THEODOLITE SURVEY

RCI4C001 SURVEYING
Module IV
Theodolite Survey: Use of theodolite, temporary adjustment, measuring horizontal andvertical angles, theodolite traversing

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Theodolite Surveying

The system of surveying in which the angles (both horizontal & vertical) are measured with the help of a theodolite, is called Theodolite surveying

Compass Surveying vs. Theodolite Surveying

- Horizontal angles are measured by using a C*ompass with respect to meridian, which is less accurate and also it is not possible to measure vertical* angles with a Compass.
- So when the objects are at a considerable distance orsituated at a considerable elevation or depression ,it becomes necessary to measure horizontal and vertical angles more precisely. So these measurements are taken by an instrument known as a *theodolite.*

How Does a Theodolite Work?

A theodolite works by combining optical plummets (or plumb bobs), a spirit (bubble level), and graduated circles to find vertical and horizontal angles in surveying. An optical plummet ensures the theodolite is placed as close to exactly vertical above the survey point. The internal spirit level makes sure the device is level to to the horizon. The graduated circles, one vertical and one horizontal, allow the user to actually survey for angles.

APPLICATIONS

- Measuring horizontal and vertical angles.
- Locating points on a line.
- Prolonging survey lines.
- Finding difference of level.
- Setting out grades
- Ranging curves
- Tacheometric Survey
- Mesurement of Bearings

CLASSIFICATION OF THEODOLITES

Theodolites may be classified as ;

A. Primary

- i) Transit Theodolite.
- ii) Non Transit Theodolite.

B. Secondary

- i) Vernier Theodolites.
- ii) Micrometer Theodolites.
- iii) Modern Theodolite

CLASSIFICATION OF THEODOLITES

A. **Transit Theodolite**: A theodolite is called a transit theodolite when its telescope can be transited i.e revolved through a complete revolution about its horizontal axis in the vertical plane.

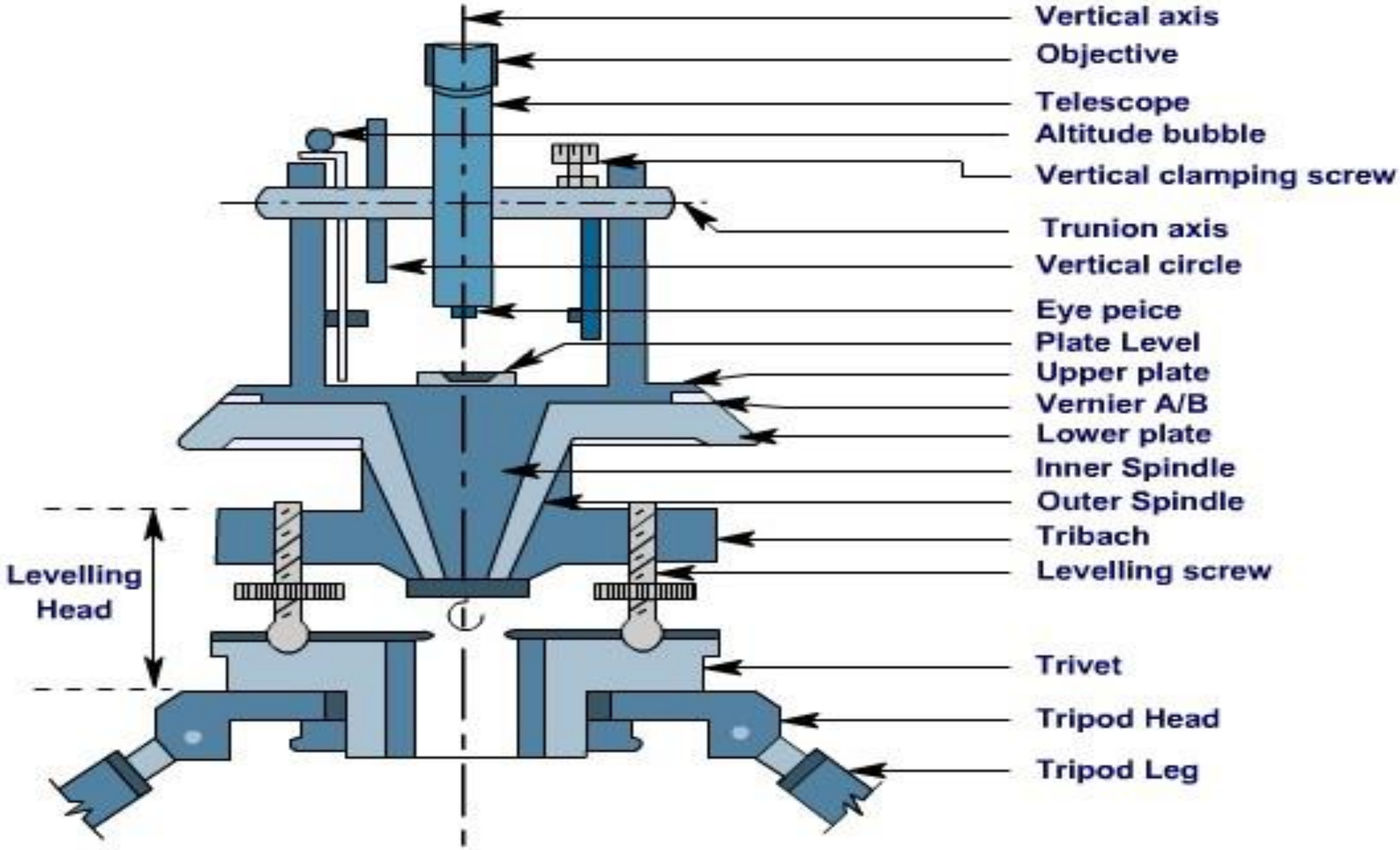
B. **Non-Transit type-** In this type the telescope is cannot be transited. They are inferior in utility and have now become *obsolete*.

Vernier Theodolite: For reading the graduated circle if verniers are used ,the theodolite is called as a Vernier Theodolite.

Micrometer Theodolite - If a *micrometer is provided* to read the graduated circle the same is called as a Micrometer Theodolite.

Vernier type theodolites are commonly used

COMPONENTS OF TRANSIT OR VERNIER THEODOLITE



Sectional view of a Thedolite

COMPONENTS OF TRANSIT OR VERNIER THEODOLITE

Transit vernier theodolite essentially consist of the following

1. Levelling Head.
2. Lower Circular Plate
3. Upper Plate.
4. Plate level.
5. Compass
6. Diaphragm.
7. T- Frame.
.8. Plumb –bob.
9. Tripod Stand.
10. Telescope

Size of Theodolite:

This is defined by the diameter of the graduated circle of the lower plate.

Common sizes are 8 cm to 12 cm while 14 cm to 25 cm are used for triangulation work or more precise works.

COMPONENTS OF TRANSIT OR VERNIER THEODOLITE

Levelling Head.

•It is the lowermost part of a theodolite. It consists of two parallel horizontal plates separated by three leveling screws.

•The lower plate with a large threaded hole in its centre is called trivet or foot plate. It provides a means to place the instrument on (tripod) stand and get it screwed. Its central aperture provides a way for suspending a plumb bob.

•The upper plate of the leveling head is called the tribrach . It contains a tapered bearing at the centre. It has three arms each carrying a leveling screw. It provides a support for the upper part of the instrument.

•The principal use of levelling head is to provide a means for levelling the instrument.

Shifting Head

•It consists of a pair of horizontal plates and an annular treaded ring. One of the plates is placed below the lower plate but above the tribrach and the other below the tribrach.

•The annular treaded ring is placed in between lower plate and the tribrach which is used to tighten/untighten the whole of the instrument.

•The shifting head is used for exact centring of the instrument after leveling has been completed.

COMPONENTS OF TRANSIT OR VERNIER THEODOLITE

Lower Plate

It is a horizontal circular plate monolithically constructe with the outer spindle. A scale is engraved at its bevell edge with divisions in degrees and minutes increasing i clockwise direction. It provides the main scale reading a horizontal angle and a means to fix / unfix the whol of the instrument.

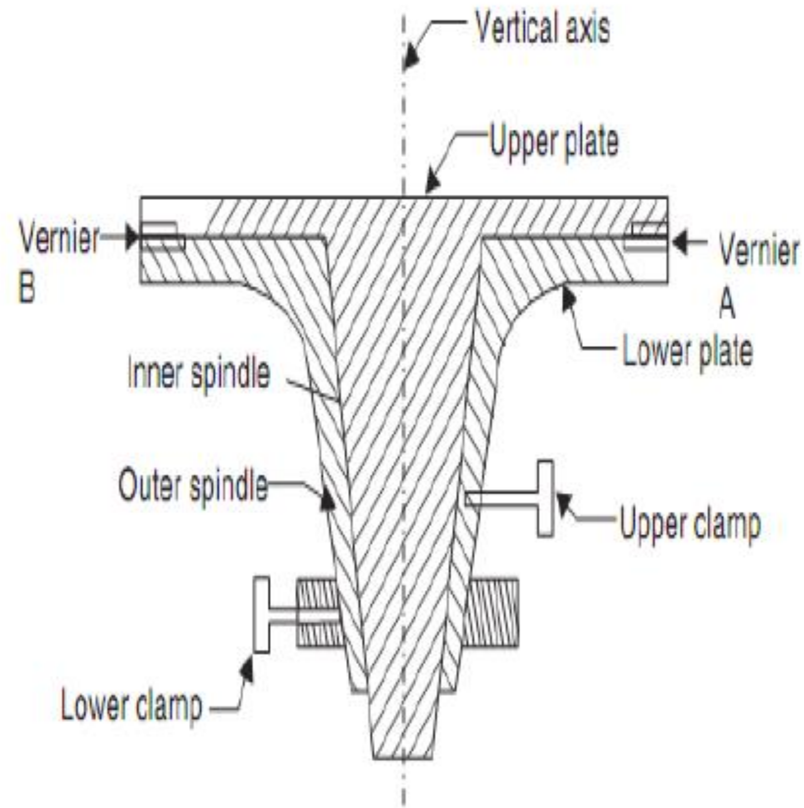


Fig. Details if Upper & Lower Plates.

Upper Plate

It is a horizontal circular plate monolithically constructe with the inner spindle. It is fitted with two diametrically opposite vernier scales designated as A and B. Functio of upper plates are to support a pair of magnifiers fo the verniers, a pair of plate levels, a pair of support frames for telescope and a means to fix / unfix the up plate of the instrument with its lower plate.

Plate Levels

A pair of level tubes are placed at right angles on the upper plate. These are used to make the vertical axis of the instrument truly vertical i.e., for leveling of the instrument.

COMPONENTS OF TRANSIT OR VERNIER THEODOLITE

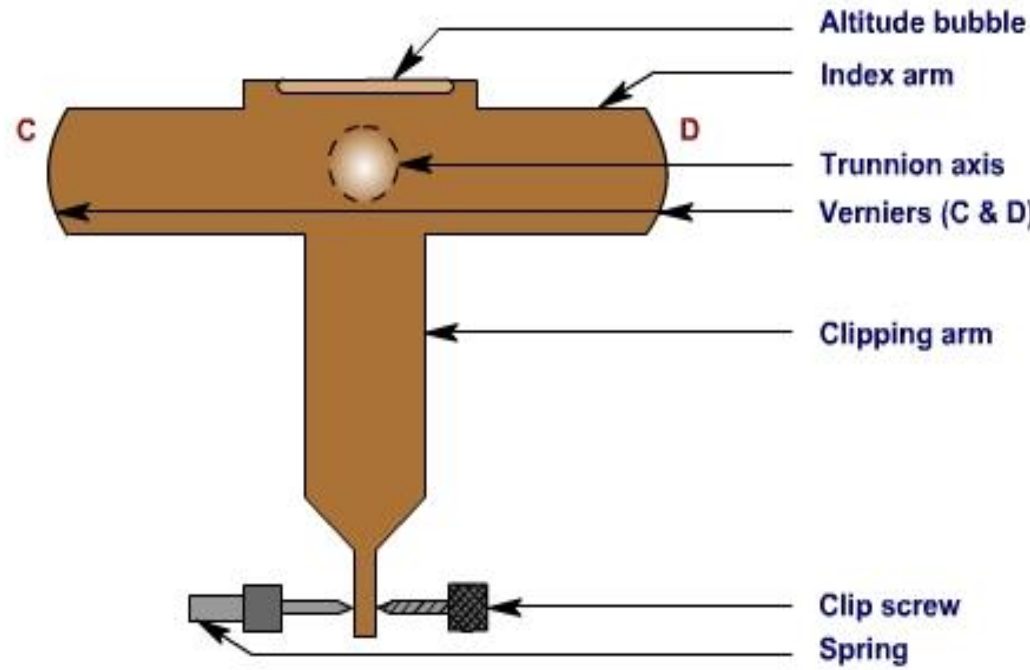
Standard (or A Frame)

Two standards resembling the letter A are attached on the upper plate. These provides the bearings of the pivots of the telescope allowing it to rotate on its trunion axis in vertical plane. The vernier frame and arm of vertical circle clamp are also attached to it.

Vernier Frame

Also called T -frame or index frame, consists of a vertical leg known as clipping arm and a horizontal bar called the index arm engraved with verniers C and D at its ends. Each of the verniers at C and D are having two scales which increases in opposite directions.

It is used as seat for altitude bubble and also provides vernier reading for vertical angle measurement



Vernier Frame

COMPONENTS OF TRANSIT OR VERNIER THEODOLITE

Telescope

The telescope of a theodolite is identical in structure and uses, as in case of a dumpy level. But, in theodolite, the telescope is mounted on a horizontal spindle called the horizontal axis or the trunnion axis to rotate it also in vertical plane.

Vertical Circle

The vertical circle is attached with the trunnion axis. It is engraved with a scale reading vertical angle in degrees and minutes. The vertical circle is divided into four quadrants each reading $0°$ to $90°$ with $0°$ - $0°$ either along vertical or in horizontal. It provides the main scale reading for vertical angle.

Altitude Bubble

A sensitive level tube placed on vernier frame is called altitude bubble. It is used to make horizontal axis truly horizontal.

Tripod Stand

The theodolite is mounted on a strong tripod when being used in the field. The legs of the tripod are solid or framed. At the lower ends of the legs, pointed steel shoes are provided to get them pushed into ground

COMPONENTS OF TRANSIT OR VERNIER THEODOLITE

ScrewsA theodolite instrument has number of screws as its component parts. These are classified into different types depending on their functions.

Leveling Screws These are present in the leveling head of a theodolite in between trivet and tribrach. These work in threaded holes in the tribrach arms and their lower ends rest in recesses in the trivet. These screws are used for leveling the instrument i.e., to make plate level axis truly horizontal.

Clamp screws These are used to fix the parts of a theodolite with which these are attached.
Lower plate Clamp Screw The clamp screw attached to the lower plate of a theodolite is called lower plate clamp screw. When it is tightened, the outer spindle gets fixed with the tribrach, and, thus, the lower plate gets fixed in position.
Upper plate Clamp Screw The clamp screw attached with the upper plate of a theodolite is called upper plate clamp screw. When it is tightened, the inner spindle gets fixed with the outer spindle and, thus, the upper plate gets fixed in position.
Vertical plate Clamp Screw It is present on a frame fixed with standard and above the shaft of trunnion axis. It is used to clamp the telescope in any plane and hence at any desired vertical angle.

COMPONENTS OF TRANSIT OR VERNIER THEODOLITE

The manipulation of the upper plate and lower plate clamp screws provide three conditions:

1. When both the upper plate clamp screw and the lower plate clamp screw are tightened, the instrument gets fully fixed.
2. When the upper plate clamp screw is tightened and the lower plate clamp screw is opened, the instrument rotates on its outer axis, There is no relative motion between the two plate and the readings in the horizontal vernier scales do not change.
3. When the lower plate clamp screw is tightened, and the upper plate is opened, the instrument rotates on the inner axis with outer axis fixed. The readings in the horizontal vernier scales change

Tangent Screws With each clamping screw, there is a tangent screw present in the instrument to provide fine movement. The tangent screws work only after its clamping screws get tightened.

- Thus when the upper clamp screw has been tightened, small movement of the upper plate can be made by the upper tangent screw
- when the lower clamp screw has been tightened, small movement of the lower plate can be made by the lower tangent screw and similarly for vertical clamp screw.

TERMS USED IN TRANSIT VERNIER THEODOLITE OPERATION

Centering :

Centering means setting the theodolite exactly over an instrument. It can be done by means of plumb bob suspended from a small hook attached to the vertical axis of the theodolite.

Transiting :

Transiting is also known as *plunging or reversing. It is the process of turning the telescope* about its horizontal axis through 1800 in the vertical plane.

Face Left :

If the vertical circle of the instrument is on the left side of the observer while taking a reading ,the position is called the *face left*.

Face Right:

If the vertical circle of the instrument is on the right side of the observer while taking a reading ,the position is called the *face right*

TERMS USED IN TRANSIT VERNIER THEODOLITE OPERATION

Changing Face :

It is the operation of bringing the vertical circle to the right of the observer ,if originally it is to the left , and vice – versa.

Leveling :

Leveling of an instrument is done to make the vertical axis of the instrument truly vertical. Generally, there are three leveling screws and two plate levels are present in a theodolite instrument.

Line of Collimation :

It is also known as the line of sight .It is an imaginary line joining the intersection of the cross- hairs of the diaphragm to the optical centre of the object- glass and its continuation.

Axis of the telescope:

It is also known an imaginary line joining the optical centre of the object- glass to the centre of eye piece.

FUNDAMENTAL LINES IN TRANSIT THEODOLITE

The fundamental lines are imagined in a theodolite instrument are

- Vertical Axis
- Horizontal axis
- Line of collimation
- Axis of the altitude level tube
- Axis of the plate level

In a perfectly adjusted instrument, the fundamental lines bear relations

1. The vertical cross hair should lie in a plane perpendicular to the horizontal axis .
2. The axis of each plate level should lie in a plane perpendicular to the vertical axis
3. The horizontal axis should be perpendicular to the vertical axis .
4. The axis of the telescope level should be parallel to the line of sight

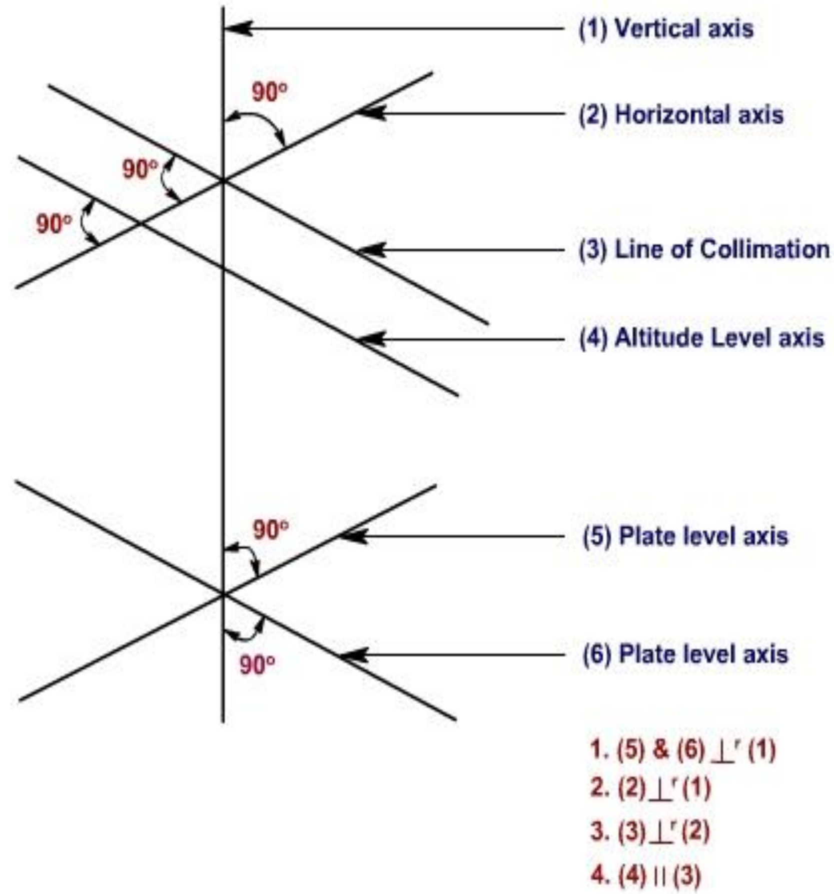


Figure 21.1 Fundamental lines of a Theodolite and their Relationship

5. The line of sight should be perpendicular to the horizontal axis at its intersection with the vertical axis . Also, the optical axis , the axis of the objective slide & the line of sight should coincide

Temporary Adjustment of Transit Theodolite

At each station point, before taking any observation, it is required to carry out some operations in sequence. The set of operations those are required to be done on an instrument in order to make it ready for taking observation is known as temporary adjustment.

It consists of following operations:

- Setting
- Centring
- Leveling
- Focussing.

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Temporary Adjustment of Transit Theodolite

Setting

The setting operation consists of fixing the theodolite with the tripod stand along with approximate leveling and centring over the station.

For setting up the instrument, the tripod is placed over the station with its legs widely spread so that the centre of the tripod head lies above the station point and its head approximately level (by eye estimation). The instrument is then fixed with the tripod by screwing through trivet. The height of the instrument should be such that observer can see through telescope conveniently. After this, a plumb bob is suspended from the bottom of the instrument and it should be such that plumb bob should point near to the station mark

Centring

The operation involved in placing the vertical axis of the instrument exactly over the station mark is known as centring.

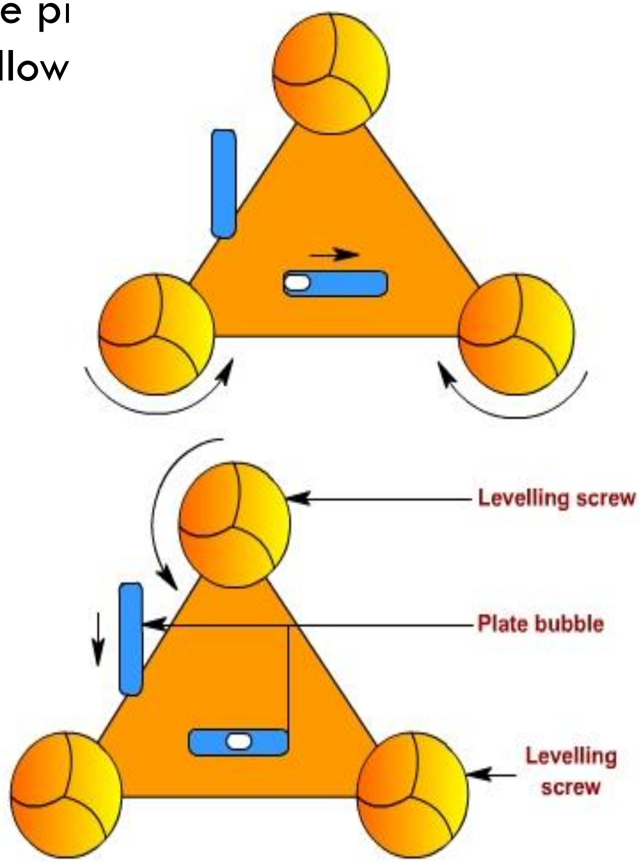
First, the approximate centring of the instrument is done by moving the tripod legs radially or circumferentially as per need of the circumstances.

Finally, exact centring is done by using the shifting head of the instrument. During this, first the screw-clamping ring of the shifting head is loosened and the upper plate of the shifting head is slid over the lower one until the plumb bob is exactly over the station mark. After the exact centring, the screw clamping ring gets tightened.

Temporary Adjustment of Transit Theodolite

Leveling

Leveling of an instrument is done to make the vertical axis of the instrument truly vertical. Generally, there are three leveling screws and two plate levels are pı instrument. Thus, leveling is being achieved by carrying out the follow



<u>Step 1:</u> Bring one of the level tube parallel to any two of the foot screws, by rotating the upper part of the instrument.

<u>Step 2:</u> The bubble is brought to the centre of the level tube by rotating both the foot screws either inward or outward. The bubble **moves in** the same direction as the left thumb

<u>Step 3:</u> The bubble of the other level tube is then brought to the centre of the level tube by rotating the third foot screw either inward or outward

<u>Step 4:</u> Repeat Step 2 and step 3 in the same quadrant till both the bubble remain central.

<u>Step 5:</u> By rotating the upper part of the instrument through 180°, the level tube is brought parallel to first two foot screws in reverse order

The bubble will remain in the centre if the instrument is in permanent adjustment. Otherwise, repeat the whole process starting from step1 to step5.

Temporary Adjustment of Transit Theodolite

Focusing

To obtain the clear reading, the image formed by the objective lens should fall in the plane of diaphragm and the focus of eye-piece should also be at the plane of diaphragm. This is being carried out by removing parallax by proper focusing of objective and eye-piece. Thus, focusing operation involves two steps

Focusing of Eye-piece

The eye-piece is focused to make the appearence of cross hairs distinct and clear. This is being carried out in steps: First, point the telescope towards the sky or hold a sheet of white paper in front of the objective; Next, move the eye-piece in or out by rotating it gradually until the cross hairs appear quite sharp and clear. Focusing of eye-piece depends on the eye-sight of observer and so for each observer it needs to adjusted accordingly

Focusing of Objective

It is done for each independent observation to bring the image of the object in the plane of cross hairs. It includes following steps of operation: First, direct the telescope towards the object for observation. Next, turn the focusing screw until the image of the object appears clear and sharp as the observer looks through properly focused eye-piece. If focusing has been done properly, there will be no parallax

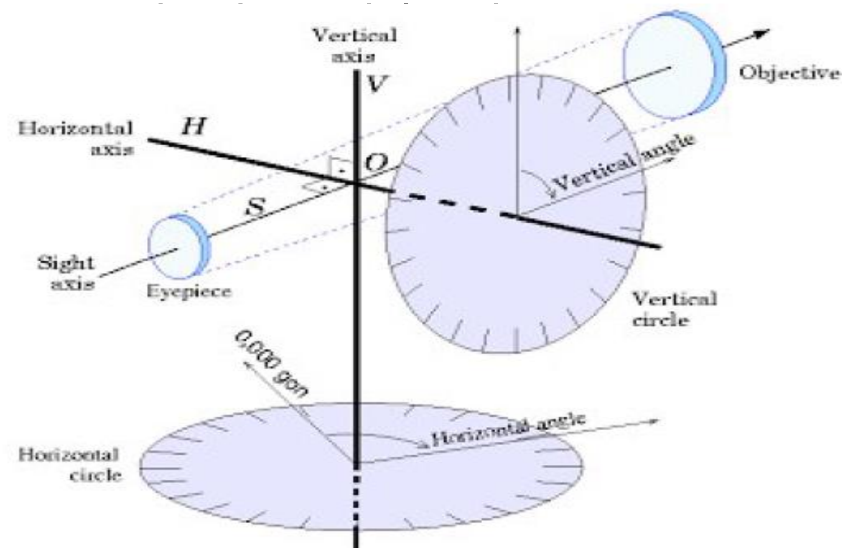
Permanent Adjustment of Transit Theodolite

An instrument is said to in permanent adjustment if it satisfies all the relations among its fundamental lines. *The permanent adjustments are made to establish the relationship between the fundamental lines of the theodolite.*

The permanent adjustment of an instrument usually gets disturbed after long or prolonged use. So, the state of relationship among different fundamental lines should be checked occasionally and corrections are required to be done, if necessary.

The operations are based on the geometry of the fundamental line and thus, may get upset one relation while rectifying other. In order permanent adjustment should be made in the order.

1. Adjustment of Vertical cross hair;
2. Adjustment of plate level axes;
3. Adjustment of line of sight;
4. Adjustment of horizontal axis;
5. Adjustment of the axis of the telescope;
6. Adjustment of vertical circle index.

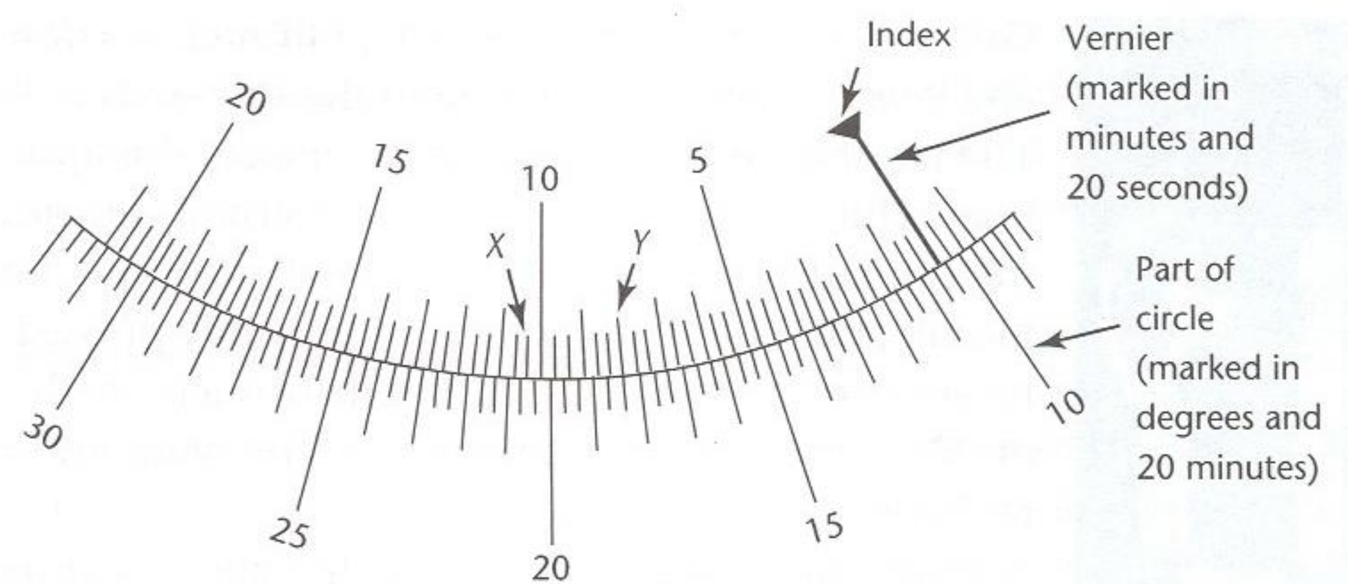


READING VERNIER TRANSIT THEODOLITE

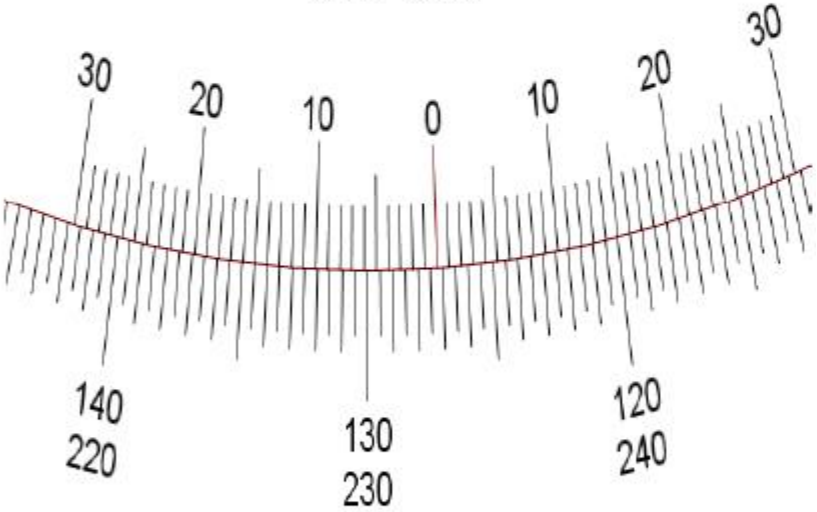
Least Count of the vernier

This is the difference between the value of the smallest division of the main scale and that of the smallest division of the vernier scale. It is the smallest value that can be measured by a theodolite.

METHOD OF READING VERNIER



READING VERNIER TRANSIT THEODOLITE



Measurement of Horizontal Angle

There are three methods of measuring horizontal angles:-

i) Ordinary Method.

ii) Repetition Method.

iii) Reiteration Method

		Face left Swing Right												Face right Swing left												Average horizontal angle		
Inst. at	Sighted to	A			B		Mean			No. of repetition	Horizontal angles			A			B		Mean			No. of repetition	Horizontal angles					
		°	'	"	'	"	°	'	"		°	'	"	°	'	"	'	"	°	'	"		°	'	"	°	'	"
O	P	00	00	00	00	00	00	00	00					00	00	00	00	00	00	00	00							
	Q	58	43	20	43	20	58	43	20	1	58	43	20	58	43	40	43	40	58	43	40	1	58	43	40			
	Q	168	19	40	19	40	168	19	40	3	58	43	33	168	19	20	19	20	168	19	20	3	58	43	27	58	43	30

Method of Repetition

When the precision of measurement of a horizontal angle is desired to be more than the least count of the instrument, repetition method is used.

In this method, the desired angle is measured several times, and average of the observed values is considered as the value of the angle. The precision thus attained is to a much finer degree than the least count of the vernier

Measurement of Horizontal Angle

To represent the direction of a line, the horizontal angle of the line from a reference line is to be measured. The steps required to be adopted are as follows:

- Two points one on each of the lines, say P and Q, are to be marked.
- A transit theodolite is to be set at the point of intersection of the lines, say at O. Initially, the instrument is in the face left condition and its temporary adjustment is to be done over the point O.
- Both the lower and upper plate main screws are to released and get the vernier A set to 0° (or 360°) mark on the main scale. After clamping the upper main screw, index of vernier A is to be brought exactly to the zero of the main scale using the upper plate tangent screw.
- At this stage the reading of the vernier B should be 180°.
- Swing the telescope in horizontal plane and point it to the left station, say P. Tighten lower plate clamp screw & bisect the signal at P exactly using the lower plate tangent screw. Record readings
- Loosen the upper plate main screw and turn the telescope the signal at Q is sighted. Tighten the upper clamp screw and bisect the ranging pole at Q exactly using the upper plate tangent screw.
- Read both the verniers A and B and record the readings. The reading of the vernier A is the angle POQ. The vernier B gives the value of angle POQ after deducting from it 180°. The mean of two values of the angles obtained from the verniers A and B is the required angle P'O'Q'.
- Change the face of the instrument to the face right by transiting telescope and swinging it by 180°
- Repeat steps 3 to 8 and determine another value of the angle P'O'Q'.
- The mean of the face left and face right observations is the final required angle P'O'Q'.

Measurement of Horizontal Angle

The **method of repetition eliminates different errors** present in measurement of horizontal angle.

1. The errors due to eccentricity of verniers and centres get eliminated as readings from both the verniers are taken.
2. The errors due to inaccurate graduations get eliminated as the readings are observed at different parts of the circle.
3. The errors due to lack in adjustment of line of collimation and the horizontal axis of the instrument get eliminated for considering both faces readings.
4. Errors due to inaccurate bisection of the object, eccentric centering etc are eliminated partially as these get counter-balanced in different observations.

However, the errors due to slip, due to displacement of station or its signal do not get eliminated and moreover, these errors are of cumulative in nature.

Measurement of Horizontal Angle

Method of Reiteration

Method of reiteration for measurement of horizontal angle is usually adopted in case several angles of well distributed points/ objects are to be measured from the same instrument station with high precision.

In this method, angles are measured successively starting from a point termed as initial station. The angle between the terminating station and the initial station is the last observation during a set of measurement of horizontal angle by method of reiteration.

This process of measuring the angles at an instrument station round the point is to obtain a check on their sum being equal to 360° and is called closing the horizon.

When the horizon is closed, the final reading of the vernier should be the same as its initial reading if there is no discrepancy.

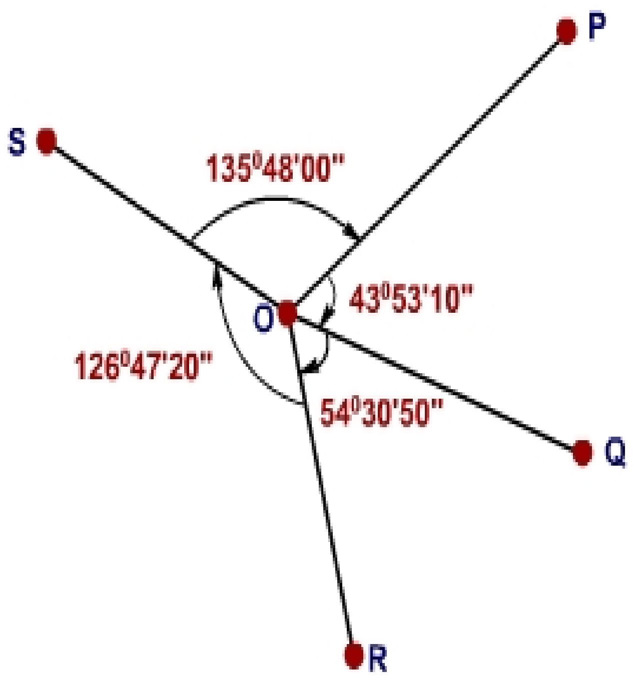
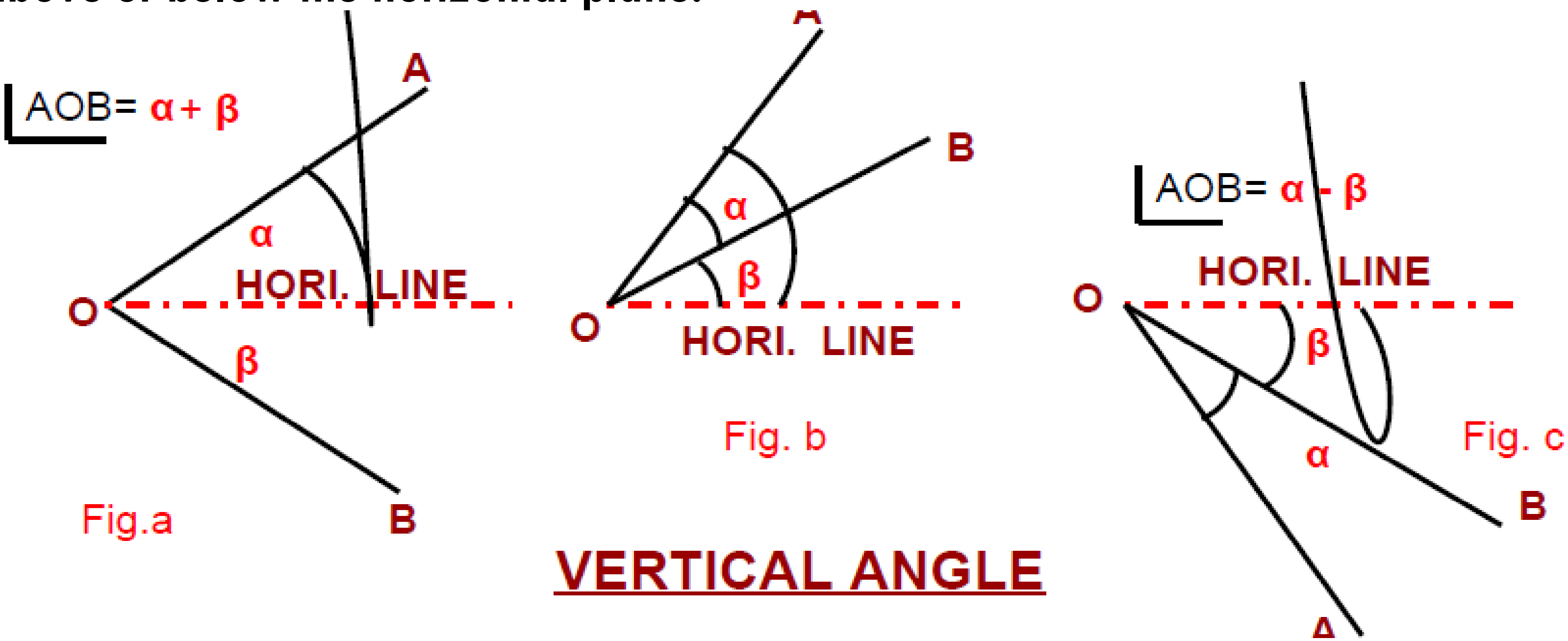


Figure shows a instrument station O where the angles POQ, QOR and ROS have to be measured by method of reiteration.

Measurement Of Vertical Angle

A vertical angle is the angle between the inclined line of sight and the horizontal plane through the trunnion axis of the instrument. Prior to the measurement of vertical angle, instrument is required to be leveled with reference to the altitude level.

It may be an angle of *elevation or depression according as the object is* above or below the horizontal plane.



VERTICAL ANGLE

Measurement Of Vertical Angle

Procedure :

1. The temporary adjustment of the instrument is to be done on the station.
2. Then, leveling of theodolite is to be done using altitude level (the operations involved are same as leveling using plate level).
3. Loosen the vertical circle clamp, and direct the telescope towards the object whose vertical angle is required to be measured. Clamp the vertical circle, and bisect the point by turning the vertical tangent screw.
4. Read and record the scale with vernier C and D in table
5. Change the face of the instrument and read the vertical angle again.
6. The required vertical angle is the average of the values in steps 4 and 5.

		Face left											Face left											Average vertical angle		
Inst. at	Sighted to	C			D		Mean			Vertical angles			C			D		Mean			Vertical angles					
		°	'	"	'	"	°	'	"	°	'	"	°	'	"	'	"	°	'	"	°	'	"	°	'	"
O	P	+28	24	20	24	00	+28	24	10	+28	24	10	+28	24	40	24	20	+28	24	30	+28	24	30	+28	24	30
	P"	-24	35	40	35	20	-24	35	40	-24	35	40	-24	36	00	35	40	-24	35	50	-24	35	40	-24	35	35

Angle POR = 53° 59' 55"

TRAVERSE SURVEYING

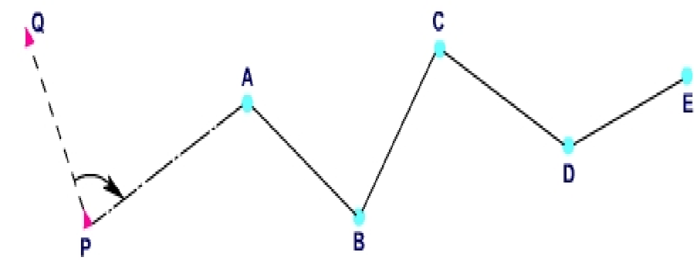
Traverse

A traverse consists of a series of straight lines connected successively at established points, along the route of a survey. The points defining the ends of the traverse line are called traverse stations or traverse points. Distances between traverse stations are known as traverse side

Fundamentally, there are two types of traverses:

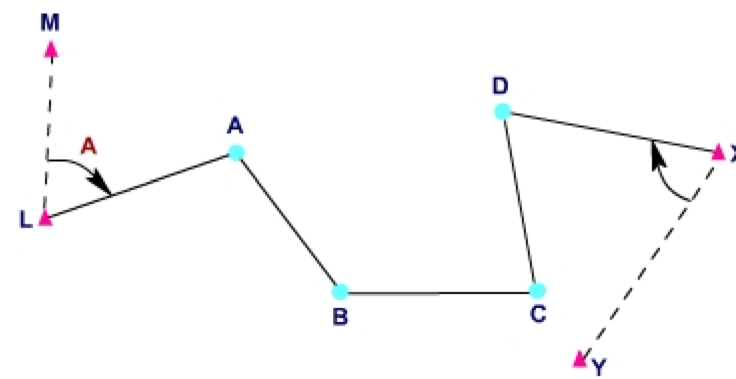
Open Traverse

An open traverse originates from a point whose position may be known or unknown but terminates to a point whose position is not known. In this type of traverse, computational check is not possible to detect error or blunder in distances or directions.



Closed Traverse

When a traverse originates from a known position and also terminates to known position then it is called a closed traverse. (If the origin and terminating points are the same then it is called closed-loop traverse This type of traverse permits an internal check on the accuracy of angular measurements



TRAVERSE SURVEYING

Traverse Surveying

Surveying for establishment of control points of a traverse consists of different steps of operation. These are

1. Reconnaissance
2. Selection of stations sites
3. Marking of stations
4. Field measurements
5. Computations

Chain Traversing

The method in which the whole work is done with chain and tape is called chain traversing. No angle measurement is used and the directions of the lines are fixed entirely by linear measurements.

Chain and Compass Traversing

In chain and compass traversing, the magnetic bearings of the survey lines are measured by a compass and the lengths of the lines are measured either with a chain or with a tape. The direction of the magnetic meridian is established at each traverse station independently. The method is also known as a tree or loose needle method.

THEODOLITE TRAVERSING

Theodolite Traversing by Fast Needle Method

The method in which the magnetic bearings of traverse lines are measured by a theodolite fitted with s compass is called traversing by fast needle method. The direction of the magnetic meridian is not established at each station but instead, the magnetic bearings of the lines are measured with a reference so that direction of the magnetic meridian established at the first station.

There are three methods of observing the bearings of lines by fast needle method.

i. Direct method with transiting,
ii. Direct method without transiting,
iii. Back bearing method.

THEODOLITE TRAVERSING

Interior Angle Traverse

The field operations in the interior angle method of traversing consist of occupation of the successive stations and a transit or theodolite is being used to measure horizontal angle.

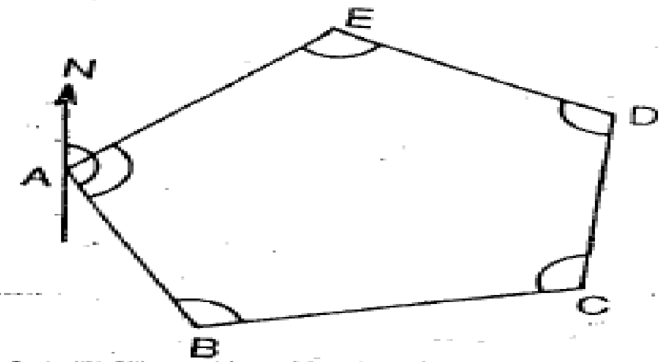
At each station the vernier is set at zero, and a backsight to the preceding station is taken. The instrument is then turned on its upper motion until the advance station is sighted and the interior angle is observed.

All interior angles is generally observed twice, once with telescope direct and other with the telescope reversed. Immediately after completion of observation, an arithmetical check on the angular error of closure should be performed to detect any blunder or excessively large error in angular measurement.

In interior angle adjustment method, the algebraic sum of the interior angles is being computed and needs to be $(2n - 4) \times 90^{\circ}$ where n is the number of sides in the traverse. If there is no difference, no error is associated with the observation

THEODOLITE TRAVERSING

Procedure



1. Consider Fig. 9.16. The theodolite is set up and centred over A. The plate bubble is levelled. Vernier A is set at 0 and vernier B at 180°. The upper clamp is fixed.
2. The telescope is oriented along the north line with the help of the tubular compass fitted to the instrument. Then the magnetic bearing of AB is measured.
3. Again vernier A is set at 0° and the upper clamp is kept fixed.
4. The lower clamp is loosened and the ranging rod at E is bisected. Now, this clamp is tightened and the upper one opened. By turning the telescope clockwise, the ranging rod at B is bisected. The readings on the verniers are noted. ∠A is obtained in this fashion.

   The face of the instrument is changed and ∠A is measured once more. The mean of the two observations gives the correct value of ∠A.
5. Similarly, the other angles are measured by centring the theodolite at B, C, D and E.

   The arithmetical check is applied as follows:

   $$(2n - 4) \times 90° = \text{Sum of interior angles}$$

   If there is any discrepancy, the error is distributed among the angles.
6. For plotting the traverse, latitudes and departures of the traverse legs are calculated. The interior details are marked by applying the plane-table or transit-and-tape method

THEODOLITE TRAVERSING

Deflection Angle Traverse

In this method of traverse surveying, successive stations are occupied and deflection angles are measured by a transit or theodolite.
At each station, a backsight is taken to the previous station with vernier A set at zero. The telescope is then reversed by plunging it.
A foresight to the next station is then taken by turning the instrument about the vertical axis on its upper motion, and the deflection angle is observed. The angle is recorded as right R or left L, according to whether the upper motion is turned clockwise or counter clockwise.

Usually, deflection angles are observed twice, once with the telescope in face left and the other in face right condition. Immediately after completion of traverse observation, an arithmetical check on the angular error of closure should be performed

Deflection angle method of traversing is being generally used for open looped closed traverse. It is most useful for the location survey of linear engineering works such as highways, railways, canals and pipelines etc.

THEODOLITE TRAVERSING

1. The theodolite is set up at A, and then centred and levelled. After this, the bearing of the line AB is measured in the usual manner.
2. The theodolite is now shifted and centred over B. The plate bubble is levelled and vernier A set at 0°. Then a backsight is taken on A. The telescope is transited and by turning it clockwise the ranging rod at C is bisected. The vernier readings are taken. Then the deflection angle ϕ_1 is determined—it is the average value of the angles obtained from verniers A and B.
3. Similarly, the other deflection angles ϕ_2 and ϕ_3 are measured.
4. A field book is prepared in which the deflection angles and offsets are clearly noted.

THEODOLITE TRAVERSING

Fast Needle/ Azimuth Traverse

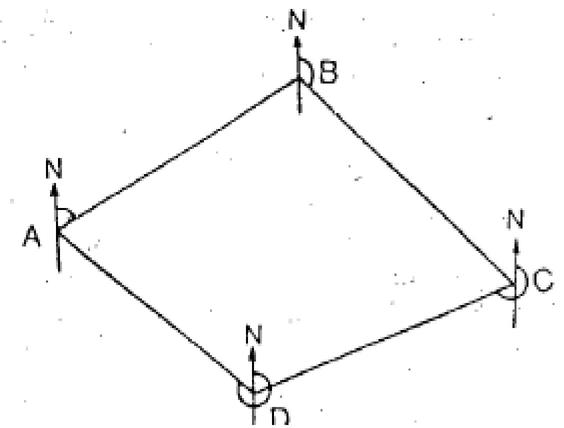
In this method, at each traverse station the back azimuth of the preceding line and the azimuth of the forward line are measured using a transit. The reference meridian may be either true or assumed. In this method, successive stations are occupied, beginning with the line of known or assumed azimuth.

At each station the transit is "oriented" by setting the A vernier or horizontal circle index to read the back azimuth (forward azimuth $\pm$ 180°) of the preceding line and then back sighting to the preceding traverse station. The instrument is then turned on the upper motion, and a foresight on the following traverse station is secured.

The reading indicated by the horizontal circle index on the clockwise circle is the azimuth of the forward line. Any angular error of closure of a traverse becomes evident by the difference between initial and final observations taken along the first line.

The method is used extensively for topographic and other surveys where a large number of details are located by angular and linear measurements from the traverse stations.

THEODOLITE TRAVERSING



1. The theodolite is set up at A. The vernier A is set at 0°. The telescope is oriented along the north line with the help of the trough compass or tubular compass fitted to the theodolite. The lower clamp is fixed.
2. The upper clamp is loosened and the ranging rod at B is bisected. The reading on vernier A gives the fore bearing of AB: say it is 30°. The backbearing of the line DA is also measured from A. Now the upper clamp is also fixed. The traverse is considered in clockwise direction.
3. The instrument is shifted and set up at B with vernier A fixed at the reading of 30°. The lower clamp is loosened and the ranging rod at A is bisected. The telescope is now transited. The upper clamp is then released and the ranging rod at C bisected. Now the reading on vernier A gives the bearing of BC: say it is 100°.
4. Again the instrument is shifted and set up at C with vernier A fixed at 100°.
5. The same process is repeated to get the fore bearing of CD.
6. Similarly, the fore bearings of the remaining sides are measured.
7. At the end of the traverse the FB and BB of DA should differ by 180°.

Sources of Error in Theodolite

1. Instrument Errors
   - a)Non-adjustment of plate bubble
   - b) Line of collimation not being perpendicular to horizontal axis .
   - c) Horizontal axis not being perpendicular to vertical axis.
   - d) Eccentricity of Inner and Outer axes
   - e) Graduation not being Uniform.

2.Personal Errors

3. Natural Errors

Mistakes during Theodolite Traverse

- Reading the wrong vernier scale
- Misreading the vernier

There are two sets of vernier scales marked on a single vernier. While taking reading, use that set of figures which increase in the same direction as the figure in the main direction.

- Reading the vernier in the wrong direction.
- Turning the wrong tangent screws
- Failing to tighten the clamp screw.
- Reading the numbers on the horizontal scale from the wrong row.
- Reading angles in the wrong direction.
- Sighting on the wrong signals or setting up over the wrong station
- Booking the wrong values
- Missing the wrong right or left in deflection angle
- Using haphazard field procedure.