Nonresidential Appendix NA2 – 2008

Appendix NA2 – Nonresidential Field Verification and Diagnostic Test Procedures

NA2.1 Air Distribution Diagnostic Measurement and Field Verification

Diagnostic inputs are used for the calculation of improved duct efficiency. The diagnostics include observation of various duct characteristics and measurement of duct leakage and system fan flows as described below in Sections NA2.3.3 through NA2.3.8. These observations and measurements replace those assumed as default values.

The diagnostic procedures include:

- Measurement of duct surface area if ducts are located outdoors or in multiple spaces as described in Section NA2.3.3.
- Observation of the insulation level for the supply (R_s) and return (R_r) ducts outside the conditioned space as described in Section NA2.3.5.
- Observation of the presence of a cool roof.
- Observation of the presence of an outdoor air economizer.
- Measurement of total duct system leakage as described in Section NA2.3.8.

Using default values instead of measured values will produce conservative (low) estimates of duct efficiency.

NA2.1.1 Purpose and Scope

NA2 contains procedures for measuring the air leakage in single zone, nonresidential air distribution systems. The methods described here apply to single zone, constant volume heating and air conditioning systems serving zones with 5000 ft^2 of floor area or less, with duct systems located in unconditioned or semi-conditioned buffer spaces or outdoors. Field measurement and verification procedures must be performed if a reduced duct leakage credit is claimed. These procedures apply to new buildings or new air conditioning systems applied to existing buildings.

The Nonresidential ACM Manual contains calculation procedures for determining distribution efficiency of single-zone nonresidential air distribution systems serving 5,000 ft^2 or less. By default, duct leakage is assumed to be untested.

NA2.2 Instrumentation Specifications

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

NA2.2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of $\pm$ 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes.

NA2.2.2 Duct Leakage Measurements

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

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.

NA2.2.3 Duct Pressurization Apparatus

The apparatus for fan pressurization duct leakage measurements shall consist of duct pressurization and flow measurement device meeting the specifications in Section NA2.2.

NA2.3 Procedure

The following sections identify input values for building and HVAC system (including ducts) using either default or diagnostic information.

NA2.3.1 Building Information and Defaults

The calculation procedure for determining air distribution efficiencies requires the following building information:

1. climate zone for the building,
2. conditioned floor area,
3. number of stories,
4. areas and U-values of surfaces enclosing space between the roof and a ceiling, and
5. surface area of ductwork if ducts are located outdoors or in multiple spaces.

Using default values rather than diagnostic procedures produce relatively low air distribution-system efficiencies. Default values shall be obtained from following sections:

1. the location of the duct system in SectionNA2.3.4,
2. the surface area and insulation level of the ducts in SectionNA2.3.3.1 and Section NA2.3.5.1,
3. the system fan flow in SectionNA2.3.6, and
4. the leakage of the duct system in Section NA2.3.8

NA2.3.2 Diagnostic Input

Diagnostic inputs are used for the calculation of improved duct efficiency. The diagnostics include observation of various duct characteristics and measurement of duct leakage and system fan flows as described in Sections NA2.3.3 through NA2.3.8. These observations and measurements replace those assumed as default values.

The diagnostic procedures include:

- Measurement of total duct system leakage as described in Section NA2.3.8.
- Measurement of duct surface area if ducts are located outdoors or in multiple spaces as described in Section NA2.3.3.2.

- Observation of the insulation level for the supply (R_s) and return (R_r) ducts outside the conditioned space as described in Section NA2.3.5.2.
- Observation of the presence of a cool roof.
- Observation of the presence of an outdoor air economizer.

NA2.3.3 Duct Surface Area

The supply-side and return-side duct surface areas shall be calculated separately. If the supply or return duct is located in more than one space, the area of that duct in each space shall be calculated separately. The duct surface area shall be determined using one of the following methods.

NA2.3.3.1 Default Duct Surface Area

The default duct surface area for supply and return shall be calculated as follows:

For supplies:

Equation NA2-1

$$A_{s,total} = K_s \, A_{floor}$$

Where K_s (supply duct surface area coefficient) shall be 0.25 for systems serving the top story only, 0.125 for systems serving the top story plus one other, and 0.08 for systems serving three or more stories.

For returns:

Equation NA2-2

$$A_{r,total} = K_r \quad A_{floor}$$

Where K_r (return duct surface area coefficient) shall be 0.15 for systems serving the top story only, 0.125 for systems serving the top story plus one other, and 0.08 for systems servings three or more stories.

If ducts are located outdoors, the outdoor duct surface area shall be calculated from the duct layout on the plans using measured duct lengths and nominal inside diameters (for round ducts) or inside perimeters (for rectangular ducts) of each outdoor duct run in the building that is within the scope of the calculation procedure. When using the default duct area, outdoor supply duct surface area shall be less than or equal to the default supply duct surface area; outdoor return duct surface area shall be less than or equal to the default return duct surface area.

The surface area of ducts located in the buffer space between ceilings and roofs shall be calculated from:

Equation NA2-3

$$A_{s,buffer} = A_{s,total} - A_{s,outdoors}$$

Equation NA2-4

$$A_{r,buffer} = A_{r,total} - A_{r,outdoors}$$

NA2.3.3.2 Measured Duct Surface Area

Measured duct surface areas shall be used when the outdoor duct surface area measured from the plans is greater than default duct surface area for either supply ducts or return ducts. If a duct system passes through

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multiple spaces that have different ambient temperature conditions as specified in NACM Appendix NA2, the duct surface area shall be measured for each space individually. The duct surface area shall be calculated from measured duct lengths and nominal inside diameters (for round ducts) or inside perimeters (for rectangular ducts) of each duct run located in buffer spaces or outdoors.

NA2.3.4 Duct Location

Duct systems covered by this procedure are those specified in the Standards §144(k)3.

NA2.3.5 Duct Wall Thermal Resistance

NA2.3.5.1 Default Duct Insulation R value

Default duct wall thermal resistance for new buildings is R-8.0, the mandatory requirement for ducts installed in newly constructed buildings, additions and new or replacement ducts installed in existing buildings. Default duct wall thermal resistance for existing ducts in existing buildings is R-4.2. An air film resistance of 0.7 {[hr-ft^2-°F/Btu[u~~TU~~)]} shall be added to the duct insulation R value to account for external and internal film resistance.

NA2.3.5.2 Diagnostic Duct Wall Thermal Resistance

Duct wall thermal resistance shall be determined from the manufacturer's specification observed during diagnostic inspection. If ducts with multiple R values are installed, the lowest duct R value shall be used. If a duct with a higher R value than 8.0 is installed, the R-value shall be clearly stated on the building plans and a visual inspection of the ducts must be performed to verify the insulation values.

NA2.3.6 Total Fan Flow

The total fan flow for an air conditioner or a heat pump for all climate zones shall be equal to 400 cfm/rated ton with rated tons defined by unit scheduled capacity at the conditions the unit's ARI rating standard from Section 112 of the Standards. Airflow through heating only furnaces shall be based on 21.7 cfm/kBtuh rated output capacity.

NA2.3.7 Duct Leakage Factor for Delivery Effectiveness Calculations

Default duct leakage factors for the Proposed Design shall be obtained from Table NA2-1, using the "Untested" values.

Duct leakage factors for the Standard Design shall be obtained from Table NA2-2, using the appropriate "Tested" value.

Duct leakage factors shown in Table NA2-1 shall be used in calculations of delivery effectiveness contained in the Nonresidential ACM Manual.

Table NA2-1 Duct Leakage Factors

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Untested duct systems	0.82
Sealed and tested duct systems in existing buildings, System tested after HVAC equipment and/or duct installation	0.915
Sealed and tested new duct systems. System tested after HVAC system installation	0.96

NA2.3.8 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. Table NA2-2 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 NA2-2 Duct Leakage Tests

Case	**User and Application**	**Leakage criteria, % of total fan flow**	**Procedure**
Sealed and tested new duct systems	Installer Testing HERS Rater Testing	6%	NA2.3.8.1
Sealed and tested altered existing duct systems	Installer Testing HERS Rater Testing	15% Total Duct Leakage	NA2.3.8.1
	Installer Testing and Inspection HERS Rater Testing and Verification	60% Reduction in Leakage and Visual Inspection	NA2.3.8.2 NA2.3.8.4
	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Test but All Accessible Ducts are Sealed And Visual Inspection	NA2.3.8.3 NA2.3.8.4

NA2.3.8.1 Total Duct Leakage Test 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 25 Pascals with all ceiling diffusers/grilles and HVAC equipment installed. When existing ducts are to be altered, this test shall be performed prior to and after duct sealing. 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 system shall be included in the test.
2. For newly installed or altered ducts, verify that cloth backed rubber adhesive duct tape has not been used.
3 Seal all the supply and return registers, except for one return register or the system fan access. Verify that all outside air dampers and/or economizers are sealed prior to pressurizing the system.
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 ($Q_{total,25}$) - this is the total duct 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 6% for new duct systems or less than 15% for altered duct systems, the system passes.

Duct systems that have passed this total leakage test will be tested by a HERS rater to show compliance.

NA2.3.8.2 Leakage Improvement from Fan Pressurization of Ducts

For altered existing duct systems which have a higher leakage percentage than the Total Duct leakage criteria in Section NA2.3.8.1, the objective of this test is to show that the original leakage is reduced through duct sealing as specified in Table NA2-2. The following procedure shall be used:

1. Use the procedure i n NA2.3.8.1 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% or greater of the original leakage, the system passes.
4. Complete the Visual Inspection specified in NA2.3.8.4.

Duct systems that have passed this leakage reduction test and the visual inspection test will be tested by a HERS rater to show compliance.

NA2.3.8.3 Sealing of All Accessible Leaks

For altered existing duct systems that do not pass the total leakage test (NA2.3.8.1), 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 Visual Inspection as specified in NA2.3.8.4.

All duct systems that could not pass either the total leakage test or the leakage improvement test will be tested and inspected by a HERS rater to show that all accessible ducts have been sealed and excessively damaged ducts have been replaced. This requires a sampling rate of 100%.

NA2.3.8.4 Visual Inspection of Accessible Duct Sealing

For altered existing duct systems that fail to be sealed to 15% of total fan flow, the objective of this inspection 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% 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

NA2.3.8.5 Labeling requirements for tested systems

A sticker shall be affixed to the exterior surface of the air handler access door with the following text in 14 point font:

"The leakage of the air distribution ducts was found to be CFM @ 25 Pascals or % of total fan flow.

This system (check one):

☐ *Has a leakage rate that is **equal to or lower** than the prescriptive requirement of 6% leakage for new duct systems or 15% leakage for alterations to existing systems. It meets the prescriptive requirements of California Title 24 Energy Efficiency Standards.*

☐ *Has a leakage rate **higher than** 6% leakage for new duct systems or 15% leakage for altered existing systems. It does NOT meet the meet or exceed the prescriptive requirements of the Title 24 standards. However, all accessible ducts were sealed.*

Signed: _____

Print name: _____

Print Company Name:_____

Print Contractor License No:_____

Print Contractor Phone No:_____

Do not remove sticker"

NA2.4 Definitions

Comment [NRP1]: Should be an upper case first letter of each definition below.

aerosol sealant closure system: A method of sealing leaks by blowing aerosolized sealant particles into the duct system which must include minute-by-minute documentation of the sealing process.

buffer space: an unconditioned or indirectly conditioned space located between a ceiling and the roof.

delivery effectiveness: The ratio of the thermal energy delivered to the conditioned space and the thermal energy entering the distribution system at the equipment heat exchanger.

distribution system efficiency: The ratio of the thermal energy consumed by the equipment with the distribution system to the energy consumed if the distribution system had no losses or impact on the equipment or building loads.

equipment efficiency: The ratio between the thermal energy entering the distribution system at the equipment heat exchanger and the energy being consumed by the equipment.

equipment factor : F_{equip} is the ratio of the equipment efficiency including the effects of the distribution system to the equipment efficiency of the equipment in isolation.

fan flowmeter device*:* A device used to measure air flow rates under a range of test pressure differences.

flow capture hood**:** A device used to capture and measure the airflow at a register.

load factor : F_{load} is the ratio of the building energy load without including distribution effects to the load including distribution system effects.

pressure pan : a device used to seal individual forced air system registers and to measure the static pressure from the register.

recovery factor : F_{recov} is the fraction of energy lost from the distribution system that enters the conditioned space.

thermal regain: The fraction of delivery system losses that are returned to the building.