FEATURES

Testing for Airtightness

by J.D. Ned Nisson

WHY TEST FOR AIRTIGHTNESS

Air leakage is not always easily spotted. It is the movement of an invisible substance (air) by forces which are unfamiliar (wind pressure, stack effect). It won't even occur until after the house is finished. No wonder construction or retrofit crews experience difficulties learning to plug up every air leak.

That's why some tests have been developed for airtightness.

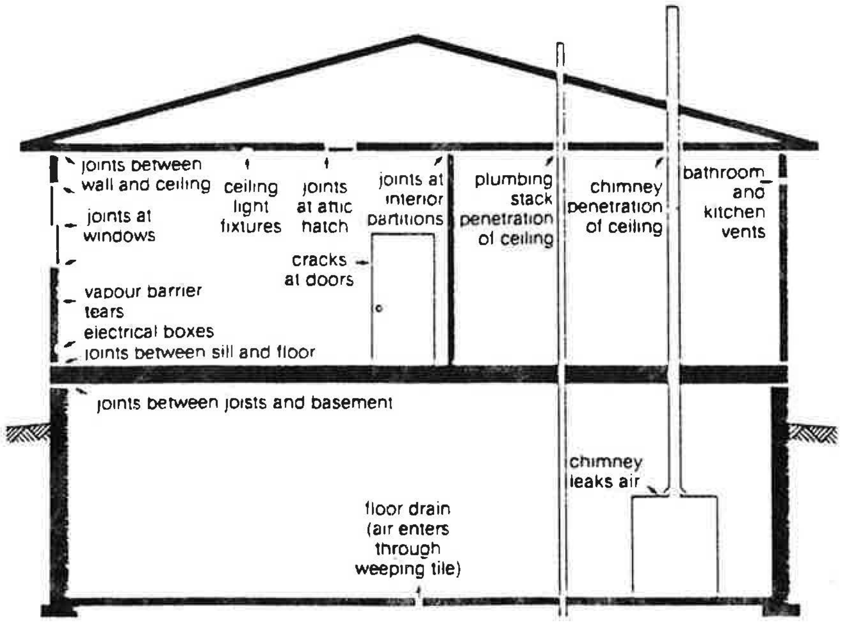
We used to think that most leakage occurred around windows and doors; all we needed to achieve airtightness, we thought, were caulking and weatherstripping. We now know that there are less obvious leakage points such as joints between sill and floor, plumbing stack penetrations, joints between wall and ceiling, and many more. Not only are these sometimes hard to think of or detect: it is also hard to know whether they were successfully sealed. For example, many workers still like to use fiberglass insulation to seal wide cracks. This doesn't work. Fiberglass is an excellent insulation and a good air filter but it is a lousy air sealant. A test for airtightness would immediately show this.

So we test for airtightness to assure quality control. There are also other reasons to test: airtightness is a way to express a house's energy efficiency for marketing purposes. Some day, probably in the near future, houses will have "energy efficiency labels" which include measured airtightness. We may also soon see airtightness requirements in building codes. Sweden already has such a code; Canada is considering it. The U.S. has some energy efficiency requirements in building codes: airtightness may become one of them. As issues of indoor air quality become resolved and as testing methods become easier, we may very well see such a code in this country.

Only with proper testing can we be certain a house is super airtight, and an airtight house is a better house. Airtight construction helps prevent moisture condensation problems in wall and ceiling cavities, and, of course, it minimizes heating and cooling requirements.

HOW TIGHT IS AIRTIGHT?

The most common unit of measure of air leakage is air changes per hour (ach/hr). One ach/hr means that one house volume of outside air is



AIR LEAKAGE SPOTS IN CONVENTIONAL HOUSING

Source: Energy Efficient Housing: A Prairie Approach, by Energy Research Development Group, Univ. of Saskatchewan, p. 3.

leaking into the house every hour. A 2000 square foot house with 8' ceilings has a volume of 16000 cubic feet. If that house has a leakage rate of 1 ach/hr, then it is leaking 16000 cubic feet of air per hour (267 cfm).

An extreme example of an airtight house is the Saskatchewan Conservation House built by the National Research Council of Canada in 1977. It has a natural infiltration rate of about 1 air change every three days or 0.014 ach/hr. The average house in the U.S. has a leakage rate between 0.5 and 1.0 ach/hr. A carefully built superinsulated house should have an air change rate between 0.1 and 0.2 ach/hr.

NOTE - Before going further, we should clarify one point. These airchange rates refer to the uncontrolled infiltration through building seams and defects. Any tight house should also have intentional and controlled ventilation through a mechanical ventilation system and/or windows. That ventilation rate may be 0.5 ach/hr or higher depending on the need to remove pollutants from the interior air.

It should also be noted that the mere fact that one ach/hr of air is leaking into a house doesn't necessarily mean that the whole house is being ventilated every hour. Some of the new air goes right back out; some of the stale air never leaves. For a complete discussion of this effect, we refer you to W. Shurcliff's book on air to air heat exchangers (see review, this issue of the Update).

THE BLOWER DOOR

The "blower door" test described below provides the builder or retrofit contractor with visual pointers of every leak area that has been missed. On a new house, the test is performed before the sheetrock goes up. The air barrier actually inflates under the depressurization and leaks are easily located. The test should be performed with the crews present so they may see their oversights and learn for the next time.

The blower door is a portable device used to exaggerate air leaks in a building envelope. It is basically a high flow fan mounted on an expandable panel which is temporarily installed in an exterior door of a house. The house can then be either pressurized or depressurized, providing steady air leakage through cracks and openings. The leaks are located using a variety of sensing devices including infrared cameras, smoke pencils and the back of the hand. (See Tom Blandy's article in this issue for a description of house doctors' use of the blower door.)

There are several blower doors now commercially available. Most come with instrumentation which measures the amount of pressure (or vacuum) being applied to the house and also the volume of air (calculated from fan speed) which is being moved to maintain that pressure. Some of the units are sold as part of a marketing package which includes retrofit materials, marketing literature, etc. They range in price from $2000 to $5000.

The blower door has two purposes. The first, and most practical, as described above, is to exaggerate air leaks so they can be plugged. The second purpose is to measure the amount of leakage in a building. The blower door is also used in some advanced energy auditing techniques, such as house doctoring to locate other forms of obscure but important energy leaks.

MEASURING AIR LEAKAGE WITH THE BLOWER DOOR

It is important for the concerned building professional to at least be familiar with the basic concepts and vocabulary of measuring air leakage.

Using the blower door, air is sucked out of the house, creating a partial vacuum inside. The amount of vacuum (actually the pressure difference between inside and outside) is measured with the blower door instruments. The unit of pressure most commonly used in this test is the "Pascal" (named after the mathematician). Usually the house is depressurized until the difference in pressure between inside and outside is 50 Pascals. How much pressure is that? It is 0.007 pounds per square inch or the amount of pressure exerted by a column of water 2" high. It is approximately equivalent to the force exerted by a 20 mph wind blowing onto all sides of a house.

The blower door instrumentation includes a tachometer to measure fan speed. Given the fan speed, one can then calculate the volume of air flowing through the fan (which represents the amount of air flowing into the building.) The rate of air leakage in cubic feet per hour divided by the house volume equals the leakage rate in air changes per hour.

Unfortunately life is never simple and neither are engineers. Some researchers prefer to express leakage in a completely different manner referred to as ELA (equivalent leakage area). Simply put, it is the area of one single hypothetical hole in the building envelope which would allow the same amount of leakage to occur. Neither method is yet considered the standard. For this discussion however, we will refer to measured leakage rates only in ach/hr.

WHAT IS THE RELATIONSHIP BETWEEN MEASURED LEAKAGE USING THE BLOWER DOOR AND THE NATURAL INFILTRATION RATE?

It is very difficult to accurately predict natural infiltration rate using blower door data. According to Gautam Dutt of Princeton University, a best estimate for natural infiltration is simply the measured leakage rate under 50 Pascals divided by 20. Simple. He adds, however, that this is a very rough approximation and that natural infiltration can be affected by microclimate, building proportions, location of openings, bypasses and internal flow resistance in the building. Researchers at Lawrence Berkeley Laboratory take a more complex approach which is beyond the scope of this article.

Why the difficulty? Because many of the factors affecting natural infiltration are complex and difficult to model mathematically. Also, the blower door test creates an artificial situation which doesn't exactly duplicate the natural situation. Here are a few examples of factors which confound attempts to predict natural infiltration from blower door measurements:

1. The blower door test is not standardized. Is the cellar included in the test? Were the measurements taken under pressurization or depressurization? Were the "intentional" openings such as furnace flue and exhaust fans sealed or unsealed during the test?

2. Since it creates very high pressure differences, the blower door may induce leaks through very small cracks which don't ordinarily leak under natural conditions.

3. The results of the blower door test are affected by wind at the site during the test.

4. (Submitted by William Shurcliff, Cambridge, MA) The blower door test is not affected by location of the leaks. As an exaggerated example, consider a three story house with no interior partitions which is completely airtight except for two large holes. In Case 1, one hole is in the east wall on the first floor and one hole is in the west wall on the third floor. In Case 2, both holes are in the east wall on the first floor.

Under natural conditions, the Case 1 house will leak lots of air, especially when it is cold outside or when the wind is blowing from the east or west. The air goes in one hole and out the other. The Case 2 house will leak much less air under natural conditions. All the forces are pushing air in through both holes but there is no path for it to flow out. There is practically no airflow through either hole.

The blower door test, on the other hand, doesn't see any difference between Case 1 and Case 2. It will pump equal amounts of air through both holes in either case.

This problem has also been pointed out in research at Princeton University. In a paper by David Harrje of Princeton (ASHRAE

Transactions 1979, Vol. 85, Part 1), it was pointed out that changing the location of openings in a test house could increase the natural ventilation by 100% or more.

Despite this apparent shortcoming, the blower door is still an incredibly useful diagnostic tool. It vastly expands the energy auditor's ability to evaluate the leakiness of a house. If a house has a measured leakage rate of 3.0 air changes per hour under 50 Pascals of pressure, it is a tight house. Period. Who cares whether the natural infiltration rate is 0.10 or 0.15 ach/hr. Either value represents a very tight house; the difference is academic. We present the above information so that you understand the limitations of the test and do not inadvertently misuse the tool beyond its limits.

WHAT ARE SOME TYPICAL VALUES OF MEASURED LEAKAGE RATES USING THE BLOWER DOOR?

At the ASHRAE meeting in Toronto last June, Robert Dumont of the Canadian National Research Council presented a summary of reported leakage rates from several studies. We present some of them here (all are measured rates at 50 Pascals pressure):

tightest measured (Winnipeg)	0.12 ach/hr
tightest Saskatchewan house	0.37 "
average of 40 special Sask. houses	1.50 "
Swedish building code standard	3.0 "
average of 97 Canadian houses built between 1961 and 1980	3.6 "
average of 20 Canadian houses built between 1946 and 1960	4.6 "
average of 19 Canadian houses built before 1945	10.4 "
average of 204 American low income houses (Grot)	22.5 "
a house in South Carolina	549 "

The last house on the list obviously needed work!

WHERE DO YOU GET A BLOWER DOOR?

First of all, you don't have to buy your own blower door to get a test done. Testing is becoming available through specialized retrofit companies, most of which perform the test and retrofit work as a package. There are also services available for new house construction which include testing and construction consultation and supervision to assure airtightness.

The cost for just a test is usually about $75 to $175. The cost for the test and retrofit work (1 day) is typically $600 to $1000 per house. The cost for new house testing and consultation varies with the scope of the work.

It is often difficult to find a testing service. Try the yellow pages under insulation contractors. There is a growing network of "house doctors" whose training is derived from the original house doctor procedures developed at Princeton University. For information or referral about house doctoring, contact:

Princeton Energy Partners, Inc.
Princeton, New Jersey

The Energy Doctor
Lubbock, Texas

The Energy Detective

Philadelphia, Penn.

Enercorp
Winnipeg, Manitoba, Canada

Below is a list of blower door manufacturers. It is not a complete list. We will add to it in future issues of the Update. We will also run short articles about users' experiences with the various doors (See Tom Blandy's article for experience with the Gadzco Door).

The Gadzco Blower Door
Contact Princeton Energy Partners, Inc., Box 1221 Princeton, NJ 08540 (609) 924 1177.

Retrotec Door Fan
Manufactured by Retrotec, 176 Bronson Ave., Ottawa, Canada K1R 6H4 (613) 234 3280.

Infiltec Air Leakage Measurement System
Manufactured by Infiltec, a Division of Saum Enterprises, Inc., Box 1533, Falls Church, VA 22041 (703) 820 7696

The Energy Door and Energy Auditor Package
Manufactured by TWV Enterprises, 4216 50th Suite F, Lubbock, TX 79413 (806) 794 4815.

Infilseal Corporation, 4660 Beechnut, Suite 248, Houston, Texas 77006 (713) 522 2656

OTHER METHODS OF TESTING FOR AIRTIGHTNESS

There are other tools and techniques for testing for airtightness and locating leakage in a house.

1. Tracer gas technique. This is mainly a research tool. It measures natural infiltration rate. A tracer gas (often sulphur hexafluoride), is injected into the house and allowed to mix well with the indoor air. An instrument called a chromatograph measures the concentration of the tracer gas in the air. As air leaks into the house, the tracer gas becomes diluted. The chromatograph continuously measures the decrease in concentration. From that data, we are able to calculate the infiltration rate.

This technique is not practical or even useful for builders or insulaton contractors. Not only is it expensive, but the measured infiltration rate is dependent upon outside weather conditions. It also doesn't help find leaks.

2. Sound detection method. This is an interesting method, based on the principle that sound waves and air pass readily through many of the same openings in building envelopes. Therefore such air infiltration can be detected by acoustic means. The method is still experimental and not widely used. At the ASHRAE conference on the Thermal Performance of the Exterior Envelopes of Buildings in 1979, David N. Keast of Bolt Beranek and Newman Inc., Cambridge, MA presented a method for building the necessary instruments from ordinary low cost "hi-fi shop" equipment. There is also a listing in the Products section of this issue of the Update for a very expensive version of the same instrument.

3. The Pressure Pulse Method. This is another new idea which looks interesting on paper but obviously still needs work. It was presented by G. Yuil of Unies Ltd., Canada at the ASHRAE meeting in Toronto last June.

The pressure pulse method works like this: one single blast of air is suddenly released from a compressed air cylinder placed inside the living space. A recording instrument measures and records the decay of the induced pressure over time (how long it takes for the pressure to die down to zero). The tighter the house, the longer the decay will take. According to Yuil, a leaky house will have a decay time of about 1.2 seconds, a typical recently built house about 5.6 seconds, and an airtight house about 24.5 seconds.

The attractiveness of the idea is that it is very quick, easy and relatively inexpensive. Its most useful application would be for building inspectors (if airtightness became a code requirement) or for a builder's final evaluation of his own work. It is not useful for finding leaks.

There are a few problems. Some have been worked out, some not. First of all, the initial pulse is equivalent to an instantaneous 20 mph gust of wind on all surfaces of the house - possible damage. The initial nozzle design pointed up. This created a downward thrust of 3500 lbs - too much for any floor. This problem was overcome with new nozzle design. A third problem was the refrigeration effect - air suddenly released through a small hole gets very cold. Finally, there is a problem with flexibility of the building walls - sheetrock and even glass will bend a little under the sudden pressure; this will introduce error into the calculation.

Yuil added finally that the test had not actually been performed on a real house yet. Any volunteers?

The House Doctor's View of the Blower Door

by Thomas Blandy

House doctoring is distinguished from other energy audit services by the use of the blower door. With a blower door, house doctors are actually able to quantify the air infiltration rate of a house. Not only can infiltration be measured, but every source can be easily located using the blower door in conjunction with other detection devices (infra-red scanner, smoke gun, back of one's hand, eyes, etc.) Once the leaks are plugged, the retrofit job can be evaluated by remeasuring infiltration.

SETTING UP THE DOOR

We use the Gadzco blower door, which consists of four parts (see illustration): a lower panel with the fan, an upper panel to fill in the top of the door, a "bridge" to fill in the middle, and the control panel. Optional but definitely recommended is a good photographic tripod for the instruments.

The door is designed to fit any doorway from 32" x 78" to 36" x 84". It can be used in other sized doorways, both larger and smaller, by jury-rigging.

To set up, we move all the parts of the door except the fan, plus all the other house-doctor equipment inside the house. The door is opened and the screen/storm blocked open. We then