Diagnostic Inspection Tools

by Don Michael Jones and Helene Roussi

Finding the right tool for the job is often half the solution. This article explores four of the hand-held tools auditors have found useful: sonic leak detectors, combustible gas detectors, infrared thermometers, and density-sensitive stud finders.

Many useful and often clever devices allow auditors to inspect residential structures with more accuracy and ease. The devices that have received a great deal of attention have been the "Big Three" of diagnostic equipment; blower doors, infrared cameras, and electronic combustion analysis equipment. *Home Energy* has covered them extensively over the years.[1]

While the Big Three are all broadly useful, there are a number of other, more specifically useful diagnostic devices on the market. Some can be used to augment the Big Three, while others are used in lieu of them when they are unavailable. We have selected four diagnostic tools that help inspect or detect air leakage, insulation coverage, framing location, and heating system safety.

Sonic Leak Detectors

Locating air leakage sites in houses has been a significant problem for auditors, especially given the often complex pathways that air travels through framing. Auditors have used the blower door extensively and it has proven very effective at unraveling the mystery of air movement. Now another device, the sonic leak detector, is also being marketed for this purpose.

Sonic leak detectors operate on the principle that sound waves travel through air and will follow the routes air takes then it penetrates the building envelope. Ultrasonic detectors can read the sound waves emitted by ultrasound sources, and pinpoint the source of the sound. The detector is a sensitive microphone that picks up ultrasonic waves—sound waves above the frequencies the human ear can hear—and converts them to sounds in a range audible to a human ear.

These devices were originally developed for industrial applications to detect leaks in pressurized systems, monitor the condition of motor bearings, detect the integrity of seals and gaskets where air tightness is essential, and detect arcking in electrical systems.

Ultrasonic waves are emitted along with certain forms of audible sound. Sibilance (hissing), friction (rubbing), and percussion (banging) produce particularly high levels of ultrasonic waves, so a variety of conditions can be diagnosed.

Destrubé Photography/Modern Products, Ltd.
Sonic leak detector

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TOOLS

Sonic leak detectors can detect "problems" in one of two ways. First, it can hear ultrasonic frequency sounds produced by an improperly functioning system, such as a hissing leak in a steam system. Second, it can detect deliberately broadcast ultrasonic waves. For this application, the auditor places the broadcaster (or "transmitter") on one side of a barrier, with the receiver on the other side. Holes, gaps, or cracks will appear as the source of the "sound leak." The aerospace industry uses sonic leak detectors in this way to check gasket seals around airplane windows and doors.

In buildings, ultrasonic detectors can locate air leakage sites. They have either an analog scale or digital readout, but only for comparing the strength of the source "noise" from one leak to another. The reading cannot be used to give the auditor a sense of the structure's overall level of tightness as a blower door can.

In order for the detector alone to hear noise, a certain level of pressure difference is required to produce ultrasonic waves. However, relying upon natural conditions, such as wind pressure, produces inconsistent results. A blower door fan could be used to produce sufficiently strong air movement into the house, but then the sonic detector would then become little more than a very expensive smoke pencil device.

To use the sonic detector without the aid of a door fan requires using an ultrasonic transmitter. The placement of these broadcasters in attics, crawlspaces, and outside of the sidewalls permits the auditor to locate leakage sites by "hearing" the ultrasonic waves entering the conditioned space through holes and cracks in the building envelope (Figure 1). Another use of the device involves placing the transmitter into warm air duct systems to locate the leakage sites found throughout that type of distribution system (Figure 2). A hole in the duct makes the detector beep.

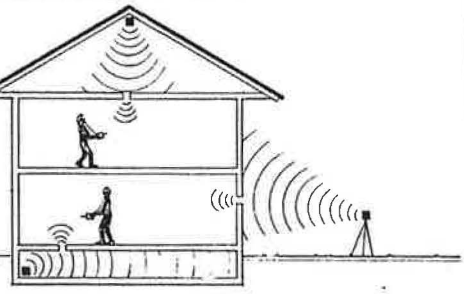

Figure 1.

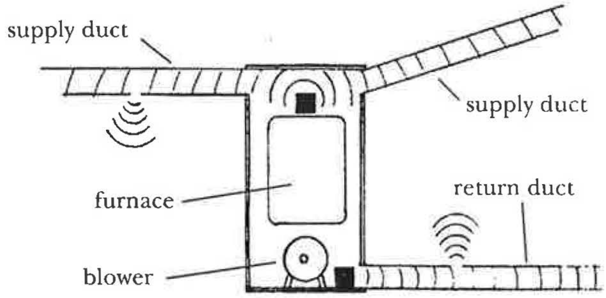

Figure 2.

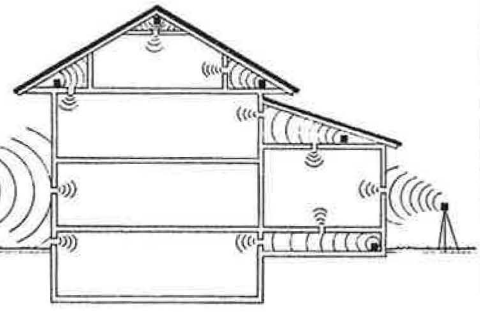

Figure 3.

U.E. Systems Inc.

Sonic leak detector

The ultrasonic technique is clearly effective at finding direct air leakage pathways. Its ability to locate the more circuitous thermal bypass routes is questionable.

Both the location and orientation of the transmitter are important. Some transmitters are slightly directional and all have limited range in terms of distance and area covered (cone of reference). These limitations must be considered when placing the transmitter, to ensure that the projected ultrasonic waves will fully blanket the surface to be inspected. While the sound waves will reflect off surrounding surfaces, the reflection will weaken the signal, as in an echo. Also, remember that thermal insulation material is often used to deaden sound transmission (as acoustical insulation).

For these reasons, both transmitters and detectors must be moved several times to test most surfaces (Figure 3). This applies to inspection of duct systems as well. The supply ducts and return ducts are separated by the heat exchanger and for best results the transmitter should be placed once on each side. The auditor must find access to

Table 1. Manufacturers of sonic leak detectors.

Manufacturer	Address	Phone	Contact	Model	Price
ICC Federated	2,200 South Street Racine, WI 53404	(800) 832-4422	Tom Nelson	Leakcheck	$650-$975*
Modern Products Ltd.	P.O. Box 683 Victoria, B.C. V8W 2P3 Canada	(604) 383-2214	Rolly Perkins	Ultra-Son	$600-$1,200*
UE Systems	12 West Main Street Elmsford, NY 10523	(800) 223-1325	Mark Goodman	Ultraprobe Series	$600-$4,000

* Price varies with accessories included in kit.

all unconditioned areas, because if any are missed, important air leakage pathways could go undetected.

Jorg Ostrowski, author of "Handheld Energy Audit Tools,"[2] says the tool's difficulty detecting bypasses is one of its biggest drawbacks. A home with metallic siding, too, can be a problem, he says, since it will reflect the ultrasound signal more than buildings made with other materials. One other warning: The signals may be disturbing to dogs.

See Table 1 for information about specific brands of sonic leak detectors.

Combustible Gas Detectors

Auditors often inspect heating equipment for both efficiency *and* safety. Safety is a major consideration when the furnace is fueled with natural gas or propane. Fuel leaks and combustion products such as carbon monoxide in the living space can be extremely hazardous.

Electronic detectors can now sense the presence of combustible gases and vapors in a living area. These devices can be extremely sensitive, indicating the presence of gases in amounts as small as 50—1,000 parts per million (ppm).

A general-purpose gas detector can detect the presence of a wide range of hazardous gases and vapors such as gasoline, methane, propane, acetylene, butane, acetone, alcohol, ammonia, and carbon monoxide, to name just the major ones. One such gas detector, the TIF 8,800, signals the presence of these gases and vapors through a Geiger counter-like ticking sound. An increase in the rate of ticking indicates the device's proximity to the source of the gas or vapor.

Since these devices are sensitive and react to a wide to a wide range of substances, both accurate calibration and understanding of the chemical make-up of household materials are crucial to their proper use. In the case of the TIF 8,800, both high and low sensitivity levels are possible. The auditor must first calibrate the detector in an uncontaminated atmosphere by adjusting the sound to either a slow ticking (low sensitivity) or a fast ticking (high sensitivity).

The auditor then takes the gas detector into the area to be inspected, usually the basement, and probes areas of potential fuel leakage with the tip of the detector. If combustible vapors are present, the ticking will increase to a steady "scream" as you approach the source.

If a scream occurs upon entering the space, some combustible vapor is present at a high concentration. Since the range of chemicals detected is broad, the culprit could be anything from a natural gas leak (methane) to a smelly cat box (ammonia). Often decreasing the sensitivity of the device will allow you to re-enter the area

Delphian Corp.

Combustible gas leak detector

Bacharach, Inc.

Carbon monoxide detector

Table 2. Manufacturers of gas detectors.

Manufacturer	Address	Phone	Contact	Model	Price
Delphian Corporation	220 Pegasus Avenue Northvale, NJ 07647	(800) 526-1008	Marilyn Ferguson	combustible gas detector	501AK $350 501NK $405
Bacharach, Inc.	625 Alpha Drive Pittsburgh, PA 15237	(412) 963-2000	John Figan	Monoxer II CO Analyzer	$550
Neotronics, Inc.	P.O. Box 370 2144 Hilton Drive Gainesville, GA 30503	(800) 535-0606	Shannon Simpson	Digislam 2,000 (combustible gases)	$1,400
TIF Instruments	9,101 NW 7th Avenue Miami, FL 33150	(800) 327-5060	Peter Sanchez	Model 8,800 (combustible gases)	$100-$200

and pinpoint the source of the gas or vapor. Volatile solvents—like those present in seam-sealing compounds—will also cause the detector to go off. This causes some confusion around pipe joints. In these cases a more traditional "soap test" can determine if there is true leakage around a gas pipe joint. And one can always use that old fall back, the human nose.

Another use of this equipment is the detection of high concentrations of carbon monoxide (over 100 parts per million). Some technicians have utilized the device to check for heat exchanger leaks by placing the probe into the plenum of an operating furnace. The device will detect substantial leakage by reacting to the carbon monoxide and other products of combustion entering the air. This technique provides the inspector with one more technique to detect dangerous levels of combustion products being forced into the home. For more information, see Table 2.

Infrared Thermometers

Almost anyone who has had an opportunity to use an infrared camera can testify to its effectiveness in locating voids in insulation. But the hefty price tag can be a powerful deterrent to integrating this device into conservation programs. A less expensive, and perhaps less familiar type of infrared equipment, the infrared thermometer, may be worth considering. These tools range in price from $500–$1,500 (see Table 3).

Infrared thermometers are very similar in function to infrared cameras. Both devices sense the infrared radiation of a surface. Both require a temperature difference between the inside and outside of a building for their operation. But while the infrared camera produces a visual image of an area, the infrared thermometer produces a digital readout of the surface temperature at one point. Voids in insulation will allow more heat transmission than will insulated areas, and this causes surfaces of uninsulated areas to be different temperatures than corresponding insulated areas. With proper training, one can learn to interpret these variations in temperature with reasonable accuracy.

The usefulness of infrared thermometers can be demonstrated by the search for sidewall insulation voids. The thermometers require approximately a 25°F temperature difference between the inside and outside of the house for clear results. For a winter test, the technician would

Capintec

Infrared thermometer

Table 3. Manufacturers of infrared (non-contact) thermometers.

Manufacturer	Address	Phone	Contact	Model	Price
Capintec Instruments, Inc.	6 Arrow Road Ramsey, NJ 07446	(201) 825-9500	Eric Weiss	Thermo-Hunter	HR-1 $995, PS-5140 $1,995
Cole-Parmer	7,425 N. Oak Park Ave. Chicago, IL 60648	(800) 323-4340	Charlie Horlbeck	cat. no. 8145-35 8158-40	$975–$1,145
Edmund Scientific Co.	101 E. Gloucester Pike Barrington, NJ 08007	(609) 573-6259	any sales representative	cat. no. 37601	$500–$1,500
Exergen Corporation	251 West Central St. Natick, MA 01760	(800) 422-3006	Marybeth Ryan	D501, D550	$699, $599
Ircon, Inc.	7,301 N. Caldwell Ave Niles, IL 60648	(800) 323-7660	any sales representative	UX40	$2,550
Land Instruments, Inc.	2525 Pearl Buck Road Bristol, PA 19007	(800) 523-8989	Mike Lutz	Compac 3	$795
Mikron, Inc.	445 West Main Street Wykoff, NJ 07481	(800) 631-0176	K. Irani	M90, M80	$2,500, $1,500
Mitchell Instruments, Inc.	1,570 Cherokee Street San Marcos, CA 92069	(619) 744-2690	John Mitchell	cat. no. OTMITRPM-2	$745–$3,000
Raytek, Inc.	P.O. Box 1820 Santa Cruz, CA 95061-1820	(408) 458-1175	Don Morgenstern	PM2	$745
Westinghouse Electric Corp.—Combustion Control Dept.	P.O. Box 901 Orville, OH 44667	(216) 682-9010	Blaine Shank	RT-570	$495

Westinghouse, Inc.
Infrared thermometer

"scan" the wall in horizontal passes, watching for cold spots, where the readout drops 4–8°F. The scan passes are horizontal to avoid misinterpreting the temperature stratification that occurs between the top and bottom of the wall. Hot air really does rise, and the tops of walls are warmer than areas close to the floor.

Figure 5. Typical wall temperatures in degrees Fahrenheit, as read by an infrared thermometer.

	(ceiling)							
	76°	83°	82°	74°	83°	75°	76°	
	79°	78°	79°	79°	78°	30°	30°	
(left)	76°	76°	77°	75°	76°	30°	30°	(right)
	73°	74°	73°	74°	74°	30°	30°	
	70°	71°	70°	70°	71°	71°	71°	
	68°	68°	67°	67°	67°	68°	67°	
	(floor)							

Figure 5 shows typical temperatures on an insulated wall, as measured by an infrared thermometer. The test was done during the winter, from the inside of the house. Note the areas that are colder when compared to other temperatures at that same height on the wall; these indicate voids or settling of insulation.

Figure 6 shows a corner of another wall as seen through an infrared camera. Voids and missed cavities a thermometer would read as low temperatures appear in the video image as dark shapes. The patterns here and in Figure 5 are very typical; by far the most common problems are incomplete fills, settling, and missed run-out or cripple cavities around windows and doors. A few passes with the thermometer will determine if those common trouble spots exist in any given wall, and in fact, insulation crews have used this device on site to do just that.

John Snell & Associates
Figure 6. IR scan of a corner of a wall with a missed cavity.

The limitations of the infrared thermometer become obvious quite quickly, however. While an infrared camera can scan an entire wall in a 20-second pass, it takes much longer to scan that same wall (in 6 or 10 horizontal strips) using an infrared thermometer. So while the infrared thermometer is useful for uncovering the most common voids, it cannot diagnose quirky and unpredictable problems that can occur in framed structures. And it is absolutely essential that anyone planning to use an infrared thermometer in the field be trained thoroughly in infrared technology. The training must include a period of in-field side-by-side comparisons between infrared camera scans and infrared thermometer readouts. Without a background in infrared imagery, the numbers produced by the thermometer quickly become confusing, and it becomes another gadget collecting dust in the storeroom.

Density-Sensitive Stud Finders

Workers insulating sidewalls are faced daily with the task of locating framing members within the walls. While probing the walls usually suffices to determine the cavity size and stud placement, this technique can be frustrating in the immediate vicinity of doors and windows. The equally frustrating, old-fashioned, magnetic stud finder requires a pass directly over the nail attaching the wall board to the stud, and may be more useful finding needles in haystacks. Even when one correctly determines the location of the studs, one quickly gets the feeling that framing around windows and doors is placed without rules, according to the whim of the carpenter. Failure to correctly locate run-out and cripple cavities in these areas can lead to major insulation voids, and to a considerable reduction in the effectiveness of the insulation job. A

Table 4. Manufacturers of density-sensitive stud finders.

Manufacturer	Address	Phone	Contact	Model	Price
Zircon International, Inc.	1580 Dell Ave. Campbell, CA 95008	(408) 866-8600	customer service representatives	Studsensor	$8–$14

Zircon Corp.

Density-sensitive stud finder

number of companies market a device for less than $20 that may help to reduce the guesswork of this task: the density-sensitive electronic stud-finder.

Stud-finders are not a new idea, but the newest generation of these devices shows considerable improvement over the originals. The first generation of stud-finders used magnets to detect the presence of nails, which were assumed to be within studs. Besides the aforementioned haystack problem, other pitfalls are obvious. Water pipes, electric wires, gas lines, etc., will contain more than enough metal to set off the detector. Magnetic stud finders are still available, and should not be confused with the density-sensitive detectors discussed in this article.

The new electronic stud-finders use variations in wall density to determine the presence of studs. The device is placed flat against the wall and moved slowly across its surface. An LED (light emitting diode) indicates an increase in wall density, presumably a stud. It is practically flawless when used on wallboard, unless the wall contains foil-backed insulation or is covered with metallic wallpaper.

Lath and plaster walls can be somewhat more tricky, as these authors quickly discovered. The first time we "discovered" a wall stud as wide as an arm span, we were bewildered. Placing the sensor directly over a lath strip was the cause of the confusion; scanning a few inches lower yielded a more traditional framing pattern. With a little practice we could identify run-out cavities, solid headers, and other variations fairly reliably.

One other caution about lath/plaster walls: At least one manufacturer warns that excessive plaster extruded between the lath strips can lead to confusing results. Although we have not run into this difficulty, it has occasionally been reported by others. The majority of lath/plaster walls seem to yield workable results. (Ed. note: for best results, the auditor may need to develop a technique to apply uniform pressure while sliding the detector across the wall.) Density-sensitive electronic stud-finders probably will not replace traditional methods of probing for wall studs and firestops. Sliding the device over every wall takes considerably more time than measuring and probing. But these devices seem to be most useful for revealing framing members around windows and doors, where their location is most capricious. ■

Endnote

1. On infrared thermography: May/June '89, p. 23-8; and Jan/Feb '86, p. 6-19.

Blower doors: besides many others, *HE* ran a series of six introductory articles on blower doors as a diagnostic tool: Mar/Apr '86, May/June '86, July/Aug '86, Sept/Oct '86, Nov/Dec '86, Jan/Feb '87. Electronic flue gas analyzers: Nov/Dec '89, p. 8.

2. "Handheld Energy Audit Tools: A Comparative Inventory," appendix to *Self-Help Retrofit Manual for Owners of Multifamily Housing Units.* Jorg and Helen Ostrowski. Calgary, Alberta: Alternative & Retrofit Energies, Inc., 1987. (403) 239-1900.