# ON THE LEVEL

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A surveyor's level is an instrument with a telescope and a level bubble, or the equivalent attached to the telescope. The telescope has a reticle, commonly called crosshairs, and there are adjustment screws that allow one to raise or lower the horizontal crosshair so that it can be positioned at the optical center of the telescope. When the level instrument is rotated about its vertical axis, the instrument must stay in the same horizontal plane.

Leveling is the operation of determining differences in elevation between points on or relatively near the surface of the earth. It is also the determination of the elevation of points (orthometric heights) relative to some level surface called a datum. (See box at end of article.)

### Field Procedures for Leveling

Referring to Figure 1, the leveling instrument is positioned so that a rod held on a position of known elevation (bench mark) can be read with ease. The eyepiece on the telescope magnifies the viewed image, and the readable distance from the level to the rod depends on the eyepiece magnification. Generally speaking, the maximum readable distance is less than 300 feet. The surveyor observes the rod reading where the horizontal crosshair intersects the rod, and this rod reading is recorded in the field book. The rod reading, called a backsight, is added to the elevation of the bench mark to get the height of instrument (HI). This HI is the elevation of the horizontal plane that contains the horizontal crosshair in the level. The rod on the bench mark is now moved along the level route and positioned at a distance from the level approximately equal to the distance of the level from the starting bench mark. This ground point is called a turning point (TP). The TP can be a rigid natural object or a special baseplate used specifically for this purpose. The rod is positioned on the TP and the surveyor observes the rod reading where the horizontal crosshair intersects the rod. The rod reading, called a foresight, is subtracted from the HI to determine the elevation of the TP. The rod remains on the TP, the level is moved along the level route, and the process just described is repeated until the final elevation is established or a tie is made to another bench mark.

It is important that the distance from the level to the backsight rod be nearly equal to the distance from the level to the foresight rod. These distances should not vary by more than 30 feet. As the level party progresses along the level route, the sum of the backsight distances should also be nearly equal to the sum of the foresight distances. (The total difference should not exceed 30 feet.) By maintaining near equality between backsight and foresight distance, an error caused by the horizontal crosshair not being in the optical center of the level telescope is canceled out.

### Accuracy of Levels

Before development of the automatic level, all leveling instruments used tubular vials to determine the level plane. The inner surface of the level vial is the arc of a circle, and the sensitivity of the vial is expressed in seconds-of-arc per 2mm division. Divisions on all level vials, whether it be a spirit level, theodolite, or total station, are 2mm apart. A rule of thumb for the setting accuracy is 1/3 the sensitivity of the vial. This means that a dumpy level with a 60 second bubble has a setting accuracy of approximately 20 seconds-of-arc. On the more precise tilting levels, a coincidence bubble is installed that provides a setting accuracy of less than one second-of-arc.

The standard measure of level instrument accuracy is the standard deviation for 1 kilometer (3280') double run leveling. You will see it in all manufacturers' brochures. For higher priced levels, the standard deviation can be as low as 0.2mm; the less expensive levels may have a standard deviation as large as 10mm.

What are the characteristics of a good level? A good textbook answer would be: The most important requirements are stability and a proper relationship between the sensitivity of the compensator and the resolving power of the telescope. A level can vary in design and quality from the most basic instruments used by contractors for site preparation to the very precise tilting and automatic levels used for First-order geodetic leveling. The price difference between the basic automatic level and the more sophisticated level is very little, compared to the increased accuracy that is obtained. In today's market, the list price of a basic automatic level, with a standard deviation of 8mm to 10mm, is about $500; the best Second-order automatic levels (without parallel plate micrometers), with a standard deviation of 0.5mm, have a list price in the $1500 to $1700 range.

It is beyond the scope of this newsletter to delve into the characteristics of the different levels. What we will try to do is answer the question: Is there such a thing as a very good level, or is a level just a level? To answer this question, we must look at the telescope and the compensator.

### Properties of the Telescope and Compensator

The purpose of the telescope is to produce a sharp image and to project the crosshairs through its optical center. The illumination or brightness of the image depends on the magnifying power, the size of the objective lens, and the quality of the glass and craftsmanship used to produce and assemble the telescope. If the objective is small, the magnification must be low to have good illumination. As the magnification increases, the size of the objective lens must also increase to have good illumination. This characteristic is evident when you visit your instrument dealer and compare automatic levels. The lower-priced instruments are small, with magnification of about 20x. The 24x and 26x instruments are larger because the objective lens must be larger for good illumination. The 30x and 32x levels are even larger. As the magnification increases, some manufacturers install two-speed focus and continuous tangent screws.

Automatic levels with a compensating device are the standard of the industry today. The compensator consists of one or more reflecting elements, usually prisms, set in the line of collimation in the telescope. One of the reflectors is suspended within the instrument by

either wires, bands, or strips of nylon, depending on the manufacturer. The orientation of this movable element is changed by gravity whenever the alignment of the instrument is changed. The design of the compensator is such that the path followed by a ray of light, entering at the center of the objective, is deflected to intersect the center of the crosshairs. A compensator automatically makes the line of sight horizontal and maintains it in that position. When the instrument is approximately leveled by means of a circular bubble, the movable component of the compensator swings free to a position that makes the line of sight horizontal. The compensator has a wide working range, up to 15 minutes-of-arc. This is why the circular bubble, with a sensitivity of 8 to 10 minutes-of-arc, need only be leveled to the extent that it stays inside the setting circle of the circular bubble vial. When you hear a rattling sound inside an automatic level, the level is not broken. This is the normal sound associated with compensator movement.

In addition to the convenience of not having to watch the bubble, automatic levels have a much higher setting accuracy than spirit levels (coincidence levels, or split bubbles as they are called, are an exception).

The following table illustrates the characteristics of severallevels that are available from your instrument dealer.

| Magnification | Setting Accuracy | Standard Deviation for 1km Double Run Leveling |
|---|---|---|
| 19x | 20.00" (level vial) | ± 10.0mm |
| 20x | 0.80" (compensator) | ± 2.5mm |
| 24x | 0.50" (compensator | ± 1.5mm |
| 32x | 0.30" (compensator) | ± 0.7mm |
| 32x | 0.25" (split bubble) | ± 0.2mm |

The next timeyour instrument dealer recommends a higher manification level, saying it is well worth the price, believe him. Leveling is the most accurate of all the surveying disciplines, but it requires a good level. The answer to the question "Is there such a thing as a very good level?" is "Absolutely **YES**.'

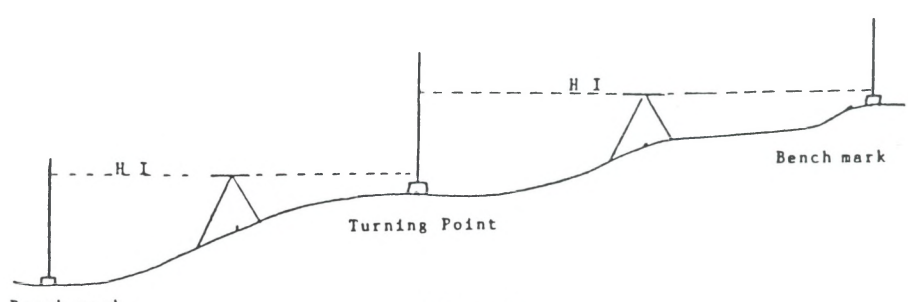


**Figure 1**