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Retrotec Inc.

DucTester Operation & Testing Manual

rev-2012-01-09

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Important Safeguards

When using electrical appliances, basic safety precautions should always be followed.

Please read the following carefully:

- Avoid contact with moving parts.
- Special attention should be made to keep children and pets away from the fan when it is operating.
- Do not insert anything into the fan casing while the fan is moving.
- Ensure that no debris is inside the fan casing before operating the fan.
- Keep hands, hair and clothing away from fan at all times.
- The fan can cause damage or injury if it were to fall on someone/something.
- Do not use equipment for other than its intended use.
- Do not stand on the fan, or use the fan to support the weight of another object.
- To protect against risk of electric shock, do not place this equipment or power cord in water or other liquid.
- Press the power plug firmly into the power receptacle on the fan. Failure to do so can cause over-heating of the power cord and damage the fan.
- Do not use ungrounded outlets or adapter plugs. Never remove or modify the grounding prong.
- Do not operate any device with a damaged electrical cord, or after an equipment malfunction.
- Use only the included power plug to operate the fan.
- Turn the unit off and unplug from any electrical outlet before moving and when not in use, or when making any adjustments to the fan motor or electrical components.
- For use under indoor conditions only.
- For use where there is no exposure to water or dusty substances or explosive materials of flammable materials.
- If dust, pollen, mould spores, chemicals or other undesirable substances can get blown into living spaces, keep those susceptible to these substances away from the test area, and wear dust masks.
- Do not pressurize a duct system with air that is polluted or exposed to any toxic substances. For example, blowing air from a car-port, into a house or duct system, while a motor vehicle is running, can quickly fill a house with toxic carbon monoxide.
- If combustion safety problems are found, tenants and building owners should be notified immediately and steps taken to correct the problem including notifying a professional heating contractor if basic remedial actions are not available.
- Air sealing duct work may change the pressure balance in a house and cause backdrafting where it did not occur before. For example, a return leaking to outdoors may have pressurized a house but when corrected, leaky supplies may reverse that and cause depressurization which could result in backdrafting hot water heaters, furnaces or fireplaces.
- Ensure proper cooling of the fan motor.
- Equipment is intended for diagnostic testing and to be operated for brief periods under supervision by a qualified operator. Not to be used in a role as a household appliance for the purpose of moving air.
- Be aware of all possible sources of combustion. Ensure any appliances do not turn on during the test. Turn off power to the appliance, or set the appliance to the "Pilot" setting. It is possible for flames to be sucked out of a combustion air inlet (flame rollout) during a test, which is a fire hazard and can result in high carbon monoxide levels.

- If combustion safety problems are found, tenants and building owners should be notified immediately and steps taken to correct the problem (including notifying a professional heating contractor if basic remedial actions are not available). Remember, the presence of elevated levels of carbon monoxide in ambient building air or in combustion products is a potentially life threatening situation. Air sealing work should not be undertaken until existing combustion safety problems are resolved, or unless air sealing is itself being used as a remedial action.

Failure to follow these instructions carefully may result in bodily injury, damage to property and/or equipment failure. Failing to operate equipment as intended may void warranty and compliance with CE mark and other listings.

1. DucTester System Equipment

Figure 1. A complete duct testing system.

Duct testing systems (DU200, DE200, DK200)

Includes the fan, a digital gauge, and a Flex Duct to attach the fan to a register. Duct testing systems also include a hard-sided fan case, a roll of Grill Mask, and all pressure tubing, and control cables bundled together securely in one easy to use umbilical.

Door Fan systems for testing tight enclosures (US200, EU200, UK200)

Figure 2. A Door Fan system for testing tight enclosures.

Includes all of the parts listed above for a typical duct testing system, except that instead of a Flex Duct, Door Fan systems include an Aluminum Frame and Cloth Door Panel to tightly fit the Model 200 fan onto a doorway. The DM-2 gauge can be placed securely into the gauge holder that's held upright onto the Aluminum Frame for easy access during a Door Fan test.

To turn a duct testing system into a Door Fan system for testing tight enclosures, you only need an Aluminum Frame and a Low-Flow Cloth Door Panel.

Table 1. Aluminum Frame dimensions.

Dimensions		With Extender Kit
Panel width	24.5 - 41.5 in (62.2 - 105.4 cm)	30 - 48 in (76 - 122 cm)
Panel height	51.5 - 95 in (131 - 241 cm)	60 - 110 in (152 - 280 cm)
Frame thickness	1.75 in (5.3 cm)	
Frame case	53 x 10 x 4 in (134 x 25 x 10 cm)	
Frame weight	14.2 lbs (6.4 kg)	

1.1. The Calibrated Model 200 Fan

Retrotec's DucTester was specifically designed for testing ducts and tight enclosures. It has more than three times the power necessary to test the leakiest duct system to current standards. The backward curved centrifugal impeller is perfect for grading high test pressures and the elliptical nozzle is extremely stable in both the pressurization and depressurization test directions, where it offers equivalent accuracy in both directions.

Model 210 and 220 - obsolete

The 210 and 220 model duct testing fans were sold with R31 and Q32 DucTester systems respectively. At 0.25hp, the fans were designed specifically for duct testing. Rendered obsolete by the Model 200 fan, Models 210 and 220 requires a manual speed control to control fan speed, but still offers a self-referencing port for easy testing in both directions. The main difference between the Model 210 and the 220 are the Fan Top designs for Speed Control connectivity.

Figure 3. Retrotec Model 210

Figure 4. Retrotec Model 220. The Model 200 is latest DucTester model.

Model 200

The Model 200 fan is included in the DU200, DE200, and DK200 duct testing systems; and included in the US200, EU200, and UK200 Door Fan systems for testing tight enclosures. This 0.25hp fan is designed for use with the DM-2 digital gauge, which will control the fan to any desired Set Pressure or Set Speed. Alternatively, it can be controlled via a manual speed control, which plugs into the Control port, allowing the gauge to be used for other tests while the fan continues to run. The Model 200 Fan has an upgraded Fan Top that includes a built in speed control, an on/off switch, and the ability to chain multiple fans together, to be controlled by a single gauge. Updated on November 2010, the Model 200 features an on/off switch, manual speed control, and dual Ethernet style Control Ports for daisy chaining speed controls.

Figure 5. Retrotec Model 200, manual speed control, and dual Ethernet style Control Ports for daisy chaining speed controls.

For procedures on how to test an enclosure using a Door Fan system, see *Residential Pressure & Air Leakage Testing* manual.

Pressure Pickups

The Model 200 has two Fan Pressure sensors, located inside the fan inlet, and two self-referencing pickups, located just above and below the fan inlet.

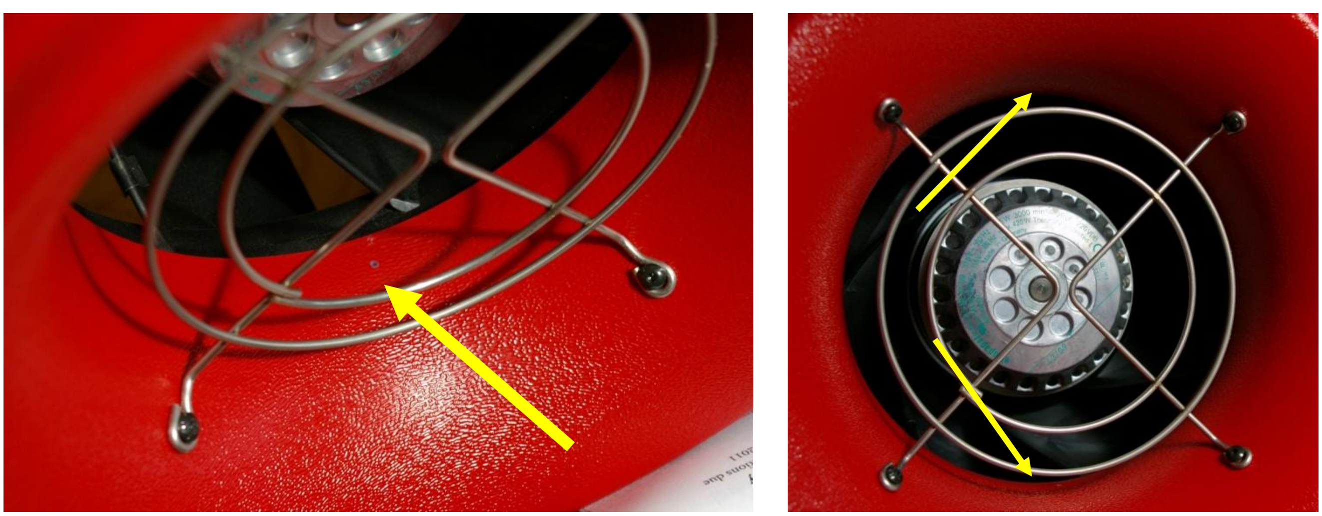


Figure 6. Fan Pressure sensors in the fan inlet.

The two Fan Pressure sensors are located just inside the fan inlet, behind the protective grill. Together, they measure the Fan Pressure, from which the fan airflow is calculated. If the sensors become blocked, it's possible to clear them by attaching a pressure tube to the yellow Ref B port, and blowing air through it gently. A whistling sound should be heard, indicating air is flowing through them.

The exterior of the inlet has two more pressure pickups. They are connected to the green B port, and are used to self-reference the fan. This insures that the measured pressure difference is always accurate.

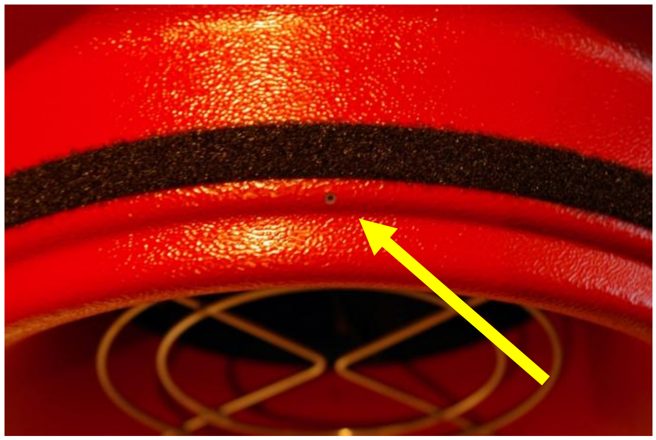


Figure 7. Self-referencing pressure pickup.

Flow Range Configurations

All Retrotec fans have multiple Flow Ranges in order to measure a wider range of air leakage flows. During testing, it’s necessary to select the correct Flow Range to achieve measurable and accurate results.

A calibrated fan measures flow by measuring the pressure developed inside the fan, which is often called Fan Pressure. As the fan speeds up, a suction pressure develops at the inlet of the fan that causes air to flow. By measuring this Fan Pressure, airflow can be calculated using pre-determined flow curves or tables, or the DM-2 gauge, which applies the same calculations automatically.

Figure 8. Three flow rings: low, medium and open, restrict flow through the fan inlet.

When the fan slows down, the Fan Pressure can become too small to accurately measure. To increase the Fan Pressure, a restriction plate is placed in front of the fan. The fan, consequently, has to turn faster to maintain the same room or duct pressure, which creates a larger, more accurate Fan Pressure. By providing a set of flow restricting plates with calibrated holes, Retrotec DucTester fans can measure flows from 5 CFM to 720 CFM.

The Model 200 has three Flow Ranges: Low, Mid, and Open. When adding restriction plates, it is important that they always be installed on the fan inlet. In order to work correctly, the plates must restrict the airflow as it enters the fan. Restricting the outflow has no effect on the inlet pressure. When depressurizing, the Flex Duct has to be removed in order to change the plates.

1.2. Digital Gauge

The DM-2 Digital Gauge is included with all Retrotec DucTester systems. The Mark II gauge can be combined with the Model 200 fan for automatic control to a Set Pressure or Set Speed. The DM-2 is a dual-channel manometer, which can automatically convert the measured Fan Pressure into a range of useful results for that meet every major testing standard in the world.

The DM-2 is also capable of taking a baseline pressure reading, and automatically recalculating results to reflect this bias pressure. It can auto zero itself to ensure no error develops during a test, and is capable of display results that are extrapolated to any pressure. For more information on configuring and using the DM-2, see the DM-2 Operations Manual.

Figure 9. DM-2 digital gauge.

1.3. Flex Duct

Retrotec's duct testing systems (DU200, DE200, DK200) include a 10", 12' long flexible duct to connect the fan to a register or duct system. A durable plastic Flange on one end is taped to a register or air handler, and connected to the Flex Duct to ensure a strong and simple seal. Velcro straps on either end securely attach the Flex Duct to the Flange and fan inlet or outlet.

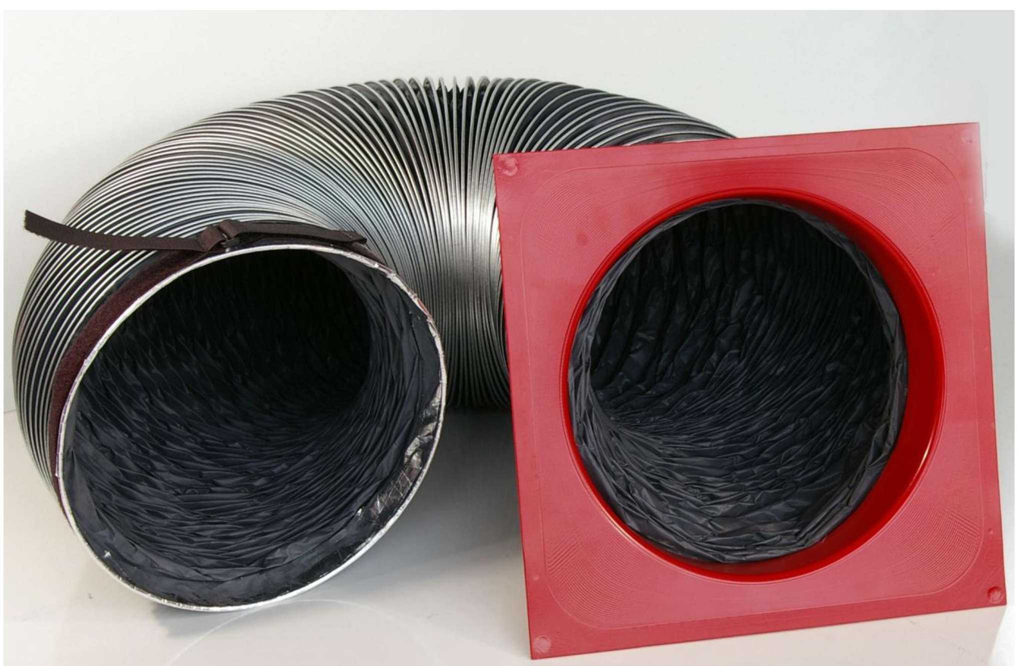


Figure 10. Flex Duct for duct testing system with Flange and strap.

1.4. Accessories

In addition to the fan, Flex Duct, and gauge, a Retrotec DucTester system includes a few additional items. Grill Mask is used to seal over registers and vents. An umbilical neatly bundles the needed pressure tubes and control cables, to prevent the user from being greeted by a tangled mess of tubes and cables before each test.

Grill Mask

Figure 11. A roll of Grill Mask to seal registers.

Grill Mask comes in a 12" wide roll. It is perforated at 12" intervals to provide easy-to-tear pieces that can seal nearly anything. Be careful applying Grill Mask to painted surfaces, as paint can be pulled off when removing it after testing.

Additional Grill Mask can be ordered from Retrotec as a single roll or three roll bundles. A handy Grill Mask dispenser is also available as an optional accessory.

Umbilical

The standard 20' long DucTester umbilical includes a yellow, green, and blue pressure tube, as well as the Ethernet control cable used to communicate with the DM-2.

2. Duct Leakage Overview

2.1. Is Duct Leakage Important?

Duct leakage is estimated to account for up to 25% of the total energy loss in a typical house. In many instances, it has a greater impact on energy use than air leaks anywhere else in the house or building envelope. Small commercial buildings often find that duct leakage is the single largest cause of performance problems.

Problems from duct leakage:

- Leaky return ducts pull unconditioned air into the duct system, and reduce the efficiency and capacity of the HVAC system.
- Conditioned (and expensive) air is lost directly to the outside, a crawlspace, or an attic.
- If moist air is pulled into return leaks, the dehumidification system is overwhelmed and the building will be uncomfortable.
- An inefficient duct system will result in people seeking alternative sources of heating or cooling, including increased use of electric heaters and fans.
- Dangerous gases, mold spores, insulations fibers, dust, and other contaminants can be drawn into the duct system and are blown into conditioned spaces.

Locating Duct Leaks

Air leakage from a duct system can be very hard to identify. Most duct systems are predominantly behind walls, in attics, crawlspaces, or other unconditioned and hard to access areas. Consequently, most duct leaks are hard to find, and tend to go unnoticed by owners and contractors alike. Unfortunately, the harder a leak is to find, the more crucial it tends to be, as these leaks are often found in hot, humid, damp, and moldy environments.

Duct Sealing Can Save Homeowners Money

A study completed in Florida examined 46 homes. They found that sealing the duct leakage reduced air conditioner use by an average of 17%. This lead to savings of $110 per year, and the repairs were a onetime cost of $200. Repeatedly, studies show that sealing leaky duct systems is one of the most cost-effective measures that a home owner can take. Heating or cooling, the same holds true in all climates. Another study in Arkansas noticed an average savings of 22% on heating bills when duct leakage sealing was performed.

Duct Leakage to the Outside

Duct systems can be either within the conditioned space (i.e. entirely enclosed in the building), or outside of the building envelope (i.e. in crawl spaces and/or attics). When ducts are contained in the conditioned space, air leaking from ducts will end up back into the home. When the ducts are outside of the conditioned space, duct air leaks go directly to the outdoors; this causes conditioned supply air to escape, and allows outdoor air to be sucked in through the return. If duct systems run within building cavities, leaked air can go to both the outdoors and inside the house.

The studies discussed above mostly reference homes with duct systems outside of the conditioned space. Duct leakage to the outdoors has the most impact on HVAC performance. However, even when all ductwork is located within the building, there can be significant loss to the outdoors.

Duct Leakage to the Inside

Less is understood about the impacts of duct leakage to the indoors. One of the major concerns is that leaky return systems can cause basements to depressurize, which can in turn cause combustion gases (from the furnace) to spill out into the home. This can cause serious health problems for the occupants, especially if the gas mixture is high in carbon monoxide, an odorless, invisible gas and deadly gas. Along with this problem, negative pressures can also cause increased moisture in the building, and possibly allow radon gas to infiltrate as well.

A Flow Conditioner is not needed for depressurization testing

Some duct testing fans require a flow conditioner, when depressurizing a duct system, in order to get correct readings. The Retrotec DucTester does not require a flow conditioner because it uses a flow nozzle, which is intrinsically stable in either direction because the flow gets compressed as it goes through the nozzle.

3. Duct Testing Procedure

There are two tests that can be performed on a duct system: a Total Duct Leakage test, and a Duct Leakage to the Outdoors test. The first test reveals the total amount of air leakage from a duct system, the second test neutralizes duct leaks to the conditioned space of the building, and calculates only the amount of air leakage that is lost outside of the conditioned space.

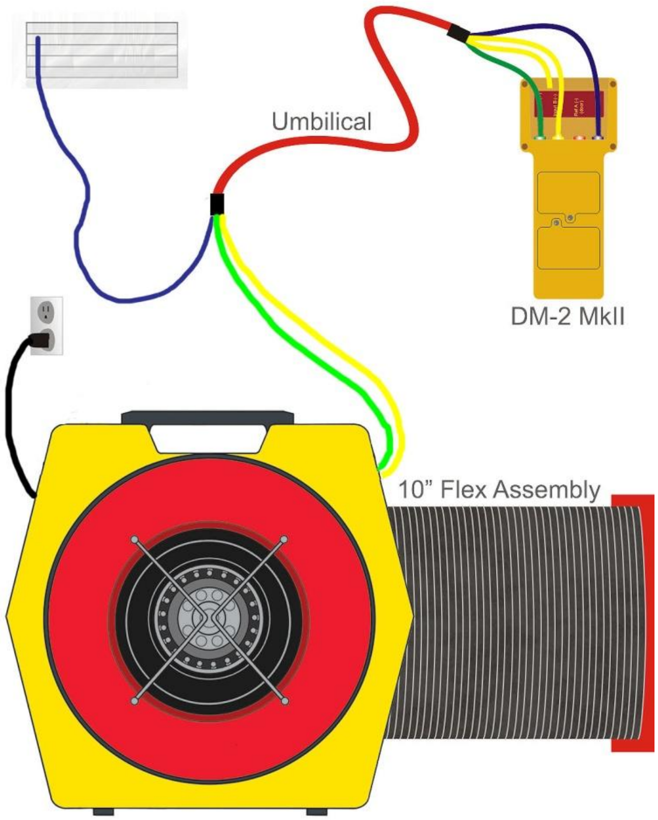


Figure 12. DucTester setup, including tubing locations and necessary connections.

3.1. DucTester Setup

Prior to beginning any test, it's important to verify that the system is functioning properly. Check that the batteries have enough power, and that the fan can be controlled either automatically or manually.

To check gauge power

1. If they're not already installed, install 4 NiMH AA batteries. The batteries will need to be charged for a minimum of 12 hours if this is the first time they're being used. Always use four batteries that are exactly the same and are charged for the same amount of time. Never use mismatched batteries.
2. Press **[On]** and then **[Exit]** to view the battery indicator in the top left corner of the screen.
3. If the batteries are less than one quarter full, connect the battery charger for approximately 12 hours.

To connect the DM-2 to the Retrotec duct testing fan

1. Connect the green, yellow, and blue pressure tubes to the corresponding colored ports on the gauge. These will typically remain connected between tests.

Figure 13. Pressure ports on the back of the gauge are color-coded to match the tubing.

Figure 14. Electrical connections on the back of the gauge include Control Cable that goes to the DM-2 (shown connected), USB cable for a PC, reset switch and DC power connection.

2. Insert the other end of the blue pressure tube into the duct system, typically through a supply register. Connecting to a return register will yield lower results unless the leakage is very low.
3. If the rechargeable batteries in the DM-2 are below one quarter power, the battery charger should be connected to the DM-2. Charge them fully overnight.
4. Connect the power cord to a wall outlet and to the fan. The Mains Power status light turns green, indicating power is connected. Turn on the power switch and adjust the Manual Speed Control Knob to verify fan operation.
5. Connect the Control Cable to both the Fan Top, and the gauge. The green Control Status light is illuminated. This will disable the Manual Speed Control Knob.
6. Connect the yellow and green tubes on the fan.

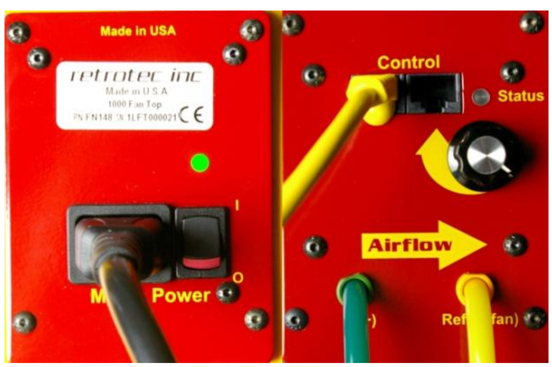


Figure 15. Model 200 Fan Top with power cord, color-coded tubing connections (green and yellow) and Control Cable.

7. To test control of the fan, press **[Set Speed] [10] [Enter]** on the DM-2. This sets the fan to 10% speed. The preferred method is using **[Set Pressure] [25] [Enter].**
8. Press **[Exit]** to stop the fan.

Select a Test Direction

Duct leakage can be measured by blowing air into the ducts to pressurize them, or by pulling air out of the ducts to depressurize them. Specific program guidelines may specify a particular test direction. Both test directions provide similar results, however depressurization testing is advantageous because it tends to pull the Grill Mask onto the registers ensuring a tighter seal. In the absence of any other requirement, Retrotec recommends depressurization.

To setup for depressurization

1. Install the Mid Range Plate, because most systems can be tested on this Flow Range.
2. Install the Flex Duct over the fan inlet and tighten the strap.

Figure 16. Install Flex Duct over the fan inlet for depressurization.

The advantage of pressurizing is that it makes changing Flow Ranges on the fan easier. If a pressurization test is needed, simply install the Flex Duct on the outlet side of the fan instead.

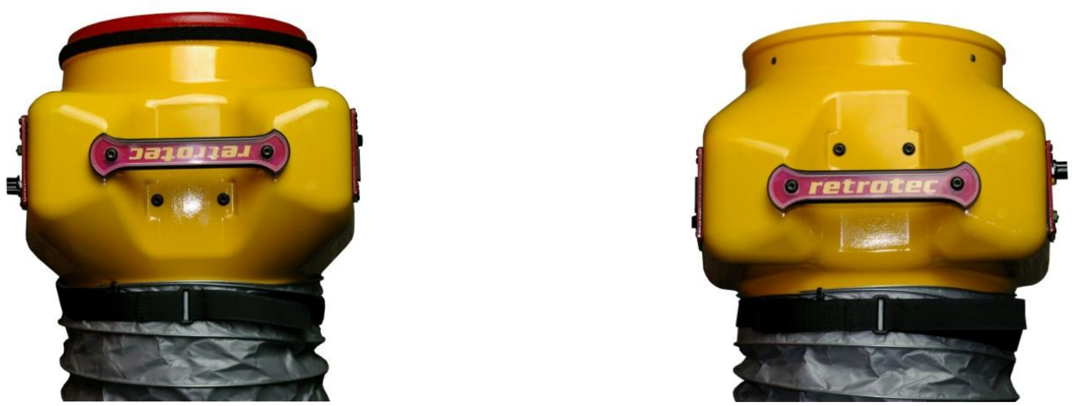


Figure 17. The Flex Duct can be placed on the fan's outlet or inlet, depending on whether the test is a pressurization test (as shown on the left) or a depressurization test (as shown on right).

Select a Flow Range

The selected Flow Range will determine the range of air leakage that the DucTester can measure. While it is possible to change the Flow Range after a test has begun, it is easiest to determine and set the Flow Range before the Flex Duct has been attached to the fan, when testing in the depressurization direction.

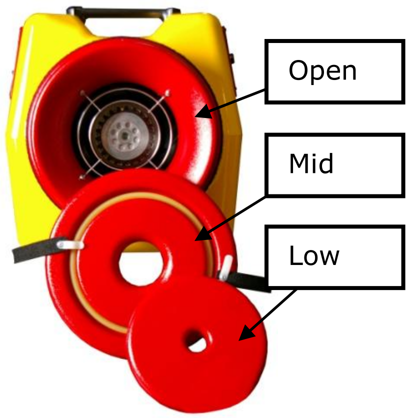


Figure 18. Range plates for the Model 200.

Selecting a Flow Range

Testing should always be done at the highest possible fan speed, which means using the most restrictive Flow Range possible. Higher fan speeds lead to the highest degree of accuracy.

Each Retrotec DucTester includes three Flow Ranges to maximize accuracy and versatility: Low, Mid, and Open.

To determine when to change Flow Ranges

1. Attach the Mid Range Ring.
2. Adjust the fan speed until the desired duct pressure is reached.
3. If "TOO LOW" or "----------" appears on channel B of the DM-2, attach the Low Range Plate.
4. Press **[Range Config]** until "Low" is displayed.

OR

1. Attach the Mid Range Plate.
2. Adjust the fan speed until the desired duct pressure is reached.
3. If the desired duct pressure cannot be reached, take the Mid Range Plate off.
4. Press **[Range Config]** until "Open" is displayed.

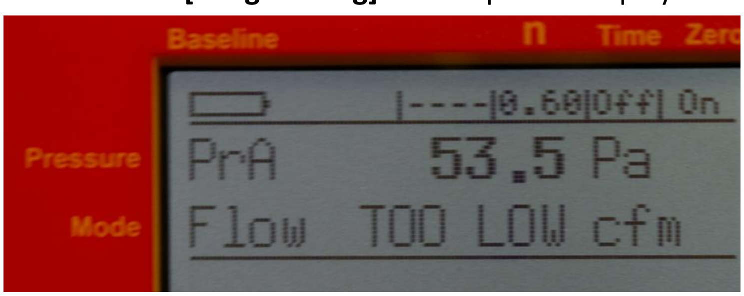


Figure 20. Change the Flow Range when the DM-2 reds "too low" or when a pressure cannot be reached.

Figure 19. Low range (left), Open range (right).

If the desired test pressure cannot be reached on the Open Flow Range, at maximum speed, try one of the following solutions:

- Look for large disconnects in the duct system by pressurizing the house with the Door Fan and putting smoke in front of the registers. Registers with high velocity smoke movement are a good indication of a potential disconnect in the duct system behind the register. Fixing the disconnect may reduce the leakage enough to continue testing the duct system.

- Test the ducts at the highest pressure that can be reached, and use the @ Pressure button to extrapolate what the flow would be at the desired pressure. The closer the readings are to the desired test pressure, the more accurate the results.
- Try the duct leakage to outdoors test, which will neutralize duct leakage to the house.

Field Check the DucTester

This check will ensure that the DucTester is connected properly, and will ensure that the measured results are within 10% of the true value. The field calibration plate is optional, and a temporary one can be easily manufactured using thin, solid, cardboard with a 4" x 4 5/8" square hole (18.6 in.^{2}) cut in the center. A 1/4 inch diameter hole should be made in one corner of the plate, as far away from the larger hole as possible.

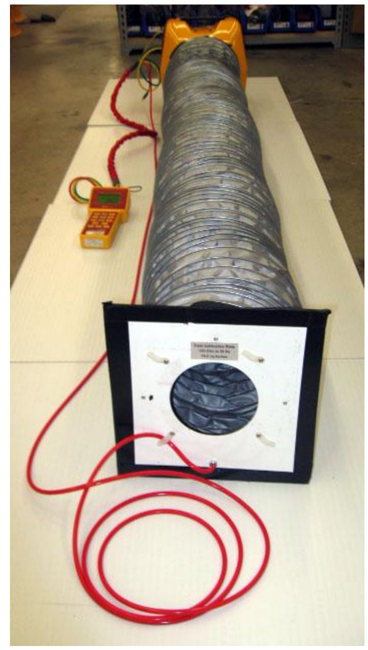


Figure 21. DucTester field calibration check setup.

To field check the DucTester calibration

1. Tape the Field Calibration Plate to the Flex Duct Flange, and attach the blue tube to the pressure pickup or into the small cut hole (if using a homemade one).
2. Stretch the Flex Duct to its full length.
3. Press **[Set Pressure] [25] [Enter]** and the fan will automatically control to 25 Pa.
4. Set Mode to flow. Press **[@ Pressure]** to display CFM @25 Pa. Compare the measured results with the flow marked on the calibration plate. A homemade plate with the specified size hole should read within 10% of 100 CFM.

Using a Pressure Pan

If a Door Fan system is available, checking all the registers with a Pressure Pan, prior to doing a duct leakage test, can be useful for finding the leakiest part of the system, and for determining the most conservative location for the DucTester system pressure pickup. A pressure pan test can also locate large disconnects in the duct system, which may prevent the acquisition of a useful result in a full duct leakage test. Set the Building Pressure to 25 Pa, and cover the register with the Pressure Pan connected to the Blue port of the DM-2; readings over 1 Pa indicate some leakage, readings over 5 Pa is severe leakage at that register and 25 Pa indicates a complete disconnect.

Figure 22. Pressure Pans, large and small shown

Table 2. Retrotec Pressure Pans

Pressure Pan	Dimensions (in)	Handles	Part number
Large	**24.5 x 24.5 x 8.75**	**2**	**PP101**
Small	**13 x 15 x 4.5**	**1**	**PP102**

For more information about conducting a Pressure Pan test, see the *Residential Pressure & Air Leakage Testing Manual*.

Connect the Flex Duct to the Duct System

The DucTester has a 10 inch by 12 foot Flex Duct with a Flange on one end which is normally connected a return grill, but which can also be connected to the air handler cabinet. When considering where to connect the DucTester to the duct system, it is important to think about airflow restriction and accessibility. For most duct tests, the DucTester should be connected to the central return (if there is one) or to the air handler cabinet itself. If there are multiple returns in a duct system, the return duct work is typically smaller in size and can cause restrictions in airflow that can create backpressures and contribute to poor and inaccurate test results. If the air handler is in a difficult location to access (i.e. in the attic or crawl space), find the closest and largest return grill to it.

To connect the Flex Duct to return connection

1. Choose the Main return with the most direct connection to the air handler. Remove filters behind the return grill.
2. Attach the Flange to the return grill using Grill Mask or high quality masking tape. Seal the remaining openings with Grill Mask.
3. Attach the open end of the Flex Duct to the Flange (which is attached to the return grill); use the Velcro strap to secure it to the Flange.
4. Place the DucTester in such a position as to minimize any major bends in the Flex Duct.

Figure 23. Flange taped onto a return register before attaching the Flex Duct

Optionally, connect a Flex Duct to the air-handler cabinet. Normally this will give the same results as connecting to a return. In cases where there is no return ducting installed, or where leaks in the return system are excessive, connecting to the air-handler might be the only option to measure the supply section of the ducts.

To connect the Flex Duct to the air handler cabinet

1. Cut a piece of cardboard the same size as the access panel to the blower compartment of the air handler unit. Cut a hole in the middle of the piece of cardboard that is slightly smaller than the square Flange.
2. Put the cardboard piece with the attached Flange onto the opening of the blower compartment access. Tape the cardboard in place and seal all four sides of the cardboard panel.
3. Attach the Flex Duct to the Flange and secure it with the Velcro strap. Ensure that the DucTester has been placed in such a position as to minimize any major bends in the Flex Duct.
4. Select a location to measure the test pressure that is induced by the DucTester. This will be measured on Channel A of the DM-2.

Figure 24. Flex Duct connected to the Flange.

Where to Measure the Pressure Difference

Figure 25. A Static Pressure Probe attached to a pressure tube allows the measurement of pressure without flow interference (e.g. inside a supply register)

When measuring extremely leaky duct systems (where the leakage is over 500 CFM), the location of the test measurement point has a significant influence on the measured results. Some programs require test results from two test measurement points. The two points are averaged, which helps eliminate error due to the test measurement point.

The highest leakage results will likely be measured when the blue tube is connected to the supply register that is furthest from the air handler. If a pressure pan test was conducted, then the register that measured the highest pressure pan reading will yield the greatest duct leakage. Conversely, using the main supply trunkline, or supply plenum, will measure lower leakage results. Measuring at the return ducting, where the DucTester is attached, will show the lowest possible leakage results.

In duct systems that are relatively tight (leakage is 200 CFM or less), the test pressure in the system is more uniform, and all locations will provide similar results. Essentially, if a duct system passes a requirement of 100 CFM or less, the test point location will not affect results in any significant way.

To measure the duct to house pressure difference

1. Insert the blue tube in a supply register, preferably located away from the fan. (Attaching a Static Pressure tube to the blue tube before inserting into the register, shown in Figure 25 will reduce fluctuations due to airflow velocities which will be greatest at the return or in the supply plenum).
2. In a leaky duct system, a second measurement location may be required. Select a register close to the location of the fan. Average the two results.

Prepare the Duct System

Preparing for a duct leakage test requires preparing both the duct system and the building. The following setup procedures are recommended by Retrotec. If the test is being conducted according to a specific program guideline, you may be required to set up the duct system and building differently than what is described below.

To prepare the duct system

1. Adjust the HVAC system controls to ensure that the air handler does not turn on during the test.
2. Remove all filters inside the ductwork including any filter that is behind the return grill (that the DucTester will be connected to).
3. Seal off all remaining supply and return registers using Grill Mask. A roll is provided with all DucTester systems.

Note: While it would be ideal to seal between the register and the wall using Grill Mask, caution must be used to prevent pulling paint off the wall.

4. Seal combustion air and ventilation inlets directly connected to the duct system. This can be done by sealing the opening on the outside of the building, but can also be done by removing the inlet from the duct work and taping off the opening.
5. Turn off all exhaust fans, dryers, and room conditioners.
6. Turn off vented combustion appliances, if there is a possibility that the area containing the appliance will become depressurized during the testing procedure.
7. When ducts run through an unconditioned space, that space must be opened to the outdoors, to relieve any pressure that may build up in that space during the test.

3.2. Total Duct Leakage

Under Pressurization

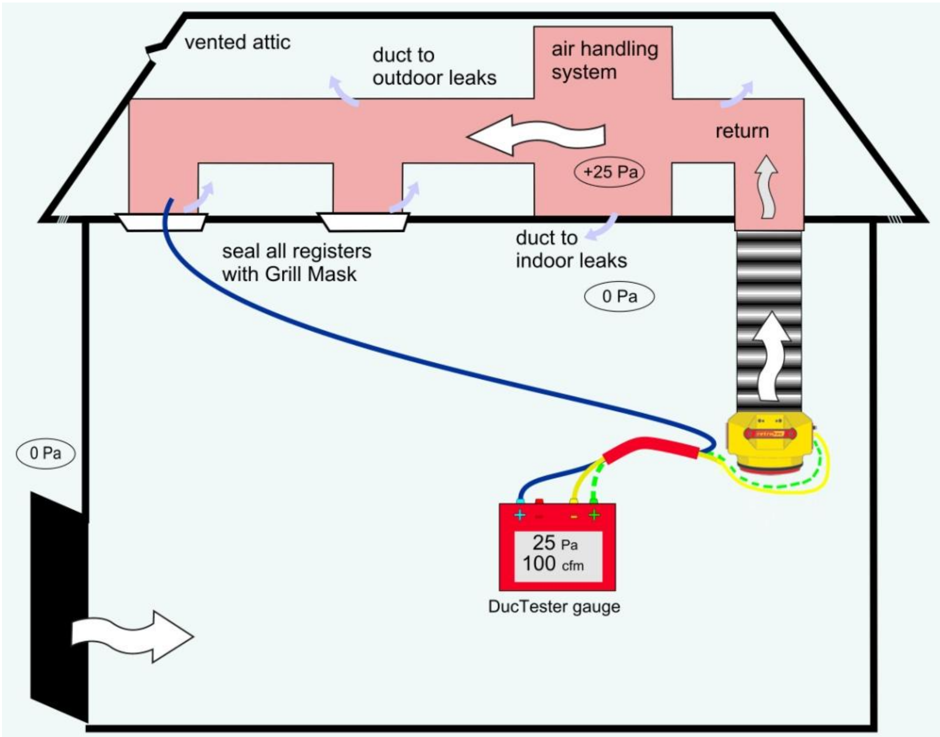


Figure 26. Total duct leakage under pressurization - DucTester and tubing setup.

Under Depressurization

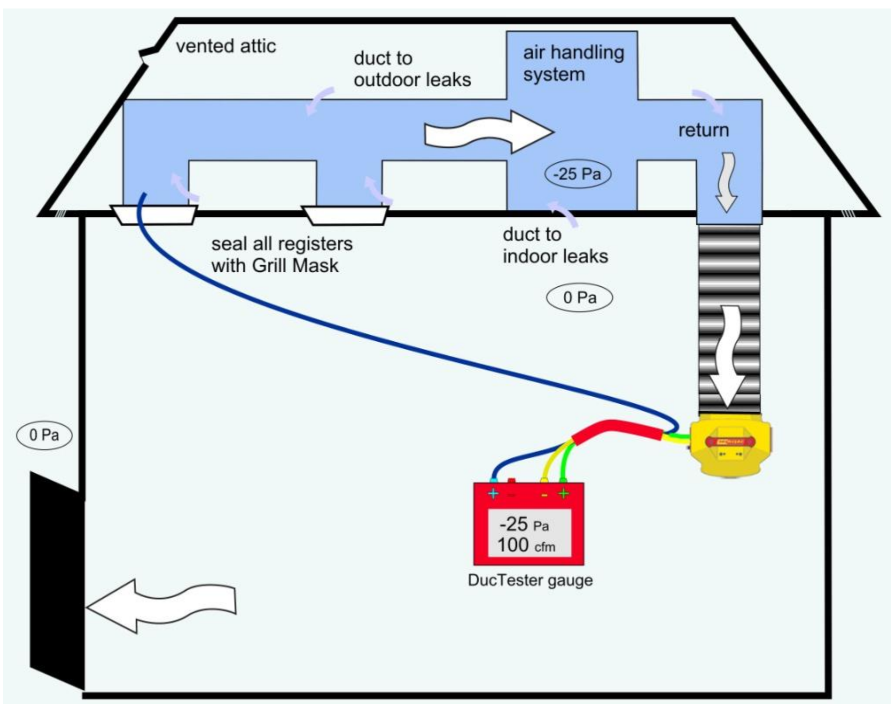


Figure 27. Total duct leakage under depressurization - DucTester and tubing setup.

A total duct leakage test measures the total amount of air leakage from a duct system. This includes both leaks to conditioned spaces, and leaks to unconditioned spaces, or the sum of duct-to-outdoor and duct-to-house leaks.

The test diagrams display testing at 25 Pa. For results at 50 Pa, substitute “50” wherever “25” appears.

To perform a total duct leakage test

1. Set up the DM-2
    a. Press **[Mode]** to cycle through available results. Typically, choose between CFM, CFM/ft^2, CFM/1000 ft^2,CFM/1000 ft^2. If the desired results do not appear, press **[Setup]**, scroll to "Mode Setup", scroll down to "Flow per Area", and choose the desired units by pressing **[▶]** or **[◀]**. Press **[Exit]** when required units are displayed and they will become available when the Mode key is pressed.
    b. Press **[Device]** to get “Retrotec DU220”
    c. Press **[Range Config]** to get "Mid".
    d. Press **[Time Avg]** to get “8s”.
    e. Press **[Auto Zero]** to get “On”.

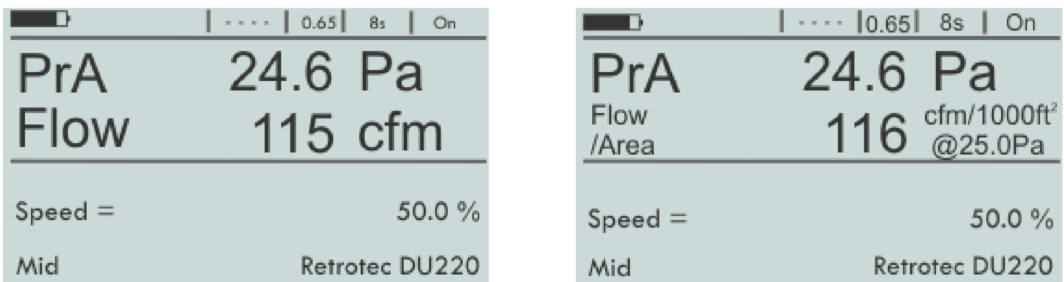


Figure 28. DM-2 screen set up for measuring flow in CFM (left) and flow per unit area @25 Pa (right).

2. Adjust speed on DucTester
    a. Use the Manual Speed Control Knob on the Fan Top. Increase the fan speed until a stable pressure of 25 Pa(or -25 Pa) is displayed on Channel A. Press **[@]** to display the results on Channel B at exactly 25 Pa. Iif “@ 25 Pa” does not appear next to the units on Channel B, change the defaults using the Mode Setup menu under "Flow" and/or "Flow/area".

    OR

    b. Use set speed on DM-2. Press **[Set Speed] [50] [Enter]** to set the fan speed to 50%. Press **[Jog/Hold]** until "Jog" appears. Use **[▲]** or **[▼]** to adjust the speed until Channel A displays 25 Pa. Press **[@ Pressure]** to view the results on Channel B at 25 Pa.

    OR

    c. Use set pressure on DM-2. Press **[Set Pressure] [25] [Enter]**. The fan will automatically accelerate and maintain a pressure of 25 Pa in the duct system. Press **[@ Pressure]** until “@ 25 Pa” is displayed to view the results at 25 Pa.
    d. If "TOO LOW" appears, or the desired test pressure cannot be reached, adjust the Flow Range.

3.3. Duct Leakage to Outdoors

Under Pressurization

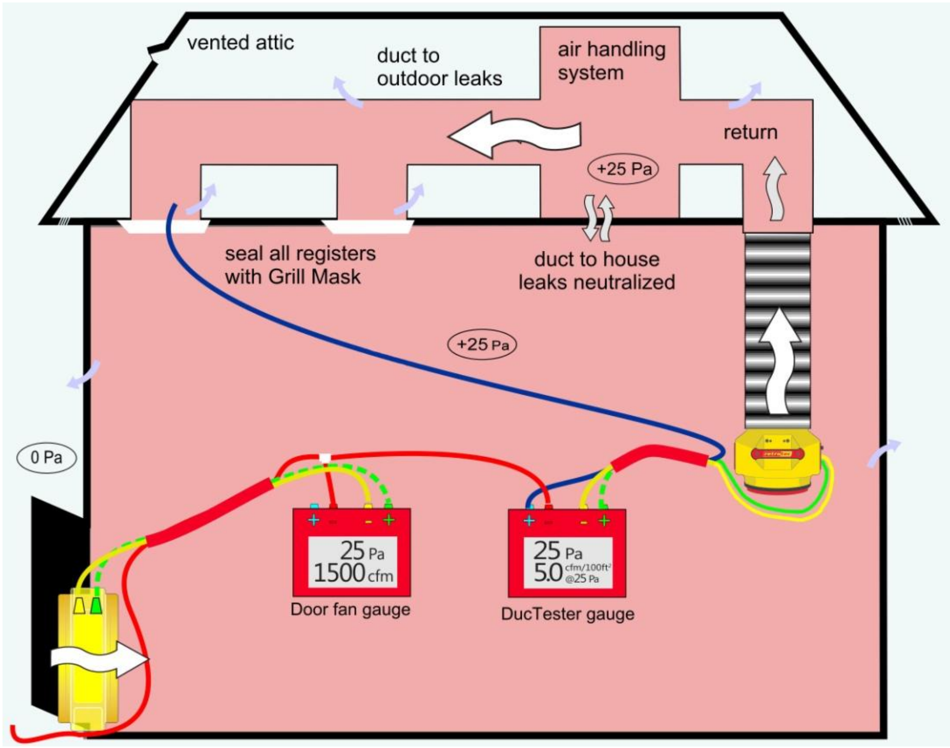


Figure 29. Duct leakage to outdoors under pressurization – Method #1.

Under Depressurization

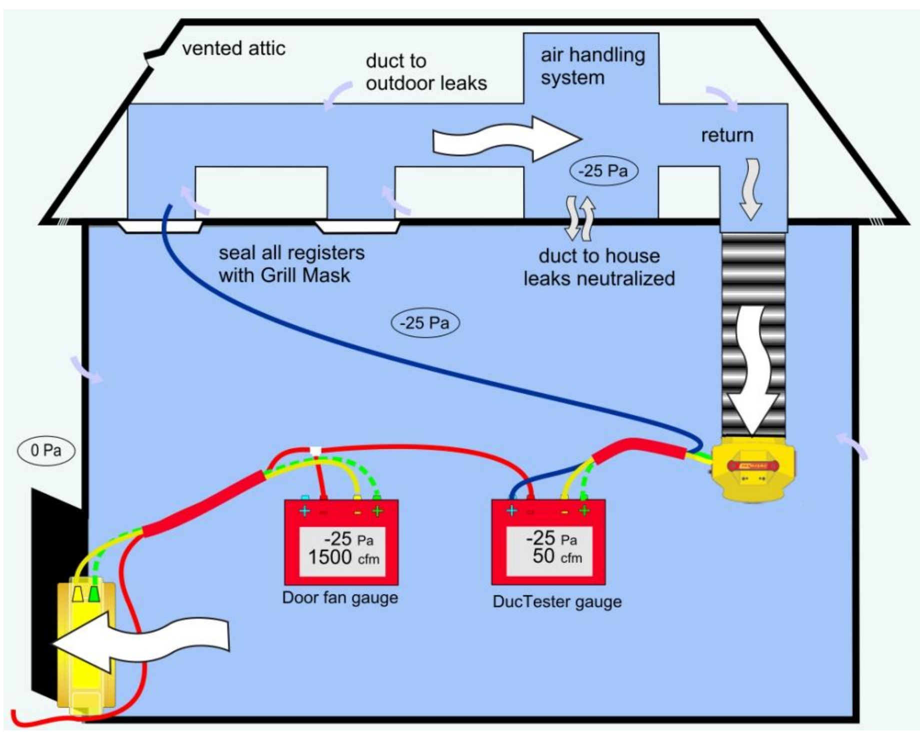


Figure 30. Duct leakage to outdoors under depressurization – Method #1.

A duct leakage to outdoors test neutralizes the duct leakage to the house (or conditioned spaces) by pressurizing it to the same pressure as the ducts. The measured duct leakage, therefore, only reflects the leaks to outdoors.

If a green, self-referencing, pressure port is available on the fan, use the green pressure tube to connect it to the DM-2.

Method #1: Set both duct and house to -25 Pa

1. Complete the previous Total Duct Leakage test.
2. Close all doors and windows and shut off exhaust fans.
3. Connect the Door Fan as displayed in the diagram.
4. Connect the red ports together with one red tube, and run the end outdoors. This allows the duct and house pressures to be measured against the same reference.
5. Set the DucTester to 25 Pa (or -25 Pa) by pressing **[Set Pressure] [25] [Enter]**. Then repeat this process for the Door Fan.
6. Press **[@ Pressure]** to display the duct leakage result "@25Pa".
7. Record duct leakage to outdoors from the DucTester gauge.

Note: if the Door Fan pressure fluctuates more than 2 Pa, press **[Time Avg]** to reduce it. If still above 2 Pa, use the Baseline feature as outlined in the DM-2 QuickGuide or DM-2 Operations Manual.

Method #2: Set duct to house to 0 Pa

1. Complete the previous Total Duct Leakage test.
2. Close all doors and windows and shut off exhaust fans.
3. Connect the Door Fan per diagram.
4. <u>With DucTester off</u>, set the Door Fan to 25 Pa by pressing [Set Pressure] [25] [Enter].
5. Press **[@]** to remove “@” from the display.
6. Set the DucTester to 0 Pa by pressing **[Set Pressure] [0] [Enter]**.
7. When 0 Pa +/– 1 is achieved, record duct leakage to outdoors from the DucTester gauge

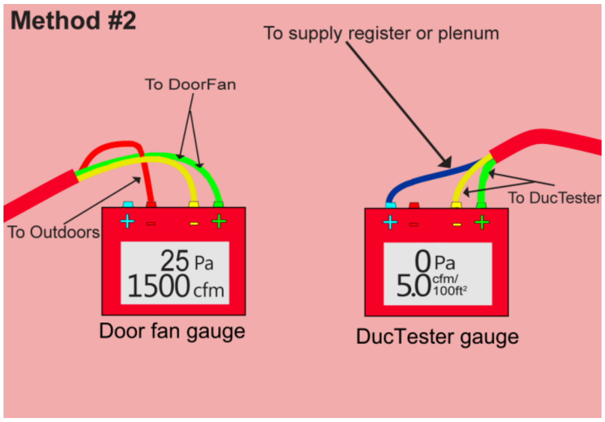


Figure 31. Duct leakage to outdoors - Method #2.

Under Pressurization, with 1 gauge

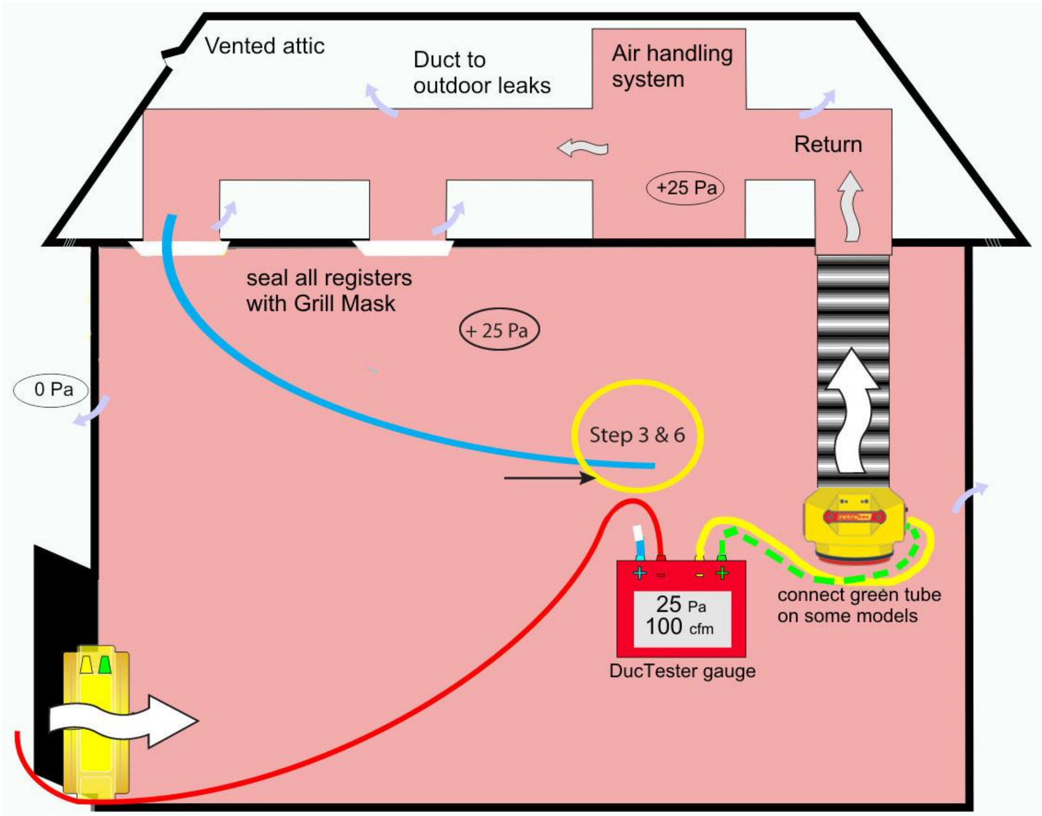


Figure 32. Duct leakage to outdoors under pressurization

Duct leakage to outdoors may be measured using only one gauge to alternatively measure the house to outdoor pressure then the duct to outdoor pressure.

When the house and ducts are at the same pressure, Channel B displays "Duct Leakage to Outdoors".

1. Set up the Door Fan to blow into the building and the DucTester to blow into the duct system.
2. Close all doors and windows and shut off any exhaust fans in the building.
3. Keep the blue port on the gauge open to the house. Manually adjust the Door Fan speed (with the Door Fan's Manual Speed Control Knob) to pressurize the building to +25 Pa on Channel A of the gauge.
4. Connect the blue tube to the gauge.
5. Manually adjust the DucTester speed (with the DucTester's Manual Speed Control Knob) to reach +25 Pa in the ducts. Wait 60 seconds.
6. Disconnect the blue tube from the gauge and readjust the door fan speed to set the building pressure to +25 Pa.
7. Connect the blue tube to the gauge; readjust the DucTester fan speed to achieve +25 Pa.
8. Record duct leakage when you're confident the building and duct pressures have both been stabilized at +25Pa.

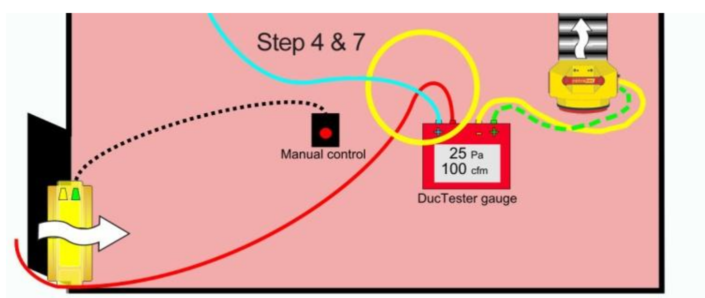


Figure 33. Duct leakage to outdoors under pressurization – this diagram shows duct leakage being measured

3.4. Duct Leakage Results

Read the total duct leakage results directly from the DM-2. In order to compare duct systems in different homes/buildings, it is necessary to normalize the leakage results for the size of the HVAC system and the size of the building. The two most common variables used to normalize duct leakage are total HVAC flow rate and the floor area of the building.

Figure 34. Some of the most common results that can be read directly off the DM-2.

Table 3. Mode Setup for various standards around the world.

Standard:	Energy Star	Northwest ENERGY STAR Homes	Title-24	WA state
Region:	North America	Montana & Idaho, USA	California, USA	Washington, USA
Pressure	Pa	Pa	Pa	Pa
Flow	CFM	CFM	CFM	CFM
(Flow) @ Pressure	50 Pa	50 Pa	25 Pa	25 Pa
EqLA	Off	Off	Off	Off
(EqLA) @ Pressure	n/a	n/a	n/a	n/a
EfLA, Effective Leakage Area	Off	Off	Off	Off
(EfLA) @ Pressure	n/a	n/a	n/a	n/a
Air Changes	/h	/h	/h	Off
(Air Changes) @ Pressure	50 Pa	50 Pa	50 Pa	n/a
Flow per Area	CFM/ft^2	CFM/ft^2	Off	Off
(Flow per Area) @ Pressure	50 Pa	50	n/a	n/a
EqLA per Area	Off	Off	Off	Off
(EqLA per Area) @ Pressure	n/a	n/a	n/a	n/a
EfLA per Area	Off	Off	Off	Off
(EfLA per Area) @ Pressure	n/a	n/a	n/a	n/a

3.5. Duct leakage program requirements

Table 4. Duct leakage requirements.

Program	Region	Leakage requirement
Abu Dhabi Building Code	Abu Dhabi: UAE	Total Duct Leakage: 12 CFM25/100 ft^2 Duct Leakage to outdoors: 8 CFM25/100 ft^2
ENERGY STAR Qualified Homes	USA	Total Duct Leakage: 6.0 CFM25/100 ft^2 of conditioned floor area. Duct Leakage to outdoors: 4.0 CFM25/100 ft^2 of conditioned floor area.
IECC International Energy Conservation Code	Global Georgia	Total Duct Leakage: 12 CFM25/100 ft^2 conditioned floor area. Duct Leakage to Outdoors: 8 CFM25/100 ft^2 conditioned floor area. Applies in States such as Georgia where the figure can also be: 6 CFM25/100 ft^2 after rough in.
Northwest ENERGY STAR Homes	ID, MO, OR, WA: USA	Total Duct Leakage: 0.06 CFM50/ft^2 of conditioned floor area or 75CFM, whichever is greater. House leakage must be less than or equal to 4 ACH50.
Title 24	CA: USA	Less than or equal to 6% of airhandler flow calculated by using 400 CFM per Ton or 21.7 CFM per 1000 BTU. 42 CFM/1000 ft^2 of floor area for climate zones 8 through 15. 30 CFM/1000 ft^2 of floor area for climate zones 7 and 16.
Washington State Energy Code	WA: USA	Total Duct Leakage: 0.06 CFM25* floor area (ft^2). Duct Leakage to Outdoors: 0.08 CFM25*floor area (ft^2).

3.6. Common mistakes

The following mistakes are commonly made when performing a duct test, and can significantly affect the results.

- Wrong Flow Range and or wrong Device selected on DM-2
- Water in tube, pinched tube
- No green reference tube attached while depressurizing ducts
- Having @ Pressure set to the wrong pressure
- Not covering all registers
- Not locating in sealing ducts running to outdoors
- Tape being blown off, usually happens in pressurization
- Furnace coming on during a test
- Too leaky to test accurately, although this is usually not an issue because tests can be performed accurately at twice the allowable duct leakage.

In some cases, especially in new construction, it is possible to find ducts that have no leaks. Some indications would be if even a very low fan speed results in a very high duct pressure, or if no flow can be measured with even the most restrictive Flow Range. One way to verify that the test is correct, and that the ducts are not leaky, is to unseal a single register. This introduces a leak to the duct system, which is measured by the equipment. If this test results in a measure leak of the approximate size of the opened register, the previous test is valid, and the system is too tight to measure any duct leakage.

3.7. Finding air leaks in the ducts

Finding leaks in the ducts can be a tricky process, and there are a number of methods used.

Using theatrical smoke

The use of theatrical smoke can be a very effective way to find leaks in a duct system. A theatrical smoke machine is used to inject non-toxic chemical smoke through the DucTester fan, and into the duct system. Walking around to check the duct systems will point out obvious leak locations where smoke appears. This can help find hard-to-detect leaks in attics and crawlspaces. Using this type of detection is called theatrical for a reason – it is quite a sight to see for homeowners and builders.

Caution: Make sure not to inject the smoke directly into the fan motor, but instead into the edge of the fan housing. Also, make sure to clean up any residue from the flow sensors, motor and fan housing when the show is over.

Using a smoke puffer

Smoke puffers work similarly to theatrical smoke for finding leaks, but on a much smaller scale. The chemical smoke is the same density as air, and therefore does not move unless there's air movement. Puff out a small amount of smoke near suspected leaks while the DucTester is running (near joints, in front of registers, etc…), and notice the smoke either being blown away or being sucked in, depending on the direction of the test.

Using an infrared camera

An infrared camera can graphically display areas where cold air is infiltrating into a house or building, or can show from the outside where hot air is exfiltrating. The camera can also show zones that are poorly insulated, which would otherwise be invisible without opening up wall sections.

Using a wet hand

Sometimes, a damp hand is more than enough to feel the movement of air around a leak. Wet skin will feel cool or cold in the path of moving air.

3.8. Using the DucTester as a Powered Flow Hood

The Retrotec DucTester can be used to measure air flows through exhaust fans and other airflow devices, without affecting their flow rate, by neutralizing the pressure that would create a resistance to flow. By using the DucTester as a Powered Flow Hood, a vent area can be "set to zero", eliminating any pressure difference. This is unlike using a traditional flow hood, where the flow hood itself creates a resistance to flow, altering what is being measured.

Use a large Retrotec Pressure Pan that has been ordered with a 10 inch diameter hole in it.

1. Pass the Flange through the 10 inch hole in the Pressure Pan and attach the Flex Duct.
2. For measuring supply flows, attach the flex to the inlet (suction) side of the fan – for return flows; attach the flex to the outlet (discharge) side of the fan.
3. Attach the Blue Tube to a connector on the Pressure Pan. Connect the other end to the Input A port (blue) on the DM-2. The Ref A (red) port should be left open.
4. Connect the green and yellow tubing to the Input B (green) and Ref B (yellow) ports on the gauge respectively. Connect the other ends to the same color connections on the DucTester.
5. Adjust the **[Set Speed]** until PrA reads a pressure of 0 Pa. Record the flow in CFM. To have the DucTester automatically acquire and maintain a 0 pressure, press **[Set Pressure] [0]** and the gauge will cause the DucTester to increase in speed to eliminate whatever pressure it sees when the keys are pressed. Ensure the pressure that is to be set to 0 actually exists before the keys are pressed because it uses the direction of the pressure to set the direction of control-meaning the fan speeds up to eliminate the pressure it first sees regardless of sign. Make sure the “@” feature is turn off otherwise erroneous results will occur due to the result being divided by whatever tiny pressure occurs above or below zero.

3.9. After Testing is Complete

Notice the conditions in the building upon arrival and be sure to restore it to that condition before leaving.

Before leaving the house

1. Remove all Grill Mask from registers.
2. Replace all filters from the return(s) and air handler.
3. Turn the furnace, air conditioning, HVAC system back on.
4. Ensure any combustible appliances that were turned off are turned back on, and that they are properly vented again.
5. Unseal any closed ventilation, or reconnect the ducts if it was disconnected.
6. Close any exterior doors or windows that were opened to unconditioned spaces.

4. Testing tight enclosures

4.1. Door Fan Setup

To turn a duct testing system (DU200, DE200, DK200) into a Door Fan system for testing tight enclosures (US200, EU200, and UK200), you only need to add an Aluminum Frame and a Low-Flow Cloth Door Panel. If you have a DucTester system, your umbilical will have a blue tube which must be connected to the red port on the gauge and passed through the panel unlike the graphic below that shows the umbilical that is used exclusively for a door fan system. It is not necessary to change your umbilical just for this color change.

Door Fan systems for testing tight enclosures should be set up as shown in Figure 35 below:

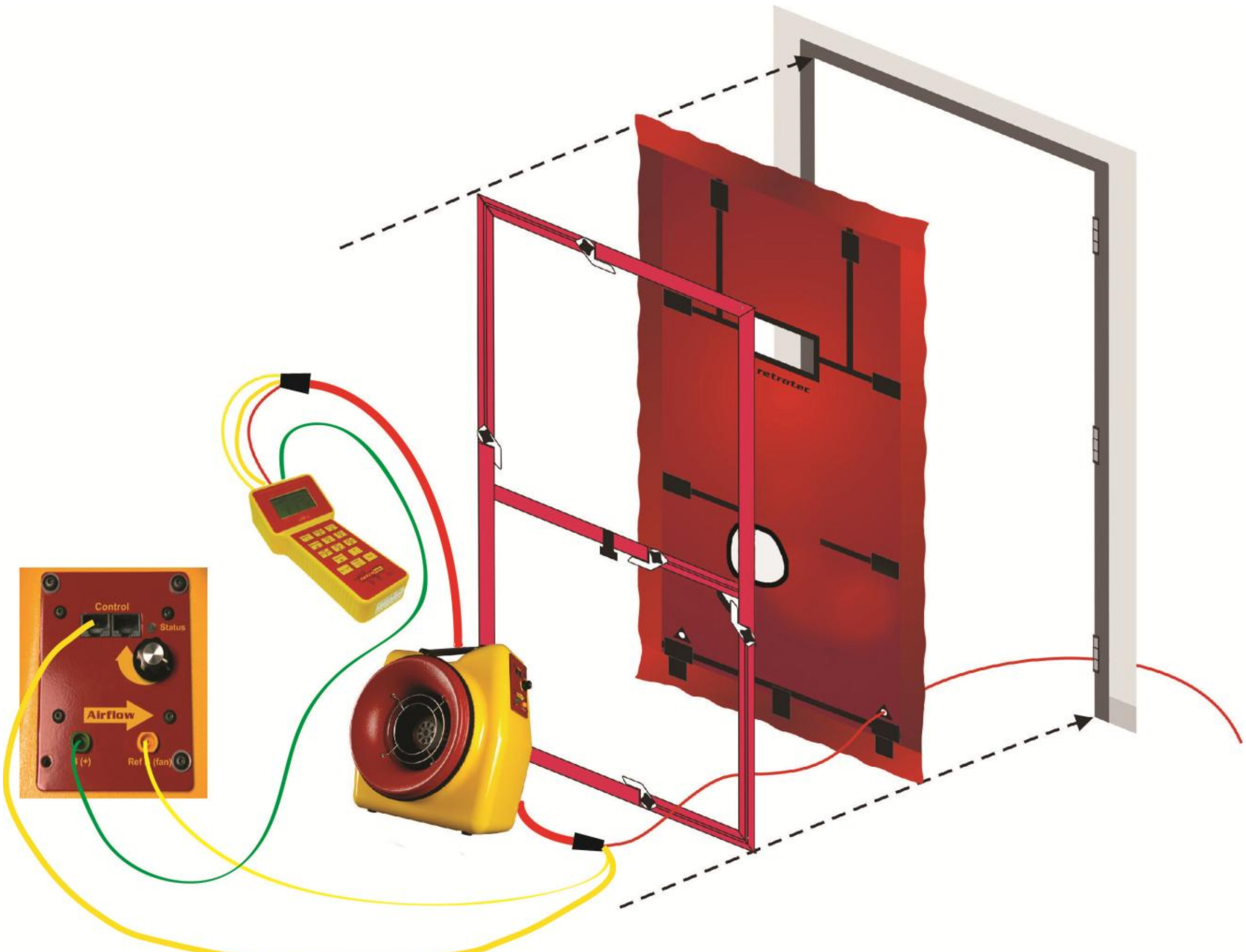


Figure 35. Door Fan setup using a Model 200 fan to test tight enclosures. The left image shows the Fan Top from a side view of the Model 200 fan with tubing and Control Cable connections.

Note: The green tube must be connected if the flow is towards the operator (i.e. air is blowing towards where the operator is standing). The Speed Control Cable can be plugged into either one of the two Control ports.

For Door Fan testing, please refer to procedures outlined in Retrotec's *Manual-Door Fan Operation* and *QuickGuide-Door Fan*.

5. Estimating HVAC System Loss from Ducts

5.1. Duct Air Leakage Measurements

In this appendix, you will learn a simple method for estimating HVAC system losses through field measurements of duct air leakage. Assumptions must be made about the HVAC and duct systems (including system airflow, operating pressure in the ductwork, supply and return breakdown of leakage, and energy loss penalty from supply and return leaks) to estimate the annual energy loss for heating or cooling in the climate in question.

This estimation technique must be looked at with caution, as duct leakage loss calculations are extremely complex, and many assumptions are being made here. The leakage rate determined using the following air leakage procedure may differ from actual operating conditions. This simple model should not be used for research purposes, program design or impact evaluations, as more sophisticated duct leakage loss models are available and more accurate.

5.2. Methodology

The equation for this estimation procedure is in part 5 of this method; follow 1-4 to determine reasonable values to use in part 5.

1. Complete a “Duct leakage to outside” test
    a. Record the leakage rate in CFM at 25 Pa (CFM25).
2. Determine the CFM25 multiplier for average operating pressure
    a. It has been assumed that 25 Pa is a representative pressure for leaks in the duct system under normal operating conditions. However, if you have evidence to suggest that another pressure would better represent leaks under normal conditions, this can be modified. Use the following table to adjust CFM25 for different average operating pressures.
    During normal operating conditions, duct pressures can vary greatly. They are much more stable during a duct leakage test. Use separate multipliers for the return and supply ducts, respectively (as necessary).

Table 5. CFM25 multipliers for average operating pressures.

Average Operating Pressure	Multiplier for CFM25
5 Pa	0.38
10 Pa	0.58
15 Pa	0.74
20 Pa	0.87
25 Pa	1.00
30 Pa	1.12
35 Pa	1.22
40 Pa	1.33
45 Pa	1.42
50 Pa	1.52
Multiplier = (Avg. Operating Pressure/25)*0.60	

b. When possible, use actual operating conditions to determine the best multiplier to use from the table above.

3. Calculate a loss factor for supply and return leaks

   a. Supply Loss Factor = (SLS x SLP x SPM)

      Where: SLS is Supply Leakage Split (default 0.5)

      SLP is Supply Leakage Penalty (default 1.0)

      SPM is Supply Pressure Multiplier (default 1.0)

      Supply Loss Factor = 0.5 * 1.0 * 1.0

      = 0.5

   b. Return Loss Factor = (RLS x RLP x RPM)

      Where: RLS is Return Leakage Split (default 0.5)

      RLP is Return Leakage Penalty (default 0.5)

      RPM is Return Pressure Multiplier (default 1.0)

      Return Loss Factor = 0.5 * 0.5 * 1.0

      = 0.25

   c. Definitions:

      i. Supply/Return Leakage Split is the percent of total measured leakage either on the supply side or the return side, depending on the equation.

      ii. Supply/Return Leakage Penalty is the effective annual energy loss penalty to the HVAC system for each percent loss due to leakage (either supply or return).

      iii. Supply/Return Pressure Multiplier is the multiplier value to be used as selected from the table above (with respects to leakage under normal operating conditions).

4. Estimate HVAC system airflow

   Estimate the total airflow from the system documentation, measured through static pressure/fan curve, or by measuring system airflow using flow measuring techniques.

5. Calculate HVAC system loss (%)

   $$\% \text{ HVAC System Loss} = \frac{CFM25\ Leakage\ to\ outside \times (Supply\ Loss\ Factor + Return\ Loss\ Factor)}{Estimated\ System\ Airflow\ in\ CFM}$$

   Example 1:

   We conduct a duct leakage to outdoors test on a 3 ton, 11 SEER heat pump system (supplies located in the attic and returns in the crawlspace). The owners report a $1300/yr cooling bill and a $700/yr heating bill. Using 25 Pa as our duct testing pressure, we measure 270 CFM25 of duct leakage to the outside. We measure a total system airflow of 1425 CFM using a total flow measurement method. We will use the default values for Supply/Return Loss Factors.

% HVAC System Loss = $\frac{270\ CFM \times (0.5+0.25)}{1425\ CFM}$

% HVAC System Loss = 14%

Annual cooling loss = 14% x $1300 = $182

Annual heating loss = 14% x $ 500 = $ 70

Annual capacity loss = 14% x 3 ton = 0.42 tons

Annual operating SEER = (1 – 14%) x 11 SEER = 9.5 SEER

Example 2:

For the same house measured above, the correct leakage split is determined (majority of leakage on the return side – 200 CFM). Assume the average operating pressure for the return side is closer to 35 Pa because it is close to the plenum takeoff.

CFM25 multiplier for return = 1.22

CFM25 multiplier for supply = 1.0 (default)

Leakage splits:

SLS = 200 CFM25 / 270 CFM25 = 0.74

RLS = 70 CFM25 / 270 CFM25 = 0.26

Loss Factors:

SLF = (0.74 x 1.0 x 1.22) = 0.9

RLF = (0.26 x 0.5 x 1.0) = 0.13

% HVAC System Loss = $\frac{270\ CFM \times (0.9+0.13)}{1425\ CFM}$

= 20%

Annual cooling loss = 20% x $1300 = $260

Annual heating loss = 20% x $ 500 = $100

Annual capacity loss = 20% x 3 ton = 0.6 tons

Annual operating SEER = (1 – 20%) x 11 SEER = 8.8 SEER

Appendix A: System Flow Equations for all Devices

The following equation can be used to determine flow, using the variables listed in the table below. Each fan has a different flow equation, incorporating N and K values related directly to that particular fan.

$$Flow = (FP - CR \times K1)^N \times (K + K3 \times FP)$$

where: FP is the Fan Pressure, and CR is the corrected room pressure

Note: CR can be determined by subtracting bias pressure from room pressure, by using the "Baseline" feature on the DM-2, or by retrieving corrected pressure from FanTestic.

To determine the fan flow for a particular Fan Pressure, insert the values for *FP*, *CR*, and the N and K values (based on the type of fan and its Range Plate/Range being used).

The Fan Pressure (FP or "PrB" reading on the DM-2) must be greater than "Min Fan Pressure" and greater than (PrA*K2)

Table 6. N and K coefficients for all DM-2 supported fans.

	Range	N	K	K1	K2	K3	MF
Model 200	Open	0.5115	30.7774	0.000	0.2	0.0000	10
	Mid	0.5415	5.9146	0.000	0.5	0.0000	25
	Low	0.6125	1.0056	-0.024	0.5	-0.0002	25
Retrotec 1000 / 2000 / 3000 / 3000SR	Open	0.5214	519.6	-0.070	0.8	-0.1150	8.6
	A	0.5030	265.0	-0.075	1.0	0.0000	12
	B	0.5000	174.8824	0.000	0.3	0.0000	10
	C8	0.5000	78.5000	-0.020	0.5	0.0160	10
	C6	0.5050	61.3000	0.054	0.5	0.0040	10
	C4	0.5140	39.3000	0.080	0.5	0.0005	10
	C2	0.5500	20.0000	0.139	0.5	-0.0027	10
	C1	0.5410	11.9239	0.122	0.4	0.0000	10
	L4	0.4800	4.0995	0.003	1.0	0.0004	10
	L2	0.5020	2.0678	0.000	0.5	0.0001	10
	L1	0.4925	1.1614	0.100	0.5	0.0001	10
Mn DuctBlaster	Open	0.5032	108.7000	0.000	1.0	0.0000	25
	Ring 1	0.5038	40.5000	0.000	1.0	0.0000	25
	Ring 2	0.5064	15.2700	0.000	1.0	0.0000	25
	Ring 3	0.5140	5.8400	0.000	1.0	0.0000	4
Mn Model 3 110 V	Open	0.4879	506.8000	0.000	1.0	0.0000	25
	A	0.4876	190.1000	0.000	1.0	0.0000	25
	B	0.4955	60.6700	0.000	1.0	0.0000	25
	C	0.5132	21.3700	0.000	1.0	0.0000	15
	D	0.4942	7.2160	0.000	1.0	0.0000	15
	E	0.5267	2.7260	0.000	1.0	0.0000	15

	Range	N	K	K1	K2	K3	MF
Mn Model 3 230 V	Open	0.4918	498.9000	0.000	1.0	0.0000	25
	A	0.4889	190.1000	0.000	1.0	0.0000	25
	B	0.4958	60.3500	0.000	1.0	0.0000	25
	C	0.5178	20.4700	0.000	1.0	0.0000	25
	D	0.5022	6.8700	0.000	1.0	0.0000	15
	E	0.5139	2.8170	0.000	1.0	0.0000	15
Mn Model 4 230 V	Open	0.4848	438.7000	0.000	1.0	0.0000	25
	A	0.4952	160.8000	0.000	1.0	0.0000	25
	B	0.4968	48.0800	0.000	1.0	0.0000	20
	C	0.5157	11.3600	0.000	1.0	0.0000	15
	D	0.5032	7.2460	0.000	1.0	0.0000	15
	E	0.5166	2.8020	0.000	1.0	0.0000	15
Infiltec E3	Open	0.5000	103.0000	0.000	1.0	0.0000	10
	7 Holes	0.5000	103.4000	0.000	1.0	0.0000	10
	4 Holes	0.5000	61.1000	0.000	1.0	0.0000	10
	3 Holes	0.5000	44.6000	0.000	1.0	0.0000	10
	2 Holes	0.5000	28.0000	0.000	1.0	0.0000	10
	1 Hole	0.5000	10.8300	0.000	1.0	0.0000	10
Mn Exhaust Fan	E1	0.5000	43.7300	0.000	1.0	0.0000	1.0
	E3	0.5000	20.7200	0.000	1.0	0.0000	1.0
	E3	0.5000	10.0700	0.000	1.0	0.0000	1.0
Mn True Flow	#14	0.5000	115.0000	0.000	1.0	0.0000	10
	#20	0.5000	154.0000	0.000	1.0	0.0000	10

Table 7. N and K coefficients for all DM-2 supported fans, Obsolete.

	Range	N	K	K1	K2	K3	MF
DU100	Open	0.4910	39.4840	0.000	1.0	0.0000	10
	2.75	0.5110	3.0110	0.000	1.0	0.0000	10
	1.23	0.5110	1.1290	0.000	1.0	0.0000	10
Retrotec 600 / 700	Open	0.5280	372.5200	0.000	1.0	0.0000	10
	12	0.5000	104.6800	0.000	1.0	0.0000	10
	8	0.5000	54.0300	0.000	1.0	0.0000	10
	6	0.5000	24.1250	0.000	1.0	0.0000	10
	2	0.5000	8.2400	0.000	1.0	0.0000	10
	1	0.5000	4.0700	0.000	1.0	0.0000	10
Retrotec 800 / 900	18F	0.4690	332.3705	0.000	1.0	0.0000	10
	18R	0.4800	374.4180	0.000	1.0	0.0000	10
	9	0.4920	153.8012	0.000	1.0	0.0000	10
	5	0.4510	102.0857	0.000	1.0	0.0000	10
	3	0.4700	54.3137	0.000	1.0	0.0000	10
	1.4	0.4670	31.8802	0.000	1.0	0.0000	10
	1.3	0.4420	28.3473	0.000	1.0	0.0000	10
	1.2	0.4830	17.7951	0.000	1.0	0.0000	10
	1.1	0.4740	12.5194	0.000	1.0	0.0000	10
	0.1	0.5100	6.0989	0.000	1.0	0.0000	10

Appendix B: Using a generator for power

Retrotec recommends a generator with inverter type AC power output. Size the generator capacity above the maximum power required in order to reduce distortion of the AC power waveform. The higher the rated power output, the better. Suggestions for minimum generator output sizes are 3000W for Door Fans and 500W for DucTesters.

Table 8. Acceptable generator power output.

<table>
<tr><th>Fan</th><th>Operating Voltage</th><th>Max Operating Current (Watts)</th><th>Max Inrush Current</th><th>Minimum Generator Power Output</th></tr>
<tr><td rowspan="2">Model 200 Series DucTester</td><td>120VAC</td><td>2A (240W)</td><td>2.5A (300 W)</td><td rowspan="4">500 W</td></tr>
<tr><td>208VAC</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="2">Model 200 w/2350 Fan Top</td><td>120VAC</td><td>2A (240W)</td><td>3A (360W)</td></tr>
<tr><td>208VAC</td><td>0.9A (187W)</td><td>1.2A (250W)</td></tr>
</table>

When selecting the generator, look for key words and phrases including:

- “inverter output”
- “utility-grade AC power”
- “suitable for sensitive electronics”

Table 9. Portable generator AC power output types.

Type of AC Power Output	Comments/Expectation	
Inverter	Best; Compatible	Recommended
AVR – Automatic Voltage Regulation	Questionable; May not perform	Not Recommended
Brushless	Worse; May not perform	Not Recommended
CycloConverter	Worst; May not perform	Not Recommended

Generators

Honda Generator EU2000 (120V, 2000W, 67 lbs)

- Works will all DucTester fan models.
- Works with both 2200 and 2350 series fans.

The Honda EU2000 provides 2000 watts and 120V AC power. It is equipped with an inverter, and is specially designed for sensitive electronic equipment. At 16.7 Amps, it meets the needs of most Retrotec equipment.

GENYX G3000HI (230V, 3000W) generator

- Works with all Retrotec Fans.

The G3000HI is equipped with an inverter, and runs at 230V and a maximum of 3000W for even the most powerful Retrotec equipment.

Portable Power Supplies

Portable power supplies can provide enough power for Retrotec DucTester fans, but are unlikely to produce sufficient power for a Door Fan. Please ensure that the power supply meets the minimum power requirements of the fan before attempting to use one.

Black and Decker Electromate 400 Model VEC026BD

- ONLY use with DucTesters with a 2350 Fan Top (per label).

The VEC026BD is a 110/120VAC power supply with a built in 400W inverter.

Appendix C : Flow Table

Table 10. Retrotec Model 200 Fans. Duct Pressure: 25 Pa. Flow: AWAY or TOWARDS (right) operator, if both green and yellow tubes are connected properly. Units in CFM.

Fan Pressure (Pa)	Open	Mid	Low
10	100		
12	110		
14	119	25	5
16	127	27	6
18	135	28	6
20	142	30	6
22	150	32	7
24	156	33	7
26	163	35	7
28	169	36	8
30	175	37	8
32	181	39	8
34	187	40	9
36	192	41	9
38	198	42	9
40	203	44	10
42	208	45	10
44	213	46	10
46	218	47	10
48	223	48	11
50	228	49	11
52	232	50	11
54	237	51	12
56	241	52	12
58	246	53	12
60	250	54	12
62	254	55	13
64	258	56	13
66	262	57	13
68	266	58	13
70	270	59	13
72	274	60	14
74	278	61	14
76	282	62	14
78	286	63	14
80	289	63	15
82	293	64	15
84	297	65	15
86	300	66	15
88	304	67	15
90	307	68	16
92	311	68	16
94	314	69	16

Fan Pressure (Pa)	Open	Mid	Low
96	318	70	16
98	321	71	16
100	324	72	17
105	333	74	17
110	341	75	18
115	349	77	18
120	356	79	18
125	364	81	19
130	371	83	19
135	378	84	20
140	385	86	20
145	392	88	21
150	399	89	21
155	406	91	21
160	413	92	22
165	419	94	22
170	426	95	23
175	432	97	23
180	438	98	23
185	444	100	24
190	451	101	24
195	457	103	24
200	463	104	25
205	468	106	25
210	474	107	26
215	480	108	26
220	486	110	26
225	491	111	27
230	497	112	27
235	502	114	27
240	508	115	28
245	513	116	28
250	518	118	28
255	524	119	28
260	529	120	29
265	534	121	29
270	539	123	29
275	544	124	30
280	549	125	30
285	554	126	30
290	559	127	31
295	564	129	31
300	569	130	31

Appendix D: Troubleshooting

Occasionally simple problems do occur with a DucTesting system. If the problem is described in any of the following sections, follow the steps to attempt to resolve the problem. If the problem persists, contact Retrotec customer support.

TOO LOW appears on display:

Backpressure refers to the pressure that the DucTester fan works against while running. Under most testing conditions, backpressure is not concern. If the backpressure is too great, the DM-2 will automatically sense it and display "Too Low", indicating that the flow signal is low compared to the pressure the fan is working against. Normally, changing to a more restrictive Flow Range will solve this problem, as long as sufficient test pressure can be reached on that Flow Range. If not, the @ feature on the gauge may be used.

Adjusting DucTester Motor Mount (for Model 220)

If, when rotating, the fan blade rubs on the fan casing, it may be necessary to adjust the motor mount. This commonly happens when the motor mount inside of the fan shifts slightly, either from being dropped or some other accident. Be very careful before attempting this procedure. Loosening the bolts too far can cause the nut to fall off inside the fan, requiring more extensive repairs. The fan can be sent back to Retrotec for adjustment, if the procedure seems too complicated or troublesome.

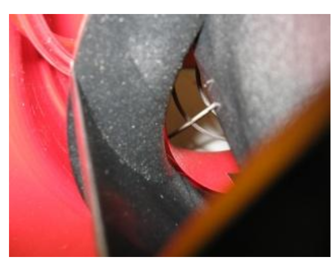
To adjust the DucTester motor mount

1. Remove the ½” Velcro strip from the fan outlet

2. Use a Phillips Head screwdriver and 5/16" wrench to remove outlet screen.

3. Lightly loosen the four Flange nuts using 7/16" wrench and 5/32" Allen key

4. Adjust the motor so it overlaps the plastic cylinder.



5. Spin the motor and listen to see if it is rubbing against the plastic plastic. Continue adjusting the motor until it ceases to rub against the plastic.

6. Tighten the four Flange nuts. Make sure that the motor does not shift as the nuts are tightened. Continue to spin the motor to listen for rubbing.

7. Once the nuts are tights, and the fan blades have stopped rubbing against the plastic, reinstall the outlet screen.

8. Retrotec recommends that a field calibration check be performed on the fan after attempting this procedure.

Gauge Reading Does Not Change

When the measured flow does not increase as fan speed increases, there can be a couple of problems. The first thing to check is the gauge. Check if "@ Pressure" is active. When "@ Pressure" is active, the gauge attempts to provide a reading at the set pressure. Therefore, regardless of fan speed, the measure flow will appear relatively unchanging. Simply press **[@ Pressure]** until there is no @ symbol next to the pressure reading.

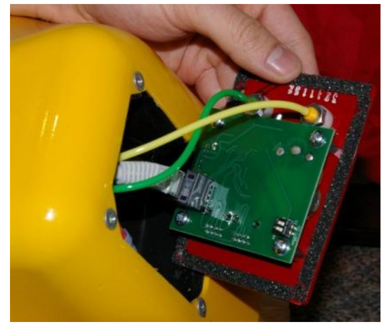
Fixing the Fan Top

Occasionally, it's possible for the Fan Pressure tubes, inside the Fan Top, to become blocked, pinched, or disconnected. This will prevent the gauge from reading changes in Fan Pressure when the fan speed changes.

- Attach a one foot length of tube to the "Ref B (Fan)" port on the Fan Top. Try sucking on the tube, you should hear a whistling sound from inside the fan as air is drawn into the two pickup points (see Figure 7).
- Do the same thing with the tube attached to the "B" port. If no sound is heard from the port, than the pressure tube(s) under the Fan Top are blocked. If both tubes are clear, there is no need to continue. Blowing air through the tube connector can remove a water drop if that was causing the blockage.

To fix a Fan Top pressure tube

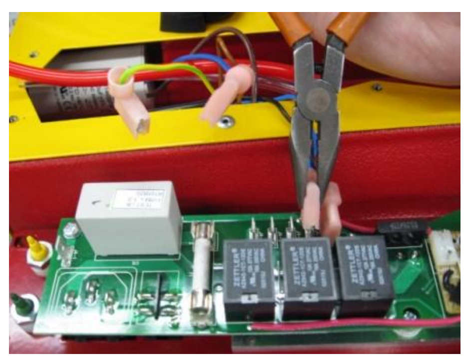
1. Remove the 2350 Fan Top, by removing the five 8-32 x 5/8" button head screws that secure it to the fan body, using the 3/32" hex (Allen) key.
2. Gently lift the Fan Top away from the fan, exposing the tubes and wires beneath.
3. If the yellow or green tubes are blocked or kinked, replace that section of tube, and re-attach the Fan Top.
4. If the tubes have become disconnected, connect the red tube to the base of the green pressure port, and connect the clear tube to the base of the yellow pressure port.
5. Re-attach the Fan Top by screwing it back to the fan body.



Occasionally it may be necessary to replace the Fan Top completely.

To replace a Fan Top

1. Remove the 2350 Fan Top, by removing the five 8-32 x 5/8" button head screws that secure it to the fan body, using the 3/32" hex (Allen) key.
2. Gently lift the Fan Top away from the fan, exposing the tubes and wires beneath.
3. Disconnect the pressure tubes.
4. Disconnect the Fan Top from wiring harness by carefully pulling all six of the flag connectors away from the PCB using a pair of pliers.
5. it's Set the old Fan Top aside, and connect the new one
6. Connect the pressure tubing to the new Fan Top. The red tube connects to the green port, and the clear tube connects to the yellow port.



7. Connect the wires to the Fan Top by attaching the flag connectors to the terminal posts on the Fan Top PCB as indicated. Be careful to no bend the PCB.

120v		**240v**	
Green	J4-1 (Labeled GRN)	Green	J4-1 (Labeled GRN)
Blue (Motor Wire)	J4-4 (Labeled WHT)	Blue (Motor Wire)	J4-5 (Labeled RED)
Black	J4-6 (Labeled BLK)	Black	J4-6 (Labeled BLK)
Blue (Capacitor Wire)	J4-2 (Labeled BRN)	Blue (Capacitor Wire)	J4-2 (Labeled BRN)

8. Check Switch ‘S1’ on PCB and ensure that Switch 2 is in the “ON” position for 120V fans, and in the “OFF” position for 240V fans.
9. Ensure the fan-top sits on the fan-top cavity flush such that the wires and/or tubing is not being pinched/crushed under fan-top.

120 240

10. Re-attach the Fan Top to the fan body with the previously removed screws.

Appendix E: Duct-Test Form

Complies w CA Title 24 **Test date: …………………/201__**

Model 102a DucTester System with DU-102 fan and DM-2 digital gauge Serial # ………………… , or

Model R31 DucTester System with DU-210 fan and DM-2 digital gauge Serial # ………………… , or

Model Q32 DucTester System with DU-220 automatic fan and DM-2A automatic digital gauge Serial # …………………

Address: ……………………………………………. Contact: ………………………… Phone: …………………..

………………………………………………….. Technician: ……………………….. ……….. ……….. …...

The DucTester measures the total leakage of a duct system by pressurizing all ducts to 25 Pascals with the air-handler off and the registers taped over.

Step ↓	…√		Detailed Description of the Step
1		Position DucTester near return	Ensure the flex will reach the return grill
2		Turn Air-handler off	Put your car keys beside the switch
3		Remove the furnace filter	Cover filter opening
4		Attach Flange + flex to return register	… or __access door in the air handler
6		Insert blue tube in a supply register	
7		Seal all other registers	do NOT seal to the wall or ceiling.
8		Open doors or windows	
9		Connect the DucTester	__ yellow tube, __ power cord, __ speed control, __green tube.
10		Connect the DM-2	
11		Turn on and set up the DM-2	
12		Create a 25 Pa pressure in the ducts	
13		Range Configuration	__ Low 1" nozzle, __Mid 2" nozzle, __Open inlet.
14		Record Flow and Pressure Record Flow with @ 25 Pa displayed. Record n and TimeAvg displayed.	____ CFM, ___ Pa with NO @ Pressure displayed. ____ CFM, __ @ 25 feature used. ___ n and ___ seconds of Time Average displayed.
15		Record Flow Direction	___ pressurize with flow into ducts, __depressurize
16		Maximum Allowable duct leakage per page 7 is:	____ CFM, ___ Pass, ___ Fail.
17		Remove tape	Remove tape from registers.
18		Turn HVAC equipment back ON	Re-install the furnace filter and turn all HVAC equipment back ON

New duct systems **must leak less than 6% of the air handler's flow.**

The Maximum allowable duct tester measurement based on 4 different ways of calculating air handler flow is:

For A/C systems multiply the Tonnage X 24 CFM. **TONNAGE ___ X 24 = _____ CFM**

Assumes 400 CFM per Ton with maximum allowable leakage of 6% = 24 CFM per Ton.

E.g. a 5 Ton system must have 5 X 24 = 120 CFM of leakage or less at a 25 Pa test pressure in the supplies.

For Heating systems divide the BTU /1000 X 1.302 CFM. **BTU _________ /1000 X 1.302 = ____CFM**

Assumes 21.7 CFM per 1000 BTU capacity with maximum allowable leakage of 6% = 1.302 CFM per 1000 BTU.

E.g. a 100,000 BTU furnace must have 100,000 / 1000 X 1.302 = 132 CFM of leakage or less.

3. For climates 8 through 15 divide the Floor Area by 1000 X 42 CFM. **Floor Area ______ / 1000 X 42 = ____CFM**

For climate zones 7 and 16 divide the Floor Area by 1000 X 30 CFM **Floor Area ______ / 1000 X 30 = ____CFM**

E.g. a 3,000 sq. ft. home must have 3,000 / 1000 X 42 = 126 CFM or less for climates 8 through 15

E.g. a 3,000 sq. ft. home must have 3,000 / 1000 X 30 = 90 CFM or less for climate zones 7 and 16.

4. Measure the fan flow divided by 100 X 6. **Measured fan flow ______ / 100 X 6 = ____CFM**

E.g. an air-handler blower flow of 2000 CFM must have 2000 / 100 X 6 = 120 CFM of leakage or less.

Existing duct systems **must leak less than 15% of the air handler's flow.**

The Maximum allowable duct tester measurement based on 4 different ways of calculating air handler flow is:

For A/C systems multiply the Tonnage X 60 CFM. **TONNAGE ___ X 60 = _____ CFM**

Assumes 400 CFM per Ton with maximum allowable leakage of 15% = 60 CFM per Ton.

E.g. a 5 Ton system must have 5 X 60 = 300 CFM of leakage or less at a 25 Pa test pressure in the supplies.

For Heating systems divide the BTU /1000 X 3.255 CFM. **BTU _________ /1000 X 3.255 = ____CFM**

Assumes 21.7 CFM per 1000 BTU capacity with maximum allowable leakage of 15% = 1.302 CFM per 1000 BTU.

E.g. a 100,000 BTU furnace must have 100,000 / 1000 X 3.255 = 326 CFM of leakage or less.

3. For climates 8 through 15 divide the Floor Area by 1000 X 42 CFM. **Floor Area ______ / 1000 X 105 = ____CFM**

For climate zones 7 and 16 divide the Floor Area by 1000 X 30 CFM **Floor Area ______ / 1000 X 75 = ____CFM**

E.g. a 3,000 sq. ft. home must have 3,000 / 1000 X 105 = 315 CFM or less for climates 8 through 15

E.g. a 3,000 sq. ft. home must have 3,000 / 1000 X 75 = 225 CFM or less for climate zones 7 and 16.

4. Measure the fan flow divided by 100 X 15. **Measured fan flow ______ / 100 X 15 = ____CFM**

E.g. an air-handler blower flow of 2000 CFM must have 2000 / 100 X 15 = 300 CFM of leakage or less.

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.
Aluminum Frame	Describes a frame over which cloth is stretched to provide a Door Panel closure for air leakage testing in buildings.
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 Retrotec fan unit that induces air flow and provides a Fan Pressure signal from which flow is measured.
CFM	Units: 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.
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)
Control port	Ethernet port on a Retrotec fan, labeled "Control"
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.
digital gauge	A gauge with an electronic pressure sensor and digital display that is capable of reading in tenths of a Pascal.
DOE	U.S. Department of Energy
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 a doorway. 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." a more correct term is door fan.

Term	Definition
Door Panel	A solid or flexible panel used to temporarily seal off a door way while allowing for the installation of a fan for the purpose of blowing air into the building in order to measure the air leakage rate or to provide a pressure to assist in the location of air leaks.
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, eq. (5).
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"**
Equivalent Leakage Area (ELA or EqLA)	In layman's terms, the ELA is the size of hole we'd have if all the building's cracks and holes could somehow be brought together. Also called: Whole Room Leakage and includes leaks through the ceiling and below the ceiling (BCLA). 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 GSB 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 it 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, eq. (5).
Fan Pressure	The pressure difference between inside the door fan and the surrounding air. This pressure can be read as "PrB" from Channel B on the DM-2. It is used by the computer to calculate the air flow rate through the Door Fan.
Fan Top	Part on the fan where the fan's tubing, Control Cable, and power connections are.
HVAC	Heating Ventilating and Air conditioning system.
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 ft^2 or m^2.
LEED	Leadership in Energy and Environmental Design

Term	Definition
Low-Flow Cloth Door Panel	Cloth Door Panel used to test tight enclosures with a Model 200 fan
Manual Speed Control Knob	The dial that is on a Fan Top to control fan speed
Open Range	A Range configuration on a Retrotec Door Fan that has no Range Rings or Range Plates attached. It is sometimes referred to as Open (22) Range since it's 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" Water Column (the pressure required to push water up 1" in a tube). One Pascal = 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 Range attachment on the Retrotec Door, which holds Ranges C8, C6, C4, C3, C2, C1, L4, L2, and L1. See Retrotec's Fan Range Configuration QuickGuide.
Range Ring	The plastic Range attachments on the Retrotec Door, which include Range A and Range B. See Retrotec's Fan Range Configuration QuickGuide.
reading	A set of simultaneous Room Pressure and Fan Pressure measurements. 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 Door Fan between inside and outside of the enclosure. This pressure is commonly measured by Channel A on the DM-2 gauge.