A High-Tech Tool Meets Low-Income Weatherization

by John Snell

Infrared cameras—once only seen in expensive R&D studies—are finding their way into weatherization programs. Several agencies time-share the equipment, using it to train crews and inspect work.

For many years infrared thermography seemed distant from the reality of the low-income weatherization program. Maybe it had a place in well-funded research studies, or maybe you could get a peek at a camera at a conference, but that was about it. I often heard such comments as, "Oh yes, I read about that in National Geographic," or "Great stuff, but how can we afford that?" Well, the equipment is no longer so obscure. If you are involved with the weatherization program, you are more likely than ever to hear about, see, use, or even *own* infrared imaging equipment. Thermography has come into its own as a weatherization tool.

To find out exactly how thermography is being used in low-income weatherization, I sent questionnaires to 360 people around the country who work in all levels of the federal program, and received 180 back.[1] I combined their responses with the personal impressions and experiences gained as a trainer of thermographic applications during the past five years. I have worked with over 500 people from weatherization programs in 16 states who are learning how this equipment works. The resulting composite picture, which I share with you here, is impressive. As of this point, at least 75 thermographic imaging systems are in regular use by weatherization programs in two dozen states.

I wanted to get at the answers to several questions in my survey. First, how is this technology being used? Second, what seem to be the best uses? And third, what does it take, beyond a piece of equipment, to successfully integrate thermography into a program?

John Snell lives in Vermont, a place where the biggest source of infrared radiation in the winter is wood stoves. He frequently travels to places with more radiant heat to get warm and train weatherization crews to use thermography.

Uses of Thermography in Weatherization Programs

Here are some ways weatherization and related agencies are using thermography.

Training: If any single application has emerged as the best use of thermography, it is the role the tool can play in training. First, it allows us to see something that was pretty much invisible before. Seeing is believing. For instance, the first time people see a thermal image of air leakage, they usually break into a smile of satisfied recognition; they usually know exactly what it is, because it looks just like they always thought it would. Figure 1 is unveiled as figure 2, which shows air leakage into a wall cavity under natural pressure conditions.

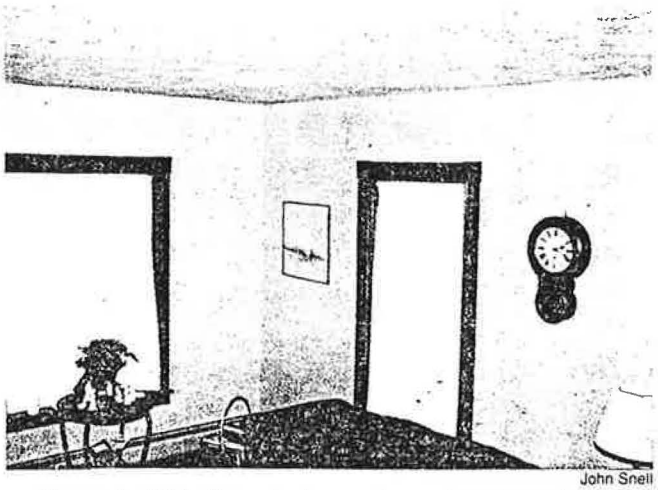

Figure 1. With the naked eye, thermal patterns in the walls can only be imagined.

Second, 90% of the imaging systems used in weatherization are video compatible. This means that the live or recorded thermal image can be played on a television for an entire crew to see; or a group of auditors in training can incrementally seal a house and watch the reduction in air leakage. With the house depressurized, the surfaces chilled by cooler outside air grow dark before their eyes.

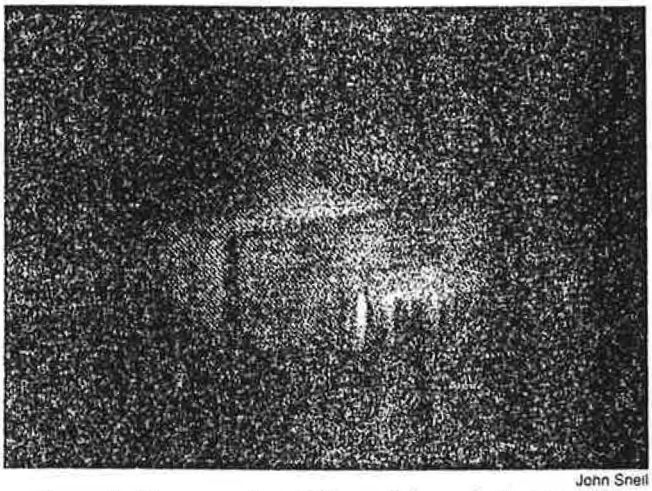

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Figure 2. The same shot as figure 1 through the infrared imager shows voids in the wall cavities (dark squares) and resulting cold air leakage into the ceiling.

This is powerful stuff! As a training tool, thermography serves to bring state monitoring staffs and local agencies into better communication with each other.

Several states, most notably Ohio and Pennsylvania, are also using thermography in their training centers. Watch for more of this as a way to justify the purchase of IR systems, which cost $14,000 to $24,000 and up.

Monitoring: The monitoring of local programs and contractors by state-level administrations is another prime use of the equipment. My survey shows two types of monitoring taking place in nearly every state using thermography. The "big stick approach" is designed to reduce the incidence of outright fraud. The monitoring agency can tell builders they're going to inspect, "so don't try to get away with inadequate insulation." A softer approach enables the monitoring agency to more fully see the local program's finished work and, as a result, to modify existing support systems or design new ones. The state's purpose with the soft approach is quality control rather than police work. The cooperative relationship allows the state to help the programs see their work and improve it.

Taken together, fraud and general quality control problems, especially for sidewall insulation, have been shown to be significant. Ron Ward, of Rhode Islanders Saving Energy (RISE), a non-profit energy conservation service (see *HE*, Jan/Feb '86), has accumulated data from over 3,000 infrared inspections. Even with solid training and monitoring, about 15% of the sidewall work failed the criterion of having less than 10 ft^2 of void area per house. The control group, with little monitoring and training (similar to conditions in the open market), contractor failure rates were five to six times higher.

As for the effectiveness of the big stick approach to monitoring, the results are hard to measure. No one knows exactly how big a problem fraud is, never mind how much is deterred by various methods of monitoring. One major fraud case was the catalyst for a bulk purchase of sixteen imaging systems in one state alone. Often the mere threat of such "Inframan vision" is enough to dissuade a dishonest contractor.

"Soft" monitoring has produced some excellent results. One local agency found that the work of a sub-contractor's

What is Infrared Thermography?

All objects emit infrared radiation, or heat. It is a form of light, but it is outside the visible range. Thermographic equipment senses this form of electromagnetic radiation, much as your eyes sense light and colors. The camera then electronically displays the radiation as a visual image, or thermogram, of the thermal patterns normally invisible to us. The equipment is relatively easy to use, about as complex as a good camera or videocamera. However, the interpretation of the thermal image can be more difficult, requiring a background in buildings and thermographic training as well as experience reading the images.

Figure 3 shows a typical imaging system, the I.S.I. Video-Therm® Model 91, and the thermal image (Figure 4) that is seen through the viewfinder of the system. In this image the cold (dark) area over the door is an insulation void.

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Figure 3. The author with camera.

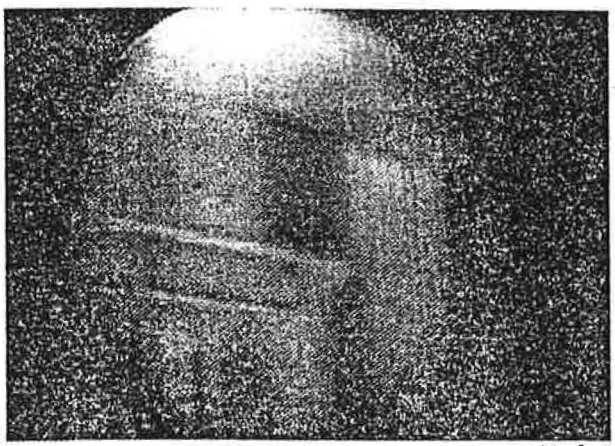

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Figure 4. What he sees.

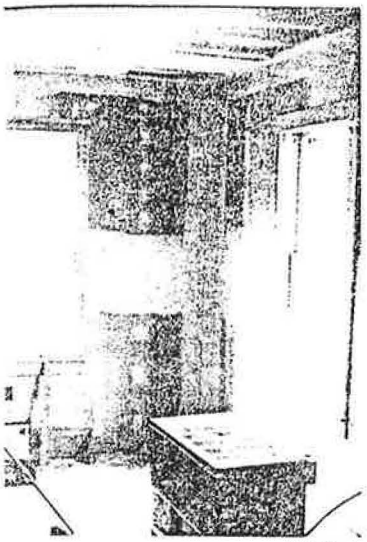

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Figure 5. Cross-braced wall.

crew, which was using a two-hole method for blowing in sidewall insulation, consistently showed inadequate thermal resistance. After it had changed to an insertion tube method, follow-up thermal inspections revealed a dramatic improvement. Figures 5 and 6 show a cross-braced wall; infrared monitoring showed that this crew had not seen the importance of following the instructions to "plumb and probe all cavities."

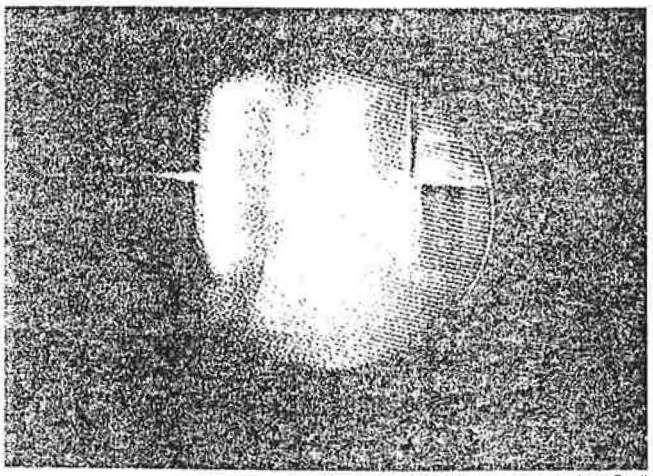

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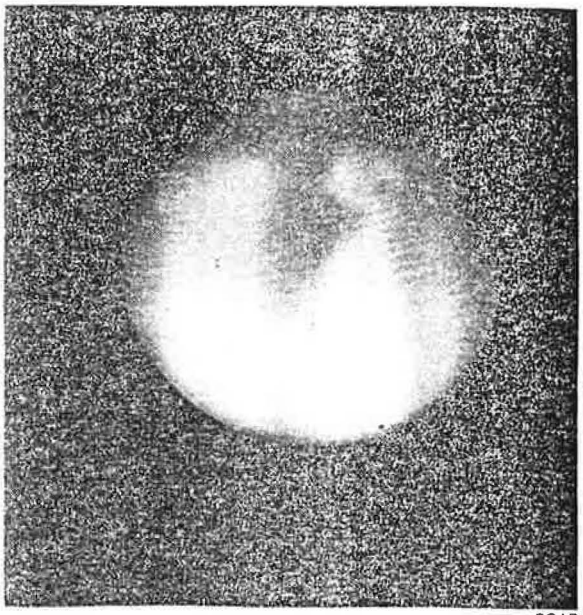
Figure 6. Thermogram of same wall.

Research and development projects: Thermography enjoys an important role in R&D. Many of the ground-breaking studies by the Center for Energy and Environmental Studies at Princeton University relied heavily on it. More recently the Coalition for Ohio Appalachian Development (COAD) made thermographic inspections an integral part of their mobile-home study. Figures 7 and 8 are thermograms taken from this study. Both are taken of the same area of wall, showing displacement of the fiber-glass insulation. In each case a 23°F temperature difference existed between the inside and the outside wall surfaces, but in figure 8 a blower door, which had been operating for five minutes, greatly enhanced the thermal pattern. Several programs reported that they hope to be undertaking R&D projects in the future, especially to test materials and installation procedures.

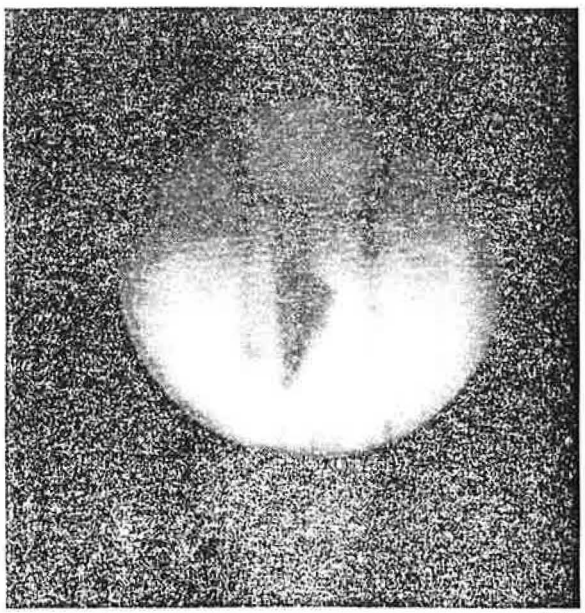
Air Sealing: Researchers and crews can learn even more by using a blower door in conjunction with the infrared camera; they can see how air leakage draws cold air through walls, even through insulation. The IR camera and the blower door, as many programs have found, each become more valuable when teamed up together. Inner wall air leakage and bypasses that might not show up clearly in a smoke test are often shockingly evident in a thermal image. The camera can also see leaks in areas that are fully insulated (especially with fiber glass) when the home is depressurized. Figures 9 and 10 show such air leakage into a wall area that is insulated with R-19 fiber glass. Leaks that show up without the blower door are even more dramatic with it turned on.

Problem solving: Ideally, every auditor and crew in the weatherization program would have easy access to an infrared imager. The information it can provide cannot be gained as easily by any other method. It is also vital to help accurately assess the problems in a building and effectively solve them, especially when they involve air leakage, moisture, or partially-insulated cavities. Currently, problem solving on individual buildings, or individual categories



COAD

Figure 7. Thermogram of displaced fiber glass.



COAD

Figure 8. Same shot with house depressurized reveals more detail.

of buildings, is only a minor use in the program. As more and more local agencies gain access to equipment, this will change. In fact, many community action programs have already discovered how quickly duct separations in mobile homes can be located—without pulling the covering off the underside of the mobile home.

Profit-making ventures: A handful of agencies are testing the waters of commercial thermography with new profit-making ventures. Some provide building inspections to sister agencies, other housing programs, or utility-sponsored conservation programs. Again, expect some growth in this application—it's a natural.

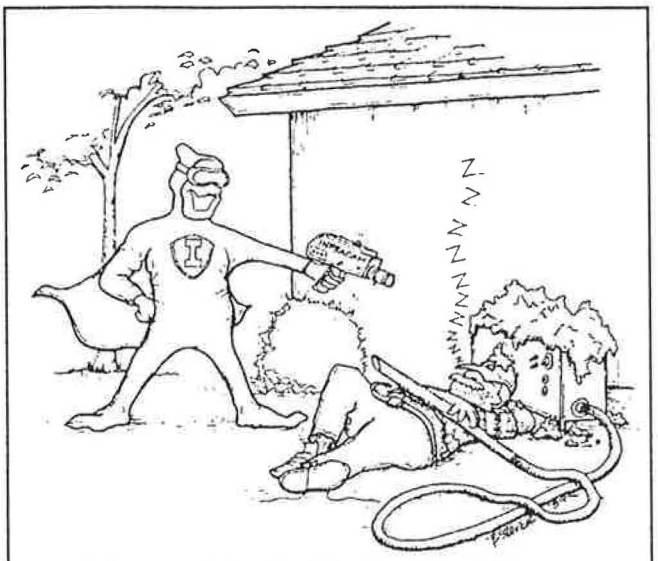
Client education: Anyone who has ever used a thermographic imager in a client's home has seen the impact it can have with the homeowner. A few utility conservation programs have incorporated thermography into client education videotapes or "vanscan"-type programs with beneficial results. This application, though, is essentially untapped.

Selecting the Right Equipment

Next to adequate administrative support, selection of appropriate equipment and the training to use it appear most important throughout the two-dozen states using thermography. Before buying equipment, it is important to define the goals of the program. If the major goal is simply to spot check each house, then consider the less-expensive point radiometer (see box). If any substantial monitoring or training is to be accomplished, then the job must fall to an imager.

A small selection of appropriate infrared imagers is available. The good news is that some fit the bill nearly perfectly. Looking at the more than 75 pieces of imaging equipment now in the field, some interesting trends emerge.

- Portability: More than 95% are very portable, i.e. not cart or harness mounted.



Inframan catches Joe Blow-in red-handed. Rick Stover

- All electric operation: More than 90% are electrically operated. The few systems that require either nitrogen or argon coolants are either underutilized or used by only a limited number of individuals; they are perfectly fine systems, but the fact that they are not all-electric makes them more difficult to share among many users.
- The most popular feature on an imager—and nearly 100% of those purchased in the last two years have it—is compatibility with video. What this means is that the live or recorded thermal image, with audio, can be shown with a VCR on a television set. The value of this feature as a training tool, in particular, is immense.
- Ease of use: This is the classic KISS (Keep It Simple Stupid) principle at work. The most widely and fully used systems are easy to operate, even if the thermographer hasn't thought about them for 3–4 months.
- Cost: New systems range from $14,000 on up. Used systems are sometimes available, but beware! Repairs, if needed, can ruin an otherwise good bargain.
- Interchangeable lenses: Several models can be quickly adapted with different lenses, much like a 35mm camera

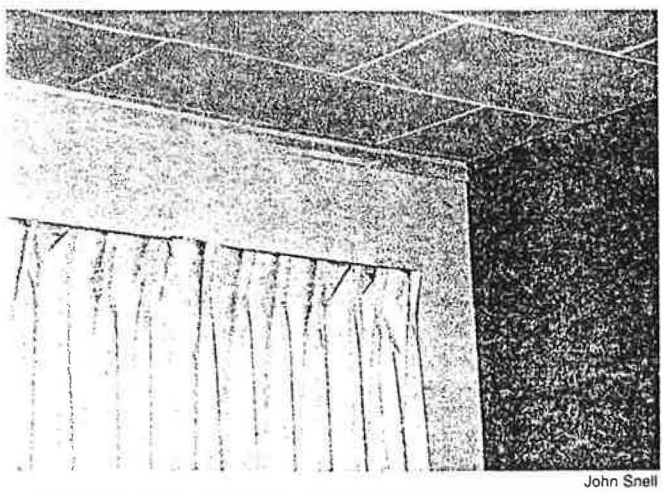


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Figure 9. Inconspicuous crack above the trim might be overlooked by an untrained retrofitter.

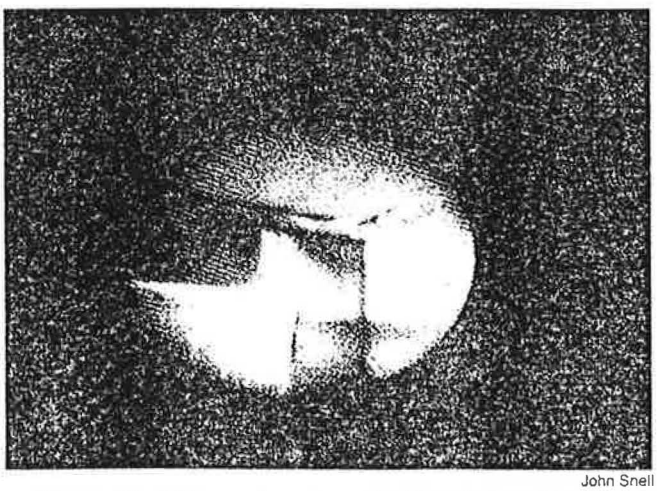

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Figure 10. A blower door teamed with an infrared imager reveals this striking image of air leakage.

difference between inside and out is needed. This is not a hard and fast rule, but, at least for beginners, it is important. Obviously that means that during some months inspections will be difficult, during others just plain impossible. Users have found several ways to get around this problem.

Most thermographers stretch the limits by working in the mornings, outside temperatures having stabilized at a minimum level overnight. Even in the summer, adequate imaging can be done on many mornings. Unfortunately, most weatherization programs like to keep their work hours on an 8–5 schedule.

Many programs keep a blower door in their bag of tricks, and use it to enhance temperature differences and conduction patterns when weather isn't favorable. (The blower-door depressurization draws outside air in through cracks and voids in a dramatic fashion, as can be seen in Figures 7 and 8.) Used with a blower door, thermography can detect air leakage even with a smaller temperature gradient; usually 5° is sufficient. (Whether outside is warmer or colder than room temperature doesn't matter.)

Inspection of ceilings, on the other hand, is easily done from the inside most any time of the day or the year. Either high or low temperatures will result in a readable image.

Because of the limited inspection season, work cannot always be checked right after it is finished. Programs must adapt their procedures so that a job can be "signed off," and the contractor paid (perhaps in part), yet keep some control over having the deficient work corrected.

What's Next?

I often hear folks speculate, with great hope, that the price of thermographic imaging equipment will come down just like calculators did years ago. I'd be willing to bet quite a lot of money that this will not happen, at least not for 5 or 10 years. In the meantime, look for equipment that does more and does it better.

Also, as the users of the first 75 systems make the value of thermography clear, you'll be seeing *more*. More equipment, more trained users, and more applications. Probably most exciting is the prospect that the technology will see expanded use at the local program level, both as a training and a quality-control tool. Look out, too, for studies that further quantify the value of thermography as a weatherization tool. Regardless, it is a tool that is here to stay, and its value is already being demonstrated extensively.

So, keep your eyes open, and you may just see some things—like infrared radiation—that you have never seen before. ■

Endnote

1. Survey results to be published in *Proceedings of the International Society for Optical Engineering* (Thermosense XI), Bellingham, WA. Preview copies available from John Snell at 17 First Ave., Montpelier, VT 05602. Tel: (802) 229-9820.