rev-2017-04-20

Residential Blower Door and Gauge Testing

Retrotec test fans, blower door systems, duct testing systems and gauges have been calibrated in our laboratory which is accredited by the ANSI-ASQ National Accreditation Board to meet requirements of international standard ISO/IEC 17025:2005. All pressure and flow devices used in the calibration are traceable to the National Institute of Standards and Technology and themselves have ISO 17025 accreditation.

Retrotec equipment and software complies with the following standards:
ASTM E779-10, ASTM E-1554, ATTMA TSL1, ATTMA TSL2, CGSB 149.10, DW/143, Energy Star, EN12237, EN13829, EN15004, FD E51-767, ISO 9972-2015, ISO 14520-2006, NEN2686, NFPA 2001-2015, RESNET, SMACNA-2002, All USA State Energy Codes, Title 24 and USACE Protocol.

*Custom calibration available upon request

Range Configurations L4, L2, L1 have measurement accuracies of ±10% and are not compliant with any of the standards specified above.

rev-2015-03-16 Section 4.6 revised for CEC. Added Russ's powered flow hood graphics.
rev-2016-06-05 Section 5.3 revised for section on creating fan curves.

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1. Air leaks when there is a pressure difference across a hole

Air leakage is the infiltration or exfiltration of air from a building. In order for leakage to occur, there must be a hole, and there must be a pressure difference across the hole. Holes, both intentional and unintentional, are unfortunately all too common in buildings.

There are five common issues that create a pressure imbalance: stack pressure, wind, exhaust or supply flows, duct leakage and forced air duct systems.

1.1 Pressure differences you will see in a home

1.1.1. Stack pressure is the major force in energy loss

The stack effect, or stack pressure, comes from the process of hot air rising, and cold air dropping. Typically, warmer inside air tends to rise in a building, and leak out of holes near the top. This air is replaced by colder outside air leaking into holes around the bottom. In warmer climates, this effect can be reversed, as the interior air is cooler, and drops to leak out of the bottom.

Stack pressure can be calculated. The pressure difference experienced is a product of a constant (0.0342), the atmospheric pressure, the building height, and the temperature difference (between the top and bottom of the stack). Essentially, pressure due to stack is proportional to the height, and temperature difference.

Figure 1: Stack pressure is caused by warm air rising and cool air falling.

1.1.2. Wind pushes air into and pulls air out of buildings

When the wind blows, pressures are created where the stream of air is stopped or slowed down by a wall, or some other part of the house. Because air has mass and wind has velocity, when the wind stops moving (as it hits a wall), its momentum turns into pressure. Everyone has felt the pressure on their body when walking on a windy day, or holding their hand out the window of your car. This pressure can be called velocity pressure. A building experiences a positive pressure that pushes against the wall on the windward side and a negative pressure on the leeward (downwind) side. This has the effect of pushing air in through the holes on the windward side and pulling air out through the holes on the leeward side.

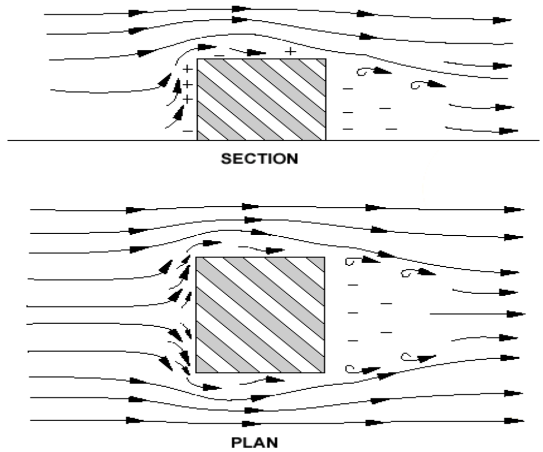


Figure 2: Wind effects on a building; the windward side is affected differently than the leeward side.

Wind pressure is a square function with velocity, which means that when the wind speed doubles the pressure quadruples. That would mean that a 20 mph wind would have four times as much force or pressure on the wall as a 10 mph wind. In a windy environment, this can translate to a significant amount of leakage.

There are two types of pressure that wind creates, stagnation pressure and velocity pressure.

Stagnation pressure- is felt over a large area in the windward side and for several feet from the building and is a result of the air stacking up due to the wind velocity. The wind's velocity is converted to a pressure.

Stagnation pressures are reduced by moving the outdoor pickup point about 15 feet from the building or away from any object that the wind will strike. Place the tube at ground level with a flat plate covering the tube. The pressure field around the building changes from side to side and because the wind direction varies somewhat; using two pickup points at least 20 feet apart will reduce these fluctuations.

Velocity pressure – is caused by the velocity impinging in the end of the tube and converting itself into a pressure at the tube end.

1.1.3. Exhaust mechanically removes energy but at least it can be controlled

Mechanical ventilation systems in a house include ones that exhaust (chimneys and exhaust fans), or supply air (supply fans). These systems can each act to pressurize or depressurize all or parts of a house. If they're not accounted for, these pressure imbalances can force air into and out of leaks in the building envelope.

1.1.4. Leaky ducts and imbalanced systems cause pressure differences

Leaky duct systems can cause pressure imbalances. If the leaks are to the outside (not to conditioned areas of the home), air will be pulled in (through leaks in the supply), or pushed out (through leaks in the return).

Forced air duct systems can contribute to air leakage if they are not correctly balanced. Unfortunately, even a well-designed system can be thrown off from the simple act of closing a door. A closed door can effectively close off a portion of a house from the duct system, limiting the flow of return air and causing a pressure imbalance.

1.2 Where Houses Leak

The attic is a major (if not *the* major) place to find leaks. Plumbing stacks often have large holes around them, as do chimneys. Beneath the insulation, a number of other leaks can usually be found. The top plate, and wire penetrations are typically quite leaky. In many cases, a dark attic is brightened by spots of light from the room below; each spot is a leak of air to the attic.

In a typical house, windows and doors occupy a very small percentage of the total leakage in a house. Where the house sits on its foundation is another major source of leakage. Dissimilar materials, usually wood and concrete, are in contact with each other, and are rarely adequately sealed. The bottom portion of the house is also where there are penetrations for plumbing and wiring. These holes are very significant, since negative pressure is usually greatest at the bottom of the house.

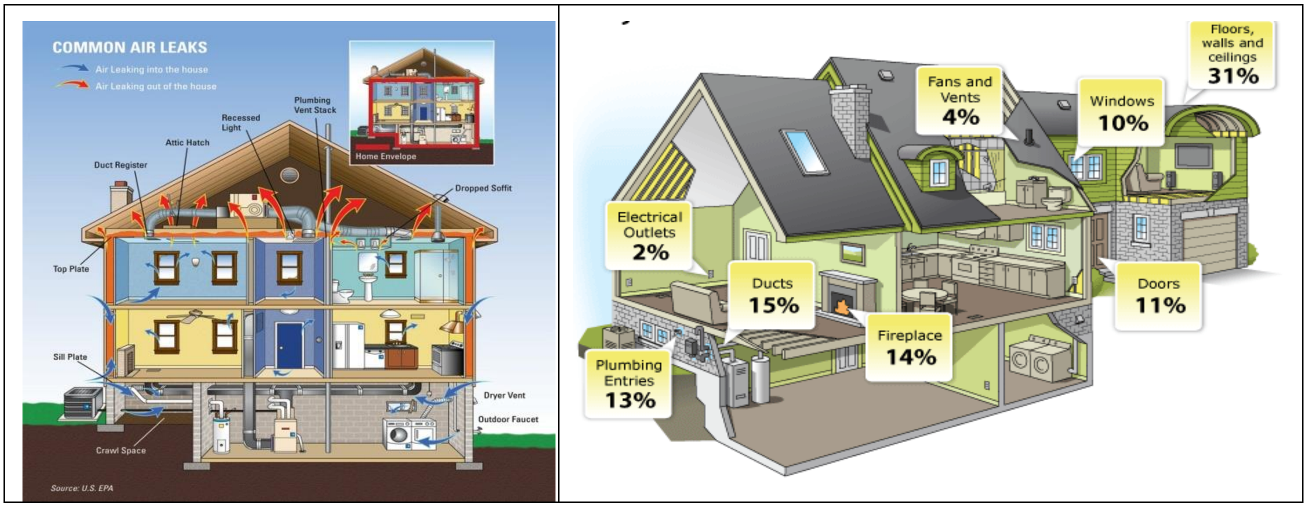


Figure 3: Houses typically experience common leak locations, including penetrations into the attic, and where dissimilar building materials meet. (Source: InsulationSmart.com)

Duct systems can also be significant contributors to air leakage. In many cases, these leaks can be the hardest to find and fix. Even small leaks in duct systems can be a major problem, if air is pulled in from polluted or contaminated areas such as carports or damp, moldy crawlspaces.

1.3 Warm Moist Air does damage in walls

In a warm humid climate, even a 1 Pa depressurization can lead to moisture problems, as moist air from outside is drawn into leaky duct systems and into the walls. This moist air then condenses and molds.

1.4 What Does Air Leakage Cost?

FanTestic software from Retrotec can calculate the annual cost for both heating and cooling associated with measured air leakage. The software uses the established Lawrence Berkeley Lab calculation technique to provide a reasonable estimate of typical air leakage.

To calculate annual heating cost

Use the following equation: $$\frac{26 \times HDD \times Fuel\ Price \times CFM50 \times 0.6}{N \times Seasonal\ Efficiency}$$

- HDD is the annual heating degree days (base 65° F) for the building location
- Fuel Price is the cost of fuel in dollars per BTU
- N is the Energy Climate Factor from the Climate Information Screen
- Seasonal Efficiency is the AFUE rating of the heating system

To calculate annual cooling cost

Use the following equation: $$\frac{0.026 \times CDD \times Fuel\ Price \times CFM50}{N \times SEER}$$

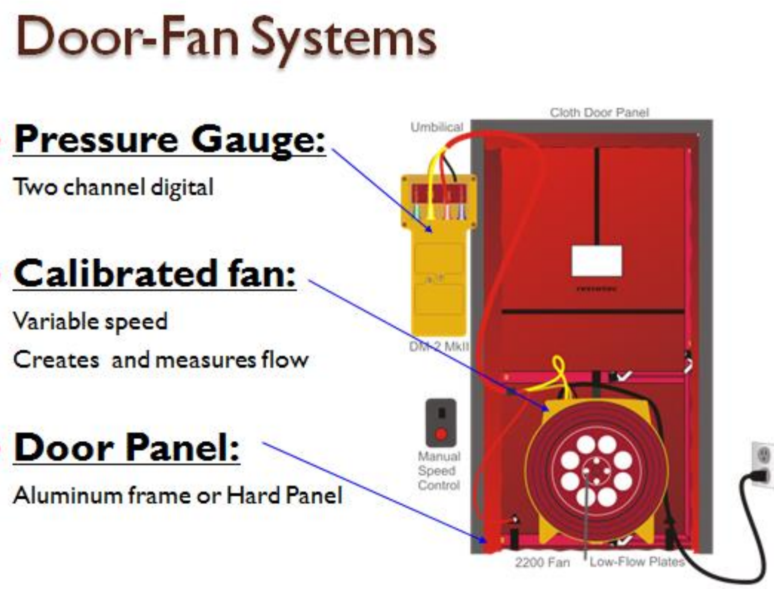
- CDD is the cooling degree days (base 70° F) for the building location
- Fuel Price is the cost of electricity in dollars per kWh.
- N is the Energy Climate Factor from the Climate Information Screen
- SEER is the SEER rating for the air conditioner.

1.5 How Blower Doors Measure Air Leakage

All Blower Door Systems consist of a door panel (which temporarily seals an open doorway), and a calibrated fan (which is installed in the panel). Fan speed is controlled either manually (with a manual dial) or automatically (with a digital gauge or specially designed software). A calibrated gauge can display results in a variety of units. Computer software can display similar results but will add more complex data analysis and automatic testing.

See Retrotec's *Blower Door Operation Manual* for more information on how to install and run a Blower Door system.

Figure 4: Components of a Blower Door system.



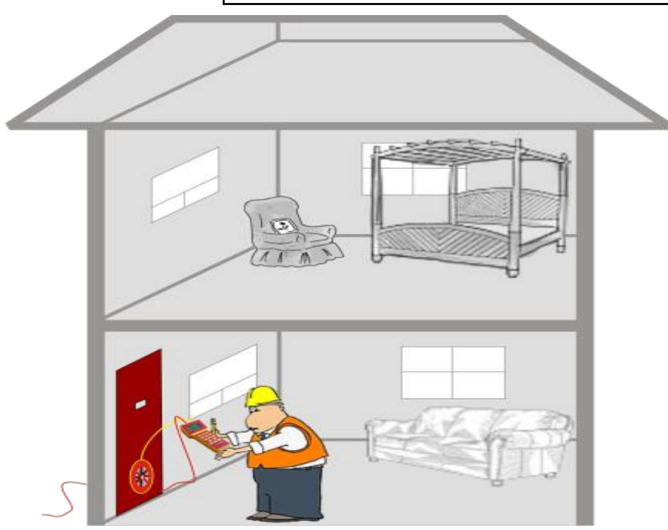


Figure 5: A Blower Door can be used to measure whole house leakage from any exterior doorway.

1.6 Reduce causes of Bias pressure to get good test results

Wind blowing across the tip of a tube will cause a significant pressure to appear on the gauge. High fluctuations of bias (baseline) pressures on the gauge (greater than 2 Pa) are a good indication that wind may be a large source of error.

Another thing to notice when the wind is blowing is that it's very difficult to establish and maintain the test pressure. In windy conditions, the readings on the house/room gauge will fluctuate. For example, when trying to establish 50 Pa, the wind will cause that pressure to go up to 55 Pa and down to 45 Pa, making it very difficult to take a reading.

There are other reasons a large Bias or Baseline pressure can appear on the gauge and these should be eliminated first before assuming wind is causing the problem. If the tube is being moved by the wind, a large rapidly fluctuating pressure will appear but can easily be eliminated by taping or tying down the tube. Next, a large and steady pressure of 10 to 70 Pa will appear if the tube end has touched water and a drop has sealed off the end. Stepping on the tube, or pinching the tube will induce a Bias pressure, so ensure that tubes are not pinched and are located away from walkways.

If air inside the exterior heats up due to the Sun shining on it and if the tube end is above or below the point where it leaves the enclosure, a stack pressure will build up inside the tube that will create a steady pressure that may increase as the tube gets hotter.

Wind velocity is always lower on the leeward side of the building. Moving pickup points away from the windward side reduces the magnitude of wind induced pressures.

Wind velocity increases with height from the ground, so placing our pickup points at ground level reduces the magnitude of fluctuations.

Covering the end of the tube without blocking it helps because the static pressure is reduced. Pop bottles or other containers help. Some testers dig holes to place the tube in. All these methods work. Flat plates on the ground work best because the openings face all directions, and the pickup point is low down. A T works well too.

Combining these methods gives a list you can go by if Baseline pressures are above 2 Pa or you simply want to increase repeatability. Your outdoor pressure pickup tube should:

- Be 15 feet from the building
- Terminate in a T
- Have 2 pickup points at least 20 feet apart attached to either side of the T
- Each point should be covered with a flat plate or box

These steps will reduce the magnitude and variation of the Baseline pressures your gauge will see. After that, time averaging or long Baseline recordings will reduce the impact of these wind pressures.

1.7 Reduce uncertainty in results by taking lots of readings

Table 1 shows tests with approximate uncertainties that can result from applying various number of Baseline points, Baseline times, and Time Averaging when taking induced pressures. As the number of Baseline points, the Baseline time, and Time Averaging used for induced pressure readings increase, the uncertainties decrease. For example, repeating the test using the same fan reduces the uncertainty by 5% in each case. Typical uncertainties would be less than half of the values shown, however the table exaggerates the uncertainty trend assuming there are errors while testing with different fans, gauges, and test conditions.

Table 1: Test result uncertainties vary by changing the number of baseline points, the baseline time, and Time Averaging for induced pressures.

Gauge error	Fan error	Baseline points	Baseline time	Baseline variation	Time Averaging for induced pressure	Uncertainty
1%	5%	1	5 s	1.5 Pa	5 s	22%
1%	5%	30	5 s	1.5 Pa	10 s	8.6%
1%	5%	30	10 s	1.5 Pa	10 s	7.9%
1%	5%	30	10 s	1.5 Pa	100 s	6.5%
1%	5%	30	20 s	0.5 Pa	100 s	5.9%

2. Preparing a Building for Air Leakage Testing

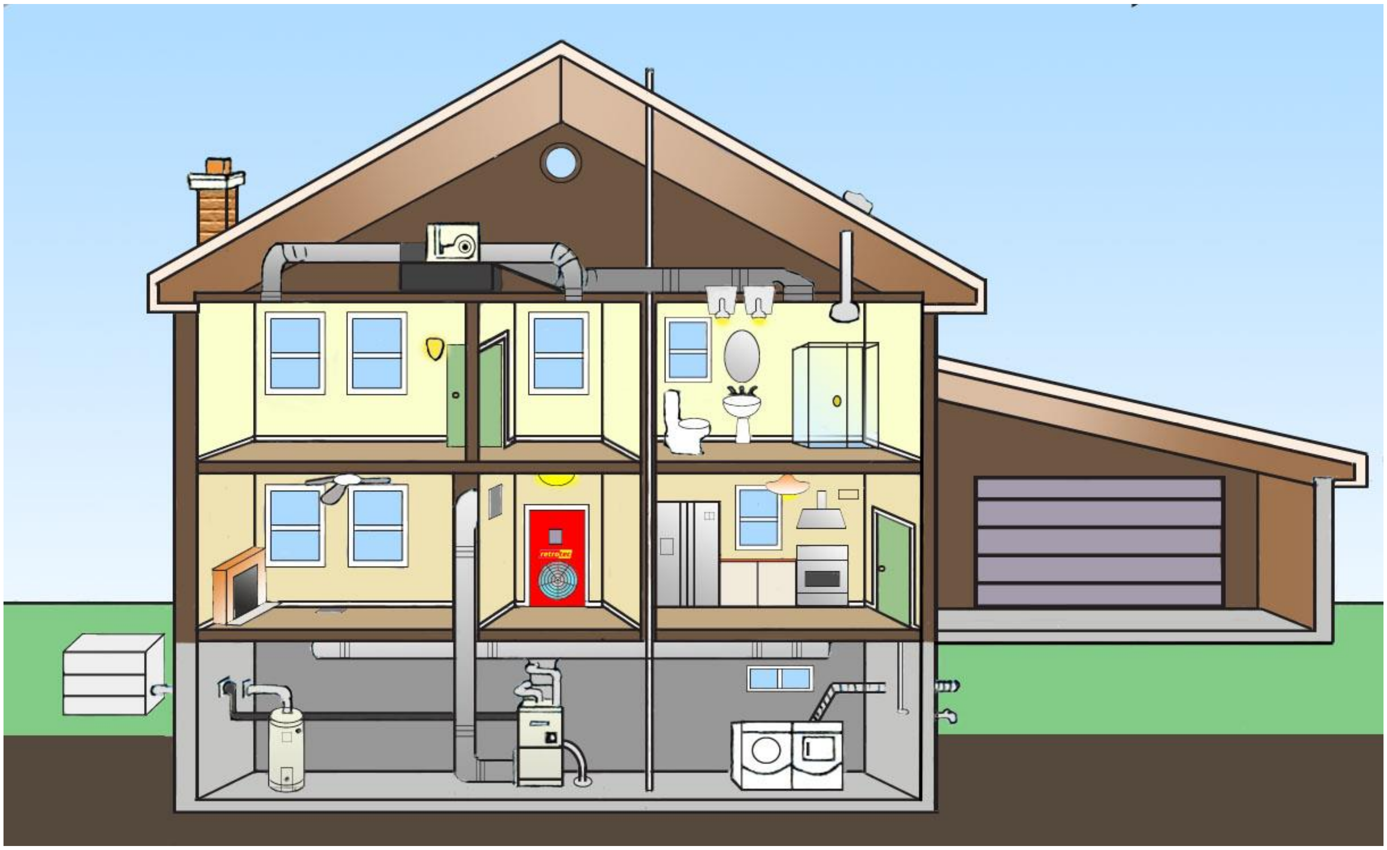


Figure 6: There are many things to consider before beginning a Blower Door test - follow the house setup check list to prepare for an air leakage test.

2.1 First considerations

It is important to properly prepare the testing area to protect testing personnel, occupants, and property. Pay special attention to safety, and basic pre-test procedures in order to ensure that a proper, accurate, and efficient job is done.

Safety

A poorly prepared house is a safety hazard. Fire is a danger, as open flames in fireplaces or gas appliances can potentially burn down a house, or asphyxiate testing staff and occupants during the test! Dust, smoke, flue gas, sewer gas, mold spores, insecticides, car exhaust and other polluting chemicals may be drawn into the house during a depressurization test and may require protection for both the tester and the occupants. Make sure these chemicals will not be drawn in during the test or protect the tester and the occupants or perform a pressurization test instead of a depressurization test. The only hazard with pressurization testing is that in cold weather, a large amount of cold air will be blown into one location in the house causing discomfort and perhaps freezing house plants.

Accuracy

Testing is meaningless if the results are not accurately recorded. A properly prepared house and equipment, as well as knowledge of the equipment and procedures, will provide more accurate results.

Consistency

Testing methods and house preparation must be consistent, in order to make test results comparable. This is particularly important during retrofitting, as it is important to know how a house performs before and after a retrofit.

Avoid Mess and Trouble

Extensive repair and cleaning costs can result from a poorly prepared enclosure. Ceiling tiles and other loose objects can all be damaged by the airflow created during a test. Watch out for fireplace soot especially.

Speak with the owner/occupants

Before beginning any preparation or testing, always explain to the occupants the testing procedure and what needs to be done. In most cases, access will be required to all areas of the house or enclosure. Advanced warning to the owner/occupants will allow them to protect valuables, and make arrangements for their time. In all cases, the test requires that all exhaust fans be off during the test, including turning the furnace/air conditioner off for the few minutes while the test is being conducted.

It is important that the homeowner not turn anything back on while the test is being performed without checking with testing staff first.

2.2 Preparation Checklist

Use the House Preparation Checklist on every test to ensure all preparation and safety checks are made on each test. Review the checklist afterwards to ensure the house is returned to its original condition.

Table 2: House Preparation Checklist

Before	After	Task	Notes
House envelope preparation			
		Select most appropriate doorway to install the Blower Door system	
		Close all exterior doors (except test doorway)	
		Door to basement, open if conditioned, close if not	
		Close all windows, storms, and skylights	
		Close all attic accesses inside the house	
		Seal any dog or cat doors with tape or grill mask	
		Close any fireplace dampers	
Inside house preparation			
		Move any loose items in the direct path of the fan airflow	
		Open any interior doors to conditioned spaces	
		Remove fluorescent light & skylight diffusers	
		Turn off all ceiling fans	
		Check for any open flames or hot embers	Immediately discontinue test if found
		Cover any cold ashes	
Buffer zones: open to the outside			
		Attic	
		Basement if unconditioned	
		Garage	
		Porch	
		Crawl space	
Exhaust appliances: turn off			

		Kitchen & bath exhaust fans	
		Whole house fan	
		Clothes dryer	
		Central vacuum system	
		Attic & crawl space power ventilators	
Other Devices:			
		Evaporative coolers - turn off	
		Window a/c units - turn off	
		Close fresh/outside air vents	
		Wall furnace - turn off	
Central heating & cooling system:			
		Turn off	
		Remove filter from grills	
		Open supply diffusers	
		If subtraction test: tape over supplies & returns	
		Close damper over fresh/make-up air intake	
		Turn off fresh air ventilation system	
Water heater:			
		Turn to pilot position, and leave keys on heater	

2.3 Preparation of Intentional Openings

A major test objective is to ensure that the entire conditioned (heated or cooled) space is kept at the same pressure relative to outside during the test. For example, when there is a 50 Pa pressure difference between the front hallway (where the Blower Door is located) and the outdoors, there also needs to be a 50 Pa pressure difference between the back bedroom and the outdoors. In order to achieve this, exterior openings such as windows must be closed and doors to conditioned spaces must be opened.

Establish what the conditioned space of the enclosure is. Conditioned areas must be included in testing, and will need to be pressurized. Unconditioned space should be allowed to match the exterior pressure.

2.3.1. Select a Doorway

It's important to select the correct doorway to use for testing.

To select a doorway

1. Select a doorway that will fit the specific Blower Door system. If the doorway is abnormally tall or wide, it will be easier to pick a different door rather than try to use cardboard or something makeshift to make the system work.
2. Ensure that there is enough space to work, including assembling the door frame and storing tools and cases, around the door area. Equipment and pressure tubing will need to be kept out of the path of the fan airflow.

3. Watch out for small objects, valuable and loose papers. It may be easier to pick a different door to install the Blower Door in, than to secure the occupant's personal possessions that will be disturbed by the flow of air.

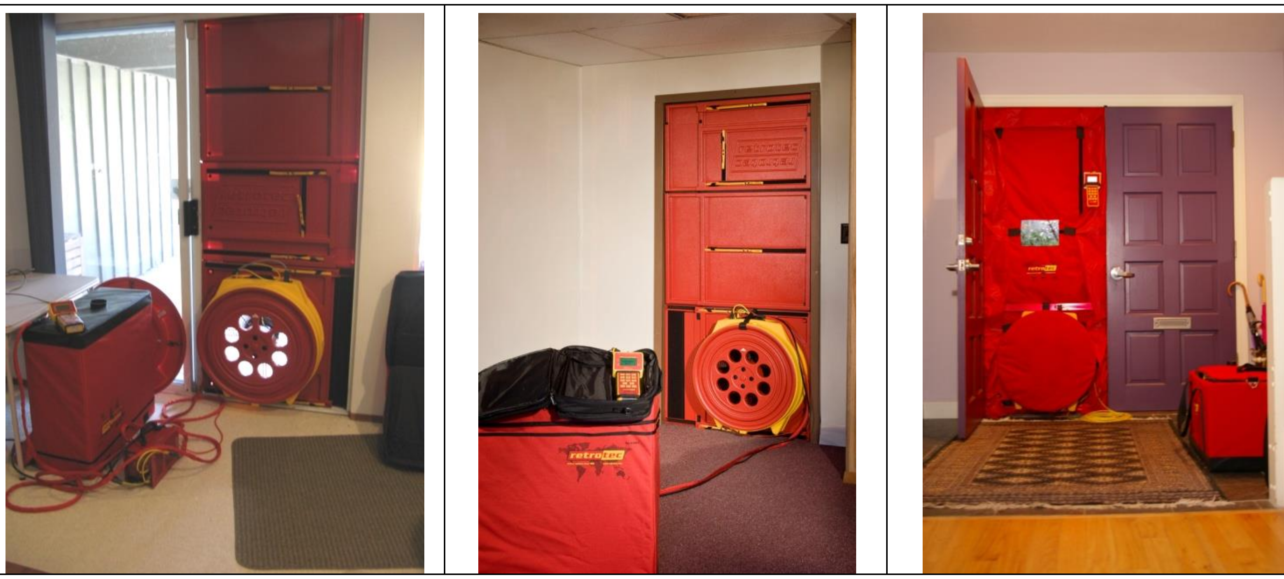


Figure 7: Properly select doorways in which to install the Blower Door system.

2.3.2. Windows and Doors

2.3.2.1. Windows

Close all windows and skylights, including the outer storm windows. Be especially aware of old hinged windows, which are sometimes poorly latched and may swing open when the pressure changes during the test. If a room or area is meant to be unconditioned, a window must be left open to allow the area to be at the outside air pressure.

2.3.2.2. Exterior Doors

Close all doors leading outside the conditioned space. This includes all exterior doors, and usually includes the door into the garage (as most garages are not conditioned). It sometimes also includes the door to the basement, if the basement is considered unconditioned.

2.3.2.3. Interior Doors

In general, open all interior doors.

Doors leading to rooms which are intentionally cooled or heated should always be open. Typically this will include doors to all rooms which have air supplies, registers, or are insulated from the outside. Closet doors must be open if there is a supply register, attic hatch or other obvious possible leak within. Although, in practice, doors to small linen closets aren't always opened, in theory all rooms inside the conditioned space should be open. Not opening these spaces could make a difference if there were large holes/leaks inside the closet.

Doors to conditioned attached garages (these are rare) must be opened.

2.3.2.4. Doors to Basements

Doors leading from upstairs into most basements (in northern climates) should be open during the test, as basements are normally conditioned by supply registers, un-insulated ducts, pipes and the un-insulated floor above.

If the basement has no usable living space, supply registers, or has insulated supply ducts or an insulated ceiling, it could be considered unconditioned, in which case the door from upstairs should be shut during the test and a basement window should be open so that the basement is at outdoor pressure.

2.3.2.5. Attic Hatches and Pull-Down Stairs

Attic hatches:

- If in the conditioned space, must be closed for the test.
- If outside the conditioned space, should be open for the test.

If the attic access is in the ceiling of an unconditioned garage, or outside of the thermal envelope, the access and the main garage overhead door should be open (even though this may not be the normal position). This is especially true if ducts or the air handler are located in the attic above, or in the garage itself. The objective is to ensure that during the test, the same pressure difference is created across all the surfaces of the pressure envelope. This requires that the attic be well ventilated.

2.3.2.6. Garage Door

Large garage doors are usually left closed. However, they must be open if the Blower Door is installed in the main door between the house and the garage. It should also be open if the air handler/furnace is located in the garage, or if there is an attic access in the garage ceiling which is being left open during the test.

2.3.2.7. Unconditioned Crawlspace Vents and Hatches

Unconditioned crawlspace vents and hatches should be open during the test.

2.3.2.8. Skylights

If the skylight has a moveable opening in it, such as a ventilation slot, it should be shut. Some skylights have lay-in translucent plastic panels at ceiling level to diffuse direct sunlight. They are sometimes quite flimsy and brittle and can get pulled down (and broken) during a test. Remove or secure them if required.

2.3.3. Exhausts and Intakes

2.3.3.1. Enclosed Furnace Rooms or Closets

Furnace rooms with separate combustion air intakes from outside (or an attic or crawlspace) are to be considered outside the thermal envelope. Ensure that gas or fuel oil appliances won't fire (for safety), but do not seal the air intakes or flues. The door to the house should be closed.

2.3.3.2. Fireplaces

Glass doors should be closed. If a damper is in place, it should be shut before conducting a test. Even when shut, many dampers will leak a considerable amount of air, often enough to blow ashes out onto the living room floor during depressurization. Clear out the fireplace or lay newspaper sections over the ashes to deflect the air stream.

The fireplace must be cold and completely out. If a house has hot, smouldering coals or ashes, but no fire, the fire will still need to be put out. The best solution is to use a metal ash bucket and take everything outdoors before quenching the coals with water.

For fireplace chimneys without a damper, perform the test without sealing the chimney. It's a big leak that needs to get fixed.

2.3.3.3. Exhaust Fans and Other Air Moving Equipment

Turn everything off that exhausts air ***from,*** or blows air ***into***, the house. This includes central air systems, bathroom fans, clothes dryers, and all other vents. It is always best if the homeowner turns them off, so that they are responsible for turning them back on when testing is complete.

Possible exhaust appliances inside of the home:

- Kitchen exhaust fans
- Downdraft stove top exhaust units
- Bathroom exhaust fans
- Clothes dryers
- Whole house cooling fans (usually located in the hallway ceiling)
- Whole house vacuums vented to outdoors
- Green-space ventilation fans

2.3.3.4. Exhaust Appliances Outside of the Home

Attic exhaust fans (powered attic ventilators) may throw off the test by depressurizing the house itself. There are two ways to shut exhaust fans down: turn the exhaust fan off with the circuit breaker, or access the attic to adjust the built in thermostat. Although less common, crawlspace ventilators can also cause this problem.

2.3.3.5. Window Air Conditioners

Window air conditioners must be off during the test. Be aware that in a northern climate, air conditioners may be removed in the fall. During summertime testing, consider sealing it off with tape and plastic to get the most representative reading for the winter operating conditions. In the south they are often left in place year-round, and testing can be conducted without any special procedures.

2.3.3.6. Central Air Conditioners

Central air conditioners must be off during the test, including the air handler. If the ducts leak to the outside, the test will be inaccurate if the air handler is running.

2.3.3.7. Cooling Ceiling Fans

It is usually ok to leave ceiling fans on, as they only blow air around in the room. However, in some cases they will accelerate leakage at the ceiling fixture, and will interfere with leak detection if using smoke, so it is recommended that they be turned off.

2.3.3.8. Solar Panel Fans

If the house has solar panels that use air from the home, the fan should not be running during the test.

2.3.3.9. Fuel Fired Appliances

Gas, oil or propane fired furnaces and water heaters must be prevented from firing during the test.

Flame rollout can occur if a vented combustion appliance fires during a depressurization test. This is a very definite fire and safety hazard. Under no circumstances should a test be conducted if measures haven't been taken to prevent appliances from firing!

All vented combustion appliances must be disabled prior to the test, including those outside the thermal envelope being tested (e.g. furnaces and water heaters in buffer zones such as combustion closets, garages, attics and crawl spaces). Buffer zones are often influenced by pressure changes in the conditioned space and may also be depressurized during the test.

To shut down fuel fired appliances:

For gas systems, turn the appliance's gas valve control from "On" to "Pilot" and leave the pilot light operating while the test is being conducted.

For fuel oil systems (with no gas valve), the main power switch can be thrown, or the fuse can be removed or switched off at the electrical panel.

Although it is best to go to the gas valve or main power switch, furnaces can also be turned off at the thermostat (if it has a Heat - Off - Cool switch). However, be aware that the homeowner may easily turn the furnace back on in the middle of the test if only the switch has been changed. Do not rely on turning the thermostat way down or way up. During a long test, the furnace may still turn on.

In cold weather, it is generally best to turn the thermostat down when first arriving in the home to allow the chimney to flush itself of smoke and for the flue pipe to cool down, as it may need to be temporarily sealed for a new home test per R-2000.

Although rare, sometimes a pilot light will go out during the test and must be re-lit. The furnace pilot is usually easily seen but water heater pilot lights are not. The water heater should fire right up when it is turned back on. If it does not, check that the pilot light is still lit by making a pencil mark on the temperature dial and turning the knob to "HOT", it should fire immediately. Return the knob to its original setting, and re-light the pilot if necessary.

Never leave a home without ensuring that the systems turned off are reactivated. A simple precaution is to leave car keys or other valuables on top of the unit, which are only reclaimed once the system is back to normal.

Figure 8. Leave your car keys on top of the furnace so you don't forget to reactivate the system.

2.3.3.10. Airtight Wood Stoves and Wood Furnaces

Airtight wood stoves and wood furnaces must not be operating when conducting a depressurization test, as they can leak smoke into the home. Notify homeowners ahead of time, so that they can ensure that the stove or furnace is not in use.

If the stove is airtight and is still smouldering, but has no fuel in it, close down the combustion air inlets and conduct a pressurization measurement. The potential for accelerating the fire in the stove must be minimized before attempting to depressurize. Disperse any coals in the stove and remove unburned material. When conducting the test, periodically shut off the Blower Door and monitor the firebox. Do not continue if there is any risk of over-firing the stove or starting a chimney fire.

2.4 Other Precautions

2.4.1. Suspended Ceilings & Fluorescent Light Diffusers

Suspended ceilings using T-bars and acoustical tiles may not be able to withstand the 50 Pa of negative pressure created during a multi-reading (point) test. The same is true for the plastic light diffusers under some fluorescent lamps. If the tile ceiling or lights are installed under an older plaster or sheetrock ceiling which has many penetrations through it, remove a tile or light diffuser leading into this cavity before starting the test.

If the suspended ceiling is the thermal envelope (such as in the typical commercial building that has insulation batts on the ceiling), removing a tile may give a very erroneous reading. Perform a single reading test at a lower pressure and don't increase the pressure without keeping an eye on the ceiling. A pressurization test isn't recommended as the tiles may lift up and give erroneous readings.

2.4.2. Fragile Decorations

Ask the homeowner to move any fragile decorations, bric-a-brac, papers etc..., which may get disturbed by the Blower Door airflow. If this is not possible, pick another doorway, or do the entire test under negative pressure only.

2.4.3. Flying Floors

Under negative pressure, a one-piece vinyl floor may rise up if it is over a leaky crawlspace. It is rare, but will significantly affect test results. Testing under positive pressure will prevent this.

2.4.4. Airstreams

Watch out for doors that may slam shut from the pressure changes during a test. In a smaller, tighter home, a sudden increase in negative pressure (from the door shutting) can spike the house pressure, and pull the whole Blower Door out of the doorway. This is highly embarrassing for the tester, and potentially damaging to the homeowner's floors.

2.4.5. Energy Efficient New Homes

Testing new energy efficient homes for a utility sponsored program, or for a builder who is building energy efficient homes, may require a different house preparation than what is described. For example, the Canadian R-2000 program specifies that furnace, water heater, wood stove and fireplace flues may be sealed for the test. Some intentional ventilation openings such as air-to-air heat exchanger intakes and exhausts may be sealed as well. The objective is to measure the tightness of the building envelope itself, independent of any mechanical systems and intentional openings. Contact the local program administrators for current requirements. Note that extra time is generally needed if openings are to be sealed off.

2.4.6. Plumbing Traps

In many homes, especially newly built ones, considerable amounts of air can flow in through the drainage system (if there is no water in the traps). This should be stopped in new construction by filling the traps with water. Use antifreeze if the home is unheated and if freezing is possible after the testing is complete.

2.5 Return the House to Pre-Test Condition.

Ensure that the building is returned to its original condition before leaving. This includes turning the thermostat and water heater temperature controls to their original setting. Always check to see that furnace, water heater and gas fireplace pilot lights have not been blown out during the test; re-light them if necessary. Remove any temporary seals from fireplaces or other openings sealed during the test. Occupants may not be aware of what was turned off or sealed for the test.

2.6 Site Conditions affect tests so need to be recorded

2.6.1. Estimate the Wind Speed

Wind speed is occasionally required to be measured for certain testing protocols. In most cases, it is simply estimated so that differences in results during retest can be explained.

2.6.2. If needed, measure the inside and outside Temperatures

Temperature measurement is not required for most tests, but there are cases where testing protocols require temperature corrections that can be 1 - 2% in total.

2.6.3. Measure and record any Existing Pressure Differentials

Prior to creating an artificial test pressure there may already be an existing pressure differential due to stack pressures, wind or HVAC operation. Checking pressure differentials across the envelope prior to installing the Blower Door equipment is recommended to identify these pressure sources.

2.6.4. Interaction with Other Site Activities

Construction and other activities require people to move in and out of the building during a leakage test. Accommodations must be made to prevent these activities from spoiling the test. In most cases if the building can remain closed for at least 10 minutes, a single point reading can be taken. If more complex tests are required, complete access to the building may be required for 30 to 90 minutes.

2.7 Only Measure the Building if required - takes a long time

Do not make these measurements unless the test results require these dimensions, because they are very time-consuming. In almost all cases, inside measurements are required.

2.7.1. Volume needed for air change rates (ACH50)

Some protocols require the volume of the building to the measured in order to calculate air-change rates. If this measurement is being made directly from the building, it may take 10 to 60 minutes to complete. It is recommended to complete this prior to installing any equipment. Volumes of the areas between floors are generally included but specific testing standards must be referenced to ascertain what is required.

2.7.2. Surface Area needed for normalized leakage areas or permeability

If normalized leakage areas or permeability is required, then the surface area of the building must be measured. This can take 10-60 minutes, and equipment should not be set up until the measurements are completed. Some testing protocols may require the dimension to be read off building plans, other times it must be measured directly on site. Recording all measurements in an organized way is recommended. The surface area of exterior walls is usually measured as if intermediate floors do not exist.

2.7.3. Floor Area needed by some protocols

In some cases, floor area must be measured in order to calculate specific leakage area that is required by some testing protocols. The floor area is generally measured to the outside walls, and does not include the area of partition walls.

3. Test a house for total Air Leakage

3.1 Initial set-up

Set up the Blower Door system(s) for a total house leakage test. Ensure that the checklist has been followed, and all precautions have been taken before turning on the fan(s). Ensure the tubing is correctly set up.

3.2 Take Building Measurements

3.3 Perform Basic Tests

3.3.1. Use the fan in the door panel to pressurize or depressurize the house

A basic air leakage test can be used to measure the total house leakage in a very short amount of time. It can also be used to locate leaks and to conduct simple zone testing.

To conduct a basic air leakage test

1. Decide whether to pressurize or depressurize the enclosure.
2. Set the door panel and fan up according to the system specifications.
3. Increase the fan speed to achieve a pressure difference of 50 Pa (this is the most common residential test pressure).
4. Measure the total house leakage.

3.4 Find Air Leakage Locations by feeling for air flow

Once a building has a pressure difference with respect to the outdoors, it can be quite easy to locate air leaks. Sealing the leaks, however, can be more difficult because air leakage often takes creative paths through a building envelope.

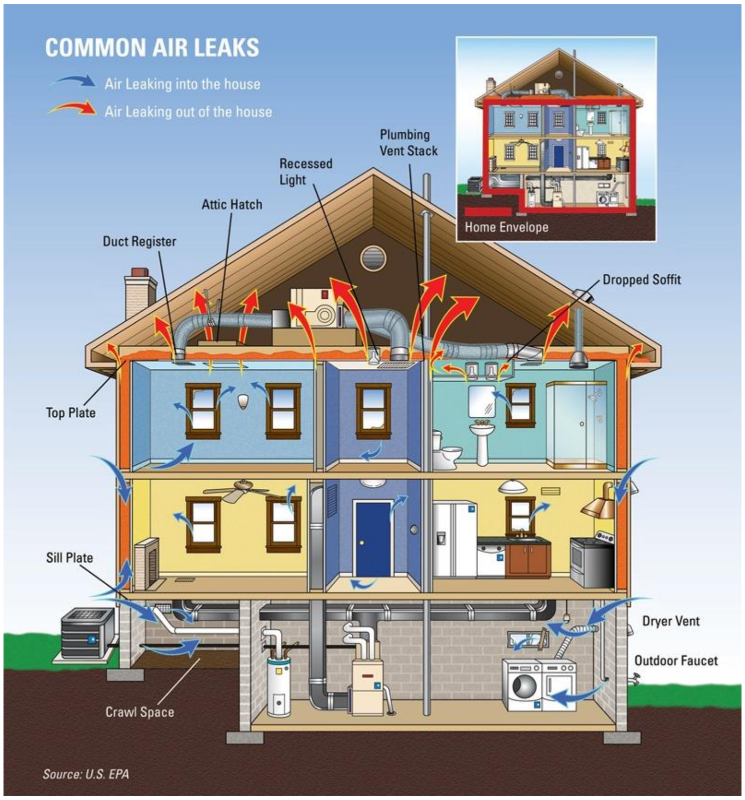


Figure 9: Common leak locations in a house.

Where to look for leaks

With the Blower Door running, take a walk around the house. There are a few common leakage sites.

- Ductwork
- Floor spaces (especially floors over unconditioned spaces, like garages)
- Recessed lights
- Attic accesses
- Chimneys
- Wall penetrations
- Sliding doors
- Rim joists (along foundations, plumbing penetrations)
- Soffits, false ceilings
- Exhaust fans

3.4.1. Locating Leaks without Tools just using your senses

The simplest and quickest method to locate air leaks is to walk around looking for leaks without any tools at all. If the door to a leaky room is nearly closed, a strong flow of air can be felt flowing through the small opening. Running a hand along a leaky window sill, or beneath leaky pot lights, will quickly determine if those are sites of leaks as well.

3.4.2. Locating Leaks with Chemical Smoke that moves with air currents

Chemical smoke is often a neutral buoyancy smoke, that doesn't move unless air is flowing in one direction. Release small puffs of smoke near potential leakage sites, and observe the smoke movement.

3.4.3. Locating Leaks with Theatrical Smoke that oozes out the cracks

Theatrical smoke can provide quite a show. It is recommended that theatrical smoke only be used in a pressurization test, since that will force the smoke outdoors, and not draw it into the house.

3.4.4. Locating Leaks with Infrared Camera to see different temperatures at leak locations

An infrared camera can be used to detect warm and cold locations, which can indicate leakage. Some training is required to operate an infrared camera properly.

3.5 Perform a Single Point Test for a Standard or Protocol

Some protocols require completion of a single-point test in order to be in compliance with the standard. In this case, the test procedure can be based on recording the result observed on a digital gauge.

1. Record all relevant test and building information before beginning the test (i.e. building dimensions, time, temperature, equipment information). A sample test form can be found in Appendix B.
2. Set up the fan to take bias pressures. This will normally be with the fan cover on, with the L4 Flow Range set-up, however follow the procedure set out by the standard for which the test is being run.
3. To collect bias pressure readings, set the gauge for 10s time averaging and put the gauge down on a table, fan case, floor, or somewhere convenient.

4. Wait 20 seconds before taking note of the pressure reading on channel A ("PrA"). Record this value directly into a software program, or on the sample test form to be entered into a software program at a later date.
5. Wait another 20 seconds before taking the next reading, and put this value into the second yellow box in the Bias Pressure row in the software.
6. Continue this process for as many bias pressure readings as the protocol requires (up to 12 individual readings).
7. Uncover the fan and employ the Flow Range that is believed to be the best one for the desired building pressure. This can easily be changed: if the flow reads "TOO LOW" on the gauge switch to a Flow Range with a smaller hole, or if the fan speed is too high, and the target pressure can't be reached, switch to a Flow Range with a larger hole.
8. Use the gauge or speed control knob to turn on the fan to reach the desired building pressure (usually 50 Pa). Example: On the DM-2 gauge press **[Set Pressure] [5] [0] [Enter]**
9. Once the fan adjusts to the desired pressure, wait 20 seconds to record the "PrA" value (building pressure), and record the fan pressure "Pr B", with both readings in Pa. Make sure that the correct Device and Flow Range are selected on the gauge, otherwise the results may be inaccurate. It may be easier to record results with the Hold, @ Pressure, and/or Time Averaging features active (if available).
10. Collect final bias pressures in the same fashion as was done in step 3. Make sure to put the fan back to the position it must be in to follow the guidelines (i.e. covered, or on the L4 Flow Range). Record the bias pressures.

3.6 Perform a Multi-Point Test

Some protocols require completion of a multi-point test in order to be in compliance with the standard. If this is the case, a multi-point test can be completed either manually (with results recorded by hand from the gauge) or automatically with a gauge connected to a computer. The following procedure details how to collect the data by recording results from a digital gauge, with examples using the Retrotec DM-2 gauge.

1. Record the appropriate building and tester information on the sample test form provided in Appendix B.
2. Set up the fan(s) to take bias pressures: this will normally be with the fan cover on, with the L4 Flow Range set-up. However, it is recommended to follow the procedure set out by the standard for which the test is being run.
3. For a multiple fan set-up, make sure all fans are covered, properly connected to their respective gauges, and all gauges are visible to the tester.
4. To collect bias pressure readings, set the gauge(s) for 10s time averaging, and put them down on a table, fan case, floor, or somewhere convenient. Wait 20 seconds before taking note of the pressure reading on channel A, "PrA". Record this value.
5. Wait another 20 seconds before taking the next reading, and continue in this way until all required bias reading points have been collected.
6. Decide on the range of building pressures that will be required, and how many test points will be taken. This will likely be defined in the protocol/standard being followed.
7. Determine the best Flow Range plate to use, in order to minimize Flow Range changes during the test. You can test this by setting the pressure to both the low end and the high end of the selected building pressure range. If the flow reads "TOO LOW" on the gauge, switch to a smaller Flow Range. If the fan speed reaches 100% without reaching the desired pressure on Channel A, switch to a larger Flow Range.
8. Uncover the fan(s) and attach the Range Ring or Plate believed to be the best one for the building pressure being induced.
9. Use the gauge(s) to turn on the fan(s), in order to reach the first desired building pressure point. Example: To begin testing at 10 Pa, press **[Set Pressure] [1] [0] [Enter]**

10. Once the fan(s) adjust to the desired pressure, wait 20 seconds, and press [Jog/Hold] twice to hold the reading currently displayed on the screen(s). Record the "PrA" value (building pressure) and the fan pressure "PrB", both in Pa. If using multiple fans, make sure to indicate which fans experience which pressures.
11. There are two methods to reach different test pressures during a test:

    a. With the DM-2, use the Jog function accessed with the Jog/Hold key to increase or decrease the building pressure to be induced. This is ideal if performing a multiple point test with closely spaced points. For instance, if you begin with a 10 Pa building pressure, and want to take the next point at 15 Pa, press **[Jog/Hold] [2]**, this will increase the "PrA" pressure by 5 Pa. Holding the arrow key will increase the pressure continuously by 10 Pa (release the button to stop).

    b. Use the Set Pressure function to set the next pressure point. This method is ideal if performing a test with a wide range between points.

12. Once the full range of building pressures and corresponding fan pressures have been recorded, take final bias pressures, in the same fashion as in step 3.

3.7 Use a Computer to run the multi-point Air Leakage Test

Performing automatic tests with a software program provides the same function as performing the tests manually. However, in this case the settings for single or multi-point tests can be preset and a simple click of a button will run the whole test without the need for user input (except for optional covering of the fan(s) during bias pressure readings and any fan range changes required during the test).

Before performing an automatic test, the panels, fans and gauges must be set up properly. After set-up, manually run the fan to make sure you can achieve minimum and maximum pressures required for your automatic test (this will assure that the fan is on the correct Flow Range). Ensure that your gauge is displaying the correct device and correct Flow Range. Press **[Mode]** to change to the "Flow" mode, so that the gauge displays the maximum and minimum flow. If "TOO LOW" appears on your gauge screen, you must change to a lower Flow Range and try again (if this happens during a test run, the test will pause for you to change the Flow Range).

Ensure that the settings for the test protocol chosen match the guidelines being followed. Any software program that is used should have a way to change settings, or to choose a particular protocol to follow. For instance, in FanTestic, Tools → Options → Settings tab. See the *FanTestic Manual* for more information specific to this program.

3.8 Set the gauge to give results for tests based on Standards

In order to meet specific standards, the Retrotec gauge can be configured in a specific way to match the testing standard and have the gauge automatically calculate the required results. Use the instructions below to setup the gauge to calculate results that meet the listed standard.

Configure the Retrotec gauge as indicated in Table 3.

Table 3: Retrotec gauge setup conditions for various standards.

[Setup]	Eco-Energy, Canada	Title-24-CA, USA	LEED, apartment test	DS/EN 13829, & France	ATTMA TS-1
n=	0.65	0.6	0.65	0.65	0.65
Surface Area	sq ft or m^2	sq ft or m^2	sq ft	m^2	m^2
Building Volume Unit	cu ft or m^3	cu ft or m^3	cu ft		
European Separator	No	No	No	Yes	No

3.9 Standards specify test procedures for air leakage testing

The following Table 4 lists the procedures for testing and results for various protocols from around the world.

Table 4: Acceptable testing conditions, test setup requirements and results for various protocols from around the world.

Standard	ASTM	CGSB	EN13829	ATTMA	USACE	WA State	LEED
Applies to	Residences	Residences	Residences	Residences & Large Buildings	Large Buildings	Large Buildings	Apartments
Origin	USA	Canada	Europe	UK	USA	WA State	North America
Acceptable conditions	41 to 95°F < 5 mph wind	<20km/h wind	<6m/s wind height x ΔT<500m°C	<6m/s wind height x ΔT<250m°C	Bias<10% of min. test OR <30% for both ways	95% confidence interval	Same as ASTM
Baseline points	10 second averages, before and after flow measurements	Before each test measurement	30 second averages, before and after a test	30 second averages, before and after flow measurements	20 second averages,12 points before and after flow measurements	10 second averages, before and after flow measurements	10 second averages, before and after flow measurements
Induced pressure point range	10 to 60 Pa	15 to 50 Pa	10 to 50 Pa	10 to 60 Pa	25 to 75 Pa	25 to 80 Pa	10 to 60 Pa
Number of points	5-10	1, 2, or 7	5	7	12	12	5
Test Direction Preferred	Both	Depress.	Both	Both	Both	Both	Both
Test Direction acceptable	Either but usually depress.	Depress.	Usually depress.	Usually press.	Both unless building requires over 125,000 CFM	Both	either
Results	EfLA @ 4Pa ACH50 CFM50	EqLA @10Pa ACH50	$(m^3/h)/m^2$	$(m^3/h)/m^2$	CFM75/sq ft	CFM75/sq ft	EfLA @ 4Pa
Required results	none	none	none	2 to 10 $(m^3/h)/m^2$	0.25 CFM75/sq ft	0.40 CFM75/sq ft	1.25 sq in/sq ft EfLA @ 4Pa

Notes on Standards

- Canadian Eco-Energy complies with CGSB 149.10
- **DS/EN 13829** is a multi-point test so the gauge is used to take multiple readings which are recorded in turn. Each reading on the gauge measures a single-point pressure of the enclosure. Flow per unit area is sometimes referred to as Air Permeability. The gauge can provide a quick single-point check of the enclosure as follows:
    1. Press **[Mode]** to scroll to the “Flow/Area” mode.
    2. Press **[Enter]** and input the Envelope Area, to display Air Permeability as specified in the standard.
    3. Results may be read directly from the gauge.

- **ATTMA: TS-1** is a UK standard is similar to DS/EN 13829. However, it has the Air Leakage Index added, which uses the same units as permeability except it uses the exposed envelope area rather than the total envelope area that permeability requires.
  1. Press **[Mode]** key to scroll to the "Flow/Area" mode
  2. Press **[Enter]** and input either the Envelope Area to display Air Permeability or the Exposed Envelope Area to display Air Leakage Index, as specified in the standard
  3. Press **[@ Pressure]** to display the Flow @ 50 Pa, Air Changes @ 50 Pa, and either Air Permeability or Air Leakage Index @ 50 Pa
  4. In order to record both Air Permeability and Air Leakage Index, re-enter the different areas from steps 1 and 2. Results may be read directly from the gauge.
- **Title-24** is a California standard. It is used to measure duct leakage in CFM at 25 Pa under pressurization, and house leakage at 50 Pa under pressurization.
  1. Assess and measure the Conditioned Floor Area CFA in sq ft as specified in the Standard.
  2. Press **[Mode]** to scroll to the "EqLA/Area" mode.
  3. Press **[Enter]** and input the CFA as measured in step 1.
  4. Press **[@ Pressure]** to display the Flow @ 25 Pa.
  5. Results for default, heating only analysis may be read.
  6. "EqLA/Area" may be read directly from the gauge.
- **LEED** is a multi-point test so the gauge is used to take multiple readings which are recorded in turn. Each reading on the gauge measures a single-point pressure of the enclosure. The gauge can also provide a quick single-point check of the enclosure as follows:
  1. Press **[Mode]** key to scroll to the "Flow/Area" mode.
  2. Press **[Enter]** and input the Envelope Area to display Air Permeability as specified in the standard.
  3. Results may be read directly from the gauge.

Table 5: Summary of esults required for various energy efficiency programs around the world.

Standard:	Eco-Energy	LEED, apartment test	USACE	DS/EN 13829; ATTMA TS-1	FR/EN 13829	Northwest ENERGY STAR	ENERGY STAR
Region:	**Canada**	**North America**	**USA**	**Europe/UK**	**France**	**ID MO OR WA**	**North America**
Pressure	Pa	Pa	Pa	Pa	Pa	Pa	Pa
Flow	L/s or CFM	Off	CFM	m³/h	m³/h	CFM	CFM
(Flow) @ Pressure	Off	n/a	75 Pa	50 Pa	50 Pa	50 Pa	50 Pa
EqLA	sq in or cm²	Off	sq ft	Off	Off	Off	Off
(EqLA) @ Pressure	10 Pa	n/a	75	n/a	n/a	n/a	n/a
EfLA, Effective Leakage Area	Off	sq in	Off	Off	cm²	Off	Off
(EfLA) @ Pressure	n/a	4 Pa	n/a	n/a	4 Pa	n/a	n/a
Air Changes	/h	Off	Off	/h	/h	/h	/h

(Air Changes) @ Pressure	50 Pa	n/a	n/a	50 Pa	50 Pa	50 Pa	50 Pa
Flow per Area	Off	Off	CFM/sq ft	$(m^3/h)/m^2$	$(m^3/h)/m^2$	CFM/sq ft	CFM/100 sq ft
(Flow per Area) @ Pressure	n/a	n/a	75	50 Pa	4 Pa	50 Pa	25 Pa
EqLA per Area	cm^2/m^2 or sq in /100 sq ft	Off	Off	Off	Off	Off	Off
(EqLA per Area) @ Pressure	10 Pa	n/a	n/a	n/a	n/a	n/a	n/a
EfLA per Area	Off	sq in / 100 sq ft	Off	Off	Off	Off	Off
(EfLA per Area) @ Pressure	n/a	4 Pa	n/a	n/a	n/a	n/a	n/a

4. Use the Blower Door System to do other tests

In addition to the standard Blower Door tests, it is possible to conduct a number of other tests with a Blower Door system.

4.1 Measure Pressure Difference/Air flow between Areas

Measuring the pressure difference or air flow between areas is often called a zone test. The area under test is called the zone and the other area is called the reference area. A basic zone test is no more than the following:

1. Check Baseline pressure: Have the gauge measure a “Baseline” for at least 60 seconds.
2. Connect the red tube to the “Ref A” (red) port on the gauge, and place the other end of the tube in the reference area.
3. Connect the blue tube to the “Input A” (blue) port on the gauge. Place the other end of the tube in the zone.
4. Channel A, “PrA” on the gauge display, displays the pressure difference between the zone and the reference area.

It is also possible to measure the pressures in zones that are outside the conditioned space, relative to the house pressure.

To measure zone pressure relative to the house pressure

1. Set up the fan system with a manual speed control and pressurize/depressurize the house to your normal test pressure (typically 50 Pa).
2. Leave the fan running so that the house is at the test (50 Pa) pressure difference to the outside. Disconnect the tubing from the Blower Door when the test pressure has been reached and is stable.
3. Connect a long blue tube to the “Input A” (blue) port on the gauge. Leave the “Ref A” (red) port open to the house.
4. Insert the other end of the blue tube into the zones to be tested. “PrA” will display the difference between the house and the tested zone. If the tested zone has many leaks to the outdoors allowing its pressure to drop to close to the outdoor pressure, you would expect the measured pressure between house and the tested zone to be close to the set test pressure difference between the house and the outdoors (50 Pa). If the zone has few leaks to the outdoors, the measured pressure will be close to 0 Pa since the zone will stay at close to the house pressure.

To measure zone pressure relative to the outdoors

1. Set up the fan system with a manual speed control and pressurize/depressurize the house to your normal test pressure (typically 50 Pa).
2. Leave the fan running so that the house is at the test (50 Pa) pressure difference to the outside. Disconnect the tubing from the Blower Door when the test pressure has been reached and is stable.
3. Connect a long blue tube to the “Input A” (blue) port on the gauge.
4. Connect a long red tube to the “Ref A” (red) port on the gauge, and run the other end outdoors.
5. Insert the other end of the blue tube into the zones to be tested. “PrA” will display the pressure difference between the tested zone and the outdoors. If the tested zone has many leaks to the outdoors, you would expect the measured pressure to be close to 0 Pa because the zone is more connected to the outdoors. If the zone has few leaks to the outdoors, then you would expect the measured pressure to be close to the set house pressure (50 Pa).

Pressure relief may be needed in any particular room that is pressurized or depressurized by 3 Pa or more, compared to the main body of the house. If combustion appliances are in a depressurized area, even a minor depressurization can interfere with their ability to draft properly.

4.2 Test how much Ducts Leak to Outdoors

A Blower Door can be used to measure “Duct Leakage to Outside” which we prefer to call “Duct Leakage to Outdoors” because “Outside” could be taken to means outside a particular zone which may still be inside the building but the intention here is to measure leakage to the great outdoors.

4.2.1. Measure Duct Leakage to Outdoors by Subtraction for tight houses

Very few State Codes allow this method: Georgia allows it. The entire house enclosure must be finished and tight.

Inaccuracy of this method

This method works reasonably well if the house is 5 ACH_{50} or less and the ducts are fairly leaky because this method relies on subtracting total house leakage from total house leakage with ducts sealed. Since the house leakage is often 1000 to 5000 CFM but the duct leakage to outdoors must be less than 100 CFM, repeatability is extremely important. Repeatability is typically 1 to 3% depending on the wind and how long readings are taken for. This 1 to 3% translates into 10 to 150 CFM meaning that measuring 100 CFM could be in error by 10 to 150%. Still, if you have a blower door and no DucTester, this method could be useful although adding the DucTester and using the Blower Door gauge would make it inexpensive to add the DucTester.

> *“If you want to measure how much a cup a coffee weighs. The method I use is - I step on my bathroom scale and weigh myself and then re-do with the cup of coffee. I subtract the 2 measurements to determine the weight of the coffee. How accurate is this method?”*
>
> *Courtesy of Joe Medosch of the Moultrie Technical College*

Modified Blower Door Subtraction Test using a DM-2

1. Setup for a depressurization basic air leakage test.
2. With the air handler off, open all registers, and remove all filters from the HVAC.
3. Seal all exterior combustion air intakes and vents, connected to the ducts.
4. Press **[Set Pressure] [50] [Enter]** to depressurize the building to -50 Pa (or manually adjust the fan speed to reach -50 Pa). Press **[@ Pressure]** until “@50” is displayed or “@25” if results at 25 are required to improve accuracy. Note: the value the **[@ Pressure]** key displays can be changed in using the Setup key.
5. The measured flow is the Whole House Leakage at 50 Pa or at 25 Pa if “@25” was used.
6. Press **[Exit]** to turn the Blower Door off.
7. Seal all supply and return registers with Grill Mask.
8. Depressurize the house to -50 Pa again. The measured flow is the Envelope Leakage at 50 Pa.
9. Measure the pressure in the duct system, either at the return or supply plenum, or behind the Grill Mask at a supply or return register. This is the Duct Pressure.
10. Use the measured Duct Pressure and determine the correction factor from Table 6.
11. Calculate the “Duct Leakage to Outdoors” by subtracting the Envelope Leakage (step 8) from the Whole House leakage (step 5), and then multiplying that result by the correction factor.

$$(\text{Whole House CFM50} - \text{Envelope CFM50}) \times (\text{Correction factor}) = \text{Duct leakage to outdoors at 50 Pa}$$

Table 6: Correction factors for duct pressure

Duct Pressure	Subtraction Correction Factor
11	6.71

Duct Pressure	Subtraction Correction Factor
31	2.14

Duct Pressure	Subtraction Correction Factor
12	6.12
13	5.63
14	5.20
15	4.83
16	4.51
17	4.23
18	3.97
19	3.74
20	3.54
21	3.35
22	3.18
23	3.03
24	2.89
25	2.76
26	2.64
27	2.52
28	2.42
29	2.32
30	2.23

Duct Pressure	Subtraction Correction Factor
32	2.06
33	1.98
34	1.91
35	1.84
36	1.78
37	1.71
38	1.65
39	1.60
40	1.54
41	1.49
42	1.44
43	1.39
44	1.34
45	1.29
46	1.24
47	1.19
48	1.14
49	1.09
50	1.00

To get duct leakage to a more commonly used 25 Pa, multiply the result by 0.64. Alternatively, set the pressure to 50 Pa for the test but use the "@25Pa" feature to estimate the flow at the desired test pressure. You must still correct this result using the Subtraction Correction Factor.

***Example:** Whole House leakage is 2200 CFM50; Envelope leakage with ducts sealed off is 2100 CFM50 the duct pressure is 39 Pa giving a correction factor of 1.60. Calculate as follows: 2200-2100 = 100 x 1.60 = 160 which means the ducts leak 160 CFM at 50 Pa. For duct leakage at 25 Pa which is required by most Codes, Multiply 160 X 0.64 = 102 CFM*

Improve the accuracy and ease of testing by pressurizing and other methods

Pressurize instead of depressurizing the house because the tape will not be blown off the registers. Retrotec 1000 and 2000 fans don't require any changes when pressurizing so long as the red tube is connected to the red port the gauge will show the positive pressure and correct automatically but other fan makes require a reference tube be attached between the gauge and outdoors on Channel B (this step is usually missed) otherwise huge error will result. Most Codes require testing in the opposite direction (depressurization) for house leakage measurement which means another test should be performed in that direction for house leakage although both results should be very similar.

Use the @50 Pa or @25 Pa feature on the gauge depending on at what pressure you want results. Take the house test pressure up to 50 Pa for both tests but the gauge will display the reading at exactly the pressure you need which will eliminate the inaccuracy of needing to get the test pressure exactly right.

Set the Time Average to 20 seconds on a calm day and one minute on a windy day or even 2 minutes on a very windy day. This will alleviate the largest source of error and takes less time than performing a multipoint test with a computer which doesn't add much more in the way of accuracy. Take test points for at least as long as the time averaging setting.

4.2.2. Test Duct Leakage to Outdoors by measuring air flow with a Flow Hood

A flow hood can be used to measure the flow going in to or coming out of a register, and can therefore determine total duct leakage to the outdoors. The house is pressurized or depressurized with all the ducts sealed and a flow hood on one register. If there is any flow measured at the register, it will be due to the pressure difference between the house and outdoors through the ducts.

To measure duct leakage with a flow hood

1. Setup the house for a basic air leakage test.
2. Turn off the air handler, and open all registers. Remove all HVAC filters.
3. Seal all combustion appliance air intakes.
4. Seal all ventilation intakes that are connected to the duct system.
5. Seal all supply and return registers, but leave the largest register that is close to the air handler open.
6. Pressurize the house to 50 Pa (or depressurize to -50 Pa).
7. Place the flow hood over the open register. Record the flow. The measured flow is an estimate of the total duct leakage to the outdoors.

Most flow hoods are capable of measuring airflow in both directions, and the house can be pressurized or depressurized. Make sure to follow the manufacturer's guidelines for proper operation of the flow hood.

4.2.3. Check to avoid errors in Leakage to Outdoors measurement

When estimating duct leakage to the outdoors with any of the methods described above, it is important to make sure that unconditioned spaces that contain ductwork have a balanced pressure with the outdoors. The estimate of duct leakage to the outdoors will be inaccurate if the unconditioned spaces become partially pressurized during the test. One way to verify that the unconditioned spaces have an equal pressure balance is to conduct a simple zone test on the unconditioned spaces.

To check the zone pressure in unconditioned spaces

1. Open vents, doors, or windows from the unconditioned spaces to the outdoors.
2. Perform a zone test on the unconditioned spaces, with the Blower Door on.

3. If the house to unconditioned space pressure difference is equal (or nearly equal) to the pressure difference between the house and outdoors, then there is nothing to worry about.
4. If the pressure difference does not equal the pressure difference between the house and outdoors, and the variance is more than 5 Pa, then the measured duct leakage to outside will be artificially low.

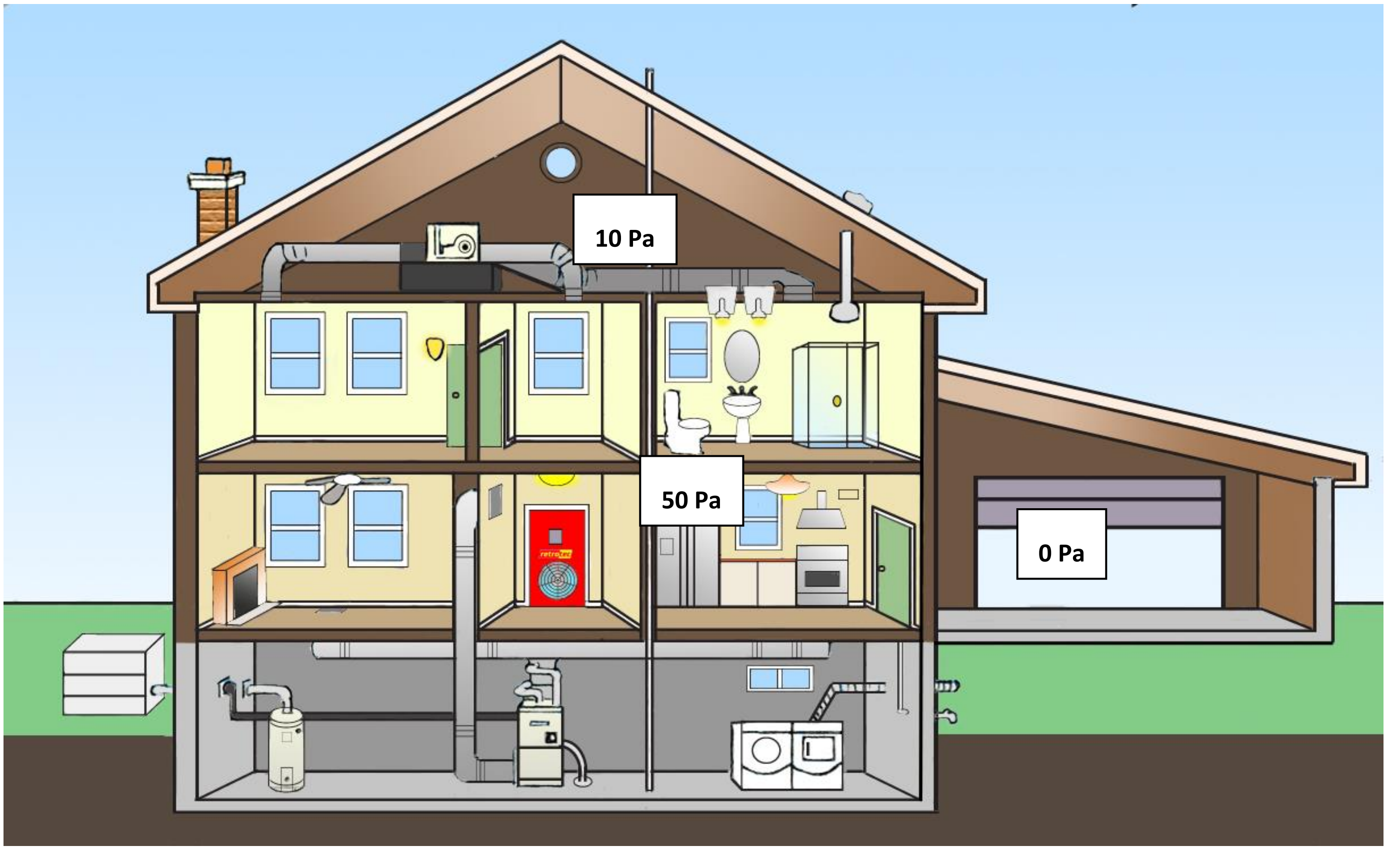


Figure 10: Zonal pressures in a home's unconditioned spaces.

In the picture in Figure 10, all displayed pressures are relative to the outdoors. The house is pressurized to 50 Pa. The unconditioned garage is open to the outdoors and has no pressure difference. The unconditioned attic, however, does not open to the outdoors, and displays a 10 Pa relative to the outdoors. Duct leaks in the attic, therefore, will not be fully reflected in the measurements made in any of the procedures as described above.

4.2.4. Create a leakage map of the duct system with a Pressure Pan test on each register

A pressure pan can be used to locate Duct Leakage to the Outdoors with a Blower Door. With the building pressurized to 50 Pa, a pressure pan can be placed over each register to take a measurement of the pressure between the duct and the room where the register is located. The larger the pressure difference, the larger the leak(s) in the nearby ducts. A general leakage map of the duct systems can be made by testing each register in the building. This method can also be used after duct repairs, to determine if all major leakage sites have been fixed.

A measurement of 50 Pa would indicate a complete disconnect of the duct system, because it indicates there is pressure difference between the house and the duct which is the same as the pressure difference between house and outdoors. Typically, a pressure pan will have a reading of 0 to - 20 Pa when the house is depressurized to -50 Pa. Higher readings indicate a higher degree of connectivity to the outdoors than to the house, and the presence of large leaks in the duct system. Ultimately, a measurement of 0 Pa would indicate no leakage from the duct system because it shows that the ducts are at the same pressure as the house (0 Pa difference).

Figure 11 Small and Large Pressure Pans

To test registers using a pressure pan

1. Connect a pressure tube from the "Input A" (blue) port on the gauge to the port on the pressure pan.
2. Place the pressure pan over the register, so that it is completely blocked. If the register is too large and cannot be totally covered by the pressure pan, seal around the register with Grill Mask, until the remaining hole can be covered by the pressure pan.

Channel A displays the pressure difference between the house and the duct system behind the register.

4.2.5. In a pressurized house, smoke will be pulled quickly into the duct near the leaks

One of the simplest ways to identify leaky sections of duct is with a smoke tester while the house is pressurized. Large duct leaks will pull a lot of air into the duct system nearby the leaky sections. This test works because when the house is pressurized, the ducts should be similarly pressurized. However, when there are large leaks to the outdoors in the duct system, the area around the leak will be at a smaller pressure than the rest of the house/duct system. Air, therefore, will be pulled into the lower pressure area, and out through the leak.

To perform a smoke test for leaky ducts

1. Turn off the air handler, and open all registers. The air filter should be removed.
2. Setup the Blower Door for a basic air leakage test, and pressurize the building to about 25 Pa.
3. Squirt a small amount of chemical smoke near each register. If the smoke is pulled into the register quickly, it is an indication that there is a significant leak to the outdoors in the nearby ducts. If the smoke does not enter the ducts, or does so slowly, there is little to no leakage in the area.

4.3 Closed bedroom door test to check pressure balance

Some rooms, especially large master bedrooms, can cause pressure balancing problems when the door to the room is closed. In some cases, a room may be more connected to the outdoors than to the rest of the house when air isn't able to pass through the doorway.

To conduct a closed room door test

1. Pressurize or depressurize the house to 50 or -50 Pa as for a basic air leakage test.
2. Use a second gauge or manually control the fan speed so that the gauge can be used for zone testing.
3. Close the door to the room and make sure the house pressure is still at 50 Pa.
4. Conduct a zone pressure test of the room.
5. If the room pressure is similar to the house pressure, then the room is well connected to the house. If the room pressure is more similar to the outside pressure (there is close to a 50 Pa difference between room and house), then the room is more connected to the outside.

4.4 Apartment air leakage

Apartments are unique in that air leakage can be from the apartment to the outdoors as in a house, but also from one apartment to an adjacent unit, to the floor above or below, or to the hall. In order to measure leakage in one specific direction, it is necessary to open doors to adjacent spaces to pressurize them the same as the outdoors, or to pressurize adjacent spaces to the same test pressure to neutralize leaks in one direction.

4.5 Closed door leakage

To measure the leakage of a door in a house:

1. Set the Blower Door up over top of the existing door with the existing door closed.
2. Measure the flow when pressurized – this is due to leakage of the door and Blower Door Panel
3. Seal the door with tape
4. Measure the flow when pressurized –this is due to leakage of the Blower Door Panel
5. Subtract measurement in Step 4 from Step 2. That gives the flow due to door leakage alone.

4.6 Measure air handler flow using a blower door

Figure 12 Flex attached to Blower Door

A blower door can be the ideal tool to measure air handler flow because it has more flow capacity than any residential airhandler. A Duct Tester can also be used in some cases but will not measure the largest residential air handler flows. In California for example, 400 CFM is required per Ton; so a 5 Ton system would need 2000 CFM of airhandler flow. Below the capacity of any duct tester.

Using the methods described in the next two sections, may be the lowest cost alternative since either a Blower Door and/or Duct Tester may already be on site when the system airflow must be measured. All that is required is to connect them to the duct work with the flexduct. Both methods will typically have errors of less than 7% or 5 CFM whichever is greater.

Since flow will be measured in real time, airhandler flow rate can be displayed on a Smart Device while adjustments are made to the system; such as opening register control dampers, opening and closing interior doors that will all affect total airhandler flow rate.

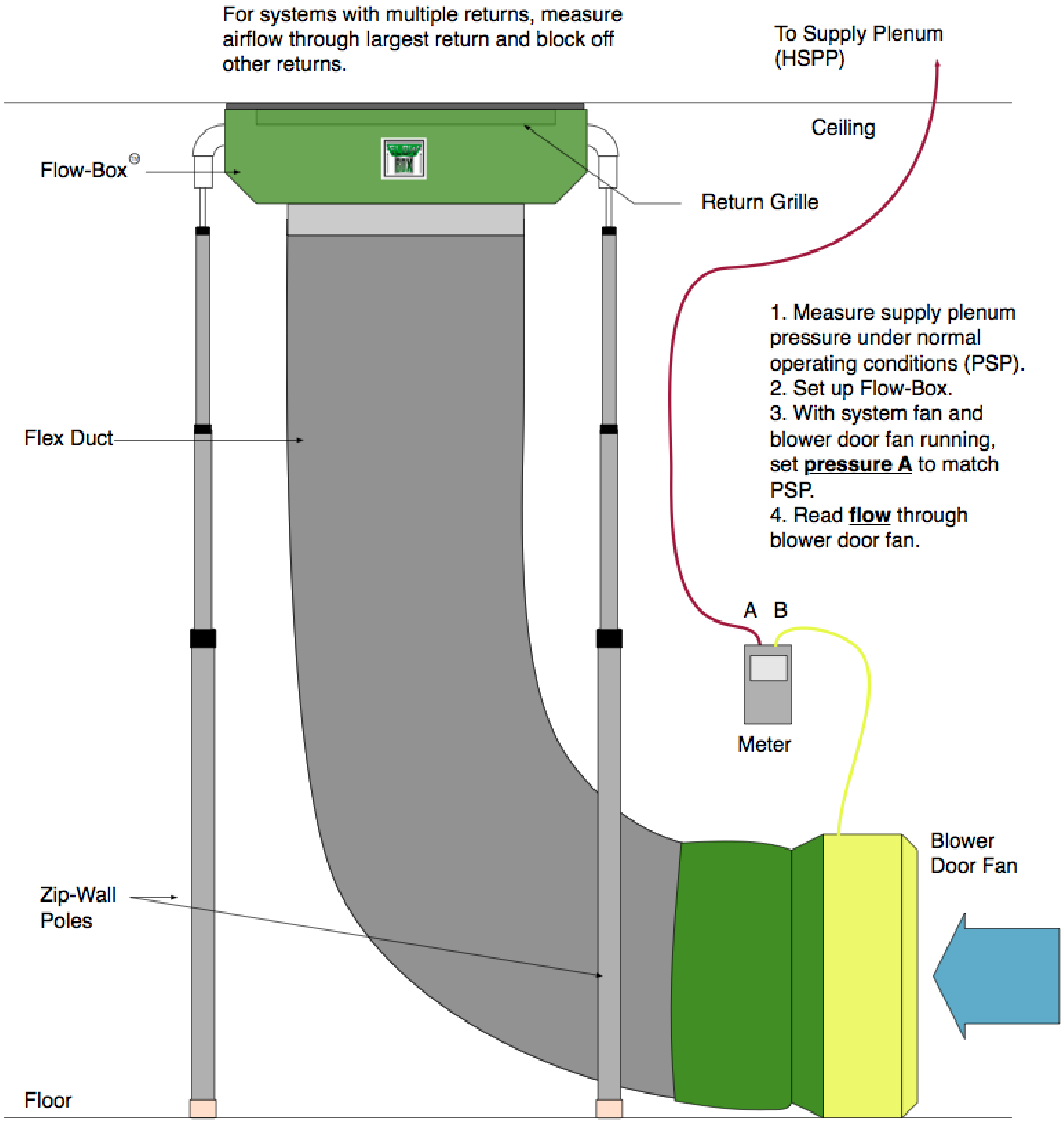
Both methods duplicate the inlet conditions to those that would be in effect at the register prior to measurement. In other words, the procedure attempts to make the flow measurement in such a way that the flow rate itself if not affected. This is in contrast to using another device such as a passive flow hood that adds resistance to flow caused by the restriction of its hood.

In the case of the first choice, the "Supply plenum matching method", the air handler flow in unaffected because the supply plenum pressure is returned to its original value by adjusting the Blower Door speed. In the case of the second choice, where the Blower Door is used as a "Powered Flow Hood", the air handler flow is also unaffected because the pressure in front of the hood set to zero by adjusting the Blower Door speed.

Figure 13 Flow-Box™ by Sierra Building Science, Inc.

4.6.1. Supply Plenum Pressure Matching Method

After inserting the Blower Door or DucTester (Test Fan) into the system, the flow will be altered. Usually reduced. The Test Fan speed is increased to compensate. Adjusting the Test Fan until the supply plenum pressure returns to its original value will ensure the true flow rate is being measured. The original flow can now be measured directly by the Blower Door's Test Fan.



Plenum Pressure Matching

1. Run the airhandler at full speed with a clean filter in place.
2. Measure the static pressure in the supply plenum with the Blue tube going to Channel A. Insert a static pressure probe in an area in the plenum where the pressure signal is stable meaning it does not fluctuate more than 3% on 5 second averaging. Record this pressure.
3. Connect a flex duct to the outlet of your Test Fan from your Blower Door or Duct Tester.
4. Connect the other end of the flex to a return or air handler cabinet using a hood that could be a flange or box attached to the flex duct. The yellow Fan Pressure tube must be connected between your test fan and gauge.
5. Adjust the Test Fan speed to recreate the original plenum pressure by tapping on “Set Pressure” then the value of the original plenum pressure measured in Step 2. Or, use the alternative method.
6. Use the “@” feature which will extrapolate your readings to the exact static pressure measured previously in the supply plenum in Step 2. Go to Step 9.
7. Record the plenum pressure before and during the flow measurement.

When the plenum pressure is matched, the pressure where the Test Fan connects to the register will be very close to zero with respect to the room such that small leaks around the connection will be insignificant. When connecting to the air handler cabinet, gaps will create more errors since the negative pressure in the cabinet will cause any leaks around the connection to be unmeasured.

If there is one main return and several small returns, the smaller ones should be taped over so all the flow is being measured through the main return. Total airhandler flow rate will be the sum of the measured value plus any leakage (hopefully minor) through the return ductwork. If this leakage is major, then obviously it must be fixed which will then yield a higher air flow measurement.

Alternative method using Set Speed:

5. Adjust the Test Fan speed using [Set Speed] to recreate the original plenum pressure.
6. Under [Settings] change the [Default @ pressure] to the original plenum pressure. Use the “@” feature which will extrapolate your readings to the exact pressure.

Alternative method using manual speed control with the knob:

5. Adjust the Test Fan speed with the control knob to recreate the original plenum pressure. If the knob appears unresponsive. Turn it to zero and then clockwise to get the fan started.
6. If there is a difference between before and after pressures, correct using this formula: CFM at normal conditions = CFM measured X square root of [(original plenum pressure)/(plenum pressure during test)].

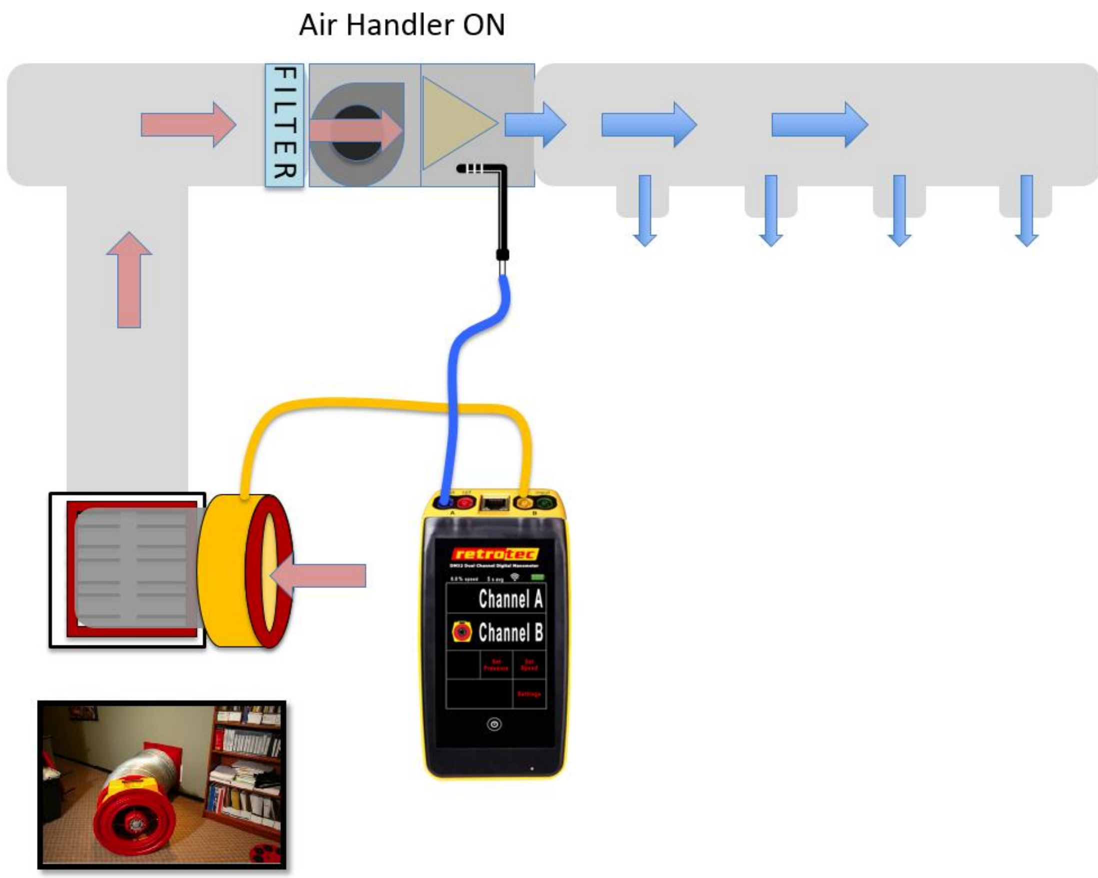


Figure 14 Supply plenum pressure matching method

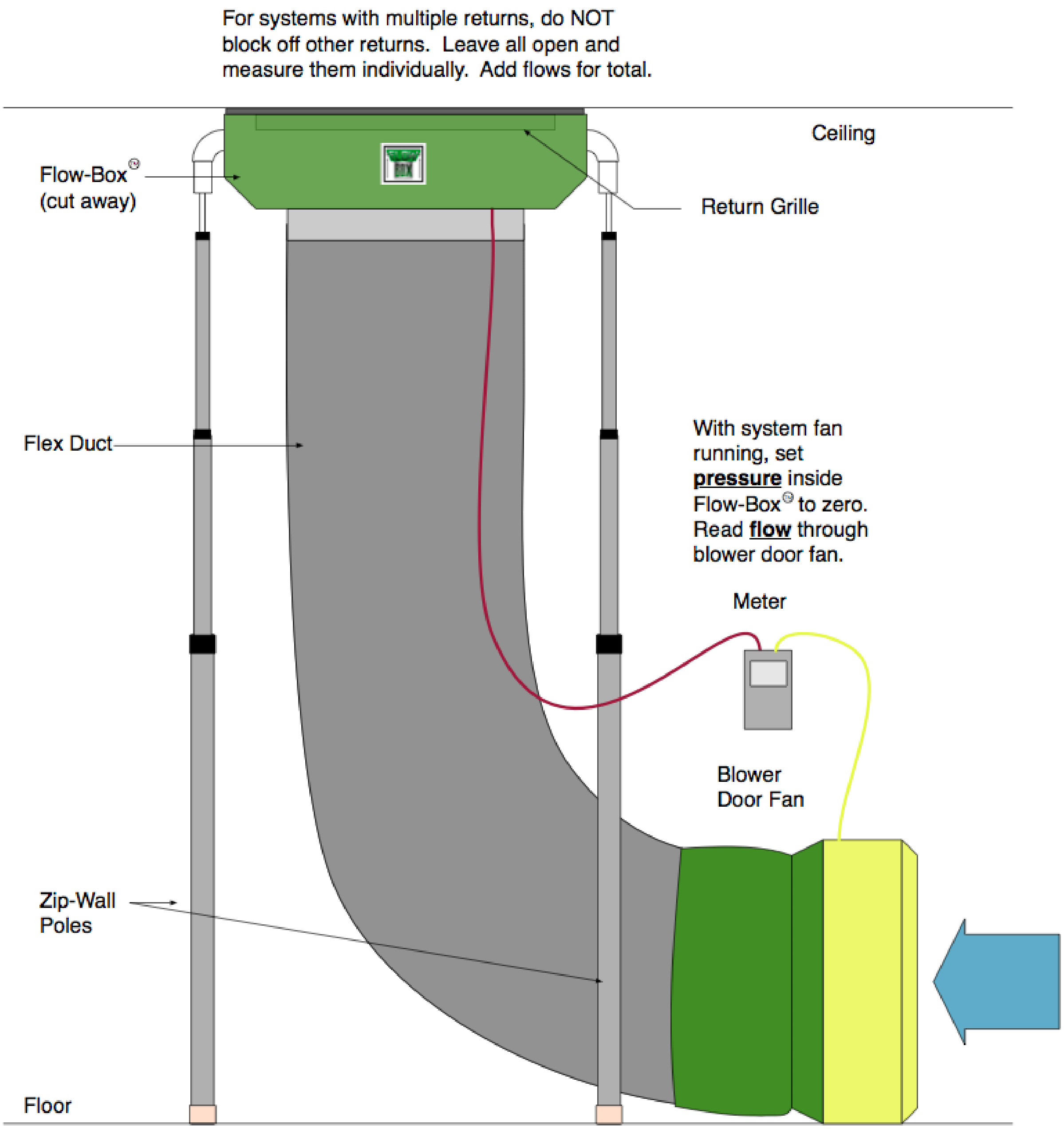
4.6.2. Using your Blower Door as a Powered Flow Hood

This method is faster than the previous one. When measuring at a return (NOT at the airhandler) the effect of inserting the hood can also be eliminated by using the Set to 0 function on the gauge. This feature will cause the Test Fan to speed up until there is no resistance to flow caused by the insertion of the hood. You can then measure the flow rate caused by the air handler through that register. Since the hood will cause turbulence and change the air flow lines into the register, this method may not be as accurate as the previous method but its advantage is that no correction need be made and connection to the supply plenum is not needed.

If there are multiple registers this method would be more accurate because the flow through each register can be measured separately, then the sum of all register could be used to determine the total air handler flow.

Typically, once installed the pressure tap on the flange will yield a negative pressure that will be displayed on Channel A. You would then Set Pressure to zero which would cause the fan to speed up and return the pressure at the flange to zero which closely approximates the condition prior to the flange being installed over the return register.

This method will NOT work when the Device is mounted to the airhandler cabinet since the pre-existing pressure will already be a large negative value and setting this to zero would eliminate all the resistance of the return ductwork and give a much larger flow rate than was actually present under normal operating conditions.



Powered Flow Hood

1. Connect the flex duct to the outlet of your Blower Door or Duct Tester (Test Fan).
2. Connect the other end of the flex to a return register using a Hood which could be a flange or box attached to the flex duct.
3. The yellow Fan Pressure tube must be connected between your test fan and gauge.
4. Connect the Blue tube between Channel A and the connection point on the Hood.
5. Run the airhandler at full speed with a clean filter in place.
6. Set gauge to 5 second averaging.

7. Tap [Set Pressure] [0] to get Test Fan to automatically adjust the pressure at the Hood back to zero. Or, use the alternative method. You will not be able to use the "@" feature.
8. Record the flow measurement.
9. Measure additional returns using the same method and add them together. Alternatively, if there is one main return, you may block the smaller returns and measure the total from one location but it may be low. If unsure, use the Plenum Matching Method.

Alternative method using Set Speed:

7. Adjust the Test Fan speed using [Set Speed] to create a zero pressure in the Hood.
8. Record the flow measurement.

Alternative method using manual speed control with the knob:

7. Adjust the Test Fan speed with the control knob to create a zero pressure in the Hood. Turn it to zero and then clockwise to get the fan started.
8. Record the flow measurement.

4.7 Measure large exhaust and intake flow rates

The previous methods can be utilized to measure large rooftop exhaust or air intake flow rates. The essential idea behind the test method is to construct a tent over the source of the flow and to use a blower door to bring the pressure inside the measurement tent to zero and in so doing to not affect the flow rate that was there originally. There are two methods to do this:

1. Measure the pressure difference across the tent with at least two pressure hoses T'd together going to the Blue port of the gauge and to connect the red port of the gauge to at least two pressure hoses T'd together going to the Red port of the gauge. This works well in calm weather but when the wind is blowing it will be difficult to determine zero pressure.
2. Measure the pressure difference between inside the duct referenced to indoors. This pressure signal can be WiFi' d to the operator on the roof who can measure the flow rate into or out of the tent required to re-establish the pressure in the duct prior to the installation of the tent.

Construction of the tent is from stock PRV pipe parts. They can be press fit together to create a framework and covered in plastic using Red Tuck Tape to hold 3 mil Poly together. The blower door fan may rest on the ground and be taped to the poly our mounted in a panel that is taped to the poly. Super tight fit is not essential because the tent will be very close to zero pressure during the measurements.

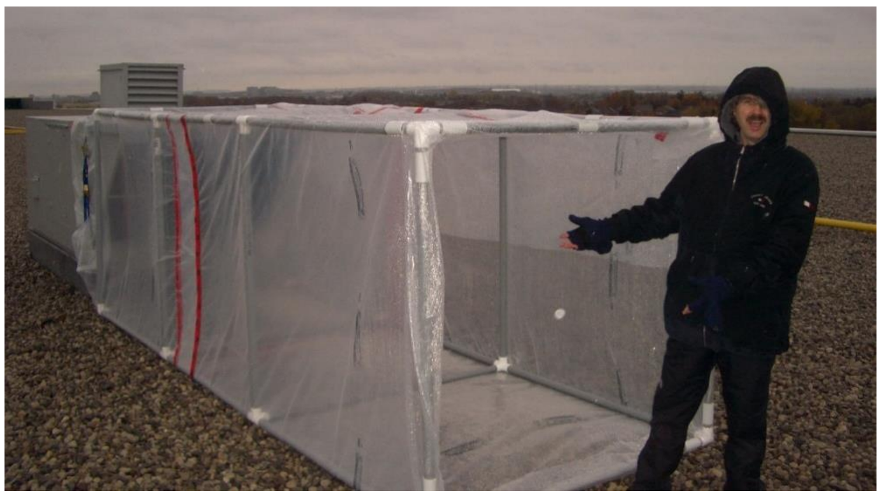


Figure 15 Tent made of poly and PVC pipe courtesy of Terry Brennan of Camroden Associates

Use the "Set Pressure" function on the gauge to set the pressure to zero for method 1 and to the duct pressure in Method 2. Do NOT use the "@" function for Method 1 but you should use it for Method 2.

Rough guidelines for the minimum size of the tent are?

Tent size on each side	Maximum flow into tent	Maximum flow out of tent
2 feet	750 CFM	1500 CFM
3 feet	1500 CFM	3000 CFM
4 feet	3000 CFM	6000 CFM
6 feet	6000 CFM	12000 CFM

Larger tents generally work better because velocities are lower.

5. Some Tests Require Pressure Gauge Only!

Some pressure measurements can be done with a pressure gauge alone. These tests do not require a Blower Door be installed.

5.1 Combustion and Safety Tests

Combustion and safety tests are best done first, because serious system problems may prevent any further testing. Combustion Appliance Zone (CAZ) testing is an important aspect of house testing that can determine if there are any major safety problems. In some cases, air sealing activities done in conjunction with a Blower Door test can cause safety problems, as a tighter house is more likely to have depressurization problems (which can lead to combustion products and/or exhaust air leaking into the house).

Please note that the combustion and safety tests in this document are for general reference only. They should not take the place of local code requirements or procedures.

Combustion products can be spilled back into the building because of the following:

- Poor or improper installation of HVAC equipment
- Blocked or partially blocked chimneys, vents, or vent connectors
- Damaged heat exchangers
- Duct systems leaks
- Cold temperatures in the chimney stack do not allow for much draft in the chimney flue
- Depressurization in the Combustion Appliance Zone (air sealing can cause hazardous depressurization conditions from exhaust fans and forced air system imbalances)

5.1.1. CAZ Pressure Measurement

Vented combustion appliances require external venting of combustion by-products for safety reasons. If any appliances are vented, it is important to determine whether any of the exhaust can back draft (be pulled back into the house).

Worst Case Depressurization Test

There are a number of combustion tests that can be performed, however the most common, and simplest test is a Worst Case CAZ test. A Worst Case test looks to see if the combined force of all depressurization devices (exhaust fans) can create a negative pressure (relative to the outdoors), in an area containing a combustion appliance. If this situation exists, it's possible that the combustion products, including the very dangerous carbon monoxide, can be pulled into the house and not be vented outside.

To setup the house for a CAZ test

1. Seal the house by closing all exterior windows and doors
2. Open all interior doors
3. Open all supply and return registers
4. Turn off all combustion appliances

The following devices can create a negative pressure (with respect to the outdoors)

- Bath exhaust fans
- Range hoods
- Clothes dryers

- Laundry room exhaust
- Attic exhaust
- HVAC air handler
- Central vacuum with canister in unconditioned space

To conduct a Worst Case Depressurization Test

1. Connect the red pressure tube to the “Ref A” (red) port on the gauge, and run it outside.
2. Press [Baseline] to start taking a baseline reading.
3. Wait for 60 seconds. Press [Enter] to apply the baseline to the Channel A readings.
4. Turn on all of the exhaust devices.
5. Close interior doors that do not lead to rooms with an exhaust device.
6. Interior doors can have different effects on house pressure. Some experimentation may be required when choosing to open or close an interior doorway. Monitor the interior pressure when interior doors are open. If the CAZ pressure becomes more negative, close the door, if not, the door can be left open.
7. A Blower Door can be used to simulate exhaust of 300 CFM for houses with fireplaces.
   Note: It is not safe to test with an actual fire burning.
8. Turn on the air handler.
9. If the pressure in the CAZ increases (becomes more positive), turn the air handler off. Interior door positions may need to be changed with the air handler on.
10. Once the most negative possible pressure has been reached, record the value of “PrA” from the gauge as the Worst Case Depressurization pressure.

Test each room with a combustion appliance. Depending on the appliances, there are safety standards that help determine the maximum safe depressurization limits. In general, a negative pressure in excess of -3 Pa would indicate a possible unsafe situation for atmospherically vented appliances. Induced draft appliances will not cause air quality problems until the negative pressure reaches -15 Pa. Discontinue testing if an excessive negative pressure develops. Potentially deadly buildups of Carbon Monoxide (CO) are possible if combustion appliances continue to run with a negative pressure in the house.

Table 7: BPI CAZ Pressure Limits

CAZ Depressurization Limits	
Venting Condition	**Limit (Pa)**
Orphan natural draft water heater (including outside chimneys)	-2
Natural draft boiler or furnace commonly vented with water heater	-3
Natural draft boiler or furnace with damper commonly vented with water heater	-5
Individual natural draft boiler or furnace	-5
Induced draft boiler or furnace commonly vented with water heater	-5
Power vented or induced draft boiler or furnace alone, or fan assisted DHW alone	-15
Chimney-top draft inducer; exhaust type or equivalent; high static pressure flame retention head oil burner; Direct vented appliances; Sealed combustion appliances	-50

5.1.2. Flue Draft Measurement

Measuring flue draft is another useful test to check the integrity of the venting system. Natural draft combustion appliances with a negative pressure inside the vent can begin back drafting combustion products back into the house.

To conduct a draft test

1. Drill a small hole in the vent pipe at the location identified in Figure 16.
2. Connect the red pressure tube to the “Ref A” (red) port on the gauge, and run it outside.
3. Connect the green pressure tube from the “Input B” (green) port on the gauge to the static pressure probe (which is inserted into the drilled hole in the appliance vent).
4. The static pressure probe will cut down the effect of air flowing quickly past the tube, which can have the same effect as wind on the pressure readings.
5. The “Ref B” (yellow) and “Input A” (blue) ports on the gauge must be open to the combustion room pressure.
6. Press [Baseline] to start taking a baseline reading.
7. Wait for 60 seconds, or for the baseline measurement to be steady. Press [Enter] to apply the baseline to the Channel A readings.
8. Turn the appliance ON, allow it to run for 5 minutes.
9. Set the gauge to measure pressure on Channel B (Mode “PrB”).
10. “PrA” is measuring the pressure from the outdoors to the CAZ, and “PrB” is measuring the draft pressure.

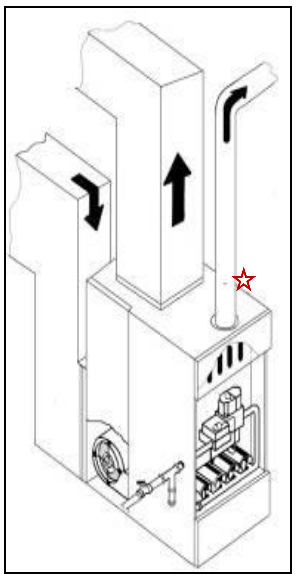
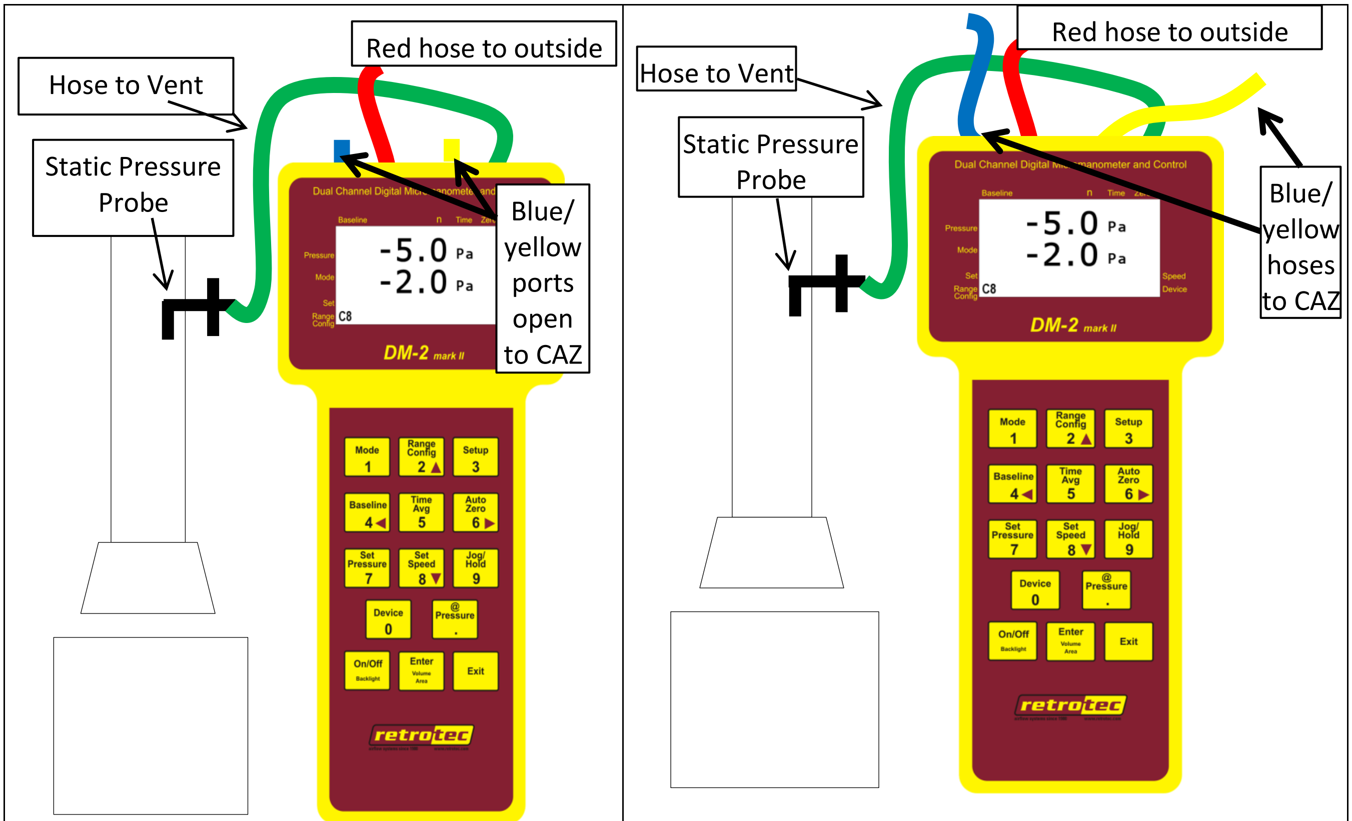


Figure 16: Combustion appliance: Drill a small vent hole where indicated by the red star



Operator inside of the CAZ	**Operator outside of the CAZ**

Figure 17: Tubing set-up for CAZ tests with the operator inside and outside of the CAZ.

Worse case acceptable draft reading per outdoor temp

<20	21-40	41-60	61-80	>80	Fuel Type	<20	21-40	41-60	61-80	>80	Fuel Type
-5Pa	-4Pa	-3Pa	-2Pa	-1Pa	GAS	-15Pa	-13Pa	-11Pa	-9Pa	-7Pa	OIL
-.02wc	-.016wc	-.012wc	-.008wc	-.004wc		-.06wc	-.053wc	-.045wc	-.038wc	-.03wc	

a. VISUALLY INSPECT VENTING (of each Combustion Appliance)
b. TURN OFF ALL COMBUSTION APPLIANCES
c. CLOSE ALL OPERABLE VENTS AND DAMPERS
d. CHECK DRYER VENT and LINT FILTER
e. CHECK FURNACE FILTER (clean or replace if needed)
f. OPEN ALL INTERIOR DOORS

NOTE: IF BLOWER DOOR IS SET UP, BE SURE FAN IS COVERED

1. Setup manometer and pressure hoses to measure CAS (WRT) Outdoors
2. Take baseline pressure and subtract if manually from all readings if manometer doesn't have baseline function _______ Pa
3. Turn on all exhaust fans (do not turn on whole-house fans)
4. Close all interior doors to rooms that do not have exhaust fans
5. If the house has a fireplace that the client uses, turn on the blower door to 300 CFM with Ring B to simulate.

	Appliance 1 Pre	Appliance 1 Post	Appliance 2 Pre	Appliance 2 Post	Appliance 3 Pre	Appliance 3 Post
6. Open door, if present, between CAZ and Main Body of house. Record Reading.						
7. Close door between CAZ and Main Body of house. Record reading. (If no door, skip to step 8).						
8. Turn on Furnace Blower. Check position of interior doors with smoke puffer for worst case. If the smoke blows towards the CAZ, leave the door shut.						
9. Open door between CAZ and Main Body of house. Record reading. (If no door, skip step)						

10. Recreate Worst Case Conditions for each CAZ (Complete this and following steps on each Heating Inspection Form)
11. Perform Worst Case Draft and Combustion Tests for each appliance under this worst case condition

*** If Ambient CO gets above 35ppm, discontinue testing and remove CAZ from worst case conditions.**
*** There should be no spillage after 1 minute of Worst Case and draft should be established after 5 minutes.**

Dominant Duct Leakage test (Main Body WRT outdoors) Baseline _______ Pa Dominant Duct ________ Pa
Pressure in individual rooms (Room WRT Main Body)

Room		Bef	Int	PR	Aft	Room		Bef	Int	PR	Aft	Room		Bef	Int	PR	Aft
1						1						1					
2						2						2					
3						3						3					

Figure 18: Example worst case flue draft test form

5.2 Pressure Balancing and Performance Testing

5.2.1. Pressure Imbalances can be Due to Forced Air Systems

Air handlers typically move from 500 to 2000 CFM of air. When their supply and return flows are not in balance, the building itself can be subject to pressure imbalances. This can increase air infiltration rates, and cause susceptibility to radon and moisture entry, combustion appliance spillage, and backdrafting. A pressure imbalance of as low as 2 Pa can cause back drafting. It is important to understand how a home's HVAC system contributes to the comfort and safety of the occupants.

Pressure imbalances can also be caused by duct leakage to the outdoors, and are exacerbated when the air handler/exhaust fans are on. If there are leaks in the supply duct, the building can suffer depressurization. Depressurization, even by 1 Pa, can lead to severe moisture problems in warm humid climates where infiltrating air carries high volumes of moisture. Infiltrating air will contact cooler surfaces (i.e. backside of gypsum board), reach the dew point and condense. Over time, this can create building integrity issues. When the leaks are in the return duct, the building will tend towards pressurization. When supply and return leaks are equivalent in size, the positive and negative pressures balance out. However this is not often the case.

The following is a set of diagnostic test procedures to help find pressure imbalances caused by leaks in the duct system. Note that these tests are sensitive to wind fluctuations so must be performed under calm conditions.

5.2.2. Run a Dominant Duct Leakage Test

This test will measure the depressurization or pressurization of the building caused by duct leakage to the outdoors while the air handler fan is running.

1. Close all exterior doors and windows, and open all interior doors.
2. Replace (cleaned) HVAC filters. Make sure the air handler and exhaust fans are off.
3. Connect the red tube to the "Ref A" (red) port on the gauge and send it outside. Keep the "Input A" (blue) port open to the building.
4. Take a Baseline on the gauge to zero out any existing bias pressures in the building.
5. Record the air handler OFF pressure from "PrA"
6. Turn on the air handler fan (or exhaust fan) and record the air handler ON pressure
7. Calculate the pressure difference between ON and OFF readings.

Repeat this test several times for more accuracy in your results.

The results can indicate the following:

- Consistent positive pressures indicate a leaky return duct system
- Consistent negative results suggest a leaky supply duct system
- The magnitude of the pressure reading will depend on the amount of imbalance and the tightness of the building being tested
- No change in building pressure indicates that there is either equal supply and return leakage to the outside, no leaks to the outside, or the building is too leaky for the duct leakage to create a measurable pressure change

5.2.3. See if rooms with Closed Doors get pressurized by air handler running

The master bedroom is often the largest room in the home and can contain several supply registers, but no return registers. Measuring the effect of closing the bedroom door on the pressure in the main part of the house can determine whether or not the bedroom is becoming pressurized during air handler activity, while other parts of the home are being depressurized. This test can be repeated for other rooms in the building that have registers, and can be closed off from the main body of the house.

1. Connect the red tube to the “Ref A” (red) port and send the tube outside. The “Input A” (blue) port should remain open to the main body of the house.
2. To monitor the pressure in the room as well, connect the green tube to the “Input B” (green) port and put the other end of the tube under the bedroom door. Keep the “Ref B“ (yellow) port open to the main body of the house.
3. Turn on the air handler and close the bedroom door. Record the pressure changes that occur after closing the bedroom door. Channel A will show the pressure difference between the main body of the house and the outdoors, while Channel B will measure the pressure difference between the main body of the house and the bedroom.
4. If the pressure in the main body of the house changes by 1 Pa or more (in either direction), consider pressure relief measures.

5.2.4. See if the house or any room gets pressurized when all Interior Doors are closed

Similar to the closed bedroom door test, this test looks at the pressure imbalances created when all interior doors are closed.

1. Set up the gauge to measure building pressure with respect to outside (red tube outside, blue port open). Take note of the pressure in the house with respect to outdoors.
2. Close all interior doors and turn on the air handler. Record the pressure change in the main body of the house. If the pressure changes by more than 2 Pa, consider pressure relief measures.

You can also measure the pressures induced by the air handler in each room by connecting the red tube to the gauge “Ref A”. Slide the end of the red tube under each door in turn to see the difference in pressure between the room and the main body of the house. Consider pressure relief measures if pressure differences exceed 3 Pa with respect to the main body.

This is often done for combustion appliance rooms to detect the potential for back drafting and spilling of combustion gases into the house.

5.2.5. Measure household exhaust fan flow

The Retrotec gauge can be used to measure the amount of air flowing through a hole. This feature enables the gauge to be used as an Exhaust Fan Flow Meter, by simply cutting a couple of holes in a cardboard box. The open end of the flow box should have rough dimensions which are at least two times the register dimensions, and the depth of the box should be at least the average of the other two dimensions.

To create an Exhaust Fan Flow Meter

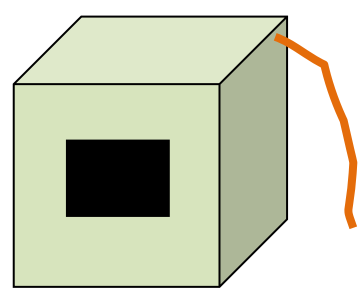


Figure 19: Exhaust fan flow meter

1. Cut a hole in one side of a medium-sized cardboard box where it is only one layer thick, and leaving about one inch of cardboard around the edge for stiffness.
2. Cut a 2" x 2" square hole in the center of the other side of the box, again where the cardboard is only one layer thick. This is the flow measuring hole. For accuracy, the small hole should be at least 1.5 inches from the edge of the box and its area should be less than half the area of the end of the box.
3. Tape any cracks in the other sides of the box to prevent air from leaking.
4. Punch a 0.25 inch diameter hole near a corner of the open end of the box for the pressure tube. Insert a tube in the hole.
5. Connect the tube to the “Ref B” (yellow) and "Input A" (blue) ports of the gauge using a T connector.
6. Fit the box over the exhaust fan grille while it is running, and seal in place around the box edges.
7. Observe the pressure in the box on “PrA”. The same pressure will show on “PrB” if “Mode” is set to Pressure.

8. Increase the size of the flow measuring hole in the box until the pressure is between 2 and 8 Pa.
9. Look up the Exhaust Flow in Table 7 based on the pressure in the box (from “PrA”) and the final area of the flow measuring hole.
10. If you have a Retrotec gauge, it can calculate the exhaust fan flow for you.
    a. Set the “Mode” to “Hole Flow”.
    b. Enter the area of the hole into the gauge using the **[Area]** key.
    c. Read the Exhaust Flow in CFM directly from the gauge on Channel B, “Hole Flow”.

Tip: Box pressure of 8 Pa or less is recommended because higher pressures will decrease the exhaust fan flow rate. Box pressures below 3 Pa are less accurate because small fluctuations in pressure will affect the flow a lot. Try the same fan with different holes to see the different results.

Table 8: Determine exhaust fan flow in CFM (grey cells) with a known hole size under known pressure conditions.

Exhaust Flow (CFM)		Hole Size (sq in)																			
		4	**5**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**
Pressure (Pa)	**1**	4	5	6	9	11	13	15	17	19	22	27	32	38	43	48	54	59	65	70	75
	2	5	7	8	11	13	16	18	21	24	26	33	40	46	53	59	66	72	79	86	92
	2	6	8	9	12	15	18	21	24	27	30	38	46	53	61	68	76	84	91	99	106
	3	7	9	11	15	19	22	26	30	34	37	47	56	65	75	84	93	102	112	121	130
	4	9	11	13	17	22	26	30	34	39	43	54	65	75	86	97	108	118	129	140	151
	5	10	12	14	19	24	29	34	38	43	48	60	72	84	96	108	120	132	144	156	168
	6	11	13	16	21	26	32	37	42	47	53	66	79	92	105	119	132	145	158	171	184
	7	11	14	17	23	28	34	40	46	51	57	71	85	100	114	128	142	157	171	185	199
	8	12	15	18	24	30	37	43	49	55	61	76	91	106	122	137	152	167	183	198	213
	9	13	16	19	26	32	39	45	52	58	65	81	97	113	129	145	161	177	194	210	226
	10	14	17	20	27	34	41	48	54	61	68	85	102	119	136	153	170	187	204	221	238
	11	14	18	21	29	36	43	50	57	64	71	89	107	125	143	161	178	196	214	232	250

5.2.6. Use a pre-built Exhaust Fan Flow Meter instead of building your own box

There are pre-built meters available, which are just a box with a hole in it of a known size as described in the previous section on “Create an Exhaust Fan Flow Meter”. If you wish to use a manufactured box with a hole in it such as the “Exhaust Fan Flow Meter” built by The Energy Conservatory, you can measure the pressure in the flow meter box on any channel of the gauge and look up the flow in the manufacturer’s table reproduced in this document. You can also use the “Hole Flow” Mode on the Retrotec gauge to do the calculation and read the result directly from the gauge as described in the previous instructions.

The Retrotec DM32 and later models of the DM-2 works directly with the “Exhaust Fan Flow Meter”. Set your gauge’s Device to “Mn Exhaust Fan” on the DM-2 or change the Device to “Exhaust” on your DM32. Connect the Meter to Channel B and read off the flow directly. Make sure you are on the correct Range Configuration which should be E1, E2 or E3. You should also check the pressure inside the flow box to ensure it’s not above 10 Pa since this excessive pressure will reduce the fan’s flow rate. If greater than 10 Pa, change to a more open Configuration on the box.

Older models of DM-2 gauge may not give flow readings. Above 10 Pa, this Mode should work fine but the procedure outlined below will always work.

When the “Exhaust Fan Flow Meter” box itself is physically set to a Range of E1, enter an area of 40.7 square inches for the “Hole Flow” Mode on your DM-2 gauge because this is the size of the hole in that box and has been verified to give the same results as the table above. If you change hole size on the “Exhaust Fan Flow Meter”, change the area in the gauge to match:

1. E1 setting, Enter 40.7 square inches
2. E2 setting, Enter 19.3 square inches
3. E3 setting, Enter 9.4 square inches

Table 9: Manufactured Flow Meter Pressure-Flow Look-up

Meter Pressure (Pa)	Flow (CFM)		
	E1	E2	E3
1.0	44	21	10
1.2	48	23	11
1.4	52	25	12
1.6	55	26	13
1.8	59	28	14
2.0	62	29	14
2.2	65	31	15
2.4	68	32	16
2.6	71	33	16
2.8	73	35	17
3.0	76	36	17
3.2	78	37	18
3.4	81	38	19
3.6	83	39	19
3.8	85	40	20
4.0	87	41	20
4.2	90	42	21
4.4	92	43	21
4.6	94	44	22
4.8	96	45	22
5.0	98	46	23
5.2	100	47	23
5.4	102	48	23
5.6	103	49	24
5.8	105	50	24
6.0	107	51	25
6.2	109	52	25
6.4	111	52	25
6.6	112	53	26
6.8	114	54	26
7.0	116	55	27
7.2	117	56	27
7.4	119	56	27
7.6	121	57	28
7.8	122	58	28
8.0	124	59	28

5.2.7. Measure air handler flow with a Flow Grid

Temporarily replacing the filter in the air handler distribution system with a grid containing holes of a known size while the air handler is running allows measurement of the airflow being produced by the air handler. If the filter location is directly adjacent to the air handler, the process will measure the total air handler flow. If the filter is located remotely at a central return, the process will measure airflow through the central return.

The Retrotec gauge can be used with the TrueFlow® Air Handler Flow Meter built by The Energy Conservatory to measure the system air flow using the reading from the Grid and the operating pressure.

Measure the Normal System Operating Pressure (NSOP)

1. Identify the air handler filter, and replace it if dirty.
2. Open all supply and return registers, and open a window or door between the building and the outside.
3. Insert a static pressure probe into the duct system in any of the following locations:

- A side of the supply plenum that does not have a trunk line, supply register, or distribution duct connected.
- A corner of the plenum that does not have any connections within eight inches.
- A side of the return plenum that does not have a trunk line, supply register, or distribution duct connected, and that is a minimum of 24 inches upstream of the TrueFlow® Meter and a minimum of 24 inches downstream of any 90 degree bends in the duct, or trunk line connections.

4. Connect a pressure tube from the static pressure probe to the “Input A” (blue) port on the gauge. If the gauge is not located inside of the house for this test, run a pressure tube from the “Ref A” (red) port to the inside of the house.
5. Turn the air handler on.
6. “PrA” is measuring the Normal System Operating Pressure in Pa.
7. Press **[Time Avg]** to select 1m (one minute) for a one minute averaging on the reading.
8. Wait two minutes before recording the Normal System Operating Pressure.
9. If the measured pressure is less than 10 Pa, or fluctuating significantly, try a different location for the static pressure probe.

Measure the TrueFlow® System Operating Pressure (TFSOP) and Total Air Handler Flow

10. After measuring the Normal System Operating Pressure, turn the air handler off and remove the existing filter.
11. Assemble the metering plate, with the necessary spacers to match the filter slot (see Table 14).
12. Install the metering plate. The front of the plate should face into the airflow. Close the filter access opening. If the plate is installed in a filter grille from a single return duct system, leave the grille door open.
13. Turn the air handler back on (to the same full blower speed setting used to measure the Normal System Operating Pressure).
14. Connect a tube from the red hose on the pressure grid to the Green “Input B” port on the gauge.
15. Connect a tube from the green hose on the pressure grid to the Yellow “Ref B” port on the gauge.
16. Choose the True Flow® as the Device on the gauge.
17. On DM-2, select the Range as either the #14 or #22 Plate.
    a. #22 must be selected on the DM-2 for Plate #20 on the True Flow Grid.
18. On DM32, select the Range as either the #14 or #20 Plate.
19. Set the gauge to display Flow on Channel B.

20. Channel A now displays the TrueFlow® System Operating Pressure, and Channel B displays the Total Air Handler Flow. If flow is not displayed, temporarily disconnect the tube on Channel A and the flow will be displayed. Channel A pressure must be at least 10 Pa otherwise no flow reading will be displayed because 10 Pa is the minimum pressure signal; even then, at pressures below 25 Pa the Flow Grid will not be very accurate. Notice the table does not show flows for Channel B less than 10 Pa.

21. To calculate the Adjusted Total Air Handler Flow choose The easy way or The hard way below. Only Retrotec has the exclusive option to make this calculation the easy way.

Correct Total Air Handler Flow reading to what it would be if the standard filter was in place instead of the TrueFlow®

The flow reading on Channel B is the Total Air Handler Flow. In order to determine the actual flow, as it would be with a standard filter in place, the Adjusted Total Air Handler Flow needs to be calculated from the Normal System Operating Pressure (NSOP) and the TrueFlow® System Operating Pressure (TFSOP).

The easy way

With a Retrotec gauge, first set n to 0.5 using the Set Up key. Then measure the supply pressure in a stable location under normal conditions with a clean filter. Let's say its 121 Pa. Set Pressure on the gauge to 121 Pa and Enter even though we aren't going to use the gauge to control anything, this step makes the calculation that comes next, easy. With the Flow Grid installed and Gauge set to the Flow Grid, measure the flow at say 1000 CFM on Channel B with a pressure of 100 Pa on Channel A. To get the gauge to perform the correction, press the [@] key until the previous supply plenum pressure appears, such as "1100 CFM @121 Pa" for this example. The flow is now corrected without any further calculations.

To confirm this calculation is correct you can set NSOP to 121 and TFSOP to 100 in the below equation. Now, do it the easy way.

The hard way:

The Adjusted Total Air Handler Flow $= \sqrt{\frac{\text{NSOP}}{\text{TFSOP}}} \times Total\ Air\ Handler\ Flow$

Eg: A total air handler flow of 1000 CFM is measured, the NSOP=75 Pa and the TFSOP =60Pa. Calculate 75/60= 1.25. Square root of 1.25 = 1.118 Multiply air handler flow of 1000 CFM by 1.118 to get an Adjusted Total Air Handler Flow of 1,118 CFM which represents the actual system air handler flow.

$\sqrt{\frac{\text{NSOP}}{\text{TFSOP}}}$ can be calculated directly or read from Table 10.

Table 10: Square roots of Normal to TrueFlow® System Operating Pressure ratios.

$\frac{NSOP}{TFSOP}$	$\sqrt{\frac{NSOP}{TFSOP}}$
1.40	1.183
1.39	1.179
1.38	1.175
1.37	1.170
1.36	1.166
1.35	1.162
1.34	1.158

$\frac{NSOP}{TFSOP}$	$\sqrt{\frac{NSOP}{TFSOP}}$
1.05	1.025
1.04	1.020
1.03	1.015
1.02	1.010
1.01	1.005
1.00	1.000
0.99	0.995

1.33	1.153	0.98	0.990
1.32	1.149	0.97	0.985
1.31	1.145	0.96	0.980
1.30	1.140	0.95	0.975
1.29	1.136	0.94	0.970
1.28	1.131	0.93	0.964
1.27	1.127	0.92	0.959
1.26	1.122	0.91	0.954
1.25	1.118	0.90	0.949
1.24	1.114	0.89	0.943
1.23	1.109	0.88	0.938
1.22	1.105	0.87	0.933
1.21	1.100	0.86	0.927
1.20	1.095	0.85	0.922
1.19	1.091	0.84	0.917
1.18	1.086	0.83	0.911
1.17	1.082	0.82	0.906
1.16	1.077	0.81	0.900
1.15	1.072	0.80	0.894
1.14	1.068	0.79	0.889
1.13	1.063	0.78	0.883
1.12	1.058	0.77	0.877
1.11	1.054	0.76	0.872
1.10	1.049	0.75	0.866
1.09	1.044	0.74	0.860
1.08	1.039	0.73	0.854
1.07	1.034	0.72	0.849
1.06	1.030	0.71	0.843

Determine Adjusted Total Air Handler Flow manually using gauge and look up tables

1. Connect the tubing from the installed metering plate to the yellow and green ports (“Ref B” and “Input B”) on the gauge.
2. Display Pressure on Channel B, “PrB” in Pascals (Pa) and record “PrB”.
3. Use Table 11 to determine the flow (in CFM) at the recorded pressure.
4. Use Table 12 to calculate adjusted airflow.

Table 11: Flow through TrueFlow® metering plates at various pressures

Pressure (Pa)	#14 (CFM)	#20 (CFM)	Pressure (Pa)	#14 (CFM)	#20 (CFM)	Pressure (Pa)	#14 (CFM)	#20 (CFM)
10	364	487	70	962	1288	130	1311	1756
11	381	511	71	969	1298	131	1316	1763
12	398	533	72	976	1307	132	1321	1769
13	415	555	73	983	1316	133	1326	1776
14	430	576	74	989	1325	134	1331	1783
15	445	596	75	996	1334	135	1336	1789
16	460	616	76	1003	1343	136	1341	1796
17	474	635	77	1009	1351	137	1346	1803
18	488	653	78	1016	1360	138	1351	1809
19	501	671	79	1022	1369	139	1356	1816
20	514	689	80	1029	1377	140	1361	1822
21	527	706	81	1035	1386	141	1366	1829
22	539	722	82	1041	1395	142	1370	1835
23	552	739	83	1048	1403	143	1375	1842
24	563	754	84	1054	1411	144	1380	1848
25	575	770	85	1060	1420	145	1385	1854
26	586	785	86	1066	1428	146	1390	1861
27	598	800	87	1073	1436	147	1394	1867
28	609	815	88	1079	1445	148	1399	1873
29	619	829	89	1085	1453	149	1404	1880
30	630	843	90	1091	1461	150	1408	1886
31	640	857	91	1097	1469	151	1413	1892
32	651	871	92	1103	1477	152	1418	1899
33	661	885	93	1109	1485	153	1422	1905
34	671	898	94	1115	1493	154	1427	1911
35	680	911	95	1121	1501	155	1432	1917
36	690	924	96	1127	1509	156	1436	1923
37	700	937	97	1133	1517	157	1441	1930

Pressure (Pa)	#14 (CFM)	#20 (CFM)
38	709	949
39	718	962
40	727	974
41	736	986
42	745	998
43	754	1010
44	763	1022
45	771	1033
46	780	1044
47	788	1056
48	797	1067
49	805	1078
50	813	1089
51	821	1100
52	829	1111
53	837	1121
54	845	1132
55	853	1142
56	861	1152
57	868	1163
58	876	1173
59	883	1183
60	891	1193
61	898	1203
62	906	1213
63	913	1222
64	920	1232
65	927	1242
66	934	1251
67	941	1261
68	948	1270
69	955	1279

Pressure (Pa)	#14 (CFM)	#20 (CFM)
98	1138	1525
99	1144	1532
100	1150	1540
101	1156	1548
102	1161	1555
103	1167	1563
104	1173	1570
105	1178	1578
106	1184	1586
107	1190	1593
108	1195	1600
109	1201	1608
110	1206	1615
111	1212	1622
112	1217	1630
113	1222	1637
114	1228	1644
115	1233	1651
116	1239	1659
117	1244	1666
118	1249	1673
119	1255	1680
120	1260	1687
121	1265	1694
122	1270	1701
123	1275	1708
124	1281	1715
125	1286	1722
126	1291	1729
127	1296	1735
128	1301	1742
129	1306	1749

Pressure (Pa)	#14 (CFM)	#20 (CFM)
158	1446	1936
159	1450	1942
160	1455	1948
161	1459	1954
162	1464	1960
163	1468	1966
164	1473	1972
165	1477	1978
166	1482	1984
167	1486	1990
168	1491	1996
169	1495	2002
170	1499	2008
171	1504	2014
172	1508	2020
173	1513	2026
174	1517	2031
175	1521	2037
176	1526	2043
177	1530	2049
178	1534	2055
179	1539	2060
180	1543	2066
181	1547	2072
182	1551	2078
183	1556	2083
184	1560	2089
185	1564	2095

Table 12: Flow Resistance Correction Factors for TrueFlow® Grid Operation (10-50 Pa).

TrueFlow® System Operating Pressure (Pa)	Normal System Operating Pressure (Pa)																				
	10	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**
10	1	1.1	1.18	1.26	1.34	1.41	1.48	1.55	1.61	1.67	1.73	1.79	1.84	1.9	1.95	2	2.05	2.1	2.14	2.19	2.24
12	0.91	1	1.08	1.15	1.22	1.29	1.35	1.41	1.47	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.87	1.91	1.96	2	2.04
14	0.85	0.93	1	1.07	1.13	1.2	1.25	1.31	1.36	1.41	1.46	1.51	1.56	1.6	1.65	1.69	1.73	1.77	1.81	1.85	1.89
16	0.79	0.87	0.94	1	1.06	1.12	1.17	1.22	1.27	1.32	1.37	1.41	1.46	1.5	1.54	1.58	1.62	1.66	1.7	1.73	1.77
18	0.75	0.82	0.88	0.94	1	1.05	1.11	1.15	1.2	1.25	1.29	1.33	1.37	1.41	1.45	1.49	1.53	1.56	1.6	1.63	1.67
20	0.71	0.77	0.84	0.89	0.95	1	1.05	1.1	1.14	1.18	1.22	1.26	1.3	1.34	1.38	1.41	1.45	1.48	1.52	1.55	1.58
22	0.67	0.74	0.8	0.85	0.9	0.95	1	1.04	1.09	1.13	1.17	1.21	1.24	1.28	1.31	1.35	1.38	1.41	1.45	1.48	1.51
24	0.65	0.71	0.76	0.82	0.87	0.91	0.96	1	1.04	1.08	1.12	1.15	1.19	1.22	1.26	1.29	1.32	1.35	1.38	1.41	1.44
26	0.62	0.68	0.73	0.78	0.83	0.88	0.92	0.96	1	1.04	1.07	1.11	1.14	1.18	1.21	1.24	1.27	1.3	1.33	1.36	1.39
28	0.6	0.65	0.71	0.76	0.8	0.85	0.89	0.93	0.96	1	1.04	1.07	1.1	1.13	1.16	1.2	1.22	1.25	1.28	1.31	1.34
30	0.58	0.63	0.68	0.73	0.77	0.82	0.86	0.89	0.93	0.97	1	1.03	1.06	1.1	1.13	1.15	1.18	1.21	1.24	1.26	1.29
32	0.56	0.61	0.66	0.71	0.75	0.79	0.83	0.87	0.9	0.94	0.97	1	1.03	1.06	1.09	1.12	1.15	1.17	1.2	1.22	1.25
34	0.54	0.59	0.64	0.69	0.73	0.77	0.8	0.84	0.87	0.91	0.94	0.97	1	1.03	1.06	1.08	1.11	1.14	1.16	1.19	1.21
36	0.53	0.58	0.62	0.67	0.71	0.75	0.78	0.82	0.85	0.88	0.91	0.94	0.97	1	1.03	1.05	1.08	1.11	1.13	1.15	1.18
38	0.51	0.56	0.61	0.65	0.69	0.73	0.76	0.79	0.83	0.86	0.89	0.92	0.95	0.97	1	1.03	1.05	1.08	1.1	1.12	1.15
40	0.5	0.55	0.59	0.63	0.67	0.71	0.74	0.77	0.81	0.84	0.87	0.89	0.92	0.95	0.97	1	1.02	1.05	1.07	1.1	1.12
42	0.49	0.53	0.58	0.62	0.65	0.69	0.72	0.76	0.79	0.82	0.85	0.87	0.9	0.93	0.95	0.98	1	1.02	1.05	1.07	1.09
44	0.48	0.52	0.56	0.6	0.64	0.67	0.71	0.74	0.77	0.8	0.83	0.85	0.88	0.9	0.93	0.95	0.98	1	1.02	1.04	1.07
46	0.47	0.51	0.55	0.59	0.63	0.66	0.69	0.72	0.75	0.78	0.81	0.83	0.86	0.88	0.91	0.93	0.96	0.98	1	1.02	1.04
48	0.46	0.5	0.54	0.58	0.61	0.65	0.68	0.71	0.74	0.76	0.79	0.82	0.84	0.87	0.89	0.91	0.94	0.96	0.98	1	1.02
50	0.45	0.49	0.53	0.57	0.6	0.63	0.66	0.69	0.72	0.75	0.77	0.8	0.82	0.85	0.87	0.89	0.92	0.94	0.96	0.98	1

Table 13: Flow Resistance Correction Factors for TrueFlow® Operation (50-150 Pa).

	Normal System Operating Pressure (Pa)																				
	50	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**	**135**	**140**	**145**	**150**
50	1	1.05	1.1	1.14	1.18	1.22	1.26	1.3	1.34	1.38	1.41	1.45	1.48	1.52	1.55	1.58	1.61	1.64	1.67	1.7	1.73
55	0.95	1	1.04	1.09	1.13	1.17	1.21	1.24	1.28	1.31	1.35	1.38	1.41	1.45	1.48	1.51	1.54	1.57	1.6	1.62	1.65
60	0.91	0.96	1	1.04	1.08	1.12	1.15	1.19	1.22	1.26	1.29	1.32	1.35	1.38	1.41	1.44	1.47	1.5	1.53	1.55	1.58
65	0.88	0.92	0.96	1	1.04	1.07	1.11	1.14	1.18	1.21	1.24	1.27	1.3	1.33	1.36	1.39	1.41	1.44	1.47	1.49	1.52
70	0.85	0.89	0.93	0.96	1	1.04	1.07	1.1	1.13	1.16	1.2	1.22	1.25	1.28	1.31	1.34	1.36	1.39	1.41	1.44	1.46
75	0.82	0.86	0.89	0.93	0.97	1	1.03	1.06	1.1	1.13	1.15	1.18	1.21	1.24	1.26	1.29	1.32	1.34	1.37	1.39	1.41
80	0.79	0.83	0.87	0.9	0.94	0.97	1	1.03	1.06	1.09	1.12	1.15	1.17	1.2	1.22	1.25	1.27	1.3	1.32	1.35	1.37
85	0.77	0.8	0.84	0.87	0.91	0.94	0.97	1	1.03	1.06	1.08	1.11	1.14	1.16	1.19	1.21	1.24	1.26	1.28	1.31	1.33
90	0.75	0.78	0.82	0.85	0.88	0.91	0.94	0.97	1	1.03	1.05	1.08	1.11	1.13	1.15	1.18	1.2	1.22	1.25	1.27	1.29
95	0.73	0.76	0.79	0.83	0.86	0.89	0.92	0.95	0.97	1	1.03	1.05	1.08	1.1	1.12	1.15	1.17	1.19	1.21	1.24	1.26
100	0.71	0.74	0.77	0.81	0.84	0.87	0.89	0.92	0.95	0.97	1	1.02	1.05	1.07	1.1	1.12	1.14	1.16	1.18	1.2	1.22
105	0.69	0.72	0.76	0.79	0.82	0.85	0.87	0.9	0.93	0.95	0.98	1	1.02	1.05	1.07	1.09	1.11	1.13	1.15	1.18	1.2
110	0.67	0.71	0.74	0.77	0.8	0.83	0.85	0.88	0.9	0.93	0.95	0.98	1	1.02	1.04	1.07	1.09	1.11	1.13	1.15	1.17
115	0.66	0.69	0.72	0.75	0.78	0.81	0.83	0.86	0.88	0.91	0.93	0.96	0.98	1	1.02	1.04	1.06	1.08	1.1	1.12	1.14
120	0.65	0.68	0.71	0.74	0.76	0.79	0.82	0.84	0.87	0.89	0.91	0.94	0.96	0.98	1	1.02	1.04	1.06	1.08	1.1	1.12
125	0.63	0.66	0.69	0.72	0.75	0.77	0.8	0.82	0.85	0.87	0.89	0.92	0.94	0.96	0.98	1	1.02	1.04	1.06	1.08	1.1
130	0.62	0.65	0.68	0.71	0.73	0.76	0.78	0.81	0.83	0.85	0.88	0.9	0.92	0.94	0.96	0.98	1	1.02	1.04	1.06	1.07
135	0.61	0.64	0.67	0.69	0.72	0.75	0.77	0.79	0.82	0.84	0.86	0.88	0.9	0.92	0.94	0.96	0.98	1	1.02	1.04	1.05
140	0.6	0.63	0.65	0.68	0.71	0.73	0.76	0.78	0.8	0.82	0.85	0.87	0.89	0.91	0.93	0.94	0.96	0.98	1	1.02	1.04
145	0.59	0.62	0.64	0.67	0.69	0.72	0.74	0.77	0.79	0.81	0.83	0.85	0.87	0.89	0.91	0.93	0.95	0.96	0.98	1	1.02
150	0.58	0.61	0.63	0.66	0.68	0.71	0.73	0.75	0.77	0.8	0.82	0.84	0.86	0.88	0.89	0.91	0.93	0.95	0.97	0.98	1

Installing spacers for the metering plate

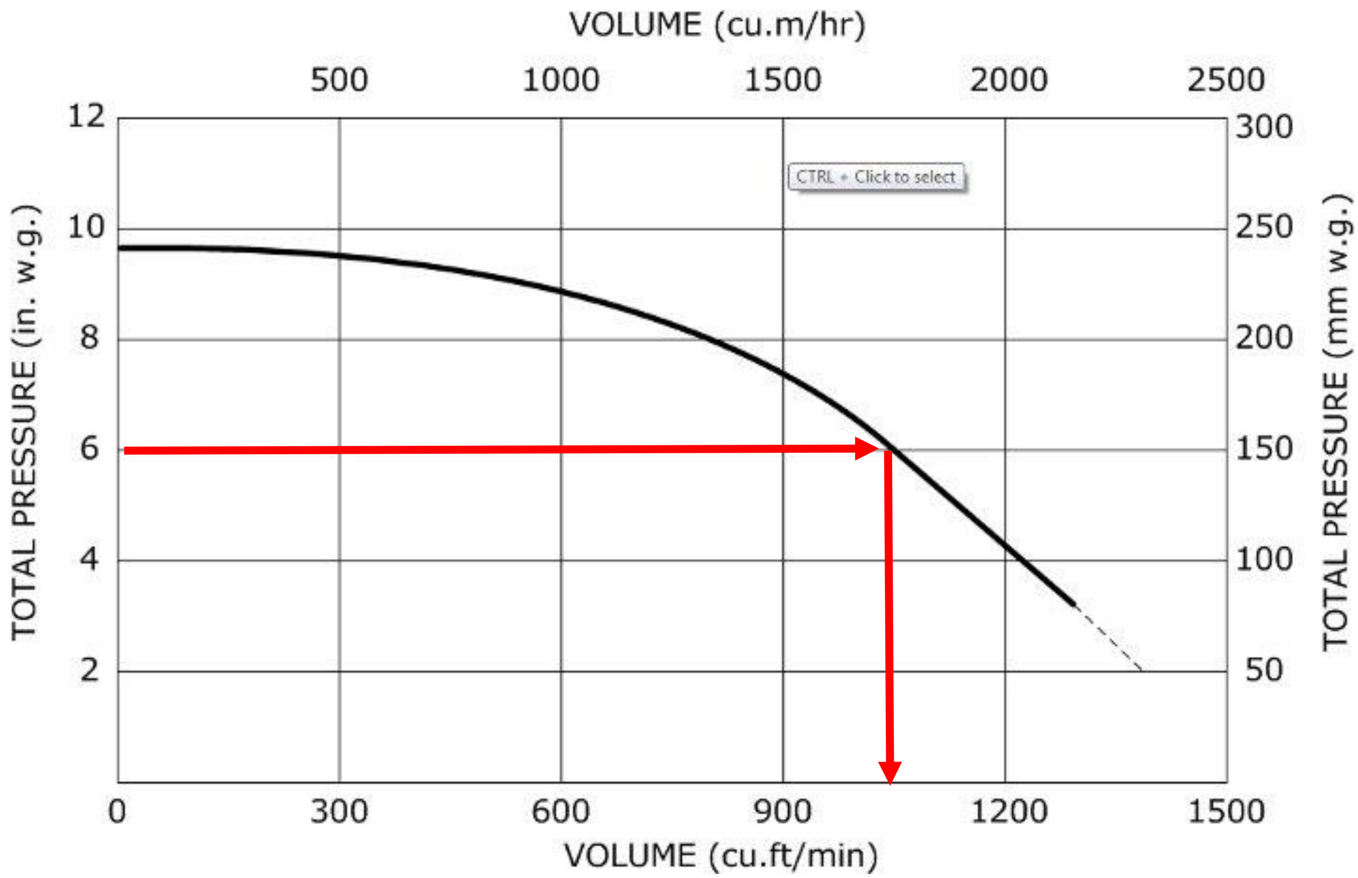
The accuracy of the metering plate is reduced if there are obstructions with six inches upstream, or two inches downstream of the plate, or if there is a 90 degree bend in the duct directly downstream. The spacers (if attached) can be used to lessen the impact of any obstructions. Simply place the spacers against the obstructions, if possible, or install the spacer so that it is on the inside corner of the bend.

Table 14: TrueFlow® Metering Plate spacer selection depending on filter size

Filter Size	Plate #	Spacer 1	Spacer 2
14x20	#14– select 14 on the DM2	-	-
14x25	#14 "	5x14	-
16x20	#14 "	2x20	-
16x24	#14 "	2x20	4x16
16x25	#14 "	2x20	5x16
18x20	#14 "	4x20	-
20x20	#20 – select 22 on the DM2	-	-
20x22	#20 "	2x20	-
20x24	#20 "	4x20	-
20x25	#20 "	5x20	-
20x30	#20 "	10x20	-
24x24	#20 "	4x20	4x24

5.3 Blower Curves

Below is shown a typical Blower Curve where Volume flow is on the X-axis and the pressure the blower is blowing into (or sucking out of) is on the Y-axis. The blower is receiving maximum power throughout the test so in essence the "blower curve" shows how Flow increases as the pressure across the blower decreases. These curves are used for determining whether a blower is suitable for a certain application or might in some cases be used to get a rough idea of the flow rate.



5.3.1. Measuring air handler flow using Blower Curves

Blower Curves can be used to measure air handler flow rate. Most manufacturers will make their blower curves available which will be needed to perform this procedure. You will need to ensure:

1. The blower is receiving its rated voltage. Sometimes the curve will state the voltage and frequency the curve was taken at. You will need to have the same voltage and frequency to get a good estimation since RPM will vary with frequency for synchronous motors and may also vary with voltage.
2. The blower wheel is clean. Curves are created with clean blower wheels so yours must be similarly clean to get a good result.
3. An accurate measurement across the blower so you know what pressure the blower is seeing. Attach a static probe upstream and downstream across the blower so you know the total static pressure it's operating at.

   If for example you measure the pressure drop at 6 in WC, the flow will be 1050 CFM or 1750 cu m/hr. Follow the 6 in WC line horizontally until it hits the Blower Curve and read down to get the flow rate.

5.3.2. Creating a Blower Curve using Hole Flow on the DM-2 or DM32 Gauge

If you do not have a Blower Curve, you can create a reasonably accurate one using a box with the blower sucking out of the box. The blower can be mounted outside and suck out of the box or mounted inside and blowing out of the box. In both cases you'll be measuring a negative pressure in the box. On the far end you'll create different sharp edged holes. Since you can measure the size of the holes and the pressure across the hole, you can use Hole Flow in your gauge to measure a series of flows and plot them against the pressures in the box.

Determine the maximum size of the hole by using this formula:

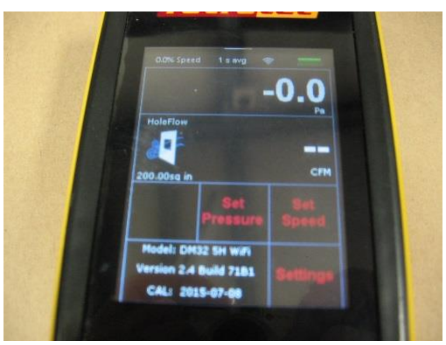
Area of the hole in square inches = Maximum expected CFM / square root of smallest pressure in Pascals / 1.075

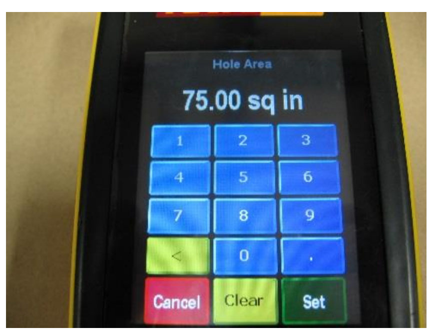
Maximum expected CFM = 806 CFM

Smallest pressure in Pascals = 100

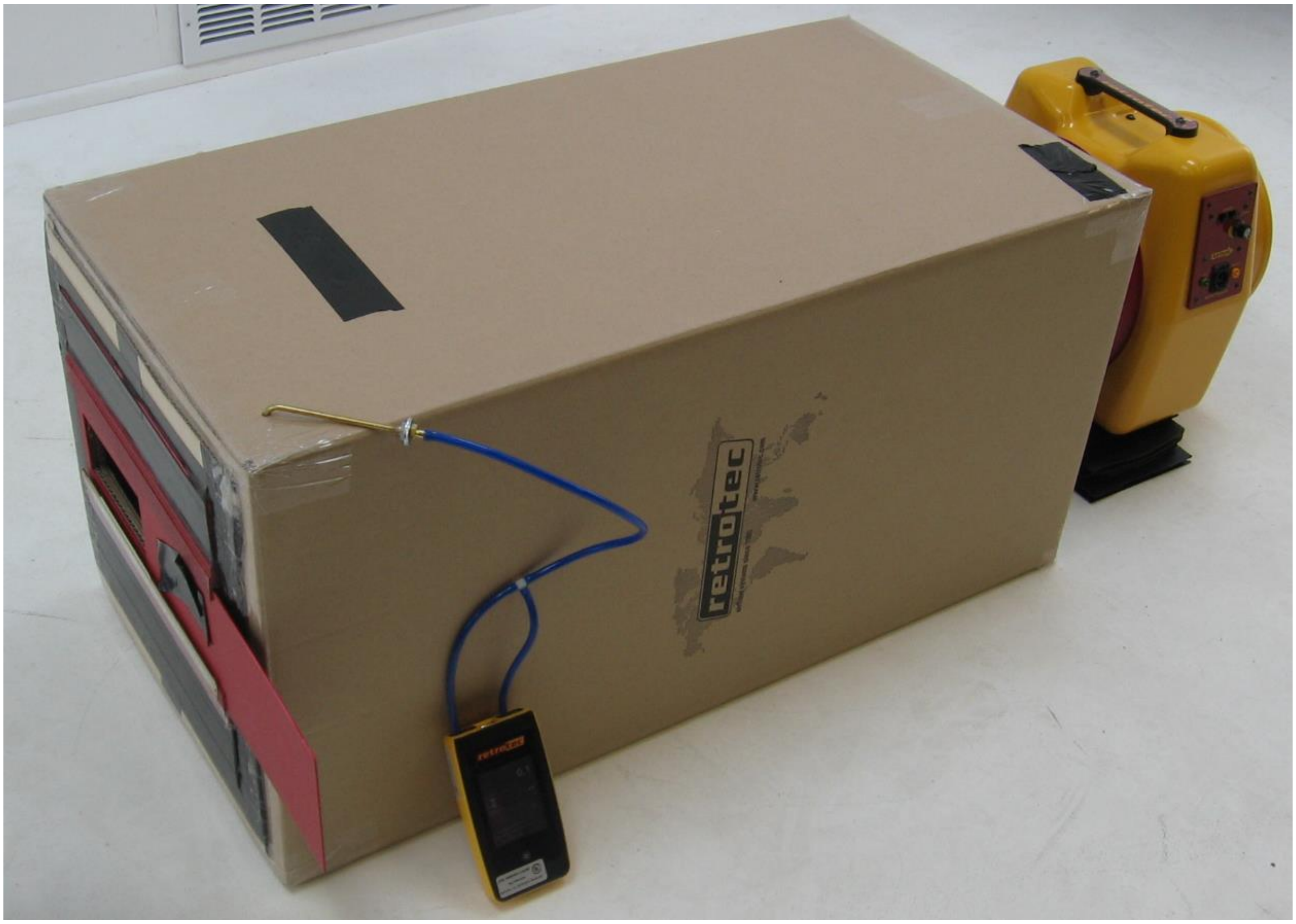
Square root of smallest pressure in Pascals = 10

Area of the hole in square inches = 806 / 10 / 1.075 = 75 square inches. Cut a hole that is 15 x 5 inches to get the required area. To the right, a slider is made of plastic to give the 75 square inch hole and will allow us to accurately reduce the hole size to get readings for larger pressure drops.





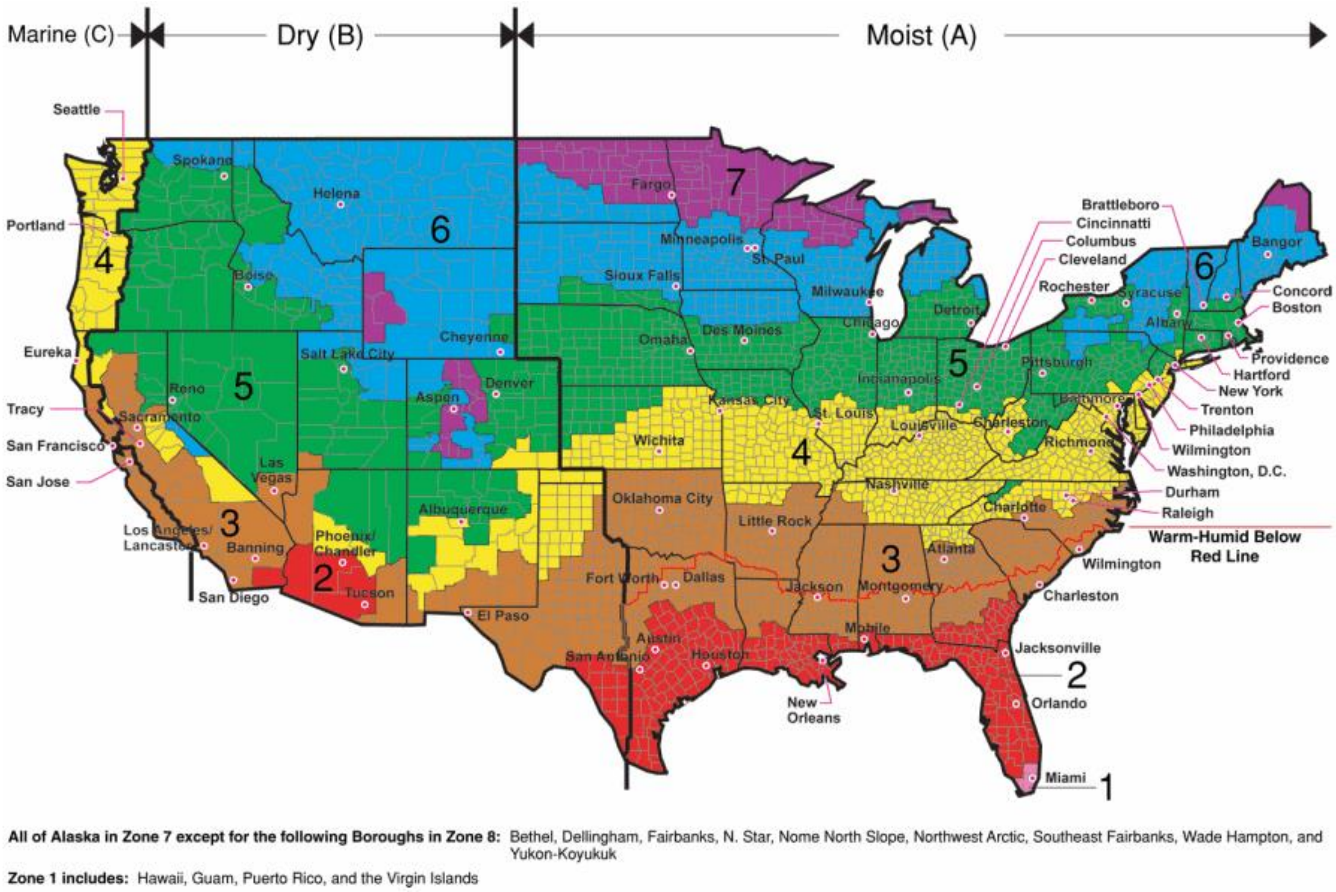
Set the Device to Hole Flow under Generic Devices. Set the Area. Use Settings to access both.



Set up your gauge like this with the tube T'd so that the box pressure goes to the Blue and Yellow on the Gauge. The blower must only run at 100% speed for all measurements to acquire the Blower Curve. Note that normal blower door and/or duct testing readings are taken with the speed adjusted to get the exact test pressure required which is totally different. Blower Curves are NOT used to measure leakage at a specific test pressure – we provide this caution because there is some confusion about how blower curves should be used. Even though that can be used to make rough flow measurements for existing installation, Blower Curves cannot be used to test ducts and building unless they are running at full speed and even then the resultant readings will only be 10% accurate at best compared to blower door and duct tester measurements that are generally below 3% error.

Appendix A: Air Tightness Requirements Tables

Many of the air tightness requirements depend on the climate zone. Climate zone information can be found at the US Department of Energy Climate Zones page.



Residential Air Tightness Requirements

Table 15: <u>Residential</u> airtightness requirements based on floor area of 2,250 sq ft, height of 8 ft, n=0.65.

Program	Standard	Region	Comments	Requirement		ACH 50 n_{50}	CFM50 /sq ft	(m^3/hr50) /m^2
North America								
R-2000	CGSB 149.10	Canada		1.5	ACH50	1.5	0.07	1.3
Vancouver	CGSB 149.10	Canada		3.5	ACH50	3.5	0.17	3.2
LEED for Homes 2008 Certified		USA Canada	Climate Zones 1 and 2, hot areas / semi-tropical	7	ACH50	7.0	0.34	6.2
			Climate Zones 3 and 4	6	ACH50	6.0	0.29	5.3
			Climate Zones 5 to 7	5	ACH50	5.0	0.24	4.4
			Climate Zone 8, extreme northern	4	ACH50	4.0	0.19	3.5
LEED for Homes 2008 2 Pts		USA Canada	Climate Zones 1 and 2, hot areas / semi-tropical	5	ACH50	5.0	0.24	4.4
			Climate Zones 3 and 4	4.25	ACH50	4.25	0.21	3.9
			Climate Zones 5 to 7	3.5	ACH50	3.5	0.17	3.2
			Climate Zone 8, extreme northern	2.75	ACH50	2.75	0.14	2.5
LEED for Homes 2008 3 Pts		USA Canada	Climate Zones 1 and 2, hot areas / semi-tropical	3	ACH50	3.0	0.14	2.6
			Climate Zones 3 and 4	2.5	ACH50	2.5	0.13	2.3
			Climate Zones 5 to 7	2.0	ACH50	2.0	0.10	1.8
			Climate Zone 8, extreme northern	1.5	ACH50	1.5	0.07	1.3
LEED for Homes 2012 1 Pt		USA Canada	Climate Zones 1 and 2, hot areas / semi-tropical	4.25	ACH50	4.25	0.21	3.9
			Climate Zones 3 and 4	3.5	ACH50	3.5	0.17	3.2
			Climate Zones 5 to 7	2.75	ACH50	2.75	0.14	2.5
			Climate Zone 8, extreme northern	2	ACH50	2.0	0.10	1.8
LEED for Homes 2012 2 Pts		USA Canada	Climate Zones 1 and 2, hot areas / semi-tropical	3	ACH50	3	0.14	2.6
			Climate Zones 3 and 4	2.5	ACH50	2.5	0.13	2.3
			Climate Zones 5 to 7	2	ACH50	2.0	0.10	1.8
			Climate Zone 8, extreme northern	1.5	ACH50	1.5	0.07	1.3
EEBA		USA	Energy and Environmental Building Association Guidelines	0.25	CFM50/sq ft	5.2	0.25	4.6
ENERGY STAR V 2.0	ASTM E779	USA	Climate Zones 1 and 2, hot areas / semi-tropical	7	ACH50	7.0	0.34	6.2
			Climate Zones 3 and 4	6	ACH50	6.0	0.29	5.3
			Climate Zones 5 to 7	5	ACH50	5.0	0.24	4.4
			Climate Zone 8, extreme northern	4	ACH50	4.0	0.19	3.5
ENERGY STAR V 3.0	ASTM E779	USA	Climate Zones 1 and 2, hot areas / semi-tropical	6	ACH50	6.0	0.29	5.3
			Climate Zones 3 and 4	5	ACH50	5.0	0.24	4.4

Program	Standard	Region	Comments	Requirement	ACH 50 n_{50}	CFM50 /sq ft	$(m^3/hr50)/m^2$
			Climate Zone 8, extreme northern	3 ACH50	3.0	0.14	2.6
LEED ETS	ASTM E779	USA	Environmental Tobacco Smoke (ETS) air quality standard	1.2 (sq in EfLA 4)/100 sq ft	4.7	0.23	4.2
LEED		USA	Air quality standard used for apartments. All 6 surfaces enclosing an apartment. Same as 1.25 sq in EfLA at 4 Pa.	0.23 CFM50/ sq ft	4.6	0.23	4.2
				1.17 (L/s 50)/m^2	4.6	0.23	4.2
IECC 2012		USA	Climate Zones 1 and 2	5 ACH50	5	0.24	4.4
			Climate Zones 3 to 8	3 ACH50	3	0.14	2.6
IECC 2009		Georgia, USA	All Climate Zones	7 ACH50	7	0.34	6.2
NC Energy Code	ASTM E779	North Carolina, USA		0.30 CFM50/sq ft	6.0	0.30	5.5
				5 ACH50	5	0.24	4.4
ORSC / OEESC		Oregon, USA	3.5 to 5 is Tight, great	3.5 ACH50	3.5	0.17	3.1
			5 to 7 is good	7 ACH50	7.0	0.34	6.2
PA housing	ASTM E779	Pennsylvania, USA	Tight < 5 PA Housing Research/Resource Center (PHRC)	5 ACH50	5.0	0.24	4.4
			Moderate < 10, Leaky > 10 Pa Housing Research/Resource Center (PHRC)	10 ACH50	10.0	0.49	9.0
Europe							
	Passivhaus	Europe		0.6 ACH50	0.6	0.03	0.55
		Austria	Naturally ventilated	3.0 ACH50	3.0	0.15	2.7
			Mechanically ventilated	1.5 ACH50	1.5	0.07	1.4
		Bulgaria	Apartments – high airtightness	<2.0 ACH50	<2.0	<0.10	<1.8
			Apartments – medium airtightness	2.0-5.0 ACH50	2.0-5.0	0.10-0.24	1.8-4.4
			Apartments – low airtightness	>5.0 ACH50	>5.0	>0.24	>4.4
			Single family houses – high airtightness	<4.0 ACH50	<4.0	<0.19	<3.5
			Single family houses – medium airtightness	4.0-10.0 ACH50	4.0-10	0.19-0.49	3.5-9.0
			Single family houses – low airtightness	>10.0 ACH50	10	0.49	9.0
	TNI 73 0329	Czech Republic	Low energy house	1.5 ACH50	1.5	0.07	1.3
	TNI 730330	Czech Republic	Natural	4.5 ACH50	4.5	0.22	4.1
			Forced	1.5 ACH50	1.5	0.07	1.3
			Forced + heat recovery	1.0 ACH50	1.0	0.05	0.9
			Forced + heat recovery passive house	0.6 ACH50	0.6	0.03	0.5
		Denmark	Residential	1.5 (L/s 50)/m^2	6.1	0.30	5.5
		Estonia	Small buildings, new	6.0 (m^3/h)/m^2	-	-	-
			Small buildings, existing	9.0 (m^3/h)/m^2	-	-	-
		Finland	Building heat loss reference	2.0 ACH50	2.0	0.10	1.8
			Energy Performance Certificate	4.0 ACH50	4.0	0.19	3.5

Program	Standard	Region	Comments	Requirement	ACH 50 n_{50}	CFM50 /sq ft	$(m^3/hr50)/m^2$
			(EPC)				
			New apartments	0.5 ACH50	0.5	0.025	0.46
		France	Single family houses	0.8 $(m^3/h4)/m^2$	4.5	0.23	4.1
			Other residential buildings	1.2 $(m^3/h4)/m^2$	6.8	0.34	6.2
		Germany	With Ventilation systems	1.5 ACH50	1.5	0.07	1.4
			Without Ventilation systems	3 ACH50	3.0	0.15	2.7
		Lithuania	Naturally ventilated	3.0 ACH50	3	0.14	2.6
			Mechanically ventilated	1.5 ACH50	1.5	0.07	1.4
		Latvia	Dwellings	3.0 ACH50	3	0.14	2.6
			Ventilated Buildings	3.0 ACH50	3	0.14	2.6
		Netherlands	With Ventilation systems	2-3 ACH50	2-3	0.10-0.14	1.8-2.6
			Without Ventilation systems	4-6 ACH50	4-6	0.19-0.30	3.5-5.5
		Norway		3.0 ACH50	3.0	0.14	2.6
		Portugal	Residential	0.6 ACH	0.6	0.03	0.5
		Slovenia	Naturally ventilated	3.0 ACH50	3.0	0.14	2.6
			Mechanically ventilated	2.0 ACH50	2.0	0.10	1.8
		Slovakia	Single family house with high quality windows	4.0 ACH50	4.0	0.19	3.5
			All other buildings	2.0 ACH50	2.0	0.10	1.8
	TS 825	Turkey	Floor multi-dwelling – High	2 ACH50	2	0.10	1.8
			Med	2-5 ACH50	2-5	0.10-0.24	1.8-4.4
			Low	>5 ACH50	>5	>0.24	>4.4
			Floor, single flats – High	<4 ACH50	<4	<0.19	<3.5
			Med	4-10 ACH50	4-10	0.19-0.49	3.5-9.0
			Low	>10 ACH50	>10	>0.49	>9.0
	ATTMA TSL1	UK	Best practice – naturally ventilated	5.0 $(m^3/h50)/m^2$	5.5	0.27	5.0
			mechanically ventilated	1.0 $(m^3/h50)/m^2$	1.1	0.55	1.0
			Normal practice – naturally ventilated	7.0 $(m^3/h50)/m^2$	7.7	0.38	7.0
			mechanically ventilated	5.0 $(m^3/h50)/m^2$	5.5	0.27	5.0
	ATTMA STd 189, GSA	UK	Best practice	1.8 $(m^3/h50)/m^2$	2.0	0.10	1.8
		UK	Dwelling regulation	5 $(m^3/h50)/m^2$	5.5	0.27	5.0
Other regions							
	CGSB 149.10	Japan	Airtight	2.24 $(cm^2$ EqLA 9.8)/m^2	6.3	0.31	5.7
Green Building Regulations		Dubai, UAE		10 $(m^3/h50)/m^2$	11	0.55	10

Large Building Air Tightness Requirements

Table 16: Commercial airtightness requirements based on a 4 storey building, 120 x 110 x 8 ft per storey, n=0.65

Standard	Region	Comments	Requirement	ACH50 n_{50}	CFM75 /sq ft	$(m^3/hr\ 50)/m^2$
North America						
ASHRAE 90.1	USA	Average	0.30 CFM75/sq ft	3.9	0.30	4.2
		Leaky	0.60 CFM75/sq ft	7.9	0.60	8.4
		Tight	0.10 CFM75/sq ft	1.3	0.10	1.4
LEED	USA	All 6 surfaces enclosing an apartment.	0.23 CFM50/sq ft	2.2	0.17	2.4
			1.17 $(L/s\ 50)/m^2$	3.9	0.30	4.2
USACE	USA	Large Buildings	0.25 CFM75/sq ft	3.3	0.25	3.5
		Large Buildings (proposed)	0.15 CFM75/sq ft	2.0	0.15	2.1
Washington State, Seattle Code	USA	WA Energy Code, 4 storeys or more. Positive induced pressure or both.	0.40 CFM75/sq ft	5.3	0.40	5.6
Europe						
Passivhaus	Europe		0.60 ACH50	0.60	0.050	0.64
	Austria	Naturally ventilated	3.0 ACH50	3.0	0.23	3.2
		Mechanically ventilated	1.5 ACH50	1.5	0.11	1.6
	Belgium		12 $(m^3/h\ 50)/m^2$	11	0.85	12
	Czech Republic	Common Buildings maximum	4.5 ACH50	4.5	0.34	4.8
		Low energy buildings	1.5 ACH50	1.5	0.11	1.6
		Passive houses	0.6 ACH50	0.6	0.046	0.64
		Mechanically ventilated buildings without heat recovery	1.5 ACH50	1.5	0.11	1.6
		Mechanically ventilated buildings with heat recovery	1.0 ACH50	1.0	0.076	1.1
	Denmark (current regulation)	Normal — New building	1.5 $(L/s\ 50)/m^2$	5.1	0.38	5.4
		Normal — Low energy building	1.0 $(L/s\ 50)/m^2$	3.4	0.26	3.6
		Building with high ceiling — New building	0.5 $(L/s\ 50)/m^2$	1.7	0.13	1.8
		Building with high ceiling — Low energy building	0.3 $(L/s\ 50)/m^2$	1.0	0.08	1.1
	Denmark (new regulations: 2020)	Normal — New building	0.5 $(L/s\ 50)/m^2$	1.7	0.13	1.8
		Building with high ceiling — New building	0.15 $(L/s\ 50)/m^2$	0.50	0.04	0.54
	Estonia	Small buildings, new	6.0 $(m^3/h\ 50)/m^2$	-	-	-
		Small buildings, existing	9.0 $(m^3/h\ 50)/m^2$	-	-	-
		Large buildings, new	3.0 $(m^3/h\ 50)/m^2$	-	-	-
		Large buildings, existing	6.0 $(m^3/h\ 50)/m^2$	-	-	-
	Finland	Building heat loss reference	2.0 ACH50	2.0	0.15	2.1
		Energy Performance Certificate (EPC)	4.0 ACH50	4.0	0.30	4.3
	France	Offices, hotels, educational and health care buildings	1.2 $(m^3/h\ 4)/m^2$	5.8	0.44	6.2
		Other buildings	2.5 $(m^3/h\ 4)/m^2$	12	0.92	12.9
DIN 4108-7	Germany	Naturally ventilated	3.0 $(m^3/h\ 50)/m^2$	2.8	0.21	3.0
		Mechanically ventilated	1.5 ACH50	1.5	0.11	1.6

Standard	Region	Comments		Requirement		ACH50 n_{50}	CFM75 /sq ft	$(m^3/hr\ 50)/m^2$
	Lithuania	Naturally ventilated		3.0	ACH50	3.0	0.23	3.2
		Mechanically ventilated		1.5	ACH50	1.5	0.11	1.6
	Latvia	Public and Industrial buildings		4.0	ACH50	4.0	0.30	4.3
		Ventilated Buildings		3.0	ACH50	3.0	0.23	3.2
	Norway			3.0	ACH50	3.0	0.23	3.2
	Slovenia	Naturally ventilated		3.0	ACH50	3.0	0.23	3.2
		Mechanically ventilated		2.0	ACH50	2.0	0.15	2.1
	Scotland	Current regulation		5.0	$(m^3/h50)/m^2$	4.7	0.36	5.0
		New regulation		1.0	$(m^3/h50)/m^2$	0.93	0.07	1.0
	Slovakia			2.0	ACH50	2.0	0.15	2.1
ATTMA TSL2	UK	Best Practice	Office – Natural Ventilation	3.0	$(m^3/h50)/m^2$	2.8	0.21	3.0
			Office – Mixed Ventilation	2.5	$(m^3/h50)/m^2$	2.3	0.18	2.5
			Office – AC/low energy	2.0	$(m^3/h50)/m^2$	3.3	0.21	2.0
			Factories/ warehouses	2.0	$(m^3/h50)/m^2$	3.3	0.21	2.0
			Supermarkets	1.0	$(m^3/h50)/m^2$	0.93	0.07	1.0
			Schools	3.0	$(m^3/h50)/m^2$	2.8	0.21	3.0
			Hospitals	5.0	$(m^3/h50)/m^2$	4.7	0.36	5.0
			Museums / archives	1.0	$(m^3/h50)/m^2$	0.93	0.07	1.0
			Cold stores	0.2	$(m^3/h50)/m^2$	0.19	0.01	0.2
		Normal Practice	Office – Natural Ventilation	7.0	$(m^3/h50)/m^2$	6.5	0.50	7.0
			Office – Mixed Ventilation	5.0	$(m^3/h50)/m^2$	4.7	0.36	5.0
			Office – AC/low energy	5.0	$(m^3/h50)/m^2$	4.7	0.36	5.0
			Factories/ warehouses	6.0	$(m^3/h50)/m^2$	5.6	0.42	6.0
			Superstores	5.0	$(m^3/h50)/m^2$	4.7	0.36	5.0
			Schools	9.0	$(m^3/h50)/m^2$	8.4	0.64	9.0
			Hospitals	9.0	$(m^3/h50)/m^2$	8.4	0.64	9.0
			Museums / archives	1.5	$(m^3/h50)/m^2$	1.4	0.11	1.5
			Cold stores	0.35	$(m^3/h50)/m^2$	0.33	0.03	0.35
	UK (current regulation)	New Building		10	$(m^3/h50)/m^2$	11	0.55	10
		Small Building (less than 500 m^3)		15	$(m^3/h50)/m^2$	16	0.82	15
		Large Building		5	$(m^3/h50)/m^2$	4.7	0.36	5.0
	UK (new regulations)	With cooling requirement		3	$(m^3/h50)/m^2$	2.8	0.21	3.0
		Without cooling requirement		5	$(m^3/h50)/m^2$	4.7	0.36	5.0
Other regions								
Abu Dhabi Building Code (IECC)	Abu Dhabi, UAE	Commercial building test		2.0	$(L/s\ 75)/m^2$	5.2	0.39	5.5
Green Building Regulations	Dubai, UAE			10	$(m^3/h50)/m^2$	9.4	0.71	10
IECC	Global			5.6	$(m^3/h50)/m^2$	5.3	0.40	5.6
Energy Conservation Building Code	India			0.4	CFM75/sq ft	5.3	0.40	5.6
	Japan	Level A		7.5	ACH50	7.5	0.57	8.0

Standard	Region	Comments	Requirement		ACH50 n_{50}	CFM75 /sq ft	(m^3/hr 50)/m^2
QSAS	Qatar	Level B	3.0	ACH50	3.0	0.23	3.2
		Level C	1.5	ACH50	1.5	0.11	1.6
		Low	0.6	(m^3/h 4)/m^2	2.9	0.22	3.1
		Med	1.1	(m^3/h 4)/m^2	5.3	0.40	5.7
		High	2.2	(m^3/h 4)/m^2	11	0.81	11.4

Air Tightness Requirements for Assemblies

Table 17: Air tightness requirements for Assemblies

Standard	Region	Comments	Requirement		ACH50 n_{50}	CFM_{75} /sq ft	(m^3/hr)$_{50}$ /m^2
North America							
Canadian NBC for RH	Canada		0.1	(L/s 50)/m^2	0.26	0.02	0.28
National Canadian Building Code	Canada	Assemblies	0.15	(L/s 50)/m^2	0.33	0.025	0.35

Comparison of different Air Leakage Results for the same enclosure

Table 18: Comparison of different units for a house 50 x 30 x 20 feet, with n=0.65; proposed units are highlighted

Result	Units	Application
1,191	CFM50	House leakage in the US
1,550	CFM75	Large building leakage in the US
0.397	CFM50/sq ft	House and duct leakage in the US
0.253	CFM50/sq ft	House and duct leakage in the US, MLR
0.192	CFM50/sq ft	House and duct leakage in the US
0.250	CFM75/sq ft	Large building leakage in the US
0.249	(CFM @ 0.3 in WC)/sq ft	Large building leakage in the US
66	sq in EfLA4	House leakage in the US
1.06	sq in EfLA4/100 sq ft	Environmental Tobacco Smoke - apartment leakage in the US
123	sq in EqLA10	House leakage in Canada and US
157	sq in EqLA50	
1.98	sq in EqLA10/100 sq ft	
2.53	sq in EqLA50/100 sq ft	
2.38	ACH50, n_{50}	Proposed for houses and large buildings worldwide
0.000107	SLA, sq in EfLA50/ sq in	House leakage in WA state must be 0.00030 or less
107	EfLA50/10^6 sq in	
175	EqLA50/10^6 sq in (surface area)	Proposed for all buildings
0.56	Q50, m^3/s	Large building leakage in Europe
196	V_4, m^3/h	All building leakage in France
2,023	V_{50}, m^3/h	Large building leakage in Europe

Result	Units	Application
3.5115	Permeability, $(m^3/h)/m^2$	Large building leakage in the UK
4.63	Air Leakage index, $(m^3/h)/m^2$	Large building leakage in the UK
562	Q50, L/s	House leakage in Canada and Europe
731	Q75, L/s	Large building leakage in Canada and Europe
0.98	(L/s 50)/m^2	Large building leakage in Canada and Europe @ 50 Pa
1.27	(L/s 75)/m^2	Large building leakage in Canada and Europe @ 75 Pa
428	cm^2 EfLA4	
0.74	cm^2 EfLA4/ m^2	
794	cm^2 EqLA10	House leakage in Canada
1,010	cm^2 EqLA50	House leakage in Canada and Europe
1.38	NLA, cm^2 EqLA10/m^2	House leakage in Canada
1.75	cm^2 EqLA50/m^2	Large building leakage in Canada and Europe
1.35	(cm^2 EqLA@9.8)/m^2	House leakage per unit floor are in Japan at 9.8 Pa

Table 19: Description of units used in requirements for air leakage

Acronym	Requirement units	Description
ACH50, n_{50}	/h	Air Changes per Hour, at 50 Pa induced pressure
	CFM50/sq ft	Cubic feet per minute, at 50 Pa induced pressure, per square foot of total enclosure surface area
CFM75/sq ft		Cubic Feet per Minute, at 75 Pa per square foot of total enclosure surface area
	cm^2 EqLA50/m^2	Square centimeters of Equivalent Leakage Area, at 50 Pa induced pressure, per square metre of enclosure surface area
	EfLA50/10^6 Surface area	Effective Leakage Area, at 50 Pa induced pressure, per million units of envelope area
	EqLA50/10^6 Surface area	Equivalent Leakage Area, at 50 Pa induced pressure, per million units of envelope area
	(L/s)/m^2	Litres per second per square metre of enclosure surface area
	(L/s 50)/m^2	Litres per second per square metre of enclosure surface area, at 50 Pa induced pressure
	$(m^3/h)/m^2$	Permeability or air leakage index usually taken at 50 Pa induced pressure
	$(m^3/h\ 50)/m^2$	Cubic metres per hour, at an induced pressure of 50 Pa, per square metre of total enclosure area to outdoors including the ground. Usually under pressurization only although most Standards recommend testing both ways.
NLA	sq in/sq ft	Square inches of EqLA referenced to 10Pa per square foot of floor area.
Q50	L/s	Volumetric air flow rate, in litres per second at 50 Pa induced pressure
ELA	sq in EfLA4	Square inches of Effective Leakage Area at a reference pressure of 4 Pa extrapolated from multiple test points taken between 15 and 60 Pa under depressurization.
	sq in EfLA4/100 sq ft	Square inches of Effective Leakage Area at 4 Pa per 100 square feet of enclosure surface area extrapolated from multiple test points taken between 15 and 60 Pa under depressurization
V_4	m^3/h	Volumetric air flow rate, in cubic meters per hour at 4 Pa induced pressure

Table 20: Resulting natural ventilation and potential savings in energy for various ACH50 values

ACH50	Natural Air Change	Rating	% of Energy bill	% savings potential	Ventilation requirements
1.5	0.075	Super	2%	none	Requires constant energy recovery ventilation
3.5	0.18	Excellent	6%	1 to 3%	Will require occasional forced ventilation
5	0.25	Better	10%	2 to 4%	May require occasional forced ventilation
7	0.35	Good	14%	2 to 5%	Does not require additional ventilation
10	0.50	Fair	20%	3 to 10%	Start of excessive energy loss and over -ventilation
20	1.0	Bad	40%	5 to 20%	Excessive energy loss and over –ventilation.

With reference to the Table 20 above:

ACH50 is the air flow at 50 Pa in CFM divided by the conditioned volume of the house.

Natural Air Change is the number of times per hour that all the air in the house will be changed, based on the value for ACH50. It is generally considered that 0.35 is sufficient but the amount is dependent upon occupancy, building dimensions, indoor pollution sources, and weather. Most homes will be under and over ventilated at different times.

% of energy bill is the amount of the total energy bill that can be attributed to air leakage.

% savings potential is attributed to the fact that leakage can be reduced by 12 to 50 % with the average being 25%. Duct leakages can double these losses.

Appendix B: Calculate flow if required test pressure cannot be reached

"n" setting for estimating flow @ pressure during house and duct leakage test

Houses and ducts have leaks through holes that will have both turbulent and laminar flow going through them. The relationship between pressure and flow is as follows:

$$flow = Pressure^{n} \times C$$

The actual flow exponent *n* for an enclosure can be calculated by measuring enclosure leakage at multiple pressure differences, from 10 to 50 Pa, and determining the slope of the line when graphing log of flow versus log of pressure. The graph of pressure versus flow will be linear if graphed on a log-log scale, and the slope will be *n*. The constant *C* is a value depending on the flow characteristics of the opening through which the air is moving, and can be thought of as the flow at 1 Pa. Once *n* is known, flow at 1 Pa can be found using the graph.

A wide open hole has an *n* of 0.5, meaning that when the pressure is quadrupled, the flow doubles. That is due to completely turbulent flow going through that hole (flow = square root of pressure, a constant for that particular hole).

$$flow = Pressure^{n}$$

$$flow = Pressure^{0.5}$$

An *n* value of 1.0 represents tiny little holes, so small that the air would not be turbulent but rather would go through the holes as laminar flow. This means that when pressure is quadrupled, the flow will also be quadrupled.

$$flow = Pressure^{1}$$

$$flow = Pressure$$

$$4 * flow = 4 * Pressure$$

Duct holes tend to be slightly larger so tend towards more laminar with less turbulent flow and larger *n* values, whereas houses have more prevalent long tiny cracks, and therefore tend to have lower *n* values.

The *n* value is saved in the gauge. Set it to 0.65 for houses, and 0.60 for ductwork. Set to 0.5 for tests on the Retrotec house simulator, while measuring air handler flow and for any large hole that is not composed of long thin cracks.

The gauge uses the *n* value to extrapolate for flows at other pressures using the following formula:

$$Flow\ at\ desired\ test\ pressure = (Flow\ at\ measured\ pressure) * \left(\frac{desired\ test\ pressure}{measured\ pressure}\right)^{n}$$

Note that because the formula is using a ratio of the two pressures, and both pressures will have the same *C*, the *C* value is not required for the extrapolation.

For example: If we guess at the n value of a duct as being 0.6 and measure 100 CFM at 20 Pa (by accident or by design), then the gauge will complete the following calculation to estimate the flow at 25 Pa:

$$flow@25\ Pa = flow@20\ Pa \times \frac{25^{0.6}}{20^{0.6}}$$

If the test pressure (20 in this case) is close to the desired reference pressure (25 Pa in this case), then the correction is small and the value of *n* does not play as large a role. However, if the test pressure is much higher or lower than the reference pressure, the error can be greater.

The @ Pressure extrapolation feature is very useful for ensuring that results taken for flow reflect the flow at the desired test pressure, even when the pressure was not adjusted perfectly and was within 5 to 10 Pa of the desired test pressure.

Extrapolation Error for Flow if gauge "*n*" doesn't match actual "*n*"

To continue the above example: The flow at 20 Pa is 100 CFM. Assume the actual *n* is 0.7, but this is unknown. Instead, 0.6 will be used.

The gauge would calculate:

$$Flow@25\ Pa = \frac{25^{n} \times CFM}{20^{n}}$$

$$Flow@25\ Pa = \frac{25^{0.6} \times 100}{20^{0.6}}$$

$$Flow@25\ Pa = 114\ CFM$$

However, if actual *n* was 0.7, the flow at 25 should have been:

$$Flow@25\ Pa = \frac{25^{0.7} \times 100}{20^{0.7}}$$

$$Flow@25\ Pa = 117\ CFM$$

This value is less than 3% off from what it should be. If the test pressure was within 1 or 2 Pa of the reference pressure of 25 Pa, the @ Pressure reading would be exact.

If a gauge has the extrapolation or flow exponent "*n*" set to an assumed value but the actual exponent (the true exponent value that describes the enclosure) differs, the flow values estimated by the gauge when extrapolating will be off by a small error amount. The tables below show the percent error that can result from entering an incorrect exponent value in the gauge and using the **[@ Pressure]** function.

If the "*n*" value on the gauge is set to 0.65 and the actual enclosure *n* is different, a small error, as shown in Table 21 will result if the **[@ Pressure]** function is used at the Achieved Pressure to estimate a result at 50 Pa.

Table 21: Errors in Estimated Flow at 50 Pa if gauge "*n*"= 0.65 differs from actual *n*

		Actual Flow Exponent (*n*) of Enclosure					
		0.50	**0.55**	**0.60**	**0.65**	**0.70**	**0.75**
Achieved Pressure (Pa)	10	-21.4%	-14.9%	-7.7%	0.0%	8.4%	17.5%
	15	-16.5%	-11.3%	-5.8%	0.0%	6.2%	12.8%
	20	-12.8%	-8.8%	-4.5%	0.0%	4.7%	9.6%
	25	-9.9%	-6.7%	-3.4%	0.0%	3.5%	7.2%
	30	-7.4%	-5.0%	-2.5%	0.0%	2.6%	5.2%
	35	-5.2%	-3.5%	-1.8%	0.0%	1.8%	3.6%
	40	-3.3%	-2.2%	-1.1%	0.0%	1.1%	2.3%
	45	-1.6%	-1.0%	-0.5%	0.0%	0.5%	1.1%
	50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	55	1.4%	1.0%	0.5%	0.0%	-0.5%	-0.9%
	60	2.8%	1.8%	0.9%	0.0%	-0.9%	-1.8%
	65	4.0%	2.7%	1.3%	0.0%	-1.3%	-2.6%
	70	5.2%	3.4%	1.7%	0.0%	-1.7%	-3.3%

If the “*n*” value on the gauge is set to 0.60 and the building *n* is different, a small error, as shown in Table 22 will result if the **[@ Pressure]** function is used at the Achieved Pressure to estimate a result at 50 Pa.

Table 22: Errors in Estimated Flow at 50 Pa if gauge "*n*" = 0.60 differs from actual *n*

		Actual Flow Exponent (*n*) of Enclosure					
		0.50	**0.55**	**0.60**	**0.65**	**0.70**	**0.75**
Achieved Pressure (Pa)	10	-14.9%	-7.7%	0.0%	8.4%	17.5%	27.3%
	15	-11.3%	-5.8%	0.0%	6.2%	12.8%	19.8%
	20	-8.8%	-4.5%	0.0%	4.7%	9.6%	14.7%
	25	-6.7%	-3.4%	0.0%	3.5%	7.2%	11.0%
	30	-5.0%	-2.5%	0.0%	2.6%	5.2%	8.0%
	35	-3.5%	-1.8%	0.0%	1.8%	3.6%	5.5%
	40	-2.2%	-1.1%	0.0%	1.1%	2.3%	3.4%
	45	-1.0%	-0.5%	0.0%	0.5%	1.1%	1.6%
	50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	55	1.0%	0.5%	0.0%	-0.5%	-0.9%	-1.4%
	60	1.8%	0.9%	0.0%	-0.9%	-1.8%	-2.7%
	65	2.7%	1.3%	0.0%	-1.3%	-2.6%	-3.9%
	70	3.4%	1.7%	0.0%	-1.7%	-3.3%	-4.9%

Achieved pressure is the actual maximum pressure achieved in the enclosure during the test.

$$\text{Error} = \left(\frac{\text{Pressure of Interest}}{\text{Achieved Pressure}}\right)^{(\text{Actual n}-\text{Assumed n})}$$

In the tables, the *Pressure of Interest* is 50Pa, and *Assumed n* is 0.65 or 0.60

The actual flow exponent *n* for an enclosure can be calculated by measuring enclosure leakage at multiple pressure differences, from 10 to 50 Pa, and determining the slope of the line on the graph of pressure versus flow which will be linear if graphed on a log-log scale, and the slope will be *n*.

Cannot Reach 50 Pa Factors for houses

If you have a situation where you cannot reach the required 50 Pa during the test, there is a way to estimate the flow at that pressure based on the measured pressure and flow you did achieve. This is the procedure the gauge uses for extrapolating the flow at the required pressure when you use the **[@ Pressure]** key. The following equation describes the relationship between the flow at the required pressure of 50 Pa and the actual measured flow at the measured pressure:

$$\text{Flow at 50 Pa} = (\text{Flow at measured pressure}) * \left(\frac{\text{50 Pa}}{\text{measured pressure}}\right)^{\text{n}}$$

$$CFM_{50} = CFM_P * \left(\frac{50}{P}\right)^n$$

Typically for ducts, the *n* value is 0.60, and for houses the *n* value is 0.65. For the flow at 25 Pa, replace “50” with “25.”

Rather than using the equation in the situation where the 50 Pa test pressure cannot be achieved, you can use tables with the factors already calculated and the following procedure. Take a flow (CFM) reading at the pressure achieved and multiply by the "Cannot reach 50 Pa factor” from Table 23 to get an estimate of the flow that would result at 50 Pa.

For example, if you read 1000 CFM at a building pressure of 30 Pa, the "Cannot reach 50 factor" from Table 23 is 1.39. To get the estimated flow at 50 Pa, make the following calculation:

$$1000\ CFM \times 1.39 = 1390\ CFM$$

Thus the estimated result for CFM at 50 Pa will be 1390 CFM.

The factors depend on the “*n*” value chosen, and Table 23 is for “*n*” of 0.65 which is typical for houses.

Table 23: Factors for when a building pressure of 50 Pa cannot be reached (“n” value of 0.65)

Pressure achieved	Cannot reach 50 factor
50	1.00
49	1.01
48	1.03
47	1.04
46	1.06
45	1.07
44	1.09
43	1.10
42	1.12
41	1.14
40	1.16
39	1.18
38	1.20
37	1.22
36	1.24
35	1.26
34	1.28
33	1.31
32	1.34
31	1.36
30	1.39
29	1.42
28	1.46

Pressure achieved	Cannot reach 50 factor
25	1.57
24	1.61
23	1.66
22	1.71
21	1.76
20	1.81
19	1.88
18	1.94
17	2.02
16	2.10
15	2.19
14	2.29
13	2.40
12	2.53
11	2.68
10	2.85
9	3.05
8	3.29
7	3.59
6	3.97
5	4.47

27	1.49
26	1.53

Cannot Reach 25 Pa Factors for ducts

Rather than using the equation in the situation where the 25 Pa test pressure cannot be achieved, you can use tables with the factors already calculated and the following procedure. Take a flow (CFM) reading at the pressure achieved and multiply by the "Cannot reach 25 Pa factor" from Table 24 to get an estimate of the flow that would result at 25 Pa.

For example, if you read 600 CFM at a building pressure of 19 Pa, the "Cannot reach 25 factor" from Table 24 is 1.18. To get the estimated flow at 25 Pa, make the following calculation:

$$600\ \mathrm{CFM} \times 1.18\ = 708\ \mathrm{CFM}$$

Thus the estimated result for CFM at 25 Pa will be 708 CFM.

The factors depend on the "*n*" value chosen, and Table 24 is for "*n*" of 0.60 which is typical for ducts.

Table 24: Factors for when a building pressure of 25 Pa cannot be reached ("*n*" value of 0.6).

Pressure achieved	Cannot reach 25 factor
25	1.00
24	1.02
23	1.05
22	1.08
21	1.11
20	1.14
19	1.18
18	1.22
17	1.26
16	1.31
15	1.36
14	1.42
13	1.48
12	1.55
11	1.64
10	1.73
9	1.85
8	1.98
7	2.15
6	2.35
5	2.63

Appendix C: Test Forms

The following four sheets act as a complete test form for a residential air leakage test under the ASTM protocol. This form should accompany the tester to the testing location, where he/she will fill in the necessary information and perform a manual or automatic (with software) test-fan test on the building. This information can then be used to create a report for the client, or be entered into FanTestic software, which will produce a report automatically.

To use these forms:

1. Select and copy the following four (4) pages.
2. Paste the copied pages into a new Word document.
3. Print the document (or take it to the site electronically).

Building Air Leakage Test Form – ASTM E779-10

Test and Building Information:

Test Technician:	Fan:		S/N:			Gauge:		S/N:	
Building Description and Information:					Contact Name:				
					Contact Phone:				
					Building Address:				
Date:		Time:							

Pre-Test Checklist:			
Before	**After**	**Task**	**Notes**
House envelope preparation			
		Select most appropriate doorway to install the Blower Door system	
		Close all exterior doors (except test doorway)	
		Door to basement, open if conditioned, close if not	
		Close all windows, storms, and skylights	
		Close all attic accesses inside the house	
		Close any fireplace dampers, open dampers afterwards	
Inside house preparation			
		Move any loose items in the direct path of the fan airflow	
		Open any interior doors to conditioned spaces	
		Turn off all ceiling fans	
		Check for any open flames or hot embers (if found, immediately discontinue test), cover cold ashes	
Open to the outside (buffer zones)			
		Attic	
		Basement if unconditioned	
		Garage	
		Crawl space	
Exhaust appliances: turn off			
		Kitchen & bath exhaust fans	
		Whole house fan	
		Clothes dryer	
		Central vacuum system	
Other Devices:			
		Evaporative coolers - turn off	
		Window a/c units - turn off	
		Close outdoor air vents	
Central heating & cooling system, Gas water heater:			
		Turn off	

		Open supply diffusers	
		Close damper over fresh/make-up air intake	
		Turn off fresh air ventilation system	
		Turn to pilot position, and leave keys on heater (so you remember to turn it back on)	

ASTM Air Leakage Testing Procedure:

	Make general observations (condition of windows, doors, walls, roof, floor, etc) and record enclosure measurements (area, volume, height). Sketch plan view of building to aid in calculating area and volume measurements.
	Record information from the following steps in the appropriate sections on sheet 3 of this document.
	Measure and record indoor and outdoor air temperatures before and after the test.(If the product between the difference in indoor/outdoor temperature multiplied by the building height is greater than 1180˚F, do not proceed with the test because stack pressure is too high to allow for accurate interpretation of results)
	Set up the fan in your selected doorway Extend pressure tubing (red) through the door panel to the outdoors (if possible, use more than one location for pressure measurement (see ASTM standard). Buildings higher than 25ft should measure exterior pressure at more than one height and average the pressure pickups using a manifold.
	Seal the fan before taking bias pressure (zero Fan Pressure measurements) readings Use the C range plate plugs or a nylon fan cover to cover the fan.
	Take a (1) bias pressure reading averaged over at least 10s before the test begins (if it is windy, or there are high bias pressures, increase the averaging period of this bias pressure reading).
	Induce pressures between 10 and 60 Pa, with increments between 5 and 10 Pa; measure building pressure and air flow rate over a 20s period. Use the “Set Pressure” feature on the gauge to induce pressures between 10 and 60 Pa (example, for 15Pa push: [Set Pressure] [1] [5] [Enter]) Record “PrA” values in the “Building gauge pressure” line Record “PrB” values in the “Blower Door pressure” line Record the flow range on the fan through which the pressures are being induced
	Take a bias pressure reading averaged over at least 10s after the test ends (if it is windy, or there are high bias pressures, increase the averaging period of this bias pressure reading).
	Repeat steps 4 to 9 in the opposite direction (i.e. perform both a pressurization AND depressurization set)

Elevation above sea level:	ft
Height above ground:	ft
Enclosure Volume:	cu ft
	sq

Building Air Leakage Test Recording Form – ASTM E779-10

Instructions: Follow the procedure outlined above; put the appropriate information into the following test form. Make certain to include information about the building location, and the type of fan/gauge used (on the front page).

The test form is laid out in the same fashion as Retrotec's FanTestic software program. Once this form is completed, the information can be entered into FanTestic to provide the results of: Air flow at STP in CFM at 50 Pa, Air change rate per hour at 50 Pa, Flow/unit floor area in CFM/sqft at 50 Pa, Flow/unit enclosure area in CFM/sqft at 50 Pa, Equivalent Leakage Area in sqin at 10 Pa, and LBL Effective Leakage Area in sq in at 4 Pa. These results can be recorded on this test form in order to keep a paper record of this test.

Test Date: ☐ Test Time: ☐

Test Set: ☐ Pressurize
☐ Depressurize

Wind speed: ☐ mph Wind direction: ☐

Temperature, initial (˚F): Indoor ☐ Outdoor ☐

Height x Temperature difference: (Indoor – Outdoor) x height of building ☐ ft˚F

Bias Pressure, initial [Pa]:												

Time per Bias Pressure: s

Building pressure [Pa]:												
Blower Door pressure [Pa]:												
Range Plate:												

Time per Building Pressure: s

Bias Pressure, final [Pa]:												

Temperature, final (˚F): Indoor ☐ Outdoor ☐

Results	Value	Units	Error (%)
Air flow at STP		CFM at 50 Pa	
Air change rate		/h at 50 Pa	
Flow / unit floor area		CFM/sqft at 50 Pa	
Flow / unit enclosure area		CFM/sqft at 50 Pa	
Equivalent Leakage Area		sq in at 10 Pa	
LBL Effective Leakage Area		sq in at 4 Pa	

Building Air Leakage Test Form – ASTM E779-10

Test Date: ______ Test Time: ______

Test Set:
- ☐ Pressurize
- ☐ Depressurize

Wind speed: ______ mph Wind direction: ______

Temperature, initial (˚F): Indoor ______ Outdoor ______

Height x Temperature difference: (Indoor – Outdoor) x height of building ______ ft˚F

Baseline Pressure, initial [Pa]:												

Time per Bias Pressure: s

Building pressure [Pa]:												
Fan pressure [Pa]:												
Range:												

Time per Building Pressure: s

Baseline Pressure, final [Pa]:												

Temperature, final (˚F): Indoor ______ Outdoor ______

Results	**Value**	**Units**	**Error (%)**
Air flow at STP		CFM at 50 Pa	
Air change rate		/h at 50 Pa	
Flow / unit floor area		CFM/sqft at 50 Pa	
Flow / unit enclosure area		CFM/sqft at 50 Pa	
Equivalent Leakage Area		sq in at 10 Pa	
LBL Effective Leakage Area		sq in at 4 Pa	

Comments:

Glossary

Term	Definition
ACH50 or ACH @ 50 Pa	Designation for "Air Changes at 50 Pa". Can be calculated by taking CFM50 x 60 minutes/ hour, divided by the house volume.
Air Changes per Hour	The number or times per hour that the volume of air in the enclosure will flow out of the enclosure. A flow rate normalized to the volume of the enclosure and allows comparison of the "leakiness" of larger volumes to the "leakiness" of smaller volumes. Always expressed in units of /h. Calculated as: General: Flow / Volume Units: $\frac{1}{h}$ $= CFM * \left(\frac{60\ min}{1\ h}\right) * \left(\frac{1}{ft^3}\right)$ $= \left(\frac{m^3}{h}\right) * \left(\frac{1}{m^3}\right)$ $= \left(\frac{m^3}{s}\right) * \left(\frac{60\ s}{1\ min}\right) * \left(\frac{60\ min}{1\ h}\right) * \left(\frac{1}{m^3}\right)$ $= \left(\frac{l}{s}\right) * \left(\frac{60\ s}{1\ min}\right) * \left(\frac{60\ min}{1\ h}\right) * \left(\frac{1\ m^3}{1000\ l}\right)$
airtightness	Pertains to how free air leakage may be in an enclosure. In actual fact, measurements can only be made of air leakage rates not airtightness itself, so one could think of these terms as being opposites. In spite of the confusion, the terms are used interchangeably. Airtightness is determined by measuring the air flow rate required to maintain a specific induced test pressure. (e.g. airtightness can be measured and reported in units of CFM/sq ft of air leakage at a uniform test pressure of 75 Pa)
ATTMA	Airtightness Testing and Measurement Association
Baseline Pressure	Pressure that exists when the enclosure has been prepared for the test, but before the fan is activated. There is always some Baseline pressure due to stack, wind, flues and active HVAC systems. There are two components of Baseline pressure. A fixed Baseline offset (usually due to stack or HVAC) and a fluctuating pressure (usually due to wind or elevator operation). A method determining baseline pressure is by having a digital gauge accumulate readings over an adjustable time period (Note: The terms "static pressure", "bias pressure," and "zero Fan Pressure difference" are used interchangeably with the term baseline pressure in other documents/standards used in the industry.)
Blower	The calibrated fan unit that induces pressure differences causing air flow and provides a Fan Pressure signal from which flow is calculated.
Blower Door	See "Door Fan". A test instrument that fits into an open doorway in order to pressurize or depressurize an enclosure. It is a calibrated fan capable of measuring air-flow, and is used while mounting it into an opening in the enclosure under test. A blower most accurately describes an air moving device of the squirrel cage variety; hence the adjective "blower" does not normally apply to the bulk of Blower Doors since they do not use a blower.
CFM	Cubic feet per minute, the units of volumetric flow
CFM50 **or CFM @ 50 Pa**	CFM @ 50 Pa is the flow rate, in cubic feet per minute, required to depressurize/pressurize the building to 50 Pascals.
CGSB	Canadian General Standards Board
Conditioned Space	An area or volume that is normally air-conditioned or heated (i.e. inside the thermal envelope). Even though supply ducts may not discharge directly into these spaces, they are considered "conditioned" if their temperature follows indoor temperature closer than outdoor. (e.g. Any space maintained above 50 F in winter and below 80 F in summer)

Term	Definition
Control Cable	An Ethernet style cable used to control Retrotec fans from a gauge
Depressurization	The process of creating a negative pressure in the enclosure by blowing air out of it. Air is drawn in from outside to replace it, showing up as "geysers" when checked with an air current tester.
Door Fan	Commonly used term for a "Blower Door", a test instrument that fits into an open doorway in order to pressurize or depressurize an enclosure. It is a calibrated fan capable of measuring air-flow, and is used while mounting it into an opening in the enclosure under test. A Door Fan is often called a "Blower Door" or an "Infiltrometer™". Door Fan is more linguistically correct than the common term "blower door", since it is not a "door," but rather a "fan" and since it does not use a "blower". The "Door Fan" is a calibrated fan temporarily mounted in doorway, hence the adjective "door" prefixing "fan".
Effective Leakage Area	A common term used to describe air flow at a pressure by equating it to an equivalent size hole in an elliptical nozzle that would pass the same air flow at the same test pressure. It is usually taken at 4 Pa and incorporates a 1.0 discharge coefficient. It is typically about half the size of an Equivalent Leakage Area that describes the same air flow rate. See ASTM E779-10, equation (5).
EfLA	See "Equivalent Leakage Area"
EN	European Norm – a set of standards in Europe
Enclosure	The surface bounding a volume, which is connected to outdoors directly. For example an apartment whose only access to outdoors was through a doorway that leads directly outdoors. Or, a building with a series of apartments or offices whose only access to the outdoors is through a common hallway then the enclosure would be the volume that bounds all of the apartments or offices.
Envelope	The surfaces composed of floor and walls and floors that separate the test volume from volume surrounding the test volume. Also see" enclosure"
EqLA	See "Equivalent Leakage Area"
Equivalent Leakage Area (ELA or EqLA)	In layman's terms: the ELA is the size of hole we would have if all the cracks and holes in the building could somehow be brought together in one spot. Also called: Whole Room Leakage and includes leaks through the ceiling and below the ceiling (BCLA). In CA2001 we measure this in units ofsq ft or m² at a reference pressure in Pascals (Pa). In Engineer's terms: the equivalent size of hole required in a flat plate to give the same flow rate having a discharge coefficient of 0.61 and taken at the Reference Pressure. This ELA is sometimes called the EqLA or Canadian ELA because it was first used in the Canadian (CGSB) air leakage standard for houses. This ELA enjoys worldwide acceptance by most testers, even in the US. This ELA should not be confused with another ELA that is often called the EfLA or Effective Leakage Area. It is very unfortunate that both these ELA's have the same acronym of ELA. The EfLA was developed for the US ASTM Standard and is smaller than the EqLA by at least a factor of 0.61 because it uses a discharge coefficient of 1.0. This EfLA is sometimes called the LBL or Lawrence Berkley Labs ELA because it was developed there and is used in the LBL Natural Air Change Model that enjoys wide usage. Apart from that usage, the EfLA is not used very much but the existence of both can create huge problems that are totally lost on some users. When EqLA is taken at a reference pressure of 75 Pa, it is often referred to as EqLA75. EqLA is typically about twice the size of an Effective Leakage Area that describes the same air flow rate. See ASTM E779-10, equation (5).
Fan Pressure	The pressure difference between inside the Blower Door and the surrounding air. This pressure can be read as "PrB" from Channel B on the gauge. It is used by the computer to calculate the air flow rate through the Blower Door.
Fan Top	Part of the fan where the tubing, Speed Control Cable, and power cable are connected.
HVAC	Heating Ventilating and Air conditioning system.

Term	Definition
Leakage	A general term used to describe holes or the area of holes in or around an enclosure.
Leakage Area	This is the same as “Leakage” but expressed in square feet or m^2.
LEED	Leadership in Energy and Environmental Design
Normalized Leakage Area, NLA	Total leakage air flow divided by test enclosure surface area.
Open Range	A Range configuration on a Blower Door that has no Range Rings or Range Plates attached. On Retrotec fans it is sometimes referred to as Open (22) Range since its diameter is 22 inches.
outdoors	Outside the building in the area around the building.
Pascal (Pa)	Often shown as “Pa”. A very small metric unit of pressure. There are 249 Pascals in 1 in WC, the pressure required to push water up 1 inch in a tube. 1 Pa = 0.000145 psi.
Pressurization	The process of creating a positive pressure in the house by blowing air into the enclosure. Air is pushed out through all the leaks, causing the smoke to move away from the operator when checked with an air current tester.
Range Plate	The metal Range attachment on the Retrotec Door, which holds Ranges C8, C6, C4, C3, C2, C1, L4, L2, and L1. See the Retrotec *Range Configuration QuickGuide*.
Range Ring	The plastic Range attachments on the Retrotec Door, which include Range A and Range B. See the Retrotec *Range Configuration QuickGuide*.
Reading	A set of simultaneous Room Pressure and Fan Pressure readings. Sometimes referred to as a data set or test point because it is plotted as one point on a graph.
Reference Pressure	The pressure at which the ELA is calculated, usually at the test pressure.
room	See “Enclosure”.
Room Pressure	The pressure difference created by the Blower Door between inside and outside of the enclosure, in this case a room. This pressure is commonly measured by Channel A on the gauge or off of the Infiltrometer 60 Pa gauge.
test boundary	Boundary of the portion of the building which is actually tested. The area of this boundary is used in the results calculation.
Test Points	Consists of a group of readings taken over a time period, which are typically averaged to produce one test point that could be used as one of the multiple points in a curve fit or overall average
Time Averaging	Refers to the digital gauge display that must have an adjustable averaging from 1 second to 1 minute for the purpose of averaging fluctuating pressure signals. Averaging can be block averages that will update for the length of the average or rolling (moving) averages that will update continuously by displaying the average over the past time period.
USACE	US Army Corps of Engineers
Zero Fan Pressure	ASTM E779-10 terminology for baseline pressure.