June 2018

Residential Air Leakage (Blower Door) Testing for Florida Code Compliance

Infiltration or uncontrolled air leakage into buildings is a result of the number and size of cracks and gaps in the building's thermal envelope (its floor, walls, ceilings, windows, and doors) and the natural and mechanical air pressure "driving forces" that the building experiences. Natural driving forces include wind, "stack effect" (air motion in buildings related to indoor-to-outdoor temperature difference and height) and atmospherically vented combustion appliances. Mechanical driving forces include fans (such as exhaust and air handler fans), duct leakage, and interior door closure (closing doors restricts airflow between rooms and the main body of the building).

To address the energy and indoor air quality impacts of air leakage in homes, the current Florida Building Code includes a building air leakage testing requirement for new Florida homes and stipulates both a maximum air leakage rate and, at the lower end, an air leakage rate "trigger" at which whole-house mechanical ventilation is required.

As discussed in more detail later in this guide, the air leakage test (or "blower door test") uses a calibrated fan and digital pressure gauge to either pressurize or depressurize a home to a standard test pressure of 50 Pascals with respect to the outside and measure the air leakage flow at that pressure. Standardization of the test procedure allows the air leakage of one home to be compared with that of another, and with the Code maximum of seven air changes per hour at 50 Pascals test pressure, or "7 ACH50."

If the tested air leakage of a new home is less than three air changes per hour at 50 Pascals test pressure (3 ACH50), current Florida Code requires whole-house mechanical ventilation be provided for it.

Why is uncontrolled air leakage important?

As its name implies, uncontrolled air leakage is outdoor airflow into buildings that is not planned or intended. While some level of outdoor air is important, too much will increase energy use, and in hot-humid climates like Florida's, introduce a lot of moisture. This air may also be pulled into the building from undesirable locations such as the attic or garage. In more extreme cases, uncontrolled airflow can lead to significant indoor air quality issues. As houses become more airtight, outdoor air is brought in via whole-house mechanical ventilation to decrease indoor pollutant concentrations, but unlike uncontrolled air leakage, mechanical ventilation allows control over how much air is brought in and the location from which it is drawn.

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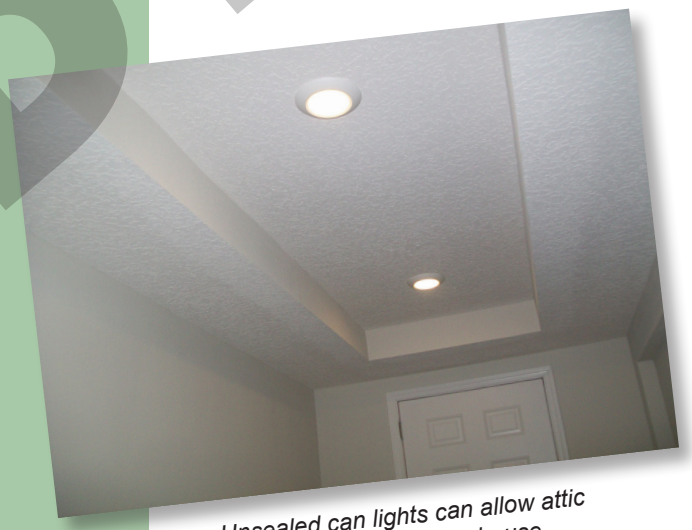
Definitions

APPROVED
Approval by the code official as a result of investigation and tests conducted by him or her, or by reason of accepted principles or tests by nationally recognized organizations.

BLOWER DOOR
A powerful fan that mounts into the frame of an exterior door and pulls air out of a building, lowering the air pressure inside the building with respect to the outside; the higher outside air pressure then causes air to flow in through all unsealed cracks and gaps.

BUILDING THERMAL ENVELOPE
The basement walls, exterior walls, floor, roof and any other building elements that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.



Unsealed can lights can allow attic air to infiltrate into a house.

ENERGY AUDITOR
A trained and certified professional who conducts energy evaluations of an existing building and uses tools to identify the building's current energy usage and the condition of the building and equipment.

ENERGY RATER
An individual certified by a building energy-efficiency rating system to perform building energy-efficiency ratings for the building type and in the rating class for which the rater is certified.

INFILTRATION
The uncontrolled inward air leakage through cracks and crevices in any building element and around windows and doors of a building caused by pressure differences across these elements due to factors such as wind, inside and outside temperature differences (stack effect), and imbalance between supply and exhaust air systems.

OUTDOOR (OUTSIDE) AIR
Air that is outside the building envelope or is taken from outside the building that has not been previously circulated through the building.

VENTILATION
The natural or mechanical process of supplying conditioned or unconditioned air to, or removing such air from, any space.

WHOLE HOUSE MECHANICAL VENTILATION SYSTEM
An exhaust system, supply system, or combination thereof that is designed to mechanically exchange indoor air with outdoor air when operating continuously or through a programmed intermittent schedule to satisfy the whole house ventilation rates.

All definitions from Chapter 2 of the residential provisions of the Florida Building Code, Energy Conservation except Blower Door adapted from energy.gov Blower Door Tests article and Energy Auditor and Energy Rater from 553.993(5) or (7), *Florida Statutes*.

Florida Building Code Testing Requirements

The 6th Edition (2017) Florida Building Code air leakage testing requirements are specified in Section R402.4.1.2 of the residential Energy Conservation volume. This code section stipulates maximum leakage rates, how the test is to be conducted, who can conduct the testing, reporting requirements, and at what point in construction the test can be performed:

"The building or dwelling unit shall be tested and verified as having an air leakage rate not exceeding seven air changes per hour in Climate Zones 1 and 2, and three air changes per hour in Climate Zones 3 through 8. Testing shall be conducted in accordance with ANSI/RESNET/ICC 380 and reported at a pressure of 0.2 inch w.g. (50 pascals). Testing shall be conducted by either individuals as defined in Section 553.993(5) or (7), Florida Statutes, or individuals licensed as set forth in Section 489.105(3)(f), (g) or (i) or an approved third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the code official. Testing shall be performed at any time after creation of all penetrations of the building thermal envelope…"

Note that the maximum air leakage rate allowed in Florida (Climate Zones 1 and 2) is up to 7 air changes per hour at a pressure of 0.2 inch w.g., or 50 pascals (also written as "7 ACH50").

Per the Florida Statutes referenced in Section R402.4.1.2 above, individuals qualified to provide air leakage testing include energy auditors, energy raters, Class A or B air-conditioning contractors and mechanical contractors, plus approved third parties. For the purposes of this code section, an approved third party is an individual approved by a code official to perform air leakage testing.

Two testing exceptions are provided:

- Section R402.4 states that dwelling units of R-2 Occupancies and multiple attached single family dwellings are permitted to comply with Section C402.5 of the commercial provisions of the Florida Energy Code. Section C402.5 allows thermal envelope leakage compliance via either a list of prescriptive requirements or through air leakage testing.
- Section R402.4.1.2 lifts the testing requirement for additions, alterations, renovations or repairs to an existing home's building thermal envelope if the new construction is less than 85 percent of the thermal envelope.

As homes become more airtight, whole-house ventilation systems are installed to mechanically exchange indoor air with outdoor air. The 6th Edition (2017) Florida Building Code, Residential volume requires whole-house mechanical ventilation when the air infiltration (leakage) rate in a home under standard test conditions is less than 3 (ACH50 < 3). Section R303.4 states:

"Where the air infiltration rate of a dwelling unit is less than 3.00 air changes per hour where tested with a blower door at a pressure of 0.2 inch w.c (50 Pa) in accordance with Section R402.4.1.2 of the Florida Building Code, Energy Conservation, the dwelling unit shall be provided with whole-house mechanical ventilation in accordance with Section M1507.3."

Who can perform a blower door test?

Per the Florida Statutes referenced in Section R402.4.1.2, individuals qualified to provide air leakage testing include energy auditors, energy raters, Class A or B air-conditioning contractors and mechanical contractors, plus approved third parties. For the purposes of this code section, an approved third party is an individual approved by a code official to perform air leakage testing.

Pressure Measurement

The natural and mechanical air pressure driving forces that buildings experience are typically measured by digital pressure gauges in Pascals. Pascals are very small units of pressure—one Pascal (or Pa) is equal to 0.004 inches of water column or 0.000145 pounds per square inch (PSI); A sheet of notebook paper exerts about one Pascal of pressure.

Building pressure measurements are made and recorded as pressure differentials— the pressure difference between one location, room or zone and another.

Digital gauges are used to make the pressure measurements. Figure 2 shows an example of these gauges. There are two sets of pressure taps at the bottom of the gauge. The two taps on the left side, or channel, of this meter can make one differential pressure measurement and the two taps on the right channel of the meter can make another measurement (so the meter can make two separate differential pressure measurements at once). Tubes attached to the taps allow measurements to be made in various spaces or areas while the gauge can remain in a convenient location.

Blower door set up for an air leakage test.

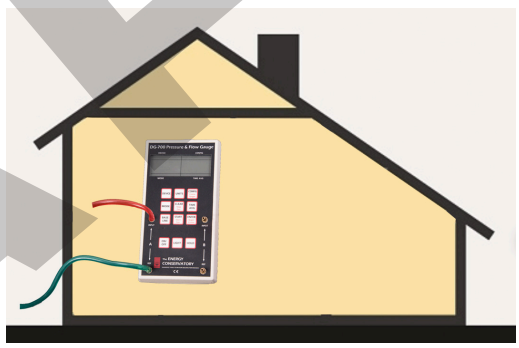


Figure 1. Measuring pressure of house main body with reference to (WRT) outside.

In the example in Figure 1, the end of the red tube is in the main body of the house while the end of the green tube is outdoors. In this case, the pressure differential between the house main body and the outdoors is being measured—or in other words—the pressure of the main body with reference to (or "WRT") the outside is being measured.

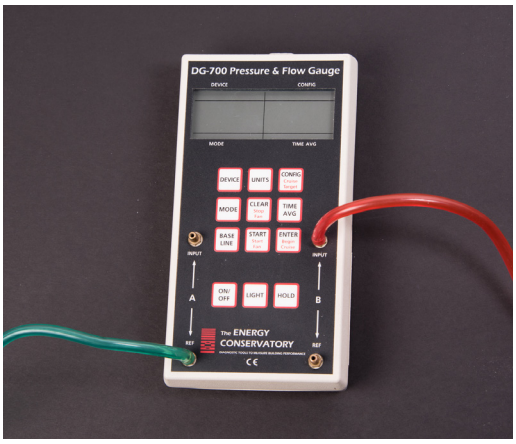


Figure 2. The Energy Conservatory DG-700 Pressure and Flow Gauge

Blower Door Components

Air leakage tests are performed using a blower door, which includes the following components:

- Digital gauge
- Calibrated variable speed fan
- Adjustable frame and curtain
- Fan speed controller with cable
- Tubing

When a qualified tester is setting-up a blower door, first the blower door frame is adjusted to fit into an exterior doorway. The frame is then removed from the doorway, the curtain is placed over the frame, and the frame and curtain combination is secured into the doorway with locking cams. The fan is then mounted into an opening in the curtain and secured to a frame crossbar with a Velcro strap, and the fan speed controller is plugged into the fan. Each calibrated fan has a pressure sensor (Figure 4) to measure the pressure at the fan with reference to the house (or where the air entering the fan is coming from). This "flow pressure" measurement is used to calculate the airflow through the fan. The fan pressure sensors require a minimum pressure to make accurate readings, so fan manufacturers provide the fans with sets of rings (Figure 5) that can be used to increase the pressure at the fan at lower flow rates. Conversely, rings can be removed to allow more airflow through the fan.

Figure 4. Pressure sensor.

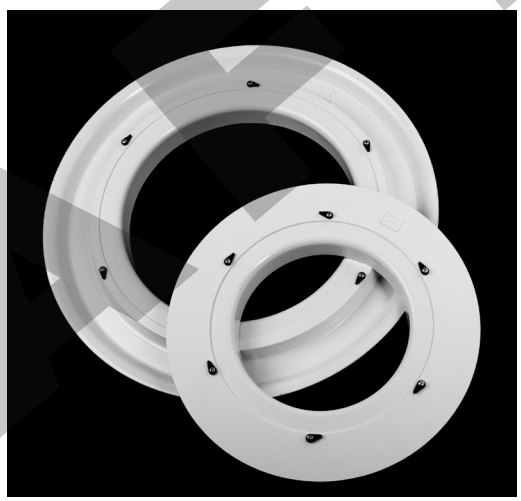


Figure 5. Rings are installed on the fan to increase or decrease airflow, thereby adjusting the flow pressure.

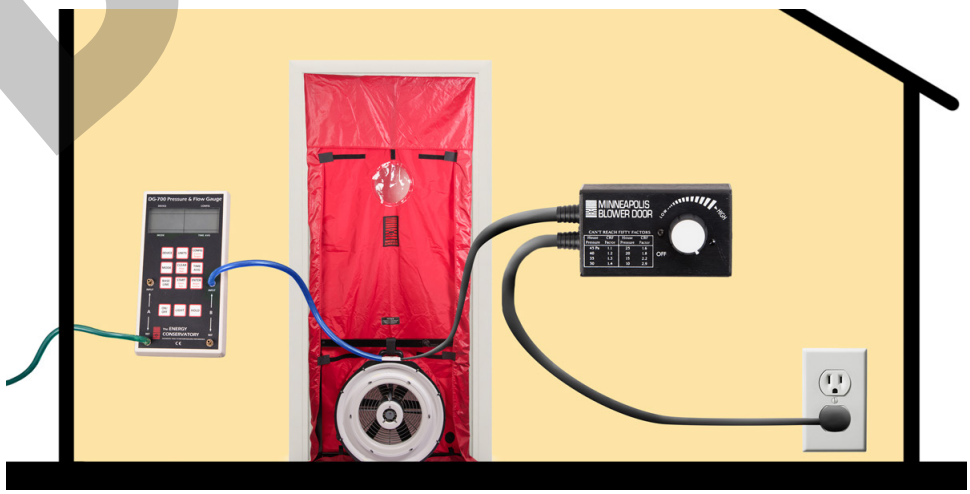


Figure 6. How blower door components are connected.

Testing and Results Reporting

A blower door test can be performed at any time, but for Florida Code compliance, it is conducted just before the Certificate of Occupancy (CO) is issued, after all piping, wiring and other penetrations of the building thermal envelope have been sealed. When conducting a blower door test, a qualified tester first prepares the house by:

- Closing all exterior doors and windows
- Opening all interior doors
- Turning off the heating and cooling system(s)
- Turning off all fans that supply air to the house or exhaust air from it
- "Safe-ing" all atmospherically vented combustion appliances by adjusting thermostats so they do not come on during the test.
- If there is a fireplace, making sure there are no hot ashes (if hot ashes, test cannot be conducted), closing the fireplace doors and/or dampers and either vacuuming cold loose ashes or covering them with newspaper.

WARNING!

Due to the potential for combustion and other health and safety issues, blower door testing should only be conducted by trained, qualified individuals.

Either a single- or multi-point blower door test can be conducted. A single point test only measures leakage at one house pressure (house With Reference To outside) of approximately 50 Pascals, while a multi-point test measures leakage over a range of house pressures (from approximately 15 Pascals to 55 Pascals). A single point test is quicker, but analysis of multi-point test results will provide additional leakage characteristic information (e.g. whether the leakage is from a larger number of smaller, thinner cracks and gaps, or smaller number of larger openings). Either test will provide adequate air leakage measurements for code compliance purposes.

In each single-point test, the tester will first take indoor and outdoor temperature measurements and baseline house WRT outside pressure readings with the blower door fan off and sealed, which are all used to increase the accuracy of the test results. The tester then conducts the blower door test and records the house pressure, fan ring used for the test and fan pressure. Entering the fan ring and fan pressure measurement together with temperature and baseline pressure readings and house altitude into software included onboard the digital gauge or other testing software provides the corrected fan airflow rate in cubic feet per minute (CFM50). Example single-point test data is provided in Table 1.

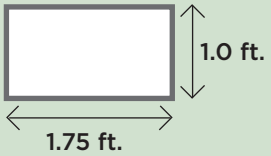
House Pressure (Pa)	Ring (Open, A, or B)	Fan Pressure (Pa)	Corrected Fan Flow (cfm)
50.2	A	96.3	1,940

Table 1. Example single-point blower door test data.

The CFM50 value and conditioned volume of the house can then be used to calculate air changes per hour at 50 Pascals (ACH50):

$$ACH50 = \frac{CFM50 \times 60}{Conditioned\ Volume}$$

The CFM50 leakage value is proportional to the number and size of cracks and gaps in the building's thermal envelope and can provide an estimate of the combined area of the holes in the envelope. This equivalent hole size is approximated, in square inches, by multiplying the CFM50 result by a 0.13 conversion factor. So the estimated equivalent hole size of the example house is 1,940 x 0.13 = 252.2 square inches, or 1.75 square feet.



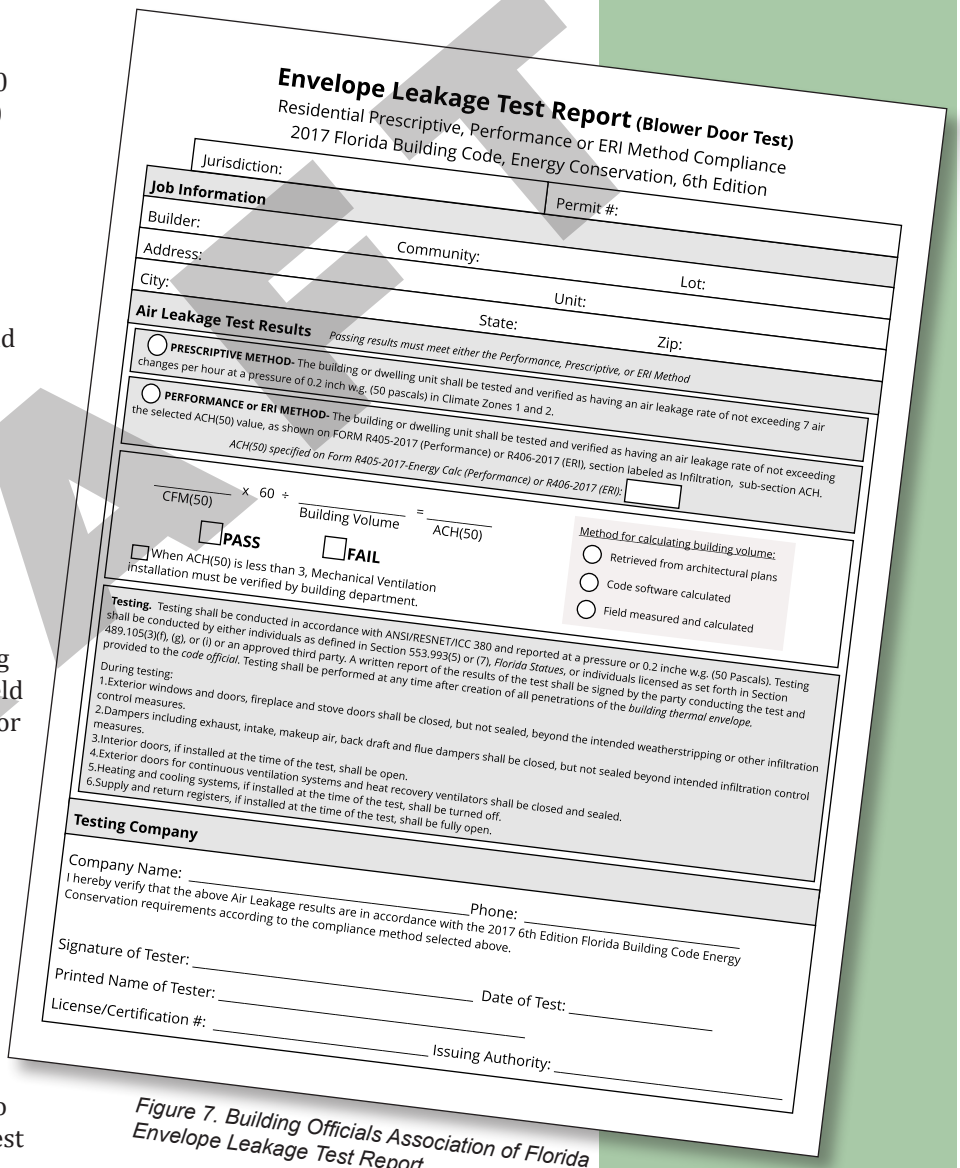
The units for CFM50 are cubic feet per minute, which is multiplied by 60 to convert minutes to hours and divided by the house volume in cubic feet to convert cubit feet to air changes. Given a conditioned house volume of 18,600 cubic feet, the ACH50 for the test results above is 1,940 x 60 / 18,600 = 6.26.

Test results are reported on a form that includes space to record the home's CFM50 measurement, conditioned volume, ACH50 value and Pass/Fail status, and an area for the tester to provide their name, company, qualification and signature. A blank Building Officials Association of Florida (BOAF) approved Envelope Leakage Test Report form (Figure 7) is available from BOAF (see Additional Resources below) and through Florida Energy Code calculation software products. Some Florida building departments require their own version of the form.

You may notice that the BOAF test form shown provides a place to indicate whether the house is complying with the Florida Energy Conservation Code via the Prescriptive, Performance or Energy Rating Index (ERI) method, and also includes a field to enter the ACH50 from the Performance or ERI compliance form[1].

For the Performance and ERI compliance methods, using an ACH50 value lower than the code maximum of 7 for the code compliance calculation will help a house pass the code. But since code credit is received for ACH50 values less than 7, if a lower value is entered for compliance, the blower door test must show that the house's leakage is at or below that lower value (rather than 7). By providing fields to indicate the ACH50 used for compliance, test forms provide project-specific air leakage verification guidance.

For example, if the proposed air leakage was originally entered on the compliance form as 5 ACH50 for the example home, then it would fail because 6.26 ACH50 exceeds 5 ACH50. If the builder had proposed 7 ACH50 on the compliance form then the 6.26 ACH50 home would pass.



Envelope Leakage Test Report (Blower Door Test)

Residential Prescriptive, Performance or ERI Method Compliance
2017 Florida Building Code, Energy Conservation, 6th Edition

Jurisdiction: Permit #:

Job Information

Builder: Community: Lot:

Address: Unit:

City: State: Zip:

Air Leakage Test Results *Possing results must meet either the Performance, Prescriptive, or ERI Method*

○ **PRESCRIPTIVE METHOD-** The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding 7 air changes per hour at a pressure of 0.2 inch w.g. (50 pascals) in Climate Zones 1 and 2.

○ **PERFORMANCE or ERI METHOD-** The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding the selected ACH(50) value, as shown on FORM R405-2017 (Performance) or R406-2017 (ERI), section labeled as Infiltration, sub-section ACH.

ACH(50) specified on Form R405-2017-Energy Calc (Performance) or R406-2017 (ERI):

CFM(50) x 60 ÷ Building Volume = ACH(50)

☐ **PASS** ☐ **FAIL**

☐ When ACH(50) is less than 3, Mechanical Ventilation installation must be verified by building department.

Method for calculating building volume:
○ Retrieved from architectural plans
○ Code software calculated
○ Field measured and calculated

Testing. Testing shall be conducted in accordance with ANSI/RESNET/ICC 380 and reported at a pressure or 0.2 inche w.g. (50 Pascals). Testing shall be conducted by either individuals as defined in Section 553.993(5) or (7), *Florida Statues*, or individuals licensed as set forth in Section 489.105(3)(f), (g), or (i) or an approved third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the *code official*. Testing shall be performed at any time after creation of all penetrations of the *building thermal envelope*.

During testing:
1.Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weatherstripping or other infiltration control measures.
2.Dampers including exhaust, intake, makeup air, back draft and flue dampers shall be closed, but not sealed beyond intended infiltration control measures.
3.Interior doors, if installed at the time of the test, shall be open.
4.Exterior doors for continuous ventilation systems and heat recovery ventilators shall be closed and sealed.
5.Heating and cooling systems, if installed at the time of the test, shall be turned off.
6.Supply and return registers, if installed at the time of the test, shall be fully open.

Testing Company

Company Name: Phone:

I hereby verify that the above Air Leakage results are in accordance with the 2017 6th Edition Florida Building Code Energy Conservation requirements according to the compliance method selected above.

Signature of Tester: Date of Test:

Printed Name of Tester:

License/Certification #: Issuing Authority:

Figure 7. Building Officials Association of Florida Envelope Leakage Test Report.

[1] Residential Chapter 4 of the Florida Energy Conservation Code provides three compliance options: Prescriptive (Sections R401 – R404), Performance (Section R405 and mandatory sections of Sections R401 - R404) or Energy Rating Index (Section R406 and mandatory sections of Section R401 – R404).

Mechanical Ventilation

As previously discussed, if a house's ACH50 is less than 3, Florida Code requires whole-house mechanical ventilation to be provided. Florida Code also stipulates minimum and maximum ventilation rates. Minimum ventilation rates based on conditioned floor area and number of bedrooms are provided in Section M1507 of the Florida Residential Code[2], and maximum rates are provided in Section R403 of the Florida Energy Conservation Code[3].

For further reading, a whole-house ventilation overview, including system type options and hot-humid climate considerations is provided in the U.S. Department of Energy Building Technologies Office's Whole-Building Delivered Ventilation article referenced in the Additional Resources section of this guide.

Additional Resources

6th Edition (2017) Florida Building Code

- Energy Conservation Volume: https://codes.iccsafe.org/public/document/FEC2017
- Residential Volume: https://codes.iccsafe.org/public/document/FRC2017

Test Equipment Manuals and Guides

- Retrotec: https://retrotec.com/manuals-guides
- The Energy Conservatory: https://support.energyconservatory.com/hc/en-us/categories/200031985-Manuals-and-Guides

Test Forms

- The Building Officials Association of Florida approved building air leakage test form is available at: http://boaf.net/page/EnvLeakageTest

Testing Standard

- The ANSI/RESNET/ICC 380 Standard for Testing Airtightness of Building Enclosures, Airtightness of Heating and Cooling Air Distribution Systems, and Airflow of Mechanical Ventilation Systems referenced in Section R402.4.1.2 of the Florida Energy Conservation Code is available at: https://codes.iccsafe.org/public/chapter/content/7325/

Whole-House Mechanical Ventilation

- Whole-Building Delivered Ventilation: https://basc.pnnl.gov/resource-guides/whole-building-delivered-ventilation#quicktabs-guides=0.

[2] See Section M1507.3.3 Mechanical ventilation rate

[3] See Section R403.6.2 Ventilation air

This publication was created by the FSEC Energy Research Center at the University of Central Florida.