# An Inside Look at **Box-Beam Levels**

The best levels balance sensitivity, accuracy, and durability

**BY JUSTIN FINK** 



uying any tool takes a certain leap of faith, but buying a level may require the biggest. Most tools have at least some physical considerations-handle comfort, trigger action, overall quality of construction-but how do you judge a box-beam level?

Levels are tricky to assess because you're really taking a gamble on long-term durability. Your level will inevitably be dropped, take a beating in the back of your truck, or slide down a wall and land on the floor. It's crucial to get a level that starts out accurate and stays accurate. That's a hard thing to see, but it's far more difficult to achieve. In speaking with five manufacturers about how they make their levels, I learned that the quality and durability of a box-beam level are determined by the aluminum extrusion, the vial, and the way that vial is mounted.

#### The frame is the backbone of a box-beam level

The frame of a box-beam level serves as an extension of the vials it holds and protects. That means the aluminum extrusion must start out straight, flat, and strong, and must remain that way no matter how many times you drop the level or drop something on it.



1 Ridged for strength Box-beam levels often have ridges that run the length of the extrusion. "The sides of old soup cans were straight and smooth," says Sola USA's Alan Karraker, "but they were also much thicker. Then manufacturers figured out that ridges could be used as a substitute for thickness with- on a surface and give out losing rigidity."

2 The bevel annoyance Beveled or rounded edges make it difficult to mark an accurate line, and edges vary by manufacturer. Although sharp edges are often included, they are more likely to dent or deform from impact, which interferes with the level's ability to sit flat an accurate reading.

**3** The myth of machining European box beams are painted on all sides. In the United States, the sides are machined. This is a holdover from when extrusion technology wasn't accurate enough to create dead-flat frames. Technology has advanced, but the U.S. market still demands the machining to be there as a quality cue.

4 Caps are like air bags Designed to protect the vulnerable ends of the frame, caps are made from impactresistant materials and covered with rubber to keep the level from slipping when leaned against a wall. Some caps are removable so that the level can be slid into a corner for accurate marking.

## **ARROW-STRAIGHT EXTRUSIONS**

Level makers design a frame and hire outside companies, such as manufacturers of aluminum ladders, to extrude aluminum to their specs. This frame is the backbone of the level and plays a crucial part in the long-term durability of the tool.



Channeled adhesive. Rather than relying on glue to anchor the vial holder to the side or bottom of the frame, some companies use a mounting block with built-in chambers. This design allows epoxy to be channeled to specific locations, which locks the holder in place inside the aluminum frame.

Stabila Type 196, 24 in., \$70



Stanley FatMax, 24 in., \$23

Good old glue. The majority of levels rely on industrial-strength adhesives to secure the vial holder to the frame of the level. Some are anchored to the rim of the cutout, others to the sides or bottom of the aluminum extrusion.

### MOUNTING THE VIAL

A peek inside the frame of several box-beam levels shows that not all mounting systems are the same. Some vial holders are glued to the top of the frame, others to the sides or bottom. The process ranges from a blob of adhesive to more complicated holders that have channels to shuttle injections of adhesive to key positions.



Sola Big Red, 24 in., \$65

If you cut a stack of box-beam levels in half and look at the profile of each, you can see differences: the size and shape, the size of the bevels on the edges, and the number and placement of holes for vials and handles. Other differences, such as the type of aluminum and slight differences in wall thickness, you can't see. All of these factors combine to strike a balance in cost, weight, strength, and long-term durability.

According to Mike Fraser, president of Stabila, the number-one failure point in levels is bending, and that typically happens right over the center vial. The second-mostcommon failure is what he calls "tip overs and fall ons," when the level either falls onto something or something falls onto it. This is a big deal because not only will the level no longer read accurately after being bent, but a bent frame is also the only thing that will void the tool's warranty.

According to John Dwyer, vice president of sales and marketing at Johnson Level, "There isn't a level maker in the world that extrudes their own aluminum." Instead, they farm out the extrusion process to dedicated manufacturers, where frames are built to each company's specs (photos facing page).

Alan Karraker, president of Sola USA, says, "Getting a decent extrusion with the holes in the right place isn't that tough. The hard part is making the vial."

#### Performance comes down to sensitivity and accuracy

Two types of vials are used in box-beam levels: tubular vials and block vials (photos p. 64). Regardless of the type of vial, there are two factors to consider: sensitivity and accuracy. The two are often confused, but they are very different.

Sensitivity is the relationship between the tilt angle of the level and the movement of the bubble. In other words, the higher the sensitivity, the faster that the bubble will



## IN SEARCH OF THE PERFECT VIAL

Old levels had pairs of bent-glass vials, one for each reading position. Nowadays, a single vial replaces the pair and is designed to be read in both standard and inverted positions. Regardless of the type of vial or the way it's shaped on the outside, the curve inside the vial is cigarshaped: tapered on both ends and wider in the middle (photo left). "The hard part," says Sola USA's Alan Karraker, "is getting this tapering exactly the same all the way around. A bump on the inside—just a little in or out—and the level won't be accurate in every direction."



properly built tubular vial is an accurate level on its own. If you were to roll the vial across a level table, the bubble would stay centered. Mounting a tubular vial in a

Tubular vial

By its nature, a

level typically leaves a lot of open space around the vial where dirt can accumulate, so these vials are often set into puck-shaped blanks. The blanks also prevent the indicator lines, which are applied to the outside of these vials, from wearing off.



lowed out. Unlike a tubular vial, a block vial doesn't become a level until it's mounted and calibrated with the frame. A block vial also has indicator lines, either stripes of paint or thin pieces of metal sprung into place, applied to the inside of the vial rather than the outside. This places the indicator lines closer to the actual bubble, reducing the

Block vial

Most box-beam levels now

use block vials, which begin

acrylic—a material chosen for its strength and trans-

parency-that is then hol-

as a solid rectangle of



#### Accuracy explained

chance of parallax error when viewing the vial.

Most levels are calibrated to the same standards: 0.029°, 0.5 mm/m, and 0.0005 in./in. All three roughly translate into a variation of the thickness of a dime over an 8-ft. distance. The most commonly promoted standard is 0.029°, which means that to center the bubble, neither end of the level should have to be raised more than 0.029° from a level surface

Room to grow. A bubble that's slightly smaller than the space between the indicator lines isn't a sign of sloppy manufacturing. As temperature drops, bubble size increases, so level makers have to size the bubble so that it will never expand to the point of being wider than the lines. A good vial will have in the neighborhood of one to two indicator-line thicknesses of space on each side of the bubble.

A bubble through thick or thin. If the liquid inside a vial is too thin, the bubble will dance all over. If the liquid is too thick, you have to worry about how long it will take for two separated bubbles (which commonly



occurs if you tap the level) to recombine—an important consideration for masons, who frequently tap on the level with their trowels.

Vial shape matters, too. Some block vials have crisp outer edges; others are rounded to help magnify the size of the bubble. Any time you're looking at an object through liquid, though, you have

to worry about parallax error, which can make the bubble and lines appear askew from certain angles.



Easy on the eyes. Black indicator lines are still the norm, but on some levels, bands of color are used to cast a colored shadow on the bubble, helping to highlight its edges. Some companies

sensitive.

Just the right radius.

vature inside the vial,

the sensitivity of the

By playing with the cur-

manufacturers can tweak

level. A machinist's level,

for example, will have a much larger radius (closer

to flat) than a carpenter's

level, making it far more

also supplement the vial with glow-in-the-dark backgrounds to help in low-light situations.



move. The two big factors that influence a vial's sensitivity are the viscosity of its fluid and the curvature of its inner walls.

Most level manufacturers keep the exact formulation of the liquid in their vials a secret, but according to Dwyer, mineral spirits is the foundation for the magic fluid. "It has a very extreme temperature range—so it won't boil and won't freeze—and it's slippery enough and has the right amount of surface tension so that the bubble will move but won't race around erratically."

According to Dave Ripplinger, vice president of sales and marketing for Empire, some level makers also create a smaller radius (steeper curve) on the inside of the vial, which makes it easier to keep the bubble in the center. "Imagine a marble rolling around inside a cereal bowl," explains Ripplinger. "It's pretty easy to keep that marble in the bowl, right? Now, put the marble on a sheet of glass and try to keep the marble from rolling off the edges."

You could go more sensitive, but then the level becomes impossible to use for carpentry. "We're talking about carpenter's levels," says Ripplinger, "but a machinist's level will be in the neighborhood of 10 times more sensitive. Slide a piece of paper under it and the bubble will go off the edge."

In terms of a box-beam level, accuracy is a broad term that refers to the size and positioning of the bubble in the center of the vial. Small inaccuracies can translate into large inaccuracies over a long distance.

A level's accuracy is often listed as 0.029°, 0.5 mm/m, or 0.0005 in./in. (center photos facing page). Dwyer says that although the 0.029° measure has become the industry standard, "you're not going to find a board that's straight enough to even allow you to take advantage of that." Fraser agrees: "We've found that when you go tighter than 0.029° accuracy, the user has not bargained for the consequence of the higher sensitivity that comes along with it."

Many users also gripe about too big of a gap between the bubble and the vial's reading lines (bottom photo facing page). To fill the vial, explains Dwyer, Johnson Level relies on the same type of machine used to fill capsules in pharmaceutical work. "It puts a precise amount of fluid in the vial, just enough to leave an air bubble that's almost, but not quite, touching the lines." The reason the bubble can't be sized to fit exactly between the lines, explains Fraser, has to do with temperature. "The bubble expands with cold weather, so we have to size it to ensure that it will never be larger than the space between the lines."

#### Vials should be easy on the eyes

The bubble inside a vial is just clear air. It's easier to see clear air when viewed against a darker background, so most manufacturers color the liquid in the vial. "What color is the most visible to the human eye?" asks Dwyer. "That's not something a marketing company determines. It's physics, and that color is green." Shades of yellow and green are most popular, but some manufacturers opt for an unconventional color to help them stand out against the competition.

#### Empire E70, 24 in., \$35



**For you, blue.** Empire has received some complaints about sunlight turning the blue liquid in its vials clear.

Stabila Type 196, 24 in., \$70



**All lit up.** Stabila offers an optional onboard light pack that illuminates the vial in low-light conditions.

Empire, for instance, uses blue liquid in its True Blue line of levels. The company, though, has received some complaints about the blue liquid turning to clear over time. "It's not that Empire can't use blue correctly," says Sola's Alan Karraker. "It's that nobody can. Blue liquid just doesn't work."

#### Mounted for the long haul

Years ago, glass vials were set into a level's wooden frame using plaster. Nowadays, manufacturers mount the vial to a holder, which is placed into the aluminum extrusion, tweaked to be level, and then secured in place. According to Fraser, durable vial mounting is a big part of what drives the price of a premium level. He says, "Imagine a 12-ft. plate level. Your 1½-in. vial has to be calibrated to the very ends of that frame. That process is incredibly expensive and very tedious."

Karraker believes that "Stabila has unquestionably the best gluing system on the market." He acknowledges, however, that there's an inherent trade-off with gluing the vial holder to the frame. "The bad part of the glue is temperature. When it's cold, the glue shrinks. When it's hot, the glue expands. Over time, this expansion and contraction cycling can slowly move the vial out of alignment." Instead, Sola relies on a two-piece plastic holder designed to cancel out movement from expansion and contraction.

#### How do you choose?

The box-beam-level market is huge, and the price spread is wide, with a 48-in. level selling for anywhere from \$40 to \$100. In addition to the familiar brand names, house brands and private-label levels from major-brand tool companies are on the rise. "Distributors are punch drunk with level options," says Fraser, "and now you have multibilliondollar shock-and-awe power-tool companies crashing the category." How do you choose? You can't see the inside of every level at the store, but there are some accuracy cues you can check when you're shopping.

Long-term use is the best indicator of quality, so it's also a good idea to ask around. Every carpenter you see at the store has a level in the truck and an opinion to go along with it.

Also, consider how often you will use the level. For occasional use, a lower-priced level will do the job. If you're a professional who relies daily on the consistent accuracy of a level, the durability of a higher-priced model makes far more sense, and the extra cost is easy to justify.

To Fraser, the bottom line is simple: "I feel that people should spend as much as they can afford on level and layout tools. Why? Because of the consequences."

Justin Fink is a senior editor. Photos by Rodney Diaz.

**TOOLSHOUND** Visit FineHomebuilding.com to see a video on choosing a box-beam level.