Chapter Eight
RESNET Standards

Effective Date

This chapter goes into effect on January 3, 2012

800 RESNET Standard for Performance Testing and Work Scope: Enclosure and Air Distribution Leakage Testing

801 Background

This Standard will present a step-by-step approach for how to measure:

- enclosure air leakage for the inspection of low rise, three stories or less, residential and light commercial buildings, and
- duct leakage associated with HVAC systems
- air flows for ventilation systems, and
- work scope and combustion safety procedures

802 Procedures for Building Enclosure Airtightness Testing

The purpose of this test procedure is to determine the airtightness of a building enclosure measured in cubic feet per minute at a 50 Pa pressure difference (*CFM50)*.

802.1 ON-SITE INSPECTION PROTOCOL

There are three acceptable airtightness test procedures:

802.1.1 Single-point test: Measuring air leakage one time at a single pressure difference as described in section 802.5

802.1.2 Multi-point test: Measuring air leakage at multiple induced pressures differences as described in section 802.6

802.1.3 Repeated single-point test: The test is similar to the single point test, but the test is done multiple times for improved accuracy and estimating uncertainty as described in section 802.7

The building may be tested by applying a positive or negative pressure. Follow all manufacturers' instructions for set up and operation of all equipment. If certain requirements of this standard cannot be met, then all deviations from the standard shall be recorded and reported.

Note: Use caution when deciding how and whether to test homes with potential airborne contaminants (e.g. fireplace ash, mold or asbestos) and refer to local, state and national protocols/standards for methods to deal with these and other contaminants.

802.2 Protocol for Preparing the Building Enclosure for Testing

802.2.1 Doors and windows that are part of the conditioned space boundary shall be closed and latched.

802.2.2 Attached garages: All exterior garage doors and windows shall be closed and latched unless the blower door is installed between the house and the garage, in which case the garage shall be opened to outside by opening at least one exterior garage door.

802.2.3 Crawlspaces: If a crawlspace is inside the conditioned space boundary, interior access doors and hatches between the house and the crawlspace shall be opened and exterior crawlspace access doors, vents and hatches shall be closed. If a crawlspace is outside the conditioned space boundary, interior access doors and hatches shall be closed. For compliance testing purposes, crawl-space vents shall be open.

802.2.4 Attics: If an attic is inside the conditioned space boundary, interior access doors and hatches between the house and the conditioned attic shall be opened; and attic exterior access doors and windows shall be closed. If an attic is outside the conditioned space boundary, interior access doors and hatches shall be closed and exterior access doors, dampers or vents shall be left in their as found position and their position during testing shall be recorded on the test report.

802.2.5 Interior Doors: Shall be open within the Conditioned Space Boundary. See the definition of "Conditioned Space Boundary" for clarification.

802.2.6 Chimney dampers and combustion-air inlets on solid fuel appliances: Dampers shall be closed. Take precautions to prevent ashes or soot from entering the house during testing. Although the general intent of this standard is to test the building in its normal operating condition, it may be necessary to temporarily seal openings to avoid drawing soot or ashes into the house. Any temporary sealing shall be noted in the test report.

802.2.7 Combustion appliance flue gas vents: Shall be left in their normal appliance-off condition.

802.2.8 Fans: Any fan or appliance capable of inducing airflow across the building enclosure shall be turned off including, but not limited to, clothes dryers, attic fans, kitchen and bathroom exhaust fans, outdoor air ventilation fans, air handlers, and crawl space and attic ventilation fans. Continuously operating ventilation systems shall be turned off and the air openings sealed, preferably at the exterior terminations.

802.2.9 Non-motorized dampers which connect the conditioned space to the exterior or to unconditioned spaces: Dampers shall be left as found. If the damper will be forced open or closed by the induced test pressure, that fact shall be reported in the test report. Clothes dryer exhaust openings should not be sealed off even if there is no dryer attached but this fact should be noted in the test report.

802.2.10 Motorized dampers which connect the conditioned space to the exterior (or to unconditioned spaces): The damper shall be placed in its closed position and shall not be further sealed.

802.2.11 Un-dampered or fixed-damper intentional openings between conditioned space and the exterior or unconditioned spaces: Shall be left open or fixed position, however, temporary blocking shall be removed. For example: fixed-damper ducts supplying outdoor air for intermittent ventilation systems (including central-fan-integrated distribution systems) shall be left in their fixed-damper position. *Exception:* Un-dampered supply-air or exhaust-air openings of *continuously operating* mechanical ventilation systems shall be sealed (preferably seal at the exterior of enclosure) and ventilation fans shall be turned off as specified above.

802.2.12 Whole building fan louvers/shutters: Shall be closed. If there is a seasonal cover, install it.

802.2.13 Evaporative coolers: The opening to the exterior shall be placed in its off condition. If there is a seasonal cover, install it.

802.2.14 Operable window trickle-vents and through-the-wall vents: Shall be closed.

802.2.15 Supply registers and return grilles: Shall be left open and uncovered.

802.2.16 Plumbing drains with p-traps: Shall be sealed or filled with water, if empty.

802.2.17 Combustion appliances: Shall remain off during the test.

Maintain the above conditions throughout the test. If during the test, induced pressures affect operable dampers, seasonal covers, etc. then reestablish the set-up and consider reversing direction of fan flow.

After testing is complete, return the building to its as found conditions prior to the test. For example, make sure that any combustion appliance pilots that were on prior to testing remain lit after testing.

802.3 Accuracy Levels for Enclosure Leakage Testing
This standard defines two levels of accuracy:

802.3.1 ***Standard level of accuracy***: level of accuracy that produces test results that can be used in the modeling software or to assess compliance with a performance standard, energy code, or specific program requirement. This is the level of accuracy that is normally attained unless there are adverse testing conditions such as high winds, an extremely leaky building or very large baseline pressure adjustments.

802.3.2 ***Reduced level of accuracy***: during adverse testing conditions or in certain applications where testing time and costs are a factor, a test with a reduced level of accuracy may be used. Such applications may include demonstrating compliance with a performance standard, energy code, or specific program requirement. However, measurements made with a reduced level of accuracy may require surpassing the threshold value by an amount which will account for the added uncertainty as defined in the sections below. RESNET accredited software that uses test results with a reduced level of accuracy shall internally adjust the calculations in accordance with this chapter.

802.4 Installation of the Blower Door Airtightness Testing System

802.4.1 Install the blower door system in an exterior doorway or window that has unrestricted access to the building and no obstructions to airflow within five feet of the fan inlet and two feet of the fan outlet. Avoid installing the system in a doorway or window exposed to the wind.

802.4.1.1 It is permissible to use a doorway or window between the conditioned space and unconditioned space as long as the unconditioned space has an unrestricted air pathway to the outdoors. For example, an attached garage or porch can be used as the unconditioned space; in that case, be sure to open all exterior windows and doors of the unconditioned space to the outdoors.

802.4.2 Install the pressure gauge(s), fans and tubing connections according to equipment manufacturer's instructions.

802.4.3 Record the indoor and outdoor temperatures in degrees F to an accuracy of 10 degrees F.

802.4.4 Record the elevation of the building site with an accuracy of 2000 feet; this may be omitted at elevations less than 5000 feet above sea level.

802.4.5 If ***ACH50***, i.e., air changes per hour @ 50 Pa, will be calculated, record the ***building volume*** (the volume enclosed by the conditioned space boundary)**.**

802.5 Procedure for Conducting a One-Point Airtightness Test (if a multi-point test will be conducted, skip to section 802.6)

802.5.1 Choose and record a ***time averaging period*** of at least 10 seconds to be used for measuring pressures. With the blower door fan sealed and off, measure and record 5, independent, ***average baseline building pressure readings*** with respect to outside to a resolution of 0.1 Pa.

802.5.2 Subtract the smallest baseline measurement from the largest recorded in Step 802.5.1 and record this as the ***baseline range***.

802.5.3 Airtightness tests with a baseline range less than 5.0 Pa, will be considered a ***<u>Standard Level of Accuracy</u>*** Test. Airtightness tests with a baseline range between 5.0 Pa and 10.0 Pa will be considered a ***<u>Reduced Level of Accuracy</u>*** Test and the results will be adjusted using Section 802.8. A one point test cannot be performed under this standard if the baseline range is greater than 10.0 Pa. Record the level of accuracy for the test as ***standard*** or ***reduced***, as appropriate**.** The baseline test may be repeated employing a longer time averaging period in order to meet the desired level of accuracy.

802.5.4 Re-measure the baseline building pressure using the same time averaging period recorded in Step 802.5.1 or use the average of the baseline pressures measured in step 802.5.1. This measurement is defined as the ***Pre-Test Baseline Building Pressure***. If desired for greater accuracy, a longer time averaging period may be used. Record the ***Pre-Test Baseline Building Pressure***.

802.5.5 Unseal the blower door fan. Turn on and adjust the fan to create an induced building pressure of approximately 50 Pa. Induced building pressure shall be defined as the (unadjusted) building pressure minus the pre-test baseline building pressure. If a 50 Pa induced building pressure cannot be achieved because the blower door fan does not have sufficient flow capacity, then achieve the highest induced building pressure possible with the equipment available.

802.5.6 A one-point test may only be performed if the maximum induced building pressure is at least 15 Pa and greater than four times the baseline pressure. If the maximum induced building pressure is less than 15 Pa, recheck that the house set up is correct and determine if any basic repairs are needed prior to further testing or modeling of the building. A multi-point test may be attempted, or multiple fans may be used. If using multiple fans, follow the manufacturer's instruction for measurement procedures.

802.5.7 Measure and record the unadjusted building pressure and nominal (not temperature and altitude corrected) fan flow using the same averaging period used in Step 802.5.4. Record the unadjusted building pressure (with 0.1 Pa resolution), nominal fan flow (with 1 CFM resolution), fan configuration (rings, pressurization or depressurization, etc), fan and manometer models and serial numbers.

802.5.8 Turn off the fan.

802.5.9 If your pressure gauge has the capability to display the induced building pressure (i.e. "baseline adjustment" feature) and adjust the fan flow value to an induced building pressure of 50 Pa (i.e. "@50 Pa" feature), then follow the manometer manufacturer's procedures for calculating the results of a one-point test and record the following values: induced building pressure, nominal CFM50, fan configuration, fan and manometer models and serial numbers. If needed calculate the following values:

- ***induced building pressure*** =
  measured building pressure minus the ***Pre-Test Baseline Building Pressure***

  Note: If a "baseline adjustment" feature of the manometer was used, then the induced building pressure is displayed on the pressure gauge.

- ***nominal CFM50*** = $(50 / \text{induced building pressure})^{0.65}$ x recorded fan flow

Note: If both a "baseline adjustment" feature and an "@50 Pa" feature were used, the nominal CFM50 is displayed directly on the pressure gauge.

If the altitude is above 5,000 feet or the difference between the inside and outside temperature is more than 30 degrees Fahrenheit then calculate the corrected CFM50 as defined below:

- ***corrected CFM50*** =
  nominal CFM50 x altitude correction factor x temperature correction factor

  where:
  altitude correction factor = 1 + .000006 x altitude, altitude is in feet
  temperature correction factors are listed in Table 802.1

802.6 Procedure for Conducting a Multi-Point Airtightness Test

802.6.1 Equipment that can automatically perform a multi-point test may be used to perform the steps below.

802.6.2 With the blower door fan sealed and off, measure and record the pre-test baseline building pressure reading with respect to outside. This measurement shall be taken over a time-averaging period of at least 10 seconds and shall have a resolution of 0.1 Pa. Record the pre-test baseline building pressure measurement.

802.6.3 Unseal the blower door fan. Turn on and adjust the fan to create an induced building pressure of approximately 60 Pa. If a 60 Pa induced building pressure cannot be achieved because the blower door fan does not have sufficient flow capacity, then adjust the fan to achieve the highest induced building pressure possible.

802.6.4 Measure the ***unadjusted building pressure*** (not baseline adjusted) and nominal fan flow (neither temperature nor altitude corrected) using the same time-averaging period used in Step 802.6.2. Record the unadjusted building pressure (with 0.1 Pa resolution), nominal fan flow (with 1 CFM resolution), fan configuration, fan model and fan serial number. Assure that the fan is being operated according to the manufacturer's instructions.

Note: since both pre- and post-test baseline measurements are required, do not use any baseline-adjustment feature of the manometer. In addition, do not use an "@50 Pa" feature because the nominal fan flow shall be recorded.

802.6.5 Take and record a minimum of 7 additional unadjusted building pressure and nominal fan flow measurements at ***target induced pressures*** which are approximately equally-spaced between 60 Pa (or the highest achievable induced building pressure) and 15 Pa. In very leaky buildings, the low end of this range may be reduced to as little as 4 Pa plus the absolute value of the baseline pressure.

802.6.6 Turn off and seal the blower door fan.

802.6.7 Measure and record the ***post-test baseline building pressure*** reading with respect to outside. This measurement shall be taken over the same time-averaging period used in Step 802.6.2 and shall have a resolution of 0.1 Pa. Record the post-test baseline building pressure measurement.

802.6.8 Enter the recorded test values, temperatures and altitude into software that can perform the necessary calculations in accordance with ASTM E779-10, Section 9.

The software program shall calculate and report: corrected CFM50 and the percent uncertainty in the corrected CFM50, at the 95% confidence level, as defined in ASTM E779-10, Section 9.

Although ACH50 may be reported, this calculation may be omitted if the ACH50 metric is not needed.

Note: To avoid a higher percent uncertainty than desired, the testing technician may choose a larger, time-averaging period and start over at Step 802.6.2.

802.6.9 If the reported uncertainty in the corrected CFM50 is less than or equal to 10.0%, then the airtightness test shall be classified as a ***Standard Level of Accuracy*** test. If the reported uncertainly in the corrected CFM50 is greater than 10.0%, the airtightness test shall be classified as a ***Reduced Level of Accuracy*** test and the results will be adjusted using Section 802.8.

802.7 Procedure for Conducting a Repeated Single Point Test

802.7.1 With the blower door fan sealed and off, measure and record the pre-test baseline building pressure reading with respect to outside. This measurement shall be taken over a time-averaging period of at least 10 seconds and shall have a resolution of 0.1 Pa. Record this value as the pre-test baseline building pressure measurement.

802.7.2 Unseal the blower door fan. Turn on and adjust the fan to create an induced building pressure of approximately 50 Pa. If a 50 Pa induced building pressure can not be achieved because the blower door fan does not have sufficient flow capacity, then achieve the highest induced building pressure possible with the equipment available.

802.7.3 If during any single repeat of this test, the induced building pressure is less than 15 Pa, recheck that the house set up is correct and determine if any basic repairs are needed prior to further testing or modeling of the building. Following any repairs or changes to the set up, the test shall be restarted from the beginning. If you can not reach at least 15 Pa every time, then use the procedures in sections 802.5 or 802.6.

802.7.4 Measure and record the unadjusted building pressure and nominal (not temperature and altitude corrected) fan flow using the same time-averaging period used in Step 802.6.2. Record the unadjusted building pressure (with 0.1 Pa resolution), nominal fan flow (with 1 CFM resolution), fan configuration (rings, pressurization or depressurization, etc), fan model and fan serial number.

Note: If your pressure gauge has the capability to display the induced building pressure (i.e. baseline adjustment feature) and the capability to adjust the fan flow value to an induced building pressure of 50 Pa (i.e. "@50 Pa" feature), then follow the manufacturer's procedures for calculating the results of a one-point test and record the following values: induced building pressure, nominal CFM50, fan configuration, fan model and fan serial number.

802.7.5 Turn off the fan.

802.7.6 Calculate the following values:

- ***induced building pressure*** = unadjusted building pressure (Pa) minus pre-test baseline building pressure (Pa).

  Note: If a baseline adjustment feature was used, then the induced building pressure is displayed on the pressure gauge.

- nominal CFM50 = (50 Pa / Induced building pressure) $^{0.65}$ x nominal fan flow.

  Note: If both a baseline adjustment feature and an "@50 Pa" feature were used, the nominal CFM50 is displayed directly on the pressure gauge.

802.7.7 Repeat Steps 802.7.1 through 802.7.6 until a minimum of 5 nominal CFM50 estimates have been recorded. The same fan configuration shall be used for each repeat.

802.7.8 Calculate the ***Average Nominal CFM50*** by summing the individual nominal CFM50 readings and dividing by the number of readings.

802.7.9 If the altitude is above 5,000 feet or the difference between the inside and outside temperature is more than 30 degrees Fahrenheit then calculate the corrected CFM50 as defined below:

Calculate the ***Average Corrected CFM50*** =
Average Nominal CFM50 x altitude correction factor x temperature correction factor

where:
altitude correction factor = 1 + .000006 x altitude, altitude is in feet
temperature correction factors are listed in Table 802.1

Table 802.1 Temperature Correction Factors for Pressurization and Depressurization Testing- Calculated according to ASTM E779-10

Correction Factors for Pressurization Testing

OUTSIDE TEMP (F)	INSIDE TEMPERATURE (F) 50	55	60	65	70	75	80	85	90
-20	1.062	1.072	1.081	1.090	1.099	1.108	1.117	1.127	1.136
-15	1.056	1.066	1.075	1.084	1.093	1.102	1.111	1.120	1.129
-10	1.051	1.060	1.069	1.078	1.087	1.096	1.105	1.114	1.123
-5	1.045	1.054	1.063	1.072	1.081	1.090	1.099	1.108	1.117
0	1.039	1.048	1.057	1.066	1.075	1.084	1.093	1.102	1.111
5	1.033	1.042	1.051	1.060	1.069	1.078	1.087	1.096	1.105
10	1.028	1.037	1.046	1.055	1.064	1.072	1.081	1.090	1.099
15	1.023	1.031	1.040	1.049	1.058	1.067	1.076	1.084	1.093
20	1.017	1.026	1.035	1.044	1.052	1.061	1.070	1.079	1.087
25	1.012	1.021	1.029	1.038	1.047	1.056	1.064	1.073	1.082
30	1.007	1.015	1.024	1.033	1.041	1.050	1.059	1.067	1.076
35	1.002	1.010	1.019	1.028	1.036	1.045	1.054	1.062	1.071
40	0.997	1.005	1.014	1.023	1.031	1.040	1.048	1.057	1.065
45	0.992	1.000	1.009	1.017	1.026	1.035	1.043	1.051	1.060
50	0.987	0.995	1.004	1.012	1.021	1.029	1.038	1.046	1.055
55	0.982	0.990	0.999	1.008	1.016	1.024	1.033	1.041	1.050
60	0.977	0.986	0.994	1.003	1.011	1.019	1.028	1.036	1.045
65	0.973	0.981	0.989	0.998	1.006	1.015	1.023	1.031	1.040
70	0.968	0.976	0.985	0.993	1.001	1.010	1.018	1.026	1.035
75	0.963	0.972	0.980	0.988	0.997	1.005	1.013	1.022	1.030
80	0.959	0.967	0.976	0.984	0.992	1.000	1.009	1.017	1.025
85	0.955	0.963	0.971	0.979	0.988	0.996	1.004	1.012	1.020
90	0.950	0.958	0.967	0.975	0.983	0.991	0.999	1.008	1.016
95	0.946	0.954	0.962	0.970	0.979	0.987	0.995	1.003	1.011
100	0.942	0.950	0.958	0.966	0.970	0.982	0.990	0.998	1.007
105	0.938	0.946	0.954	0.962	0.970	0.978	0.986	0.994	1.002
110	0.933	0.942	0.950	0.952	0.966	0.974	0.982	0.990	0.998

Correction Factors for Depressurization Testing

OUTSIDE TEMP (F)	INSIDE TEMPERATURE (F) 50	55	60	65	70	75	80	85	90
-20	0.865	0.861	0.857	0.853	0.849	0.845	0.841	0.837	0.833
-15	0.874	0.870	0.866	0.862	0.858	0.854	0.850	0.846	0.842
-10	0.883	0.879	0.874	0.870	0.866	0.862	0.858	0.854	0.850
-5	0.892	0.887	0.883	0.879	0.875	0.871	0.867	0.863	0.859
0	0.900	0.896	0.892	0.887	0.883	0.879	0.875	0.871	0.867
5	0.909	0.905	0.900	0.896	0.892	0.888	0.883	0.879	0.875
10	0.918	0.913	0.909	0.905	0.900	0.896	0.892	0.888	0.884
15	0.927	0.922	0.918	0.913	0.909	0.905	0.900	0.896	0.892
20	0.935	0.931	0.926	0.922	0.917	0.913	0.909	0.905	0.900
25	0.944	0.939	0.935	0.930	0.926	0.922	0.917	0.913	0.909
30	0.952	0.948	0.943	0.939	0.934	0.930	0.926	0.921	0.917
35	0.961	0.956	0.952	0.947	0.943	0.938	0.934	0.930	0.925
40	0.970	0.965	0.960	0.956	0.951	0.947	0.942	0.938	0.934
45	0.978	0.974	0.969	0.964	0.960	0.955	0.951	0.946	0.942
50	0.987	0.982	0.977	0.973	0.968	0.963	0.959	0.955	0.950
55	0.995	0.990	0.986	0.981	0.976	0.972	0.967	0.963	0.958
60	1.004	0.999	0.994	0.989	0.985	0.980	0.976	0.971	0.967
65	1.012	1.008	1.003	0.998	0.993	0.988	0.984	0.979	0.975
70	1.021	1.016	1.011	1.006	1.001	0.997	0.992	0.988	0.983
75	1.029	1.024	1.019	1.015	1.010	1.005	1.000	0.996	0.991
80	1.038	1.033	1.028	1.023	1.018	1.013	1.009	1.004	0.999
85	1.046	1.041	1.036	1.031	1.026	1.022	1.017	1.012	1.008
90	1.055	1.050	1.045	1.040	1.035	1.030	1.025	1.020	1.016
95	1.063	1.058	1.053	1.048	1.043	1.038	1.033	1.028	1.024
100	1.072	1.066	1.061	1.056	1.051	1.046	1.041	1.037	1.032
105	1.080	1.075	1.070	1.064	1.059	1.054	1.050	1.045	1.040
110	1.088	1.083	1.078	1.073	1.068	1.063	1.058	1.053	1.048

802.7.10 Estimate the precision uncertainty using one of the two following methods

802.7.10.1 Standard Statistical Process – Use a calculator or computer to compute the Standard Deviation of the repeated Nominal CFM50 readings. Divide this Standard Deviation by the square root of the number of readings. Multiply the result by the t-statistic in table 802.2 corresponding to the number of readings taken. Convert this result to a percentage of the Average Nominal CFM50.

Table 802.2 Precision Uncertainty: Values of t-statistic

Number of readings	t-statistic
5	2.78

6	2.57
7	2.45
8	2.37
9	2.31

802.7.11 If a software program is used, it shall at a minimum calculate and report:

802.7.11.1 Average CFM50, corrected for altitude and temperature

802.7.11.2 The percent uncertainty in the CFM50, at the 95% confidence level, as calculated in 802.7.10.

802.7.11.3 ACH50 (air changes per hour @ 50 Pa) = (CFM50 x 60) / building volume (in cubic feet). This calculation may be omitted if the ACH50 metric is not needed.

802.7.12 If the reported uncertainty in the CFM50 is less than or equal to 10.0%, then the airtightness test shall be classified as a Standard Level of Accuracy test as defined in section 802.3. If the reported uncertainly in the CFM50 is greater than 10.0%, the airtightness test shall be classified as a Reduced Level of Accuracy test as defined in section 802.3.

802.8 Application of Results

802.8.1 Adjusting CFM50 for Tests with a Reduced Level of Accuracy. When using results classified as having a Reduced Level of Accuracy, an adjustment shall be used in certain situations. The adjustment is done to improve the probability that the tested building meets the required performance threshold. The adjusted CFM50 in these situations is defined as:

adjusted CFM50 = extending factor x corrected CFM50,
where:

For a One-point Test, classified as Reduced Level of Accuracy:
extending factor = 1 + 0.1 x (50 / the induced pressure)

For a Multi-point Test, classified as Reduced Level of Accuracy:
extending factor = 1 + (% uncertainty / 100)

adjusted CFM50 value shall be used when:

- determining whether or not a building meets an airtightness threshold, and
- conducting a Home Energy Rating for the purpose of compliance with any standard, energy code or program.

adjusted CFM50 value shall NOT be used when:

- calculating the expected energy savings from retrofit,
- conducting an energy audit, or
- assessing the relative airtightness of a group of buildings.

802.8.2 Other Leakage Metrics:

ELA may be calculated by: ***ELA*** = 0.055 x CFM50
Where ELA is in square inches

ACH50 = corrected CFM50 x 60 / building volume (in cubic feet)

Specific Leakage Area may be calculated by:
SLA = 0.00694 x ELA/ building floor area (square feet)
Where ELA (Effective Leakage Area) referenced to 4 pa is in square inches

Normalized Leakage Area may be calculated by:
NLA = SLA x $(S)^{0.3}$***, where S is the number of stories above grade***

802.9 Equipment Accuracy and Requirements

Blower door fans used for building air leakage testing shall measure airflow (after making any necessary air density corrections) with an accuracy of +/- 5%. Pressure gauges shall measure pressure differences with a resolution of 0.1 Pa and have an accuracy of +/- 1% of reading or 0.5Pa, whichever is greater.

Blower door and associated pressure testing instruments shall be tested annually for calibration by the HERS Rating Provider or Certified Rater. The provider shall use a standard for field testing of calibration provided by the equipment manufacturer. Magnehelic Gauges cannot be field tested and shall be recalibrated by the Blower Door manufacturer annually. Field check the fan and flow measuring systems for defects and maintain them according to manufacturers recommendations. The HERS Rating Provider or Certified Rater shall maintain a written log of the annual calibration check to verify all equipment accuracy for a period of three (3) years. These records shall be made available within 3 business days to the RESNET Quality Assurance Administrator upon request.

803 On-site Inspection Procedures for Duct Leakage Testing

The purpose of these test procedures is to make a determination of the amount of leakage of a duct system, either total system leakage or leakage to outside of the conditioned space. Because total duct leakage (to both inside and outside the conditioned space) at 25 Pascals should always be greater than the leakage to outside, the total leakage may be used instead of leakage to outside for determining that a system meets a required threshold. The total leakage value may be entered into software as if it were leakage to the outside for this purpose. However, total leakage should not be substituted for leakage to outside when conducting an energy audit or predicting savings from retrofits, except as indicated. Table 803.1 summarizes the test methods approved for use in the RESNET Standards.

803.1 Air Handler Flow

For the purposes of determining if a total duct leakage test method may be used (see table 803.1), the Air handler flow can be measured in accordance with ASHRAE Standard152-2004, ASTM E1554-2007, or by using the following default values: 400 CFM per ton of air conditioner or heat pump capacity or 200 CFM per 12,000 Btu/h of furnace (output) capacity whichever is greater.

Table 803.1- Duct Leakage Test Methods

Test Method	Test pressure	Conversion to operating pressure	Supply/Return	Notes
Leakage to the Outside Tests				
RESNET Standard Section 803.7	25 Pa	No conversion	Assume ½ supply and ½ return	
ASHRAE 152 Annex B	25 Pa	½ plenum pressure for supply and return individually	Separate	
ASTM E1554-07 Method A: "DeltaQ"	Normal Operation	n/a	Separate	Can be used for energy auditing but not compliance testing. To limit precision errors this test is only allowed in this RESNET Standard if the Building Enclosure Leakage is less than 2500 cfm @ 50 Pa
ASTM E1554 Method B	25 Pa	½ plenum pressure for supply and return individually	Separate	
Total Duct Leakage Tests				The total leakage may be used instead of leakage to outside for compliance testing. It may be used for energy audits or savings estimates if the total leakage is less than 10% of air handler flow**.**
RESNET Standard Section 803.5	25 Pa	No conversion	Assume ½ supply and ½ return	
ASHRAE 152 Annex C	25 Pa	½ plenum pressure or assume 62.5 Pa	Assumes ½ supply and ½ return	2.5% of air handler flow added if testing done without air handler. 2.5% added if testing done without registers/grilles.

803.2 RESNET Simplified Test Procedures
For purposes of this chapter, duct leakage may be measured by either pressurizing or depressurizing the duct system. Tests measure either total leakage or leakage to the outside. Total leakage includes all leaks in the air distribution system and leakage to the outside only refers to leaks to outside the conditioned space. The following text mentions only pressurization, but depressurization may also be used.

Testing of the duct system(s) of a building is accomplished by use of a duct leakage testing device and, when testing leakage to outside, a blower door. For total duct leakage, the duct leakage tester is attached and used to pressurize the duct system to 25 Pa. This test measures all duct leakage including leakage between the ducts and the conditioned space and leakage between the ducts and any unconditioned space or outside.
When performing a duct leakage to outside test, a blower door is also used to pressurize the building to 25 Pa while the duct leakage tester is used to equalize the pressure inside the duct system with the building pressure induced by the blower door (e.g 25 Pa). Multiple blower doors may be used if the conditioned space can't be uniformly pressurized with a single blower door (for example- a conditioned crawlspace). Because the ducts and the conditioned space of the building are theoretically at the same pressure, little or no air flows through leaks between the ducts and the conditioned space and the duct leakage tester only measures the leakage between the ducts and spaces outside the conditioned space. When ducts are entirely within the conditioned space boundary, 100% of the system is visible at the time of testing and the system is fully ducted (i.e., no building cavities are used to transport air) the ducts do not have to be tested and the ducts may be assumed to have no leakage to outside the conditioned space.

803.2.1 Multifamily Buildings
For multifamily buildings where each unit has its own duct system, each unit may be tested individually using the procedures in this RESNET standard. Each unit should be treated as if it is a single family dwelling. The leakage to outside test is performed using a blower door in the main entry to the unit to pressurize the individual unit with reference to outside. If the main entry door is in an interior hallway then the hallway needs to be well connected to outside through open windows or doors or an exterior window or door (such as to deck or patio) may be used. Similarly, only the ducts in the unit under test are pressurized. For compliance testing, use measured leakage to outside. For energy audits or savings estimates, it may be assumed that the leakage to outside is one-half of this measured leakage. For compliance testing, the total leakage test method may be used instead of leakage to outside.

803.3 Protocol for Preparing the Building and the Duct System for a Duct Leakage Test (Items 803.3.1-803.3.8 are used for both Total and Outside Leakage tests)

803.3.1 Adjust the HVAC system controls so that the air handler fan does not turn on during the test.

803.3.2 Turn off any fans that could change the pressure in either the conditioned space or any spaces containing ducts or air handlers (bathroom fans, clothes dryers, kitchen vent hood, attic fan, etc.).

803.3.2 Turn off all vented combustion appliances if there is a possibility that the space containing the appliance will be depressurized during the test procedure.

803.3.3 Remove all filters from the duct system and air handler cabinet. If the duct leakage testing system is installed at a central return grille, also remove the filter from that grille.

803.3.4 Any intentional openings into the duct system such as combustion air or ventilation ducts shall be left in their normal non-ventilation operating position. Motorized dampers should be closed.

803.3.5 If ducts run through unconditioned spaces such as attics, garages or crawlspaces, open vents, access panels, doors, or windows between those spaces and the outside to eliminate pressure changes due to duct leakage during the test procedure.

803.3.6 Supply registers and return grilles shall be temporarily sealed in some manner so as to allow for the pressurization of the duct system.

803.3.7 Zone and bypass (not balancing) dampers shall be set to the open position to allow uniform pressures throughout the duct system.

Total leakage test only: Fully open at least one door, window or comparable opening between the building and outside to prevent changes in building pressure when the duct leakage testing system is running.

Leakage to the outside test only: All exterior doors and windows between the building and outside shall be closed, and other openings to the outside that may hinder the ability of a blower door fan to pressurize the building to 25 Pa with reference to outside should be closed or covered in some manner. Interior doors shall be open.

803.4 Installation of the Duct Leakage Testing System (used for both total leakage and leakage to outside tests)

803.4.1 Attach the duct leakage tester system to the largest return grille closest to the air handler. Use the manufacturer’s recommended installation procedure that is consistent with the mode (i.e. pressurization vs. depressurization) of the test being performed. Be sure the remaining opening in the return grille is temporarily sealed.

When testing a duct system with 3 or more returns, installation of the duct leakage tester at the air handler cabinet may be a better attachment location.

Document the attachment location of the duct leakage testing system.

803.4.2 Select a location to measure duct pressure. Choose one of the following three locations to measure duct pressure:

- The largest supply register closest to the air handler, or
- The main supply trunk line, or
- The supply plenum can be used if the duct leakage tester is installed at a central return.

Document the duct pressure measurement location.

803.4.3 Insert a pressure probe into the duct system at the chosen measurement location. If measuring at the supply trunk line or supply plenum, you must use a static pressure probe (be sure the probe is pointing into the air stream). If measuring at a supply register, you may use a static pressure probe, or you may simply insert a straight pressure probe or the end of a piece of flexible tubing.

803.4.4 Install the pressure gauge and tubing connections in accordance with the manufacturer's instructions and the test mode (pressurization vs. depressurization) being used. The duct system pressure should be measured with reference to the inside of the building. Turn on and configure the pressure gauge for the test procedure being performed.

803.5 Procedure for Conducting a Total Duct Leakage Test

803.5.1 Select the appropriate range (e.g. flow ring) of the duct leakage testing fan and configure the flow gauge to match the selected range.

803.5.2 Turn on the duct leakage testing fan and increase fan speed until the duct system has been pressurized to 25 Pa (+/- 0.5 Pa). Measure and record the duct pressure reading (0.1 Pa resolution) and the fan flow reading (1 CFM resolution) using a 5 second averaging period. Also record the fan configuration (range), fan and manometer models and serial numbers. Be sure the fan is being operated according to the manufacturer's instructions.

If 25 Pa of duct pressure cannot be achieved because the duct testing fan does not have sufficient flow capacity, then achieve the highest duct pressure possible with the equipment available and record the values above.

> **Note:** If your pressure gauge has the capability to adjust the fan flow value to a duct pressure of 25 Pa (i.e. @25 Pa feature), then follow the manufacturer's procedures for conducting a one-point total leakage test, and record the following values: duct pressure, CFM25 (or fan flow in CFM and pressure in Pa if 25 Pa not achieved), fan configuration, fan and manometer models and serial numbers. If your gauge does not have an @25 feature and the measured duct pressure was not exactly 25 Pa, calculate and record CFM25 as: $CFM25 = (25\ Pa/\ duct\ pressure)^{0.6} \times fan\ flow$.

803.5.3 Turn off the duct testing fan.

803.6 Installation of the Blower Door System (used for leakage to outside test only)

803.6.1 Install the blower door system in an exterior doorway that has unrestricted access to the building and no obstructions to air flow within five feet of the fan inlet. The blower door fan should be installed in a configuration that is consistent with the mode of the duct leakage test (i.e. pressurization vs. depressurization).

803.6.2 Install the pressure gauge(s), fan and tubing connections as per manufacturer's instructions.

803.7 Procedure for Conducting a Duct Leakage to Outside Test

803.7.1 With both the blower door and duct leakage fans sealed, measure the baseline building pressure with reference to outside using a 5 second averaging period.

803.7.2 Unseal the blower door fan. Turn on the blower door fan and pressurize the building by 25 Pa (+/- 0.5 Pa) from the measured baseline building pressure (i.e. change the building pressure by 25 Pa). **Note:** If your pressure gauge has the capability to display the induced building pressure (i.e. baseline adjustment feature), then follow the manufacturer's procedures for pressurizing the building by 25 Pa.

803.7.3 With the blower door fan continuing to run, unseal the duct leakage testing fan and select the appropriate range on the duct leakage testing fan. Configure the duct leakage testing system gauge to match the selected range.

803.7.4 Turn on the duct leakage testing fan and increase fan speed until the duct system pressure reads 0.0 (+/- 0.1 Pa). **Note:** The duct system pressure should be measured with reference to the inside of the building.

803.7.5 Re-check the blower door pressure gauge and if necessary, re-adjust the blower door fan to maintain a 25 Pa pressurization. **Note:** If the blower door fan is being operated with a "cruise control" feature, it is not necessary to recheck the blower door pressure gauge.

803.7.6 Return to the duct leakage pressure gauge and if necessary, re-adjust the duct leakage testing fan until the duct system pressure reads 0.0.

803.7.7 Record the following values: building pressure, duct pressure, CFM of flow through the duct testing fan, duct testing fan configuration, duct testing fan and manometer models and serial numbers. Calculate and record CFM25: CFM25 = $(25\ \text{Pa}/\text{building pressure})^{.6}$ x duct leakage fan flow.

803.7.8 Turn off both the blower door and duct leakage testing fans.

Note: If the blower door system is unable to pressurize the building to 25 Pa because the blower door fan does not have sufficient flow capacity, then you will need to conduct the test at the highest achievable building pressure and adjust the measured duct leakage as described in step 803.7.7.

<u>Note:</u> If the duct testing fan was unable to create a pressure difference of zero between the duct system and the building (while the blower door is pressurizing the building to 25 Pa) because the duct testing fan does not have sufficient flow capacity, then the test will need to be performed at a lower building pressure and adjust the measured duct leakage as described in step 803.7.7.

803.8 Application of Results

803.8.1 The results of the total duct leakage test represent the total amount of duct leakage both to the inside and to the outside of the conditioned space and represent the overall leakage of the entire system. The total leakage may be of use in some programs where the total system duct leakage is required.

803.8.2 The duct leakage to the outside test is designed to measure only the duct leakage occurring to the outside of the conditioned space. Many programs use this measurement as the determining factor as to whether a duct system fails or passes.

803.8.3 If rating software requires separate input of supply and return leakage that have not individually been measured you shall assume that ½ of the total measured leakage is in the supply and ½ is in the return.

803.9 Equipment Accuracy and Requirements

Duct testing fans used for determining either total leakage or leakage to outside shall measure airflow with an accuracy of +/-5%. Pressure gauges shall measure pressure differences with a resolution of 0.1 Pa and have an accuracy of +/-1% of the reading or 0.5 Pa, whichever is greater.

Blower doors, duct testers, and associated pressure testing instruments shall be field-tested annually for calibration. The calibration procedure shall follow the equipment manufacturer’s recommendations.

The HERS Rating Provider or Certified Rater shall maintain a written log of the annual calibration check to verify all equipment accuracy for a period of three (3) years. These records shall be made available within 3 business days to the RESNET Quality Assurance Administrator upon request.

804 On-site Inspection Procedures for ventilation air flow Testing

The purpose of these test procedures are to measure the air flows through whole house ventilation systems and local exhausts. The test procedures treat the air flows into and out of the grille being measured separately. The Air Flow Resistance method may only be used on systems that do not have multiple branches in the ventilation air duct system. Use of a manometer with manufacturer-installed calibrated ports (common on ERV/HRV equipment) is an acceptable method if the manufacturer’s instructions are followed

804.1 Air Flows into Grilles

804.1.1 Powered Flow Hood

A powered flow hood consists of:

- A flow capture device that is to be placed over the grille to be measured. The flow capture element needs to be large enough to cover the whole grille and be airtight.
- A pressure measuring system inside the flow capture element that is designed and installed to measure the static pressure inside the flow capture element.
- A manometer to measure the pressure difference between the inside of the flow capture element and the room.
- An air flow meter to measure the air flow through the air flow capture element. The air flow meter shall measure airflow with an accuracy of +/-5%.
- A variable-speed fan to move air through the flow capture element and the flow meter.

804.1.1.1 Place the flow capture element over the grille to be measured.

804.1.1.2 Turn on the air flow assisting fan and adjust the airflow until zero pressure difference is measured between the flow capture element and the room.

804.1.1.3 Record the air flow through the air flow meter.

804.1.2 Air Flow Resistance

The Air Flow Resistance method measures the pressure difference across a flow capture element with a known air flow resistance. A rectangular user fabricated box can be used if the size of the hole is not greater than half the size of the box in each direction and the distance from the hole to the grill is at least as large as the larger dimension of the hole. User fabricated devices shall be approved by a provider prior to use.

804.1.2.1 Place the flow capture element over the grille to be measured. Ensure there is air tight seal around the grille and the flow device so that all of the air entering the grill goes through the device.

804.1.2.2 Measure the pressure difference (ΔP) between the flow capture element and the room at a corner of the inlet side of the box. The hole in the flow capture device should be sized so that the pressure difference is between 1 and 5 Pa.

804.1.2.3 Calculate the air flow using the manufacturer's calibration of the air flow resistance device.

For user fabricated devices that do not have a manufacturer's calibration, the following equations may be used to calculate the air flow.

Air Flow (cfm) = Open Area$\times 1.07 \times (\Delta P)^{0.5}$; for Area in in^2, ΔP in Pa
Air Flow (L/s) = Open Area$\times 0.078 \times (\Delta P)^{0.5}$; for Area in cm^2, ΔP in Pa

804.2 Air Flows Out of Grilles

804.2.1 Powered Flow Hood

The measurement procedure is the same as for air flow into grilles (Section 804.1.1) but with the fan and flowmeter arranged to have flow out of the grille.

804.2.2 Bag Inflation

The Bag Inflation method requires the use of a bag of a known volume, a method to hold the bag open (typically a lightweight frame of wood, plastic or metal wire), a shutter to start the air flow and a stopwatch.

804.2.2.1 Completely empty the bag of air and place a shutter over its opening.

804.2.2.2 Rapidly withdraw the shutter and start the stopwatch.

804.2.2.3 When the bag is completely full stop the stopwatch.

804.2.2.4 Calculate the airflow by dividing the bag volume by the elapsed time. Calculate the air flow in cfm as 8 X bag volume in gallons/number of seconds

804.2.2.5 Repeat measurement one or more times and average the results.

804.2.2.6 How to Choose a Bag

Plastic thickness. Bags made from thinner material often do not fill uniformly because the air flow from the register blows them about too much. If the bag sides flap a lot and measuring the same register twice gives results that differ by more than 20%, then try a bag with thicker material.

Use the right sized bags. Bags that fill in under two seconds will have increased errors because of resolution issues in timing how fast the bag is filled. Conversely, bags that are too large for a given register flow will have increased leakage around the edges of the bag before it fills completely and may not generate enough pressure to push a bag into its final shape. Aim for a fill time of 2 to 20 seconds.

804.3 Equipment Accuracy Requirements and Specification

The manometer shall measure pressure differences with a resolution of 0.1 Pa and have an accuracy of +/-1% of the reading or 0.5 Pa, whichever is greater.

805 Work Scope and Combustion Safety Procedures

805.1 These protocols shall be followed by RESNET-accredited Raters and Auditors (hereinafter referred to collectively as “Auditors”) performing combustion appliance testing or writing work scopes for repairs.

805.2 If the Auditor has been trained and certified in accordance with a RESNET approved “equivalent home performance certification program” or the Building Performance Institute

(BPI) Standards, the Auditor may follow protocols in accordance with those equivalent standards.

805.3 RESNET-accredited Training Providers shall train HERS Auditors on these protocols through either field exercise or through simulated conditions. A written exam administered by a RESNET-accredited Trainer is also required, provided by RESNET. The test shall cover the content of these guidelines with a minimum of 25 questions. A minimum score of 80% is required to pass.

805.4 Prior to conducting any test that affects the operating pressures in the home, the Auditor shall inquire whether a person that has environmental sensitivities (asthma, allergies, chemical sensitivity, etc.) is present in the home. If such a person is present, the Auditor shall not perform such tests without written disclosure from the affected party (or responsible adult). The written disclosure shall state (at a minimum) that "during the period of testing, some amount of dust, particles, or soil gases already present in the home may become airborne." Without a signed disclosure, the Auditor shall either reschedule the test for a time when they will not be present, or ask them to leave the home during the testing process. The Auditor shall also inquire as to the presence of pets that may potentially be affected by testing procedures.

806 Gas Leakage Test

806.1 If there is a noticeable odor indicating gas buildup within the home, the occupants and Auditor shall leave the house and the appropriate authorities and utility providers shall be notified from outside the home.

806.2 The Auditor should use a gas detector upon entry into the home to detect the presence of natural gas. If gas is suspected or confirmed, ensure that switches are not operated while exiting and no ignition concerns are present. The audit shall not proceed until the proper authorities have deemed it safe to re-enter the home. If there is no noticeable odor indicating gas buildup within the home, the Auditor shall determine if there are gas leaks in the fittings and connections of natural gas appliances within the home and natural gas/liquid propane supply lines following these protocols.

806.3 Inspect all fittings and joints in supply lines and appliance connectors and confirm suspected leaks with leak-detection fluid. Identify for repair or replacement any kinked, corroded or visibly worn flexible gas lines and any flexible connectors manufactured prior to 1974.

806.4 Equipment needed

- Combustible gas detector capable of measuring 20 ppm
- Leak detection fluid (non-corrosive)

807 Worst Case Depressurization Test

This test procedure measures the pressure in the Combustion Appliance Zone (CAZ) and provides visual evidence of spillage potential.

If there are any vented combustion appliances that use indoor air to vent combustion gases and which are not classified as a category 3 or 4 according to NFPA standard 54, then a worst case depressurization test shall be performed using the following protocol.

807.1 Check the combustion appliance zone for the presence of flammable or explosive material near a combustion source.

807.2 Visually inspect venting system for proper size and horizontal pitch and determine there is no blockage or restriction, leakage, corrosion or other deficiencies that could cause an unsafe condition.

807.2.1 Inspect burners and crossovers for blockage and corrosion.

807.2.2 Inspect furnace heat exchangers for cracks, openings or excessive corrosion.

807.3 Close all the exterior doors and windows of the home.

807.4 Close fireplace damper(s) if fireplace is present.

807.5 Close any interior doors between the CAZ and the remainder of the house, ensuring that all vented appliances and exhaust fans have been turned off.

807.6 Measure the baseline pressure difference between the CAZ with respect to (WRT) outside (ambient) and baseline CO levels. Set the gauge to read pressure and record the baseline pressure.

807.7 Turn on all exhaust fans in the home (kitchen range hood, bath exhaust, clothes dryer, etc.) that exhaust air outside the building envelope.

807.8 Record pressure in CAZ with respect to Outside.

807.9 Turn on the air handler. Record pressure in CAZ with respect to outside. If air handler makes the CAZ more positive (or less negative), turn it off. If the air handler is kept on, close interior doors to any rooms that have no return registers.

807.10 If fireplace is present install blower door and set to exhaust 300 CFM to simulate fireplace in operation.

807.11 Record net change in pressure difference within the CAZ WRT outside between baseline and worst case depressurization conditions. Record the position of doors and conditions of fans and air handler. When the net change in CAZ pressure is lower (more negative) than the limits specified below, the work scope shall specify remediation through pressure balancing, duct sealing, and/or other pressure-relief measures, as applicable.

807.12 Turn on vented combustion appliance with the smallest Btu capacity. Operate appliance for 5 minutes then measure CO levels according to the carbon monoxide test procedure below, and check appliance draft using a smoke pencil at the draft diverter. If the smoke is not fully drawn up the flue, the appliance has spillage under worst case depressurization. Record if there is any spillage and record CO level. When spillage occurs or CO exceeds the limits specified below in section 9, the work scope shall specify remediation, including equipment repair or replacement, and/or building pressure remediation, as applicable. If both spillage and high CO are found during the test, the homeowner should be notified of the conditions and that it needs immediate remediation.

807.13 Turn on all the other combustion appliances, one at a time, within the CAZ and repeat step 1.12 on each of them.

807.14 If spillage or high CO occurs in any appliance(s) under worst case depressurization, retest that appliance(s) under natural conditions.

807.14.1 Turn off the combustion appliances.

807.14.2 Turn off the exhaust fans.

807.14.3 Open the interior doors.

807.14.4 Let the vent cool.

807.14.5 Test CO and spillage under natural conditions. If the test failed under worst-case, but passes under natural conditions, the work scope shall specify building pressure remediation, as applicable.

807.14.6 If an appliance fails under natural conditions, the Auditor shall inform the homeowner of the problem, and the work scope shall specify remediation, including equipment or vent system repair or replacement, as applicable.

CAZ Pressure Limits
-15 Pa for pellet stoves with exhaust fans and sealed vents

-5 Pa for Atmospheric vented oil or gas system (classified as a category 1 or 2 according to NFPA standard 54, such as oil power burner; fan-assisted or induced-draft gas; solid-fuel–burning appliance other than pellet stoves with exhaust fans and sealed vents)

If ambient CO levels exceed 35 ppm at any time, stop any testing and turn the combustion appliances off. Open all the exterior doors and windows. No one should enter the home until the CO levels drop below 35 ppm. The combustion appliance causing the increase in CO levels must be repaired by a qualified technician prior to completing the combustion appliance tests, unless the work scope calls for replacement of the appliance(s).

808 Carbon Monoxide Testing

Test all spaces (including attached garages, crawlspaces, basements) containing combustion appliances for carbon monoxide using the following protocols.

808.1 CO testing of ambient air shall be performed continuously while performing a Worst Case Depressurization Test and/or under natural conditions, as required by paragraph 807.14.

808.2 Equipment used shall:

- Be capable of measuring carbon monoxide (CO) levels from 0 to 2,000 ppm (parts per million)
- Have a resolution of 1 ppm
- Have an accuracy rate of + 5 ppm
- Be calibrated annually by the manufacturer (or using manufacturer's instructions) and evidence of the calibration shall be submitted to the Rating Provider Quality Assurance Designee

808.3 Zero the carbon monoxide meter outside the building away from any combustion outlets or automobile traffic areas.

808.4 Take a measurement of CO levels within the home upon entering to establish a baseline. Do not measure near combustion appliances while they are operating. If ambient CO levels are higher than 35 ppm during normal appliance operation, turn off the appliance, ventilate the space, and evacuate the building. The building may be reentered once ambient CO levels have gone below 35 ppm.

808.5 For atmospherically-vented appliances:

808.5.1 Take a measurement of vent gases upstream of (before they reach) the draft diverter.

808.5.2 Appliance must operate for at least 5 minutes before taking sample.

808.5.3 Take sample during worst-case depressurization test and/or under natural conditions, as required by paragraph 1.14. Record the CO level.

808.6 For direct- or power-vented appliances:

808.6.1 Sample must be taken at vent termination.

808.6.2 Appliance must operate for at least 5 minutes before taking sample.

808.6.3 Take sample during worst-case depressurization test and/or under natural conditions, as required by paragraph 1.14. Record the CO level.

808.7 For LP- or natural gas ovens:

808.7.1 Open a window or door to the outside.

808.7.2 Remove any foil or cooking utensils within the oven.

808.7.3 Verify that the oven is not in self-cleaning mode.

808.7.4 Turn oven on to highest temperature setting.

808.7.5 Close the oven door and begin monitoring the CO levels in the kitchen, 5 feet from the oven at countertop height. Record CO levels.

808.7.6 Measure the CO levels within the oven vent.

808.7.6.1 Samples must be taken while burner is firing.

808.7.6.2 Operate burner for at least 5 minutes while sampling flue gases.

808.7.6.3 If CO levels are higher than 100 ppm, repeat the flue gas sampling until the CO levels stop falling.

808.7.6.4 Record the steady state CO reading in ppm and turn off oven.

808.8 If measured CO levels are higher than 100 ppm (200 for oven), or an appliance fails to meet manufacturer's specifications for CO production (whichever is higher), the work scope shall specify replacement or repair of the appliance, and the homeowner shall be notified of the need for service by a qualified technician.

808.9 If ambient CO levels exceed 35 ppm at any time, stop any testing and turn the combustion appliances off. Open all the exterior doors and windows. No one should enter the home until the CO levels drop below 35 ppm. The combustion appliance causing the increase in CO levels must be repaired by a qualified technician prior to completing the combustion appliance tests, unless the work scope calls for replacement of the appliance(s).

809 Work Scope for Contractors

809.1 Requirements

809.1.1 All work must meet applicable codes and regulations for the jurisdiction.

809.1.2 When air sealing is being performed the work scope shall specify CAZ depressurization testing to be performed at the end of each workday.

809.1.3 The work scope for recommended improvements will be determined by the Auditor and shall be based upon the findings of the assessment, the client's needs and budget, and priorities identified during combustion appliance testing, subject to health and safety requirements.

809.1.4 The work scope shall clearly identify for the client any remedial actions which require prompt attention, affect safety, or require a licensed trade.

809.1.5 The work scope shall provide sufficient specification that the client may obtain reasonably comparable bids from alternative sources for making recommended improvements.

809.1.6 All scopes of work shall include this statement: "**The estimated energy use and savings information contained in the audit report does not constitute a guarantee or warranty of actual energy cost or usage.**"

809.1.7 The work scope shall be developed based on the Auditor's diagnosis and analysis. Emphasis shall be on:

- bringing air distribution system components inside the building enclosure when it is feasible, or sealing and insulating ducts when it is not
- improving airflow and total HVAC system efficiency as applicable
- upgrades to the building enclosure as applicable
- improvements to lighting and appliances as applicable

809.1.8 The scopes shall reflect the "house as a system" approach, recognizing measure interaction. The following statement shall be included whenever a fireplace or combustion appliance is located within the building enclosure:

> "This work scope is not a list of recommendations that may be implemented independently; any exclusions or variations to this scope may increase the risk of flue gas spillage, back-drafting, carbon monoxide production and/or moisture problems within the home."

809.1.9 When specifying equipment replacement, new equipment sizing shall be based on the proposed, upgraded condition of the building enclosure and duct system.

809.1.10 The work scope shall call for post-work combustion appliance testing in accordance with these guidelines when any work affecting enclosure or duct tightness, or building pressures, is specified.

809.2 Work Scope: Carbon Monoxide

809.2.1 The source of the CO must be repaired or replaced and the problem corrected prior to commencing work on other tasks on the work scope, unless remediation of the CO production is specifically related to one or more of those tasks (such as duct repairs that will correct a large negative pressure in the CAZ).

809.2.2 If there are combustion appliances within the building envelope, a carbon monoxide detector should be specified in the main area of each floor according to manufacturer's recommendations, typically in the hallway outside each bedroom area.

809.2.3 If measured CO levels are higher than 100 ppm (200 for oven), or an appliance fails to meet manufacturer's specifications for CO production (whichever is higher), the work scope shall specify replacement or repair of the appliance, and the homeowner shall be notified of the need for service by a qualified technician.

809.3 Work Scope: Worst Case Depressurization

809.3.1 If the results of the Worst Case Depressurization Test indicate the potential for backdrafting by failing the CAZ pressure limits or spillage test, remediation of the failure must be addressed in the work scope, through one or more of the following (as applicable): targeted air- and duct-sealing, room pressure balancing, exhaust fan makeup air, or appliance replacement (with power- or direct-vented equipment). As an alternative, the combustion appliance zone may be isolated by creating a sealed combustion closet containing the combustion appliances that has the proper amount of combustion air supplied to it according to the applicable version of the IRC. Adequate sealing for isolation purposes shall include air sealing and duct sealing (especially of adjacent platform or cavity return ducts) and confirmed by another CAZ depressurization test.

809.3.2 The work scope should specify replacement of atmospheric-vented combustion appliances with high-efficiency sealed combustion, direct vent, or power vented appliances when feasible. If the home has unvented combustion appliances, the /Auditor shall recommend they be disconnected and replaced with vented combustion appliances.

809.3.3 If unvented combustion appliances are not removed or replaced with vented combustion appliances or electric appliances, the work scope shall not specify measures that affect the air tightness of the envelope, including air sealing, duct sealing, sidewall insulation, or window replacements. Duct sealing outside the thermal envelope may be specified in IECC climate zones 1-3.

Auditor Referenced Standards

These referenced standards provide guidance for the Auditor in the performance of their role as an auditor or home energy rater (diagnostic testing, analysis, writing scopes of work).

1. Mortgage Industry National Home Energy Rating Systems Standards, published by the Residential Energy Services Network, latest version, www.resnet.us

2. ASHRAE/ANSI Standard 119-1998 RA-2004 Air Leakage Performance for Detached Single-Family Residential Buildings, published by the American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc., www.ashrae.org

3. ASHRAE/ANSI Standard 152-2004 Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems, published by the American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc., www.ashrae.org

4. ASTM E1998-02(2007) “Standard Guide for Assessing Depressurization-Induced Backdrafting and Spillage from Vented Combustion Appliances”, published by ASTM International, www.astm.org

5. ASTM E1827-96(2007) “Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door”, published by ASTM International, www.astm.org

6. ASTM E1554-07 “Standard Test Methods for Determining Air Leakage of Air Distribution Systems by Fan Pressurization”, published by ASTM International, www.astm.org

7. Reflective Insulation, Radiant Barriers and Radiation Control Coatings, published by the Reflective Insulation Manufacturers Association- International, www.rimainternational.org

8. Protocols for Verifying HVAC Systems to the ACCA Quality Installation Standard, published by the Air Conditioning Contractors of America, www.acca.org (currently in draft)

9. Verifying ACCA Manual J® Procedures, published by the Air Conditioning Contractors of America, www.acca.org

10. Verifying ACCA Manual S® Procedures, published by the Air Conditioning Contractors of America, www.acca.org

11. Verifying ACCA Manual D® Procedures, published by the Air Conditioning Contractors of America, www.acca.org

12. NAIMA Fibrous Glass Duct Installation Check List, published by the North American Insulation Manufacturers Association, www.naima.org

13. AHRI Certification Directory, published by the Air-conditioning, Heating and Refrigeration Institute, www.ahridirectory.org

Contractor Work Scope Referenced Standards

These referenced standards should be referenced in the work scope, as applicable to provide guidance for the contractor to perform the work scope.

1. International Residential Code for One- and Two-Family Dwellings- 2006, published by the International Code Council, Inc., www.iccsafe.org

2. International Energy Conservation Code- 2006, published by the International Code Council, Inc., www.iccsafe.org

3. International Mechanical Code- 2006, published by the International Code Council, Inc, www.iccsafe.org

4. International Fuel Gas Code- 2006, published by the International Code Council, Inc., www.iccsafe.org

5. ANSI/ACCA Standard 5 QI-2007 HVAC Quality Installation Specification, published by the Air Conditioning Contractors of America, www.acca.org

6. Manual J, Residential Load Calculation, 8th edition, published by the Air Conditioning Contractors of America, www.acca.org

7. Manual D, Residential Duct Systems,3rd edition, published by the Air Conditioning Contractors of America, www.acca.org

8. Manual S, Residential Equipment Selection, published by the Air Conditioning Contractors of America, www.acca.org

9. Manual RS, Comfort, Air Quality, & Efficiency by Design, published by the Air Conditioning Contractors of America, www.acca.org

10. Manual T, Air Distribution Basics, published by the Air Conditioning Contractors of America, www.acca.org

11. Manual H, Heat Pump Systems, published by the Air Conditioning Contractors of America, www.acca.org

12. Manual G, Selection of Distribution Systems, published by the Air Conditioning Contractors of America, www.acca.org

13. ASHRAE Standard 62.2 Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings, published by the American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc., www.ashrae.org

14. ASHRAE Standard 52.2 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size , published by the American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc., www.ashrae.org

15. ASTM Standard C1015-06 "Standard Practice for Installation of Cellulosic and Mineral Fiber Loose-Fill Thermal Insulation", published by ASTM International, www.astm.org

16. ASTM Standard C1320-05 "Standard Practice for Installation of Mineral Fiber Batt and Blanket Thermal Insulation for Light Frame Construction", published by ASTM International, www.astm.org

17. ASTM Standard C727-01 (2007)e1 "Standard Practice for Installation and Use of Reflective Insulation in Building Constructions", published by ASTM International, www.astm.org

18. ASTM Standard C1158-05 "Standard Practice for Installation and Use of Radiant

Barrier Systems in Building Constructions", published by ASTM International, www.astm.org

19. ASTM Standard E2112-07 "Standard Practice for Installation of Exterior Windows, Doors and Skylights", published by ASTM International, www.astm.org

20. Flexible Duct Performance and Installation Standards 4th edition, published by the Air Diffusion Council, www.flexibleduct.org

21. Fibrous Glass Duct Construction Standards, 5th edition, published by the North American Insulation Manufacturers Association, www.naima.org

22. FTC Trade Regulation Rule 16 CRF 460, Labeling and Advertising of Home Insulation, published by the Federal Trade Commission, www.ftc.gov

Sample Work Scope Form
(This is informative and does not contain requirements necessary for conformance to these guidelines.)

Work Scope for ___________________________________
All work will be performed according the following checked standards

This work scope is not a list of recommendations that may be implemented independently; any exclusion to this scope may increase the risk of flue gas spillage, back-drafting, carbon monoxide production or moisture problems within the home.

What qualifications are required from contractors/technicians conducting the work:

What work needs to be performed:

Where the work needs to be performed:

How the work is to be performed (referenced Standard(s)):