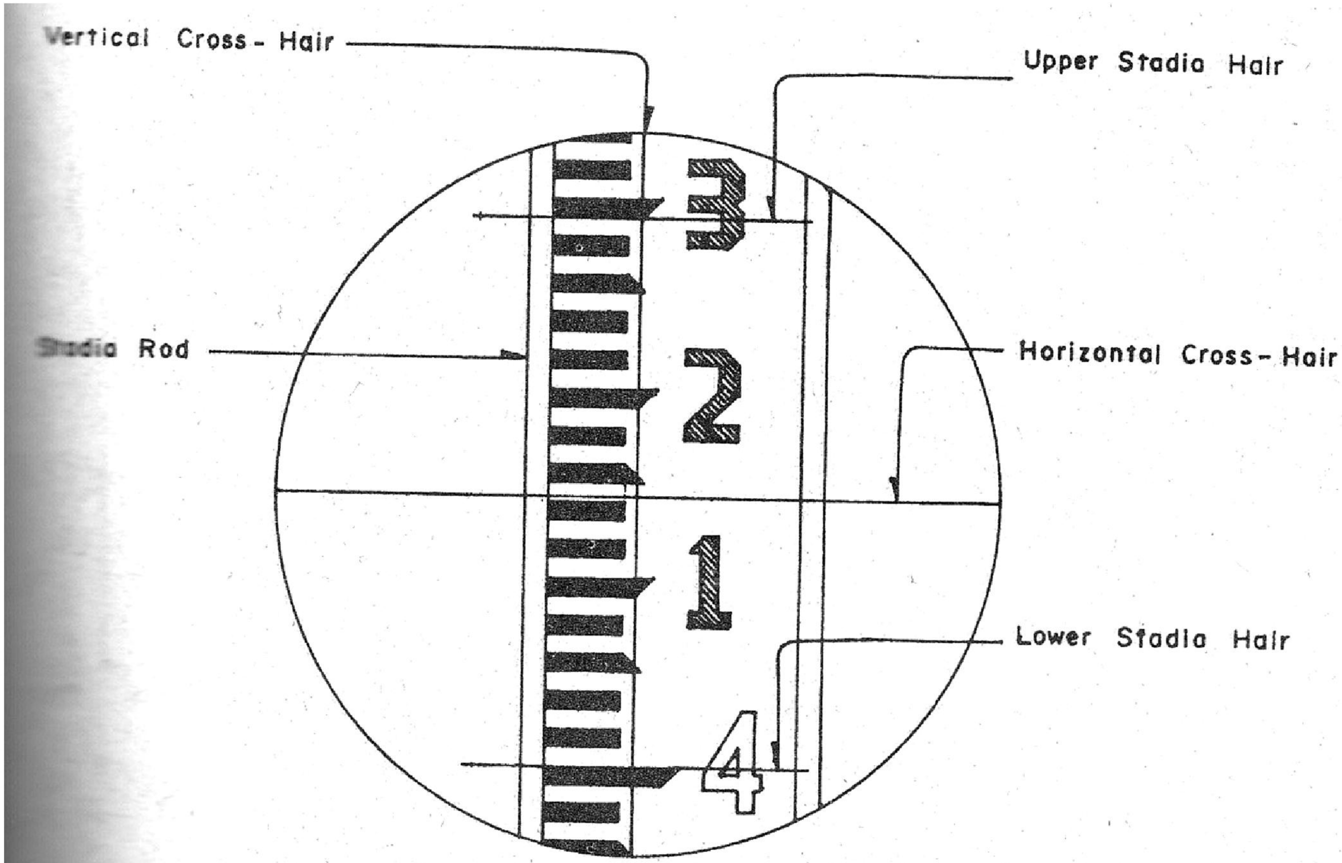


Fig. 2-1. Determining stadia interval on level rod.

Tacheometry

Observation of stadia interval, s

When undertaking more precise stadia measurements. The observations on the rod may have to be made by using two targets on the rod.

During very hot and humid weather conditions, the intercept of the lower stadia hair with the rod should not be brought near the ground. This is done to avoid the excessive effects of atmospheric refraction.

The observed stadia interval should always be checked by reading the interval between the horizontal cross hair and a stadia hair and observing if this is about one-half of the whole interval.

Tacheometry

Observation of stadia interval, s

It is very important that the stadia rod is held plumb when a reading is taken on it as any inclination of the rod from the vertical will introduce an error into the computed distance.

For accurate plumbing of the rod, a rod level should be used especially when highly inclined sights are taken.

Tacheometry

Illustrative Problems

1) In **determining the stadia interval factor (K)** of a transit, a stadia rod was held vertically at several points along measured distances from the instrument (see accompanying figure), and the corresponding stadia hair readings were observed. The distances and the observed readings were recorded as follows:

POINT	DISTANCE FROM TRANSIT TO ROD (m)	STADIA HAIR READINGS	
		UPPER (m)	LOWER (m)
a	30	0.96	0.66
b	45	1.10	0.64
c	60	1.21	0.60
d	75	1.35	0.58
e	90	1.47	0.56
f	105	1.57	0.53
g	120	1.72	0.50

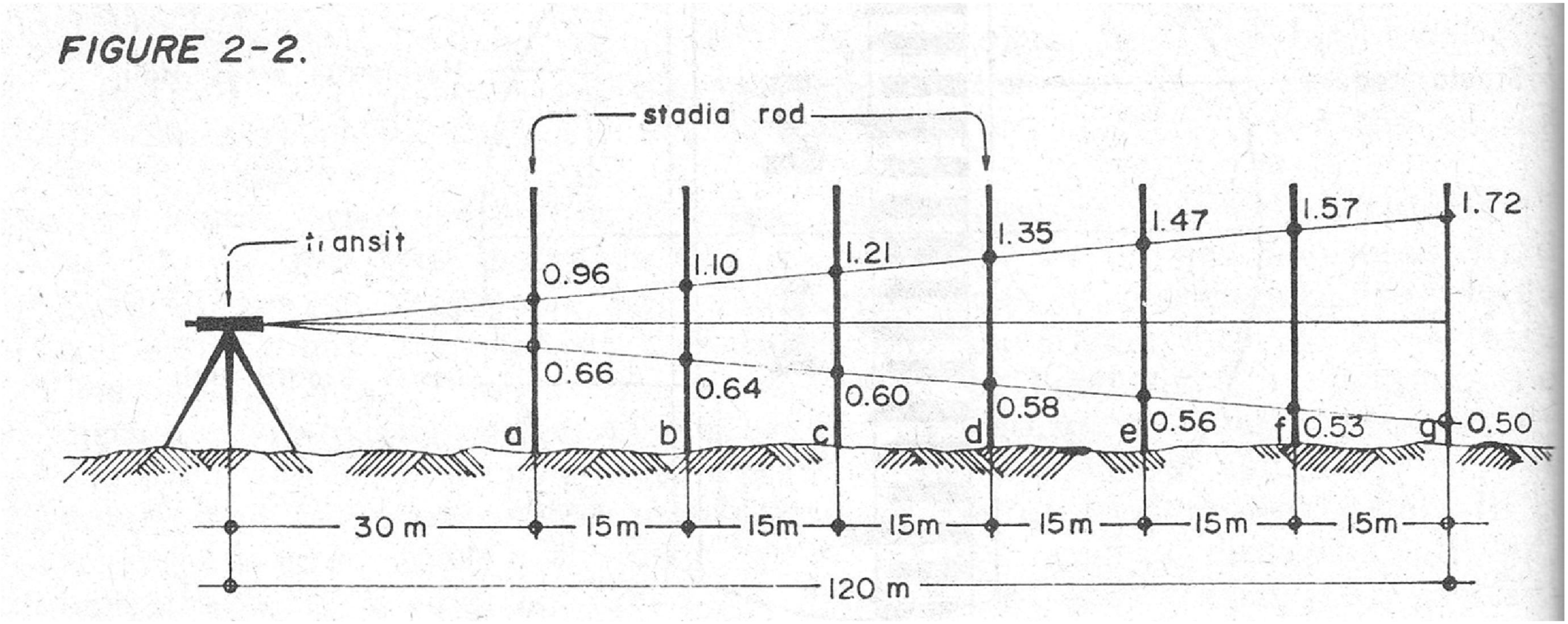
Determine the stadia interval factor of the instrument. Assume that the stadia constant (C) is zero.

Tacheometry

Illustrative Problems

1) **Determining the stadia interval factor (K)**

$$D = Ks + C$$



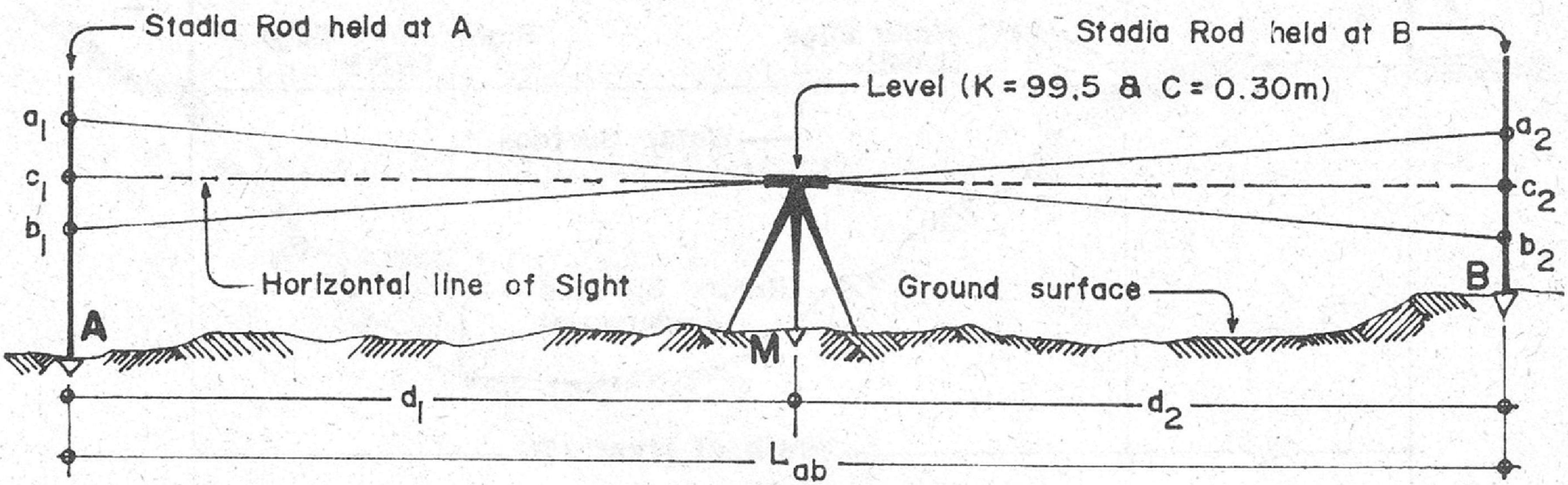
Tacheometry

Illustrative Problems

2) **Horizontal stadia sights.** An engineer's level with a stadia constant of 0.30m was set up on the line between two points, A and B, and the following hair readings were observed. If the stadia interval factor of the level is 99.5, determine the length of the line AB.

ROD POSITION	HAIR READINGS		
	UPPER (a)	MIDDLE (c)	LOWER (b)
ROD HELD AT A	1.330m	1.175m	1.020m
ROD HELD AT B	1.972	1.854	1.736

FIGURE 2-3.

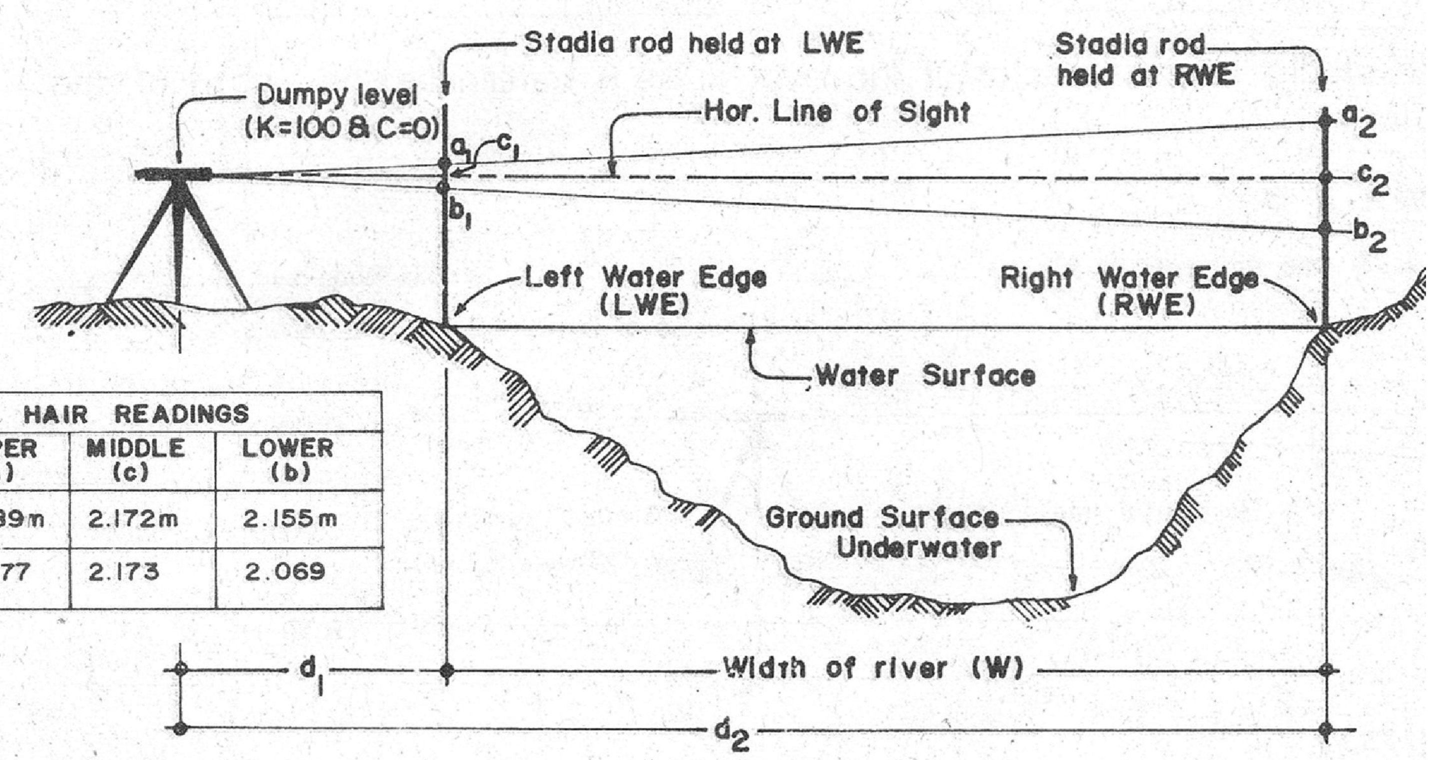


Tacheometry

Illustrative Problems

2) **Horizontal stadia sights.** A dumpy level with an internal focusing telescope was set up on the left bank of a river and the rod readings tabulated below were taken on a stadia rod held successively at the left and right water edges. If the stadia interval factor of the instrument is 100, determine the width of the river.

FIGURE 2-4.



ROD POSITION	HAIR READINGS		
	UPPER (a)	MIDDLE (c)	LOWER (b)
ROD HELD AT LWE	2.189m	2.172m	2.155m
ROD HELD AT RWE	2.277	2.173	2.069

Tacheometry

Inclined Stadia Sights

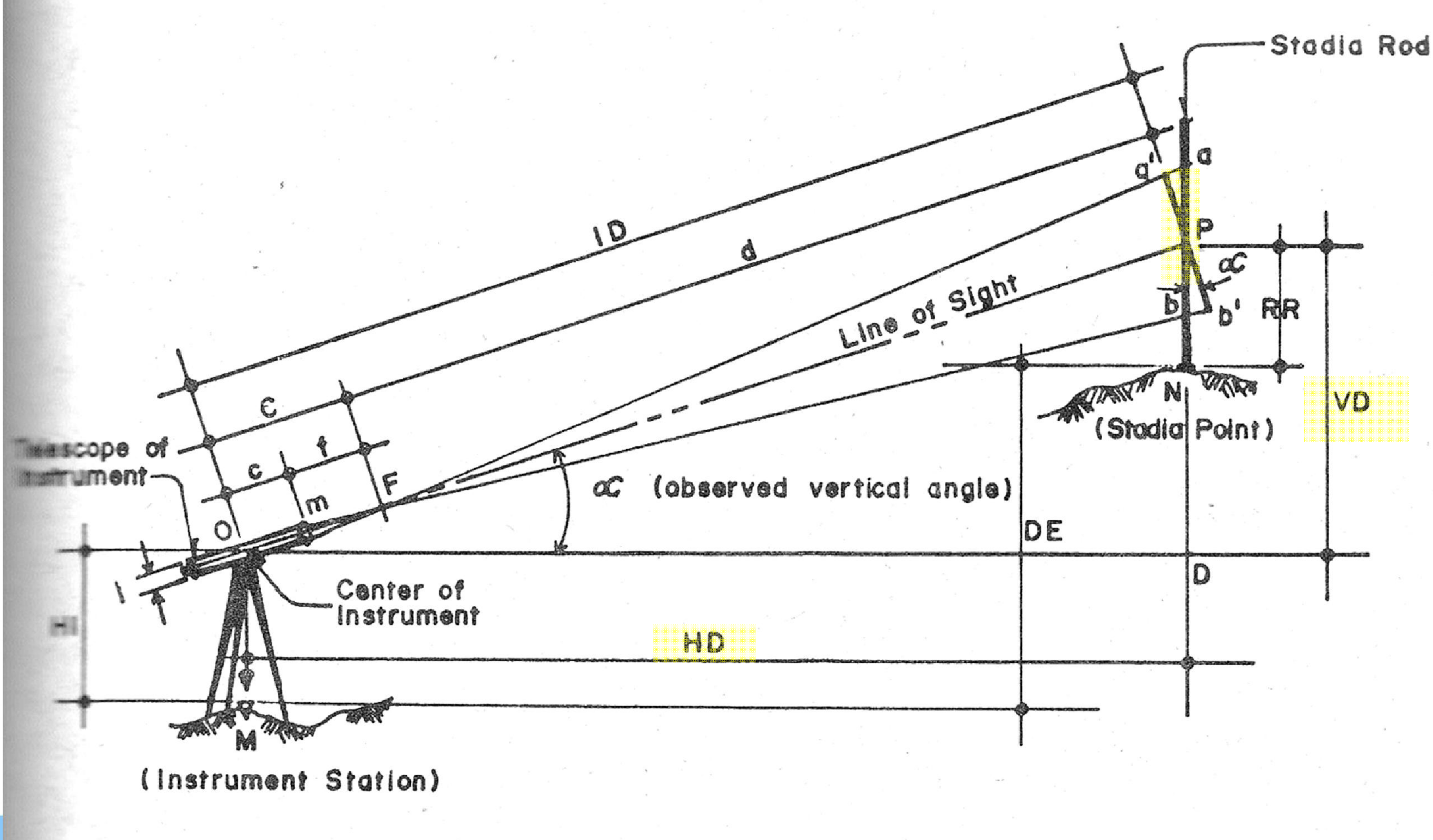
In actual field practice, most stadia measurements are inclined because of varying topography, but the interval is still read on a vertically held rod.

The inclined measurement which is also dependent on the observed vertical angle, is reduced to horizontal and vertical components of the inclined line of sight.

Tacheometry

(Fig. 3-1)

INCLINED STADIA SIGHTS



Tacheometry

Inclined Stadia Sights

The length of the inclined line of sight from O to P is

$$ID = K\left(a'b'\right) + C$$

Since ab is equal to the stadia interval s; then a'b' is equal to scosα. Substituting the value of a'b', the inclined distance is:

$$ID = Ks\cos\alpha + C$$

Tacheometry

Inclined Stadia Sights

The vertical component of the inclined distance is determined by

$$VD = (ID)\sin\alpha$$
$$= (Ks\cos\alpha + C)\sin\alpha$$
$$\boxed{VD = Ks\cos\alpha\sin\alpha + C\sin\alpha}$$

Tacheometry

Inclined Stadia Sights

The horizontal component of the inclined distnce may be determined as follows

$$HD = (ID)\cos\alpha$$

$$= (Ks\cos\alpha + C)\cos\alpha$$

$$\boxed{HD = Ks\cos^2\alpha + C\cos\alpha}$$

Tacheometry

<u>Inclined Stadia Sights</u>

For instruments with internal focusing telescopes, the second term in all of the above equations is omitted, its resulting value being equal to zero.

For vertical angles less that 3 degrees, stadia distances may be computed just as for horizontal sights without any appreciable error.

Tacheometry

Inclined Stadia Sights, Illustrative Problems

1) The following data were obtained by stadia measurement: vertical angle = +18°23', and observed stadia intercept = 2.20m. The stadia interval factor of the instrument used is 95.5 and C = 0.30m. If the height of instrument is 1.62m, and the rod reading is taken at 1.95m, determine the following:

a) Horizontal stadia distance (HD) from A to B
b) Vertical stadia distance (VD) from the center of the instrument to the point on the rod bisected by the horizontal hair.
c) Inclined or slope distance (ID) from the instrument center to the point on the rod bisected by the horizontal cross hair.
d) Difference in elevation (DE) between the point over which the instrument is set-up and the point on which the rod was held.

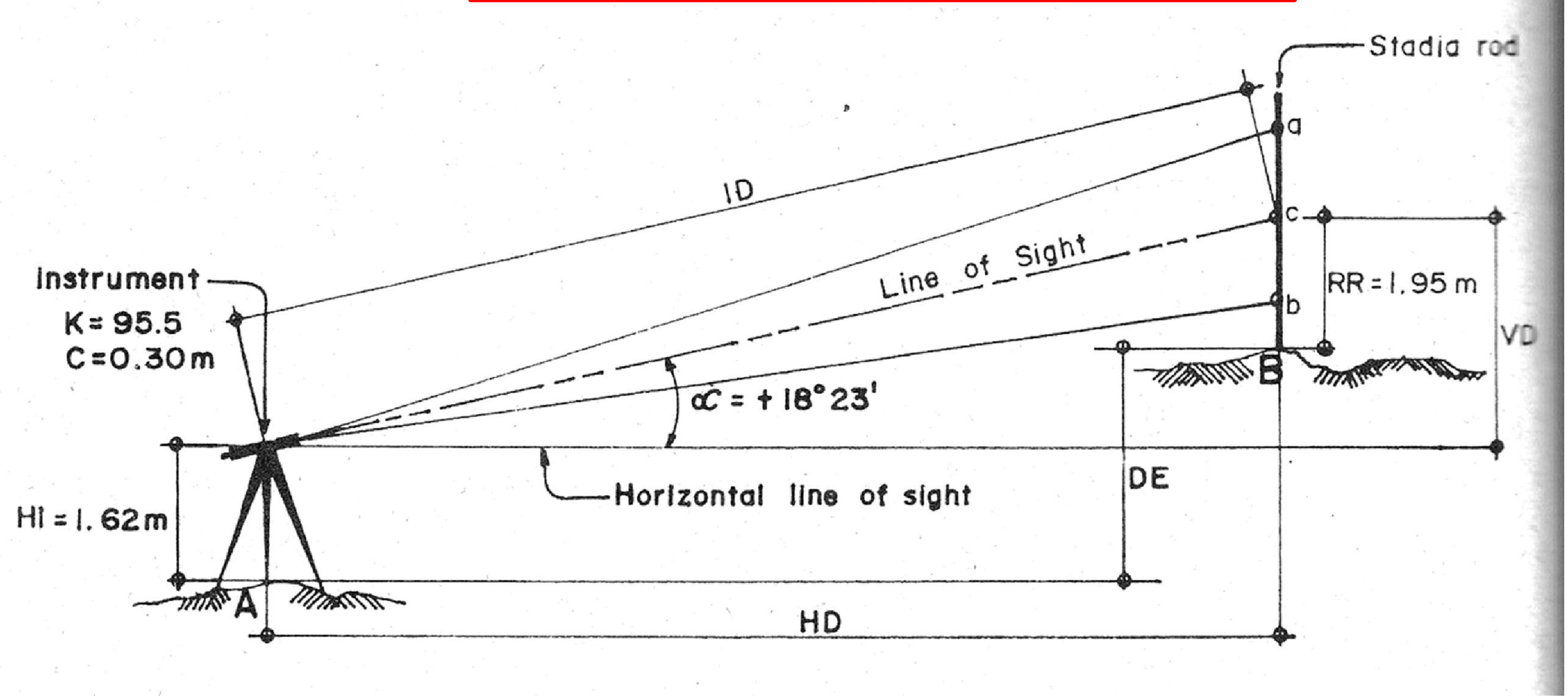
Tacheometry

Inclined Stadia Sights, Illustrative Problems

1)

$$HD = Ks\cos^2\alpha + C\cos\alpha$$
$$VD = Ks\cos\alpha\sin\alpha + C\sin\alpha$$
$$ID = Ks\cos\alpha + C$$

FIGURE 3-2.



Tacheometry

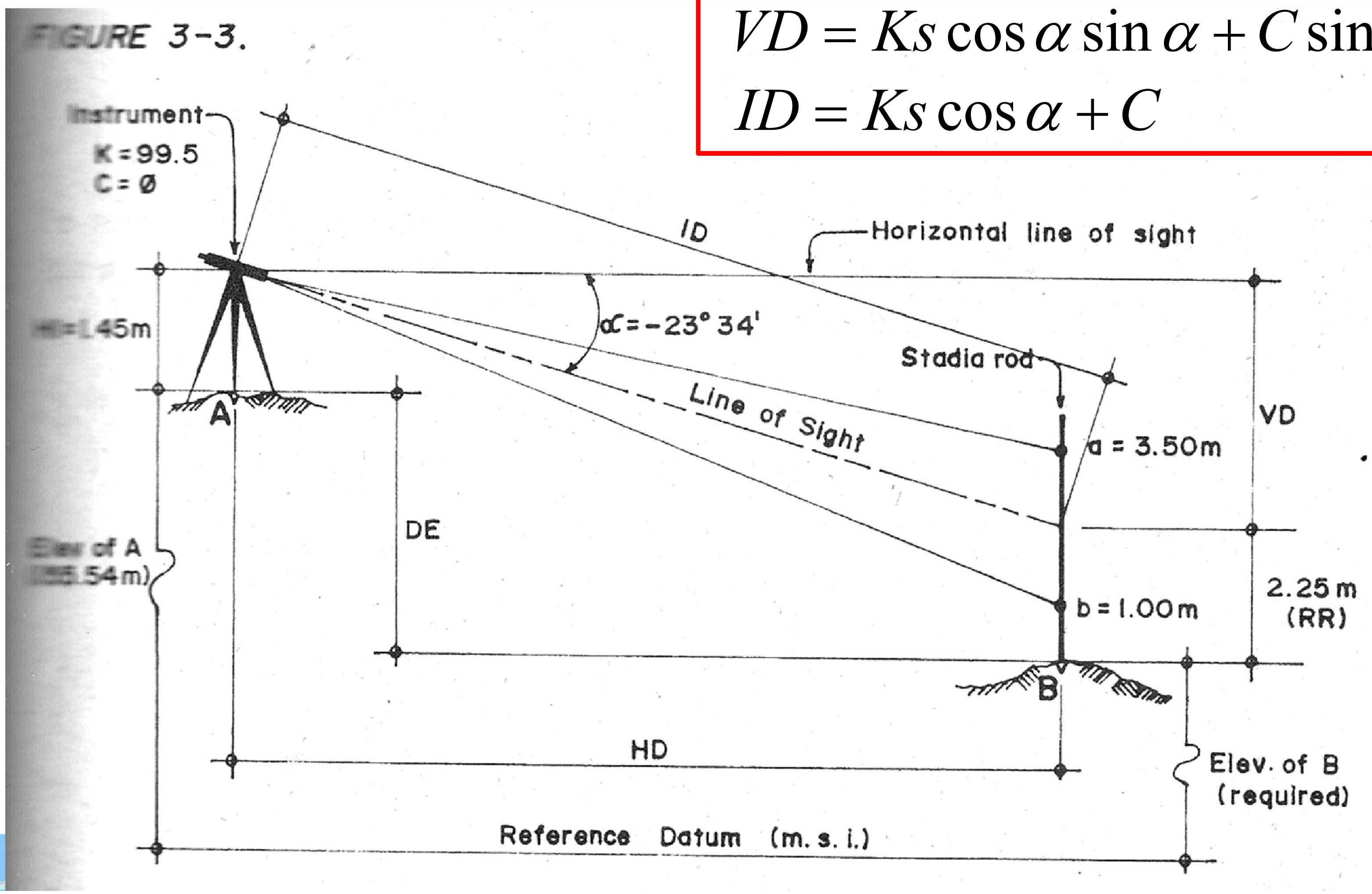
Illustrative Problems

$$HD = Ks\cos^2\alpha + C\cos\alpha$$

$$VD = Ks\cos\alpha\sin\alpha + C\sin\alpha$$

$$ID = Ks\cos\alpha + C$$

2)

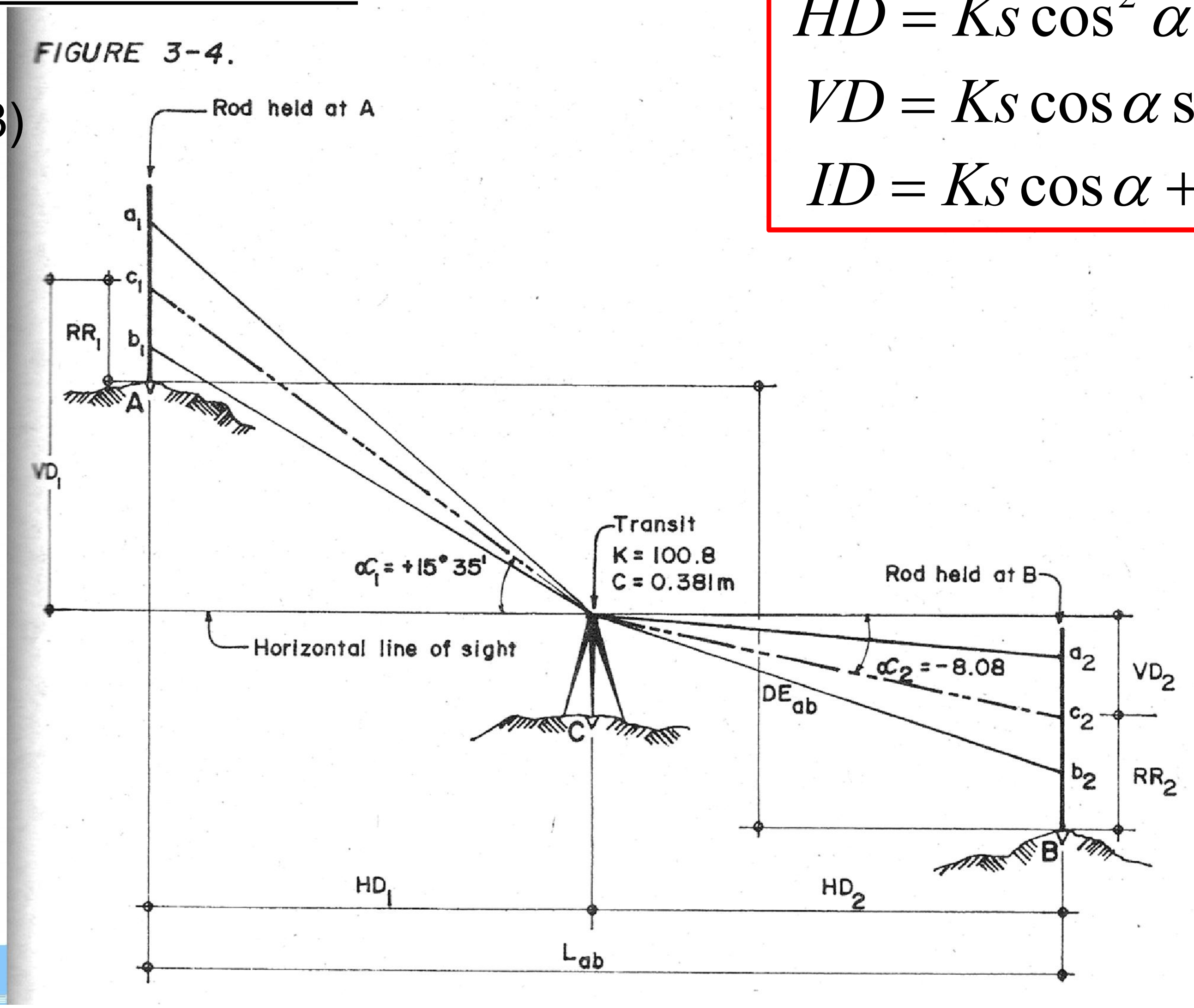


Tacheometry

Illustrative Problems

$$HD = Ks\cos^2\alpha + C\cos\alpha$$
$$VD = Ks\cos\alpha\sin\alpha + C\sin\alpha$$
$$ID = Ks\cos\alpha + C$$

3)



Tacheometry

Indirect Levelling by Stadia

- Complete the stadia level notes shown below and perform arithmetic check. Assume that K=100 and C=0.

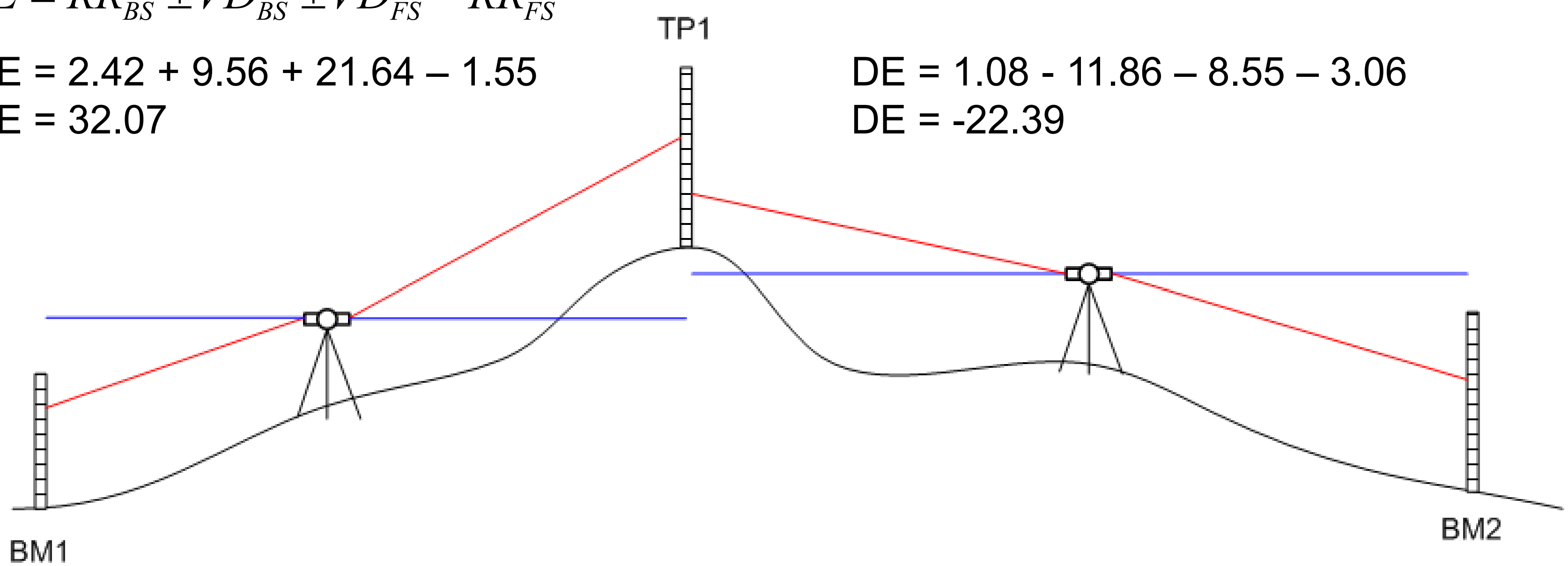
sta	Backsight				Foresight				DE (m)	Elev (m)
	s (m)	α	RR (m)	VD (m)	s (m)	α	RR (m)	VD (m)		
BM1	1.245	-4°25’	2.42							75.0
TP1	2.044	3°20’	1.08		1.515	8°18’	1.55			
BM2					1.438	-3°25’	3.06			

sta	Backsight				Foresight				DE (m)	Elev (m)
	s (m)	α	RR (m)	VD (m)	s (m)	α	RR (m)	VD (m)		
BM1	1.245	-4°25’	2.42	9.56						75.0
TP1	2.044	3°20’	1.08	11.86	1.515	8°18’	1.55	21.64	32.07	107.07
BM2					1.438	-3°25’	3.06	8.55	-22.39	84.68

$$DE = RR_{BS} \pm VD_{BS} \pm VD_{FS} - RR_{FS}$$

DE = 2.42 + 9.56 + 21.64 – 1.55
DE = 32.07

DE = 1.08 - 11.86 – 8.55 – 3.06
DE = -22.39



Tacheometry

<u>Stadia Traverse</u>

- The principal characteristic of a stadia traverse is the use of the stadia method in measuring the length of the traverse lines instead of the tape
- The following quantities are obtained:
  - Horizontal length of each line of the traverse
  - Direction of each line which may be a bearing or an azimuth
  - Elevation of the stations of the traverse and their differences in elevation

Tacheometry

Stadia Traverse (Problem)

Following are stadia intervals and vertical angles for a transit-stadia traverse. The elevation of station A is 461.08m, stadia interval factor is 100.0 and C = 0.0. Rod readings are taken at height of instrument. Compute the length of each course, the traverse perimeter, and the elevations of the traverse stations.

Station	Obs	Stadia Interval	Vertical Angle
B	A	2.59	0°46’
	C	1.33	8°15’
C	B	1.32	-8°16’
	D	3.8	-2°25’
D	C	3.78	2°20’
	E	2.19	-1°33’

Tacheometry

<u>Subtense Bar</u>

A two metre bar. The distance is determined by measuring the angle between the two ends of the bar. The farther the distance the smaller the angle.

Tacheometry

Subtense Bar (Problem)

A subtense bar 2 meters long is set up near the middle of a traverse line MN. At M, the angle subtended is 38’05”, and at N the angle is 63’16”. Find the length of MN.

Department of Civil Engineering