Theodolite

COMPONENTS OF A THEODOLITE

INTRODUCTION

- The theodolite is used to measure horizontal and vertical angles. The **accuracy** with which these angles can be measured **ranges from 5mins to 0,1 secs**. It is a very important instrument in plane surveying.
- Its essential components are:

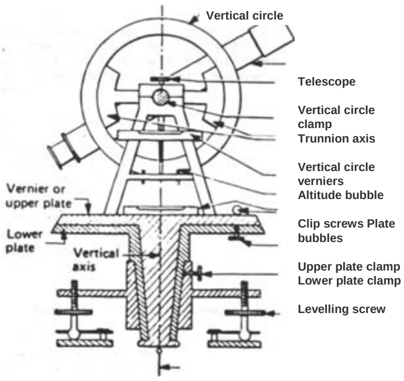
  - a **telescope** which can rotate or transit through 360° about a transverse horizontal axis.

  - The bearings for this horizontal or trunnion axis are mounted in two vertical pillars or **standards**. The standards are mounted on a **horizontal upper plate**.

  - The upper plate rotates through 360° about a **vertical** or alidade axis, the bearing for the alidade axis is mounted in a **lower horizontal plate**.

  - Rotation of the upper plate about the alidade axis is known as **traversing** the instrument. The horizontal plates can be levelled by means of three **foot screws** located beneath the lower plate, in a similar way to a level.

Simplified Diagram Of An Early Vernier Theodolite Showing Most Of The Main Components



DESCRIPTION OF MAIN COMPONENTS

1. Telescope

- It has the same features as in a level graticule with eyepiece and internal focussing for the telescope itself. The same precautions for focussing the eyepiece and eliminating parallax should be applied.

DESCRIPTION OF MAIN COMPONENTS

2. Vertical Scale (or Vertical Circle)

- The **vertical circle** is a full 360° scale. It is mounted within one of the standards with its centre co-linear with the trunnion axis. It is used to measure the angle between the line of sight (collimation axis) of the telescope and the horizontal. This is known as the **vertical angle.**
- Note that the side of the instrument where the standard containing the scale is found is referred to as the **face** of the instrument.

DESCRIPTION OF MAIN COMPONENTS

3. Vertical Clamp and Tangent Screw

- In order to hold the telescope at a particular vertical angle a vertical clamp is provided. This is located on one of the standards and its release will allow free transiting of the telescope. When clamped, the telescope can be slowly transited using another fine adjustment screw known as the vertical tangent screw.

DESCRIPTION OF MAIN COMPONENTS

4. Upper Plate

- The upper plate is the base on which the standards and vertical circle are placed. Rotation or **transiting** of the upper plate about a vertical (alidade) axis will also cause the entire standards/telescope assembly to rotate in an identical manner. For the instrument to be in correct adjustment it is therefore necessary that the upper plate must be perpendicular to the alidade axis and parallel to the trunnion axis. Also, before the instrument is used, the upper plate must be "levelled". This is achieved by adjustment of three **foot screws** and observing a precise tube bubble. This bubble is known as the **plate bubble** and is placed on the upper plate.

DESCRIPTION OF MAIN COMPONENTS

5. The Lower Plate

- The lower plate is the **base** of the whole instrument. It houses the foot screws and the bearing for the vertical axis. It is rigidly attached to the tripod mounting assembly and does not move.

DESCRIPTION OF MAIN COMPONENTS

6. Horizontal Scale (or Horizontal Circle)

- The horizontal circle is a full 3600 scale. It is often placed **between the upper and lower plates** with its centre co-linear with the vertical axis. It is capable of full independent rotation about the trunnion axis so that any particular direction may be arbitrarily set to read zero.
- It is used to define the horizontal direction in which the telescope is sighted. Therefore a horizontal angle measurement requires two horizontal scale readings taken by observing two different targets.
- The difference between these readings will be the horizontal angle subtended by the two targets at the theodolite station.

DESCRIPTION OF MAIN COMPONENTS

7. The Upper Horizontal Clamp and Tangent Screw.

- The upper horizontal clamp is provided to clamp the upper plate to the horizontal circle. Once the clamp is released the instrument is free to traverse through 360° around the horizontal circle. When clamped, the instrument can be gradually transited around the circle by use of the upper horizontal tangent screw. It is the upper clamp and tangent screw which are used during a sequence or "round" of horizontal angle measurements.

DESCRIPTION OF MAIN COMPONENTS

8. The Lower Horizontal Clamp and Tangent Screw.

- The lower horizontal clamp is provided to clamp the horizontal circle to the lower plate. Once the clamp is released the circle is free to rotate about the vertical axis. When clamped, the horizontal circle can be gradually rotated using the lower-horizontal tangent screw. The lower clamp and tangent screw must only be used at the start of a sequence or "round" of horizontal angle measurements to set the first reading to zero (if so desired).

DESCRIPTION OF MAIN COMPONENTS

9. Circle Reading and Optical Micrometer

- Modern instruments usually have one eyepiece for reading both circles. It is usually located on one of the standards. The vertical and horizontal circles require illumination in order to read them. This is usually provided by small circular mirrors which can be angled and rotated to reflect maximum light onto the circles.

DESCRIPTION OF MAIN COMPONENTS

10. Optical Plumb

- Unlike optical levels, theodolites must be set up over fixed control stations, often defined by wooden pegs and nails. Positioning of the instrument must be achieved to nail head accuracy. Modern instruments have an optical plumb to achieve this. It consists of an eyepiece set in the lower plate. The line of sight through the eyepiece, which is reflected vertically downwards beneath the instrument by means of a prism, is precisely in line with the vertical axis.

DESCRIPTION OF MAIN COMPONENTS

Comments

1. Horizontal Clamps and Tangent Screws.

- Great care must be taken not to confuse the upper and lower horizontal clamps and tangent screws. With the upper clamp released, the instrument rotates around the horizontal circle. With the lower released, the instrument and circle rotate around the lower plate.

DESCRIPTION OF MAIN COMPONENTS

Comments

1. Horizontal Clamps and Tangent Screws.

- Great care must be taken not to confuse the upper and lower horizontal clamps and tangent screws. With the upper clamp released, the instrument rotates around the horizontal circle. With the lower released, the instrument and circle rotate around the lower plate.

- The upper tangent screw moves the instrument relative to the circle, the lower tangent screw moves the instrument and circle relative to the lower plate. Tangent screws only work when the clamps are tightened, they have ***limited travel and must not be forced.***

DESCRIPTION OF MAIN COMPONENTS

Comments

2. Instrument Station.

- Since the function of the instrument is to measure vertical and horizontal angles subtended at the instrument, the position of the instrument is important (unlike the position of a level). Theodolites are therefore set up over ***control stations*** which are permanent locations. The art of setting up a theodolite over a station <to nail head accuracy) and getting it level is best demonstrated rather than described.

DESCRIPTION OF MAIN COMPONENTS

Comments

3. Familiarisation

- On a modern theodolite there should be the following controls (silver knobs):
  - Telescope focussing
  - Vertical clamp
  - Vertical tangent screw
  - Vertical circle fine adjustment screw (if not an automatic indexing instrument)
  - Microptic adjustment
  - Upper horizontal clamp
  - Lower horizontal clamp (note that on some instruments the two horizontal clamps are combined into one).
  - h) Upper Horizontal tangent screw
  - i) Lower horizontal tangent screw.

DESCRIPTION OF MAIN COMPONENTS

Comments

- When one considers additional features such as illuminating mirrors, eyepiece focussing, a precise plate bubble (possibly a vertical circle precise bubble), an approximate circular bubble), optical plumb and foot screws, one realises that a theodolite is a ***complicated*** **and** ***very expensive*** i ns t rument.

- So regarding the practical side:
  Make sure you understand ***the function of every control.*** Different types of instrument will have different features.

- Treat the instrument with great care. Never force screws. Never force the instrument into its box. Always thoroughly dry the instrument with tissues if it gets wet. Never replace a wet instrument in its box. Report any accidents or faults.

OPERATION OF A THEODOLITE

Before operating, the theodolite needs to be placed directly over the station (so called nail accuracy), and then level it. This has to be done at the same time as described below. (*this is better done in practice than describe in words!*)

OPERATION OF A THEODOLITE

A. <u>Precise levelling and positioning of theodolite</u>

1. Set tripod *and* instrument with optical plumb *almost* over the station.
2. Unclamp one of the horizontal clamp (either will do) and traverse the instrument so that the plate bubble is parallel to two of the footscrews.
3. Adjust those two footscrews until the plate bubble is level.
4. Traverse the instrument so that the bubble is perpendicular to the already adjusted footscrews.
5. Re-level using the third footscrew.

OPERATION OF A THEODOLITE

A. <u>Precise levelling and positioning of theodolite</u>

6. Traverse the instrument in the same direction and re-align parallel to the first two footscrews.
7. Repeat stage 3 and then traverse as in 4. Then repeat stages 5-7, until the best mean level bubble is obtained (to one division accuracy).
8. Unclamp the base of the instrument and <u>while viewing</u> through optical plumb, <u>slide</u> the instrument across the tripod base until it is exactly over the station. Do not rotate the instrument about the tripod base. (Note that it might be necessary to repeat stages 1-7!!).

OPERATION OF A THEODOLITE

<u>B. Zeroing the Horizontal circle</u>

1. Unclamp the Upper Horizontal clamp.
2. Traverse the instrument until the horizontal circle reads *approximately* zero.
3. Re-clamp the Upper Clamp.
4. Adjust the Upper Horizontal Tangent Screw until the reading is approximately zero.
5. Select a target whose direction you wish to assign a zero scale reading.
6. Unclamp the <u>Lower</u> Horizontal clamp.

OPERATION OF A THEODOLITE

<u>B. Zeroing the Horizontal circle</u>

7. Traverse the instrument (and circle) until the telescope is pointing approximately at the selected target.
8. Re-clamp and, sighting through the telescope, align the vertical graticule precisely onto the target using the <u>Lower</u> Horizontal Tangent Screw. It is important that you approach the target in the direction in which you intend to continue to traverse to the next target. This is to minimize errors and is dealt with in more detail later.

   The instrument is now correctly sighted onto the target and is reading zero. The <u>lower</u> horizontal clamp and <u>lower</u> tangent screw should <u>not</u> be touched again until this particular ‘round’ of readings has been completed.

OPERATION OF A THEODOLITE

<u>C. “FACE” and “SWING”</u>

- As defined earlier in the subject, the standard which houses the vertical circle is called the <u>Face</u> of the instrument. If, when sighting through the telescope, this standard (the face) is on your left, then <u>FACE LEFT</u> is recorded for all readings taken. If on the right, then we record <u>FACE RIGHT</u>.
- The <u>Swing</u> of the instrument is defined as the <u>direction</u> in which the theodolite is traversed (i.e. rotated about vertical axis). If, when traversing, the telescope lens moves to the left we record readings as <u>SWING LEFT</u>. If on the right, we record readings as <u>SWING RIGHT</u>.
- Every horizontal circle reading <u>must</u> be booked with the face and swing identified. Usually it is conventional to work with opposite face and swing, i.e. FL/SR and FR/SL.

OPERATION OF A THEODOLITE

D. Taking a round of Horizontal readings
The following procedure would normally be adopted to measure the horizontal angle subtended at the theodolite station T by the two targets A and B.

1. Set Horizontal scale to zero and ensure both clamps are tightened.
2. Select Face (L or R) by transiting the telescope (if necessary).
3. Release the lower horizontal clamp. Traverse the instrument to approach target A using the appropriate Swing direction (L or R) stopping just short of the target.
4. Clamp the lower clamp.

OPERATION OF A THEODOLITE

D. Taking a round of Horizontal readings
The following procedure would normally be adopted to measure the horizontal angle subtended at the theodolite station T by the two targets A and B.

5. Adjust the lower horizontal tangent screw to complete the swing movement and bring the graticule cross precisely in line with target A. Do not "overshoot"!
6. Read and book the horizontal scale reading (which should be zero).
7. Now unclamp the Upper horizontal clamp. Traverse the instrument to approach target B using the same swing as before, stopping just short of target. Re-tighten (clamp) the upper clamp.

OPERATION OF A THEODOLITE

D. Taking a round of Horizontal readings
The following procedure would normally be adopted to measure the horizontal angle subtended at the theodolite station T by the two targets A and B.

8. Adjust the upper horizontal tangent screw to complete the swing movement and bring the graticule cross in line with target B.
9. Read and book the horizontal scale reading.

OPERATION OF A THEODOLITE

D. Taking a round of Horizontal readings

- Now if we transit the telescope by approximately 180º, this will be facing away from target B. By repeating stages 8-10 above (opposite swing now), another reading is recorded for target B and then at A (continuing traverse).
- This round of readings is now complete and will give us two versions of the same angle. Depending on the nature of the work and the accuracy required we may produce more rounds of readings, using opposite faces and swings or different positions on the horizontal circle producing 4 or even 8 versions of the same angle.
- The reason for this systematic approach using different combinations of face, swing and osition on the horizontal circle is to minimise systematic errors.

OPERATION OF A THEODOLITE

E. Booking Horizontal Angle Readings

An example, based on the description in D, is given below. Note that face left and face right readings on the same target differ by approximately 180º, if the instrument is in precise adjustment.

OPERATION OF A THEODOLITE

E. Booking Horizontal Angle Readings

Instrument Station (I.S.)	Target	Face/Swing	Horiz.Circle (° ′ ″)	Reduced Angle (° ′ ″)
T	A	L/R	000-00-00	136-34-20
T	B	L/R	136-34-20	
T	B	R/L	316-34-40	136-34-30
T	A	R/L	180-00-10	

The mean value is 136º- 34′- 25″.

OPERATION OF A THEODOLITE

E. Booking Horizontal Angle Readings

- Note that the horizontal scale is always graduated so that readings increase in a clockwise sense. Also, the reduced angle is clockwise from A to B (i.e. reading at B minus reading at A or say RB-RA).
- However, consider the case of reducing as RA-RB .This would have represented the clockwise rotation from B to A and the booking should have been as follows.

OPERATION OF A THEODOLITE

E. Booking Horizontal Angle Readings

Instrument Station (I.S.)	Target	Face/Swing	Horiz.Circle (° ′ ″)	Reduced Angle (° ′ ″)
T	A	L/R	360-00-00	223-25-40
T	B	L/R	136-34-20	
T	B	R/L	316-34-40	223-25-30
T	A	R/L	180-00-10	

The mean value is 223º- 25′- 35″.

OPERATION OF A THEODOLITE

E. Booking Horizontal Angle Readings

- Both reductions are equally acceptable, but the important question is: which angle has been obtained? It is easy to work out with common sense by visualizing the real situation. This approach is good enough when angles are close to 90º but will not necessarily work for angles close to 180º!