Nonresidential Appendix NA2

Appendix NA2 – Nonresidential Field Verification and Diagnostic Test Procedures

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NA2.1 ~~Air Distribution Diagnostic Measurement and~~ Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems

~~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 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 roofing product.~~
- ~~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

- NA2.1 contains procedures for ~~measuring~~ field verification and diagnostic testing ~~the~~ for air leakage in single zone, constant volume, nonresidential air distribution systems~~. The methods described here apply to single zone, constant volume heating and air conditioning systems~~ serving zones with 5000 ft² of conditioned floor area or less~~, with duct systems located in unconditioned or semi-conditioned buffer spaces or outdoors~~ as required by Standards section 140.4(l). ~~Field measurement and verification procedures must be performed if a reduced duct leakage credit is claimed.~~
- ~~These~~ NA2.1 procedures ~~apply~~ are applicable to new space conditioning systems in newly constructed buildings ~~or~~ and to new or altered ~~air~~ space conditioning systems ~~applied~~ in ~~to~~ existing buildings.
- NA2.1 procedures shall be used by installers, HERS Raters, and others who perform field verification of air distribution systems as required by Standards Section 140.4(l).
- Table NA2.1-1 provides a summary of the duct leakage verification and diagnostic test protocols included in Section NA2.1, and the compliance criteria.

~~The Nonresidential ACM Manual contains calculation procedures for determining distribution efficiency of single-zone nonresidential air distribution systems serving 5,000 ft² or less. By default, duct leakage is assumed to be untested.~~

NA2.1.2 Instrumentation Specifications

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

NA2.1.2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of plus or minus~~±~~ 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes, Dwyer A303 or equivalent.

NA2.1.2.2 Duct Leakage Measurements

~~The~~ All measurements of duct leakage airflow ~~air flows during duct leakage testing~~ shall have an accuracy of ~~±~~ plus or minus 3 percent~~-~~ of measured airflow or better using digital gauges.

NA2.1.2.3 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 specified in Section NA2.1.2. ~~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.~~

NA2.1.3 ~~Duct Pressurization~~ Diagnostic Apparatus

NA2.1.3.1 Apparatus for Duct Pressurization and Leakage Flow Measurement

The apparatus for duct system ~~fan~~ pressurization and duct system leakage measurements shall consist of a duct system pressurization and leakage airflow measurement device meeting the specifications in Section NA2.1.2~~NA2.2~~.

NA2.1.3.2 Apparatus for Smoke-Test of Accessible-Duct Sealing (Existing Duct Systems)

The apparatus for determining leakage in and verifying sealing of all accessible leaks in existing duct systems provide means for introducing controllable amounts of non-toxic visual or theatrical smoke into the duct pressurization apparatus for identifying leaks in accessible portions of the duct system. The means for generating smoke shall have sufficient capacity to ensure that any accessible leaks will emit visibly identifiable smoke.

NA2.1.4 Verification and Diagnostic Procedures

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

~~NA2.1.5 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 Section NA2.3.4,~~

~~2. the surface area and insulation level of the ducts in Section NA2.3.3.1 and Section NA2.3.5.1,~~

~~3. the system fan flow in Section NA2.3.6, and~~

~~4. the leakage of the duct system in Section NA2.3.8~~

NA2.1.6 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.

NA2.1.7 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.

NA2.1.7.1 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

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

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

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

NA2.1.7.2 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 multiple spaces that have different ambient temperature conditions as specified in Section 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.

NA2.1.8 Duct Location

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

NA2.1.9 Duct Wall Thermal Resistance

NA2.1.9.1 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-ft²-°F/BTU] shall be added to the duct insulation R value to account for external and internal film resistance.

NA2.1.9.2 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.

NA2.1.9.3NA2.1.4.1 Total Fan FlowNominal Air Handler Airflow

The nominal air handler airflow used to determine the target leakage rate for compliancetotal fan flow for an air conditioner or a heat pump for all climate zones shall be equal to 400 cfm per /rated ton of cooling capacity with rated tons defined by unit scheduled capacity at the conditions the unit's ARI rating standard from §112. Airflow throughNominal air handler airflow for heating only system furnaces shall be based on 21.7 cfm per /kBtu/hr of rated heating output capacity.

NA2.1.10 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

	as = ar =
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

NA2.1.10.1NA2.1.4.2 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is shall be used by installers and raters HERS Raters to verify that total duct leakage meets the compliance criteria for any sealed duct systems specified in the compliance documentsfor which field verification and diagnostic testing is required. Table NA2-2Table NA2.1-1 shows summarizes the leakage criteria and and the diagnostic test procedures that may shall 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 NA2.1-1 NA2-2 – Duct Leakage Tests Verification and Diagnostic Test Protocols and Compliance Criteria

Case	User and Application	Leakage Compliance eCriteria, (% of Nominal Air Handler Airflow)total fan flow	Procedure(s)
Sealed and tested new- duct systems	Installer Testing HERS Rater Testing	6%	NA2.3.8.1NA2.1.4.2.1
Sealed and tested altered existing duct systems	Installer Testing HERS Rater Testing	15% Total Duct Leakage	NA2.1.4.2.1NA2.3.8.1
	Installer Testing and Inspection HERS Rater Testing and Verification	60% Reduction in Leakage and Visual Inspection	NA2.3.8.2 NA2.3.8.4
Sealed and tested altered existing duct systems	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Test but All Accessible Ducts are Sealed And Visual Inspection and Smoke Test with 100% Verification	NA2.3.8.3NA2.1.4.2.2 NA2.3.8.4NA2.1.4.2.3 NA2.1.4.2.4

NA2.1.10.1.1NA2.1.4.2.1 Diagnostic Total Duct Leakage Test from Fan Pressurization of Ducts

The objective of this procedure is for an installer to determine or and a rater HERS Rater to verify the total leakage of a new or altered duct system. The total duct leakage shall be determined by pressurizing the entire duct systemboth the supply and return ducts to 25 Pascals (0.1 inches water) with respect to outsidewith 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 registers and return ~~registers~~grilles, except for one large centrally located return ~~register~~ grille or the ~~system fan~~air handler cabinet access door or panel. 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~~ return grille or the air handler cabinet access door or ~~door~~panel.
5. Install a static pressure probe at a supply register located close to the air handler, or at the supply plenum.
6. Adjust the fan flowmeter to produce a positive 25 Pa~~scal~~ (0.1 inches water) pressure ~~difference between the supply duct and the outside or~~ at the supply register or the supply plenum with respect to the outside or with respect to 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 Pa (0.1 inches water)~~scals~~.

~~8.~~ Divide the duct leakage flow by the ~~total fan~~ nominal air handler airflow determined by the procedure in Section NA2.1.4.1 and convert to a percentage. If the duct leakage flow percentage is equal to or less than ~~6 percent for new duct systems or less than 15 percent for altered duct systems,~~the target compliance criterion from Table NA2.1-1, the system passes.

~~9.~~8. ~~Duct systems that have passed this total leakage test will be tested by a HERS rater to show compliance.~~

~~***NA2.1.10.2 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 in 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 percent 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.~~

~~NA2.1.10.2.1~~NA2.1.4.2.2 Sealing of All Accessible Leaks

For altered existing duct systems that ~~do not~~ are unable to pass the ~~total~~ leakage test in Section ~~(NA2.3.8.1~~NA2.1.4.2.1~~)~~, the objective of this test is to ~~show~~ verify 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 test specified in Section NA2.1.4.2.1.
2. Seal all accessible ducts
3. After sealing is complete, again use the procedure in NA2.1.4.2.1 to measure the leakage after duct sealing.~~s~~

~~1. Complete the Smoke Test as specified in NA2.1.4.2.3.~~

4.

~~2.~~5. Complete the Visual Inspection as specified in ~~NA2.3.8.4~~NA2.1.4.2.4.

All duct systems that ~~could not~~fail to pass ~~either~~ the ~~total~~ leakage test ~~or the leakage improvement test~~ specified in Section NA2.1.4.2.1 ~~will~~ shall be tested and inspected by a HERS ~~rater~~ Rater to ~~show~~ verify that all accessible ducts have been sealed and ~~excessively~~ damaged ducts have been replaced. Compliance with HERS verification requirements shall not utilize group sampling procedures when the installer used the Sealing of All Accessible Leaks procedure in Section NA2.1.4.2.2~~This requires a sampling rate of 100 percent~~.

NA2.1.4.2.3 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 (0.1 inches water) 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 one of the following conditions is met:
   - No visible smoke exits the accessible portions of the duct system.
   - Smoke only emanates from the furnace cabinet which is gasketed and sealed by the manufacturer and no visible smoke exits from the accessible portions of the duct system.

~~NA2.1.10.2.2~~**NA2.1.4.2.4 Visual Inspection of Accessible Duct Sealing**

For altered existing duct systems that are unable to pass the leakage test in Section NA2.1.4.2.1~~fail to be sealed to 15 percent 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:~~

Visually inspect to verify that the following locations have been sealed:

1. Connections to plenums and other connections to the ~~forced~~ air ~~-~~handling unit.
2. Refrigerant line and other penetrations into the ~~forced~~ air-handling unit.
3. Air handler access door or panel (do not use permanent sealing material, metal tape is acceptable).
4. Register boots sealed to surrounding material.
5. Connections between lengths of duct, as well as connections to takeoffs, wyes, tees, and splitter boxes.

~~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 vaporvapor retarder 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~~

~~**NA2.1.10.2.3 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 percent of total fan flow.~~

~~This system (check one):~~

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

~~☐ Has a leakage rate higher than 6 percent leakage for new duct systems or 15 percent leakage for altered existing systems. It does NOT meet the meet or exceed the prescriptive requirements of the 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"

NA2.2 Definitions

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: Fequip 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: Fload 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: Frecov 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.