Diagnostic Tools for Energy-Minded Remodelers

Applying building science in the field can help to deliver safer, healthier, and more energy-efficient projects

BY DON JACKSON

The past several years have seen a flurry of activity on the home-energy front. Federal tax incentives and dozens of rebate programs have focused attention on cutting residential energy consumption. Energy audits are now common in many areas of the country, and building codes have stepped up insulation and air-sealing requirements, and are even beginning to require blower-door testing and duct-testing on new construction. Homeowners are more aware than ever of these trends, with more and more wishing to tighten their houses so that they can save money on their utility bills.

This isn't unfamiliar territory for remodelers, many of whom already participate in programs that require third-party energy auditors to verify that a project is meeting reduction targets. With most programs, there's typically a blower-door test before work begins and another one at the end of the job. Unfortunately, when it's most needed—

Photo this page: Don Jackson

CHASING AIR LEAKS

Air infiltration severely compromises a building's comfort, durability, and efficiency. Therefore, any serious effort to improve the performance of an existing house must start with air-sealing. In fact, adding insulation without first plugging the holes in the building envelope may be a complete waste of time. Some air-leakage points are obvious, but it takes detective work to find others.

BLOWER-DOOR KIT

The blower-door kit is the most important diagnostic tool a remodeler can own. It's used most commonly to depressurize a building to measure total air leakage through the building shell, but perhaps more important, it allows remodelers to find the source of the leaks. With the building depressurized, you can use smoke puffers and thermal imagery to pinpoint the actual holes in the building envelope. Used with a pressure pan or a duct-testing fan, a blower door also can help to locate and quantify duct-system leakage. Blower doors also can help to reveal framing cavities, such as partition walls and soffits, that are coupled to the outdoors.

A basic kit includes the fan; a digital gauge (the manometer) that controls fan speed, measures pressure, and calculates results; pressure tubing; and a nylon door panel and aluminum frame used to mount the fan in a doorway. A series of plastic rings is snapped into the fan housing to restrict airflow incrementally, thereby increasing flow pressure above the minimum to get an accurate reading. The tighter the house, the smaller the ring.

The two blower-door manufacturers serving the residential home-performance market, the Energy Conservatory and Retrotec, have both been in business for more than 30 years, and both make excellent equipment. Their basic kits are similar, and each has features to recommend it. In general, the Retrotec DM2 manometer has more settings and programmed functions than the Energy Conservatory's DG700 manometer. For example, the DM2, in addition to measuring total airflow, also calculates values such as air changes per hour and effective leakage area. The newest manometer from Retrotec, the DM32, is a touch-screen model and is able to accept firmware upgrades. By contrast, the Energy Conservatory's manometer is more basic and simpler to operate. There are far more of the Energy Conservatory's blower doors in use in the weatherization and home-performance industries, so the community of peer support is far larger.

A basic Minneapolis Blower Door kit (shown here with a model 3 fan and the DG700 manometer) from the Energy Conservatory costs around $2500; an entry-level Retrotec kit (with a model 1000 fan and a DM2 manometer) costs around $2800.

SMOKE PUFFERS

A variety of chemical smoke devices are available, but not all are ideal for tracing air leaks during a blower-door test. For instance, while smoke matches ($8, top left) and the refillable Smoke-Pen ($40, bottom left) are fairly inexpensive and are useful for testing the draft on a gas water heater, they aren't as desirable in a situation where the heat produced might affect the direction the smoke travels. Many experienced home-performance contractors prefer devices that use a caustic chemical (titanium dioxide), because the smoke produced is neutrally buoyant—it hangs in the air and is especially sensitive to air pressure. For those who want to avoid working with caustic chemicals, there are several nontoxic puffers, such as the battery-powered Smoke Pencil ($55, right), that use a nontoxic glycol solution.

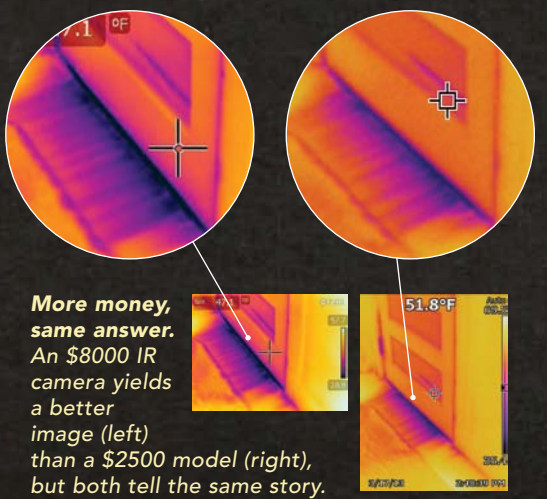
Bottom photos, facing page: Don Jackson

THERMAL IMAGER

Used by itself, a thermal imager (also known as an infrared camera) can locate missing insulation and detect thermal bridging. Used in tandem with a blower door, it can help to pinpoint air leaks in the building envelope. This device works by sensing thermal radiation from the surface it's pointed at and then converting the radiation measurement to temperature, which it displays in a colored or gray-scale image.

Professional-quality thermal imagers range in price from $2000 to more than $20,000. For a remodeler, the two most important specs to look for are focal-plane array and thermal sensitivity. The focal-plane array is the matrix of tiny sensors, called detectors; as with pixels in a digital camera, more is better. The bare minimum for effective home-performance work is 120x120 (160x120 is also common for entry-level models). The next step up, 320x240, can add thousands of dollars to the price, and though image resolution is improved, it's not necessary for home-retrofit work.

Thermal sensitivity is the imager's ability to distinguish between small variations in surface radiation. This rating is sometimes expressed in millikelvins (mK), but more often in degrees Celsius (°C). In both cases, a smaller number means greater sensitivity; the minimum to look for is 0.1°C. Greater sensitivity expands the range of time—both hours of the day and seasons of the year—in which the tool can be used effectively. More expensive models often include helpful features such as a built-in digital camera, but you'll also be paying for advanced features that are overkill for home-retrofit work.



More money, same answer. *An $8000 IR camera yields a better image (left) than a $2500 model (right), but both tell the same story.*

THERMAL IMAGER COMPARISON

Model	Flir i7	Testo 875-1	Fluke T100	Testo 875i-1	Flir E40bx
Cost	$1995	$2195	$2495	$2895	$3995
Thermal sensitivity	0.1°C	0.08°C	0.1°C	0.05°C	0.045°C
Focal-plane array	140x140	160x120	160x120	160x120	160x120
Focus	Auto	Manual	Auto	Manual	Manual
Digital camera	No	No	No	Yes	Yes
Field of view	29°H x 29°V	32°H x 23°V	22.5°H x 31°V	32°H x 23°V	25°H x 19°V

All models meet minimum proposed RESNET standard for thermographic inspections of buildings.

while workers are opening walls or probing the attic for air leaks—a blower door may not be available, at least not for free. If the goal is to tighten and insulate existing homes well enough to achieve meaningful energy savings, remodelers will need to do their own blower-door tests and thermal imaging. In addition, as long as they work in homes that have combustion appliances, they're going to have to learn the basics of combustion safety (sidebar, pp. 50-51).

An integrated approach

A meaningful commitment to home-performance diagnostics—including training and equipment—costs $10,000 to $20,000. Over time, a company's investment in training—getting BPI (Building Performance Institute) or RESNET (Residential Energy Services Network) certifications, studying thermography, attending conferences for continuing education—will outstrip the cost of the equipment. Will the effort, however, make a meaningful contribution to a remodeler's bottom line?

"When you're good at diagnostics, people tend to come to you for all sorts of building-performance issues," says Paul Eldrenkamp, the owner and founder of Byggmeister, a remodeling company in the Boston area. "I recently visited a house that had chronic ice dams. Everybody was looking at the ice as a roofing problem, but I could see that there was a lot of leaky ductwork in the attic." Eldrenkamp ran pressure tests with the blower door and showed the customer the heat loss using thermal imagery. "From outside, you could see the roof glowing," he says. "No wonder the snow's melting and freezing at the eaves." Byggmeister air-sealed the attic and added insulation. "It became a bigger job from a revenue standpoint, but more important, it provided a long-term solution for the ice dams and addressed high gas bills and comfort issues," says Eldrenkamp.

Eldrenkamp began to integrate energy diagnostics into his company in 2004 with the purchase of a blower door, which was followed in quick succession by an infrared camera, moisture meters, and data loggers. For a while, Eldrenkamp tried providing energy audits as a sideline to his bustling remodeling business, but he found that it wasn't worth it. "At that point, you're really just selling time, not leveraging that time. Unless you turn it into a project, it's going to be an uphill battle to make money. Plus,

COMBUSTION SAFETY

As long as there continue to be natural-draft combustion appliances in homes, remodelers who make significant improvements to a building's air barrier must be trained to prevent carbon-monoxide (CO) problems. This is why weatherization contractors practice the mantra "Test in, test out," paying special attention to the combustion-appliance zone (CAZ)—where furnaces, boilers, and water heaters are located—to make sure that plenty of air is available for clean combustion and to prevent backdrafting. In addition to the manometer that's part of the blower-door kit, combustion-safety testing requires a sizable investment in three additional—and probably unfamiliar—tools: a gas-leak detector, a personal ambient CO monitor, and a combustion analyzer.

GAS-LEAK DETECTOR

This tool is used to check for gas leaks along all visible propane or natural-gas lines, starting outdoors and working toward each appliance. It emits an audible ticking sound that increases in frequency as the sensor gets closer to the leak. Most units, like the Sensit TKX shown here ($205), have an adjustment knob for setting the audible tick rate, as well as a visual indicator, usually a series of red LED lights, that signals when gas is present.

Gas-leak detectors should have a sensitivity of 20 ppm. In addition to methane, propane, and natural gas, most will detect vapors from many organic solvents. To prevent accidental ignition, the battery-compartment cover on these tools typically is held firmly in place with a screw.

PERSONAL CARBON MONOXIDE MONITOR

This sensor is designed to alert workers to increases in ambient CO that occur in the CAZ while work is being done. The unit shown here, the Sensit P100 ($200), is typical. It's a single-gas monitor designed to clip to a belt or hang around the neck. With a sensitivity of 1 ppm, it comes preset to sound low-level and high-level alarms, and to take a time-weighted average for monitoring safe exposure limits. The unit shown here is on all the time; it's designed to be used for two years, then replaced.

you're competing with all those auditors who are subsidized by utility programs."

Sam Hagerman, co-owner of Hammer & Hand, a building and remodeling company in Portland, Ore., had a similar experience. The firm began by doing performance audits and upgrades as part of a statewide incentive program but gradually incorporated the work into its otherwise standard remodeling jobs. "Now we bring in a home-performance team to analyze the house at the same time we're bringing in the plumber and electrician to price the job," says Hagerman. "When you roll up with the equipment and a small crew, then spend a few hours using it while the owner is there with you, they realize you know what you're doing."

Remodelers have a competitive advantage

When it comes to energy upgrades of existing homes, remodelers are in a good position because they're already good at analyzing problems and solving them, and they know how buildings are put together. On almost every job, the remodelers are covering, penetrating, moving, or somehow changing the house's air and thermal barriers. Taking it to the next level—measuring the results of the changes being made—only makes sense.

"I can usually tell when an energy audit was done by someone who doesn't know remodeling," says Eldrenkamp. "They'll point to flaws in the building envelope that just aren't worth worrying about, like the thermal image that showed a big cold spot on a wall. Turns out that's where the electric meter was mounted outside, and inside, there was some very expensive wallpaper. There may be a void in the insulation, but you know it's not something you're going to deal with."

First steps

Builders and remodelers who decide to learn energy diagnostics should start by taking a

COMBUSTION ANALYZER

Although this tool is most commonly seen in the hands of an HVAC technician, a remodeler who is performing proper CAZ testing will need it for measuring CO in the exhaust of all natural-draft combustion appliances in the house. This includes gas-, oil-, coal-, and wood-fired furnaces, water heaters, boilers, and space heaters as well as gas ranges and clothes dryers.

With its probe inserted in a vent pipe, the combustion analyzer measures oxygen, carbon monoxide, and stack temperature, then uses the results to calculate combustion efficiency and a value called CO air free, or COAF. This is the value that is used when determining whether an appliance passes or fails the CO test; a single-sensor CO detector cannot measure COAF. A combustion analyzer also must have a nitrogen-oxide (NOx) filter; otherwise, the CO reading will be artificially elevated. Newer models include a NOx filter, and older models can use an add-on filter ($40). The Testo 310 (shown here) has a NOx filter and all the features needed for following BPI protocols; it costs $625, or $790 with a wireless printer (right). Combustion analyzers need periodic recalibration, typically after a year, which is usually done by the supplier or the manufacturer's service center.

building-science course that leads toward BPI certification. "It doesn't make sense to just go out and buy the equipment," says Hagerman. "First, get a foundation of building science under your belt. There's a lot of equipment out there that isn't being used properly because the operators aren't trained."

Robert Kahabka, of Woodhull, N.Y., has been teaching home-performance diagnostics for 25 years. For remodelers, he recommends starting with the BPI Building Analyst training: "This is the most comprehensive of the certificates. It provides a rigorous introduction to building science, and it covers the subtleties of pressure changes in the home and how they relate to the combustion-appliance zone. These are the things that are most critical and need to be nailed down first."

The best courses include hands-on training time and fieldwork in addition to class time. "You can get the book knowledge, and you can get the tools, but it's the experience that really teaches. Every house is different, and the ways the occupants use the houses are different," says Tamasin Sterner, who runs Pure Energy Coach and who has been training weatherization professionals for the past 30 years. "It takes about 30 houses before you know what to do to really impact energy use."

Given most remodelers' lack of familiarity with building-science measurements, Eldrenkamp recommends that novices try newly purchased energy-audit tools at home. "Monitor your own house for a while until you figure out how to associate certain characteristics with certain numbers," Eldrenkamp says. "It's good to be a guinea pig on your own place; that gives you some context for when you do diagnostics on a client's house." □

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