Zone Pressure Diagnostics

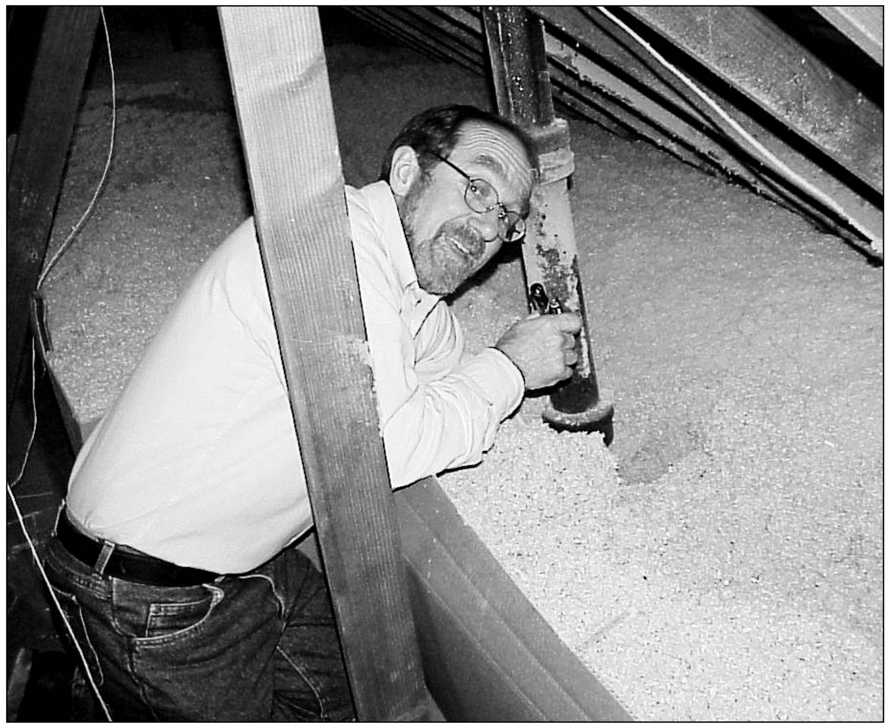
A new protocol shows how to make a valuable diagnostic test even more useful.

by David Bohac

Since 1990, zone pressure diagnostics (ZPD) has become an established tool for diagnosing indirect air leakage paths in houses (see "User-Friendly Pressure Diagnostics," *HE* Sept/Oct '94, p. 19). ZPDs are used to identify and measure series leaks, or leaks that pass through several zones of the house. For example, air leaking through the attic roof must first move from the living spaces into the attic through the attic floor (see Figure 1). ZPDs measure the pressure difference between the living space and the bordering zone (such as the attic), and between the bordering zone and the outdoors. These bordering zones can also be basements, garages, kneewall areas, or particular rooms (see Table 1).

ZPD testing relies on the principle that the ratio of the pressure difference across the interior and exterior boundaries of a series leak is a direct function of their leakage area. Michael Blasnik developed the set of ZPD techniques known as the Blasnik methods. These methods have become well established among weatherization crews, with hundreds of users across the country. Field technicians can choose from three different methods:

- the Hole method—adding a hole of known size to one side of the flow path and measuring how the pressure differences change;
- the Flow method—making a large opening (such as a door) between the house and the zone and measuring the change in the flow rate of the blower; and
- the Vent method—estimating the amount of attic venting to the outside through roofs, gables, ridges, turbines, or other openings.



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Jim Fitzgerald is inspecting a bypass that has been buried in cellular insulation.

All three methods are based on depressurizing (or pressurizing) the house by about 50 Pa and making one or more additional pressure measurements. For example, if the ceiling and roof are equally leaky, the pressure difference across the ceiling will be midway between the inside and the outside pressure—25 Pa when the house is at 50 Pa. If the ceiling is completely airtight, the pressure difference across it will be 50 Pa and the pressure difference across the roof will be 0 Pa. If the ceiling is somewhat tighter than the roof, the attic pressure will be closer to the outside than the inside.

When to Use ZPDs

Simple visual inspection, blower door-assisted visual inspection using chemical smoke, and infrared camera scans are often used to identify air leakage paths. ZPD tests can aid in identifying and measuring leakage paths, but the expected value of the ZPD results should be greater than the cost (and hassle) of performing the test. The expected value of a given test depends on how important it is to know the answer, and how accurate that answer is likely to be. There are three main reasons for wanting to know the zone air leakage. In order of importance, these reasons are

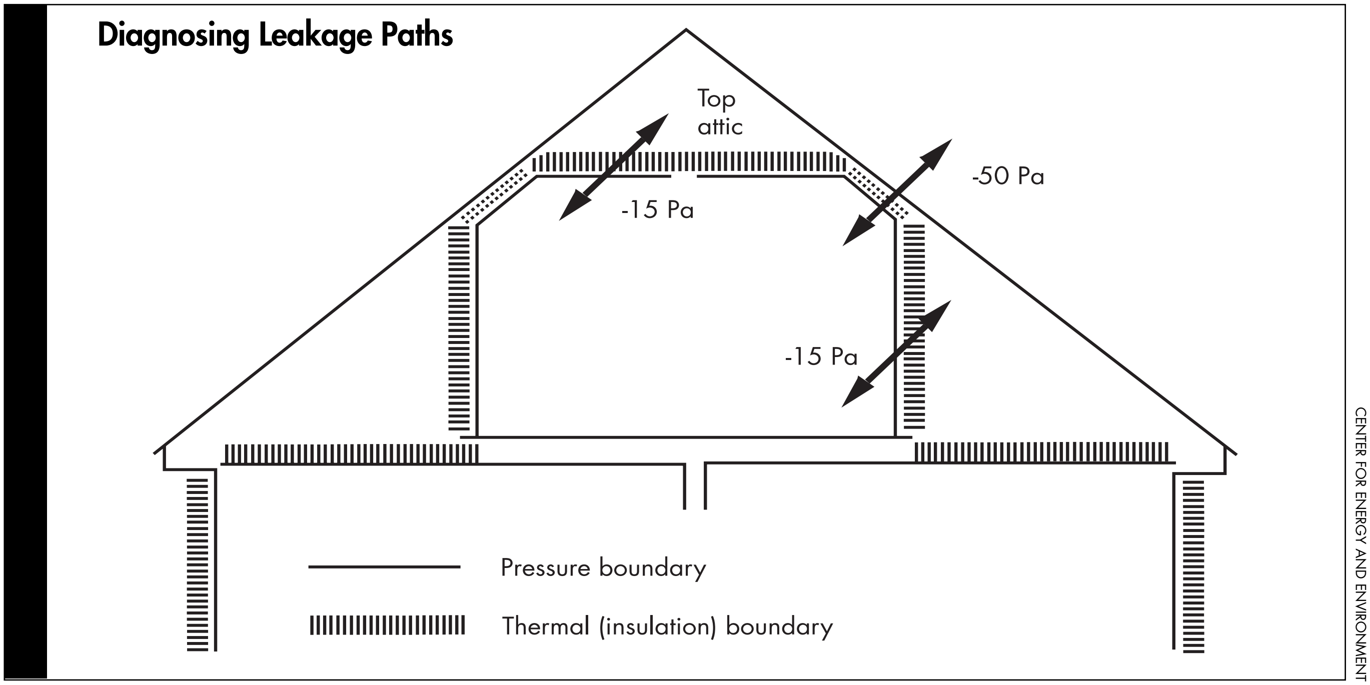

Figure 1. Air leaks can be diagnosed by measuring the pressure differences across various house boundaries.

Table 1. Leakage Pathways

Zone	Interior Surfaces	Exterior Surfaces
Attic	Top floor ceiling, bypass paths	Roof, gables, soffits
Basement	Basement ceiling	Basement walls
Garage	House/garage wall, garage ceiling	Exterior garage walls
Knee-wall area	Knee-wall, floor system	Roof, soffits, end walls
Bedroom	Interior partition walls, floor, ceiling	Exterior walls, ceiling

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• To assess a known or likely indoor air quality (IAQ) problem, such as a garage or a moldy crawlspace connection to a living area.

• To identify potential building durability threats, such as attic moisture buildup. The level of importance is even greater where there are other factors that give cause for concern. Examples include over-tight houses or houses with high indoor relative humidity that are located in a cold climate.

• To identify leaks that can be sealed to increase energy savings. In most situations, the biggest holes are obvious without a ZPD test. This is the least important reason to test, unless the climate is severe, or the house has unexpectedly high leakage.

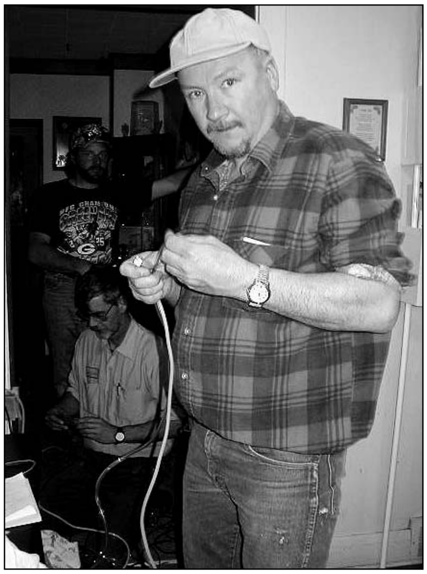
In other words, it is most important to perform ZPD tests when IAQ problems and threats to building durability have been identified. It becomes less important when saving energy in a moderate climate is the goal. For example, it is more important to test a moldy house in Minnesota than a poorly insulated house in Ohio. It is likely that the protocol may differ (or tightness guidelines may vary) based on the type of climate.

ZPDs are probably most widely used for prioritizing air sealing. By estimating the available air leakage reduction potential of various locations within a house, a crew can make informed decisions about where best to spend their time. Some groups within and outside of the low-income weatherization community have also set performance specifications based on ZPDs. For example, the American Lung Association's Health House program specifies a maximum amount of garage-to-house leakage, as determined using ZPDs.

Developing a Protocol

Despite widespread use, there are substantial differences in the way field technicians use ZPDs. There is no established protocol for deciding when to use ZPDs, which of the three methods to use, or how to make the best measurements.

A project team comprised of staff from my organization, the Center for Energy and Environment, Michael



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(left) Tom Kalina of West CAP is preparing to perform a zone pressure diagnostic test, with help from Adrian Scott and Roger Drury. *(right)* Here Tom is sealing a cardboard template to a kneewall attic door.

Blasnik & Associates, and the Energy Conservatory developed and tested protocols for ZPDs used by weatherization crews, and developed methods for determining the accuracy of ZPDs. The overall goal of the project was to develop a more effective ZPD protocol that could be more widely adopted for weatherization crews. Our work was supported through funding provided by the Energy Center of Wisconsin, DOE, DOE's Chicago Region, State Weatherization Agencies, and the states of Minnesota, Wisconsin, Iowa, Ohio, and Indiana.

In developing the protocol we relied on both laboratory test results and tests conducted by weatherization crews in the field. We conducted laboratory tests to measure the relationship between the physical and effective area of different openings used in the Hole method. We also performed numerous simulations and made measurements at two staff houses to look at how initial house pressures and measurement errors affect ZPD conclusions. In the field, six different weatherization crews conducted extensive ZPD measurements on their program houses to provide information on the frequency of occurrence of zone conditions, investigate the reliability of the different ZPD methods, and compare the postweatherization air leakage reduction measured by ZPDs to whole-house air leakage tests.

What We Learned

Measurements of nine different hole types were performed at the Energy Conservatory test laboratory. The results indicate that a small rectangular hole cut in a piece of cardboard and placed over an opening has an effective area about equal to the opening. This is true even when there is framing or an insulation dam around the opening and for openings with a length no more than 40% of the width (larger holes were not tested). The air flow rate through other types of holes, resembling small open attic access hatches or partially opened hatches, was up to 37% higher than that for holes without hatches that had the same area. This would cause the Hole method to overestimate zone leakage by 37%. It is difficult to predict the amount of overestimate just by looking at the opening. When access hatches are used to make an opening, a good rule of thumb is to increase the actual area by 20% for the Hole method calculation.

The Flow method calculations, which depend on the change in the blower flow rate when the opening is made, provide another means of estimating leakage—even when a smaller opening is used. It was hoped that the results of the two calculations could be combined to produce more accurate leakage estimates. Unfortunately, simulations showed that the house baseline pressures and pressure measurement errors produced similar errors for both calculation methods. We did find that the Flow method results can be used as a valuable check for the Hole method results.

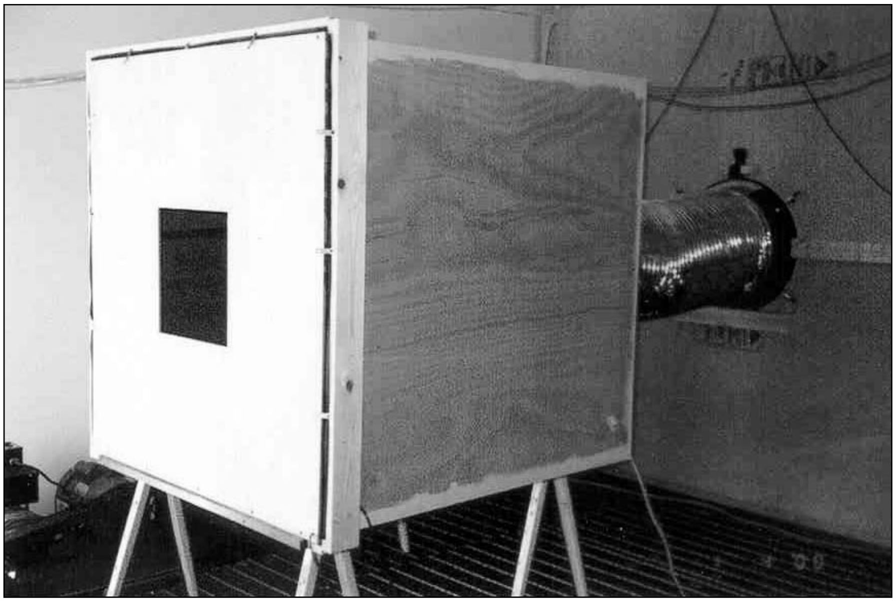
Resolving Discrepancies

In most cases where there are discrepancies between the two leakage results, we recommend that the results from the Flow method calculation be used. The main reason for this recommendation is that the measurement of some attic access openings using the Hole method can have large errors in the effective area. We also recommend that the access to the zone be completely opened, or that a traditional open-door test be performed. This reduces the uncertainty relative to the area of the opening and provides better information on possible connections between zones.

Most people who have used ZPDs recognize that connections between zones result in an overestimate of the leakage. For example, an open floor joist between two side attics will cause the attic leaks to be counted twice. The degree to which this occurs depends on the relative size of the connection compared to the size of the attic leaks. We found that the relative overestimate due to a connection is about equal to the percentage change in the pressure of one side attic when an opening is made to another side attic. The overestimate is likely to be unacceptably large when this figure exceeds 20%.

Field Testing ZPDs

Six low-income weatherization crews from three states completed extensive field tests on 69 houses. More than 50% of these houses were built before 1930, and 19% were built before 1900. There was a fairly even distribution of one-, one-and-a-half, and two- story houses.



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(left) This laboratory setup was used to measure hole equivalent leakage areas. For each test hole, pressures and flow were measured at several target pressures and analyzed by the Energy Conservatory's TECTITE software. *(above)* Adrian Scott of West CAP conducts a ZPD test, using a DG3 gauge.

Almost all of the houses had basements. The average total floor area was slightly greater that 1,900 ft^2. Approximately half of all leaky zones identified in the houses were attics (about 20% of these were kneewalls). Few houses had crawlspaces or attached garages. Compared to typical low-income weatherization houses, the houses studied were generally tight, with a median overall leakage of 2,250 CFM$_{50}$.

The field tests produced over 1,000 ZPD measurements. One of the findings from the test results was that, after the houses were treated, fewer than 10% of the tested zones had significant connections to other zones. Before the houses were weatherized, over 25% of all zones had significant connections, and more than 50% of the kneewall attics had significant connections. This indicates that it is important to check the change in the pressure of surrounding zones when an opening is made to a zone as part of a ZPD test, particularly before houses have been treated.

When the houses were depressurized to 50 Pa, a majority of the zones had initial pressures that were measurable (greater than 2–3 Pa). The typical attic-to-outside pressure for kneewall attics was 17 Pa, and it was 6.7 Pa for non-kneewall attics. An error analysis showed that for about 80% of the zones the error of the series leakage was less than 25%, or 200 CFM. The results from the Hole and Flow calculation methods generally agreed quite closely; they had a correlation of 0.92. Statistical error analysis indicated that the differences between the methods were consistent with expectations. This indicates that ZPDs are fairly reliable for a large fraction of zones.

The field project was originally intended to further assess the accuracy of ZPDs by comparing overall whole-house leakage reductions from air sealing to the predicted change based on the ZPD tests. However, there were several logistical factors that made this comparison problematic, including very small leakage reductions and air sealing work performed on the exterior envelopes of the houses. The resulting comparison showed essentially no relationship between the ZPD predictions and the measured whole-house leakage reductions, but this finding was not considered reliable.

The results of the weatherization crew's ZPD tests show that Vent method calculations are a poor substitute for Hole method or Flow method calculations. However, no attempt was made to incorporate background construction leakage into the vent calculations, causing an average 50% underestimate. The Vent method would be more reliable if this background leakage could be estimated. However, the Vent method may still be useful as a rough screening tool and as a way to provide guidelines related to the use of pressure-only diagnostic approaches.

The results of the project were used to produce a recommended protocol to guide weatherization crews on the use of ZPDs in program houses. The protocol specifies when it is appropriate to use ZPDs and what type of ZPDs should be used. Agencies will need to customize the protocol for their own use by determining house and zone tightness limits. It is expected that further refinements will be made as weatherization crews start using the protocol.

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For more information:

The full report, *An Investigation into Zone Pressure Diagnostic Protocols for Low-Income Weatherization Crews,* is available for free through the Web site of the Energy Center of Wisconsin (www.ecw.org). Click on the link for "Publications" to download the report.