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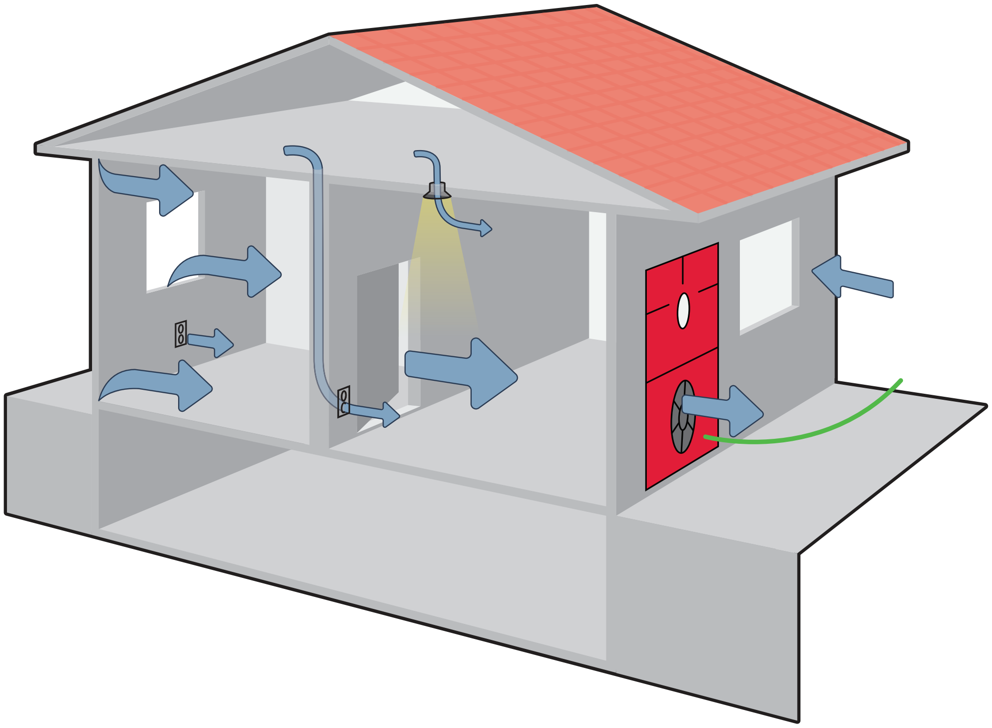
Blower Door Basics



Informational Guide

IMPROVE HOMEOWNER SATISFACTION BY SOLVING AIRTIGHTNESS AND LEAKAGE ISSUES

A Guide to Blower Door Tests

The airtightness of the building envelope is an important key to understanding the performance of any new house. Uncontrolled air leakage can result in high fuel bills, failure of building components, and increased builder callbacks. As a result, more and more time is being spent by the building trades sealing up new houses in an effort to reduce problems associated with air leakage.

Yet at the same time, many builders are continuing to rely on uncontrolled air leakage through holes and cracks in the building envelope to provide adequate ventilation for the occupants. Newspaper articles and trade journals dramatizing moisture and indoor air quality problems in new airtight houses have begun to alarm both builders and homeowners. It is not uncommon these days for builders to hear complaints of excess moisture or stale odors in their brand new houses.

Despite the growing importance of house airtightness, many builders do not know how tight they are building their houses. Until recently, the building community has tended to rely on subjective estimates of airtightness. Unfortunately, it is virtually impossible to accurately estimate the tightness level of houses by visual inspection alone. And without knowing house airtightness, it is difficult to assess the need for, or to design an effective approach to comfort, moisture control, ventilation or indoor air quality. And increasingly local building codes are requiring builders to document the airtightness level of their homes as part of the inspection process.

In this guide from The Energy Conservatory, you'll learn how blower door tests can help you determine a building's airtightness and find air leaks to seal. We'll also discuss the essential components of a blower door system and how to set up a building for testing.

BLOWER DOOR AND AIR LEAKAGE BASICS

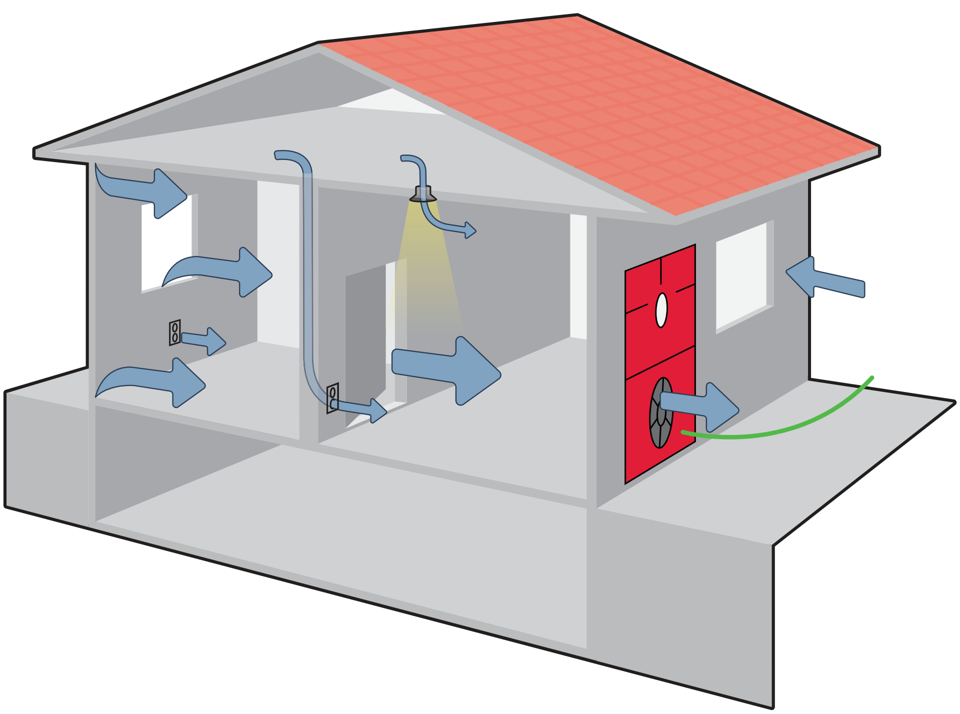
The easiest way to measure house airtightness is with a diagnostic tool called a blower door. The blower door consists of a powerful, calibrated fan that is temporarily sealed into an exterior doorway. The fan blows air out of the house to create a slight pressure difference between inside and outside. This pressure difference forces air through all holes and penetrations in the exterior envelope. Blower door tests are typically performed at a pressure difference of 50 Pa (0.2 inches of water column).

By simultaneously measuring the air flow through the fan and its effect on the air pressure in the house, the blower door system measures the airtightness of the entire building envelope. The tighter the building (e.g. fewer holes), the less air you need from the blower door fan to create a change in house pressure.

Airtightness measurements are presented in a number of different formats including:

- Air flow needed to generate 50 Pa of pressure difference (CFM50)
- Air changes per hour at 50 Pa of pressure difference (ACH50)
- Square inches of leakage

It takes about 20 minutes to set-up a blower door and do a test to document the airtightness of a house. In addition to assessing the overall airtightness level of the building envelope, the blower door can be used to estimate the amount of leakage between the conditioned space of the building and attached structural components such as garages, attics and crawlspaces. It can also be used to estimate the amount of outside leakage in forced air duct systems. And because the blower door forces air through all holes and penetrations, these problem spots are easier to find using chemical smoke, an infrared camera or simply feeling with your hand. The airtightness measurement can also help you assess the potential for backdrafting of natural draft appliances by exhaust fans and other mechanical devices.



FOUR MAIN CAUSES OF AIR LEAKAGE IN BUILDINGS

For air leakage to occur, there must be both a hole or crack in a building, and a driving force to push the air through the hole. This is true for air leaks into or out of a building.

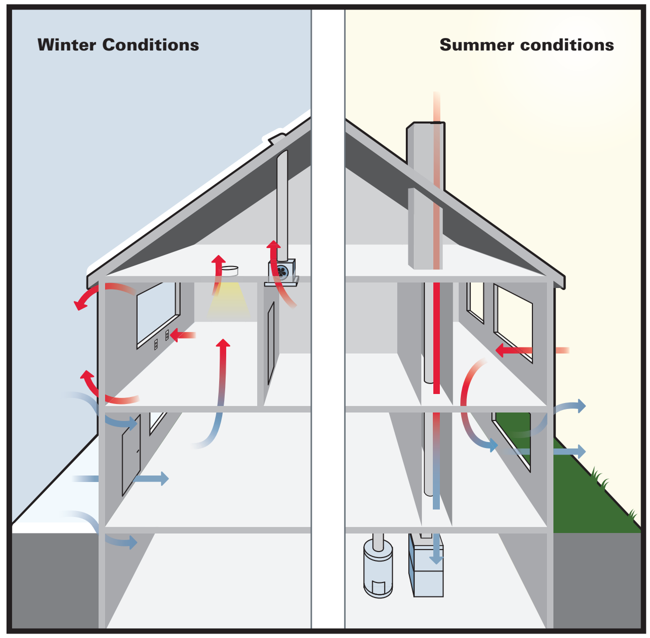
The most common cause of air leakage is stack effect. Other typical causes are wind pressure, point-source exhaust or supply devices, and duct leakage to the outside.

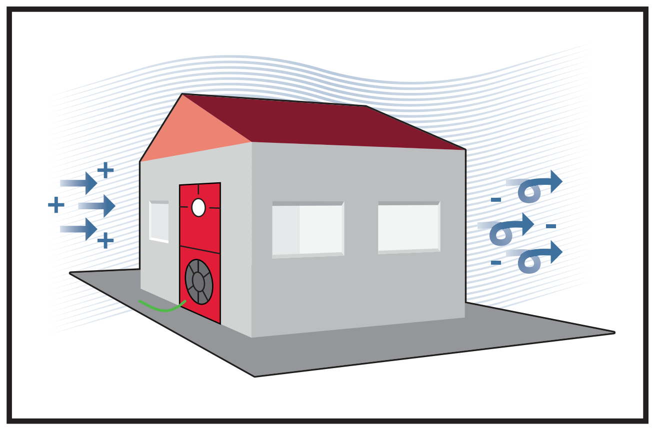
1. Stack effect: Stack effect happens when warm, buoyant air rises and leaks out of the top of a building. That air is replaced by colder outside air entering the bottom of the building.

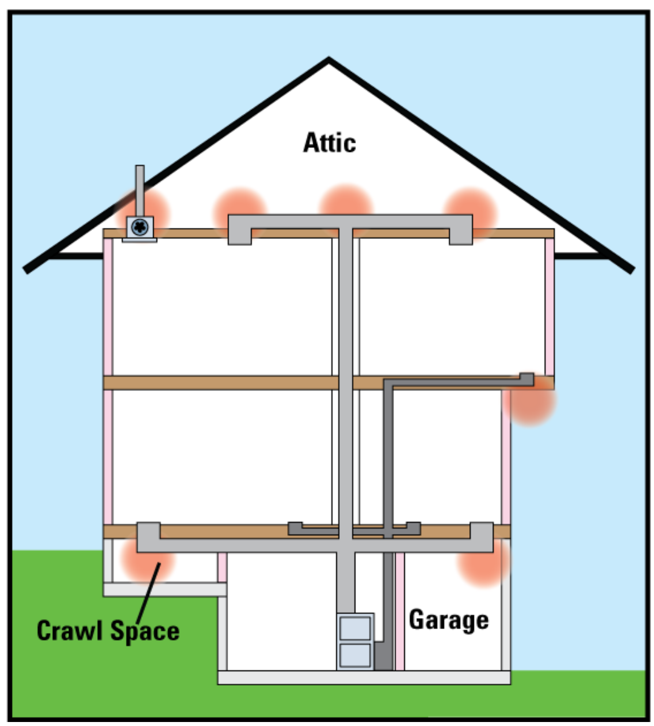
2. Wind pressure: Wind blowing on a building will cause outside air to enter on the windward side of the building and leak out of the leeward side.

3. Point-source exhaust or supply devices: Exhaust devices pull air out of a building when they operate. That air is replaced by outside air that enters the building through holes and cracks. Supply devices deliver air into the building, which forces indoor air to leak out of the building.

4. Duct leakage to the outside: In forced-air duct systems, leaks to the outside create pressures that increase air leakage in buildings. Leaks in supply ducts cause negative building pressures. Leaks in return ducts create positive pressures.







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COMMON AIR LEAKAGE SITES

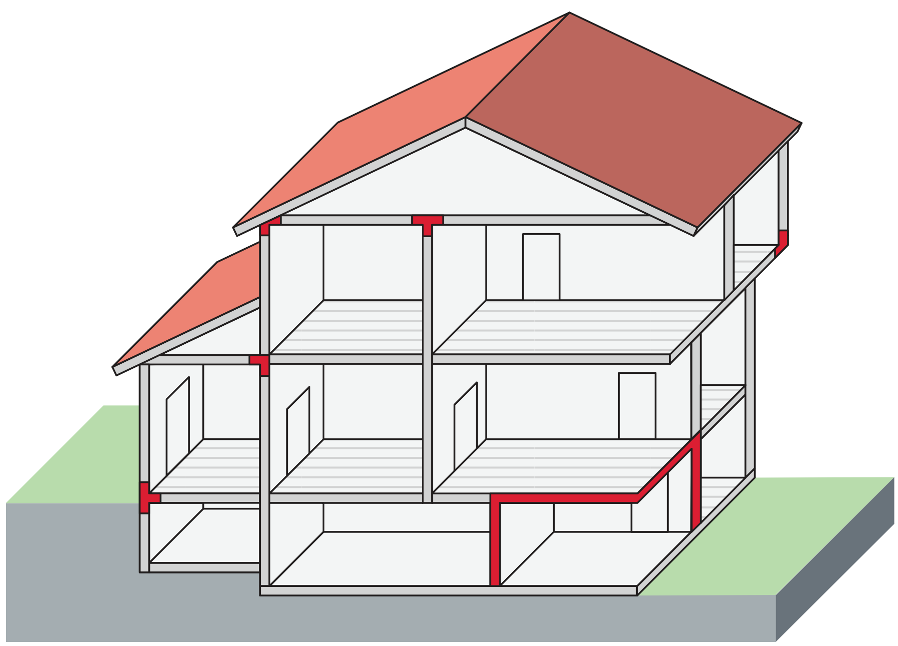
Air leakage sites may occur through cracks and holes in the building envelope, via hidden construction details and in forced-air duct systems.

As warm air rises because of stack effect, it tends to escape through cracks and holes near the top of the building. This causes a slight negative pressure at the bottom of the building, pulling in cold air through holes in the lower level. Air sealing activities usually begin at the top of the building because this is where the largest positive pressures exist and where many of the largest leakage sites and potential condensation problems can be found.

The next most important location of leaks is in the lowest part of the building. The bottom of the building is subject to the largest negative pressures, which leads to cold air infiltration. **Importantly, if natural draft combustion appliances are present, do not seal lower-level building leaks unless you have first addressed leaks in the attic or top part of the building. Sealing only lower-level leakage areas while leaving large leaks in the top of the building could create enough negative pressure to cause combustion appliance backdrafting.**

There can also be large leakage paths from hidden construction details. Common locations are attached porches, cantilevered floors and overhangs. The use of densely blown cellulose insulation or other barrier-type air sealing techniques at these key junctures often results in dramatic air leakage reductions.

Forced-air system ductwork can also be a major air leakage site. Even small leaks in ductwork can result in significant air leakage because of the high pressures found in ducts whenever the heating or cooling system operates.



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BLOWER DOOR SYSTEM COMPONENTS

The Energy Conservatory's Single Fan Minneapolis Blower Door system includes the following components:

- Blower door fan, flow sensor and fan speed controller
- Accessory case with DG-1000 pressure and fan flow gauge
- Adjustable aluminum door frame and nylon door panel

Software and apps are also available to help you document and analyze blower door test results.

Blower Door Fan, Flow Sensor and Fan Speed Controller

The calibrated blower door fan consists of a molded fan housing with a 3/4 horsepower motor. A flow sensor is attached to the end of the motor. Air flow through the fan is determined by measuring the pressure at the flow sensor. Fan speed is adjusted by using the fan speed controller.

The blower door fan can accurately measure airflow over a wide range of flow rates by using calibrated flow rings that attach to the fan. The standard Minneapolis Blower Door system comes with two flow rings capable of measuring flows as high as 6,000 cubic feet per minute (CFM) and as low as 300 (CFM). Three optional flow rings are available to allow flow measurements as low as 85 CFM, 30 CFM and 11 CFM.

Test instrumentation: DG-1000 Pressure and Fan Flow Gauge

The DG-1000 is a touch-screen digital pressure and flow gauge. The gauge has two separate measurement channels that allow you to simultaneously monitor the building pressure and blower door fan flow during the test.

The DG-1000 is able to directly display air flow through the blower door fan, and can measure pressures with a range of -2,500 to +2,500 Pascals (-10 to +10 inches of water). The DG-1000 also has built-in WiFi and other networking options that allow it to connect with TEC software and apps to control and document airtightness tests.

Note: TEC also manufactures multi-fan blower door systems to test larger structures.

Adjustable Aluminum Door Frame and Nylon Panel

An adjustable aluminum door frame and nylon panel seal the fan into any typical-size, exterior residential doorway. The frame can be quickly assembled and broken down to simplify storage and transport, or can be transported completely assembled.

Test Software and Apps

The Energy Conservatory offers a number of blower door test analysis software programs and apps to calculate airtightness, display test results and store test data. These include:

- TECTITE (and TECTITE Express) software for PCs: This program allows you to conduct manual and fully automated blower door tests, analyze and store test data, and document and present test results.

- TEC Auto Test for iOS and Android: This app is an automated building and duct system airtightness testing app for mobile devices, which can wirelessly connect to the DG-1000 gauge. TEC Auto Test can easily create and share airtightness test reports.

- TEC Gauge for iOS and Android: This app provides wireless control and display for the DG-1000 gauge, and lets you store and share readings from your gauge.

- TECLOG4 software for PCs. This program can be used to data log pressure readings from one or more DG-1000 gauges. In addition, TECLOG4 can be used to control TEC's multi-fan blower door systems and to document airtightness in larger structures.

Visit energyconservatory.com for more information and access to these programs and apps.

SETTING UP A BUILDING FOR TESTING

After installing the blower door system (see “this document” for detailed instructions on how to install the blower door system), you will need to set up the building for the airtightness test.

The Minneapolis Blower Door can be used in a variety of buildings and for different types of tests. The most common test is for single family residential structures. Other building tests include commercial and governmental buildings, multi-family and mixed-use buildings, cleanroom or isolation rooms, server rooms and other critical environments with fire suppression systems, as well general room and building airtightness. Tests can be one-point or multi-point, pressurized or depressurized or both, with a single fan or multiple fans.

The following steps are appropriate for testing existing buildings to determine retrofit air sealing potential and weatherization effectiveness, or to estimate natural infiltration rates.

Step 1: Prepare Adjustable Openings

- Close all storm and prime windows.

- Close all exterior doors and interior attic or crawlspace hatches which are connected to conditioned spaces. Also close exterior crawl space hatches and vents if they are normally closed most of the year.

- Open all interior doors to rooms that are conditioned. The object here is to treat the entire building as one conditioned space and to subject all of the leaks in the building to the same pressure difference. Because few house basements can be completely sealed from the house and usually some conditioning of the basement is desirable, they are typically included as conditioned space.

- Tape plastic over window air conditioners if they appear to be a source of air leakage into the building and they are typically removed during a large part of the year.

Step 2: Prepare Combustion Appliances and Exhaust Devices

- Adjust all combustion appliances so they do not turn on during the test. This is commonly done by temporarily turning off power to the appliance, or setting the appliance to the “Pilot” setting. Note: If combustion appliances turn on during a depressurization test, it is possible for flames to be sucked out of the combustion air inlet (flame rollout). This is a fire hazard and can possibly result in high CO levels.

- If there are attached spaces (e.g. townhouses) that could contain a vented combustion appliance, either adjust those appliances to prevent them from turning on during the test, or be sure that the attached spaces are not depressurized or pressurized when the Blower Door is operating.

- Be sure that fires in fireplaces and woodstoves are completely out. Take precautions to prevent ashes from being sucked into the building during the test. In most cases it will be necessary to either tape doors shut, clean out the ashes, and/or cover the ashes with newspaper.

- Turn off all exhaust fans, vented dryers, air conditioners, ventilation system fans and air handler fans.

If you conduct tests according to specific program guidelines, you may need to prepare the building differently than described above.

Additional steps may also be needed for new buildings if the blower door test is being used to document construction airtightness quality and performance. Common new construction preparations include:

- Exterior windows and doors, fireplace and stove doors are typically closed, but not sealed, beyond the intended weatherstripping or other infiltration control measures.

- Dampers including exhaust, intake, makeup air, backdraft and flue dampers are typically closed, but not sealed beyond intended infiltration control measures.

- Interior doors, if installed at the time of the test, are typically open.

- Exterior doors for continuous ventilation systems and heat recovery ventilators are typicall closed and sealed.

- Heating and cooling systems, if installed at the time of the test, should be turned off.

- Supply and return registers, if installed at the time of the test, should be fully open.

Consult the requirements of the applicable building code as your preparation requirements may be different.

BASIC TEST RESULTS

Basic test results from a one-point test can be manually calculated to provide a quick assessment of the airtightness of the building.

We recommend that you use software for more complicated calculation procedures such as:

- Analysis of multi-point test data
- Calculated physical leakage areas
- Estimated natural infiltration rates
- Estimated cost of air leakage
- Ventilation guidelines

Airtightness test results can be presented in a number of standardized formats. Below is an explanation of different test result formats based on air leakage at 50 Pascals (Pa).

CFM50

CFM50 is the most commonly used measure of building airtightness. It gives a quick indication of the total air leakage of the building envelope. CFM50 is the airflow (in cubic feet per minute) needed from the blower door fan to create a change in building pressure of 50 Pa (0.2 inches of water column).

When conducting a one-point test at 50 Pa of building pressure, you are directly measuring CFM50. Air leakage at 50 Pa can also be presented in units of liters per second (l/s), or cubic meters per hour (m3/h).

Percent Reduction in CFM50

Performing a one-point CFM50 test before and after airtightening work will help you determine the impact of your efforts on the building's airtightness. Reductions in CFM50 as large as 40 to 50 percent are often achieved by high-level weatherization programs working on leaky houses.

Here is the formula to calculate percent reduction in CFM50:

$$\text{Percent reduction} = \frac{CFM50\ (\text{before}) - \text{CFM50 (after)}}{CFM50\ (\text{before})} \times 100$$

Air changes per hour at 50 Pa (ACH50)

ACH50 normalizes the CFM50 test result to the conditioned interior building volume. ACH50 tells how many times per hour the entire volume of air in the building is replaced when the building envelope is subjected to 50 Pa of pressure.

Here is the formula to calculate ACH50:

$$\text{ACH50} = \frac{CFM50\ \text{x}\ 60}{Building\ volume\ (cubic\ feet)}$$

The International Energy Conservation Code uses ACH50 for its building airtightness standard. It is also commonly used to compare the airtightness of various sized buildings to each other.

CFM50 per Square Foot of Building Envelope

CFM50 per square foot of building envelope normalizes the CFM50 result by the square feet of exterior building envelope area. This test result format is commonly used for commercial buildings. It is also used in some locations for residential standards, and is commonly used to compare the airtightness of various sized buildings to each other.

Here is the formula to calculate CFM50 per square foot of surface area:

$$\text{CFM50 per square foot of building envelope} = \frac{CFM50}{Square\ feet\ of\ building\ envelope}$$

Note: Residential buildings above five stories and commercial buildings are typically tested at 75 Pascals, in which case CFM75 should be used in the calculation. See the formula below.

$$\text{CFM75 per square foot of building envelope} = \frac{CFM75}{Square\ feet\ of\ building\ envelope}$$

FINDING AIR LEAKS

Once you've determined the building's airtightness, you may need to find and seal air leaks.

Air leaks between the interior and exterior of the building often follow long and complicated leakage paths. Typically, the air sealing goal is to find where leaks cross the exterior envelope of the building, then concentrate sealing activities on those areas. There are three common techniques that can be used in conjunction with the blower door to find air leaks.

Technique 1: Use Your Hand

The easiest and most often used method for finding air leaks is to check for leaks with your hand while the home is depressurized. An entire room can be checked quickly if there is a door between it and the rest of the house. Standing just outside of the room, close the door most of the way, leaving about a 1-inch crack. A large blast of air coming through the crack indicates large leaks between that room and outside.

For this technique, let the blower door fan run at a speed that generates between 20 Pa and 30 Pa of building pressure. Always use the same pressure to get a good feel for what is a big leak and what is not.

Technique 2: Use a Fog Puffer

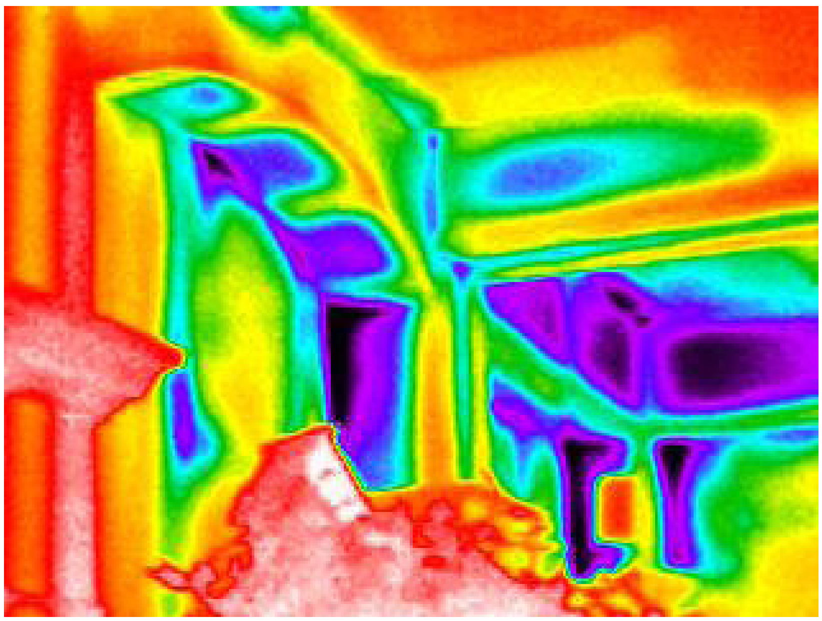
Many important leaks are found between the house and the attic, or between the house and a ventilated crawl space. These leaks are usually hard to find unless you physically go into the attic or crawl space. The use of a handheld fog puffer is often helpful in these areas.

With the house depressurized and the crawl space or attic access door shut, squirt small puffs of fog toward suspected leakage sites from the attic or crawl space, and watch to see if the smoke gets sucked into the leak. With a piece of tubing attached to the smoke puffer, you can often reach deep into corners or hard-to-reach spots. A fog puffer or a pressure pan is a necessity when looking for leaks in forced-air ductwork.

Technique 3: Use an Infrared Camera

The ideal technique for finding leaks is to use an infrared scanner as the blower door runs. This procedure usually involves performing two infrared scans from the interior of the building – one before turning on the blower door and one after the blower door has been depressurizing the building for five to 10 minutes. Pressurizing the building and inspecting from the outside can also be useful.

If air being sucked in through the leaks is either warmer or colder than the interior of the house, the area surrounding the leakage path will change temperature and show up on the infrared scanner screen. A temperature difference of about 5 to 10 degrees is sufficient to expose important leaks. If there is little temperature difference between inside and outside, an infrared scan may still be possible if the indoor space has been cooled from the ground or warmed from solar radiation on the roof.



NOTES

LINKS TO ADDITONAL INFORMATION

Conducting a Blower Door Test
Scan the QR code above or go to:
https://youtu.be/Ga7csP7M170

Equipment Maintenance and Calibratrion
Scan the QR code above or go to:
https://energyconservatory.com/calibration-repair/

RESOURCES FOR COMMON TESTING STANDARDS

The building setup and test procedures in this document are recommended by The Energy Conservatory. If you need to perform a blower door airtightness test that exactly meets a specific test procedure or standard, you should obtain a copy of the standard.

Here is a list of resources and links for common testing standards:

- **Canadian General Standards Board (CGSB)** *www.tpsgc-pwgsc.gc.ca*
- **ASTM** *www.astm.org*
- **RESNET** *www.resnet.us*
- **International Energy Conservation Code (IECC)** *www.iccsafe.org*
- **ASHRAE** *www.ashrae.org*
- **The Energy Conservatory** *www.energyconservatory.com*

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