Theodolite Adjustment

The most significant errors affecting the operation of a theodolite are geometrically cancelled by recording angle readings in both direct and inverted positions. However, that does not negate the benefits of a well-calibrated instrument. In practice, many observations are made on one side only (in topographic mapping, for example). Also, with a finely-tuned instrument, a discrepancy in the readings will help identify other problems (e.g., an unstable tripod, observation or recording blunders).

The mechanics of the calibration procedure will depend on the theodolite. This is only a discussion of the underlying geometry. Be aware that an electronic theodolite may have a routine that will measure these errors and adjust the readings accordingly. This has certain advantages over mechanical adjustments. No weather seals are broken, there is no wear on the screws, and there is little chance of inadvertently introducing some other error in the adjustment process.

Four calibration procedures are given below. Their order is important, particularly for the last two on the list. If a steeple check were performed before the double deflection, then two errors would be observed together, and it would not be possible to isolate them.

1. Vertical Axis — Leveling the Instrument
2. Vertical Collimation
3. Line of Sight Perpendicular to Trunnion — Double Deflection Check
4. Trunnion Axis Level — Steeple Check

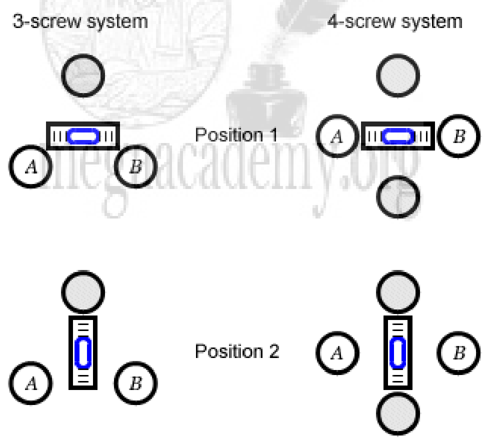
The Adjustments:

1. Vertical Axis — Leveling the Instrument

The first step in calibrating an instrument is to see that it is properly leveled. If an instrument is not leveled, then the vertical axis is not plumb, and that is the axis about which horizontal angles are measured.

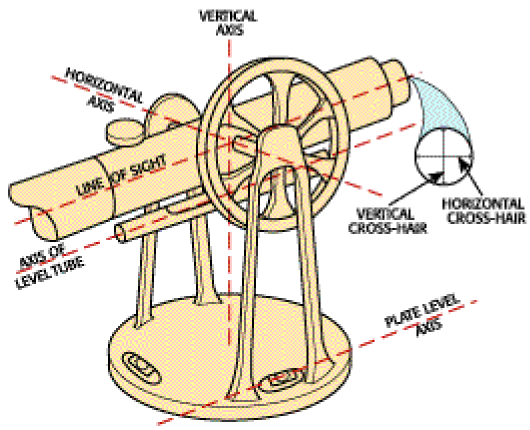
The instrument or (more likely) the Tribrach may have a circular bull's-eye leveling vial, which is precise enough for centering and for low-order work. The tube leveling vial is much more precise. The vertical axis must be perpendicular to this vial. Imagine a line running lengthwise through the center of the vial. When the vial is level, then the axis is perpendicular to this one level line. If it is perpendicular to any two level lines, then it is plumb, perpendicular to all level lines. It is best to level the vial in two perpendicular positions, which is why some instruments have two vials mounted at right angles.

Tribrach

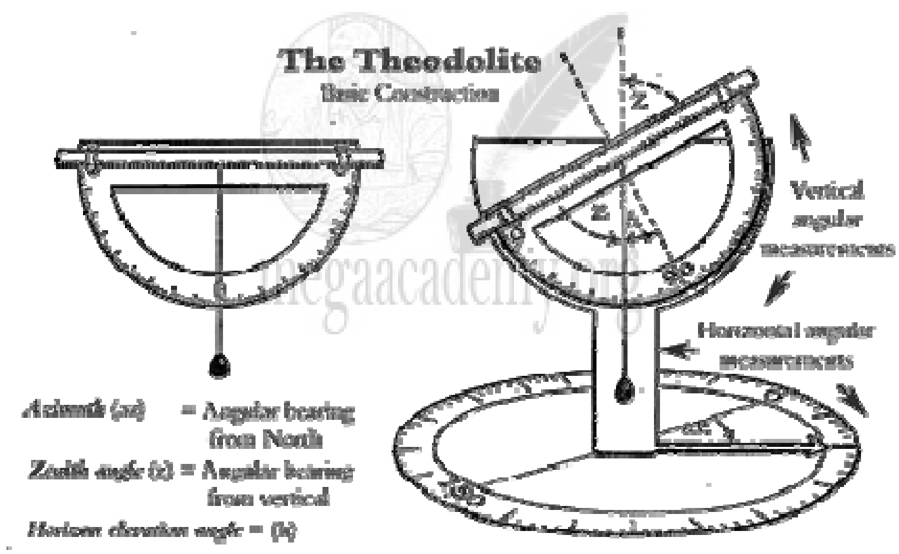


Begin in position 1 as shown here, with the vial aligned with two leveling screws, *A* and *B*. In the case of a four-screw system, pick two opposite screws. After leveling in position one, turn 90° to position 2. Level again, using only the screw(s) not aligned with the first position. If this is done correctly, then the second leveling causes the instrument to teeter on line *A* and *B*, so the first line remains level.

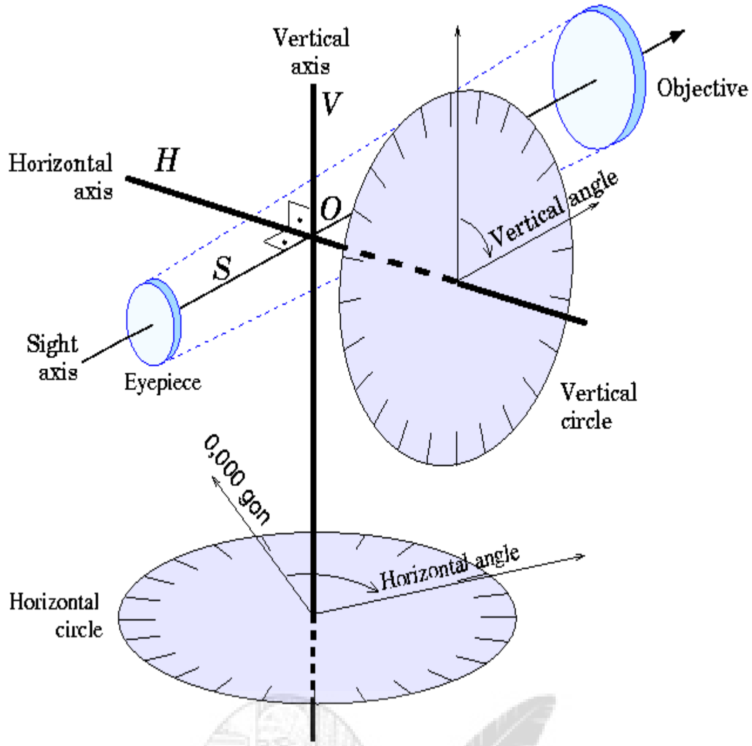
Now check the level vial itself. After leveling in position 2, turn 180°. If the vial is not still level, then that is because it is not perpendicular to the vertical axis. The bubble shows two times the error. Turn the vial adjustment (usually a single) until the bubble goes halfway toward the center. Re-level and check it again.



Fundamental Axis



Theodolite Basic Construction



Fundamental Axis

Having completed this, the vertical axis is plumb, so it would be a good time to check the bulls-eye vial. Without touching the leveling screws, turn the bulls-eye adjustments (there must be at least two) to move the bubble to the center. Although it would be practical to adjust the optical plummet at this time, that really is a separate procedure, and it is not required for the adjustments that follow. The instrument does not need to be centered on any particular point.

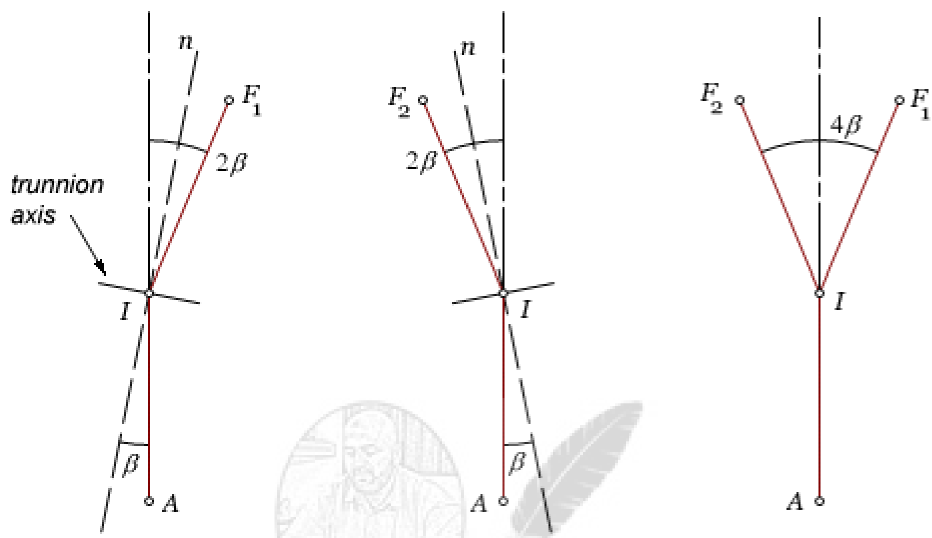
Vertical Collimation

Next is the vertical collimation. Take direct and inverted vertical angle readings on a target. The sum of the readings is 360° plus two times the error. Depending on the model of instrument, the error might be taken out of the reading by adjusting the vertical scale, with a vertical adjustment of the crosshair, or with an electronic calibration procedure.

Line of Sight Perpendicular to Trunnion — Double Deflection Check

The next error to address is that caused by the line of sight not being perpendicular to the trunnion axis. In this step, it is important to use something very close to a horizontal line of sight. This way even if the trunnion axis is out of level, it introduces zero error on a level sight. With a level sight, any error can be attributed to the line of sight being off center.

Take a backsight in direct position. Without releasing the horizontal motion, plunge the scope over to an inverted position and set a mark at a foresight (also level). This is a zero-deflection staking, 180°. On the left side of the illustration, the instrument is at point I, the backsight is point A, and point F_1 is set at the foresight. Line n is perpendicular to the trunnion axis, as the line of sight should be. The line of sight is deflected from line n by an angle β. The error in the backsight reverses direction in the foresight. The foresight direction is in error by two times the deflection error (2β).

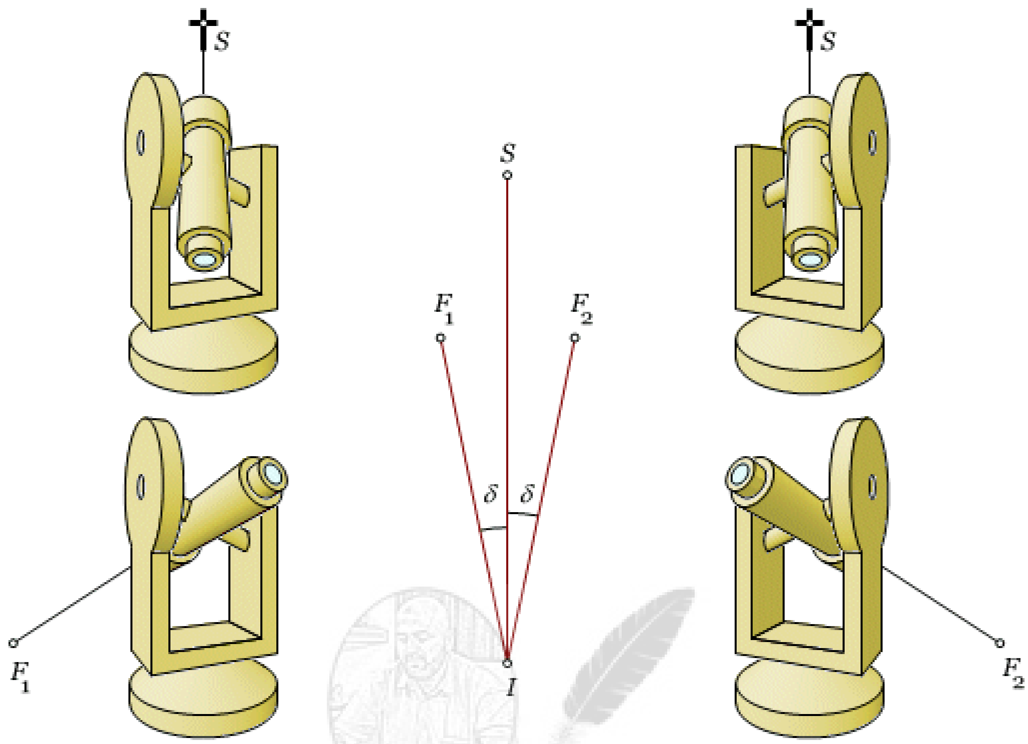


Turn to the same backsight in inverted position. Plunge the scope again, and in direct position, set another mark at the foresight, F_2, as shown in the center of the picture. The angle between the two foresight marks is four times the deflection error. It is corrected by moving the crosshair horizontally.

Note that this last check was made without reading the horizontal scale. It would also be possible to take direct and inverted readings on the same target. The difference between the readings is 180° plus two times the deflection error. A drawback is that this method takes the scale reading on faith. There is certainly some eccentricity in the scale. Another problem is that, depending on the instrument, the pointing of the scope may have much greater precision than the scale reading. This particularly applies to the older vernier theodolites.

Trunnion Axis Level — Steeple Check

At this point, the only error left is that cause by the trunnion axis being out of level. That calls for a tower check. Find a natural sight that can be observed at a very steep upward vertical angle (such as a tower). Backsight it in direct position. Without releasing the horizontal motion, set out a foresight on the level, or, if possible, at a steep downward angle. Repeat the procedure in inverted position. In this illustration, the second mark is to the right of the first and the right end of the trunnion axis needs to be raised, or the left end lowered. The deflection error, δ, refers to the difference between the backsight and foresight directions. It is not a measure of the axis tilt. An angle of 2δ will be subtended between the two foresights.



On modern instruments there typically is no exposed adjustment screw for the alignment of the trunnion axis, and not many instrument operators would have the confidence to open the housing and look for it. It is still a good thing to be aware of the instrument's condition.

Reference: http://whistleralley.com/surveying/theoadjust