M O N T A N A

Building and Duct Tightness Testing Guide

A Guide to Conducting Building Air Tightness Testing and Duct Tightness Testing in Accordance with the 2018 International Energy Conservation Code

Prepared by the National Center for Appropriate Technology

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At the time of publication Montana is holding listening sessions for the 2021 IECC with adoption anticipated in early 2022. Check the NorthWestern Energy Efficiency Plus website for details.

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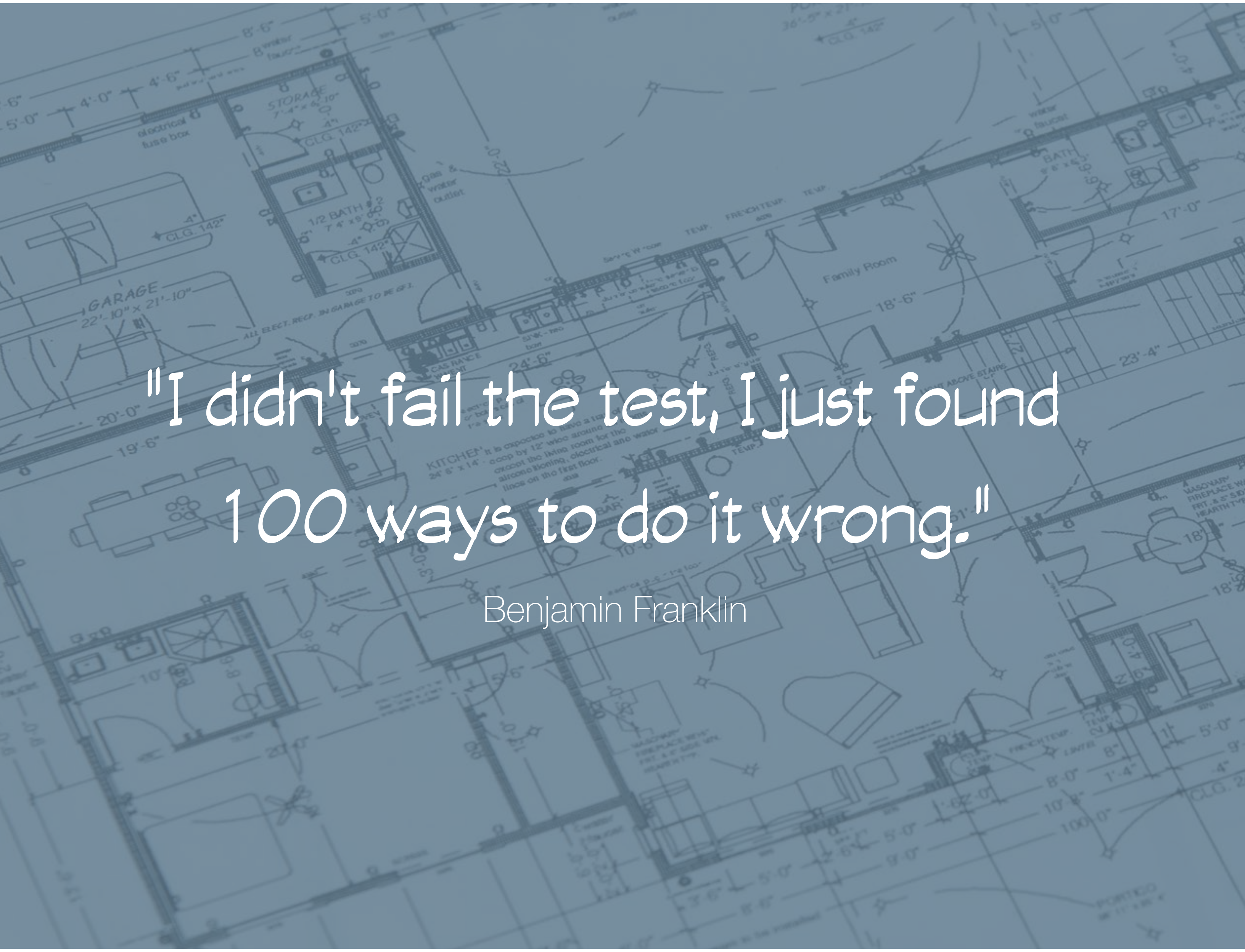

"I didn't fail the test, I just found 100 ways to do it wrong."
Benjamin Franklin

1 Introduction

This is a guide to conducting building envelope tightness and duct tightness testing in accordance with the 2018 International Energy Conservation Code (IECC). It was prepared as the workbook for a one-day training class. As such, this guide includes only a limited number of building pressure diagnostic tests that may be useful in the analysis of building and duct tightness. More comprehensive training in envelope tightness and duct tightness testing is available in certification training offered for Home Energy Raters (HERS), Building Performance Institute Building Analysts, and the U.S. Department of Energy (DOE) Weatherization Assistance Program (WAP).

Tests such as those addressed in this guide are increasingly used to assess construction quality and performance. This approach is often referred to as *performance testing*.

Building envelope and duct tightness testing were introduced to the 2009 IECC. The 2009 IECC and 2012 IECC provide little information about how to actually conduct a building tightness test and no information about how to conduct a duct tightness test. The 2015 IECC referenced two standards for conducting a house tightness test, with a third standard being added to the 2018 IECC. The 2018 IECC includes no standards or instructions for how to conduct a duct tightness test.

This guide describes how to conduct building envelope and duct tightness testing according to RESNET/ICC Standard 380, the standard added to the 2018 IECC. RESNET stands for Residential Energy Serivces Network. ICC is short for for the International Codes Council. Standard 380 is the most user friendly of the three standards included in the 2018 IECC and also includes procedures for conducting duct tightness testing and measuring exhaust ventilation airflow, which are not addressed in the other two standards. Because Home Energy Raters use Standard 380 when conducting ratings, it is fast becoming the most commonly used standard for envelope and duct tightness testing.

The State of Montana adopted the 2018 IECC, with some amendments, as the Montana energy code. This energy code and required performance testing is mandatory for all residential new construction and additions. The Montana energy code is applicable to all residential construction both inside and outside local code enforcement jurisdictions.

2 Why Is Testing Important?

President Ronald Reagan used an old Russian proverb in speaking to Soviet President Mikhail Gorbachev about an arms control treaty. Although it was a very old adage, Reagan quoted the phrase in Russian to Gorbachev, to underline his meaning. That phrase, “Trust, but verify,” can be applied to almost all aspects of the energy code. Prior to the 2012 IECC, there was more trust than verification regarding building tightness. Today, building envelope and duct tightness testing have become commonplace. Since November 2015, blower door testing has been mandatory for all new residential construction in Montana, both within and outside local code enforcement jurisdictions. Duct tightness testing is required unless the ducts and air handlers are located entirely within the building thermal envelope.

By testing the performance of their houses, builders demonstrate a commitment to energy-efficient, safe, and comfortable home construction. Documented proof of test results provides a competitive advantage by demonstrating attention to detail and added home value. In today’s marketplace, performance testing creates a reputation for quality and professionalism.

Why is Building Tightness Testing Important?

Current building science is based on the adage “Build tight, ventilate right.” It has been documented that natural ventilation provides too much outside air sometimes and too little outside air at other times. To provide the right amount of outside air, it is necessary to limit unintentional or accidental envelope air leakage and to provide adequate outside air with mechanical ventilation. A tight house will have lower heating bills due to less heat loss and fewer drafts to decrease comfort. Whole-house mechancial ventilation is now a reqirement of the Montana energy code.

When a building’s airtightness has been addressed properly, occupants complain less of temperature-control issues. A tight house reduces the chance of mold and rot because moisture is less likely to enter and become trapped in building cavities. Without proper tightness, even in very well-insulated buildings, interior conditioned air will escape through the leaks in the building envelope, and unconditioned exterior air will enter. Tight homes have better-performing ventilation systems and potentially require smaller heating and cooling equipment capacities.

Builders, architects, and homeowners can know the tightness of their houses only with testing. Leaky houses often exhibit problems that can include frozen pipes, ice dams, drafts, and inadequate space conditioning.

Why Is Duct Leakage Testing Important?

Tightly sealed ducts can reduce utility bills. Tight ducts improve indoor air quality because leaky ducts in attics, unfinished basements, crawlspaces, and garages can allow dirt, dust, moisture, pollen, pests, and fumes to enter the home. When ducts are leaky, heating and cooling systems have to work harder to condition the home. Duct sealing, along with proper insulation, allows the installation of smaller, less costly heating and cooling systems. When ducts are properly sealed, they deliver conditioned air more effectively to all rooms—helping to ensure a more constant temperature and improved comfort throughout the home. Following are several principles that apply to duct tightness:

- For ducts located in an unconditioned attic, any leaks in the supply system tend to depressurize a house, while return-system leaks tend to pressurize a house. Either condition can cause problems.
- Duct leaks outside a home's thermal envelope waste more energy than duct leaks inside a home's thermal envelope.
- Even if ducts are located inside a home's thermal envelope, duct leaks can still connect to the outdoors. For example, supply-system leaks in a floor joist space between the first and second floors of a two-story home can pressurize the joist space, forcing conditioned air outdoors through leaks at the rim joist.
- Duct tightness testing can identify disconnected duct joints or missing supply register boots that might otherwise go undetected.
- It's much easier to seal duct seams during construction than in an existing house.

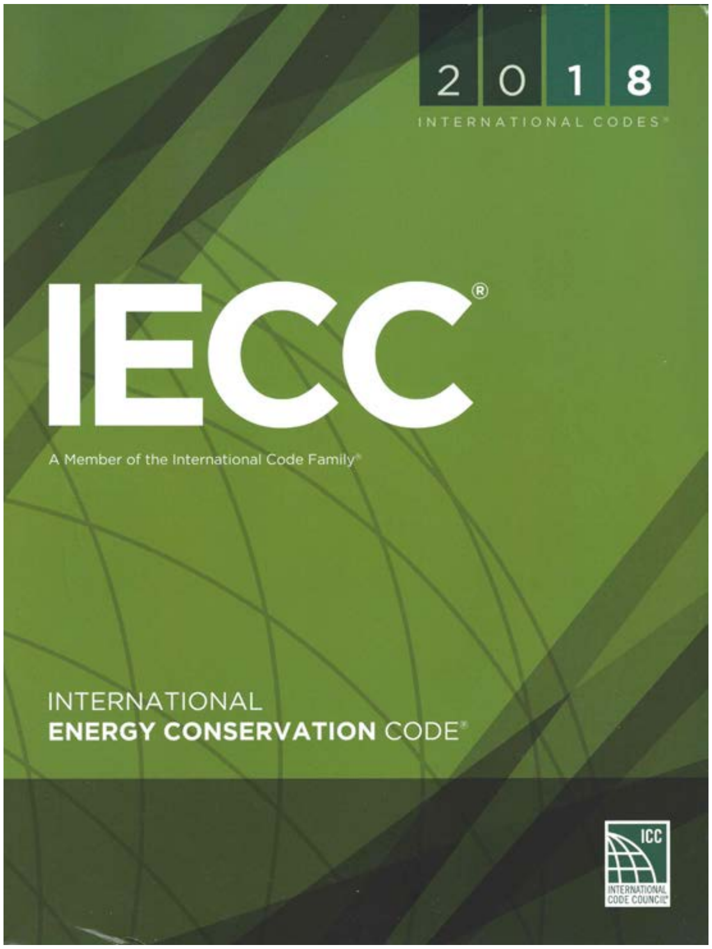
3 The Energy Code and Tightness Testing

In 2015, two building tightness testing standards were added to the IECC in order to promote more accurate and consistent test results. A third building envelope tightness standard was added to the 2018 IECC.

The maximum building envelope air leakage allowed by the 2009 IECC is seven air changes per hour (ACH50) when tested at 50 Pascals (Pa) of pressure difference. For Montana's climate zone, the 2012 IECC allowed only three ACH50. Three ACH50 has remained the IECC envelope air leakage limit through the 2018 edition.

Montana amended the 2009 IECC by lowering the limit to four ACH50. Four ACH50 remains the building air leakage limit in Montana.

Duct tightness testing was introduced to the IECC in the 2009 edition when two types of tests were allowed: the Total Leakage Test and the Leakage to the Outside Test. The 2012 IECC allowed only the Total Leakage Test. The IECC requirements for duct tightness have remained unchanged since that 2012 edition. Montana amended the 2012 IECC by allowing both types of tests. The 2018 IECC allows only the Total Leakage Test. Duct tightness testing is not required when the ducts and air handler are located entirely within the building thermal envelope.



Reference Standards

Incorporating testing standards into the IECC helps ensure that the tests are performed correctly, are accurate, and are replicable. The 2018 IECC requires technicians to follow one of three test standards for the building envelope tightness testing.

The 2018 IECC also includes six instructions, holdover language from the 2012 edition, that describe how the house should be configured during the building envelope tightness test. The three reference standards included in the 2018 IECC provide much greater detail about how to conduct a test. With the addition of the three reference standards, the six instructions are superfluous since the standards, being more specific, take precedence.

This guide describes how to conduct building and duct tightness testing according to the RESNET/ICC 380 Standard. As mentioned previously, Standard 380 is the most user-friendly of the three standards and also includes methodologies for conducting duct tightness testing and measuring exhaust ventilation airflow.

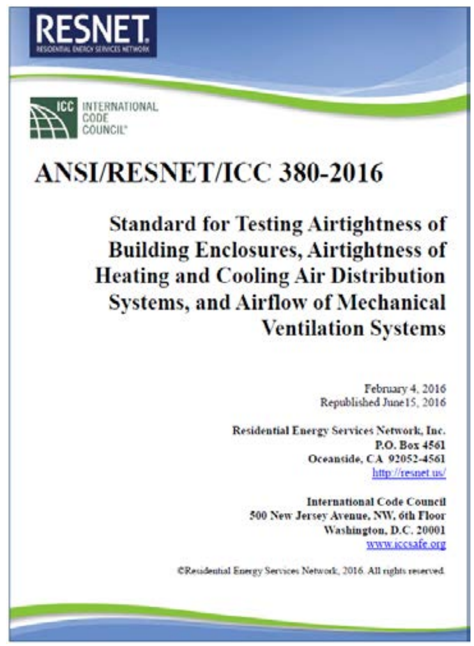
The key characteristics of each standard are described below to allow readers to compare some of the unique features of each.

ASTM E779 – Standard Test Method for Determining Air Leakage Rate by Fan Pressurization

- Both a pressurization and a depressurization test are required.
- Multi-Point Tests are required with five data points minimum.
- Wind speed must be recorded.
- Outside air temperature must be recorded.
- Inside air temperature must be recorded.
- Barometric pressure must be recorded.
- Site altitude must be recorded.
- Adjustments must be made for altitude and air temperature.
- Detailed reporting is required.

ASTM 1827 – Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door

- Both a pressurization and a depressurization test are allowed.
- Both a One-Point Test and a Two-Point Test are allowed.
- Outside air temperature must be recorded.
- Inside air temperature must be recorded.
- Site altitude must be recorded.
- Must average five pressure and airflow measurements.
- Adjustments must be made for altitude and air temperature.
- Detailed reporting is required.


RESNET
RESIDENTIAL ENERGY SERVICES NETWORK

ICC INTERNATIONAL CODE COUNCIL

ANSI/RESNET/ICC 380-2016

Standard for Testing Airtightness of Building Enclosures, Airtightness of Heating and Cooling Air Distribution Systems, and Airflow of Mechanical Ventilation Systems

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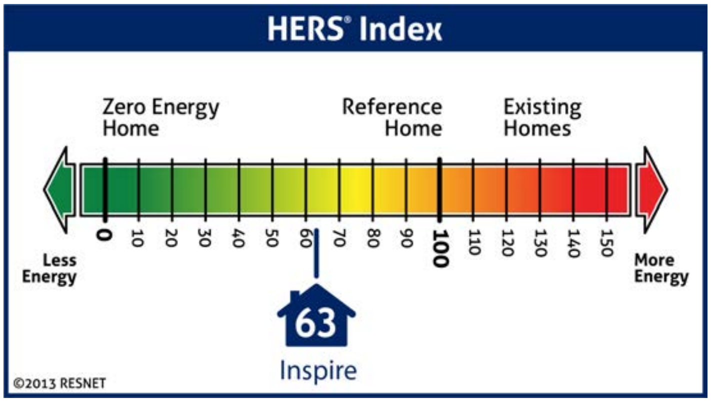
RESNET/ICC 380 – Standard for Testing Airtightness of Building Enclosures, Airtightness of Heating and Cooling Air Distribution Systems, and Airflow of Mechanical Ventilation Systems

- Both pressurization and depressurization tests are allowed.
- Both a One-Point and a Multi-Point Test are allowed.
- Outside air temperature must be recorded.
- Inside air temperature must be recorded.
- Site altitude must be recorded.
- Results must be adjusted for altitude and temperature.
- Recorded fan airflow rate must be increased by 10% for One-Point Tests.
- Detailed reporting is required.

The 2018 IECC does not reference a standard for duct tightness testing but, in this guide, Standard 380 is used as a basis for conducting duct testing.

Energy Rating Index (ERI). A Leakage to the Outside Test is required for the ERI compliance path. The ERI was first introduced in the 2015 IECC and provides flexibility for builders by allowing them to bring in a third-party rater, such as a RESNET HERS Rater, to give the home a numerical score of its energy efficiency. The RESNET Standard 301 for home energy rating is the only ERI methodology that currently complies with the IECC.



The ERI for a home is similar to the miles per gallon (MPG) rating for a car and provides a way for homebuyers to compare the energy efficiency of one house to another. The lower the number, the more energy-efficient the home, with zero being a *net zero energy* home. On the opposite end, a home with an ERI of 100 is as efficient as a home built to the 2006 IECC.

The ERI compliance path gives credit for installed high-efficiency items that aren't covered in the 2018 IECC. These items, such as solar panels, high-efficiency HVAC systems, and appliances can compensate for decreased efficiency in the building envelope.

The use of on-site power generation determines the prescriptive envelope backstop (minimum allowed characteristics regardless of the ERI score). If renewables are used, the 2015 IECC prescriptive requirements must be met. If renewables are not used, then the 2009 IECC requirements remain the backstop. The Montana climate zone (Zone 6) maximum ERI score was raised from 54 in the 2015 IECC to 61 in the 2018 IECC.

4 The Building Science of Performance Testing

Building science is a collection of knowledge that allows us to understand the physical behavior of the building as a system and how this impacts energy efficiency, durability, comfort, and indoor air quality. Performance testing plays a key role in our understanding of building science today. Building envelope tightness and duct tightness testing are based on physical properties, such as air pressure, airflow, stack effect, effect of wind, and backdrafting. These basic concepts are explained below.

Air Pressure. Air molecules constantly bounce off each other and everything around them. The air molecules inside an inflated balloon, ball, or tire are at higher pressure than the molecules outside. The force exerted by these air molecules is called *air pressure*. Where air molecules have greater density (more tightly packed together), air pressure is high. Where air molecules are less dense (less tightly packed together), air pressure is low. A manometer, or pressure gauge, measures the pressure difference between different volumes of air.

The earliest manometer was simply an inverted U-shaped hose partially filled with water. When the air pressure at one open end of the hose is different than the air pressure

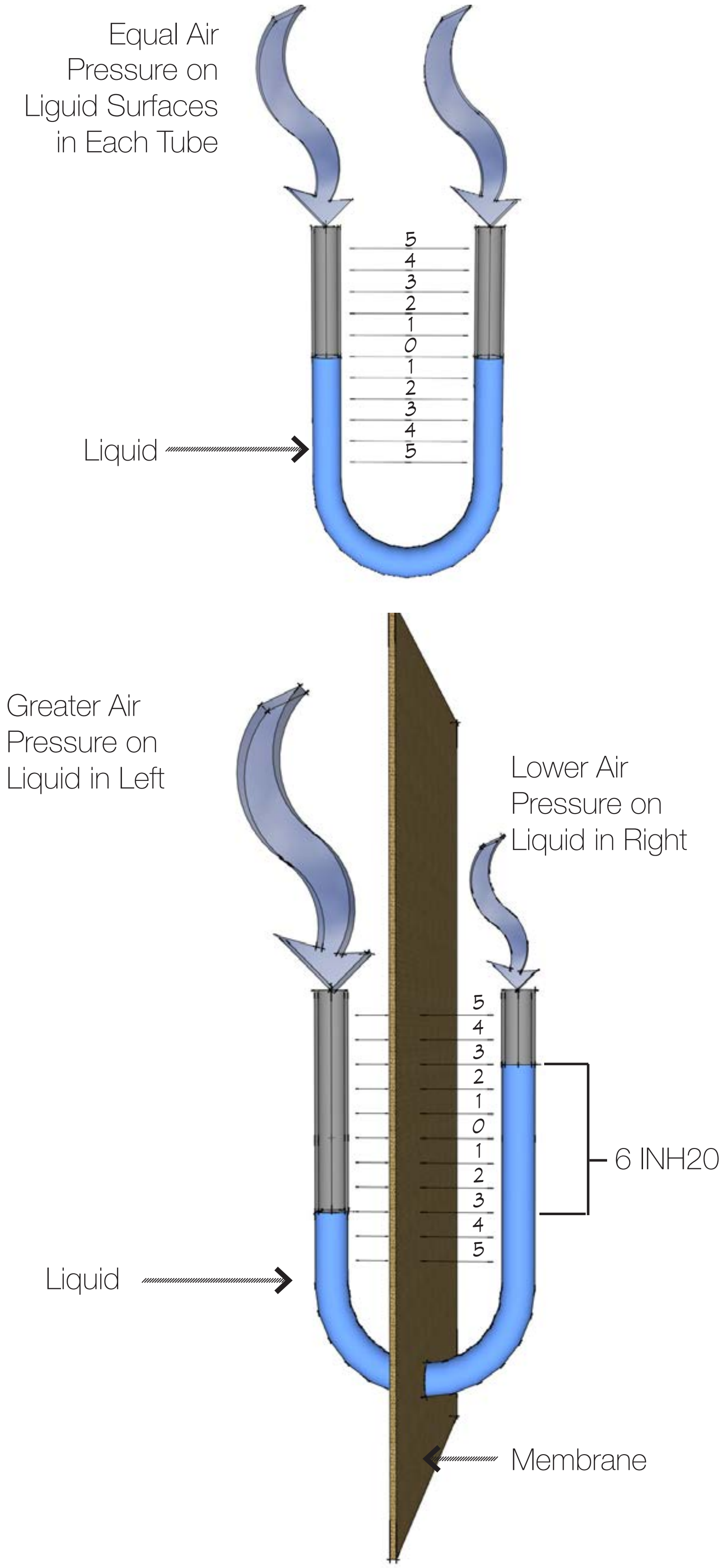


Figure 4-1. Conceptual Manometer

1 INH20 = 250 Pascals
6 INH20 X 250 PA = 1,500 PA

at the other open end, the water level in the hose will change accordingly. The difference in the water level, a measure of air pressure, is called *inches of water* (inH2O). Another unit of pressure is the Pascal (Pa). Pascals are generally used when working with performance testing since they allow us to work with whole numbers. Working with inH2O would require dealing with decimal values.

In performance testing, we speak of the pressure in one area *with reference to* (WRT) the pressure in another area. In the lower diagram of Figure 4-1, the pressure on the left side of the membrane is positive WRT the area on the right of the membrane. The diagrams in Figure 4-2 illustrate the conditions that create neutral, positive, and negative pressure in the house WRT the outside. The blue arrows have been added to show the direction of infiltration and exfiltration through the buiing envelope.

Air Density. The energy code reference standards require that air pressure differences caused by altitude be considered when calculating building envelope air leakage rates. Atmospheric air pressure and air density decrease as altitude increases because there is less air pushing on it from above. At higher elevations, there are fewer air molecules per unit volume than at lower elevations.

Air Pressure Based on Altitude

SEA LEVEL	101,000 PA
3,000 FEET	91,000 PA
4,000 FEET	88,000 PA
5,000 FEET	85,000 PA
6,000 FEET	82,000 PA
7,000 FEET	79,000 PA

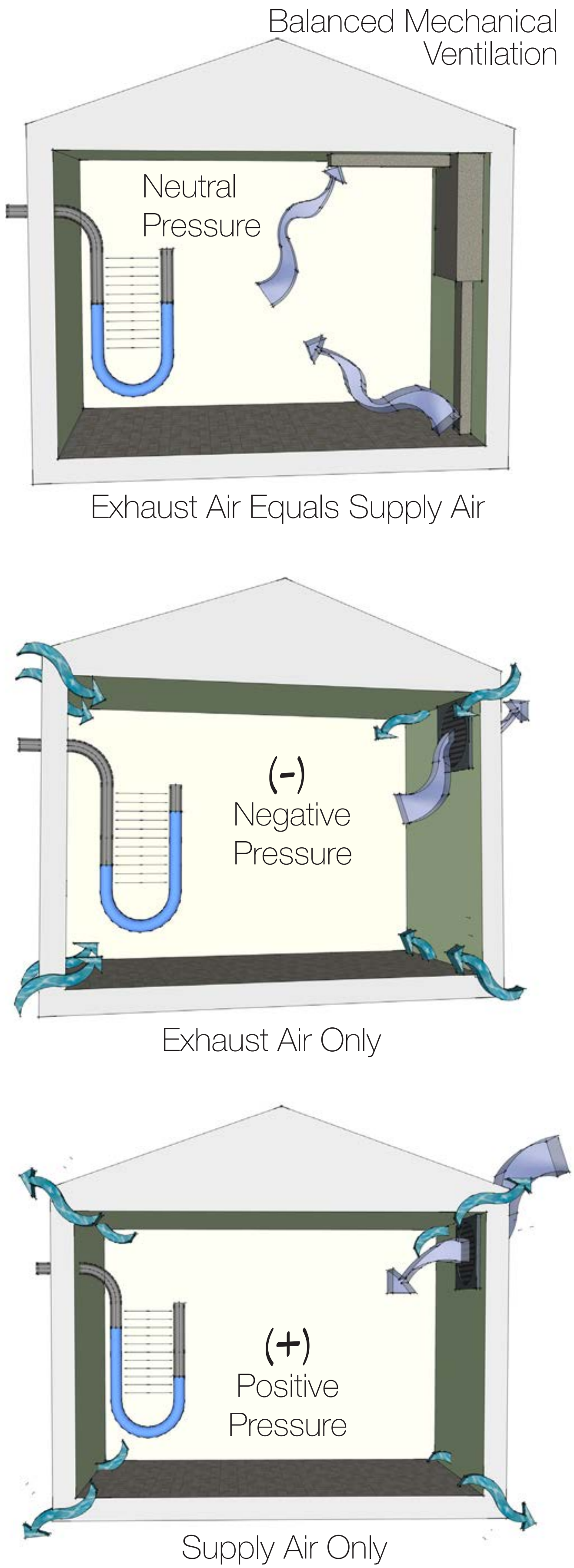


Figure 4-2.
House Pressure WRT Outside

Airflow Basics. Air flows according to basic physics. For our purposes, the following concepts are important.

- For air to move through a membrane, you need a hole and a pressure difference.
- Air always flows from high (or positive) pressure to low (or negative) pressure.
- Air In = Air Out. The same amount of air in cubic feet per minute (CFM) must enter the building as leaves the building.
- When air is added or removed from a single-zone building, the pressure in the building with reference to outside changes by exactly the same amount everywhere. For a building to act as a single zone, all interior doors must be open.

Stack Effect. The stack effect is the movement of air within a building that leads to infiltration and exfiltration through the building envelope. The process is based on the buoyancy of warm air. Warm, buoyant air is less dense and rises. Cooler air is denser and falls. The difference in indoor-to-outdoor air density resulting from temperature differences drives this process. During the cold months of the year, the warm air collects at the top of the building while the cooler air collects lower in the building. During the warm months of the year, the warm air collects lower in the building while the cool air collects at the top of the building.

Stack effect is much stronger in cold climates during the heating season than in hot climates during the cooling season. In the winter, when warm air collects at the top of the building, air leaks to the outside high in the building. Infiltration occurs lower in the building. The neutral pressure plane occurs where half of the air leaks are above and half are below. No air leaks occur at the neutral pressure plane since there is no pressure difference between the interior WRT the outside.

- Pressure x Hole Size = Airflow Quantity
- The larger the opening, the greater the airflow.
- If one CFM of air leaves a building, then one CFM of air must enter the building.

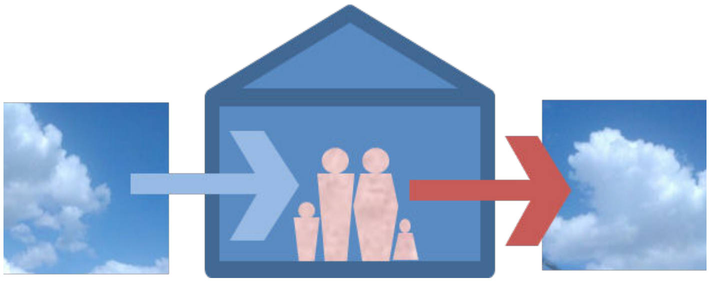


Figure 4-3. Air In = Air Out

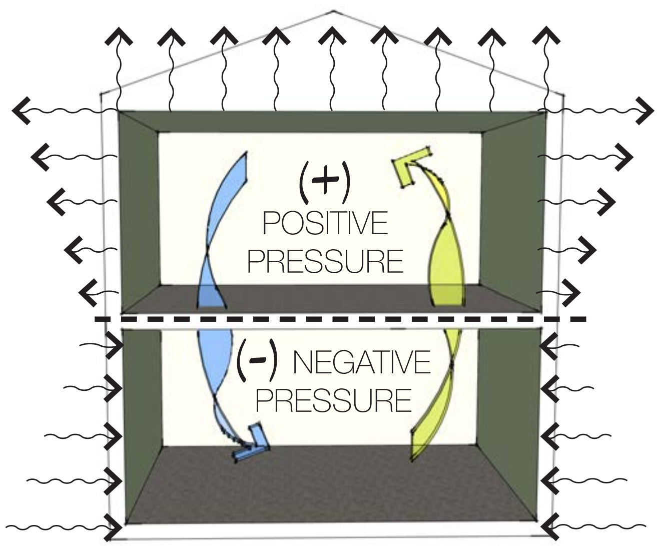


Figure 4-4. Stack Effect - Winter

In summer, the effect is reversed with positive pressure and exhfiltration at the bottom of the building and negative pressure and infiltration at the top of the house.

Wind Effect. Wind exerts positive pressure on the windward walls of a building, causing air infiltration on the side of the building facing the wind. On the leeward side, negative pressure causes suction that pulls air out of the house through the envelope. Wind creates a greater positive pressure, WRT outside, in the house interior on the windward side and a greater negative pressure on the leeward side.

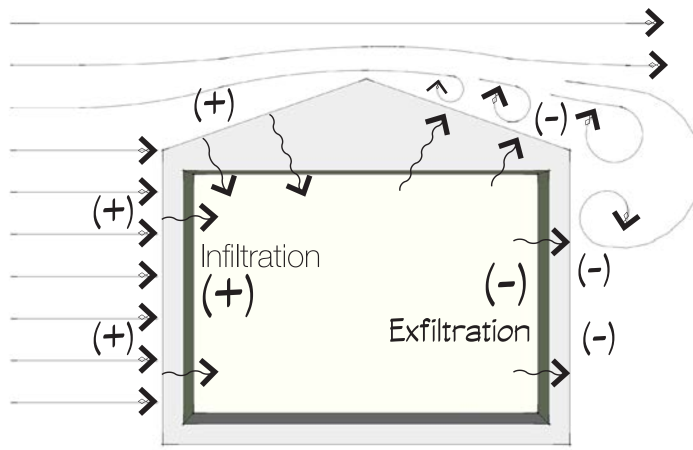


Figure 4-5. Wind Effect

Backdrafting. The emphasis of this guide is building envelope tightness and duct tightness testing. However, every performance-testing technician should be aware of backdrafting. Backdrafting occurs when combustion gases are drawn into the living space instead of being exhausted through the chimney or flue.

Atmospherically-vented fossil-fuel water heaters, boilers, and furnaces are designed to exhaust by-products of combustion to the outdoors through a flue. These hot gases rise up through the flue and exit the home because flu gases are less dense than indoor air. The pressure difference that drives the movement of combustion gases up and out of the flue can be overcome by exhaust fans, fireplaces, and clothes dryers that create a negative pressure in the combustion appliance zone (CAZ). When CAZ pressure is negative enough, combustion gases can be sucked back into the house and may potentially harm or kill building occupants. Carbon monoxide is a dangerous combustion exhaust component because it is odorless, colorless, and toxic. Improperly designed flues or flue blockages can also cause backdrafting.

To understand how backdrafting can occur in any given home, it is useful to know how combustion appliances such as water heaters, furnaces, and boilers expel combustion gases.

Atmospheric Draft. The combustion appliance takes the air needed for combustion from the indoor space where

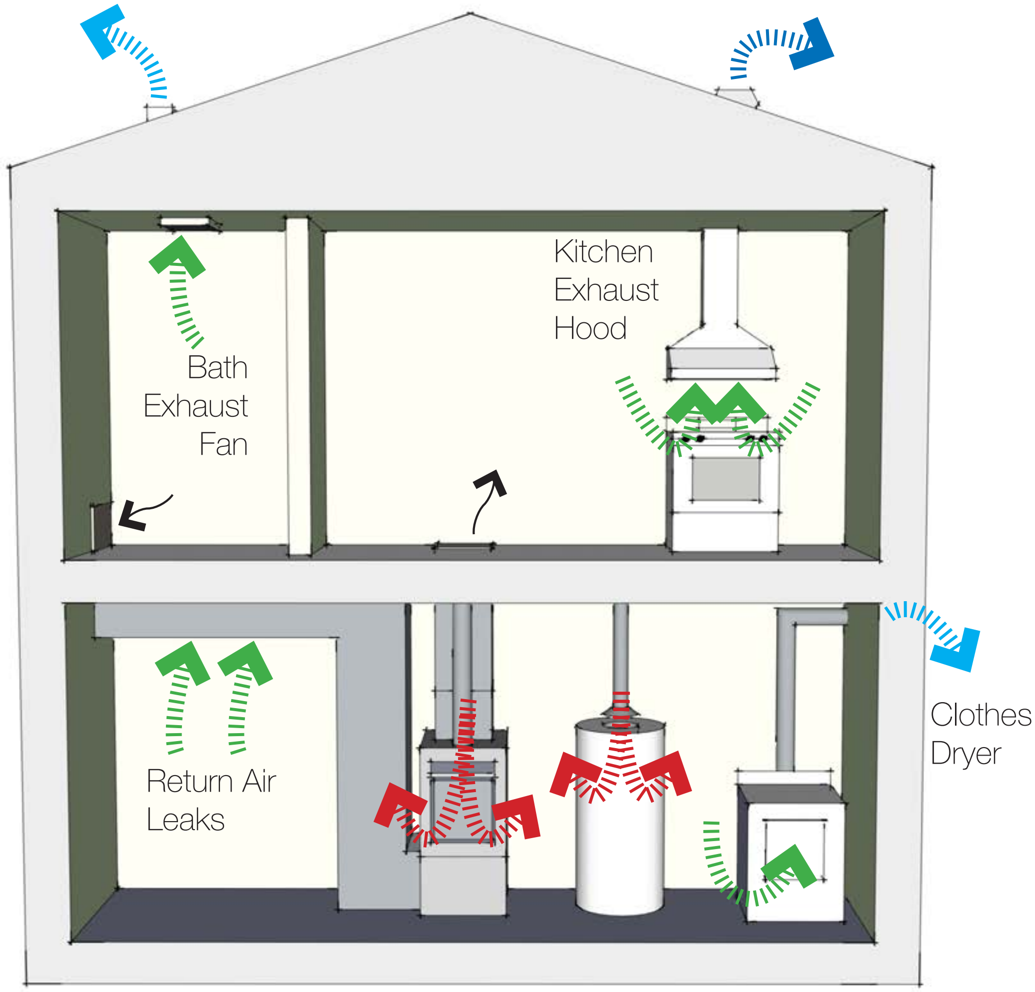


Figure 4-6. Backdraft Air Movement

it is located, the CAZ. Combustion gases rise through the flue solely by the force of convection. Most backdrafting is the result of the atmospherically-vented gas water heaters operating in spaces that have a negative pressure WRT outside due to the operation of exhaust fans, clothes dryer, and other factors.

Induced Draft. This system incorporates a fan that creates a controlled draft. The potential for backdrafting is reduced because the induced draft is usually strong enough to overcome any competing pull from indoor exhaust fans and the clothes dryer.

Sealed Combustion. In sealed combustion appliances, the combustion air intake and the exhaust venting system are completely sealed off from household air. Combustion air is drawn directly from the outdoors through a pipe that is designed for that purpose. The potential for backdrafting is nearly eliminated because the rate of ventilation is not influenced by indoor air pressure, and the vented gas has no pathway into the home.

Combustion Appliance Zone Depressurization Test. Combustion appliances such as natural gas, propane, and fuel oil water heaters, furnaces, boilers, and fireplaces need to exhaust their combustion by-products to the exterior. The potenital for backdrafting can be eliminated by excluding fossil fuel appliances or by installing only sealed-combustion appliances. If atmospherically-vented appliances are present, it is a good idea to test the house to see if conditions in the home can create backdrafting. Such a test, called a *CAZ Depressurization Test*, is detailed later in this guide.

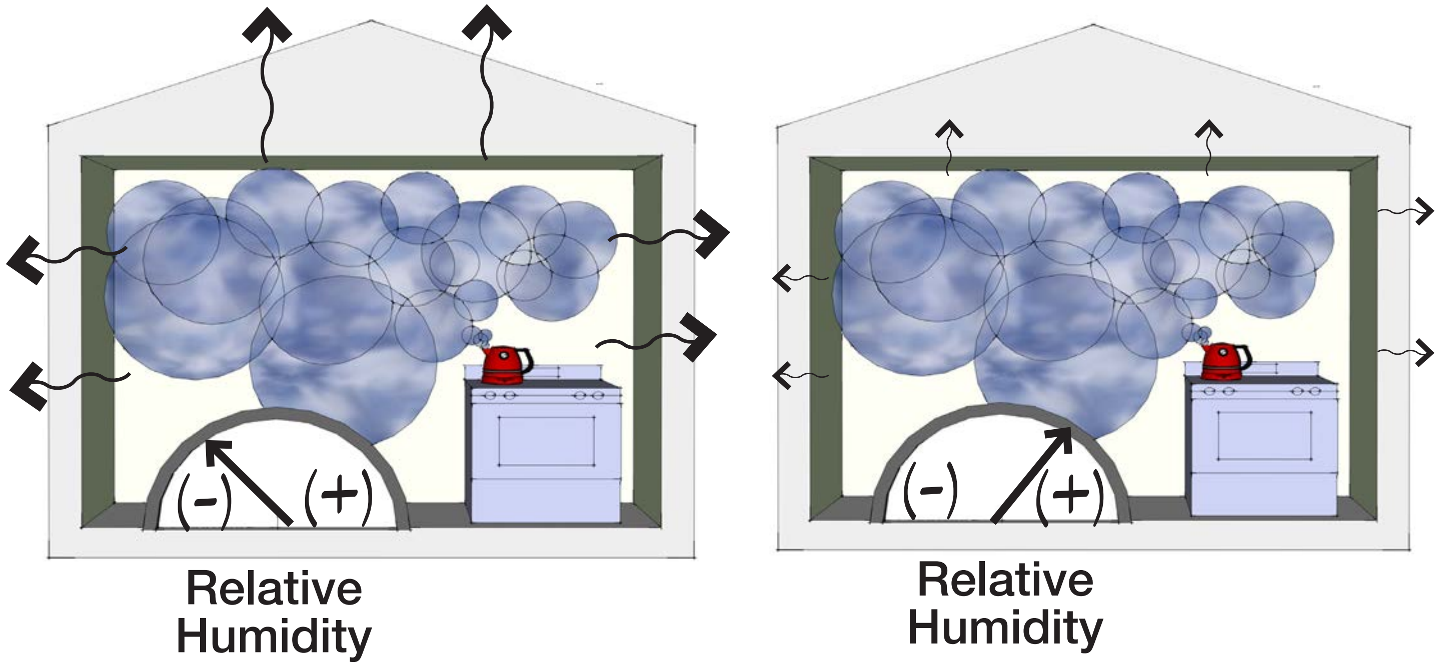


Figure 4-7. Tighter Building Envelope = Greater Relative Humidity

The worst-case CAZ Depressurization Test creates negative pressure in the room or space in which the combustion appliance is located. All exterior windows and doors are closed. Every device in the home that contributes to a negative CAZ pressure with WRT outside is activated. Interior doors are positioned to create the greatest negative pressure in the CAZ.

Air handlers can depressurize the CAZ if the return duct is leaky. The air handler fan must be activated to determine if it contributes to a more negative CAZ pressure. Once the exhaust appliances and interior doors are configured to achieve the most negative pressure in the CAZ WRT to outside, that value is evaluated according to the characteristics of the installed appliance(s). If the CAZ worst-case pressure is more negative than the allowable limit, then actions should be taken to mitigate the problem. Those actions might include adding makeup air to the house, removing the atmospherically-vented appliance, reducing the exhaust flow of over-sized exhaust equipment, sealing air leaks in return ducts, and sealing leaks in supply ducts located outside the building thermal envelope.

House Tightness and Humidity. Humidity is a measure of the amount of water vapor in the air. Humidity can be measured in several ways, but relative humidity is the most common. Relative humidity is the percentage of water vapor needed for condensation to occur. Condensation is when water vapor turns to a liquid.

Humidity in a home is important because too much humidity can lead to condensation on cold surfaces such as windows and closet walls. Condensation can lead to mold and resulting health issues. Building material degradation is another problem caused by excessive humidity. Relative humidity levels between 30% and 50% are commonly recommended for homes. When water vapor enters building wall and ceiling cavities, condensation and mold can occur without being seen until significant damage is done.

If a relatively leaky house is made tighter, the relative humidity will increase if the amount of water vapor being added to the house remains the same. Adding exhaust ventilation can significantly reduce the relative humidity in the home if the outside air drawn into the home is relatively dry.

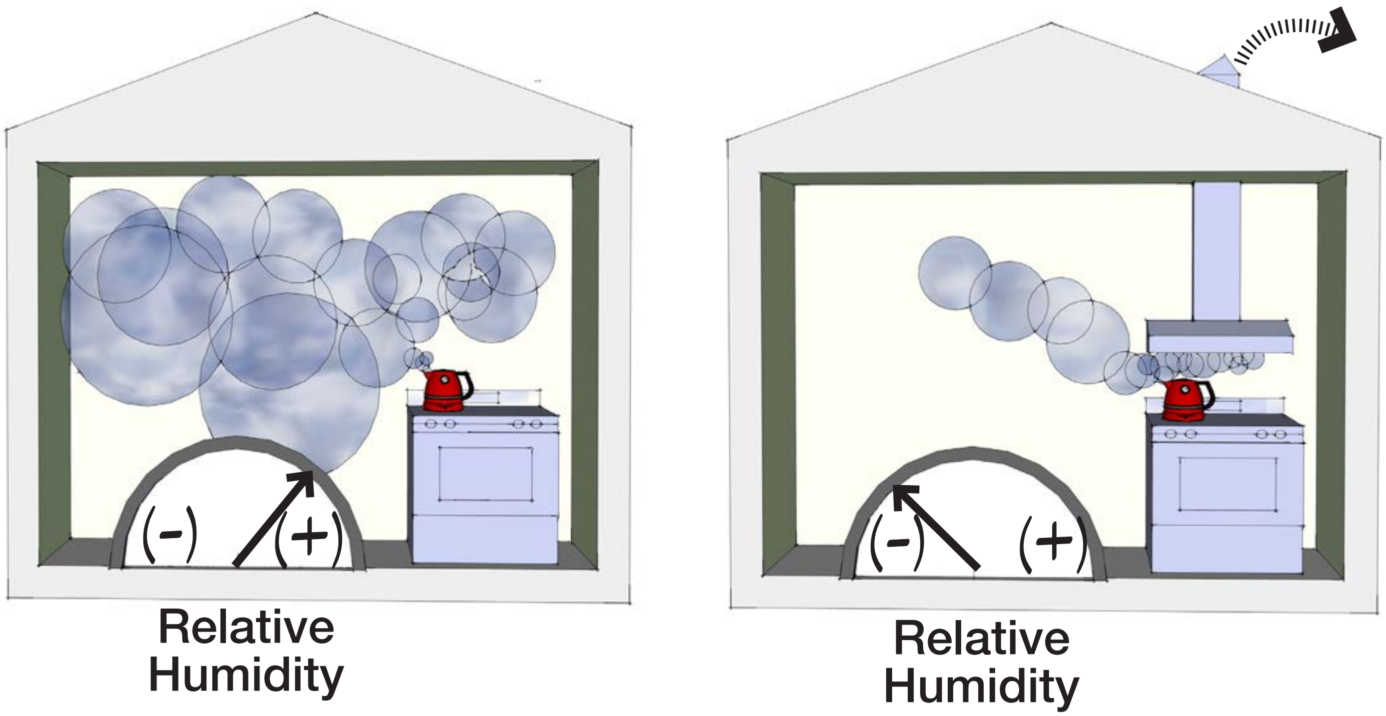


Figure 4-8. Exhaust Ventilation Can Reduce House Humidity Levels

5 Digital Manometers

The objective of performance testers should be consistently accurate test results. Performing building envelope and duct tightness tests can be a complicated process, but equipment advances in the last few years have made accurate and consistent tests easier to achieve. The basic equipment required for performance testing includes:

- Manometer and tubing
- Blower door fan
- Blower door skirt
- Duct testing fan

Blower doors became commercially available in the United States in the early 1980s. The Energy Conservatory began manufacturing blower doors and manometers in 1982 and dominated the market for many years. Currently, the two most significant manufacturers of equipment for performance testing in North America are the Energy Conservatory and Retrotec. Programs such as the U.S. DOE Weatherization Assistance Program, ENERGY STAR for New Homes, and RESNET's HERS Ratings introduced performance testing to the marketplace.

Today the most common manometer in the marketplace is the Energy Conservatory DG-700. This has been the workhorse of the industry for over 30 years. The Energy Conservatory no longer manufacturers the DG-700 and instead offers the DG-1000, which is a more sophisticated WiFi-enabled digital manometer with a touch screen. The Energy Conservatory continues to provide calibration and support services for the DG-700.

Retrotec manufacturers the DM-2, which is a push-button digital manometer along the lines of the DG-700. The

DG-700 DG-1000 DM-2 DM-32

Figure 5-1. Digital Manometers

The DG-700 and DG-1000 are Energy Conservatory products.

The DM-2 and DM-32 are Retrotec products.

DM-32 is the Retrotec touch-screen digital manometer. The DM-32 is available with WiFi capability.

One obvious difference between the Energy Conservatory and the Retrotec manometers is the location of the pressure taps, where tubing is attached to the manometer. Pressure taps on the Energy Conservatory manometers are located on the front of the device, while the tubing attaches to the Retrotec manometers on the top of the device. Although there are differences in appearance, all of these devices are similar in their most basic features and functions, which include:

- **Two Channels.** It is possible to read pressure on two different channels. Typically, the units are set up to read pressure on one channel and airflow on the other.
- **Mode Selection.** The technician must enter the proper mode, which determines if each channel will measure pressure or flow.
- **Device Selection.** Each manometer may be used with a range of devices (blower door, duct tightness tester, exhaust fan airflow hood, etc.). The technician must enter which device is connected to the manometer.
- **Configuration.** The blower door fan and duct tightness tester fan have a number of rings that are used to vary the size of the fan opening. The technician must enter the appropriate ring configuration on the manometer.
- **Automated Testing.** These manometers provide an automated testing feature that provides computerized control of the fan and automated flow and pressure measurements. Some of the very earliest push-button manometers do not include this feature.

The touch-screen manometers are beginning to replace the older push-button models. For purposes of illustration, this guide uses a diagram that most closely resembles a DG-700, since that unit is most common in the workplace. It also lends itself to illustration since the selection buttons and tubing taps are easily visible on the front of the device. All of the manometers discussed above can provide accurate pressure and flow test results. This guide describes how to conduct tests according to the RESNET/ICC 380 Standard but does not detail how to use specific equipment. This guide is no substitute for being thoroughly familiar with the operating manual of the equipment being used.

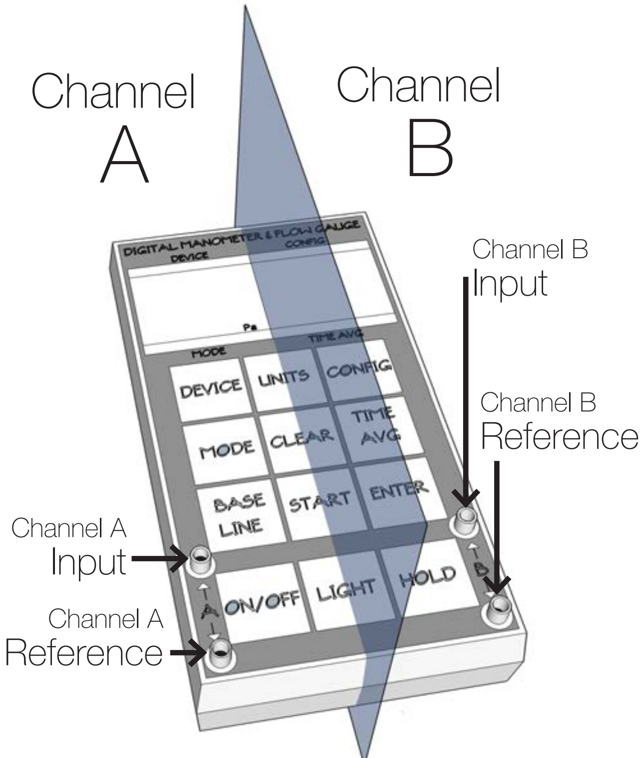


FIG. 5-2.
Two-Channel Digital Manometer

As illustrated in Figure 5-2, today's digital manometers provide two channels. Both channels can be used to measure differential pressure or one channel can measure pressure differential while the other measures airflow. It may be useful to imagine the two channels of a digital manometers as being two distinct devices, both controlled by the inputs on the face. The channels are typically referred to as Channel A and Channel B. Channel A provides pressure differential readings assoicated with the Channel A *input* and *reference* taps. The input and reference taps are like the open ends of the U-shaped tube of the conceptual manometer of Figure 5-2. The taps are used for connecting tubing that extends the distance at which pressure can be measured.

> **ALERT:** It is important to keep the two-channel concept in mind when you are setting up the manometer. Accurate pressure readings can only be achieved if taken from the input and reference taps on the same channel.

The pressure at the input tap relative to the pressure at the reference tap is referred to as "pressure at Tap A with reference to (WRT) pressure at Tap B." In Figure 5-3, the manometer mode is set to measure pressure difference in both Channel A and Channel B. In this example, the blower door fan is depressurizing the house. Channel A reads a pressure differential of minus 50 Pa in the house WRT the outside. The end of the tube connected to Reference Tap A is placed outside the house through the blower door skirt, allowing it to sense outside air pressure.

Channel B reads a pressure differential of negative 25 Pa in the house WRT the attic. No tubes are neccessary at the input taps since those taps are exposed to the house air pressure.

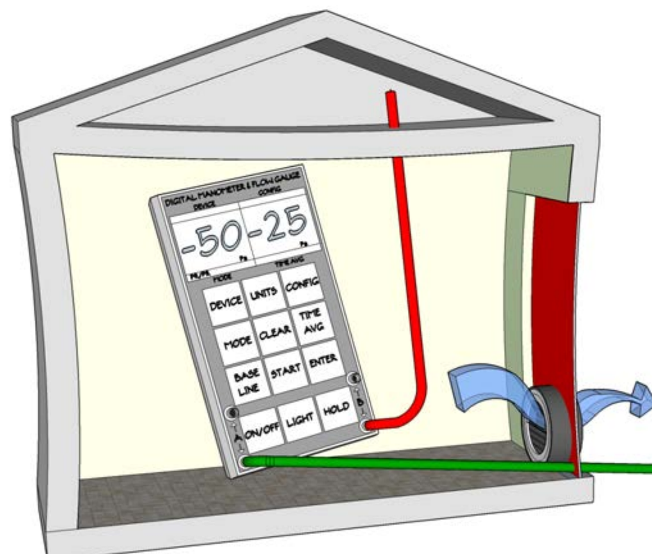


FIG. 5-3.
House Pressure WRT Outside (Channel A) and WRT Attic (Channel B)

Setting Up the Manometer

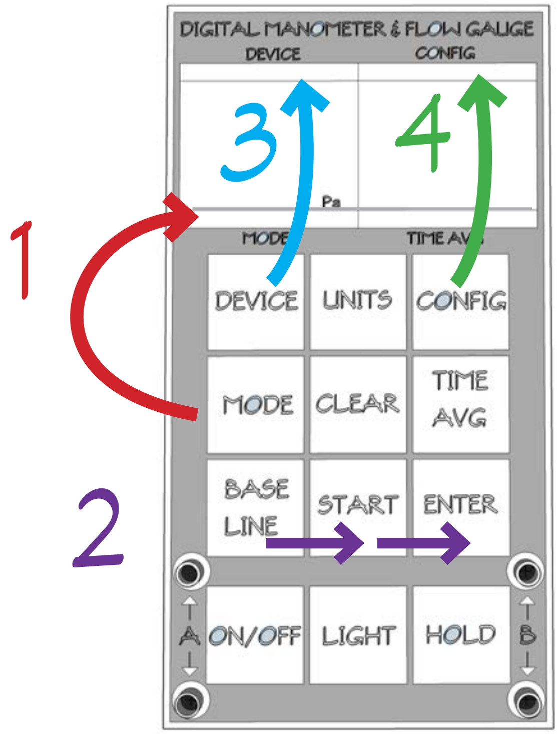
The process of setting up the manometer, after it is turned on, for building tightness testing includes four basic steps as illustrated in Figure 5-4. The four steps are:

Step 1. Enter the appropriate ***mode***.

Step 2. Perform the ***baseline*** procedure.

Step 3. Enter the appropriate ***device***.

Step 4. Enter the appropriate ***configuration***.



Note: No Baseline Procedure is Performaned in Duct Testing.

Figure 5-4. Manometer Setup

The process of setting up the manometer is similar if performing duct tightness testing, although in duct testing, no baseline procedure is performed. The input procedure and the contents of the output screen vary by manufacturer and manometer type. The Figure 5-4 manometer diagram displays the inputs selected in the boxes at the top and bottom of the output screen. You will need to refer to the manufacturer's manual to determine how your particular model is designed to indicate mode, device, and configuration settings.

ALERT: This guide does not attempt to provide detailed instructions for the operation of each type of manometer. The process described and illustrated here provides general guidance that must be augmented by information from the manufacturer for a specific manometer model. Both The Energy Conservatory and Retrotec provide manuals and instructional videos.

Figure 5-5. STEP 1: MODE
Determines the function of each channel, the four options are shown below:
Pressure/Pressure (PR/PR) Both Channels A & B read pressure differential between input and reference taps.
Pressure/Flow (PR/FL) Channel A reads pressure differential; Channel B reads airflow.
Pressure/Flow@50 (PR/FL@50) Channel A reads pressure differential; Channel B reads estimated flow at 50 Pa.
Pressure/Flow@25 (PR/FL@25) Channel A reads pressure differential; Channel B reads the estimated airflow at 25 Pa.

The Mode Settings

The mode setting establishes the function of each channel. The most common mode setting is Channel A set to measure pressure differential and Channel B set to measure airflow. There are two types of airflow settings. The *PR/FL* mode displays the airflow on Channel B. This quantity is the air flowing through the fan with the house at the pressure displayed on Channel A.

The *PR/FL@50* mode functions differently and is useful when the target test pressure (50 Pa for a blower door test) can't be achieved with an open fan operating at full speed. When the mode is set to *PR/FL@50,* a CFM50 leakage estimate will automatically be displayed on Channel B. The leakage estimate displayed on Channel B is continuously adjusted by the manometer to what it would be if the test pressure were actually 50 Pa. The adjustment calculation is based on the *Can't Reach 50 Factor* discussed on page 15.

Can’t Reach 50 Factor

The PR/FL@50 mode is not the only way to deal with a one-point blower door test where the blower door fan is unable to depressurize or pressurize the building to 50 Pa (±3 Pa), even with an open fan operating at full speed.

A tester who chooses to use the PR/FL mode setting in a situation where a pressure differential of 50 Pa can’t be achieved must perform a manual calculation procedure to estimate what the airflow would have been if the house pressure WRT the outside had been 50 Pa. The tester must apply a Can’t Reach 50 (CRF) Factor to the displayed airflow and calculate this result. The manometer manufacturer provides a Can’t Reach 50 Factor Table. If a house can only be depressurized to 35 Pa, then the Can’t Reach 50 Factor for 35 Pa is multiplied by the airflow reading at 35 Pa, which yields the estimated airflow at 50 Pa. In most cases today, there is no need to manually use the Can’t Reach 50 Factor, since the PR/FL@50 and PR/FL@25 modes perform that calculation.

Figure 5-5.
Sample Can’t Reach 50 Factor Table

Building Pressure (Pa)	Factor
48	1.03
46	1.06
44	1.09
42	1.12
40	1.16
38	1.2
36	1.24
34	1.28
32	1.34
30	1.39
28	1.46
26	1.53
24	1.61
22	1.71
20	1.81
18	1.94
16	2.1
14	2.29
12	2.53
10	2.85

Source: The Energy Conservatory

Can’t Reach 50 Factor: An Example

Let’s assume the mode selected on the manometer for a blower door test is set to PR/FL. The measured house pressure WRT the outside is -34 Pa with fan fully open and at maximum speed. The measured air flow is 4,000 CFM. The CRF factor for 34 Pa is 1.28. The estimated flow at 50 Pa is 4,000 CFM x 1.28 = 5,120 CFM.

ALERT: It is appropriate to apply the CRF factor only if the mode is set to PR/FL. Applying the CRF factor to an airflow reading when the mode was set to PR/FL@50 would result in an incorrect value.

PR/FL@25 Modes

The discussion above, using the PR/FL@50 mode, assumes that you are performing a blower door test. The PR/FL@25 mode is appropriate when testing for duct tightness. The standard test pressure for duct tightness testing is 25 Pa for energy code compliance. The PRFL@25 mode may be used when performing a Total Duct Leakage Test. If the target test pressure cannot be achieved with the fan fully open and at high speed, then the tester can either apply the Can’t Reach 50 Factor with the mode set to PR/FL, or set the mode to PR/FL@25, which automatically displays estimated airflow at 50 Pa. A Can’t Reach 25 table will be provided by the manufacturer.

ALERT: When performing a Leakage to the Outside Test, the mode must be set to PR/FL. Use of the PR/FL@25 mode will result in an incorrect reading.

Figure 5-6. STEP 2: BASELINE
To Conduct Baseline Procedure:
a. Close Fan Opening
b. Initiate Baseline Procedure
c. End Procedure After Appropriate Time
d. Manometer Now Automatically Adjusts for Natural Pressure

Baseline Procedure

The baseline procedure is performed when testing for house tightness but not when testing for duct tightness. After selecting the mode, the next step is to perform a baseline to account for house pressure differential that exists naturally without the effect of the blower door fan.

This procedure may be performed manually by subtracting the baseline pressure from the readings taken with the blower door fan operating. The manual process can be a bit tedious and invites calculation errors. Digital manometers will make this adjustment automatically by using their baseline feature. In the conceptual manometer shown in Figure 5-4, the baseline procedure involves the row of buttons that includes Baseline, Start, and Enter.

With the fan opening fully closed, press the Baseline button and then the Start button. Pressing the Enter button will complete the procedure. The appropriate time required before pressing Enter is based on wind conditions. If the wind is calm, a 10-second baseline period is sufficient. If the wind is gusting, the baseline period should be longer, perhaps 30 to 60 seconds. The manometer takes an average natural house pressure over the baseline period. That average is automatically subtracted from future pressure readings until the manometer is turned off or another baseline procedure is initated.

ALERT: The baseline procedure is NOT performed when testing for duct tightness.

Entering the Device

The manometer may be used with several devices such as a blower door or duct tester fan. It is important that the correst device is selected.

Configuring the Manometer

The final step in seting up the manometer is configuration. The opening size for the tester fans and the exhaust hood can be adjusted. The tester fans are equipped with a number of rings, which, in effect, change the opening size. The exhaust hood has a three-position sliding door. Each opening size is associated with a flow range. Each time a ring is added or removed, the manometer configuration setting must also be changed. The configuration setting will be discussed in more detail in the sections describing the different tests. It is important to note that the smaller the fan opening used for the test, the more accurate the result will be.

Figure 5-7. Step 3: DEVICE
Typical Device Options Include:
Blower Door Fan Model
Duct Tester Fan Model
TrueFlow Airflow Plate
Exhaust Fan Hood

Figure 5-8. Step 4: Configuration
Configures the Device Opening:
OPEN - No Rings Installed
A1 - Ring A Blower Door; Ring 1 Duct Tester; Position E1 Exhaust Hood
B2 - Ring B Blower Door; Ring 2 Duct Tester; Position E2 Exhaust Hood
C3 - Ring C Blower Door; Ring 3 Duct Tester; Position E3 Exhaust Hood

6 Building Envelope Tightness Testing

A building envelope tightness test is also referred to as a blower door test, and both terms are used interchangeably in this guide. The energy code sets the envelope leakage limit at four air changes per hour at 50 Pa (ACH50). Air changes per hour refers to how many times in one hour the entire volume of air inside the building exchanges with outside air. If the entire volume of house air is exchanged with outside air in one hour, that is one air change per hour. Leakier houses have higher ACH50 values and, therefore, higher heating and cooling costs, and greater potential for moisture, comfort, and health problems. To determine ACH50, the blower door creates a pressure difference of 50 Pa between inside and outside. The fan airflow required to maintain the test pressure of 50 Pa, measured in cubic feet per minute (CFM), is used to calculate ACH50.

As the blower door fan exhausts air from the house, it pulls air into the house through air leaks in the building envelope and ducts located outside the building envelope. These leaks can be found by using chemical smoke, an infrared camera, or simply by feeling with the back of a hand.

Older Existing Homes	Over 10 ACH50
Typicall New Home in 2000	7 ACH50
2009 IECC	7 ACH50
Montana Code (2010 to Present)	4 ACH50
ENERGY STAR Homes	4 ACH50
Missoula Multifamily*	3.16 ACH50
2015 IECC	3 ACH50
2018 IECC	3 ACH50
DOE Zero Energy Ready Home	3 ACH50
Missoula Single Family*	2.7 ACH50
Passive House	0.6 ACH50

* From Building Department Data 2015 - 2017

Figure 6-1.
House Tightness Examples

Figure 6-2.
Blower Door Fan and Rings

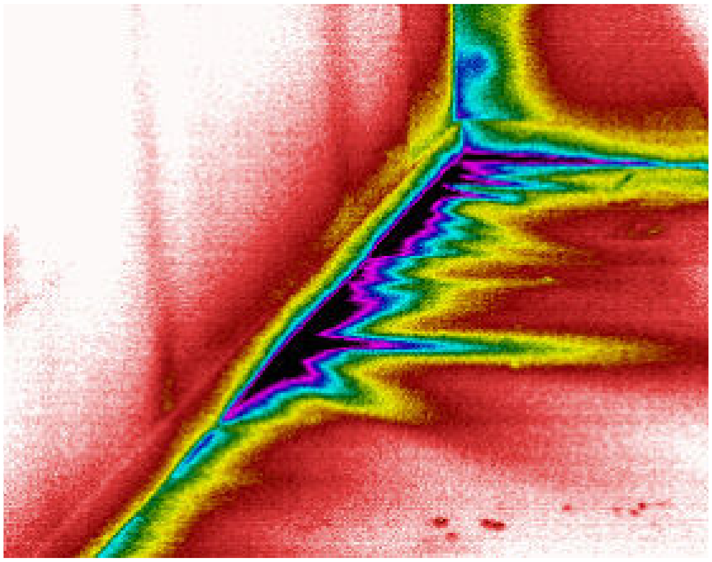


Figure 6-3. Infrared Photos of Air Leaks at the Base of a Wall

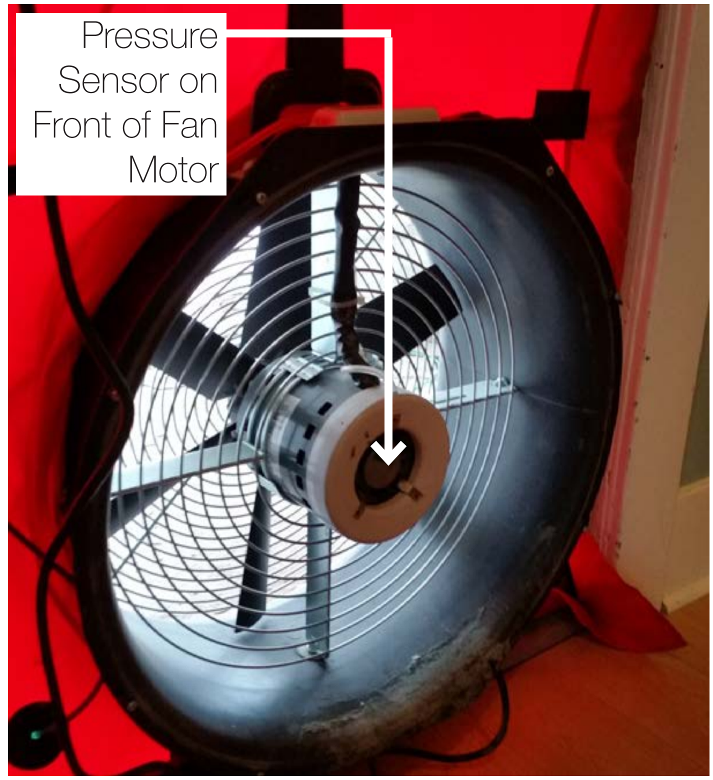


Figure 6-5. Fan Pressure Sensor

Building Envelope Tightness Test Summary

In addition to the manometer, required equipment includes the blower door skirt, blower door fan, and fan speed controller. The blower door fan consists of a molded fan housing with a motor and a series of flow rings. The rings allow the technician to adjust the size of the fan opening. Airflow through the fan is determined by measuring the air pressure at the flow sensor attached to the fan. Some older blower door fans have a flow-direction switch, but other models move air in only one direction. To reverse flow in these models, the fan itself must be installed in the opposite direction. The blower door fan can accurately measure airflow over a wide range with the use of the flow rings.

Sample Ring Airflow Ranges (CFM)	
Open (no flow ring)	6,100 - 2,435
Ring A	2,800 - 915
Ring B	1,100 - 300

Figure 6-4. Sample Ring Airflow Ranges

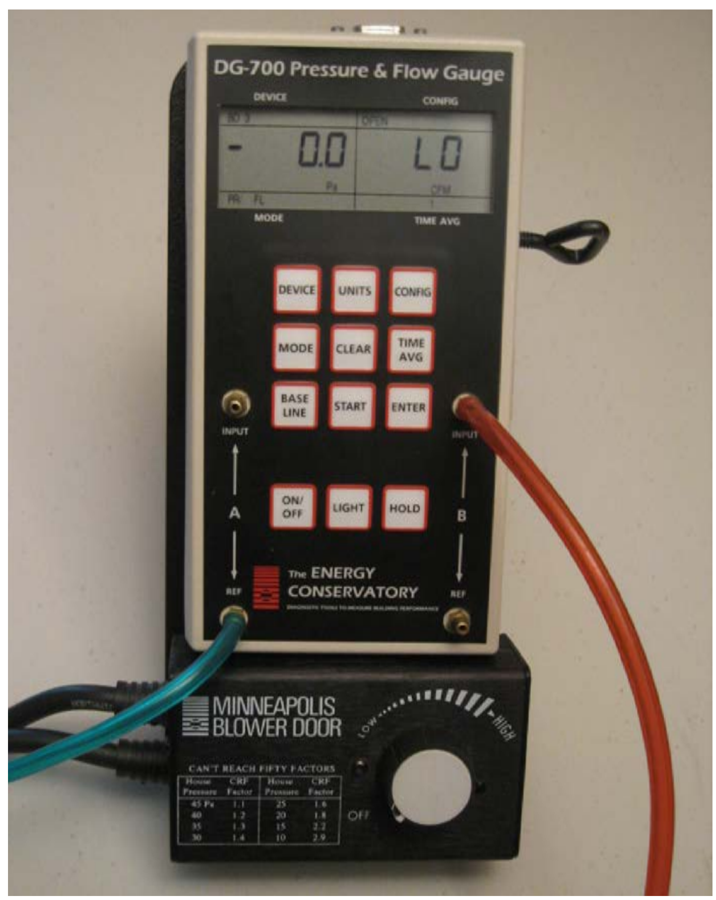


Figure 6-6. Fan Speed Controller with Manometer

The table in Figure 6-4 shows the airflow ranges of a typical blower door fan. The greatest accuracy is achieved by installing the flow ring with the smallest opening area, while still providing the fan sufficient airflow to achieve the test pressure. Standing directly in front of the fan may result in erroneous readings.

An exterior door is fitted with a nylon skirt with an opening for the fan. A digital manometer is used to measure the pressure difference and the air flow through the fan. The motor speed controller allows the technician to control the speed of the fan. The airflow measured at 50 Pa, along with house volume, is used to calculate the air change rate for the house. While the blower door testing process is not complex, it takes care to properly set up the house and configure the digital manometer.

Preparing the house for the test includes closing all exterior doors and windows and disabling all combustion appliances and exhaust fans. All interior doors are left in the open position to equalize air pressure throughout the house.

To Pressurize or Depressurize?

Both depressurization (fan air flow is out of the house) and pressurization (fan air flow is into the house) blower door tests, when performed properly, will yield the same results.

In new construction, for code compliance, depressurization testing is the norm. There are several benefits to conducting a depressurization test in new construction:

- The test setup takes less time since the backdraft dampers do not need to be sealed.
- The blower door is designed to provide access to the flow rings only when the fan is installed for depressurization.
- It is easier for a technician to locate envelope air leaks when the house is depressurized.

Pressurization blower door tests are performed primarily in existing homes when there is a possibility that asbestos or other unwanted dust or particles may be present in the

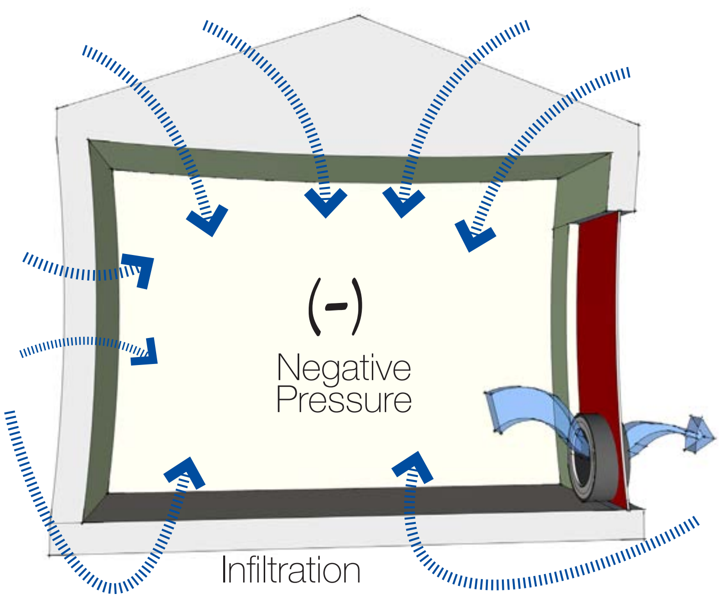


Figure 6-7.
Depressurization Test

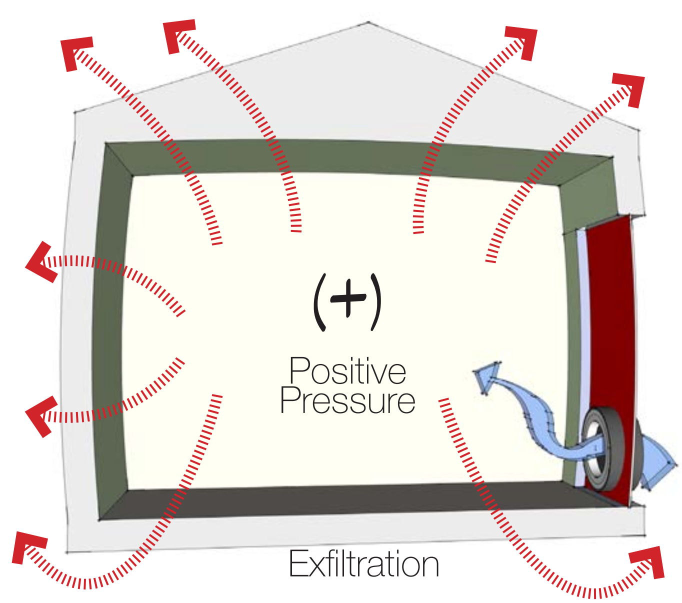


Figure 6-8.
Pressurization Test

building cavities. A pressurization blower door test usually takes longer to perform, since the exhaust backdraft dampers must be sealed before testing occurs. Below are some factors that suggest that a depressurization test is not appropriate:

- Presence of mold anywhere in the home
- Suspicion of or presence of Vermiculite (asbestos) insulation in attic or wall cavities
- Suspicion of or presence of any friable asbestos
- Wood fireplace that is burning or ash that could be drawn into the home
- Lead dust from lead based paint in house

ALERT: In order to 'pressurize' for blower door testing, the technician MUST turn the entire fan around. Merely flipping the flow-direction switch that is on some fans will not yield accurate measurements.

Figure 6-9.
Place Vented Combustion Appliances in Off or Pilot-Only Mode

Blower Door Test

STEP 1

Building Preparation

According to the energy code, the blower door test may be performed at any time after creation of all penetrations in the building thermal envelope. The testing process can be described in five steps: building preparation, test equipment installation, testing, calculations, and recording.

- ☐ **Close Exterior Doors and Windows.** Close and latch all doors and windows between the conditioned space volume and the outside, including all other openings.
- ☐ **Close Attached Garage Doors and Windows.** Close and latch all exterior garage doors and windows. If the blower door is installed between the conditioned space and the garage, at least one exterior garage door must remain open.
- ☐ **Configure Crawlspaces.** Record the position of the crawlspace access doors and hatches. When the access doors and hatches between conditioned space and the crawlspace are closed per the requirements noted for vented and unvented crawlspaces below, the crawlspace is excluded from infiltration volume and conditioned space volume.
  - **Vented Crawlspace.** Close interior access doors and hatches between the conditioned space and the vented crawlspace. Leave exterior crawlspace access doors, hatches, and vents in their as-found position.
  - **Unvented Crawlspace.** Open all access doors and hatches between the conditioned space and unvented crawlspace. Close exterior crawlspace access doors, hatches, and vents.

Note: As an alternative to insulating the floor over a crawlspase, the IECC allows insulation of the crawlspace walls. If the crawlspace walls are insulated, then the crawlspace may not be vented to the outside. Montana does allow temporary venting of an unvented crawlspace durning construction.

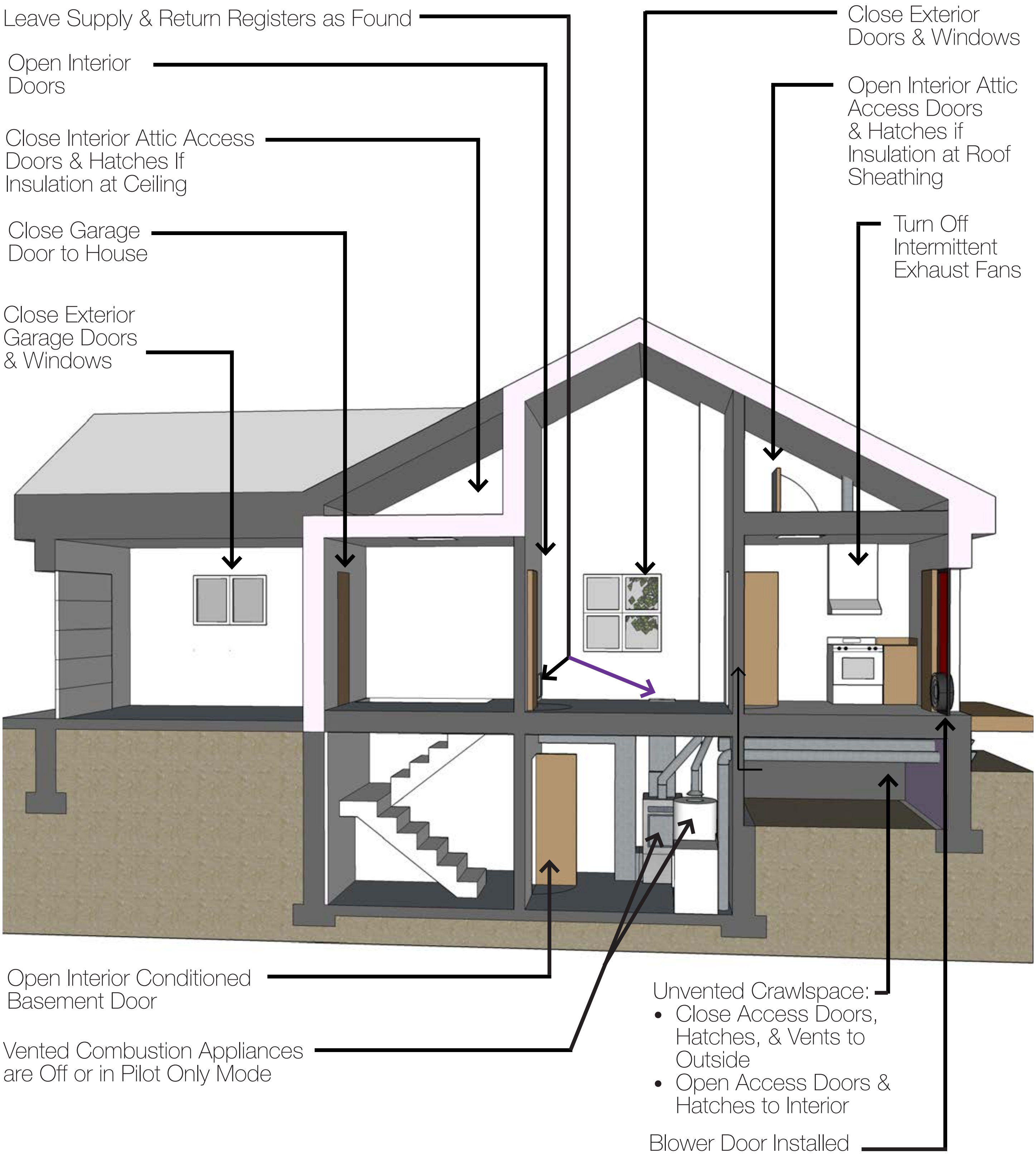


Figure 6-10.
Blower Door Test Building Preparation Common Configuration

Exception: Multifamily Buildings with Continuous Crawlspace. Close interior access doors and hatches between the dwelling unit under testing and the crawlspace where the crawlspace volume is continuous below multiple adjacent dwelling units. Leave exterior crawlspace access doors, hatches, and vents in their as-found position.

■ **Configure Attics.** Record positions of attic access doors and hatches. When the access doors and hatches between the conditioned space and the attic are closed due to requirements noted immediately below, the attic is excluded from infiltration volume and conditioned space volume.

■ **Attic is Not Both Air Sealed and Insulated at the Roof Deck (Includes Vented Attics).** Close access doors and hatches between the conditioned space and the attic. Leave exterior attic access doors, hatches, and vents in their as-found position.

■ **Attic is Both Air Sealed and Insulated at the Roof Deck (Includes Unvented Attics).** Open interior access doors and hatches between the conditioned space and attic. Close exterior access doors, vents, and hatches.

Exception: Multifamily Buildings with Continuous Attic. Close interior access doors and hatches between the dwelling unit under testing and the attic. Leave exterior attic access doors, hatches, and vents in their as-found position.

☐ **Configure Basements.** Record the position of basement doors. When doors between the conditioned space and the basement are closed due to requirements noted immediately below, exclude the basement from infiltration volume and conditioned space volume.

■ **Open All Doors Between the Conditioned Space and Basement.** Close (to the extent possible) exterior basement access doors, vents, and hatches.

Exception: Floor Above the Basement is Air Sealed

and Insulated. Close doors between the basement and conditioned-space volume. Leave exterior basement access doors, hatches, and vents in their as-found position.

Exception: Multifamily Buildings with Continuous Basement. Close interior doors between the dwelling unit under testing and the basement. Leave exterior basement access doors, hatches, and vents in their as-found position.

- ☐ **Open Interior Doors.** Open all doors between rooms inside the conditioned space.
- ☐ **Close Chimney Dampers and Combustion-Air Inlets on Solid Fuel Appliances.** Close chimney dampers and combustion-air inlets on solid-fuel appliances. Take precautions to prevent ashes or soot from entering the dwelling unit during testing.

Figure 6-11. Close Chimney Dampers and Combustion-Air Inlets on Solid Fuel Appliances

- ☐ **Combustion Appliance Flue Vents.** Leave as-found.
- ☐ **Turn Off Fans.** Turn off any fan or appliance capable of inducing airflow across the building enclosure including, but not limited to, clothes dryers, attic fans, kitchen and bathroom exhaust fans, air handlers, ventilation fans used in a whole-building mechanical ventilation system, and crawlspace and attic ventilation fans. This requirement includes accessible fans in adjacent attached dwelling units.
- ☐ **Configure Dampers.**
  - ■ **Non-Motorized Dampers.** Leave non-motorized dampers, such as pressure-activated operable and fixed dampers, that connect the conditioned space to the exterior or to unconditioned space in their as-found positions.
  - ■ **Motorized Dampers.** Close, but do not further seal, motorized dampers that connect the conditioned space to the exterior or to unconditioned space.
- ☐ **Configure Non-Dampered Openings.** For ventilation, combustion air and make-up air openings that connect the conditioned space to the exterior or to unconditioned space:
  - ■ **Intermittently Operating Local Exhaust.** Leave open non-dampered ventilation openings of intermittently operating local exhaust ventilation systems.
  - ■ **Intermittently Operating Whole-Building Ventilation.** Do not seal non-dampered ventilation openings of intermittently operating whole-building ventilation systems, including HVAC fan-integrated outdoor air inlets.
  - ■ **Continuously Operating Local Exhaust.** Seal, at the exterior of the enclosure where conditions allow, non-dampered ventilation openings of continuously operating local exhaust ventilation systems.
  - ■ **Continuously Operating Whole-Building Ventilation.** Seal, at the exterior of the enclosure where conditions allow, non-dampered ventilation openings of continuously operating whole-building ventilation systems.

- ■ **Intentional Openings.** Leave open all other non-dampered intentional openings.
- ☐ **Close Whole-Building Fan Louvers/Shutters.** Close whole-building fan louvers and shutters. Install seasonal cover, if present.
- ☐ **Close Evaporative Coolers.** Place the opening to the exterior of evaporative coolers in its off position. Install seasonal cover, if present.
- ☐ **Close Window Trickle-Vents and Through-the-Wall Vents.** Close operable window trickle-vents and through-the-wall vents.
- ☐ **Leave Supply Registers and Return Grilles As Found.** Leave supply registers and return grilles as found and uncovered.
- ☐ **Fill or Seal Empty P-Traps.** If p-traps at plumbing drains are empty, seal or fill with water.
- ☐ **Configure Vented Combustion Appliances.** Place vented combustion appliances in off or "pilot only" mode for the duration of the test.

Figure 6-12.
Blower Door Frame and Skirt

Blower Door Test STEP 2

Test Equipment Installation

- ☐ **Install Blower Door Fan.** Install the blower door skirt and fan in an exterior doorway that has an unrestricted air pathway into the building and no obstructions to airflow within 5 feet of the fan inlet and 2 feet of the fan outlet. The system should not be installed in a doorway or window exposed to wind. For multifamily dwelling units, if the main entry door is in an interior hallway then the hallway must be well connected to outside through open windows or doors, or an exterior window or door is to be used.

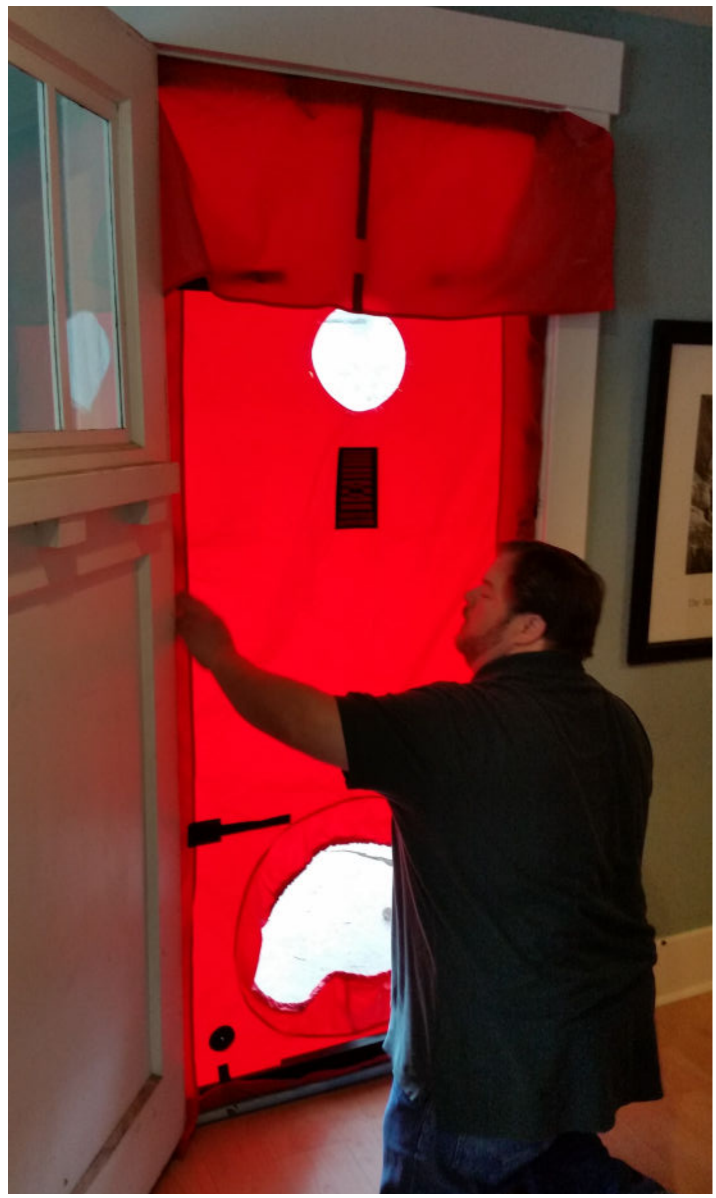


Figure 6-13. Blower Door Frame and Skirt Installation

Figure 6-14. Mounting Blower Door Fan in Frame

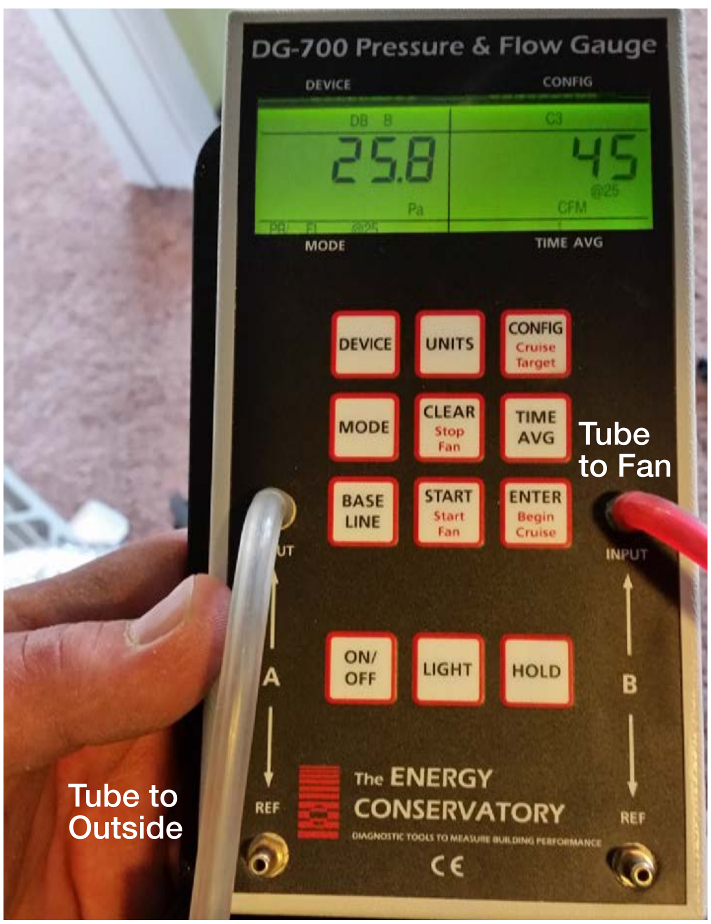


Figure 6-15.
Digital Manometer with Tubing

- ☐ **Install Tubing.** Install tubing to measure the difference in pressure between the enclosure and the outdoors in accordance with manufacturer's instructions. Position the tubing, especially vertical sections, out of direct sunlight.
- ☐ **Measure Temperature.** Measure and record indoor and outdoor temperatures using a thermometer. Observe general weather conditions.
- ☐ **Record Altitude.** Record the altitude of the building site above sea level with an accuracy of 500 feet.
- ☐ **Record Model and Serial Numbers.** Record the model and serial number(s) of manometer and test fan.
- ☐ **Record Infiltration Volume.** Record the infiltration volume of the dwelling unit.

Blower Door Test STEP 3

ONE-POINT AIR TIGHTNESS TEST

RESNET/ICC 380 allows either a One-Point Test or a Multi-Point Test. The discussion below emphasizes the One-Point Test, since it will be used most often in typical new construction. Multi-Point Testing provides greater accuracy especially in windy conditions.

- ☐ **Measure Pre-Test Baseline Building Pressure.** Record the pressure (average value over at least a 10-second period) of the house WRT the outside with the blower door fan turned off and sealed.
- ☐ **Create Pressure Difference Across Building Enclosure of 50 Pa.** Unseal and configure the blower door fan and adjust motor speed to create an induced enclosure pressure difference of 50 (±3 Pa). The pressure difference must consider natural pressure difference. This value may be positive or negative, depending on whether the enclosure is pressurized or depressurized for the test.

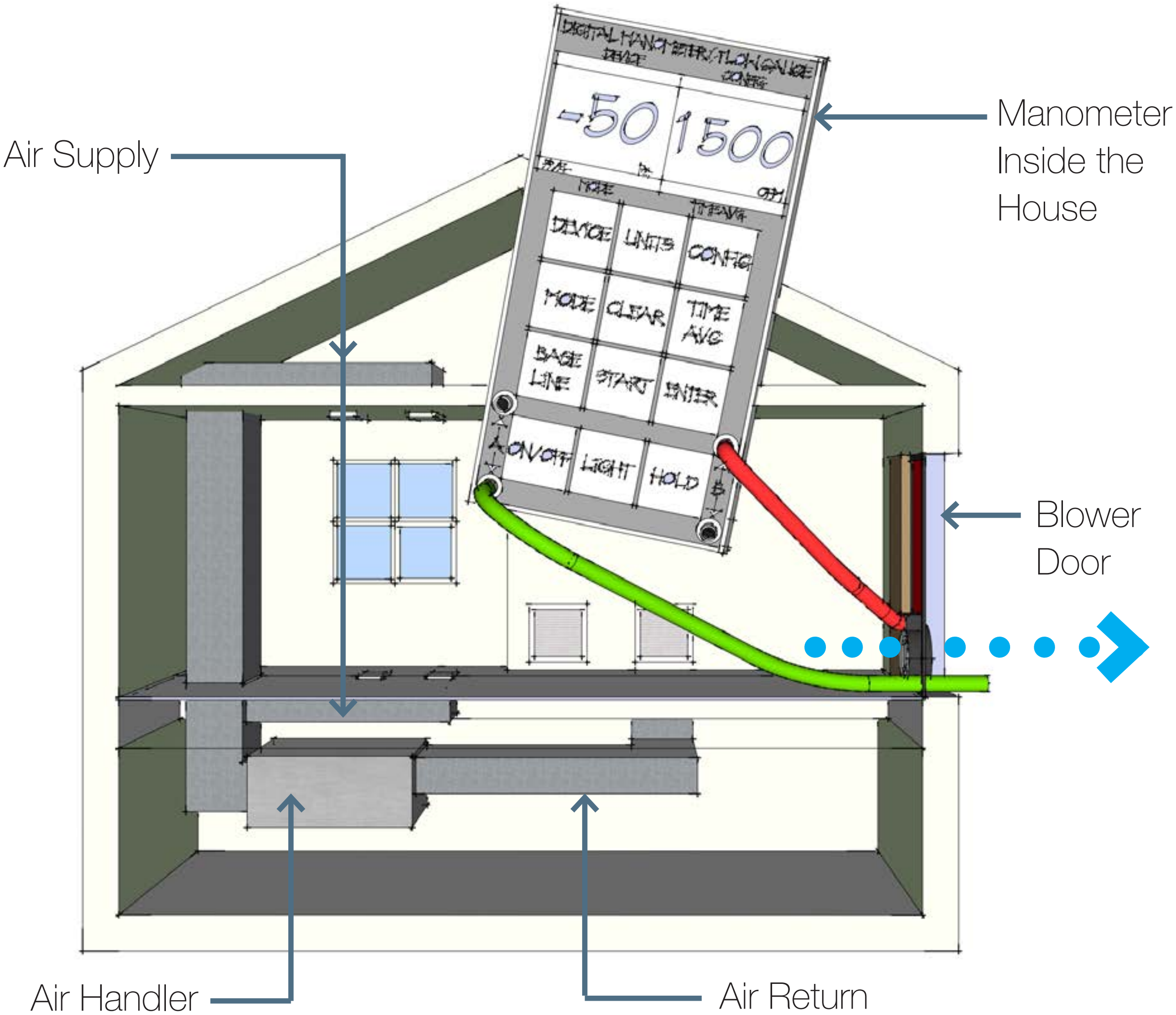


Figure 6-16. Blower Door Test - Depressurization

- **50 Pa Pressure Difference Achieved.** If a 50 Pa induced enclosure pressure difference is achieved, record the average value of the induced enclosure pressure difference (measured over at least a 10-second period) and the airflow in CFM.

- **50 Pa Pressure Difference Not Achieved.** If a 50 Pa induced enclosure pressure difference is not achieved, then use additional blower door fans or record the highest induced enclosure pressure difference and airflow that was achieved with the equipment available, measured over at least a 10-second period. A minimum of 15 Pa must be induced across the enclosure for the test to be valid.

- **Can't Reach 50 Factor Pa Adjustment.** If an induced enclosure pressure difference of 50 Pa is not achieved, then the recorded airflow must be converted to an estimated airflow at 50 Pa (CFM50) using the adjustment table provided by the equipment manufacturer. Such a table for building enclosure testing is often referred to as a *Can't Reach 50 Factor Table*. Refer to Section 5 of this guide for more information. Alternatively, a manometer that is equipped to automatically make the conversion to CFM50 is permitted to be used. Typically the manometer test mode that includes this conversion is PR/FL@50.

Nominal Airflow = Measured Airflow X Can't Reach 50 Factor

Blower Door Test

STEP 4

Calculations

Corrections for air temperature and altitude in building tightness testing were added to the energy code in the 2015 IECC and are inlcuded in the 2018 IECC. While these adjustments will be new for most Montana performance-testing technicians, the need for greater precision has been recognized nationally for some time.

- ☐ **Correct CFM50 for Air Temperature and Altitude.** Calculate corrected CFM50 by making the adjustments for air density and viscosity using Appendix XI of ASTM E779-10, by using software such as TectiteTM, or by using the formula below. Altitude adjustment is necessary if the site is greater than 5,000 feet above sea level. Temperature correction is necessary if the difference between indoor and outdoor temperature is greater than 30^{o}F.

Corrected CFM = Nominal CFM50 x TCF x ACF

ACF = Altitude Correction Factor = 1 + (.000006 x altitude ft.)

TCF = Temperature Correction Factor (From Figure 6-15. You may need to interpolate between values.)

ALERT: RESNET/ICC 380 requires corrections to account for density and viscosity differences in air due to altitude and temperature. Standard 380 references ASTM E779-10. Software provided by equipment manufacturers may be used to satisfy these requirements, but only if the software is compliant with ASTM E779-10.

While both major equipment manufacturers offer compliant software, a spreadsheet calculator tool based on ASTM E770-10 was created as an alternative means of compliance. The calculator tool is free and can be found, along with detailed instructions, on the RESNET website.

EXAMPLE 4.1

Air Temperature and Altitude Correction

The airflow reading (Nominal) is 1,600 CFM. The house tested is located at an altitude of 6,000 feet above sea level. The outdoor temperature at the time of the depressurization test was 0^{0}F and the indoor temperature was 60^{0}F. What is the corrected airflow?

ACF = 1 + (0.000006 x 6,000 Feet) = 1.036

TCF = 0.941 (From Air Density Correction Factors: De-pressurization Table, Figure 6-17.)

Corrected Airflow = 1,600 CFM x 1.036 x 0.941

Corrected Airflow = 1,560 CFM

- ☐ **Calculate Adjusted Airflow and ACH50.** Following is the procedure to convert airflow test results to air changes per hour (ACH50).

  1. Calculate Adjusted Airflow (CFM50). One-Point Test only.

  Adjusted CFM50 = 1.1 x Corrected CFM50

  2. Calculate ACH50.

$$\text{ACH50} = \frac{\text{(Adjusted CFM50 x 60)}}{\text{Infiltration Volume}}$$

Note: The results of a Multi-Point Test do not need to be adjusted by 10 percent as is required for One-Point Test results.

EXAMPLE 4.2

Calculate ACH50

Assume the home's measured airflow at 50 Pa test pressure has been corrected for air temperature and altitude, per the previous example. The house volume is 32,000 ft^3. The corrected airflow is 1,560 CFM. Calculate the air changes per hour. First, the airflow must be adjusted if a One-Point Test is conducted.

Adjusted CFM50 = 1.1 x 1,560 CFM = 1,716 CFM

Next calculate the ACH50.

ACH50 = (1,716 CFM x 60) / 32,000 ft^3 = 3.2 ACH50

Air Density Correction Factors: Depressurization									
Outside	Inside Temperature								
Temp	50	55	60	65	70	75	80	85	90
-20	0.929	0.924	0.92	0.915	0.911	0.907	0.903	0.898	0.894
-15	0.934	0.93	0.925	0.921	0.916	0.912	0.908	0.904	0.899
-10	0.939	0.935	0.93	0.926	0.921	0.917	0.913	0.909	0.904
-5	0.945	0.94	0.935	0.931	0.927	0.922	0.918	0.914	0.909
0	0.95	0.945	0.941	0.936	0.932	0.927	0.923	0.919	0.914
5	0.955	0.95	0.946	0.941	0.937	0.932	0.928	0.924	0.919
10	0.96	0.955	0.951	0.946	0.942	0.937	0.933	0.929	0.924
15	0.965	0.96	0.956	0.951	0.947	0.942	0.938	0.934	0.929
20	0.97	0.965	0.961	0.956	0.952	0.947	0.943	0.938	0.934
25	0.975	0.97	0.966	0.961	0.957	0.952	0.948	0.943	0.939
30	0.98	0.975	0.971	0.966	0.962	0.957	0.953	0.948	0.944
35	0.985	0.98	0.976	0.971	0.966	0.962	0.957	0.953	0.949
40	0.99	0.985	0.981	0.976	0.971	0.967	0.962	0.958	0.953
45	0.995	0.99	0.985	0.981	0.976	0.972	0.967	0.963	0.958
50	1	0.995	0.99	0.986	0.981	0.976	0.972	0.967	0.963
55	1.005	1	0.995	0.99	0.986	0.981	0.977	0.972	0.968
60	1.01	1.005	1	0.995	0.991	0.986	0.981	0.977	0.972
65	1.015	1.01	1.005	1	0.995	0.991	0.986	0.981	0.977
70	1.019	1.014	1.01	1.005	1	0.995	0.991	0.986	0.982
75	1.024	1.019	1.014	1.009	1.005	1	0.995	0.991	0.986
80	1.029	1.024	1.019	1.014	1.009	1.005	1	0.995	0.991
85	1.034	1.029	1.024	1.019	1.014	1.009	1.005	1	0.995
90	1.038	1.033	1.028	1.024	1.019	1.014	1.009	1.005	1
95	1.043	1.038	1.033	1.028	1.023	1.019	1.014	1.009	1.005
100	1.048	1.043	1.038	1.033	1.028	1.023	1.018	1.014	1.009
105	1.053	1.047	1.042	1.037	1.033	1.028	1.023	1.018	1.014
110	1.057	1.052	1.047	1.042	1.037	1.032	1.027	1.023	1.018

Figure 6-17.
Air Density Correction Factors: Depressurization

Air Density Correction Factors: Pressurization									
Outside	Inside Temperature								
Temp	50	55	60	65	70	75	80	85	90
-20	1.077	1.082	1.087	1.092	1.098	1.103	1.108	1.113	1.118
-15	1.071	1.076	1.081	1.086	1.091	1.097	1.102	1.107	1.112
-10	1.065	1.07	1.075	1.08	1.085	1.09	1.096	1.101	1.106
-5	1.059	1.064	1.069	1.074	1.079	1.084	1.089	1.095	1.1
0	1.053	1.058	1.063	1.068	1.073	1.078	1.084	1.089	1.094
5	1.047	1.052	1.058	1.063	1.068	1.073	1.078	1.083	1.088
10	1.042	1.047	1.052	1.057	1.062	1.067	1.072	1.077	1.082
15	1.036	1.041	1.046	1.051	1.056	1.061	1.066	1.071	1.076
20	1.031	1.036	1.041	1.046	1.051	1.056	1.061	1.066	1.07
25	1.025	1.03	1.035	1.04	1.045	1.05	1.055	1.06	1.065
30	1.02	1.025	1.03	1.035	1.04	1.045	1.05	1.055	1.059
35	1.015	1.02	1.025	1.03	1.035	1.04	1.044	1.049	1.054
40	1.01	1.015	1.02	1.025	1.03	1.034	1.039	1.044	1.049
45	1.005	1.01	1.015	1.02	1.024	1.029	1.034	1.039	1.044
50	1	1.005	1.01	1.015	1.019	1.024	1.029	1.034	1.038
55	0.995	1	1.005	1.01	1.014	1.019	1.024	1.029	1.033
60	0.99	0.995	1	1.005	1.01	1.014	1.019	1.024	1.028
65	0.986	0.99	0.995	1	1.005	1.009	1.014	1.019	1.024
70	0.981	0.986	0.991	0.995	1	1.005	1.009	1.014	1.019
75	0.976	0.981	0.986	0.991	0.995	1	1.005	1.009	1.014
80	0.972	0.977	0.981	0.986	0.991	0.995	1	1.005	1.009
85	0.967	0.972	0.977	0.981	0.986	0.991	0.995	1	1.005
90	0.963	0.968	0.972	0.977	0.982	0.986	0.991	0.995	1
95	0.959	0.963	0.968	0.973	0.977	0.982	0.986	0.991	0.995
100	0.954	0.959	0.964	0.968	0.973	0.977	0.982	0.987	0.991
105	0.95	0.955	0.959	0.964	0.969	0.973	0.978	0.982	0.987
110	0.946	0.951	0.955	0.96	0.964	0.969	0.973	0.978	0.982

Figure 6-18.
Air Density Correction Factors: Pressurization

Blower Door Test STEP 5

Record Test Factors and Results

RESNET/ICC 380 details test conditions and results that must be recorded. Appendix 1, *Building Tightness Test Record Form*, details the required information. All of the information required by this form must be provided to comply with the IECC referenced standards.

Code Citation: 2018 IECC, R402.4.1.2 Testing
A written report of the results of the test shall be signed by the party conducting the test and provided to the code official.

Who May Conduct a Blower Door Test?

Code Citation: 2018 IECC, R402.4.1.2 Testing
Where required by the code official, testing shall be conducted by an approved ~~third~~ party.

This provision in the IECC was amended by Montana. The Montana amendment removed the word "third" to allow homebuilders to test their own houses. Since 2014, interpretation of this provision by local building code officials has varied.

- ☐ **Return House to Pretest Condition.** Before the testing technician leaves the house, the building must be returned to its pretest condition. This includes turning the thermostat and water heater temperature controls to their original settings. Check to see that furnace, water heater, and gas fireplace pilot lights have not been blown out during the blower door test and re-light them if necessary. Remove any temporary tape or other air-sealing materials from fireplaces, woodstoves, or other openings.

TROUBLESHOOTING

There are several possible reasons for an inaccurate test result. A few of the most common problems are discussed below:

Improper House Setup. If the technician fails to properly prepare the house for testing, the results will be inaccurate. An exterior window or door that is not closed tightly will result in an incorrect result, as will not opening all interior doors.

Improper Calibration. Testing equipment, especially the manometer, will not yield accurate results if it is out of calibration. Manufacturers establish minimum calibration periods. While digital manometers are typically sent to the manufacturer for calibration, fans can be calibrated in the field according to the manufacturer's instructions.

Not Correcting for Air Temperature Density. During a blower door test, the flow sensor measures the air flow through the fan, which is equal to the air flowing back into the building through air leaks. A correction is necessary when the inside and outside temperature, and therefore the densities of the inside and outside air, are not the same. Temperature correction is necessary if the difference between indoor and outdoor temperature is greater than 30°F. At 30°F outside air temperature, the difference is almost 7%. At 0°F outside air temperature, the difference is about 12%.

Not Correcting for Altitude Air Density. Failure to correct for air density due to elevation above sea level will lead to an inaccurate result. Altitude adjustment is necessary if the site is greater than 5,000 feet above sea level.

Wind. Wind can be a significant challenge for building tightness testing. A fairly constant wind can be accounted for by the baseline procedure to adjust for the natural pressure occurring at the time of the test. Dealing with gusty wind conditions is more challenging. Following are some strategies that may be used to obtain a more accurate result if returning to perform the test when conditions ar more appropriate is not feasible:

- Move the reference tube end away from the windward side of the building.
- Place the reference tube end at ground level.
- Cover the end of the tube, protecting it from the wind, without blocking it. Flat plates have been used for this purpose.
- Terminate the reference tube end with a "T" fitting with each resulting tube end at least 20 feet apart.
- Use longer periods of time averaging for baseline and air-flow procedures. Increasing the time averaging periods decreases uncertainties.

Tube Problems. The tube could be crimped or there could be water in the tube.

MULTI-POINT AIRTIGHTNESS TEST

RESNET/ICC 380 allows for either a One-Point Test or Multi-Point Test for building tightness testing. The One-Point Test is typically simpler to perform. The Multi-Point Test is slightly more complex to perform unless the technician is using software provided by their equipment manufacturer. Performing a Multi-Point Test is made relatively easy when using the software to automate the testing process.

The Multi-Point Test provides a more reliable result, especially in windy conditions. House preparation, blower door installation, and baseline procedure are the same for both types of tests, with the exception of computer connections.

The results of a Multi-Point Test must be corrected for air temperature and altitude by the same procedure detailed for a One-Point Test. However, that corrected airflow does not have to be increased by 10 percent as is the case with a One-Point Test.

The difference in the two testing procedures occurs in taking the airflow readings. In a Multi-Point Test, at least five induced enclosure pressure differences (referred to as *pressure stations*) must be recorded at approximately equally-spaced pressures between 10 Pa and either 60 Pa or the highest achievable pressure difference up to 60 Pa.

At each pressure station, the average value of the induced enclosure pressure difference, the airflow, and the temperature, measured over at least a 10-second period, must be recorded. ***The highest induced enclosure pressure difference must be at least 25 Pa or the Single-Point Airtightness Test must be used.***

ALERT: A One-Point Test must be adjusted by increasing the airflow by 10 percent. No such adjustment must be made if a Multi-Point Test is performed.

MULTIFAMILY AIRTIGHTNESS TEST

In a building envelope tightness test of a single-family home, all measured air leakage is to the outside. In multifamily buildings, it is a challenge to measure leakage to the outside without including leakage to the adjacent spaces. It is air leakage to the outside that is important for energy use and code compliance.

The energy code offers no guidance on how to conduct multifamily building envelope air leakage tests. However,

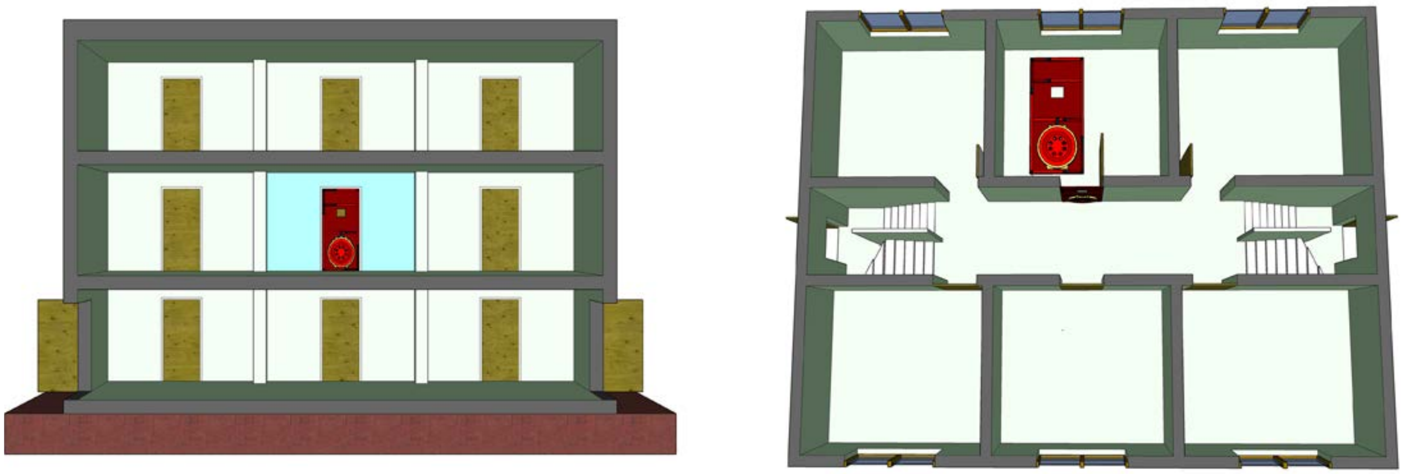


Figure 16-19. Multifamily Compartmentalization Test

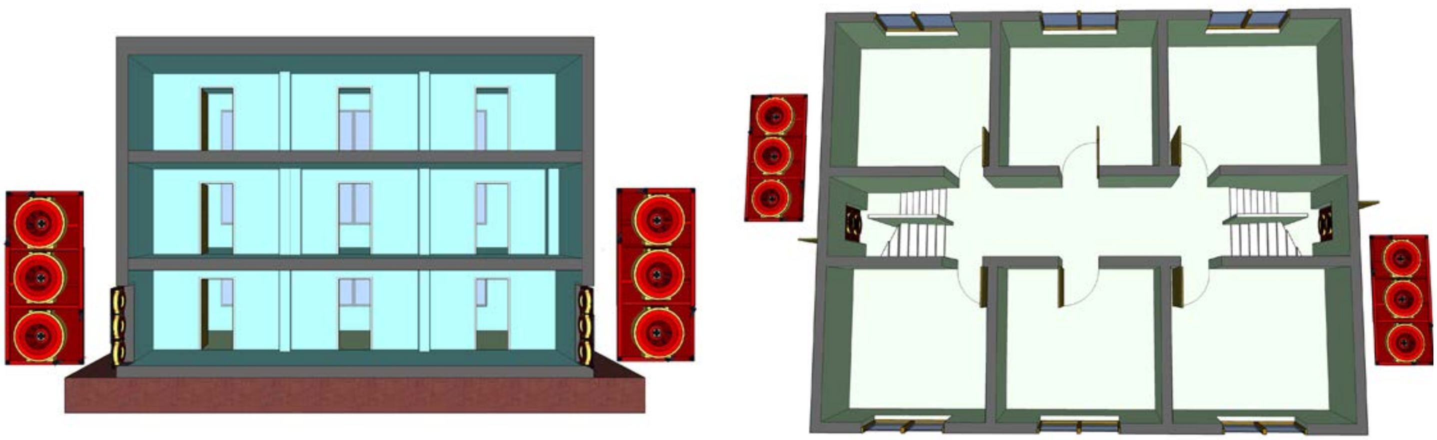


Figure 16-20. Multifamily Whole-Building Test

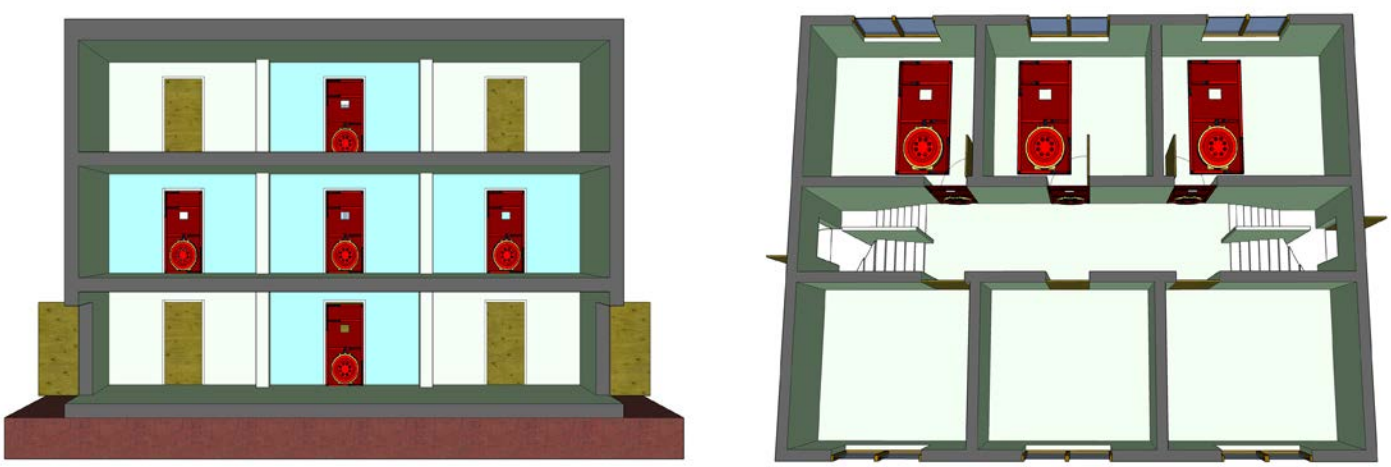


Figure 16-21. Multifamily Adjacent Spaces Guarded Test

RESNET has developed a document titled *RESNET Guidelines for Multifamily Energy Rating* that discusses the testing options. In that document, four options for performing building airtightness testing are identified. Two of the four options involve *guarded tests* and are very similar. Each of these options are discussed briefly below. Refer to that document for the complete procedure.

Compartmentalization Test. This test measures total leakage from the unit, including both leakage to the outside and leakage to adjacent spaces. This test typically yields the highest and most conservative dwelling-unit air-leakage result but requires only a single blower door fan. Test procedures are the same as described for single-family buildings with the special instructions noted below:

- Adjacent spaces on the same floor must be connected to the outside and maintained at outside pressure.
- Exhaust fans and appliances (i.e., clothes dryers, attic fans, kitchen and bathroom exhaust fans, outdoor air ventilation fans, air handlers, and crawlspace and attic ventilation fans) are turned off. Continuously operating individual ventilation systems are turned off and sealed. Continuously operating central ventilation systems are sealed at the dwelling-unit registers.
- Undampered or fixed-damper intentional openings are left open or in their fixed position. Fixed-damper ducts supplying outdoor air for intermittent ventilation systems (including central-fan-integrated distribution systems) are left in their fixed-damper position. Undampered supply-air or exhaust-air openings of continuously operating individual mechanical ventilation systems are sealed and ventilation fans are turned off. Undampered supply-air or exhaust-air openings of continuously operating central mechanical ventilation systems are sealed at the dwelling unit registers.

Whole Building Test. This test treats the whole building as a single zone. All measured air leakage is to the outside. Multiple blower door fans may be required if the building is large. Test procedures are according to RESNET/ICC 380 for single-family homes with some special instructions noted in *RESNET Guidelines for Multifamily Energy Rating*.

Guarded Tests. RESNET/ICC 380 identifies two types of guarded tests. Both measure leakage to the outside from the tested dwelling unit. This test is more accurate than a compartmentalization test but requires multiple blower doors and more building preparation time. No leakage will be measured across walls, ceilings, or floors if the pressure in the adjacent units is the same WRT outside as the unit being tested.

The **Adjacent Spaces Guarded Test** measures only leakage to the outside from the tested dwelling unit. It's called a guarded test because it uses secondary "guard" blower doors placed in the spaces adjacent to the target unit.

The **Mult-Zone Guarded Test** also measures leakage to the outside from the tested dwelling unit. This test is most appropriate for attached townhouses or multifamily buildings with corridors open to the outside, where an Adjacent Spaces Guarded Test is not feasible. This test is similar to the Adjacent Spaces Guarded Test but instead of only pressurizing adjacent spaces, all building zones are pressurized.

Test procedures are essentially the same as RESNET/ICC 380 for single-family homes with some special instructions noted in *RESNET Guidelines for Multifamily Energy Rating*.

For the Multi-Zone Guarded Test, blower door fans are installed in an exterior opening in all adjacent building spaces, as well as in the target unit. All adjacent building spaces are maintained at the same test pressure as the target unit, which neutralizes any inter-unit leakage.

7 Duct Tightness Testing

A duct tightness test involves using a fan to pressurize the duct system to measure how much air leaks out through cracks and holes. The supply and return registers are sealed for the test. There are two types of duct tightness tests. The Total Leakage Test measures leakage from the entire duct system regardless of whether it is located inside or outside the conditioned space. This is the only test allowed by the 2018 IECC for basic tightness testing.

The Leakage to the Outside Test is more complex because the blower door fan must also be used to pressurize the house. The Leakage to the Outside Test is required for an ERI energy code compliance and a HERS Rating.

A duct pressure test is not required by code if the air handler and all ducts are located inside the building thermal envelope. The code allows ducts to be located outside the building thermal envelope but keeping ducts inside eliminates the need for duct tightness testing and reduces energy use. Duct leakage in unconditioned spaces can be a cause of builder callbacks for comfort issues, moisture problems, and high energy bills.

Duct Air Tightness Test Summary

To conduct a Total Leakage Test, all supply and return registers are sealed. The duct tightness tester fan is attached at the air handler cabinet or the largest return register. The airflow required to bring the duct system to 25 Pa pressure WRT the house is equal to the air leaking out of the duct system at that pressure. The Total Leakage Test is simpler and takes less time to perform than the Leakage to the Outside Test.

In conducting a Leakage to the Outside Test, the blower door fan must also be used to pressurize the house to 25 Pa WRT to outside. The duct tester fan is then used to bring the pressure in the duct system to zero WRT the house. Since air requires an opening and a pressure difference to flow, the Leakage to the Outside Test eliminates leakage within the house from the test results since duct pressure is the same pressure as the house. Therefore, the only leakage measured with the duct tester fan will be outside of the conditioned space.

Total Leakage Test Procedure

(RESNET/ICC 380)

The Total Leakage Test may be performed either at rough-in or post-construction. The table below indicates the air leakage allowed by the 2018 IECC per 100 ft^2 of conditioned floor area at 25 Pa.

The testing procedure consists of four steps: building preparation, test equipment installation, testing, and calculations. The steps are provided in a checklist format on the following pages.

Test Conditions	Duct System Air Leakage Limits *	Air Handler Installed?
Rough-in Test	$\leq$ 4 CFM/100 ft^2	Yes
Rough-in Test	$\leq$ 3 CFM/100 ft^2	No
Post-construction Test	$\leq$ 4 CFM/100 ft^2	Yes

* - Based on conditioned floor area, tested at 25 Pa.

Figure 7-1. Total Duct Leakage Limits

Total Leakage Test **STEP 1**

Building Preparation

- ☐ **HVAC System Installation Must Be Complete.** All components of the HVAC system for the dwelling unit along with the duct system must be installed, with the exception of registers.
- ☐ **Turn Off Air Handler Fan.**
- ☐ **Turn Off Exhaust and Supply Fans.** For example, bathroom fans, clothes dryers, kitchen vent hood, and attic fan must be turned off.
- ☐ **Turn Off Vented Combustion Appliances.** All vented combustion appliances must be disabled.
- ☐ **Remove Duct System and Air Handler Filters.**
- ☐ **Configure Dampers within Duct System.**
  - **Non-motorized Dampers.** Leave as found (i.e., pressure-activated operable dampers, fixed dampers). For example, a fixed damper in a duct supplying outdoor air for an intermittent ventilation system that utilizes the HVAC fan must be left in its as-found position.
  - **Motorized Dampers.** Place in closed position but do not seal.
  - **Zone and Bypass Dampers.** Set all to their open position.
  - **Balancing Dampers.** Leave all in their as-found position.
- ☐ **Configure Non-Dampered Ventilation Openings within Duct System.**
  - **Intermittently Operating Whole-Building Ventilation System Openings.** Seal, including HVAC fan-integrated outdoor air inlets.

Duct Mask

Painters Tape

Toe-Kick Registers

Figure 7-2. Sealing Supply Registers

Unless the supply register under a cabinet is ducted directly to the register in the toe-kick space, it will be almost impossible for the system to comply with the energy code. An excellent alternative is have the builder place the register in the floor outside the cabinet or install a duct from the floor boot to the toe-kick register.

- **Continuously Operating Whole-Building Ventilation System Openings.** Seal, at the exterior of the enclosure where conditions allow.

- [ ] **Seal Supply and Return Registers.** Temporarily seal at both the face and the perimeter. Registers atop carpets are permitted to be removed and the face of the duct boot temporarily sealed during testing. For dwelling units without registers and grilles present, the face of the duct boots are to be sealed instead.

The duct tester fan may be located in either of two locations.

Figure 7-4.
Turn Off Exhaust Fans

Figure 7-3.
Sealing Registers
There are a number of innovative products entering the market for sealing duct supply and return registers for duct tightness testing.

Figure 7-5.
Sealing Registers
Testing occupied homes can make locating all registers a real challenge.

Total Leakage Test **STEP 2**

Install Test Equipment

- ☐ **Air Handler Cabinet.** The air-handler return-air cabinet access panel is removed and the duct leakage tester fan is attached to the blower compartment. Permitted for all systems.

Static Pressure Probe Location Options.

- In supply register closest to the air handler; or
- In the main supply trunk line, at least 5 feet from the air handler; or
- In the supply plenum; or
- One static pressure probe in one of the three locations noted above, and a second probe located in the return plenum or in the closest return grille to the air handler, unless this is where the duct leakage tester is installed, in which case the second closest return grille to the air handler is used. The return duct system pressure probe must not be located in the airstream of the duct tester fan.

- ☐ **Return Register.** The duct leakage tester fan is attached to the largest return register in the system. For systems with multiple returns of equal size, the return closest to the air handler is used. Use of the return register is permitted only when the following conditions exist:

- Duct system has three or fewer return grilles; or
- Duct leakage is less than 50 cfm at 25 Pa; or
- Air handler blower access is in an attic or crawlspace that has limited or restricted entry or exit.

Static Pressure Probe Location.

- In supply register closest to the air handler; or
- In the main supply trunk line, at least 5 feet from the air handler; or
- In the supply plenum; or
- One static pressure probe in one of three locations noted above, and a second probe located in the return plenum or in the closest return grille to the air handler, unless this is where the duct leakage tester fan is installed, in which case the second closest return grille to the air handler is used. The return duct system pressure probe must not be located in the airstream of the duct tester. Both the supply-side and return-side duct system pressure probes are connected to a "T" fitting, and the third leg of the "T" is connected to the manometer.

Figure 7-6. Static Pressure Probe
Pressure probe may be inserted into the trunk duct pointed toward the air handler fan.

Total Leakage Test

STEP 3

Conduct Total Leakage Test

- **Open Unconditioned Space to Outside.** Open any vents, access panels, doors, or windows between the unconditioned space volume (attics, garages, crawlspaces, etc.) and the outside.
- **Open Conditioned Space to Outside.** Open at least one door, window, or comparable opening between the building and the outside to prevent changes in building pressure when the duct leakage tester fan is running.
- **Open All Interior Doors.**
- **Create Induced Duct System Pressure.** Turn on and adjust duct tester fan to create an induced duct system pressure difference of 25 ± 3 Pa WRT outside.
- **Record Duct System Pressure and Air Flow.** If a 25 Pa induced duct system pressure difference is achieved, then a 10-second average air flow (CFM25) value is recorded. Record the 10-second duct system pressure difference of the test. If a 25 Pa induced duct system pressure difference is **not** achieved, then record the 10-second airflow that was achieved along with the highest induced duct system pressure difference achieved.
- **Record Fan Pressurization or Depressurization.** Record whether the duct leakage tester fan is pressurizing or depressurizing the duct system. Refer to the manufacturer's manual for the manometer and tubing setup appropriate for a depressurization test, which will differ from the setup for the pressurization test.
- **Can't Reach 25 Pa Adjustment.** If an induced duct system pressure difference of 25 Pa was not achieved, then the recorded airflow must be converted to a nominal airflow at 25 Pa (CFM25) using the adjustment table provided by the equipment manufacturer. Such tables are often referred to as *Can't Reach 25 Factor Tables.* Alternately, a manometer that is equipped to automatically make the conversion to CFM25 may be used. Typically the manometer test mode that includes this conversion is PR/FL@25.

Sample Ring Airflow Ranges (CFM)	
Open (no flow ring)	1500 - 600
Ring 1	800 - 225
Ring 2	300 - 90
Ring 3	125 - 10

Figure 7-7.
Sample Ring Airflow Ranges

Figure 7-8.
Duct Tester Fan and Rings

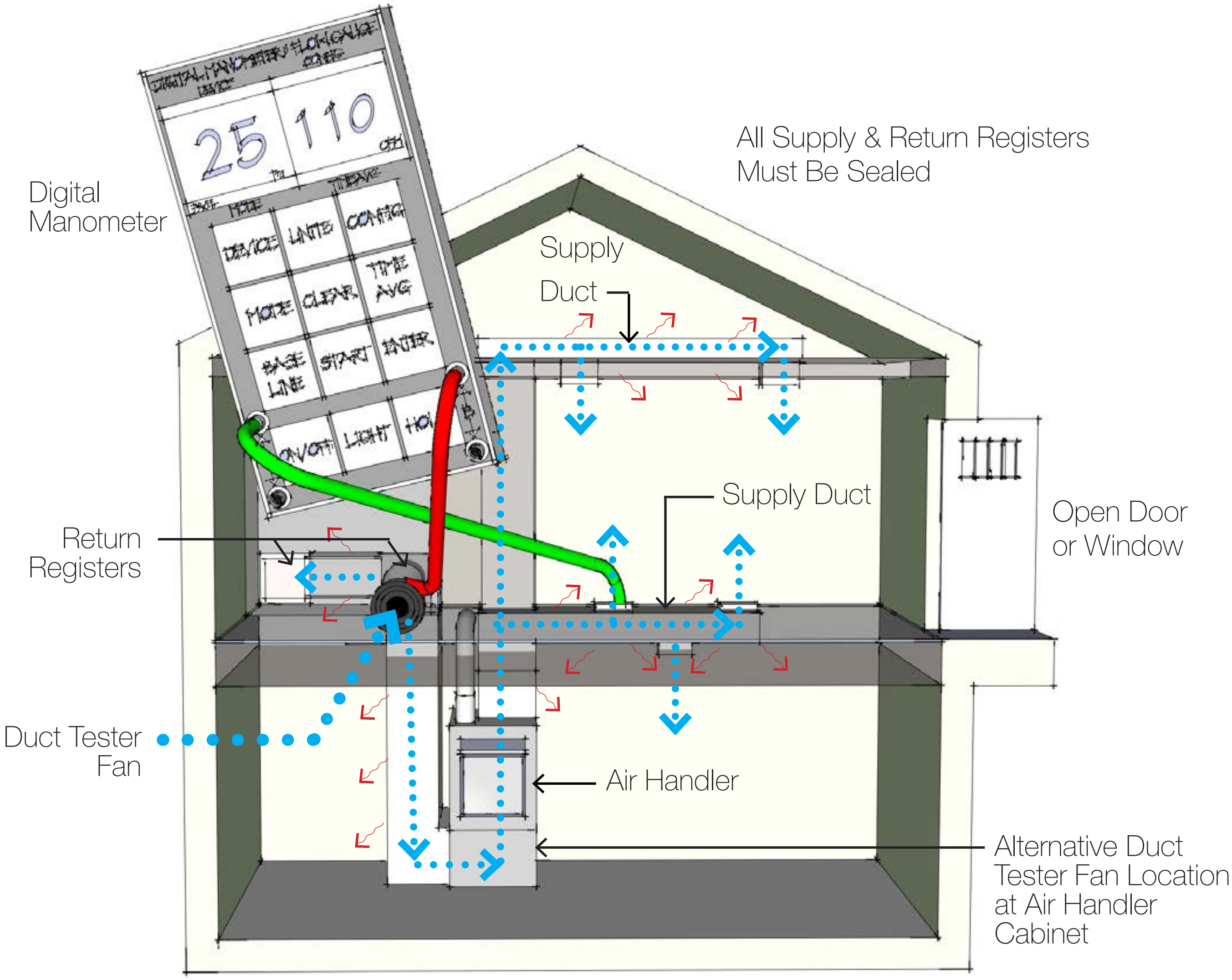


Figure 7-9. Total Duct Leakage Test

At Return Grille

At Air-Handler Cabinet

Figure 7-10. Duct Tester Fan Mounting Locations

Total Leakage Test **STEP 4**

Record Test Factors and Results

- ☐ RESNET/ICC 380 details the test conditions and results that must be recorded. Appendix 2, *Duct Tightness Test Record Form*, details required information.

Leakage To Outside Test Procedure

The Leakage to the Outside Test must be performed post-construction. This test is not allowed for compliance by the 2018 IECC but is used as a part of the ERI compliance path. The building and equipment setup for the Leakage to the Outside Test is similar to that of the Total Leakage Test, with the addition of a blower door and fan to pressurize the house. The testing process consists of three steps: building preparation, test equipment installation, and testing. The procedure is detailed in a checklist format below.

LEAKAGE TO OUTSIDE TEST STEP 1

Building Preparation

- ☐ **HVAC System Installation Complete.** All components that are included in the HVAC design for the dwelling unit and integrated with the duct system must be installed, with the exception of registers. For a Leakage to the Outside Test, these components include windows and doors that are necessary for a complete building envelope.
- ☐ **Turn Off Air Handler Fan.**
- ☐ **Turn Off Exhaust and Supply Fans.** For example, bathroom fans, clothes dryers, kitchen vent hood, and attic fan must be turned off.
- ☐ **Turn Off Vented Combustion Appliances.** All vented combustion appliances must be turned off.
- ☐ **Remove Duct System and Air Handler Filters.**
- ☐ **Configure Dampers within Duct System.**
  - ■ Non-motorized dampers are left as found (i.e., pressure-activated operable dampers, fixed dampers). For example, a fixed damper in a duct supplying outdoor air for an intermittent ventilation system that utilizes the HVAC fan must be left in its as-found position.
  - ■ Motorized dampers are placed in closed position but not sealed.
  - ■ All zone and bypass dampers are set to their open position.
  - ■ All balancing dampers are left in their as-found position.
- ☐ **Configure Non-Dampered Ventilation Openings within Duct System.**
  - ■ Seal intermittently operating whole-building ventilation system openings, including HVAC fan-integrated outdoor air inlets.
  - ■ Seal (at the exterior of the enclosure where conditions allow) continuously operating whole-building ventilation system openings.
  - ■ Temporarily seal supply and return registers at both the face and the perimeter. Registers atop carpets are permitted to be removed and the face of the duct boot temporarily sealed during testing. For dwelling units without registers and grilles present, the face of the duct boots are sealed instead.
- ☐ **Configure Exterior Doors and Windows.** Close all exterior doors, windows, and other openings in conditioned spaces with potential to hinder the ability of the blower door fan to achieve a house pressure of 25 Pa WRT outdside.
- ☐ **Open All Interior Doors.**
  - ■ **Open Unconditioned Space to Outside.** Open any vents, access panels, doors, or windows between the unconditioned space volume (attics, garages, crawlspaces, etc.) and the outside.

LEAKAGE TO OUTSIDE TEST **STEP 2**

Install Test Equipment

The duct tester fan may be located in either of two locations.

☐ **At Air Handler Cabinet.** The air handler cabinet access panel is removed and the duct leakage tester fan is attached to the blower compartment access. Permitted for all systems.

Static Pressure Probe Location Options.

- In supply register closest to the air handler; or
- In the main supply trunk line, at least 5 feet from the air handler; or
- In the supply plenum; or
- One static pressure probe in one of three locations noted above, and a second probe located in the return plenum or in the closest return grill to the air handler, unless this is where the duct leakage tester is installed, in which case the second closest return grille to the air handler is used. The return duct system pressure probe may not be located in the airstream of the duct tester.

☐ **At Return Grille.** The duct leakage tester fan is attached to the largest return grille in the system. For systems with multiple returns of equal largest size, the return closest to the air handler is used. Permitted only when the following conditions exist:

- System has three or fewer return grilles; or
- Total duct leakage is less than 50 cfm at 25 Pa; or
- Air handler blower access is in an attic or crawlspace that has limited or restricted entry or exit.

Static Pressure Probe Location.

- In supply register closest to the air handler; or
- In the main supply trunk line, at least 5 feet from the air handler; or
- In the supply plenum; or
- One static pressure probe in one of three locations noted above, and a second probe located in the return plenum or in the closest return grille to the air handler, unless this is where the duct leakage tester fan is installed, in which case the second closest return grille to the air handler is used. The return duct system pressure probe must not be located in the airstream of the duct tester. Both the supply- and return-side duct system pressure probes must be connected to a "T" fitting, and the third leg of the "T" is connected to the manometer.

Figure 7-11.
Duct Tester Fan Mounted at Crawlspace Heat Pump

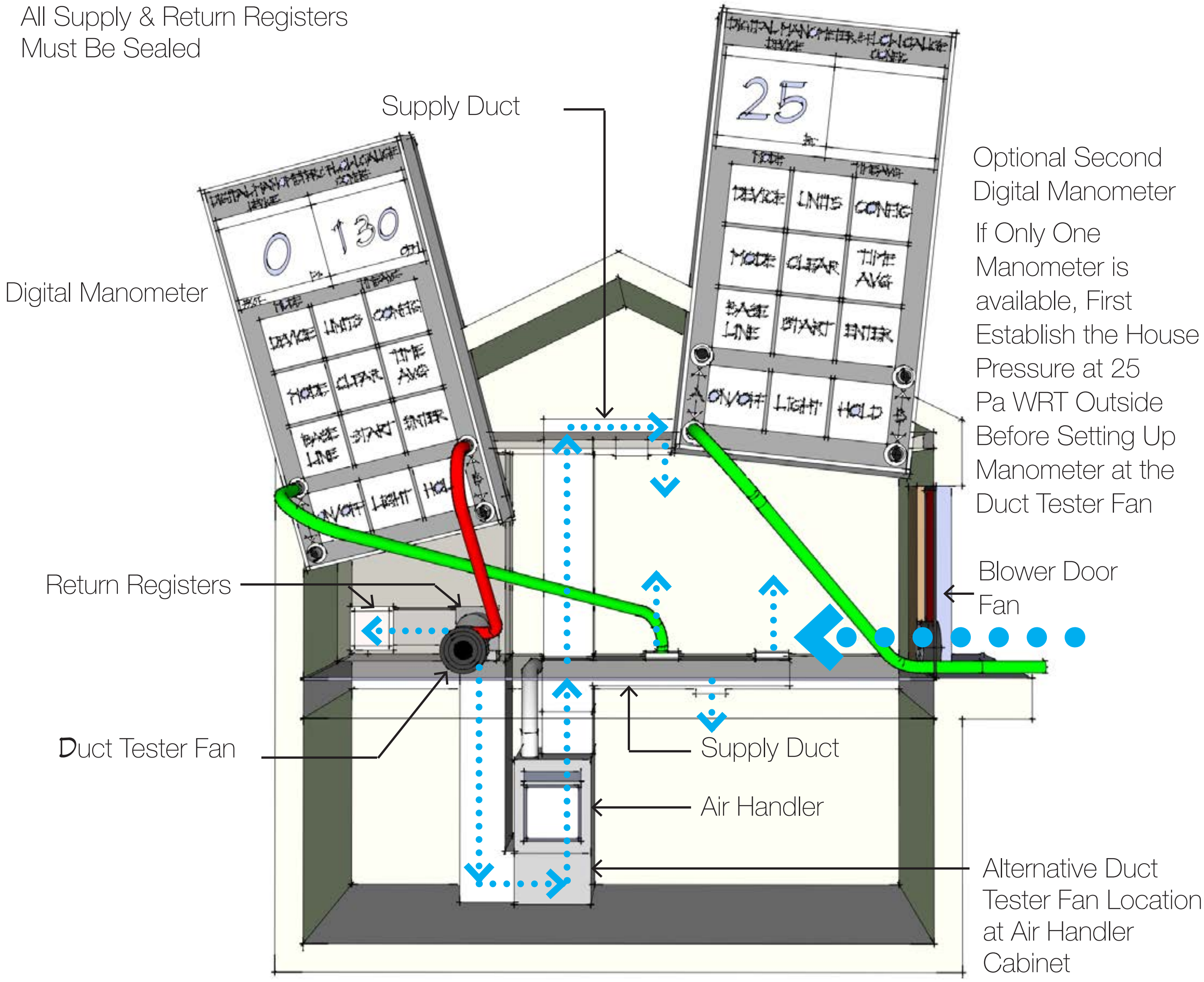


FIG. 7-12. Leakage to Outside Test

LEAKAGE TO OUTSIDE TEST **STEP 3**

Conduct Leakage to Outside Test

- ☐ **Install Blower Door.** Blower door is installed to pressurize house if duct system is to be pressurized for test.

- ☐ **Pre-Test Baseline Building Pressure.** Measure the pressure difference (average value over at least a 10-second period) across the building enclosure (outside as reference) with the blower door fan sealed and turned off.

- ☐ **Achieve Pre-Test Induced Enclosure Pressure Difference.** Unseal blower door fan, turned on, and adjust to create an induced enclosure pressure difference of 25 ± 3 Pa (or the highest achievable value up to 25 Pa) accounting for the pre-test baseline building pressure. Note that this value will be positive if the duct system is being pressurized for the test. If a 25 Pa induced enclosure pressure difference is not achieved, then the highest possible value up to 25 Pa must be achieved with the equipment available.

- ☐ **Zero Induced Duct System Pressure Difference.** Unseal, turn on, and adjust to create an induced duct system pressure difference of 0.0 ± 0.5 Pa, relative to the dwelling unit. If an induced duct system pressure difference of 0.0 ± 0.5 Pa is not achieved, then the airflow of the blower door fan for the enclosure is reduced until an induced duct system pressure difference of 0.0 ± 3 Pa is achieved.

- ☐ **Re-Check Induced Enclosure Pressure Difference.** Adjust blower door fan to achieve an enclosure pressure difference of 25 ± 3 Pa accounting for the pre-test baseline building pressure induced enclosure pressure difference.

- ☐ **Re-Check Induced Duct System Pressure Difference.** Re-check the induced duct system pressure difference by adjusting the Duct Leakage Tester Fan to maintain the induced duct system pressure difference at 0.0 ± 3 Pa WRT the enclosed space.

- ☐ **Repeat Adjustments until Test Conditions are Achieved.** Repeat adjustments to blower door fan and duct leakage tester fan until the induced enclosure pressure difference is maintained at 25 Pa (or the highest achievable value up to 25 Pa) and the induced duct system pressure difference is 0.0 ± 3 Pa with reference to the enclosed space.

  - ■ Record the average value of the induced enclosure pressure difference, the induced duct system pressure difference, and the airflow at CFM25 (measured over at least a 10-second period) when a 25 Pa induced enclosure pressure difference is achieved.

  - ■ Record the average value of the highest induced enclosure pressure difference, the induced duct system pressure difference, and the airflow that was achieved with the equipment available, (over at least a 10-second period) if a 25 Pa induced enclosure pressure difference is not achieved.

- ☐ **Record If Fans Are Pressurizing or Depressurizing.** Record whether the blower door fan is pressurizing or depressurizing the dwelling unit and whether the duct leakage tester fan is pressurizing or depressurizing the duct system.

Figure 7-13.
Duct Tester Fan Mounted at Base of Air Handler Cabinet

- [ ] **Can't Reach 25 Pa Adjustment Mode (if necessary).** If a house pressure difference WRT outside of 25 Pa is not achieved, then the recorded airflow (CFM measured) must be converted to a nominal airflow at 25 Pa (CFM25) using the adjustment table provided by the equipment manufacturer. Such tables are often referred to as a *Can't Reach 25 Factor Table*. Alternately, a manometer that is equipped to automatically make the conversion to CFM25 is permitted to be used. Typically, the manometer test mode that includes this conversion is PR/FL@25.

LEAKAGE TO OUTSIDE TEST **STEP 4**

Record Test Conditions and Results

RESNET/ICC 380 specifies the test conditions, and results that must be recorded. Appendix 2, *Duct Tightness Test Record Form*, details the necessary information.

Is Partial Duct System Testing an Acceptable Practice?

Should a technician be allowed to test only that portion of the duct system that is located outside the building thermal envelope? There are two reasons why this approach is not acceptable. The first reason is the use of the phrase "across the entire system" by the code when addressing duct testing requirements. The second reason has to do with the physics of the test procedure. Testing only isolated sections of ducts outside the building thermal envelope will not capture indirect leakage to the outside. For example, a leaky supply duct in a floor-joist cavity could pressurize that cavity, resulting in air leakage to the outside through a poorly sealed rim joist. While the code language is somewhat ambiguous, partial duct testing is clearly not a good practice and should not be accepted by code officials.

8 Measuring Mechanical Ventilation Airflow

Building tight houses without providing proper ventilation can increase the potential for health and safety problems. Higher moisture levels found in inadequately ventilated houses create an ideal environment for mold, dust mites, and other causes of respiratory problems and allergies.

Most builders have no idea whether the ventilation equipment they install is operating as designed. Many builders assume, for example, that a bathroom exhaust fan rated at 75 cfm is moving 75 cfm of air. Typically, the fan delivers less that its rated airflow. Testing is the only way to know for sure. The reduction in actual airflow is usually caused by the duct that connects the fan to the outside. Size of the duct, length of the duct, number of turns, severity of the turns, and constrictions in the duct can reduce actual airflow.

There are several methods for measuring airflow through exhaust fans, central ventilation systems, and heat-recovery ventilators. Passive flow hoods and powered flow hoods are the most common intruments used to measure ventilation airflow. Powered flow hoods have some advantages, such as accuracy, but are considerably more expensive than passive flow hoods.

Passive Flow Hood at Inlet Terminal

A passive flow hood is a device consisting of a flow capture box capable of creating an airtight perimeter seal around the inlet terminal; and a digital manometer capable of measuring the volumetric airflow. The most commonly used passive flow hood is the Exhaust Fan Flow Meter manufactured by The Energy Conservatory.

Figure 8-1. Passive Flow Hood Manufactured by the Energy Conservatory

□ The flow hood is placed over the inlet terminal, ensuring that an airtight perimeter seal has been created. The inlet terminal is the opening to the exhaust fan in the house. Passive flow hoods are not accurate when placed at the outlet terminal outside the house.

□ A tube is connected from the digital manometer to the flow hood. The appropriate device is selected on the manometer, as is the configuration. Configuration is related to the opening size in the flow hood and is analogous to the ring configuration in the blower door fan.

□ The pressure difference between the flow capture element and the room is measured. If the pressure difference exceeds manufacturer's recommendations or if no manufacturer's recommendations and pressure difference exceeds 8 Pa, then the procedure is to be terminated and no results recorded. If the pressure difference is ≤ 8 Pa, then the average volumetric airflow through the airflow meter, measured over at least a 10-second period, is recorded.

Powered Flow Hood at Inlet or Outlet Terminal

Powered flow hoods are comprised of a standard flow hood plus a fan, pressure gauge, and controller. The fan speed is set to ensure the register pressure is the same as the ambient room pressure. The hood includes a flow capture element capable of creating an airtight perimeter seal around the inlet terminal, an airflow meter capable of measuring the volumetric airflow, a variable-speed fan that is capable of moving air through the flow capture element and airflow meter, and a manometer.

- ☐ The hood is placed over the inlet or outlet terminal with a tight seal at the perimeter. The variable-speed fan is turned on and the airflow adjusted until, using the manometer, zero pressure difference (± 0.1 Pa) is measured between the flow capture element and the room. Read and record the average volumetric airflow through the airflow meter, measured over at least a 10-second period.

Figure 8-2. Powered Flow Hood Manculactured by Retrotec

Figure 8-3. Long or Crimped Exhaust Fan Ducts Reduce Actual Exhaust Airflow

Figure 8-4. Inadequate Mechanical Ventilation Can Contribute to Mold and Other Moisture-Related Problems

9 Room Zonal Pressure Test

Inadequate return-air pathways can create pressure imbalances from indoors to outdoors or room to room that cause problems in a home. Most homes are equipped with supply ducts that deliver conditioned air to every room but often there is no dedicated return-air pathway from the room back to the furnace. It is common for one or two large return-air grilles to be located in the central areas of the home to serve the entire house.

The result of inadequate return air is room-to-room pressure imbalances that lead to uneven room temperatures, and negative pressures in the combustion appliance zone that can potentially cause backdrafting of atmospherically-vented appliances. Over-pressurization in rooms can lead to the increased movement of warm, humid air into building cavities, causing moisture problems in walls and ceilings.

In most new homes, if the bedroom doors are closed, there's no easy way for the air to get back to the return-air grille located in the central zone. As a result, each bedroom becomes pressurized. The ENERGY STAR New Homes program requires that the pressure between bedrooms and the common area be tested to assure that the pressure difference is no more than 3 Pa.

Room Zonal Pressure Test Procedure

- ☐ **Doors and Windows.** Close all exterior doors and windows.
- ☐ **Building Preparation.** Turn off all other house exhaust fans. Close the room door.
- ☐ **Turn On Air Handler Fan.**
- ☐ **Room Pressure.** Read the pressure in the room WRT the central return zone.
- ☐ **Fixing the Problem.** If the pressure in the room WRT the central return zone exceeds 3 Pa, there are four possible options to solve the pressurized-room problem. Each bedroom needs either a dedicated return air ducted back to the furnace, door undercut, transfer grill, or crossover duct.

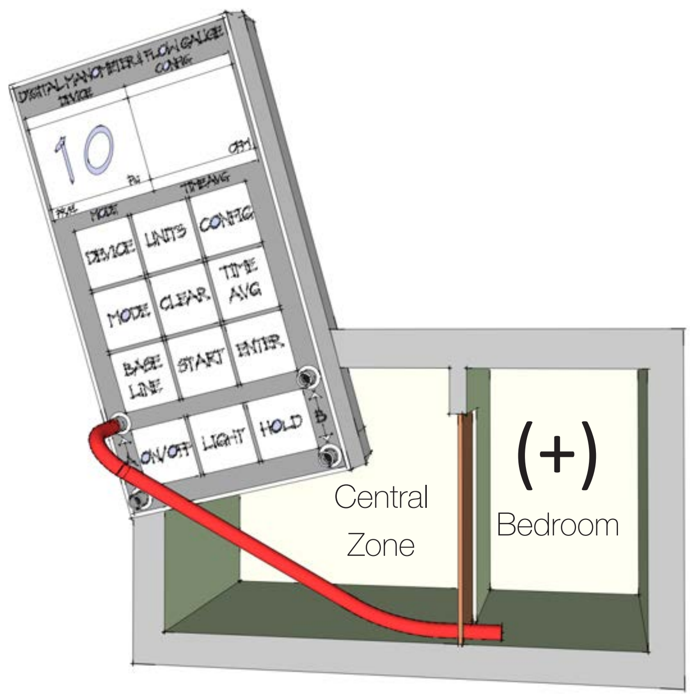


Figure 9-1. What Is the Pressure in the Room WRT the Central Zone

A general guideline is that the pressure in a room with the door closed should not exceed 3 Pa WRT the central return zone.

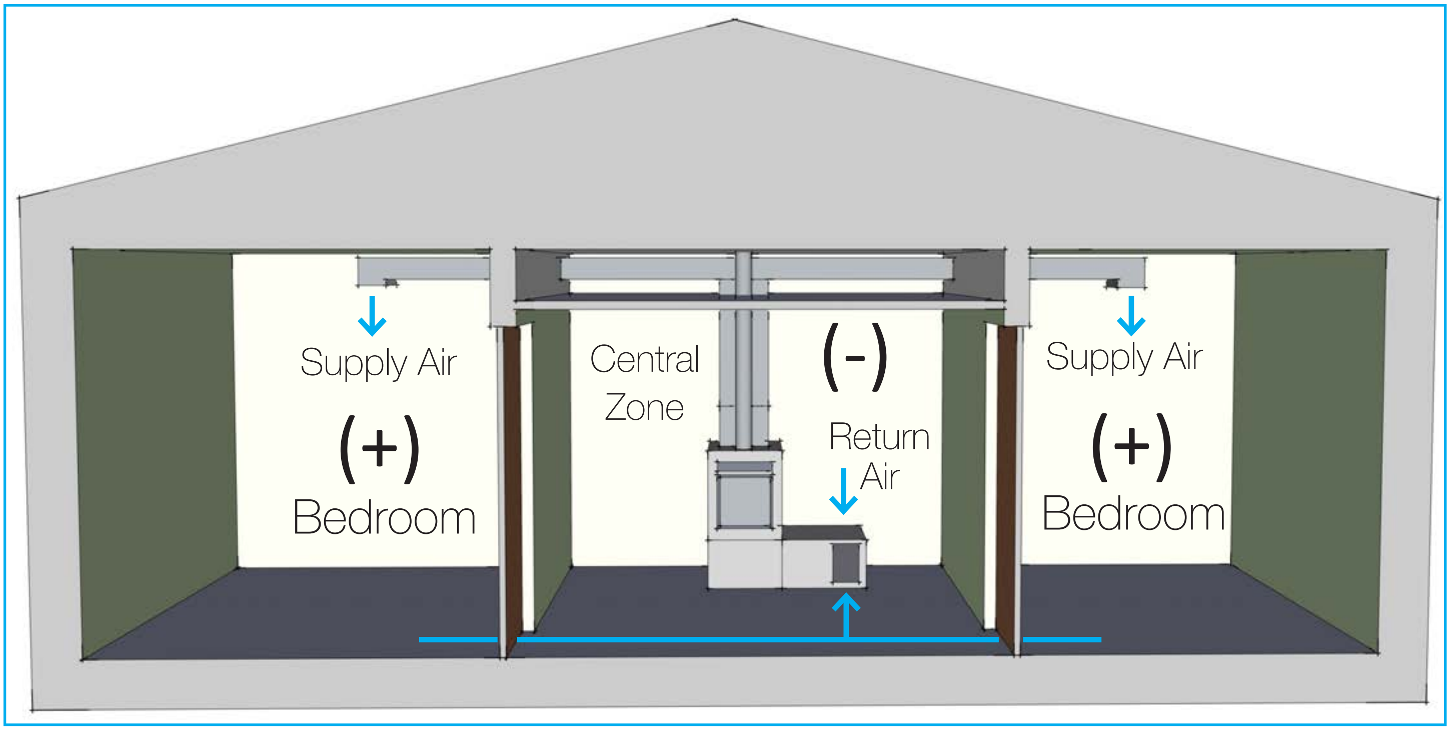
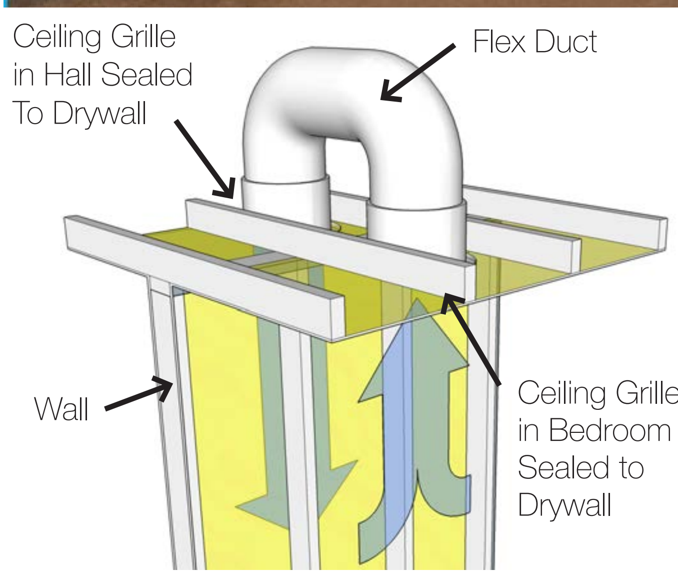
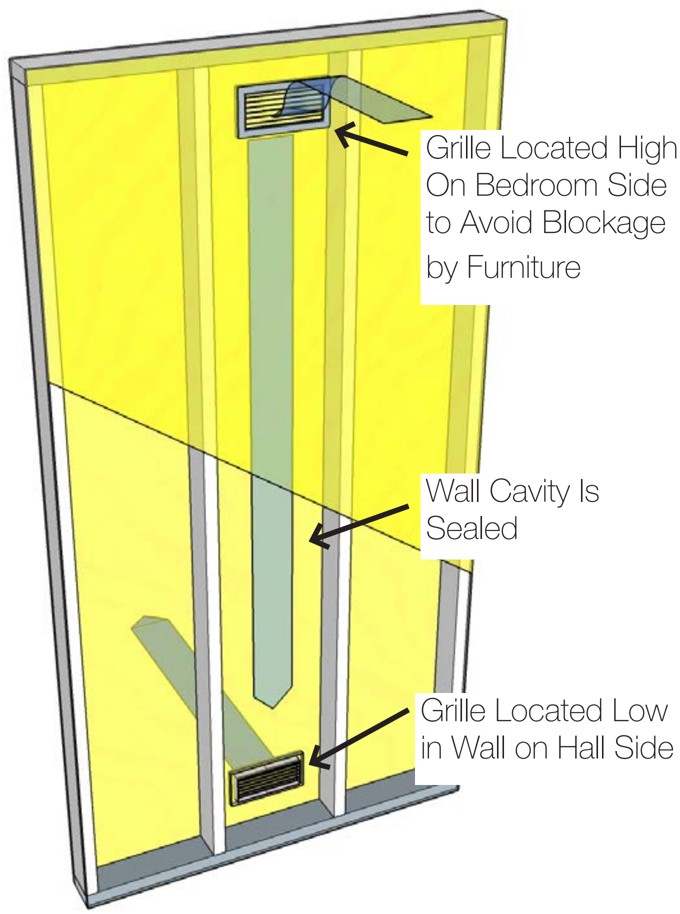


Figure 9-2. Room Zonal Pressure Diagram



Crossover Duct



Transfer Grill

Figure 9-3. Pressure Relief Options

10 Combustion Appliance Zone Depressurization

The objective of CAZ depressurization testing is to determine if combustion appliances will vent properly under worst-case conditions and protect the occupant from the hazards of backdrafting. There are several entities that have published procedures for CAZ depressurization testing. The published procedures include *ACCA Standard 12 Home Evaluation and Performance Improvement*, *Performance Tested Comfort System (PTCS) Duct Program Standards and Testing Procedures*, *2015 IECC Appendix RA*, and *Building Performance Institute Building Analyst Professional Standards.*

The procedure described below is a simplified procedure that draws from several of these standards and is most appropriate for the atmospherically-vented appliances found in new homes. For existing homes and more complicated systems, refer to one of the publications noted above.

The two test indicators of potential backdrafting problems are: (1) too negative a CAZ pressure WRT outside; and (2) whether spillage occurs at the appliance during the worst-case depressurization condition. Spillage occurs when combustion gases emerge from an appliance or venting system into the CAZ during operation.

Application. CAZ depressurization testing is applicable to dwelling units containing an atmospherically-vented appliance or direct-vent or integral-vent appliance drawing combustion air from inside of the dwelling unit. Testing may be performed after all penetrations of the building thermal envelope are created. Dwelling units containing only sealed-combustion, direct-vent, or integral-vent appliances that do not draw combustion air from inside of the building or dwelling unit are generally not susceptible to backdrafting.

If the depressurization is greater than the value given in Figure 10-2, modifications should be made to reduce the depressurization. If the supply ducts have been well sealed, the induced depressurization is likely a result of door closer effects and may be mitigated by undercutting doors, installing transfer grilles or new returns into rooms without returns, or possibly providing supplemental make-up combustion air to the CAZ.

CAZ Depressurization Test Procedure.

The testing process can be described in three steps: setup and baseline pressure, worst-case depressurization reading, and spillage test. The steps in the testing process are provided in a checklist format.

Combustion Appliance Zone Depressurization **STEP 1**

Setup and Baseline Pressure Reading

- ☐ **Building Preparation.** The dwelling unit should be set up for normal heating-season operation. Close all exterior windows and doors, and attic hatches. Temporary openings to the outside, such as for uninstalled windows or doors, must be sealed.
- ☐ **Drain Traps.** Seal or fill with water.
- ☐ **Combustion Appliances.** Turn off or set to the pilot setting.

- ☐ **Baseline Pressure.** With the building or dwelling unit in this configuration, measure and record the baseline pressure in the CAZ WRT outside.

Combustion Appliance Zone Depressurization **STEP 2**

Worst-Case Depressurization Reading

- ☐ **Indoor Carbon Monoxide Levels.** Monitor indoor ambient carbon monoxide (CO) levels in the breathing zone continuously during testing, and abort the test when indoor ambient CO exceeds 35 ppm by turning off the appliance, ventilating the space, and evacuating the building. The CO problem must be corrected prior to completing combustion safety testing.

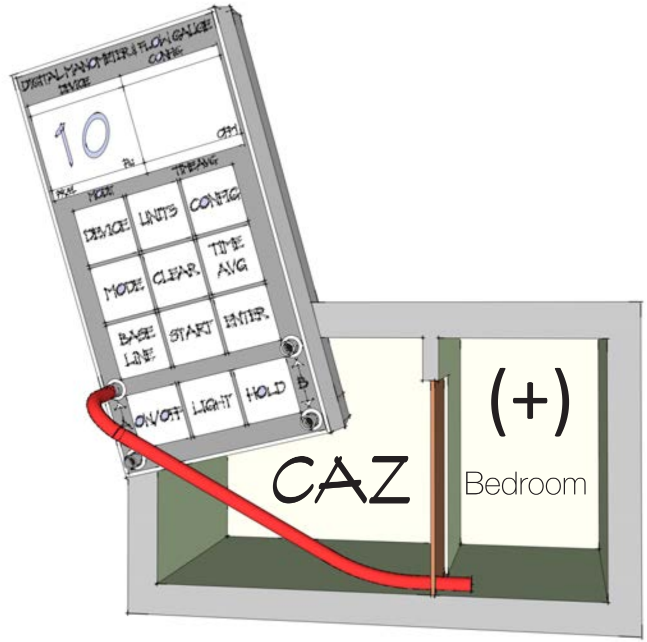
- ☐ **Exhaust Fans and Appliances.** Turn on all indoor fans: bathroom exhaust, range hood, clothes dryer, and powered attic ventilation fans (with the exception of whole-house exhaust fans).

- ☐ **Air-Handler Fan.** Turn on the air-handler fan. If the pressure differential in the CAZ WRT to outside gets more negative, leave the air handler on; otherwise, turn it off.

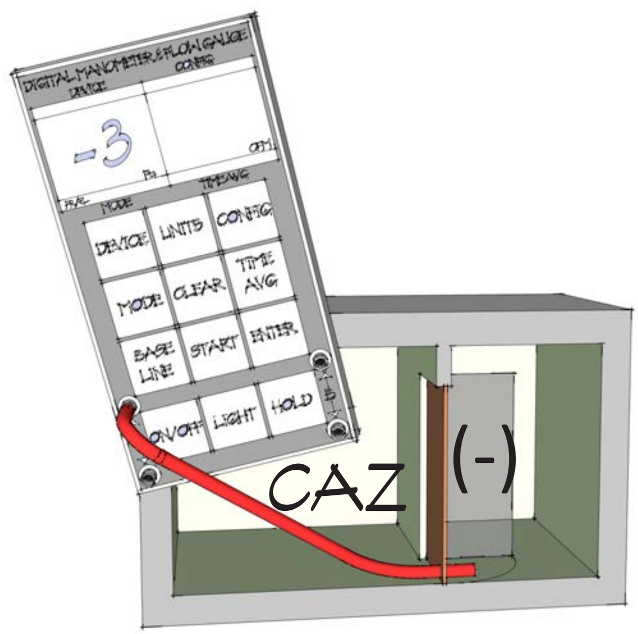
- ☐ **Interior Doors.** Open or close interior doors to the CAZ, rooms with exhaust fans (e.g., bathroom), and other interior rooms to achieve the most negative pressure in the CAZ WRT the outside.

- ☐ **Calculations.** Record nominal depressurization reading. Calculate net worst-case depressurization by adjusting for baseline reading. If the manometer has a baseline function, then the manual calculation is unnecessary.

Net Worst-Case Depressuization = **Nominal CAZ Pressure WRT Outside** - **Baseline Pressure**



If pressure in zone behind closed door is positive WRT the CAZ, leave the door closed for the test.



If pressure in zone behind closed door is negative WRT the CAZ, open the door for the test.

Figure 10-1. Interior Door Position Based On Pressure WRT Central Zone

Figure 10-2. Depressurization Limit Table

Appliance Type and Venting Condition	Depressurization Limit
Atmospherically-vented water heater (WH)	-2 Pascals
Atmospherically-vented boiler or furnace common-vented with atmospherically-vented water heater	-3 Pascals
Atmospherically-vented boiler or furnace, equipped with a flue damper, and common-vented with an atmospherically-vented water heater	-5 Pascals
Atmospherically-vented boiler or furnace alone	-5 Pascals
Atmospherically-vented, fan assisted boiler or furnace common-vented with atmospherically vented water heater	-5 Pascals
Decorative vented gas appliance	-5 Pascals
Individual natural draft furnace/boiler	-5 Pascals
Power-vented and induced-draft boiler or furnace alone, or fan-assisted water heater alone	-15 Pascals
Direct-vented and sealed combustion appliances	-50 Pascals

Source: Appendix RA, 2015 IECC.

Worst-Case Depressurization Example

Baseline Pressure Reading: **-1.0 Pa**

Worst-Case CAZ Pressure WRT Outside: **-5.0 Pa**

Actions Taken to achieve worst-case CAZ pressure:

- Configure interior doors
- Turn on air handler, exhaust fans, clothes dryer

Baseline Adjusted Pressure: **-5.0 Pa - (-1.0) = -4.0 Pa**

Depressurization Limit (from Depressurization Limit Table): **-3.0 Pa**

Result: **House Fails Test**

Actions Should Be Taken to Resolve Problem

- ☐ **Fix the Problem.** If net CAZ depressurization limits are exceeded under worst-case conditions in accordance with the table above, additional combustion air must be provided or other modifications must be made to building air-leakage performance or exhaust appliances such that depressurization is brought within the limits prescribed.

FIG. 10-3. EXHAUST FANS AND APPLIANCES CAN DEPRESSURIZE THE CAZ

Combustion Appliance Zone Depressurization

STEP 3

Spillage Test

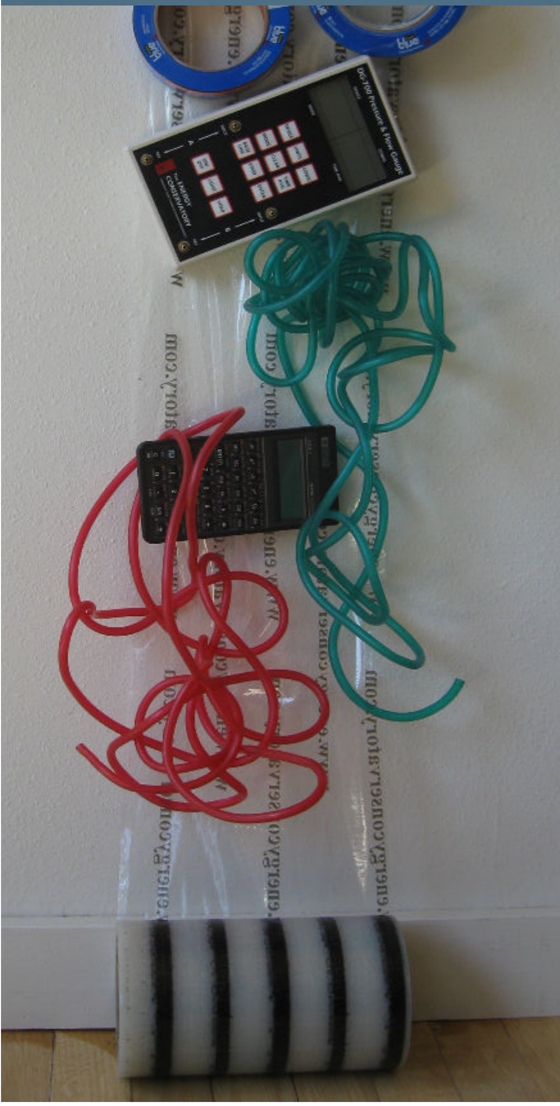
Another method to assess the adverse effect on flue function caused by exhaust fans and whole-house mechanical ventilation systems is the *spillage test*. A failed spillage test may indicate dangerous flue gases are being drawn into the room containing the appliance. Spillage test procedure follows:

- ☐ **Make-up Air Systems, Combustion Air Ducting, and Ventilation Systems.** Do not seal.
- ☐ **Vent or Flue Temperature.** Should be at room temperature.
- ☐ **Fireplace Damper.** Close.
- ☐ **Smallest Btu Input Appliance.** Place the smallest Btu input appliance (typically the water heater) being tested into operation first and adjust the thermostat so the appliance operates continuously.
- ☐ **Test for Spillage.** Test for spillage at the draft hood relief opening after five minutes of operation. Use a smoke stick to test for air movement into or out of the flue. The complete circumference of the draft hood relief opening must be tested.

  If smoke is pulled into the flue, then the combustion appliance passes. If draft is not established in five minutes around the complete circumference of the draft hood opening, then the combustion appliance fails the test.
- ☐ **Test Additional Appliances.** For additional fossil-fuel appliances in the same CAZ, turn on the next appliance being tested so it operates at full input while the previous appliance continues to operate. Test for spillage at the draft hood relief opening after five minutes of operation.
- ☐ **Fix the Problem.** If an appliance fails the spillage test, then additional combustion air must be provided or other modifications must be made to building air-leakage performance or exhaust appliances such that the appliance no longer fails the spillage test. This typically requires modifications to reduce the depressurization, such as adding combustion air to the CAZ or other modifications to building air leakage or exhaust appliances. Induced depressurization may be a result of door closer effects and may be mitigated by undercutting doors, or installing transfer grilles or new returns into rooms without returns. Return duct leaks in the CAZ is another common cause of depressurization.

Figure 10-4.
Flue Spillage Test

Appendices



1. Building Envelope Tightness Test Record Form

2. Duct Tightness Test Record Form

3. Key Definitions

4. References

Building Envelope Tightness Test Record Form

Building and Tester Information

Test Date _____/______/______ Time________________ ☐AM ☐PM

Name (Printed)_____________________ ____

Tester Signature

Phone _____________________

Company ____

Tester Email ____

Manometer: Manufacturer_____________________ Model_________ Serial # ___________

Fan: Manufacturer_____________________ Model_________ Serial # ___________

Building Address______________________________________ City_____________________

Building and Test Conditions Information

☐Open ☐Closed Position of crawlspace doors and hatches

☐Open ☐Closed Position of attic doors and hatches between conditioned space and attic

☐Open ☐Closed Position of attic doors and hatches between attic and exterior

☐Open ☐Closed Position of door(s) to basement

____ Location of Blower Door Fan(s)

_____________°F Indoor Temperature ____________ °F Outdoor Temperature

____ Weather Observations

________________ft Altitude of Site

________________ft^3 Infiltration Volume

☐Press ☐Depress Was the dwelling pressurized or depressurized for test?

Results and Calculations

________Pa Building Enclosure Baseline Pressure

☐Yes ☐No Was 50 Pa (±3 Pa) pressure (house WRT outside) achieved?

If Yes,________Pa Test pressure in house WRT outside (adjusted for baseline)

If Yes, ________CFM50 Airflow

If No, ________Pa Test pressure in house WRT outside (considering baseline)

If No, ________CFM Airflow

If No, ________CFM50 Calculated Airflow at 50 Pa based on test pressure

☐Calc'd by Manometer ☐Calc'd Manually

_______$CFM50_{Corrected}$ **Corrected CFM50** [CFM50 corrected for air temp. and altitude]

_______$CFM50_{Adjusted}$ **Adjusted CFM50 *If One-Point Test*** [$CFM50_{Adjusted} = 1.1 \times CFM50_{Corrected}$]

☐ ACH50 **Calculated ACH50** [$ACH50 = CFM50_{Adjusted} \times 60$ /Infiltration Volume]

Based on RESNET/ICC Standard 380 - Provide All Information to Comply with Standard

Duct Tightness Test Record Form

Building & Tester Information

Test Date _____/______/______ Time_______________ ☐AM ☐PM

Name (Printed)___________________ ____

Tester Signature

Phone ___________________

Company ____

Tester Email ____

Manometer: Manufacturer____________________ Model_________ Serial # __________

Fan: Manufacturer____________________ Model_________ Serial # __________

Building Address_____________________________________ City________________

Total Duct Leakage Test

☐Air Handler Cabinet ☐Return Register Location of Duct Tester Fan

____Location of duct system pressure probe(s)

☐Press ☐Depress Was the duct system pressurized or depressurized for test?

☐Yes ☐No Was 25 Pa ±3 Pa achieved for test?

If Yes, ☐ CFM25 Airflow (CFM25 Nominal)

If No, ________ Pa Duct system test pressure achieved

If No, ________ CFM Airflow at test pressure

If No, ☐ CFM25 Calculated airflow at 25 Pa based on test pressure

☐Calc'd by Manometer ☐Calc'd Manually

_____________ft^2 Dwelling Conditioned Floor Area

_____________CFM Code Allowed Duct Leakage (Conditioned Floor Area x 0.04 CFM/ft^2)

Leakage to the Outside Test

☐Air Handler Cabinet ☐Return Register Location of Duct Tester Fan

____Location of duct system pressure probe(s)

☐Press ☐Depress Was the house pressurized or depressurized for test?

☐Press ☐Depress Was the duct system pressurized or depressurized for test?

☐Yes ☐No Was duct system pressure of 0.0 Pa (±3 Pa) WRT the house achieved?

The Leakage to the Outside Test is Not Allowed by the 2018 IECC. It is included here for use with the energy code ERI compliance path.

If Yes, ________ Pa Building enclosure pressure difference

If Yes, ________ Pa Duct system pressure difference

If Yes, ☐ CFM25 Airflow

If No, ________ Pa Highest building enclosure pressure achieved

If No, ________ Pa Duct system pressure difference

If No, ________ CFM25 Airflow

If No, ☐ CFM25 Calculated airflow at 25 Pa based on test pressure

☐Calc'd by Manometer ☐Calc'd Manually

Key Definitions

Following are critical definitions that must be applied properly if an accurate building tightness test result is to be obtained. These definitions have been adapted from RESNET/ICC 380.

Conditioned-Space Volume

The volume within a building serviced by a space-heating or -cooling system designed to maintain space conditions at 78°F (26°C) for cooling and 68°F (20°C) for heating. The following specific volumes are addressed to ensure consistent application of this definition:

- **Floor Cavity**: If the volume both above and below a floor cavity is conditioned, then the volume of the floor cavity is also included. Otherwise, the volume of the floor cavity is not included.
- **Wall Cavity**: If the volume of at least one of the spaces horizontally adjacent to a wall cavity is conditioned, then the volume of the wall cavity is also included. Otherwise, the volume of the wall cavity is not included.
- **Attic:** Not included unless both air sealed and insulated at the roof deck.
- **Vented Crawlspace**: Not included.
- **Garage:** Not included, even when it is conditioned.
- **Thermally Isolated Sunroom:** Not included.
- **Other Spaces:** An attic that is both air-sealed and insulated at the roof deck, an unvented crawlspace, and a basement is included only if the technician conducting evaluations has either:
  - Obtained an ACCA Manual J, S, and either B or D report and verified that both the heating and cooling equipment and distribution system are designed to offset the entire design load of the volume; or
  - Verified through visual inspection that both the heating and cooling equipment and distribution system serve the volume and, in the judgement of the technician, are capable of maintaining 68°F heating and 78°F cooling temperatures.

Conditioned Floor Area (CFA)

The floor area of the conditioned space volume within a building, not including the floor area of attics, crawlspaces, and basements below air-sealed and insulated floors. The floor area of following specific spaces are addressed to ensure consistent application of this definition:

- **Wall Cavity:** Included if adjacent to conditioned space volume.
- **Basement:** Included if the technician conducting the evaluation has either:
  - Obtained an ACCA Manual J, S, and either B or D report and verified that both the heating and cooling equipment and distribution system are designed to offset the entire design load of the volume; or
  - Verified through visual inspection that both the heating and cooling equipment and distribution system serve the volume and, in the judgement of the technician conducting evaluations, are capable of maintaining 68°F heating and 78°F cooling temperatures.
- **Garage:** Not included, even when it is conditioned.

- **Thermally Isolated Sunroom:** Not included.
- **Attic:** Not included, even when it is conditioned-space volume.
- **Crawlspace:** Not included, even when it is conditioned-space volume.

Infiltration Volume

The sum of the conditioned-space volume and additional adjacent volumes in the dwelling unit that meet the following criteria:

- **Crawlspaces:** Included when the access doors or hatches between the crawlspace and conditioned-space volume are open during the enclosure airtightness test.
- **Attics:** Included when the access doors or access hatches between the attic and conditioned space volume are open during the enclosure airtightness test.
- **Basements:** Included where the doors between the basement and conditioned space volume are open during the enclosure airtightness test.

Unconditioned Space Volume

The volume within a building that is not conditioned-space volume but contains heat sources or sinks that influence the temperature of the area or room. The following volumes of specific spaces are addressed to ensure consistent application of this definition:

- **Floor Cavity:** Included if either one or both of the volumes above and below a floor cavity is unconditioned.
- **Wall Cavity:** Included if the volume of both of the spaces horizontally adjacent to a wall cavity are unconditioned.
- **Attic:** Included if an attic that is not both air sealed and insulated at the roof deck.
- **Vented Crawlspace:** Included.
- **Attached Garage:** Included, even when it is conditioned.
- **Thermally Isolated Sunroom:** Included.
- **Other Spaces:** The volume of an attic that is both air-sealed and insulated at the roof deck, the volume of an unvented crawlspace, and the volume of a basement shall be included unless it meets the definition of conditioned-space volume.

References & Resources

References

2018 IECC
2018 International Energy Conservation Code
International Code Council, Inc. (www.iccsafe.org)

ASTM E779 -10 Standard Test Methods for Determining Air Leakage Rate by Fan Pressurization
ASTM International (www.astm.org)

ASTM E1827 - 11 Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door
ASTM International (www.astm.org)

RESNET Guidelines for Multifamily Ratings
Residential Energy Services Network, Inc.
www.resnet.us/professional/standards/Adopted_RESNET_Guidlines_for_Multifamily_Ratings_8-29-14.pdf

RESNET/ICC 380 ANSI/RESNET/ICC 380-2016 with Addendum A-2017 Standard for Testing Airtightness of Building Enclosures, Airtightness of Heating and Cooling Air Distribution Systems, and Airflow of Mechanical Ventilation Systems
Residential Energy Services Network, Inc. (www.resnet.us) and International Code Council, Inc. (www.iccsafe.org)

Other Useful Publications

Volume 12. USDOE Building America Best Practices Series:
Builders Challenge to 40% Whole-House Energy Savings in the Cold and Very Cold Climates
Prepared by PNNL and ORNL, 2011. Available online from the Building America website.

Builder's Guide to Cold Climates
By Joseph Lstiburek
Building Science Press, 2006

Internet Resources

ENERGY STAR New Homes
U.S. Environmental Protection Agency
www.energystar.gov/newhomes

Indoor airPlus
U.S Environmental Protection Agency
www.epa.gov/indoorairplus

International Code Council, Inc.
www.iccsafe.org

Residential Energy Services Network (RESNET)
www.resnet.us

National Fenestration Rating Council (NFRC)
www.nfrc.org

Efficient Windows Collaborative
www.efficientwindows.org/

Building America Program
U.S. Department of Energy
www.energy.gov/eere/buildings/building-america-bringing-building-innovations-market

Energize Montana (Energy Codes)
Montana Department of Environmental Quality
http://deq.mt.gov/Energy/EnergizeMT/EnergyCode

NOTES

“Quality is not an act. It is a habit.”

Aristotle

NCAT NATIONAL CENTER FOR APPROPRIATE TECHNOLOGY

NorthWestern Energy | Efficiency Plus

At the time of publication Montana is holding listening sessions for the 2021 IECC with adoption anticipated in early 2022. Check the NorthWestern Energy Efficiency Plus website for details.