

ACM RESIDENTIAL ~~MANUAL~~ APPENDIX RA4 -2008

Appendix RA4C - 2008 – Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems

RA4C.1 Purpose and Scope

ACM RA4C-20085 contains procedures for measuring the air leakage in forced air distribution systems as well as procedures for verifying duct location, surface area and R-value.

ACM RA4C-20085 applies to air distribution systems in both new and existing low-rise residential buildings.

ACM RA4C-20085 provides required procedures for installers, HERS raters and others who need to perform field verification and diagnostic testing to verify the efficiency of air distribution systems. Algorithms for determining distribution system efficiency are contained in Chapter 4 of the residential ACM Manual. Table RA4-1 is a summary of the tests and criteria included in ACM RA4C-20085.

Table RA4C-1 – Summary of Diagnostic Measurements

Diagnostic	Description	Procedure
Supply Duct Location, Surface Area and R-factor	Verify that duct system was installed according to the design, including location, size and length of ducts, duct insulation R-value and installation of buried ducts.	RA4C-1 Diagnostic Supply Duct Location, Surface Area and R-value
Duct Leakage	Verify that duct leakage is less than the criteria or in the case of existing ducts that all accessible leaks have been sealed	RA4.4.3 Diagnostic Duct Leakage

RA4C.2 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

RA4.C2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes as specified by the measurement equipment manufacturer.

RA4.C2.2 Duct Leakage Measurements

The measurement of air flows during duct leakage testing shall have an accuracy of $\pm 3\%$ of measured flow using digital gauges.

RA4.C2.3 Calibration

All instrumentation used for duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the above accuracy requirement. All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the

person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.

RA4G.3 Apparatus

RA4G.3.1 Duct Pressurization

The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in Section [RA4-G2](#).

RA4.G.3.2 Duct Leakage to Outside (Existing Duct Systems)

The apparatus for measuring duct leakage to outside shall include a fan that is capable of maintaining the pressure within the conditioned spaces in the house 25 Pa relative to the outdoors. The fan most commonly used for this purpose is known as a "blower door", and is typically installed within a temporary seal of an open doorway.

RA4.G.3.3 Smoke-Test of Accessible-Duct Sealing (Existing Duct Systems)

The apparatus for determining and verifying sealing of all accessible ducts shall also include means for introducing controllable amounts of non-toxic visual smoke into the duct pressurization apparatus for identifying leaks in accessible portions of the duct system. Adequate smoke shall be used to assure that any accessible leaks will emit visibly identifiable smoke.

RA4.G.4 Procedures

This section describes procedures that may be used to verify diagnostic inputs for the calculation of improved duct efficiency.

RA4.G.4.1 Diagnostic Supply Duct Location, Surface Area and R-value

The performance calculations in [Residential ACM Manual, Section R4.8](#) allow credit for duct systems that are designed to be in advantageous locations, with reduced supply duct surface areas and/or higher than default R-values. Compliance credit may be taken for one or more of these duct system improvements in any combination. The procedure in this section is used to verify that the duct system is installed according to the design and meets the requirements for compliance credit.

RA4.G.4.1.1 Duct System Design Requirements

The design shall show the location of equipment and all supply and return registers. The size, R-value, and location of each duct segment shall be shown in the design drawing which shall be cross referenced to the Supply Duct System Details report in the CF1-R. For ducts buried in attic insulation, the portion in contact with the ceiling or deeply buried shall be shown and the design shall include provisions for ducts crossing each other, interacting with the structure, and changing vertical location to connect with elevated equipment or registers as required. Credit shall be allowed for buried ducts only in areas where the ceiling is level and there is at least 6 inches of space between the outer jacket of the installed duct and the roof sheathing above.

RA4.G.4.1.2 Verifying the Duct System Installation

The location of all supply and return registers shall be verified from an inspection of the interior of the dwelling unit. The location of the equipment and the size, R-value and location of each duct segment shall be verified by observation in the spaces where they are located. Deviations from the design shall not be allowed.

RA4.G.4.1.3 Verification for Ducts Buried in Attic Insulation

The procedure of [RA4.G.4.2.2](#) shall be carried out prior covering the ducts with insulation. Ducts to be buried shall be insulated to R4.2 or greater. In addition ducts designed to be in contact with the ceiling shall be in continuous contact with the ceiling drywall or ceiling structure not more than 3.5 inches from the ceiling drywall.

A sign must be hung near the attic access reading “Caution: Buried Ducts. Markers indicate location of buried ducts.” All ducts which will be completely buried shall have vertical markers which will be visible after insulation installation at not more than every 8 feet of duct length and at the beginning and end of each duct run.

After the ceiling insulation is installed, the R-value and type of insulation listed on the Duct System Details shall be verified. Ceiling insulation shall be level and uniform, mounding at ducts is not allowed.

RA4.C.4.2 System Fan Flow

For the purpose of establishing duct leakage criteria, the total fan flow shall be calculated using RA4.C.4.2.1, RA4.C.4.2.2 or RA4.C.4.2.3.

RA4.C.4.2.1 Default System Fan Flow

Default system fan flow may be used only for homes where the duct system is being tested before the air conditioning and heating system is installed and the equipment specification is not known. For heating only systems the default fan flow shall be 0.5 CFM/CFA. For systems with cooling, the default fan flow shall be 400 CFM per ton of rated cooling capacity calculated by the ACM using the procedure in Appendix RA6E or the heating only value whichever is greater.

RA4.C.4.2.2 Nominal System Fan Flow

For heating only systems the fan flow shall be $21.7 \text{ CFM} \times \text{Heating Capacity in thousands of Btu/hr.}$ For systems with cooling, the fan flow shall be 400 CFM per nominal ton of rated cooling capacity at ARI conditions or the heating only value, whichever is greater.

RA4.C.4.2.3 Measured System Fan Flow

The fan flow ~~shall be~~ shall be as measured according to the procedure in Appendix RA6E-20085.

RA4.C.4.3 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is used by installers and raters to verify that total leakage meets the criteria for any sealed duct system specified in the compliance documents. Diagnostic Duct Leakage from Fan Pressurization of Ducts (Section RA4.C.4.3.1) is the only procedure that may be used by a HERS rater to verify duct sealing in a new home. Table RA4C-2 shows the leakage criteria and test procedures that may be used to demonstrate compliance. In addition to the minimum tests shown, existing duct systems may be tested to show they comply with the criteria for new duct systems.

Table RA4C-2 Duct Leakage Tests

Case	User and Application	Leakage criteria, % of total fan flow	Procedure
Sealed and tested new duct systems	Installer Testing at Final HERS Rater Testing	6%	RA4.C4.3.1
	Installer Testing at Rough-in, Air Handling Unit Installed	6% Installer Inspection at Final	RA4.C4.3.2.1 RA4.C4.3.2.3
	Installer Testing at Rough-in, Air Handling Unit Not Installed	4% Installer Inspection at Final	RA4.C4.3.2.2 RA4.C4.3.2.3
Sealed and tested altered existing duct system	Installer Testing HERS Rater Testing	15% Total Duct Leakage	RA4.C4.3.1
	Installer Testing HERS Rater Testing	10% Leakage to Outside	RA4.C4.3.3.
	Installer Testing and Inspection HERS Rater Testing and Verification	60% Reduction in Leakage and Inspection and Smoke Test	RA4.C4.3.4 RA4.C4.3.6 and RA4.C4.3.7
	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Test but All Accessible Ducts are Sealed Inspection and Smoke Test with 100% Verification	RA4.C4.3.5 RA4.C4.3.6 and RA4.C4.3.7

RA4.C.4.3.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

The objective of this procedure is for an installer to determine or a rater to verify the total leakage of a new or altered duct system. The total duct leakage shall be determined by pressurizing both the supply and return ducts to a pressure difference of 25 Pascals. The following procedure shall be used for the fan pressurization tests:

1. Verify that the air handler, supply and return plenums and all the connectors, transition pieces, duct boots and registers are installed. The entire duct system shall be included in the total leakage test.
2. For newly installed or altered ducts, verify that cloth backed rubber adhesive duct tape has not been used and if a platform or other building cavity used to house the air distribution system has been newly installed or altered, it contains a duct or is ducted with duct board or sheet metal.
3. Seal all the supply and return registers, except for one return register or the system fan access.
4. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
5. Install a static pressure probe at a supply.
6. Adjust the fan flowmeter to produce a 25 Pascal (0.1 in water) pressure difference between the supply duct and the outside or the building space with the entry door open to the outside.
7. Record the flow through the flowmeter, this is the leakage flow at 25 Pascals.
8. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RA4C-2 the system passes.

When the diagnostic leakage test is performed and the measured total duct leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in [Residential ACM Manual](#), Table R4-4314 [Duct/Air Handler Leakage Factors](#).

RA4.C.4.3.2 Diagnostic Duct Leakage at Rough-in Construction Stage

Installers may determine duct leakage in new construction by using diagnostic measurements at the rough-in building construction stage prior to installation of the interior finishing. When using this measurement technique, the installer shall complete additional inspection (as described in section RA4.C4.3.2.3) of duct integrity after the finishing wall has been installed. In addition, after the finishing wall is installed, spaces

between the register boots and the wallboard shall be sealed. Cloth backed rubber adhesive duct tapes shall not be used to seal the space between the register boot and the wall board.

The duct leakage measurement at rough-in construction stage shall be performed using a fan pressurization device. The duct leakage shall be determined by pressurizing both the supply and return ducts to 25 Pa. The following procedure (either RA4.C.4.3.2.1 or RA4.C.4.3.2.2) shall be used:

RA4.C.4.3.2.1 For Ducts with the Air Handling Unit Installed and Connected:

For total leakage:

1. Verify that supply and return plenums and all the connectors, transition pieces and duct boots have been installed. If a platform or other building cavity is used to house the air distribution system, it shall contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test. All joints shall be inspected to ensure that no cloth backed rubber adhesive duct tape is used.
2. Seal all the supply duct boots and return boxes except for one return duct box.
3. Attach the fan flowmeter device at the unsealed duct box.
4. Insert a static pressure probe at one of the sealed supply duct boots.
5. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the duct system and outside or the building space with the entry door open to the outside.
6. Record the flow through the flowmeter, this is the leakage flow at 25 Pascals.
7. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RA4.C.2 the system passes..

RA4.C.4.3.2.2 For Ducts with Air Handling Unit Not Yet Installed:

For total leakage:

1. Verify that all the connectors, transition pieces and duct boots have been installed. If a platform or other building cavity is used to house the air distribution system, it must contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test.
2. Use a duct connector to connect supply and/or return duct box to the fan flowmeter. Supply and return leaks may be tested separately. If there is only one return register, the supply and return leaks shall be tested at the same time.
3. Seal all the supply duct boots and/or return boxes except for one supply or return duct box.
4. Attach the fan flowmeter device at the unsealed duct box.
5. Insert a static pressure probe at one of the sealed supply duct boots.
6. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the building conditioned space and the duct system.
7. Record the flow through the flowmeter; this is the leakage flow at 25 Pascals.
8. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RA4.C-2 the system passes.

RA4.C.4.3.2.3 Installer Visual Inspection at Final Construction Stage

After installing the interior finishing wall and verifying that one of the above rough-in tests was completed, the following procedure shall be used:

1. Remove at least one supply and one return register, and verify that the spaces between the register boot and the interior finishing wall are properly sealed.

2. If the house rough-in duct leakage test was conducted without an air handler installed, inspect the connection points between the air handler and the supply and return plenums to verify that the connection points are properly sealed.
3. Inspect all joints to ensure that no cloth backed rubber adhesive duct tape is used.

RA4.C.4.3.3 Duct Leakage to Outside from Fan Pressurization of Ducts

The objective of this test for altered existing duct systems only is to provide an alternate measurement of duct leakage to outdoors. The total duct leakage to outdoors shall be determined by pressurizing the ducts and the conditioned spaces of the house to 25 Pa. The following procedure shall be used for the fan pressurization test of leakage to outside:

1. Seal all the supply and return registers except one return register or the fan access door.
2. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
3. Install a static pressure probe at the supply plenum.
4. Attach a blower door to an external doorway.
5. If any ducts are located in an unconditioned basement, all doors or accesses between the conditioned space and the basement shall be closed, and at least one operable door or window (if it exists) between the basement and outside shall be opened during the test.
6. If the ducts are located in a conditioned basement, any door between the basement and the remaining conditioned space shall be opened, and any basement doors or windows to outside must be closed during the test.
7. Adjust the blower door fan to provide 25 Pa [0.1 inches of water] pressure difference between the conditioned space and outside.
8. Adjust the fan/flowmeter to maintain zero pressure (± 0.5 Pa [± 0.002 inches water]) between the ducts and the conditioned space, and adjust the blower door fan to maintain 25 Pa (± 0.5 Pa) -[0.1 inch water (± 0.002 inches water)] between the conditioned space and outside. This step may require several iterations.
9. Record the flow through the flowmeter (Q_{25} [$Q_{0.1}$]); this is the duct leakage at 25 Pa [0.1 inch water].
10. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RA4C-2 the system passes.

RCRA.4.3.4 Leakage Improvement from Fan Pressurization of Ducts

For altered existing duct systems which do not pass the Total Leakage (RA4.C4.3.1) or Leakage to Outside (RA4.C4.3.3) tests, the objective of this test is to show that the original leakage is reduced through duct sealing as specified in Table RA4C-2. The following procedure shall be used:

1. Use the procedure in RA4.C4.3.1 to measure the leakage before commencing duct sealing.
2. After sealing is complete use the same procedure to measure the leakage after duct sealing.
3. Subtract the sealed leakage from the original leakage and divide the remainder by the original leakage. If the leakage reduction is 60%- ~~percent~~ or greater of the original leakage, the system passes.
4. Complete the Smoke Test specified in RA4.C4.3.6
5. Complete the Visual Inspection specified in RA4.C4.3.7.

RA4C.4.3.5 Sealing of All Accessible Leaks

For altered existing duct systems that do not pass any of the Total Leakage (RA4.C4.3.1), Leakage to Outside (RA4.C4.3.3) or Leakage Improvement (RA4.C4.3.4) tests, the objective of this test is to show that all accessible leaks are sealed and that excessively damaged ducts have been replaced. The following procedure shall be used:

1. Complete each of the leakage tests

2. Complete the Smoke Test as specified in [RA4.C4.3.6](#)
3. Complete the Visual Inspection as specified in [RA4.C4.3.7](#).
4. Install required label on the system stating that the system fails the leakage tests.

[RA4.C.4.3.6](#) Smoke-Test of Accessible-Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of the smoke test is to confirm that all accessible leaks have been sealed. The following procedure shall be used:

1. Inject either theatrical or other non-toxic smoke into a fan pressurization device that is maintaining a duct pressure difference of 25 Pa relative to the duct surroundings, with all grilles and registers in the duct system sealed.
2. Visually inspect all accessible portions of the duct system during smoke injection.
3. The system shall pass the test if either of the following conditions are met:
 - i. No visible smoke exits the accessible portions of the duct system.; or
 - ii. Smoke only emanates from the portion of the HVAC equipment containing the furnace vestibule which is gasketed and sealed by the manufacturer rather than from the ducts.

[RA4.C.4.3.7](#) Visual Inspection of Accessible Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of this inspection in conjunction with the smoke test ([RA4.C4.3.6](#)) is to confirm that all accessible leaks have been sealed and that excessively damaged ducts have been replaced. The following procedure shall be used:

1. Visually inspect to verify that the following locations have been sealed:
 - Connections to plenums and other connections to the forced air unit
 - Refrigerant line and other penetrations into the forced air unit
 - Air handler door panel (do not use permanent sealing material, metal tape is acceptable)
 - Register boots sealed to surrounding material
 - Connections between lengths of duct, as well as connections to takeoffs, wyes, tees, and splitter boxes.
2. Visually inspect to verify that portions of the duct system that are excessively damaged have been replaced. Ducts that are considered to be excessively damaged are:
 - Flex ducts with the vapor barrier split or cracked with a total linear split or crack length greater than 12 inches
 - Crushed ducts where cross-sectional area is reduced by 30% percent or more
 - Metal ducts with rust or corrosion resulting in leaks greater than 2 inches in any dimension
 - Ducts that have been subject to animal infestation resulting in leaks greater than 2 inches in any dimension

[RA4.4.3.8](#) Low Leakage Ducts in Conditioned Space

When ducts are located in conditioned space, additional credit is available for Low Leakage Ducts, defined as duct systems for which air leakage to outside conditions is equal to or less than 25 cfm when measured in accordance with Section RA4.4.3.3, steps 1 through 10. This credit for Low Leakage Ducts in Conditioned Space, is in addition to the credit for tight ducts which requires HERS verification, and must be used in combination with the existing credit for verified ducts in conditioned space. The ACM credit is calculated by reducing the duct air leakage factors shown in Table R4-14 of the Residential ACM.

RA4.4.3.9 Verified Low Leakage Air Handler

A credit is available for Low Leakage Air Handlers. For factory sealed air handler unit tested by the manufacturer and certified to the Commission to have achieved a 2 percent or less leakage rate at 1-inch water gauge when all air inlets, air outlets and condensate drain port(s), when present, are sealed at an air pressure of 1-inch water gauge with no greater than 2-percent of design cubic foot per minute discharge.

The ACM credit for calculating this credit is located in Table R4-14 of the Residential ACM: