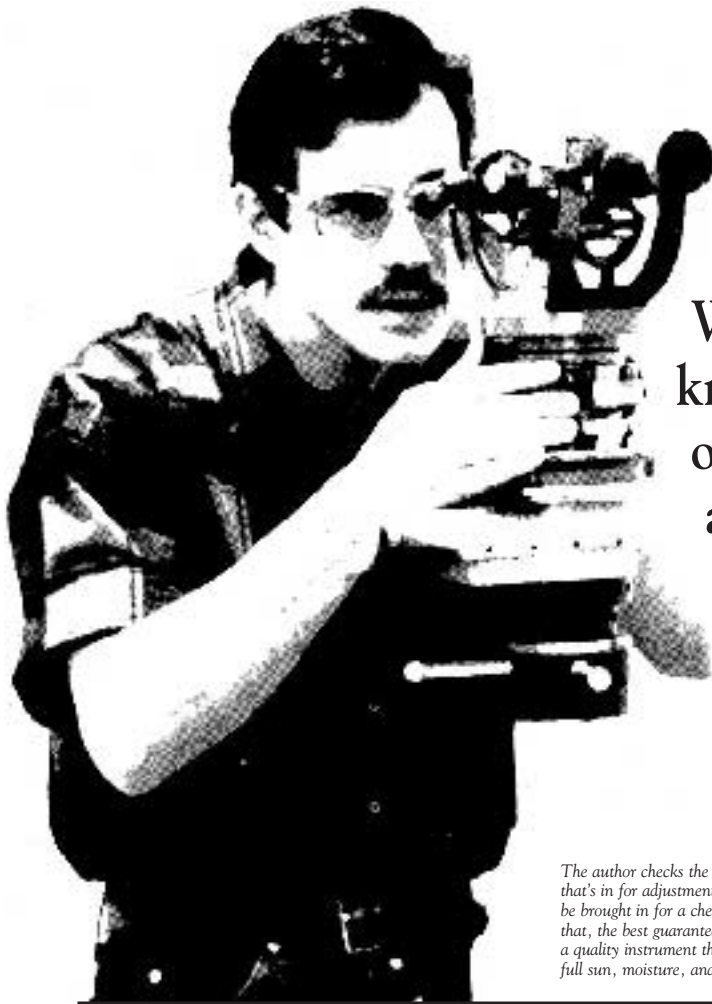


Shopping for Transits & Builders Levels



When choosing a transit, know what level of accuracy you need and which designs to avoid

By Kenneth Bull

The author checks the calibration on a transit that's in for adjustment. Transits and levels should be brought in for a check every six months. After that, the best guarantee of accuracy in the field is a quality instrument that gets limited amounts of full sun, moisture, and abuse.

It happens to me about once a month. Somebody brings in a transit they bought for \$200 or \$300 and wants me to adjust it. I calibrate the instrument (see photo above), make sure everything is tight, and double check my work the next day. But a week or two later, the owner calls and says, "It's out of calibration again! Why?"

Why, indeed. Like tools of any kind, optical levels and transits aren't all created equal. There are some cheaply built instruments on the market, and even some of the best companies make models on the lower end of the spectrum that

should be avoided.

First, some definitions. When I say level, I'm talking about an *optical level* (often called a "builders level" or "Dumpy level") that will only shoot horizontally. A *transit*, on the other hand, will shoot both horizontally and vertically because the telescope not only swings a full circle shooting a level line, but its telescope can be tilted vertically as well. Most builders like the versatility a transit gives them.

You can avoid a lot of problems by buying at the upper-end, but most builders can't justify paying 10 or 20 times the price of a skill saw, when

the saw will get used every day and the transit won't. And most residential contractors really don't need the sophisticated instruments required by surveyors and engineers. But they do need an instrument they can trust.

The answer — whether you're buying new or used — is to determine the level of accuracy you need, and then look in that category for one that is built to hold its accuracy in the field.

Transit Types

Transits are categorized according to the smallest increment they distinguish on their vernier scales (see

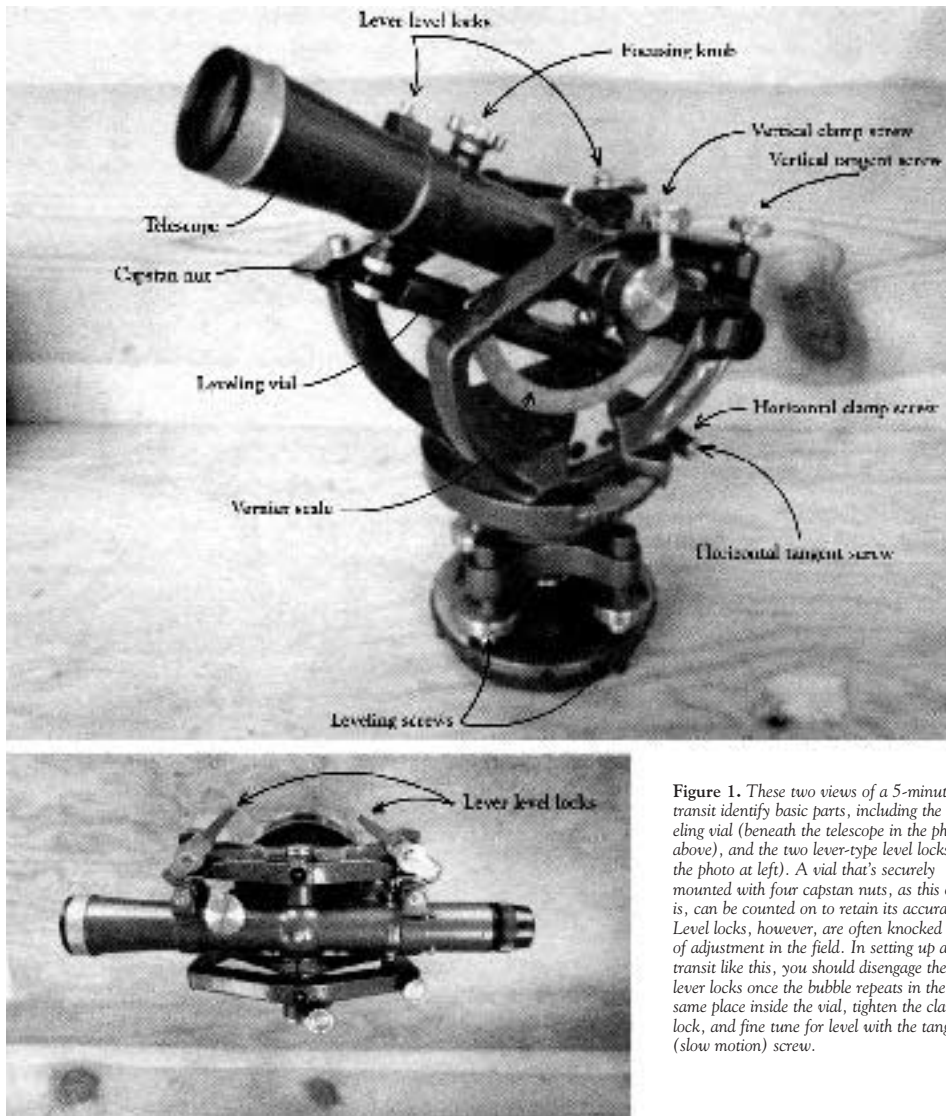


Figure 1. These two views of a 5-minute transit identify basic parts, including the leveling vial (beneath the telescope in the photo above), and the two lever-type level locks (in the photo at left). A vial that's securely mounted with four capstan nuts, as this one is, can be counted on to retain its accuracy. Level locks, however, are often knocked out of adjustment in the field. In setting up a transit like this, you should disengage the lever locks once the bubble repeats in the same place inside the vial, tighten the clamp lock, and fine tune for level with the tangent (slow motion) screw.

Figure 1). These graduations are in minutes (and on the higher end in seconds), so transits are referred to as 15-minute, 5-minute, 1-minute, or 20-second instruments. These designations aren't as mysterious as they might sound. Basically, minutes and seconds are just divisions of a circle: in every circle there are 360 degrees; in every degree there are 60 minutes; and in every minute there are 60 seconds.

At each level of accuracy, the instruments tend to share certain features and a basic price spread. However, the range of overall quality in these categories is wide, and that's where you have to be careful.

Fifteen-minute transits. These instruments run between \$200 and \$400. They can be calibrated for a level line accuracy (the error involved in shooting elevations) of plus or minus

1/4 inch at 100 feet. But some are so fragile the slightest bump will produce a level line error of 3 inches or more at 100 feet.

Fifteen-minute transits are characterized by a barrel diameter of less than 1 inch at the eyepiece, as shown in Figure 2. You should check less expensive models for optical clarity at longer distances, particularly if you are used to shooting a tape measure rather than a rod.

These transits have an allowable error of plus or minus 15 minutes when swinging horizontal angles. This works out to about plus or minus 5 inches at 100 feet since one minute represents about 1/3 of an inch at that distance ($15 \times 1/3 = 5$). However, some instruments don't come up to that standard, and can read between 6 and 10 inches off in 100 feet. You can imagine how this would affect a foundation layout on a hillside where you're relying on the transit to establish angles because you can't pull diagonals.

The leveling plates (what the instrument turns on horizontally) on most 15-minute transits are one of two "weak links." They are fastened with narrow posts to the transit head, and are made of relatively thin aluminum or brass. This makes them susceptible to wobble, wear, dents, and bends. I often have builders bring in 15-minute transits with the complaint that they can get the leveling bubble to center in

the vial when it's over the leveling screws, but not at all other points. This indicates a dented or warped plate.

How the leveling vial is fastened to the telescope is even more important. Better transits use a vial that is mounted to two posts on the telescope with capstan nuts above and below the vial casing, as shown in Figure 1. It's a system based on direct contact of materials, and it holds its adjustment well.

Unfortunately even some of the best manufacturers now use spring-loaded vials on their transits instead. These are much less reliable in my experience. Most 15-minute instruments, including the one I referred to at the beginning of this article, use spring-loaded vials.

A rock-solid connection between the telescope and the vial is particularly important when shooting level lines with a transit since you're relying on the vial to level the telescope. If the instrument has been properly adjusted so that the vial itself is parallel with the telescope line-of-sight, you'll be shooting a level line when the bubble "repeats" in the middle of the vial. But that's only if it remains parallel to the telescope — something you can't count on with a spring-loaded vial.

Five-minute transits. These cost \$600 to \$900. They are what most contractors buy and are the most rugged. Level line accuracy on some are very good — plus or minus 1/8 inch at 100 feet. As the category designation indicates, they have an angle-turning accuracy of about 1 2/3 inches (plus or minus) per 100 feet. They are a good choice if you stay away from models with spring-loaded leveling vials.

Like 15-minute transits, almost all 5-minute transits have lever-type level locks that are designed to help level the instrument. I adjust these levers so they position the telescope and vial perpendicular to the vertical axis of the instrument when they're engaged — but they are the first thing to go out of calibration when the transit is bumped. When this happens, the "locked in" position is no longer perpendicular or level, and leaves the builder wondering why he can't get his bubble to repeat in the middle of the vial. You need to disengage the lever locks once the bubble repeats in the same place inside the vial, tighten the clamp lock, and use the slow motion (tangent) screw to make the bubble repeat in the center of the vial. If the vial is securely mounted, and you follow this procedure, then level locks won't prevent the instrument from shooting accurately.

If you work in windy weather much, you might be interested in an option called an *optical plummet*. It will sight the instrument over a benchmark without using a plumb bob, but doesn't affect the operation of the transit in any other way. This option typically isn't available on 15-minute transits because it adds another \$100 or so to the price tag.

One-minute transits. These instruments cost \$1,000 to \$1,200 and are a major step up in accuracy from the previous two categories. Level accuracy on some is plus or minus 1/8 inch per 100 feet (this is really the practical limit for any transit out in the field). Angle turning accuracy is about plus or minus 1/3 inch at 100 feet. These transits don't have lever level locks.

The telescope on a 1-minute transit will pass through the standards and shoot a 360-degree plane vertically. The vertical circle will also be a full ring 360 degrees — an easy way to identify these transits — and will be

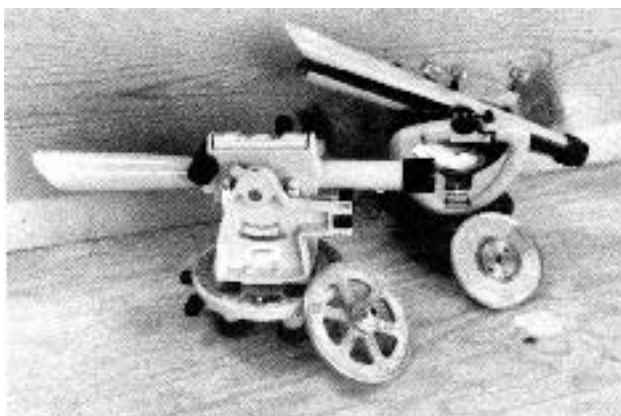


Figure 2. Inexpensive 15-minute transits don't hold up well in the field. Their leveling plates (shown here leaning against the transits) are often made of relatively thin brass or aluminum, which dents and bends easily. In addition, leveling vials on many are mounted to their telescopes with screws and tension springs rather than solid posts and nuts.

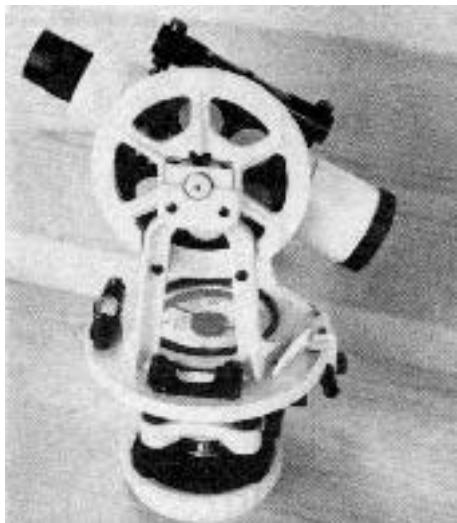


Figure 3. A 1-minute transit has a full-circle vertical scale and guard. This model includes two leveling vials on the base, and a compass.

protected by its own circle guard (see Figure 3). The horizontal circle will be fully enclosed with a window where the vernier meets the circle. The horizontal circle will also have its own lock and tangent screw.

Twenty-second transits. At \$2,000 to \$3,500, these are primarily used by surveyors, engineers, highway contractors, etc. Level accuracy is the same $\frac{1}{8}$ inch; angle-turning accuracy will be about $\frac{1}{8}$ inch per 100 feet. Most models are now almost totally enclosed with only the lock screws, tangent screws, and leveling screws exposed. There will be two verniers and windows for the horizontal circle, and one vernier and window for the vertical circle.

Some 20-second transits are in *theodolite* form. Theodolites employ glass horizontal and vertical circles with a system of mirrors and prisms that pick up the readings and bring them to a much magnified display called an optical reader. This makes angles much easier and faster to read. These theodolites range in price from \$3,000 to \$4,000.

Level Categories

Some builders can get by with just a level much of the time. They are mechanically simpler (which means less expensive construction doesn't influence their accuracy quite as much), less expensive, and easier to set up than a transit.

"Builders" level. If accuracy of plus or minus $\frac{1}{4}$ inch at 75 feet is good enough, you can buy a level and tripod for as little as \$300 or \$400.

Although you do need to examine the overall sturdiness of the instrument (see Figure 4), a spring-loaded vial isn't as negative a factor with a

builders level as it is with a transit because the telescope is fixed perpendicular to the vertical axis of the instrument.

So, in the field, when the bubble repeats in the same place within the vial — indicating the vertical axis of the instrument is plumb — the telescope should be shooting level even if the vial isn't perfectly parallel. (In general with levels, you should trust the perpendicularity of the scope to the base rather than the vial.)

And even if the telescope isn't shooting perfectly level, it will be consistent in whatever error it has. In other words, when the bubble repeats in the same place inside the vial for the full 360 degrees of rotation, the telescope is inclined to the same degree all the way around. So if the telescope is shooting $\frac{1}{4}$ inch high at 100 feet, it will shoot $\frac{1}{4}$ inch high at 100 feet in all directions.

Automatic level. If you need greater accuracy, consider an automatic level. Accuracy is plus or minus $\frac{1}{16}$ inch at 100 feet for models in the \$600 range. These levels use a pendulum suspended within the line-of-sight that is fitted with mirrors or prisms. When the instrument is out of level a little bit, the pendulum swings with gravity, and the line-of-sight is corrected so it's still describing a level line.

Automatic levels are a time saver. The level bubble is in a round bull's eye vial. Place the bubble in the center and the pendulum levels the line of sight from there. A good one can be purchased for around \$750 for the instrument and tripod. You can pay less, but there's a greater chance of ending up with a poor quality level unless you have the experience to tell the difference.

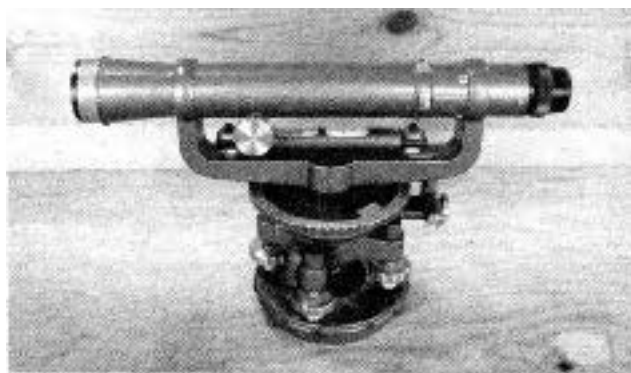


Figure 4. This builders or "Dumpy" level doesn't allow you to shoot vertically, but it's adequate for many building projects.

Laser level. These can be a good investment because they eliminate an instrument man. You set them up, and then just let them do the rest. Most have an automatic leveling system, but you need to check.

Be careful of laser levels that are sold by lumberyards and larger hardware stores; they tend to buy the cheaper models so their customers can afford them. Plan to pay at least \$2,000.

Purchasing and Care

You can buy transits and levels lots of places these days — even mail order catalogues — but I think the best source is a store that specializes in them. This way you'll see many more brands and models, and you will be dealing with salespeople who know how the instruments work and can help you find one with the level of accuracy and durability you need. These will be listed in the Yellow Pages under "Survey Supplies." Another good source of advice is someone who has owned a model (not just a brand name) you're interested in for a year or two.

At the time you buy, make sure you have the instrument calibrated by a competent technician. Insist on this, even if you're told the factory adjusts them before they go out. The longer an instrument spends in the field, the further out of calibration it can get; there's no point in starting out already off the mark.

Most instrument repair shops (you'll find these listed under "Survey Equipment Repair") urge you to bring your transit in every six months. I agree, although you should check occasionally to see that it's shooting level in the field, to make sure it doesn't need to go in sooner (or to cheat a little on the six months if you're in the middle of a big job).

To do this, set up shots from opposite sides of your site. If one of your shots at your second location is an inch higher than the one at your first location, all of your shots from that second location should be one inch higher. Any error will show up best at short and long shots; equidistant shots tend to equal out any instrument error. This test relies on the principle that when shooting level planes, no matter where you set up, those planes will be parallel.

Transits and levels get out of calibration more quickly when they're left in the sun or treated roughly — they really can't take much abuse. They should ride in the cab with you, not in the bed of your pickup. It's also important to store them in a dry place because they can and do corrode. Humidity in the telescope will also condense and bead up on spider web or fiberglass crosshairs, causing them to fall with the weight.

Older Transits & Levels

Generally, older transits and levels were made better and with better materials. They used brass — not plastic — adjustment knobs and leveling feet. There are exceptions, of course; some of the older ones are really junk. If you do have an old instrument, check with someone knowledgeable before getting rid of it.

One change for the better in the last 50 years is internal focusing slides. Up until the 1940s, telescopes had external focusing; when you turned the focusing knob, the telescope would get longer or shorter. Internal focusing slides eliminate the extra barrel length that can sag on bushings, and the grease on the exterior that attracts dirt.

Another change is the use of aluminum instead of brass. Aluminum is stronger and springier, but also corrodes more easily. I have come across instruments that were stored wet and were completely ruined by the time they got to me, with white powder — aluminum oxide — everywhere and all the screws permanently corroded in place.

Buying a used instrument at a garage sale, flea market, or estate sale is a bit of a gamble because of the many variables involved, but then the price is often worth the risk. Here are a few tips that should help:

- If the telescope barrel is an inch or less in diameter at the eyepiece, it is probably a fifteen-minute instrument. Asking price can be as low as \$25 to \$100. See if the bubble will repeat in the same place inside the vial. Even check it at 45° to the leveling screws. If the bubble runs off, the vertical axis has runout and the repair bill will run about \$75. If the bubble can be made to repeat in the same place, you can get it calibrated for about \$25 or \$30.
- If the telescope barrel is about 1 $\frac{1}{2}$ inches in diameter and uses level locks, it is probably a five-minute transit. Make sure the vial is securely mounted, and check to see if the bubble can be made to repeat in the same place inside the vial when reversing the instrument. Check it for the full 360°. If the bubble repeats well, the vertical axis does not have runout, and the instrument can probably be adjusted. Asking price will run \$100 to \$500.
- If it's an automatic level, lightly shake the instrument and listen for the pendulum moving. Or field test it right there. Shoot a short and long shot (20 and 100 feet) from two opposite locations. Your relative elevations from your second location should agree with your first location. Cost is \$100 to \$400, but be careful because it will run you about \$300 to repair the compensator (the suspended mirror that allows the instrument to adjust for level).
- A builders level should be checked to be sure the turning motion is smooth and easy. Also make sure the bubble can be made to repeat in the same place. But it's not a major problem if the bubble won't stay in the middle; the vial may simply need adjusting. If the bubble can not be made to repeat someplace, the vertical axis has runout or is bent. Fixing this can cost as much as \$200 or it may even be unrepairable. Asking price for a new 12-inch builders level with a barrel diameter larger than 1.2 inches is about \$600 new; you'll see them used for anywhere from \$75 to \$300. An 18-inch level costs \$800 new, and should go for \$100 to \$400.

In general, you should check to see if the bubble can be made to repeat in the same place inside the vial. Turn all knobs to make sure they work and are not bent. Look through the telescope and make sure crosshairs are intact and that the clarity of the optics is okay at a distance. And before you purchase, make sure to add in cleaning costs. A full clean on a 5-minute transit can be as much as \$140. But do your homework and you could get lucky and find a good instrument for pennies. ■

Kenneth Bull manages the repair department at H & L Hendry Engineering Sales in Concord, California. He has calibrated and repaired survey equipment for 12 years.