BSR/ASHRAE Standard 37-2009R

Public Review Draft

Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment

Second Public Review (May 2024)
(Draft Shows Proposed Independent Substantive Changes to Previous Public Review Draft)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

ASHRAE, 180 Technology Parkway, Peachtree Corners GA 30092

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[Note to Reviewers: This public review draft makes proposed independent substantive changes to the previous public review draft. These changes are indicated in the text by underlining (for additions) and strikethrough (for deletions) except where the reviewer instructions specifically describe some other means of showing the changes. Only these changes to the current standard are open for review and comment at this time. Additional material is provided for context only and is not open for comment except as it relates to the proposed changes.]

FOREWORD

This is a major revision of Standard 37-2009 (RA 2019). Applicable sections of Standard 116-2010 have been added to provide an inclusive testing and rating method. This standard was prepared under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). It may be used, in whole or in part, by an association or government agency with due credit to ASHRAE. Adherence is strictly on a voluntary basis and merely in the interests of obtaining uniform standards throughout the industry.

1. PURPOSE

1.1 This standard provides test methods and calculations for steady-state, cyclic, and part-load performance and methods for establishing seasonal performance for unitary air-conditioning and heat pump equipment, including single capacity, multiple capacity, variable capacity, unloading, or multiple compressors for ducted and ductless systems.

2. SCOPE

2.1 This standard applies to electrically driven mechanical-compression unitary air conditioners and heat pumps consisting of one or more assemblies that include an indoor air coil(s), a compressor(s), and an outdoor coil(s). Where such equipment is provided in more than one assembly, the separated assemblies are designed to be used together.

2.2 This standard does not include methods of testing the following:

(a) cooling coils for separate use
(b) condensing units for separate use
(c) room air conditioners
(d) heat-operated unitary equipment
(e) liquid chilling packages
(f) multiple indoor air coils operating simultaneously in heating and cooling modes
(g) cyclic testing of air-cooled unitary air conditioners and heat pumps with rated cooling capacity greater than 19.05 kW (65,000 Btu/h) or, in the case of heating-only heat pumps, rated heating capacity greater than 19.05 kW (65,000 Btu/h).

3. DEFINITIONS

AHRI: Air-Conditioning, Heating, and Refrigeration Institute.

air-conditioner~~ing system~~: assembly of equipment for air treatment to simultaneously control its temperature, humidity, cleanliness, and distribution to meet the requirements of a conditioned space.

~~***cooling (heating) air-conditioning system:*** specific air-treating combination that may consist of means for ventilation, air circulation, humidity control, air cleaning, and heat transfer, with controlled means for cooling (heating). Specific air-treating equipment consisting of a means for ventilation, air circulation, humidity control, air cleaning, heat transfer or any combination thereof.~~

~~***packaged air conditioner:***(sometimes referred to as a self-contained unit), complete air-conditioning unit, including refrigeration compressor, cooling coils, fans, filters, automatic controls, and any optional accessories, assembled into one casing.~~

~~***split air-conditioning system:*** air-conditioning system consisting of equipment provided in more than one assembly or enclosure, usually with supply air distribution equipment housed separately from refrigerant condensing equipment.~~

air sampling device: combination of air sampling tree(s), conduit, fan, dry-bulb and water vapor content measurement device used to determine dry-bulb temperature and water vapor content of an air sample.

air sampling tree: an assembly consisting of a manifold with branch tubes which contain multiple sampling holes that draw an air sample from a critical location from the unit under test (including but not limited to the indoor air inlet, indoor air outlet, and outdoor air inlet).

air, standard: air weighing 1.20 kg/m^3 (0.075 lb/ft^3), which approximates dry air at a temperature of 21.11°C (70°F) and a barometric pressure of 101.325 kPa (29.92 in. Hg).

apparatus: as used in this standard, this term refers exclusively to test room facilities and instrumentation.

aspirating psychrometer: a piece of equipment with a monitored airflow section that draws uniform airflow through the measurement section and has probes for measurement of air temperature and water vapor content.

capacity, heating: the rate, expressed in W (Btu/h), of increase in the dry-bulb temperature (adds sensible heat) of the air passing through the equipment under specified conditions of operation.

capacity, latent cooling: the rate, expressed in W (Btu/h),), of removal of latent heat (reduces the moisture content) from the air passing through the equipment under specified conditions of operation.

capacity, sensible cooling: the rate, expressed in W (Btu/h), of decrease in the dry-bulb temperature (removes sensible heat) of the air passing through the equipment under specified conditions of operation.

capacity, total cooling: the rate, expressed in W (Btu/h), of removal of heat (latent and sensible) from the air passing through the equipment under specified conditions of operation.

~~***coefficient of performance, heating (COP):*** the heating efficiency expressed as a dimensionless ratio of net heating capacity divided by the total input power under designated operating conditions.~~

coil, indoor: the heat exchanger that removes heat from or adds heat to the conditioned space.

coil, outdoor: the heat exchanger that rejects heat to, or absorbs heat from, a source external to the conditioned space.

degradation coefficient (C_D): factor of efficiency loss due to the cycling of the unit.

Dew-point Hygrometer: An instrument used to determine the water vapor content of air by detecting visible condensation of moisture on a cooled surface.

~~***energy:***~~
~~(a) capability for doing work.~~
~~(b) capacity for producing an effect, having multiple forms, consisting of either stored or transient that are able to be transformed from one form into another. Forms include thermal (heat), mechanical (work), electrical, radiant, and chemical.~~

~~***energy-efficiency ratio, cooling (EER):*** the cooling efficiency expressed as a ratio of net cooling capacity in Btu/h to the total input power in Watts under designated operating conditions.~~

equilibrium: the steady-state condition where the fluctuations of variables being measured remain within stated limits (as given in Section 8.9.2.1).

equipment: as used in this standard, this term refers exclusively to the unitary equipment to be tested.

equipment, unitary: one or more factory-made assemblies that include, but are not limited to, combinations of evaporator(s) or cooling coil(s), compressor(s), and condenser(s). Further defined as provided in Section 2 and Section 4.

heat, latent: the change in enthalpy associated with a change in humidity ratio, caused by the addition or removal of moisture.

heat, sensible: the energy exchanged by a thermodynamic system that relates to a change of temperature.

~~***heat pump, cooling and heating:*** system designed to utilize alternately or simultaneously the heat extracted at a low temperature and the heat rejected at a higher temperature for cooling and heating functions, respectively.~~

heat pump: thermodynamic heating/refrigerating system to transfer heat. The condenser and evaporator may change roles to transfer heat in either direction. By receiving the flow of air, a heat pump is used to cool or heat.

packaged system: (sometimes referred to as a self-contained unit), complete air-conditioner or heat pump, including refrigeration compressor, cooling coils, fans, filters, automatic controls, and any optional accessories, assembled into one casing.

pressure, standard barometric: barometric pressure of 101.325 kPa (14.696 psi, 29.92 in Hg).

refrigerant, volatile: a refrigerant that changes from the liquid to the vapor state in the process of absorbing heat.
split system: air-conditioner or heat pump consisting of equipment provided in more than one assembly or enclosure, usually with supply air distribution equipment housed separately from refrigerant condensing equipment.

4. CLASSIFICATIONS

Unitary equipment within the scope of this standard are classified as follows:

4.1 Component Arrangement:

(a) Units employing compressor(s), indoor air coil(s), and outdoor coil(s) in a single package assembly.
(b) Units employing compressor(s) and indoor coil(s) in one or more assemblies with remote outdoor coil(s).
(c) Units employing indoor coil assemblies, with outdoor coil(s) and compressor(s) in one or more assemblies.

4.2 Method of Outdoor Coil Heat Exchange:

(a) air,
(b) liquid, and
(c) evaporative cooled condensing.

5. INSTRUMENTS AND MEASUREMENT APPARATUS

5.1 General

5.1.1 Instruments and data acquisition systems shall be selected to meet the measurement system accuracy specified in this section.

5.1.2 Measurements from the instruments shall be traceable to primary or secondary standards calibrated by the National Institute of Standards and Technology (NIST) or to the Bureau International des Poids et Mesures (BIPM) if a National Metrology Institute (NMI) other than NIST is used. Instruments shall be recalibrated on regular intervals that do not exceed the intervals prescribed by the instrument manufacturer, and calibration records shall be maintained. Instruments shall be installed in accordance with the instrument manufacturer's requirements, or the manufacturer's accuracy does not apply.

5.1.3 Instruments shall be applied and used in accordance with the following standards unless otherwise specified in specific section requirements:

a. Temperature – ASHRAE Standard 41.1-2020.
b. Airflow– ASHRAE Standard 41.2-2018.
c. Pressure – ASHRAE Standard 41.3-2014.
d. Humidity – ASHRAE Standard 41.6-2014.
e. Liquid Flow – ASHRAE Standard 41.8-2016.
f. Refrigerant Flow – ASHRAE Standard 41.10-2020.
g. Power – ASHRAE Standard 41.11-2020.

5.1.3.1 Where there are differences between this document and these ANSI/ASHRAE 41 series standards, this document shall prevail.

5.1.4 Instrument accuracies shall be as indicated in Table 1

Table 1: Instrument Accuracy

Type of Measurement	**Purpose**	**Required Accuracy**
Temperature	Wet Bulb for Water Vapor Content	+/- 0.11-ºC (0.20-ºF)[2]
	Air Dry-bulb Steady	+/- 0.11-ºC (0.20-ºF)
	Air Dry-bulb Cyclic	+/- 0.1~~6~~7ºC (0.30-ºF)[1]
	Volatile Refrigerant	+/- 0.~~6~~56ºC (1.00-ºF)
	Water or nonvolatile refrigerant	+/- 0.11-ºC (0.20-ºF)
Dew Point Hygrometer	Water Vapor Content	+/- 0.22-ºC (0.40-ºF)[2]
Relative Humidity	Water Vapor Content	+/- 0.7~~1.2~~ % RH[2]
Pressure	Barometric Pressure	+/- 100 pa (0.030 inHg)
	Refrigerant and Liquid	±1.0 % of the reading, or 0.5 psig whichever is greater
	Nozzle pressure difference and nozzle exit velocity pressure	+/-1 % of reading
	Duct static pressure	±2.5 Pa (±0.010 in. of water)
Electric Power Input	System Components[3]	+/- 1 % of reading
	Standby power for measurements less than 50W	+/- 0.5 W
	Heaters and apparatus furnishing heat loads[4]	+/- 1 % of reading
Electric Energy Input (Wh) or Average Electric Power Input (W)	Total System Energy/Power Input	+/- 0.5 % of reading
Voltage	Equipment Input Voltage	+/- 1.0 % of reading
Flow	Volatile Refrigerant	+/- 1.0 % of reading
	Liquid	+/- 1.0 % of reading
Rotational Speed	Fan Speed	+/- 1.0 % of reading
Time	Any	+/- 2 seconds
Mass	Condensate	±1.0 % of the reading, or 22.68 g (0.05 lb) whichever is greater

[1]After calibration with steady-state dry-bulb temperature measurement as described in sections 5~~.1.4~~.4.1 and 5.5.2.
[2] Accuracy at 26.67/19.44°C (80/67-°F)
[3]For example, fan motors, compressor motors, or other equipment accessories.
[4]Including heaters for indirect airflow measurement per section 7.7.1.2.

5.2 Pressure measurements and differential pressure measurements shall be made with electronic pressure transducers.

5.3 Electrical Instruments

5.3.1 Electrical input voltage, frequency, power and energy shall be measured by digital power instruments. Voltages shall be measured at the equipment terminals. If there is not enough space for all of the voltage sense leads to be connected, -minimize the voltage drop between the equipment terminals and the voltage sensing location such that the voltage drop is no more than 1.0% of the nominal nameplate voltage.

5.3.2 If using an integrating Watt-Hour measurement instrument, energy measurements shall be recorded at intervals specified in section 8.7 for cooling tests and section 8.8 for heating tests.~~ No Steady State power criteria exists.~~

5.3.3 If using a non-integrating Watt measurement instrument, power measurements shall be recorded at intervals of 10 second or less. ~~If~~ In cases where the power measurement fluctuation total observed range exceeds 6% of the mean, regardless of cause, Integrating Watt-Hour measurements shall be used.~~using a non-integrating Watt measurement instrument, power measurements shall be recorded at intervals of 10 second or less.~~

> ***Informative Note:*** Digital compressors operating at part load may require the use of an integrating watt measurement instrument.

~~When using Digital Compressors significant power fluctuations often exist. In cases where power measurement fluctuations exceed 6% of the mean, Integrating Watt-Hour measurements shall be used.~~

5.4 Air Measurement

5.4.1 Air Measurement Instruments. The instrumentation used for making non-steady-~~-~~state test measurements shall be the same as steady-state testing or calibrated to match steady-state instrumentation prior to performing cyclic or defrost testing. For non-steady-state test measurements, the instruments used shall have the following performance, or better:
(a) Have a differential temperature accuracy of ±0.~~16~~17°C (±0.3°F) of indicated value after calibration with the primary steady-state temperature measurement device as indicated in Section 5.1.4 and 5.5.2.
(b) Have a total system response time of 2.5 seconds or less. The response time for this standard is defined as the time required for the instrumentation to obtain 63% of the final steady-state value when subjected to a step change in temperature of 8.3°C (15°F) or more in air. Evaluation of response time shall be based on measuring temperature in air having the same velocity as occurs at the location where the temperature is measured during air-conditioner or heat pump system testing.

5.4.2 Air measurement apparatus. An air sampling device shall collect a sample of air at the inlet and outlet locations on the indoor section of the unit under test for steady state tests. An air sampling device shall collect a sample of air at the outdoor inlet of the unit under test location for steady state tests of air-cooled and air-source equipment. An air sampling device shall collect a sample of air at outdoor outlet locations for steady state tests where the outdoor enthalpy method is the secondary method for steady state tests. Measure the dry-bulb and water vapor content of the sampled air.

5.4.2.1 Air Sampling Tree Requirements

5.4.2.1.1 The air sampling tree is intended to draw a sample of the air at the critical locations of a unit under test. An example configuration for the air sampling tree is shown in Figure 1. It shall be constructed of stainless steel, plastic or other durable materials. It shall have a main flow trunk tube with a series of branch tubes connected to the trunk tube. Holes shall be on the side of the sampler facing the upstream direction of the air source. Other sizes and rectangular shapes are allowed, and shall be scaled accordingly with the following requirements:

1. Minimum hole density of 6 holes per 0.093 m^2 (1 ft^2) of area to be sampled
2. Sampler branch tube pitch (spacing) of 15.24 ± 7.62 cm (6 ± 3in)
3. Manifold trunk to branch diameter ratio having a minimum of 3:1 ratio
4. Hole pitch (spacing) shall be equally distributed over the branch (1/2 pitch from the closed end to the nearest hole)
5. Maximum individual hole to branch diameter ratio of 1:2

Informative Note: 1:3 or less individual hole to branch diameter ratio preferred

5.4.2.1.2 The minimum average velocity through the air sampling tree holes shall be 0.762 m/s (2.50 ft/s) as determined by evaluating the sum of the open area of the holes as compared to the flow area in the aspirating psychrometer or conduit transferring the sample of air to the air dry-bulb and water vapor content measurement location.

Informative Note: It is preferred to have the sampler holes increase in size with distance from the trunk of the sampler tree.

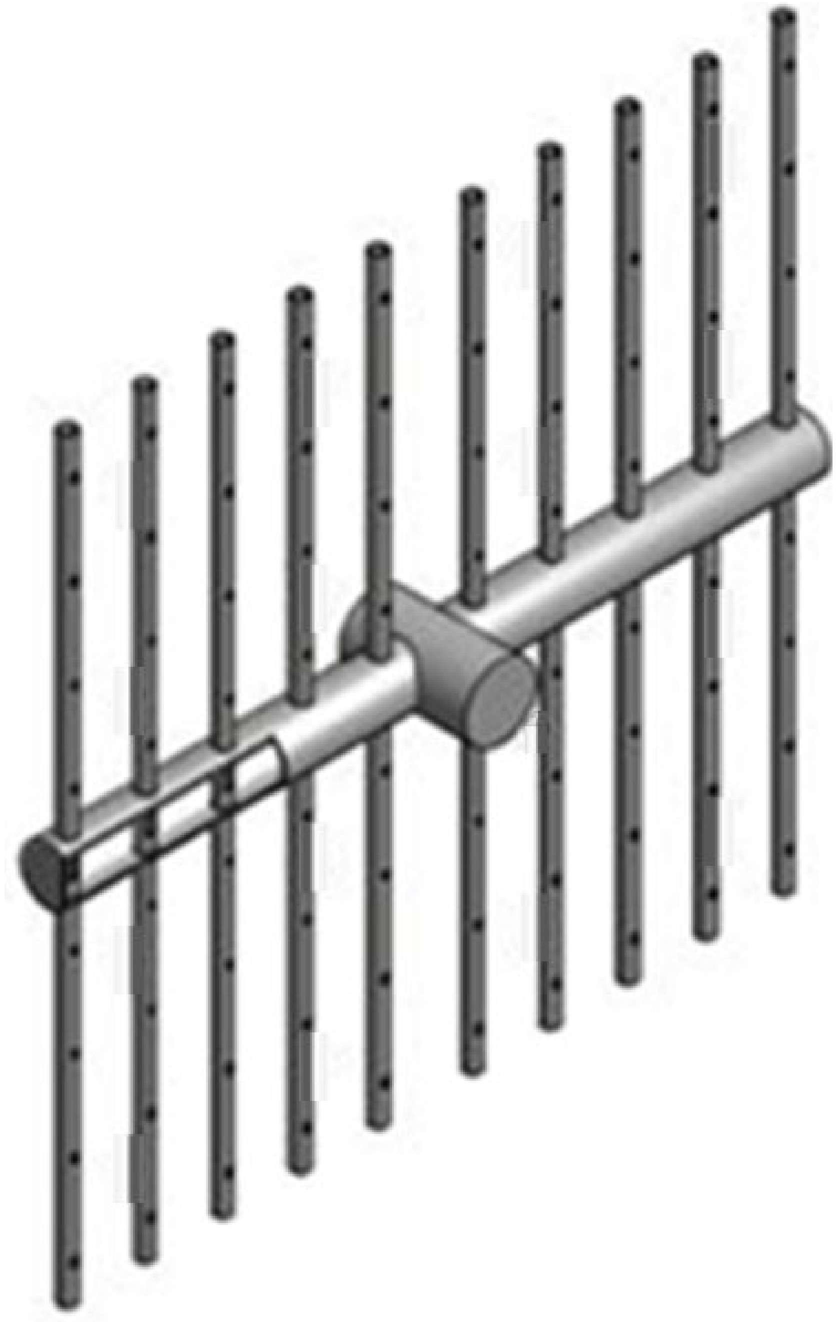


Figure 1 Example air sampling tree.

5.4.2.2 Aspirating Psychrometer Requirements

5.4.2.2.1 The aspirating psychrometer consists of a flow section and a fan to draw air through the flow section and measures an average value of the sampled air stream. At a minimum, the flow section shall have a means for measuring the air dry-bulb temperature as described in ASHRAE 41.1-2013 and a means for measuring the water vapor content as described in ASHRAE 41.6-

2014. The aspirating psychrometer shall include a means to adjust airflow to maintain required velocity across the sensors.

5.4.2.2.2 The aspirating psychrometer shall be made of plastic (such as polycarbonate), aluminum or other metallic materials. Outside diameters shall be between 5.08 cm (2 in) and 15.24 cm (6 in). Aspirating psychrometers shall be designed such that radiant heat from the motor does not affect sensor measurements. For aspirating psychrometers with wet-bulb sensors, velocity across the wet bulb sensor shall be 5.08 ± 1.02 m/s (1000 ± 200 ft/min). For all other aspirating psychrometers, velocity shall be as specified by the sensor manufacturer.

5.4.2.2.3 For the outlet aspirating psychrometer, the aspirator shall discharge sampled air back into the duct downstream of the sampler and, where the optional cyclic damper is installed, downstream of the damper.

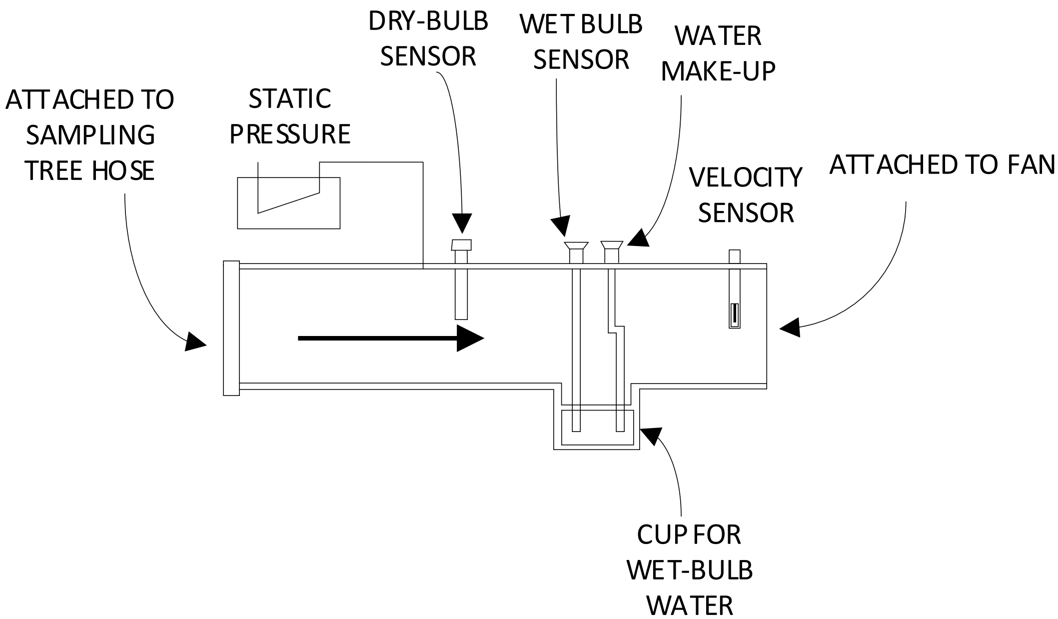


Figure 2 Aspirating Psychrometer

5.4.2.3 Chilled Mirror Dew-point Hygrometer Requirements

5.4.2.3.1 If used, apply chilled mirror dew-point hygrometers as specified in Section 7.1 of ASHRAE Standard 41.6–2014. For the outlet hygrometer, t~~T~~he sampled air shall be discharged into the duct downstream of the sampler and, where the optional cyclic damper is installed, downstream of the damper.

Informative Note: In addition, applying a chilled mirror with a sensor that measures the dew-point directly within the psychrometer will minimize the time lag observed by pulling the air sample separately out of the psychrometer into a remote sensor located elsewhere in the laboratory. Mounting the sensor in a horizontal orientation also allows for the accumulated condensate to drain from the sensor rather than building up on the mirror causing potential flooding.

5.4.2.3.2 If a chilled mirror dew-point hygrometer is used a sample shall be drawn through the device following the manufacturer instructions.

5.4.2.4 Air Property Measurement

5.4.2.4.1 Air properties shall be calculated using dry-bulb temperature and pressure at the air sampler location, and the humidity ratio calculated for the measurement location of the water vapor content.

5.4.2.4.2 When dry-bulb temperature at the measurement location of the water vapor content deviates from dry-bulb temperature at the air sampling location (for example, when a sampling tree is separated from the sensor by long lengths of interconnecting tubing) by more than 0.2~~7~~8 ºC (0.5-ºF), the dry-bulb temperature shall be measured at both locations.

5.4.2.4.3 The humidity ratio shall be calculated using the pressure measured at the water vapor content sensor location if the 124.42 pa (0.5 in. of water) threshold of section 5.4.2.5.2 is exceeded and using ~~the air~~the air dry-bulb temperature measured at the water vapor content sensor location if the 0.2~~7~~8-ºC (0.5-ºF) threshold of section 5.4.2.4.2 is exceeded.

5.4.2.5 Water vapor content measurement.

5.4.2.5.1 If using an aspirating psychrometer, it shall be applied as specified in Sections 7.2 and 7.3 of ANSIASHRAE 41.6–2014. The temperature sensor (wick removed) shall be accurate to within ±0.11°C (±0.2°F). If using a dew-point hygrometer, it shall be applied as specified in Section 7.1 of ANSI/ASHRAE 41.6–2014 (either of the two methods described in Section 7.3 of ANSI/ASHRAE 41.6-2014 shall be used for measurement of water vapor content of air that is below freezing temperature). The dew-point hygrometers shall be accurate to within ±0.22°C (0.4°F) when operated at conditions that result in the evaluation of dew-point temperatures above 1.67°C (35 °F). If using a relative humidity (RH) sensor, it shall be accurate to within ±1.2% RH (at the 26.67/19.44°C (80/67 °F) test condition).

Informative Note:
Other means to determine the psychrometric state of air may be used when measurement accuracy is equivalent to or better than the accuracy achieved from using a wet-bulb temperature sensor that meets the above specifications.

Informative Note:
An example configuration for the water vapor content measurement is shown in Figure 2. In most typical applications, there are typically two sets of measurements for temperature and water vapor content, one for the rough room control, and the other for the fine control

and actual measurement. Applications may also use an additional temperature measurement directly after the sampling tree.

5.4.2.5.2 Gauge pPressure or barometric pressure at the location of the water vapor content measurement (wet bulb measurement, dew-point hygrometer, or RH sensor) or barometric pressure shall be measured and used to calculate humidity ratio if deviations from the test chamber barometric pressure are moreless than 124.42 pa (0.5 in. of water), shall be measured and used to calculate humidity ratio.

5.5 Thermopile grid and Thermocouple grid

5.5.1 The sampling tree shall be equipped with a thermopile grid or grid of individual thermocouples to measure the average temperature average difference of inlet and outlet air temperatures or the average temperature of the airflow over the sampling tree.

5.5.2 For the optional cyclic and frost accumulation tests, the temperature difference between inlet air and outlet air shall be measured by a dry-bulb temperature sensor grid. ANSI/ASHRAE Standard 41.1-2013 Section 5.3.5 shall be referred to for the number of sensors and positioning in the flow area for any type of sensor used. The sensor grids shall be calibrated to match the primary steady state temperature measurement device prior to each respective test as described in Section 5.4.1The sensor grids shall be calibrated to match the primary steady state temperature measurement device prior to each respective test.

5.5.3 Refer to ANSI/ASHRAE Standard 41.1-2020 Section C2 for application of thermocouple circuits. Emphasis shall be placed on Section C2.10.1 requirements for equal resistance to minimize any bias in the grid measurement.

5.5.4 When required, a grid of individual thermocouples shall be used to provide confirm temperature uniformity and mixing. Temperature uniformity shall be validated per section 8.1.4. Mixing shall be validated at the outlet dry-bulb temperature sensor grid by measuring the difference between minimum and maximum of time-averaged temperature readings across all sensor positions. This difference shall not exceed 0.83°C (1.5°F). This applies to indoor air enthalpy and outdoor air enthalpy (when used) outlet measurements.

If that range is exceeded, mMixing devices will be requiredshall be installed at outlet grid locations to reduce the difference such that it meets the requirement if that range is exceeded. Consult ANSI/ASHRAE Standard 41.1-2013 for proper methods of achieving mixing.

Informative note: When required a 40% maximum open area perforated screen may be located in the outlet air portion of the apparatus upstream of the thermopile or thermocouple grid after the mixing device.

5.6 Nozzle Airflow Measuring Apparatus

Shall be in accordance with ASHRAE 41.2 – 2018 or as follows:

5.6.1 As shown in Figure 3, the nozzle airflow measuring apparatus consists of a receiving chamber and a discharge chamber separated by a partition containing one or more nozzles. Air from the equipment under test is conveyed through a duct to the receiving chamber, passes through the nozzle or nozzles, and is then exhausted to the test room or channeled to the reconditioning equipment.

5.6.2 The nozzle airflow measuring apparatus and its connections to the equipment outlet shall be sealed so that air leakage does not exceed 1.0% of the airflow rate being measured.

5.6.3 The center-to-center distance between nozzles in use shall be not less than three times the throat diameter of the largest nozzle, and the distance from the center of any nozzle to the nearest discharge or receiving chamber side wall shall be not less than 1.5 times its throat diameter.

5.6.4 Diffusers shall be installed in the receiving chamber located at least 1.5 times the largest nozzle throat diameter upstream of the partition wall. Diffusers in the discharge chamber shall be located at least 2.5 times the largest nozzle throat diameter downstream of the exit plane of the largest nozzle.

5.6.5 An exhaust fan, capable of providing the necessary static pressure at the equipment outlet, shall be installed at or downstream of the discharge chamber outlet~~in one wall of the discharge chamber~~, and a means shall be provided to vary the capacity of this fan.

5.6.6 The static pressure drop across the nozzle or nozzles shall be measured with ~~a manometer or~~ an electronic pressure transducer. One side of the pressure measuring device shall be connected to four manifolded pressure taps installed within the receiving chamber. The other side of the pressure measuring device shall be connected to four manifolded pressure taps installed within the discharge chamber. Alternatively, if ~~a manometer or an electronic pressure transducer~~the manifolded pressure tap method cannot be used, a pitot tube as shown in Figure 3 to measure the velocity head of the airstream leaving the nozzle or nozzles shall be used but when more than one nozzle is in use, the pitot tube reading shall be determined for each nozzle.

5.6.7 Requirements for how to fabricate and manifold the static pressure taps, if used in measuring air volume rate, are provided in section 6.4.1.

5.6.8 Means shall be provided to determine the air density and pressure at the nozzle inlet as determined per ANSI/ASHRAE 41.2-2018.

5.6.9 Nozzle geometry shall be determined per ANSI/ASHRAE 41.2-2018 Figure 9-3.

5.6.10 The throat air velocity of any nozzle in use shall be not less than 15.24 m/s (3000 fpm) or more than 35.56 m/s (7000 fpm).

5.6.11 ~~For airflow nozzles having a throat length to throat diameter ratio of 0.6 (see ANSI/ASHRAE 41.2-2018 Figure 9-3), t~~The nozzle default coefficient of discharge shall be calculated as follows:[6]

$$C = 0.9986 - \frac{7.006}{\sqrt{Re}} + \frac{134.6}{Re}$$

For Reynolds numbers (Re) of 12,000 and above, the Reynolds number is calculated as follows:

$$Re = \left(\frac{1}{1000}\right)\frac{DV}{\mu v_n'} = \left(\frac{1}{1000}\right)\frac{DV}{\mu v_n'}\left(C\sqrt{2P_v v_n'}\right)$$
$$= \left(\frac{\sqrt{2}}{1000}\right)\frac{D}{\mu}\left(C\sqrt{\frac{P_v(1+W_n)}{v_n}}\right)$$

where *V* is expressed in units of m/s and *D* in units of mm.

$$Re = \left(\frac{1}{60 * 12}\right)\frac{DV}{\mu v_n'} = \left(\frac{1}{720}\right)\frac{DV}{\mu v_n'}\left(775.9C\sqrt{2P_v v_n'}\right)$$
$$= \left(\frac{1097}{720}\right)\frac{D}{\mu}\left(C\sqrt{\frac{P_v(1+W_n)}{v_n}}\right)$$

Where V is expressed in Units of ft/min and D in units of inches

The dynamic viscosity (μ) of gaseous air behaving as an ideal gas at moderate pressures and temperatures is calculated using the following equation:

$$\mu = (17.23 + 0.048 t_a) \text{ x } 10^{-6}$$

where μ is expressed in kg/m·s and t_a in °C.

$$\mu = (11.00 + 0.018 t_a) \times 10^{-6}$$

Where μ is expressed in lbm/ft·s and t_a in ºF

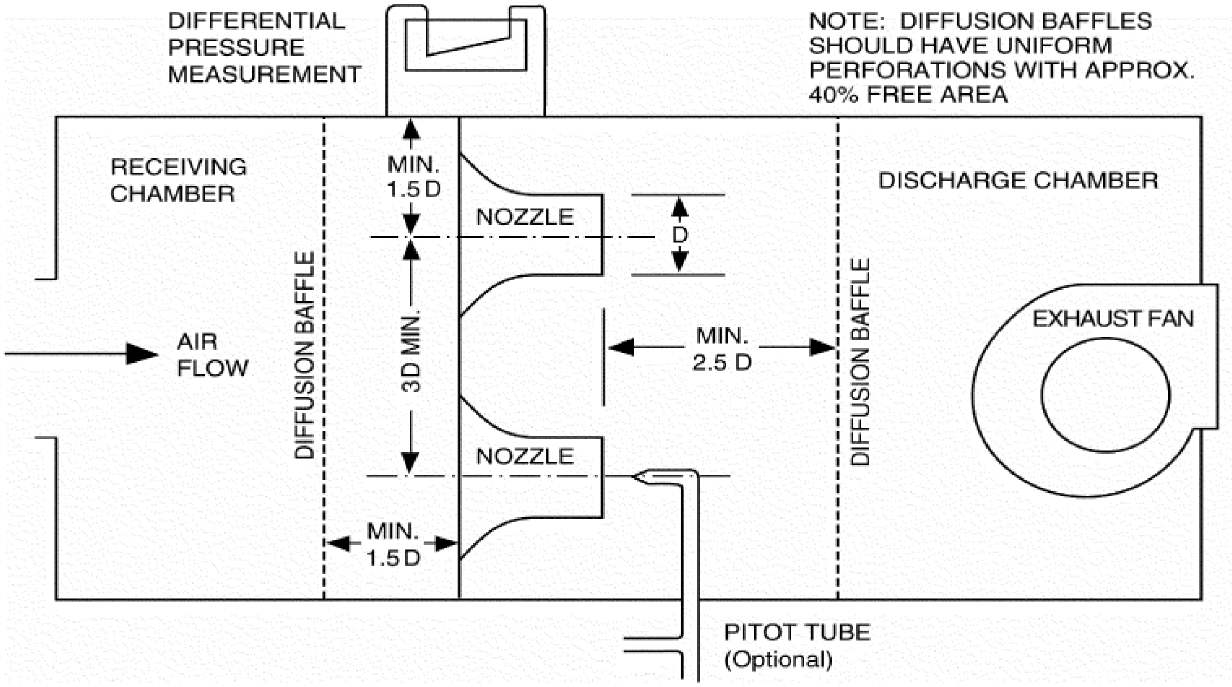


Figure 3 Nozzle airflow measuring apparatus.

6. Test Facility Arrangements

6.1 The test facility arrangements shown in Figures 4, 5, 6, 7, and 8 illustrate various possible configurations and shall not be construed as applying specifically or solely to the types of equipment shown.

6.1.1 The tunnel air-enthalpy arrangement is illustrated in Figure 4. The equipment to be tested shall be located in a test room or rooms. An air-measuring device shall be attached to the air outlet of the equipment (indoor or outdoor or both, as applicable). This device discharges directly into the test room or space, and shall be provided with a means for:

- Measuring the dry-bulb temperatures and water vapor content of the air entering and leaving the unit
- Measuring and Controlling airflow and differential pressure across the unit
- Controlling the air entering the unit at the specified dry-bulb temperature and water vapor content

6.1.2 The loop air-enthalpy arrangement is illustrated in Figure 5. This arrangement differs from the tunnel arrangement in that discharge of the air-measuring device shall be connected to the reconditioning equipment that shall be, in turn, connected to the equipment inlet. The resulting test "loop" shall be sealed so that air leakage at places that influence capacity measurements does not exceed 1.0% of the test flow rate. Dew-point shall be within 1.11°C (2°F) of the required inlet conditions.

Informative note: It is preferred that the Maintain the dry-bulb temperature in the test room is maintained within ±2.78°C (±5.0°F) of the required dry-bulb temperature test condition for the air entering the indoor unit. Dew-point shall be within 1.1°C (2°F) of the required inlet conditions.

6.1.3 Figure 6 illustrates the calorimeter air-enthalpy arrangement. An enclosure as shown in Figure 6 shall be used when the compressor is in the indoor section and separately ventilated. In this arrangement, an enclosure shall be placed over the equipment, or applicable part of the equipment under test. This enclosure shall be constructed from a non-hygroscopic material, be essentially airtight and shall be insulated. It shall be large enough to permit inlet air to circulate freely between the equipment and the enclosure and in no case shall the enclosure be closer than 15.24 cm (6 inches) to any part of the test unit. The inlet to the enclosure shall be remotely located from the test unit inlet so as to cause circulation throughout the entire enclosed space. An air-measuring device is connected to the test unit air outlet. This device shall be well insulated where it passes through the enclosed space. Dry-bulb temperatures and water vapor content of the air entering the equipment shall be measured at the enclosure inlet. Dry-bulb temperatures, water vapor content and differential pressure measurements shall be made using the methods described in Section 5.

6.1.4 The room air-enthalpy arrangement is shown in Figure 7. The equipment to be tested shall be located in the test rooms. An air-measuring device is attached to the equipment air outlet (evaporator or condenser, as applicable), then, in turn, connected to the reconditioning equipment. The discharge air from the reconditioning apparatus is returned to the test room(s). The dry bulb temperatures and water vapor content is measured where the air enters the equipment, and differential pressure between the discharge and inlet of the equipment is measured.
The discharge air from the reconditioning apparatus at the specified dry-bulb temperatures and water vapor content is provided to a location where air-sampling devices and pressure sensors measure dry-bulb temperatures, water vapor content and differential pressure as required.

6.1.5 A Multi-split Multiroom arrangement is illustrated in Figure 8. This arrangement utilizes more than one indoor conditioned spaces and one or more conditioned outdoor space(s). The tunnel air-enthalpy, loop air-enthalpy, calorimeter air-enthalpy and room air-enthalpy arrangements are permitted where applicable.

6.1.6 Figure 9 illustrates the specific order of the equipment as the air progresses through the enthalpy and pressure measurement apparatus. Alternate provisions for moving and conditioning the air leaving the airflow measuring device and supplying air at the proper conditions to the equipment inlet may be used other than those shown in Figures 4, 5, 6, 7, and 8, provided the test facility arrangements comply with the prescribed methods of measuring airflow rate, dry-bulb temperatures, water vapor content, and differential pressures-.If a means of handling the air leaving the airflow measuring device and supplying air at the proper conditions to the equipment

~~inlet as shown in Figures 5, 6, 7, 8, and 9 is unable to be used, an alternate means shall be employed provided this approach does not interfere with the prescribed method of measuring airflow rate, dry-bulb temperatures, water vapor content and differential pressures.~~

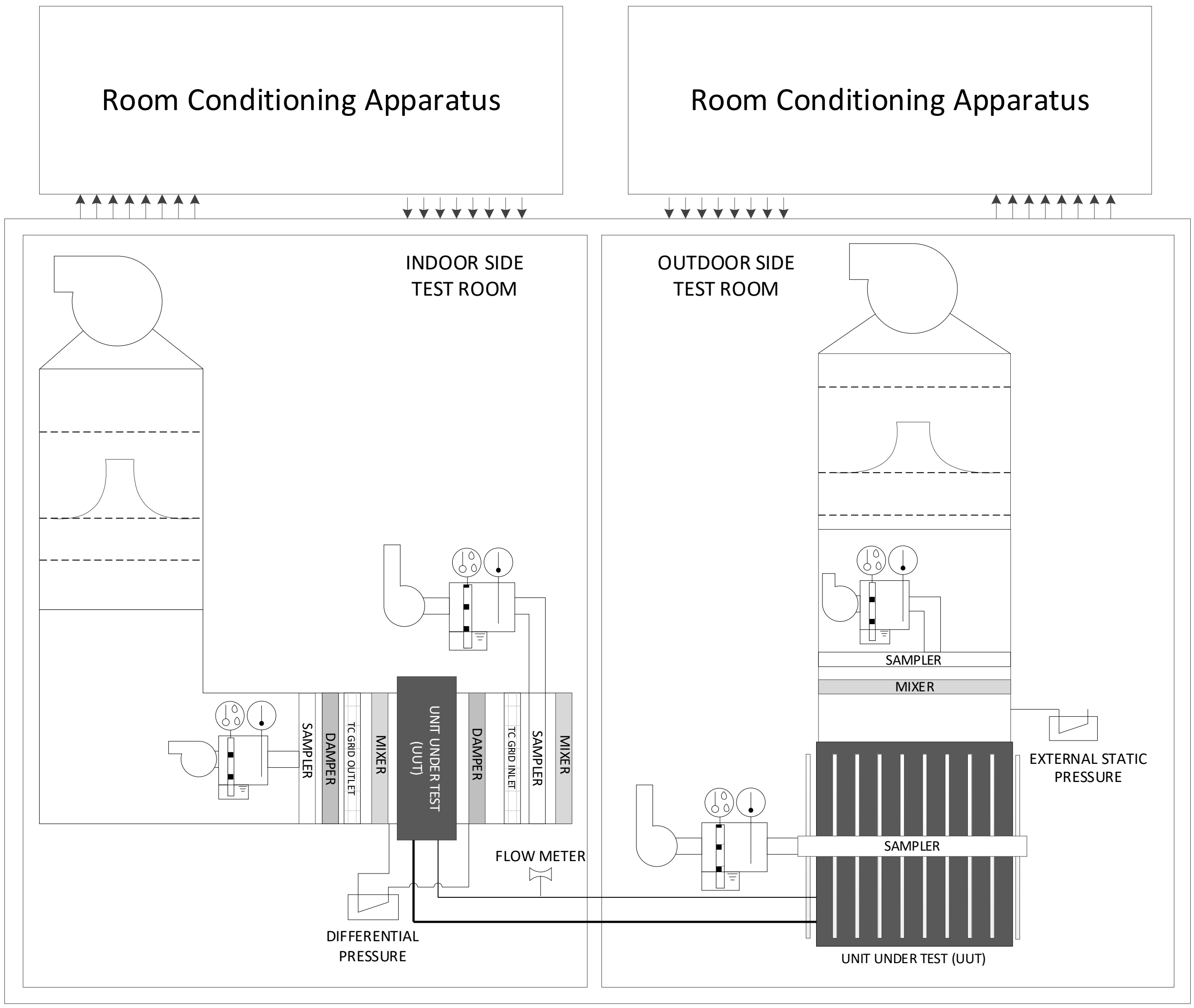
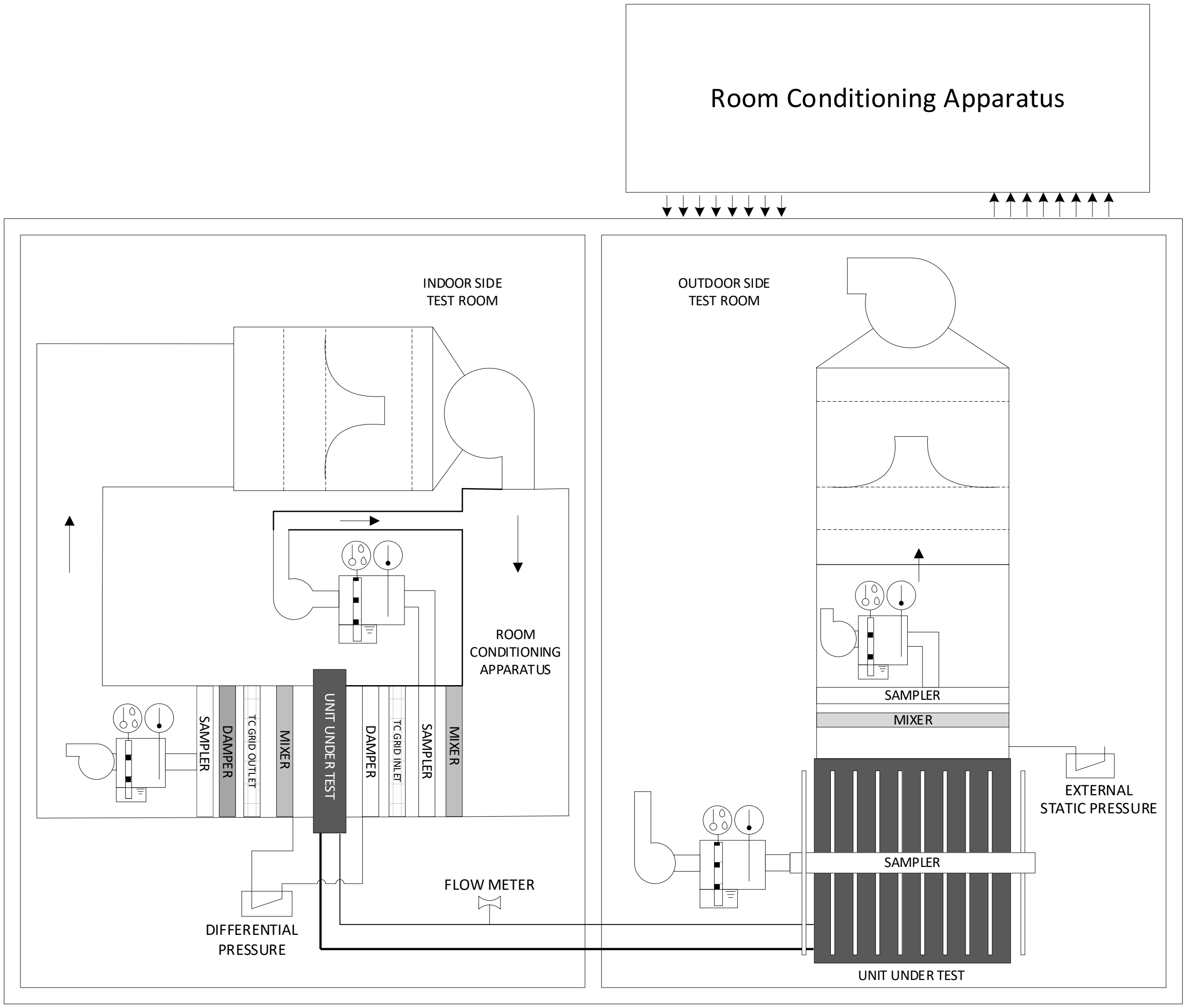
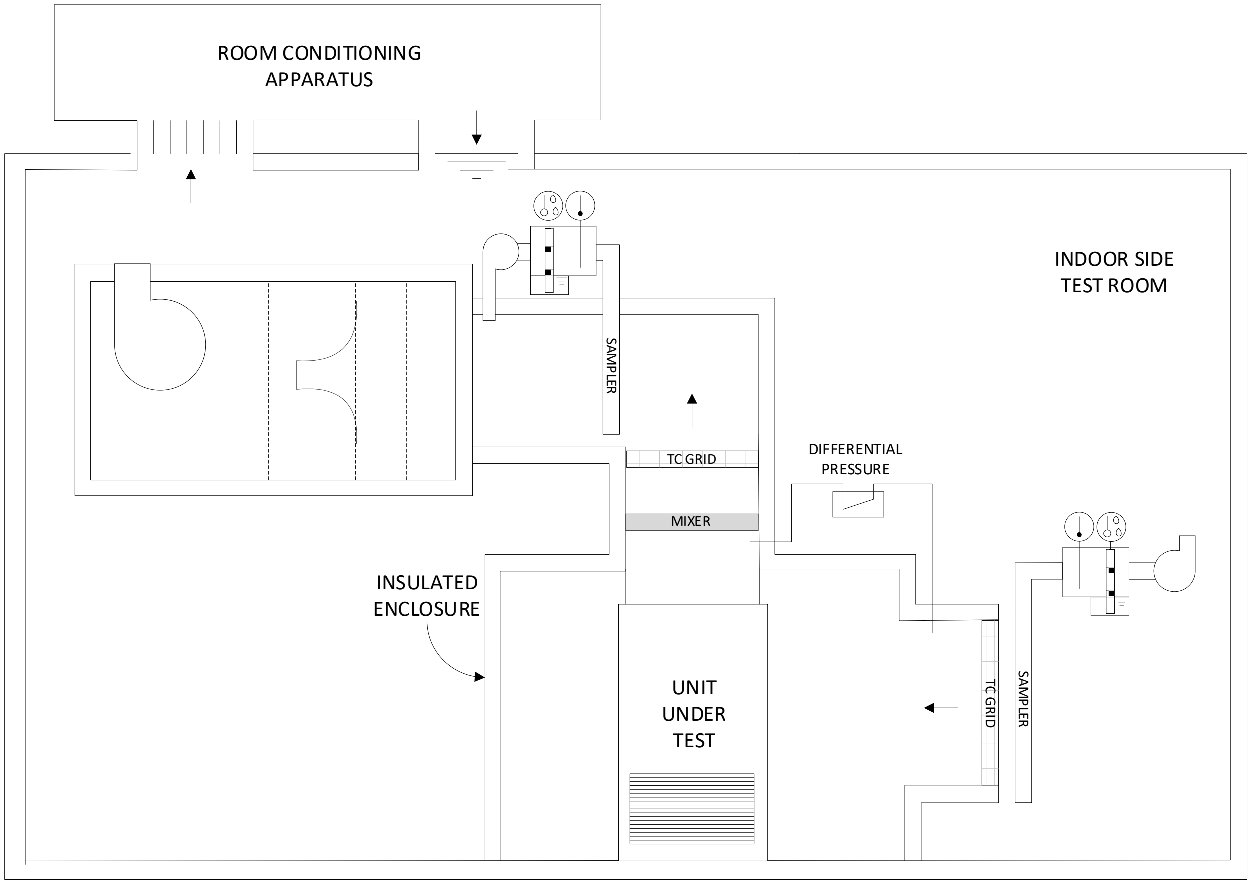


Figure 4 Tunnel air-enthalpy arrangement.



<u>Figure 5</u> Loop air-enthalpy arrangement.



<u>Figure 6</u> Calorimeter air-enthalpy arrangement.

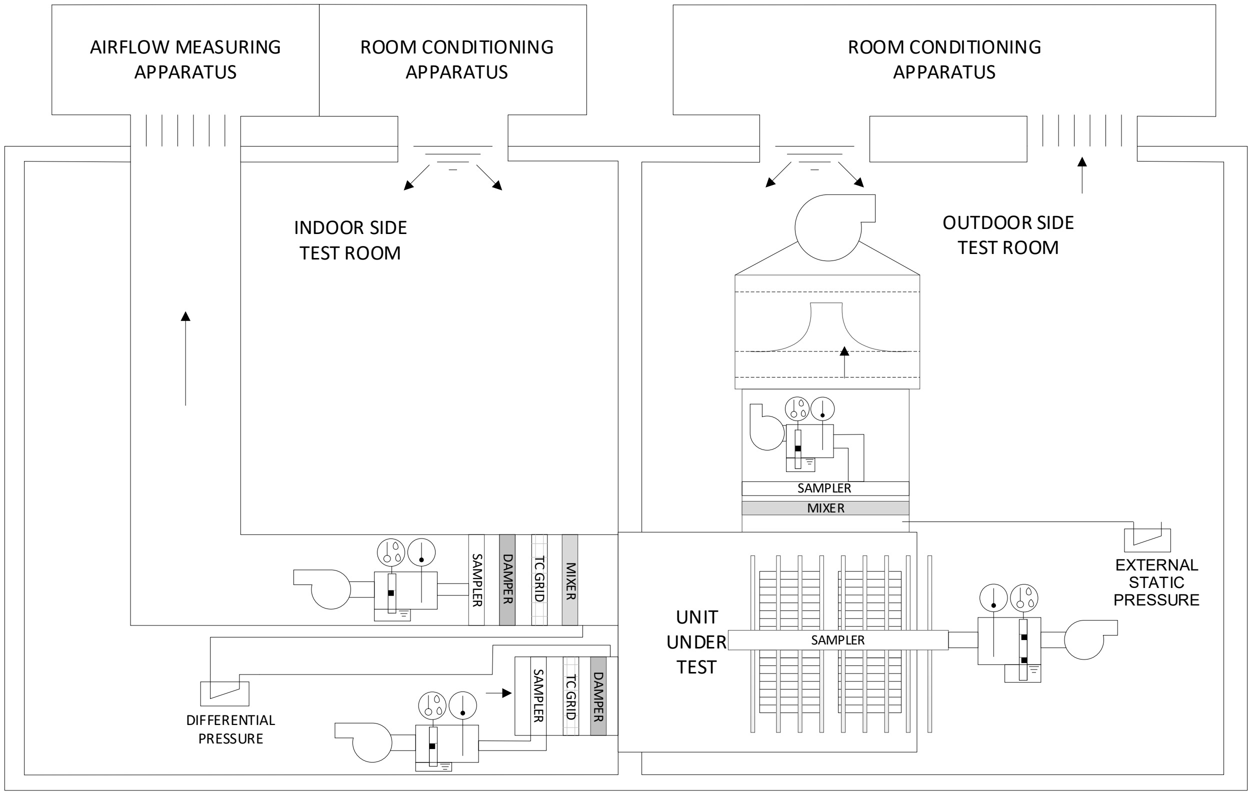


Figure 7 Room air-enthalpy arrangement.

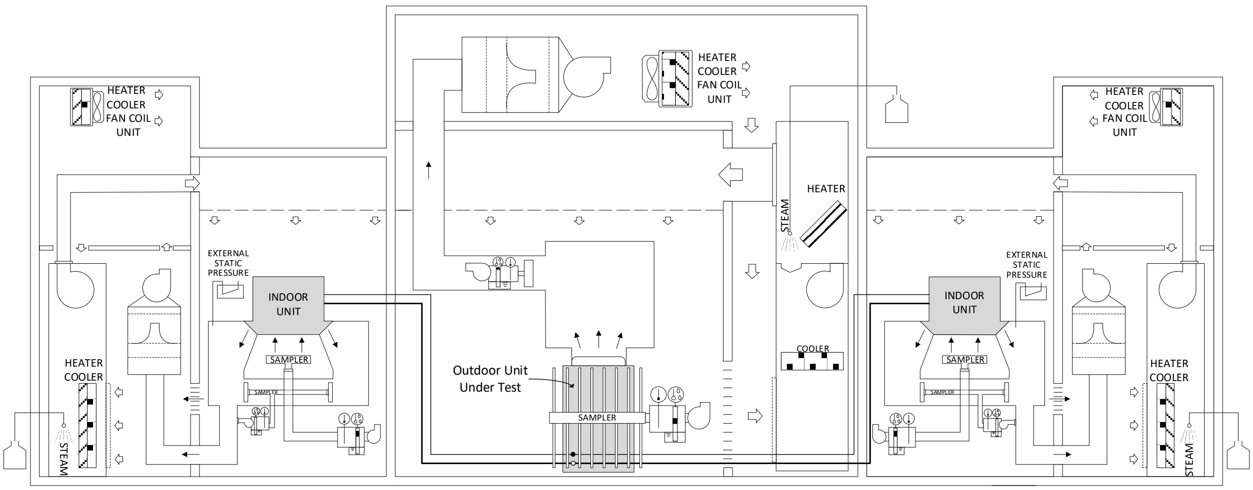


Figure 8 Multi-split Multiroom arrangement

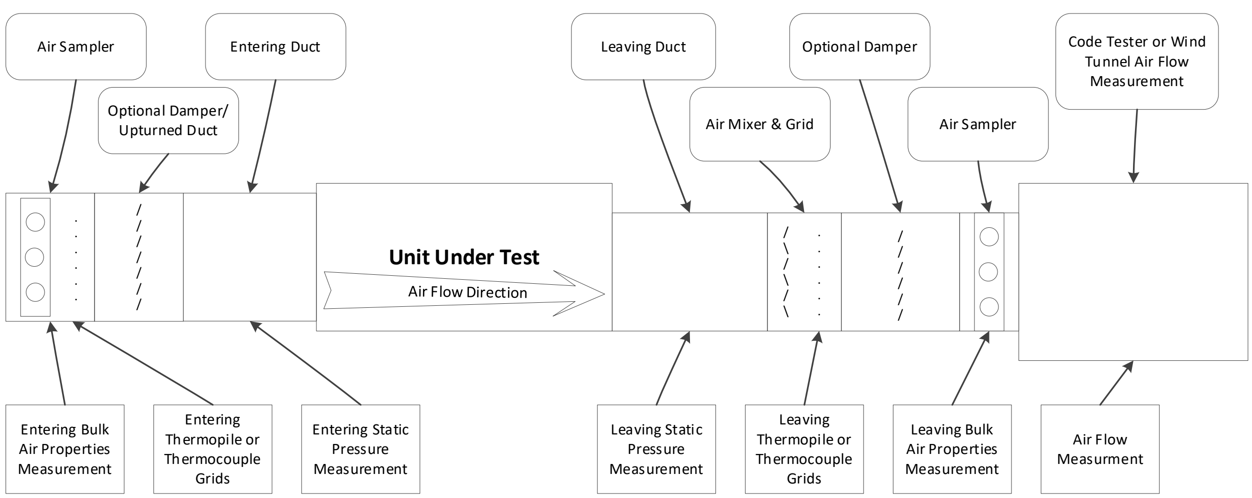


Figure 9 Simplified diagram of enthalpy and pressure measurement apparatus.

Table 2: Enthalpy and Pressure measurement Apparatus Figure 9 Reference Sections

Air Sampler	5.4.2 & 6.2.2
Optional Damper/Upturned Duct	6.3
Entering Duct	6.4
Leaving Duct	6.4
Air Mixer and Grid	5.5 & 6.2.2
Optional Damper	6.3
Air Sampler	6.2.2
Code Tester or Wind Tunnel Air Flow Measurement	5.6

6.2 Enthalpy Measurement Apparatus. Configurations for the test apparatus are provided below. In all cases, a means for determining the dry-bulb temperature and water vapor content of the air entering and leaving the unit and for measuring the airflow and differential pressure shall be provided.

6.2.1 Indoor Apparatus Overall Construction and Implementation

6.2.1.1 The test apparatus is a physical arrangement of dampers, mixers, thermopile or thermocouple grids, and ducts (see Figure 9 for a simplified layout of components). ~~Dampers, bends, and transitions shall be located outside pressure-measuring locations, as shown in Figures 16,17, and 18 in both the inlet and outlet air ducts.~~ Dampers, bends, transitions, air condition measurement apparatus, and mixers shall be upstream of inlet pressure measuring locations and downstream of discharge pressure measuring locations, as shown in Figures 15, 16, and 17.

6.2.1.2 The entire test apparatus shall not have a leakage rate that exceeds 1.3 L/s/kW (10 cfm/ton) (for the smallest capacity unit that will be tested in the facility) or 9.4 L/s (20 cfm), whichever is higher, when a negative pressure of 0.248 kPa (1.0 in. of water) is maintained at the apparatus exit location.

6.2.1.3 The test apparatus including the interconnecting ductwork shall be insulated to have a minimum R-value of 3.35 m^2·K/W (19 ft^2·°F·hr/Btu). For coil-only indoor units sold as uncased coils~~units not employing an enclosure~~, the coil shall be tested with a sealed ~~n~~ enclosure constructed of 2.54 cm (1 inch) fiberglass duct board. For units sold with enclosures or cabinets, no extra insulating or sealing of the enclosure or cabinet of the unit under test shall be employed. Duct losses shall be calculated using conduction factors, temperature difference between the inside and outside of the duct, and the total duct surface area between the unit and the temperature measurement location (see section 7.3.3.3). Ducts that are exposed to multiple ambient temperatures shall be divided into zones and each zone calculated separately.

6.2.2 General Air Sampling Requirements

6.2.2.1 The nominal face area of the airflow shall be divided into a number of equal area sampling sections with aspect ratios no greater than 2 to 1. Each section shall have one air sampling tree, except as described in 6.2.2.3.4.

6.2.2.2 The air sampler trees shall be located at the geometric center of each section being sampled; orient the branches either horizontally or vertically A maximum of four -air sampling trees shall be connected to each air property measurement device.

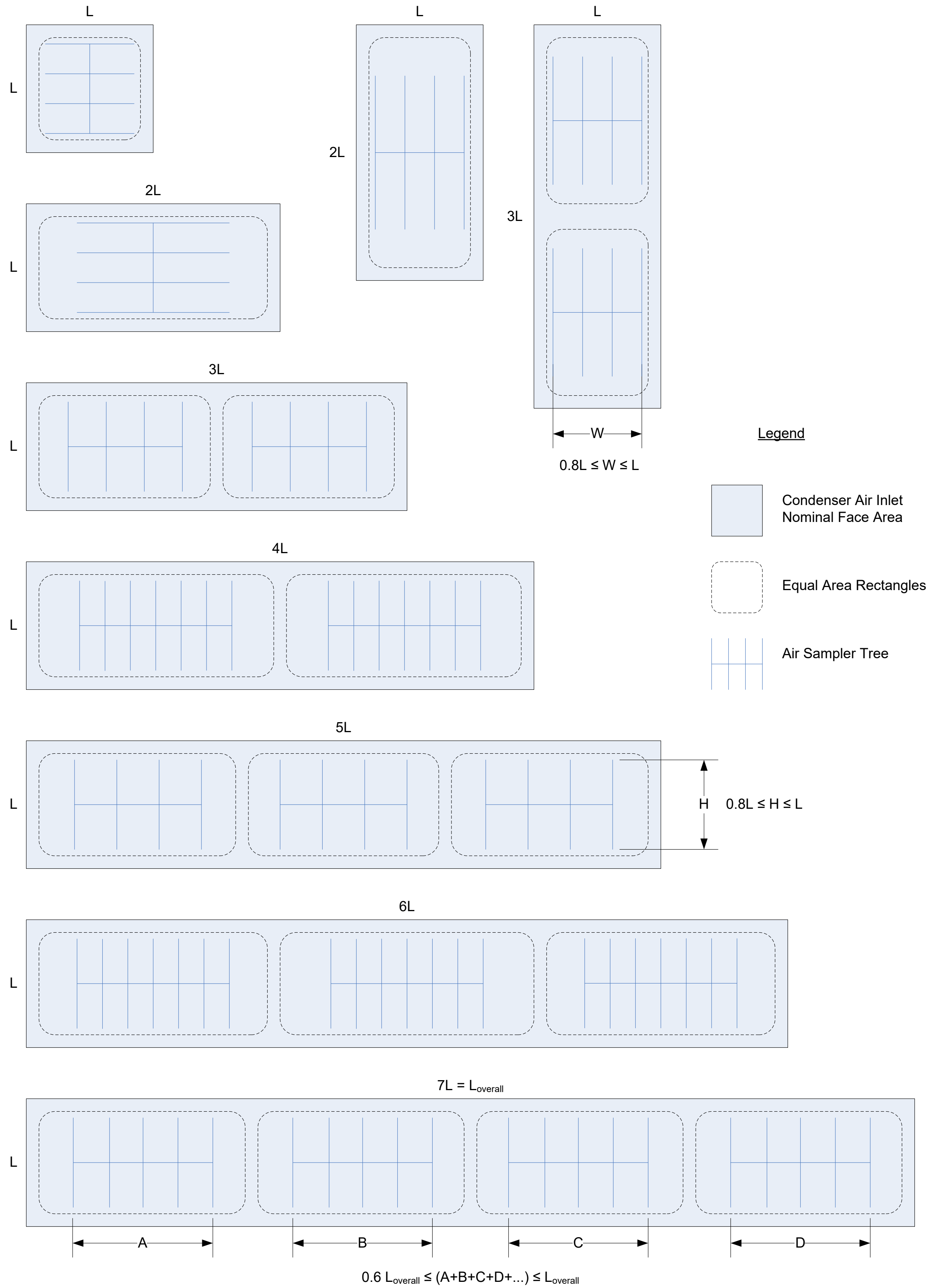

L
L
2L
L
3L
L
4L
L
5L
L
6L
L
7L = L_overall
L
A
B
C
D
0.6 L_overall ≤ (A+B+C+D+...) ≤ L_overall
L
2L
L
3L
W
0.8L ≤ W ≤ L
H
0.8L ≤ H ≤ L
Legend
Condenser Air Inlet Nominal Face Area
Equal Area Rectangles
Air Sampler Tree

Figure 10 Determination of Measurement Rectangles and Required Number of air sampling trees

6.2.2.3 Outdoor Inlet Air Sampling Requirements

6.2.2.3.1 The conduit connecting the air sampler tree to the air dry-bulb and water vapor content measurement location shall be insulated to an R-value of 0.7 $m^2 \cdot K/W$ (4 $ft^2 \cdot °F \cdot hr/Btu$) and shall not come within 5.08 cm (2 in) of the chamber floor.

6.2.2.3.2 For the outdoor air inlet location, multiple temperature measurements shall be used to determine the air temperature distribution and the mean air temperature as shown in Figures 10, 11, 12, and 13.

6.2.2.3.3 ~~The~~ Each outdoor air inlet air sampling tree shall be equipped with a thermopile grid or individual thermocouples to measure the average temperature of the airflow over the air sampling tree. The air sampling trees shall be placed within 15–30 cm (6-12 in) of the unit to minimize the risk of damage to the unit while ensuring that the air sampling tubes are measuring the air going into the unit rather than the room air around the unit. Any sampler holes directly exposed to condenser discharge air shall be blocked to prevent sampling of non-conditioned air.

6.2.2.3.4 The Air Sampling Trees in the outdoor air inlet location shall be sized to cover at least 80% of the height and 60% of the width of the air entrance to the unit (for long horizontal coils~~),~~ ~~or~~) or shall cover at least 80% of the width and 60% of the height of the air entrance (for tall vertical coils). If the air sampler tree is larger than the face area of the side being measured, then the holes outside the air entrance to the unit shall be blocked. Except where described below, each outdoor coil side shall have at least one air sampling tree.

The air property measurement device(s) shall meet the velocity, temperature and pressure measurement requirements specified in Section 5.4.2. Install a thermopile or thermocouple grid on each rectangular area without an air sampling tree.

Informative Note: For units with a nominal air inlet face area less than or equal to 6 m^2 (64.6 ft^2) and with four or fewer air sampling tree(s), a minimum of one air property measurement device is recommended. For units with a nominal air inlet face area greater than 6 m^2 (64.6 ft^2) or more than four air sampling tree(s), a minimum of two air property measurement devices are recommended. If the number of equal area sampling rectangles require more than eight air sampling trees, additional air property measurements devices are recommended. Alternatively, eight air sampling trees are recommended on the largest rectangular areas, provided air sampling tree(s) are used on each side of test unit that has air inlets, and the air property measurement devices are connected to air sampling tree(s) on opposing sides.

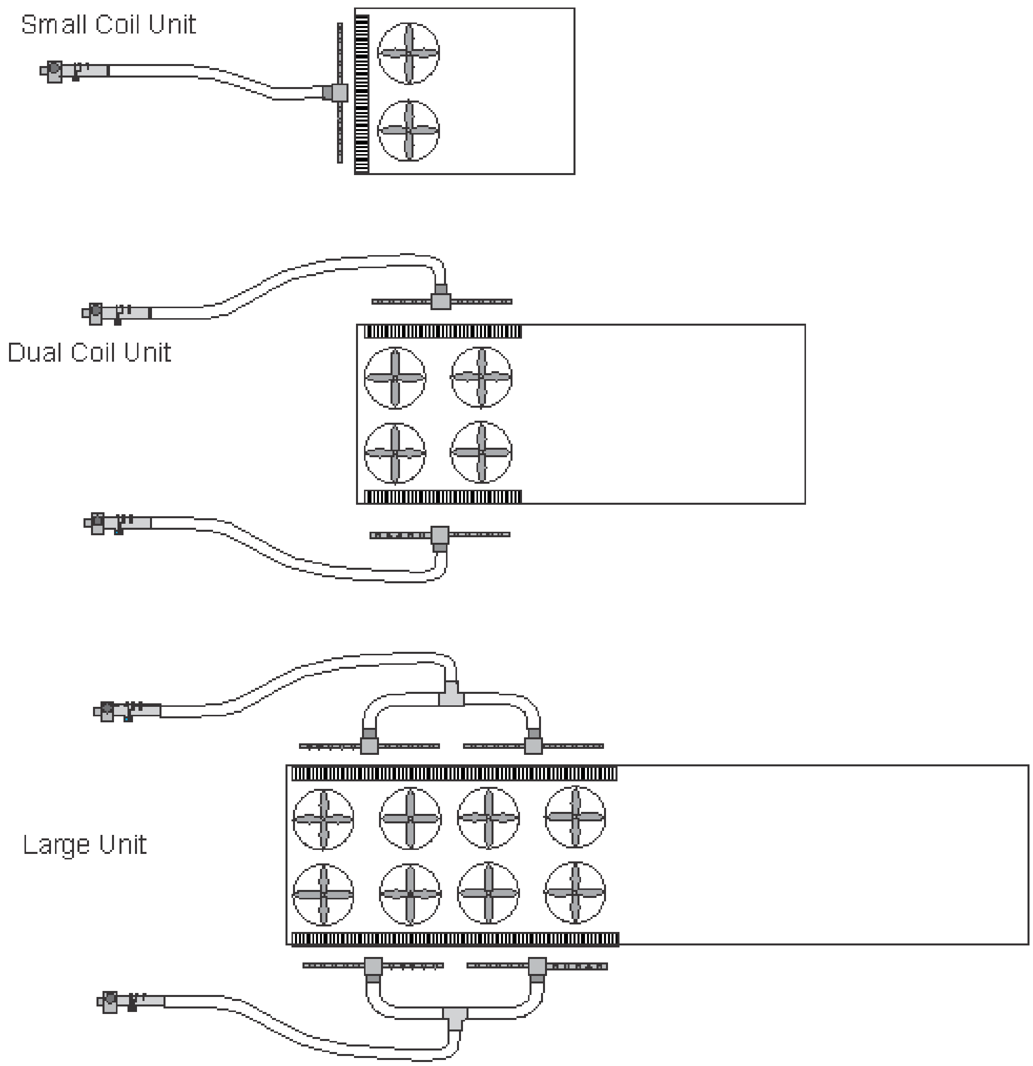


Figure 11 Example Test Setup Configurations

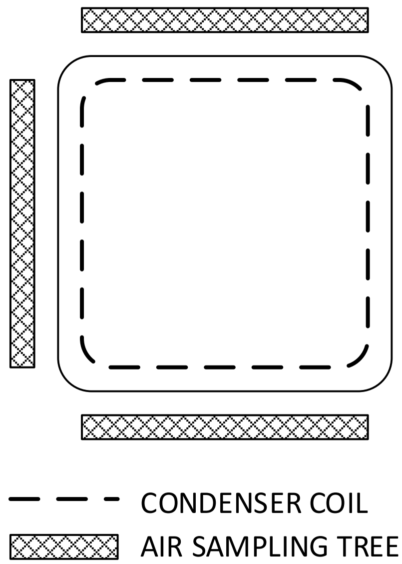


Figure 12. Single Module Air Sampling Tree Placement Example

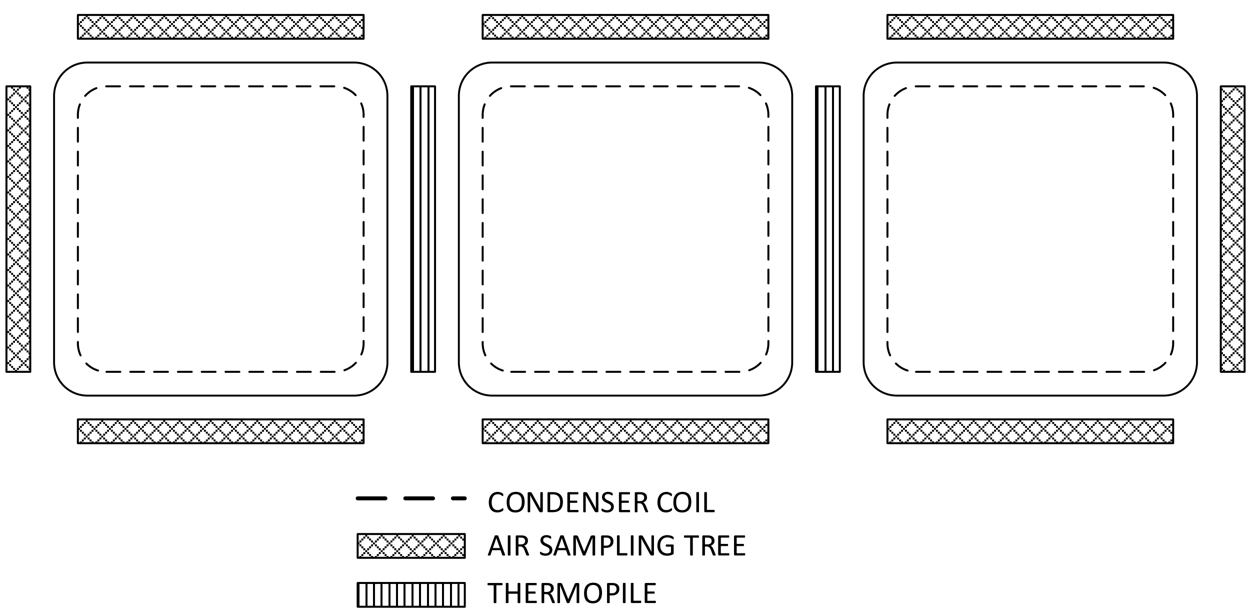


Figure 13. Multiple Module Air Sampling Tree Placement Example

6.2.2.4 Indoor inlet air sampling requirements

Follow the requirements for outdoor inlet air sampling requirements as described in Section 6.2.2.3, except for the following:

If air is sampled within a duct, the air sampling tree shall be installed with the rectangle defined by the air sampler inlet holes oriented parallel with and centered in the duct cross section—this rectangle shall have dimensions that are at least 75 % of the duct's respective dimensions.

In the case of non-ducted units having multiple indoor coils where an inlet plenum is not connected to the air inlet during testing (for example, a unit other than ceiling cassette), locate an air sampling tree with thermocouple grid or thermopile for duplicate measurement of dry bulb temperature (as required in Section 6.2.2.3.3) locate an air sampling tree with dry-bulb temperature measurement 15-30 cm (6-12 in) upstream from the inlet of each indoor coil that is being sampled.

6.2.2.4.1 In the case of non-ducted units having multiple indoor coils where an inlet plenum is connected to the air inlet during testing, additionally locate a thermocouple grid 15-30 cm (6-12 in) upstream from the inlet of each indoor coil.

6.2.2.4.2 When inlet dampers are utilized, the inlet grid shall be positioned upstream of an inlet damper.

6.2.2.4.3 When using an insulated upturned inlet duct, the inlet grid shall be located at the entrance of the inlet duct.

6.2.2.4.4 When cyclic testing will not be performed, the inlet grid shall be located upstream of the required inlet duct.

6.2.2.4.5 Inlet air property measurements shall be taken upstream of static pressure taps on the inlet duct (if installed). Outlet air temperature measurements shall be taken downstream of the static pressure taps on the outlet. Examples of Llocations of thermocouple grids and air samplers for measuring temperatures are shown in Figures 4, 5, 6, 7, 8 and 9.

6.2.2.5. Outlet air sampling requirements

Follow the requirements for outdoor inlet air sampling requirements as described in Section 6.2.2.3, except for the following.

6.2.2.5.1 The outlet thermopile or thermocouple grid shall be positioned upstream of the outlet air sampling device and downstream of the ASHRAE required outlet plenum described in Section 6.4.2.2 duct. If a mixer is used, the thermopile or thermocouple grid shall be downstream of the mixer.

In the case of multiple indoor coils discharging into a common plenum, additionally locate a thermocouple grid 15-30 cm (6-12 in) upstream of the location where the individual duct for each indoor coil joins the plenumupstream from the outlet of each indoor coil.

6.3 Cyclic Damper (Optional)

6.3.1 Use an inlet and outlet air Damper Box or Airflow Prevention Device when testing Ducted Systems if conducting Cyclic Tests. Otherwise, install an outlet air Damper Box or Airflow Prevention Device when testing heat pumps, both ducted and non-ducted, that cycle off the indoor fan during Defrost Cycles if no other means exists for preventing natural or forced convection through the Indoor Unit when the indoor fan is off. The dampers shall be insulated per Section 6.2.1.3.

6.3.2 Install the Damper Box immediately upstream of the required inlet plenum. The cross-sectional dimensions of the Damper Box shall be equal to or greater than the dimensions of the indoor unit inlet. If needed, use an adaptor plate ~~or~~ with a short transition duct section to connect the Damper Box with the unit's inlet plenum. ~~If an inlet plenum is not used, add static pressure taps at the center of each face of a rectangular Airflow Prevention Device.~~ Insulate the ductwork and inlet plenum with thermal insulation that has a nominal overall resistance (R-value) of at least $3.35 m^2 \cdot K/W$ ($19\ h \cdot ft^2 \cdot °F/Btu$).

6.3.3 The dampers shall be capable of being completely opened or completely closed within a period not to exceed 10 seconds for each action. Dampers shall achieve a positive seal within 10 seconds. Airflow through the equipment being tested shall stop within 10 seconds after the airflow measuring device fan is de-energized. The differential pressure (ΔP) at the nozzle shall be within 2% of steady state ΔP within 15 seconds from the time the air-measuring device fan is re-energized.

6.3.4 If using an outlet air Damper Box, install it within the interconnecting duct at a location upstream of the location where air from the sampling device is reintroduced or upstream of the in-duct sensor that measures water vapor content of the outlet air. The leakage rate from the combination of the outlet plenum, the closed damper, and the duct section that connects these two components shall not exceed 1% of the lowest measured airflow or 566 l/min (20 cfm) whichever is greater when a negative pressure of 0.248 kPa (1.0 in. of water) is maintained at the outlet of the outlet air damper.

6.3.5 As an alternate to an actuated inlet damper, a cold trap, consisting of an upturned duct, is shown in Figure 19. An inlet upturned duct is a length of ductwork installed upstream of the indoor unit under test to prevent natural convection transfer out of the duct during the compressor OFF period. If an inlet upturned duct is used, install minimum 4 temperature sensors at the inlet opening of the indoor upturned duct evenly spaced across the inlet area. The average temperature at this location, measured during the compressor OFF period of the cyclic test, shall not drop more than 0.56°C (1°F) below the ON period average temperature at this location.

Informative note: Volume and inlet height of upturned duct may need to be increased if the temperature drop exceeds the requirement. Care must be taken to ensure the inlet air sampling system is not pulling air from the upturned inlet duct.

~~**6.3.6** It is allowable to alter the arrangement and size(s) of the components to meet the physical requirements of the unit to be tested.~~

6.4 External Static Pressure Measurement Apparatus Several configurations for the test apparatus are provided below. In all cases, a means for determining the airflow and differential pressure shall be provided.

6.4.1 Apparatus Overall Construction and Implementation

6.4.1.1 A tap shall be centered on the dimensions perpendicular to airflow~~A tap shall be located at the center of each face of each plenum, if rectangular, or~~ at four evenly distributed locations ~~along the perimeter of an oval or round plenum with a 10% tolerance on the location measurement~~as described in Section 6.4.2.1.1 or Section 6.4.2.2.1.

6.4.1.2 Pressure taps ~~consist of 6.25 mm (0.25 in.) diameter nipples soldered to the outer plenum surfaces and centered over 1 mm (0.040 in.) diameter holes through the plenum. The edges of these holes shall be free of burrs and other surface irregularities~~shall be constructed in accordance with ANSI/ASHRAE Standard 41.2-2018 Figure 8-1.

6.4.1.3 Static pressure taps shall be manifolded using one of the connection options shown in Figure 14.

6.4.1.4 Connect one side of the differential pressure instrument to the manifolded pressure taps installed in the outlet plenum. Connect the other side of the instrument to the manifolded pressure taps located in the inlet plenum. For ~~non-ducted systems~~systems that are tested with multiple outlet plenums, measure the static pressure within each outlet plenum relative to the ~~surrounding atmosphere.~~unit inlet.

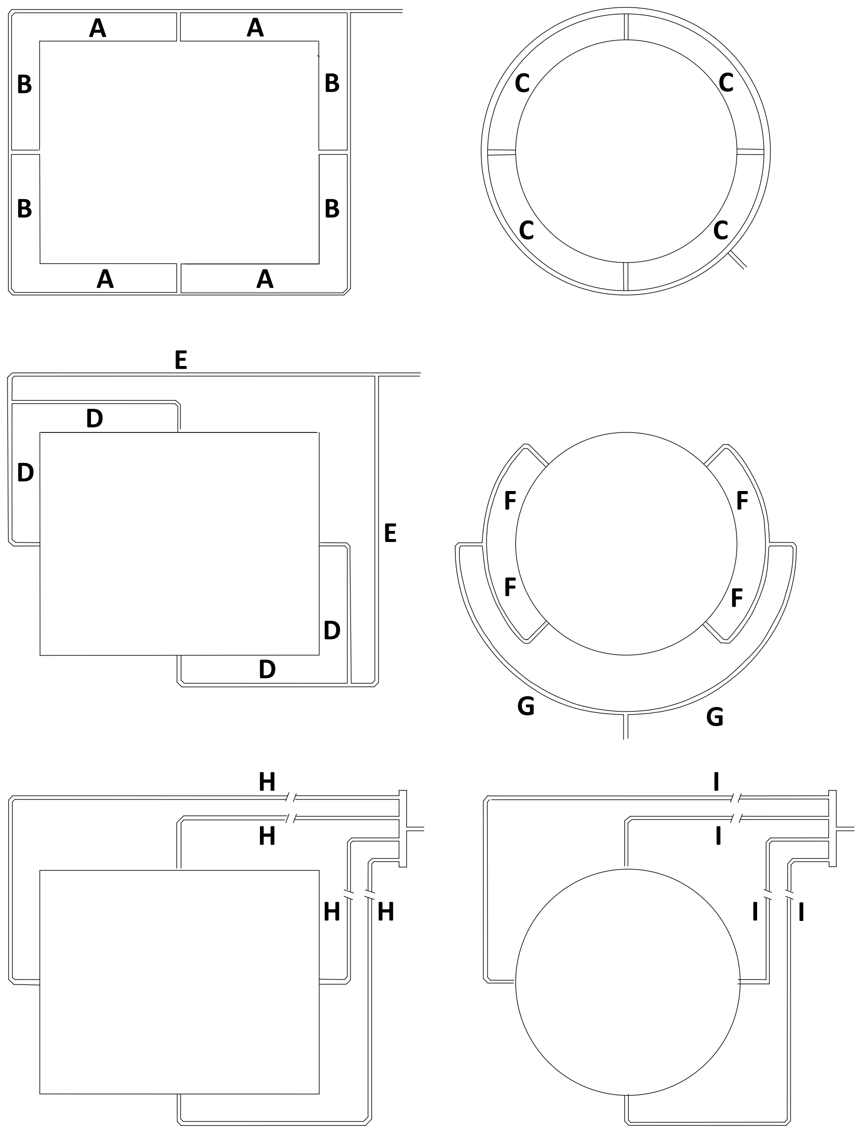


Figure 14 Connection options for static pressure taps.

6.4.2 Units with a Fan Downstream of the Indoor Coil and a Single Outlet

6.4.2.1 Inlet Plenum

If the test room has sufficient space, use an inlet duct as described in Section 6.4.2.1.1. Otherwise, use an inlet duct as described in Section 6.4.2.1.2.

6.4.2.1.1 ~~If space within the test room permits, a full inlet duct connection shall be installed. If used, t~~The inlet duct shall have cross-sectional dimensions equal to those of the equipment. It shall ~~and if space allows, be fabricated with~~ have a ~~length~~ minimum length of 1.5 equivalent diameters, $1.5 \cdot \sqrt{\frac{\pi D_i^2}{4}}$ for circular ducts, where D_i is the duct inner diameter, or $1.5 \cdot \sqrt{C \cdot D}$ for rectangular ducts, where C and D are the interior cross-sectional dimensions of the duct. The static pressure measurement plane is located 0.5 equivalent diameters, $0.5 \cdot \sqrt{\frac{\pi D_i^2}{4}}$ for circular ducts or $0.5 \cdot \sqrt{C \cdot D}$ for rectangular ducts upstream of the unit inlet connection with a tolerance of ± 10% of this half equivalent diameter. The length of the inlet duct, $1.5 \cdot \sqrt{C \cdot D}$, is a minimum dimension.

Examples of this configuration are shown by the setups given in Figures 16 and 17., C and D only refer to duct dimensions in these figures.

6.4.2.1.2 If space within the test room does not permit the full inlet plenum connection, an abbreviated inlet plenum shall be installed. The inlet plenum shall have cross-sectional dimensions equal to those of the equipment and a minimum length of 15.2 cm (6.0 inches). Four static pressure taps shall be in the center of each face, -with a tolerance for location parallel to air flow of ± 10% of duct length and tolerance for location perpendicular to air flow of ± 10% of corresponding duct face width perpendicular to air flow. This inlet duct shall be connected directly to the inlet of the unit.

6.4.2.2 Outlet Plenum

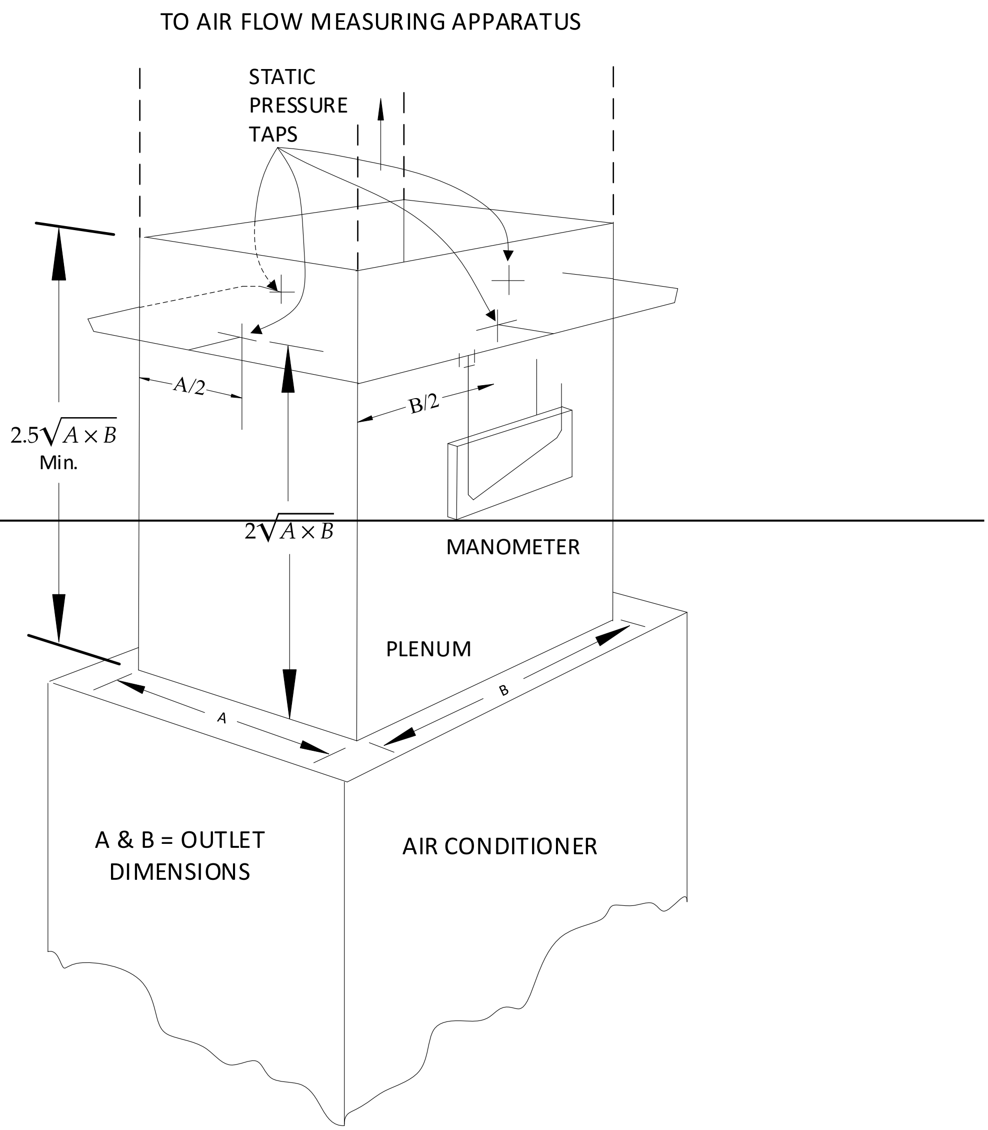
If the test room has sufficient space, use an outlet duct as described in Section 6.4.2.2.1. Otherwise, use an outlet duct as described in Section 6.4.2.2.2.

6.4.2.2.1 If space within the test room permits, a full outlet plenum shall be attached to the outlet of the discharge side of the equipment. The outlet is plenum shall have cross-sectional dimensions equal to the dimensions of the equipment outlet. It shall and if space allows, be fabricated as shown by the setups given in Figures 15, 16 and 17 and discharge into the mixer (if used) prior to the air sampling section upstream of the airflow measurement device (see Figure 9 for reference).

The discharge plenum duct length -shall be 2.5 equivalent diameters, $2.5 \cdot \sqrt{\frac{\pi D_o^2}{4}}$ for circular ducts, where D_o is the duct inner diameter or $2.5 \cdot \sqrt{A \cdot B}$ for rectangular ducts, where A and B are the interior cross-sectional dimensions of the duct.

The static pressure measurement plane is located 2.0 equivalent diameters, $2.0 \cdot \sqrt{\frac{\pi D_o^2}{4}}$ or for circular ducts or $2.0 \cdot \sqrt{A \cdot B}$ for rectangular ducts -downstream of the unit inlet outlet connection with a tolerance of ± 2.105% of this 2-equivalent-diameter dimension.

6.4.2.2.2 If space within the test room does not permit the full outlet plenum connection, an alternative outlet duct connection shall be installed. A square elbow with turning vanes shall be attached to the outlet of the discharge side of the equipment. The orientation of the elbow shall be such that the discharge of the elbow is parallel to the flow of the air and flow from inlet to outlet of the elbow follows the direction of rotation of the blower (see Figure 18). The dimensions of the duct connected to the outlet of the elbow and the location of the static measurement plane shall follow Section 6.4.2.2.1 using the outlet plane of the elbow as the starting reference point. The outlet duct shall discharge into the mixer (if used) prior to the air sampling section upstream of the airflow measurement device (see Figure 9 for reference).


TO AIR FLOW MEASURING APPARATUS
STATIC
PRESSURE
TAPS
A/2
B/2
$2.5\sqrt{A \times B}$
Min.
$2\sqrt{A \times B}$
MANOMETER
PLENUM
A
B
A & B = OUTLET
DIMENSIONS
AIR CONDITIONER

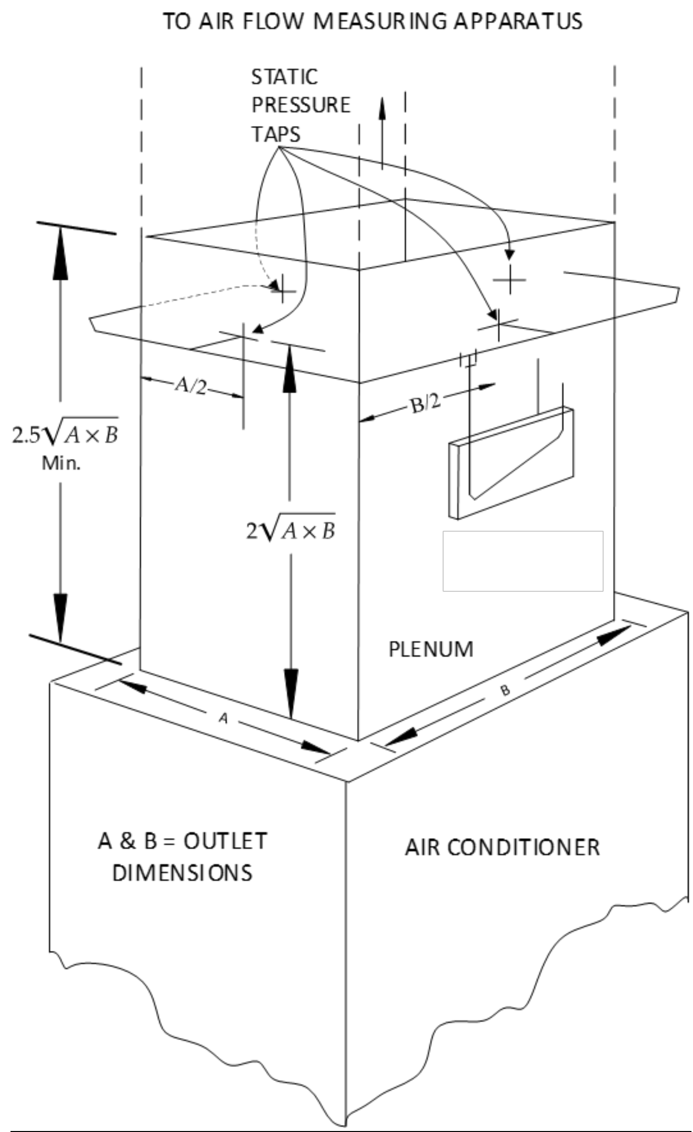
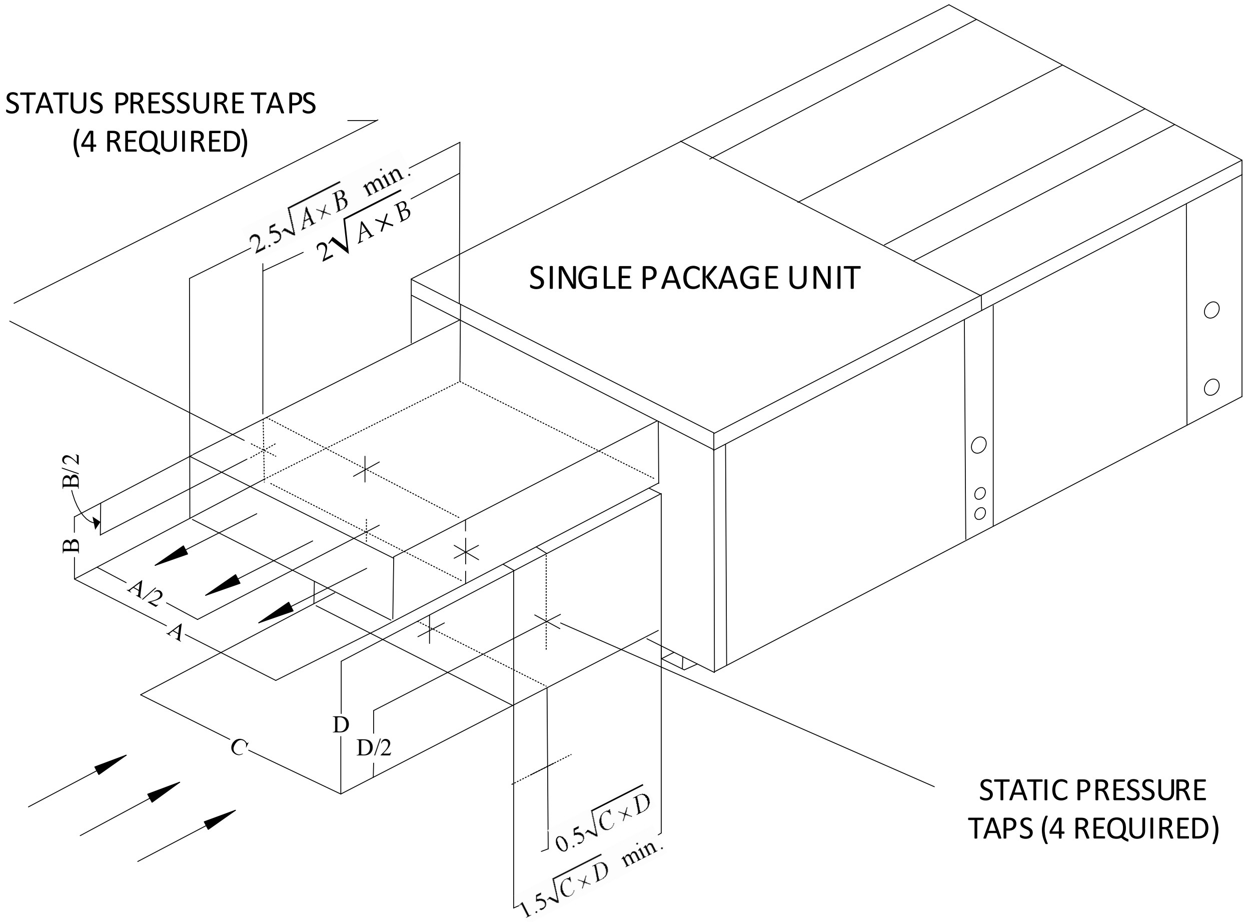


Figure 15 External static pressure measurement for equipment outlet.



<u>Figure 16</u> -External static pressure measurement.

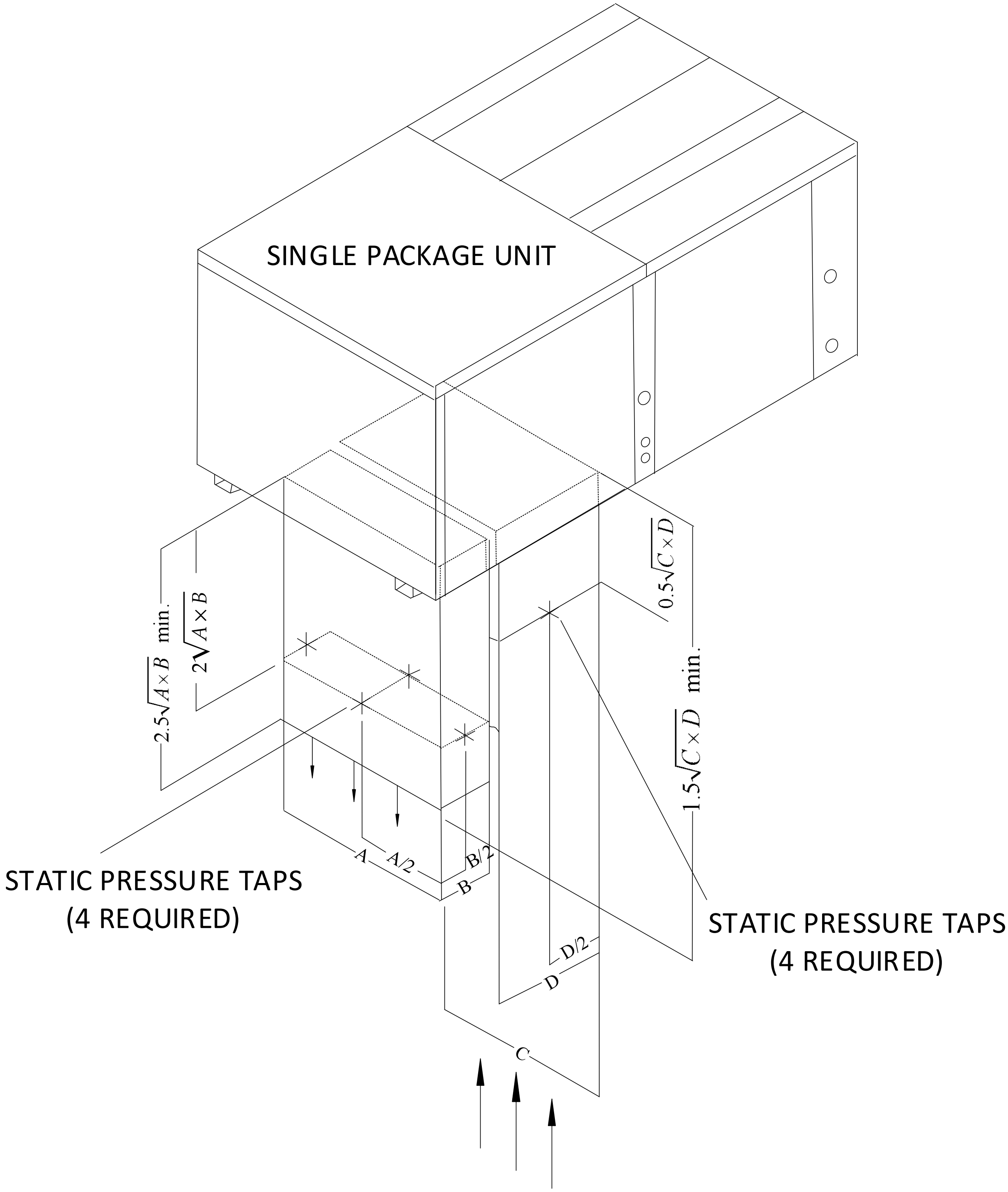
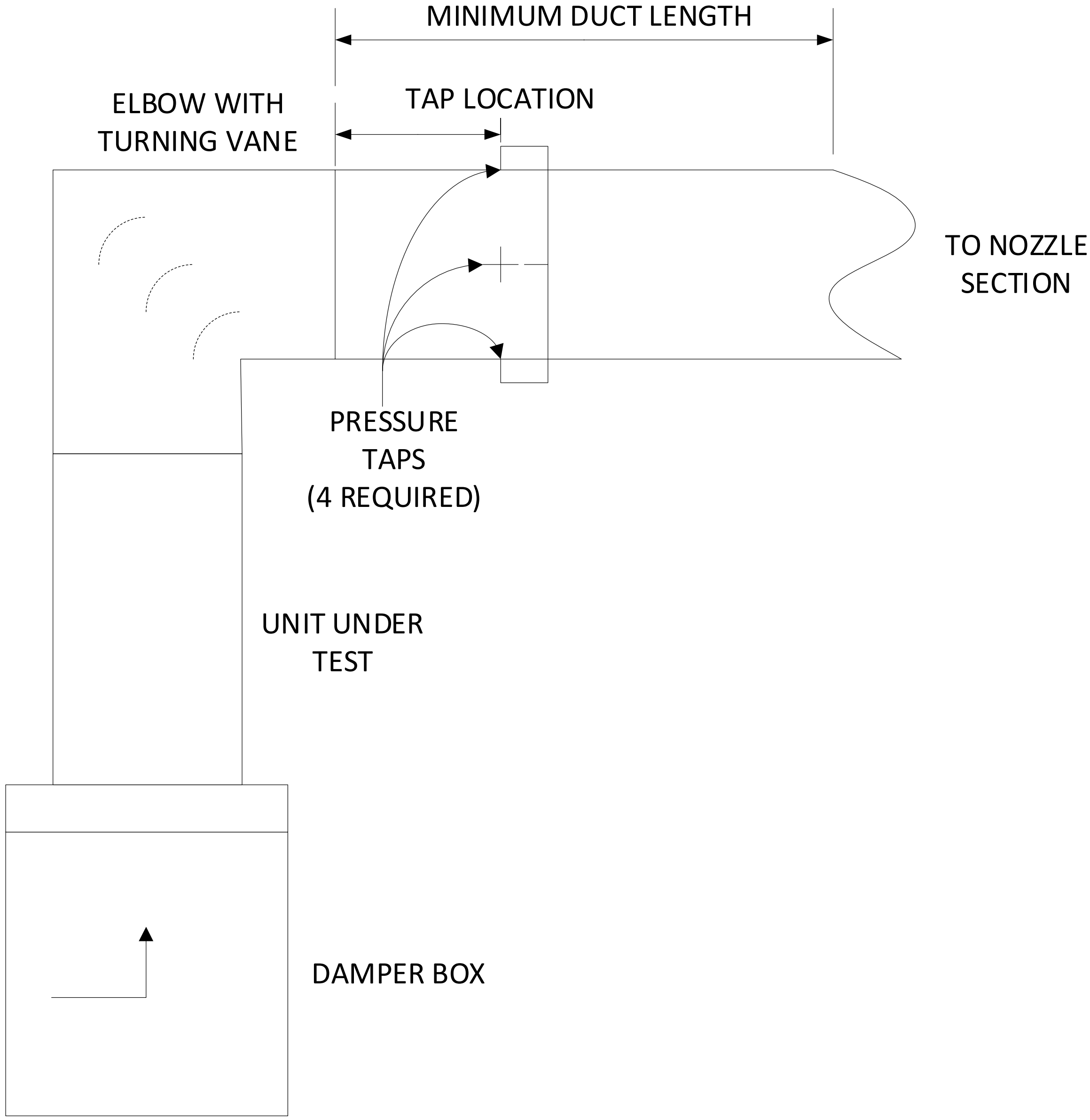


Figure 17 External static pressure measurement.



<u>Figure 18</u> Alternate Ductwork from RP-1581 - Details are defined in Sections 6.4.2 and 6.4.3

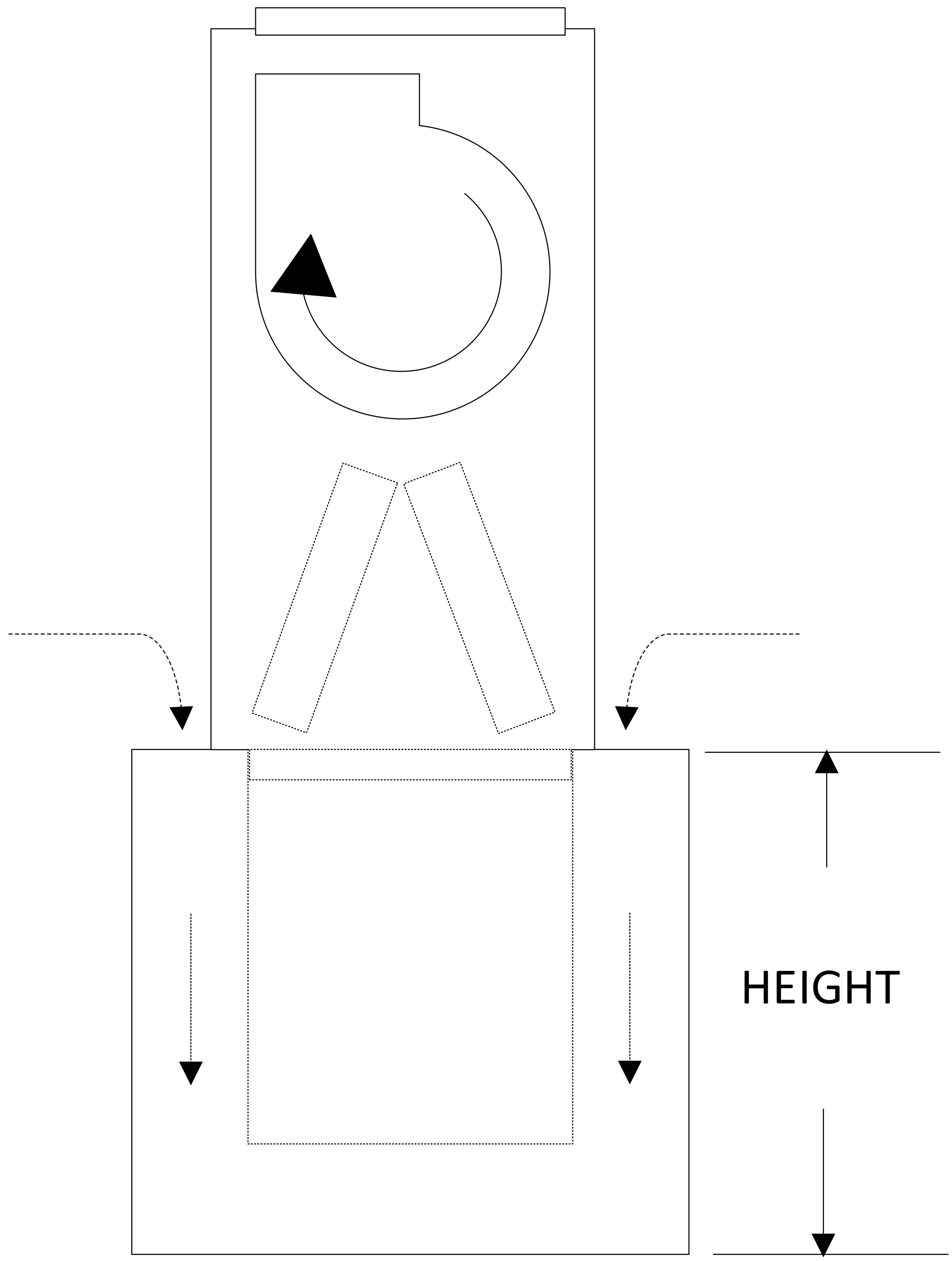


Figure 19 Example Upturned Duct - Details are defined in Section 6.3.5

6.4.3 Units without a Fan or with a Fan Upstream of the Indoor Coil and a Single Outlet

6.4.3.1 Inlet Plenum

Refer to Section 6.4.2.1 for specific details.

6.4.3.2 Outlet Plenum

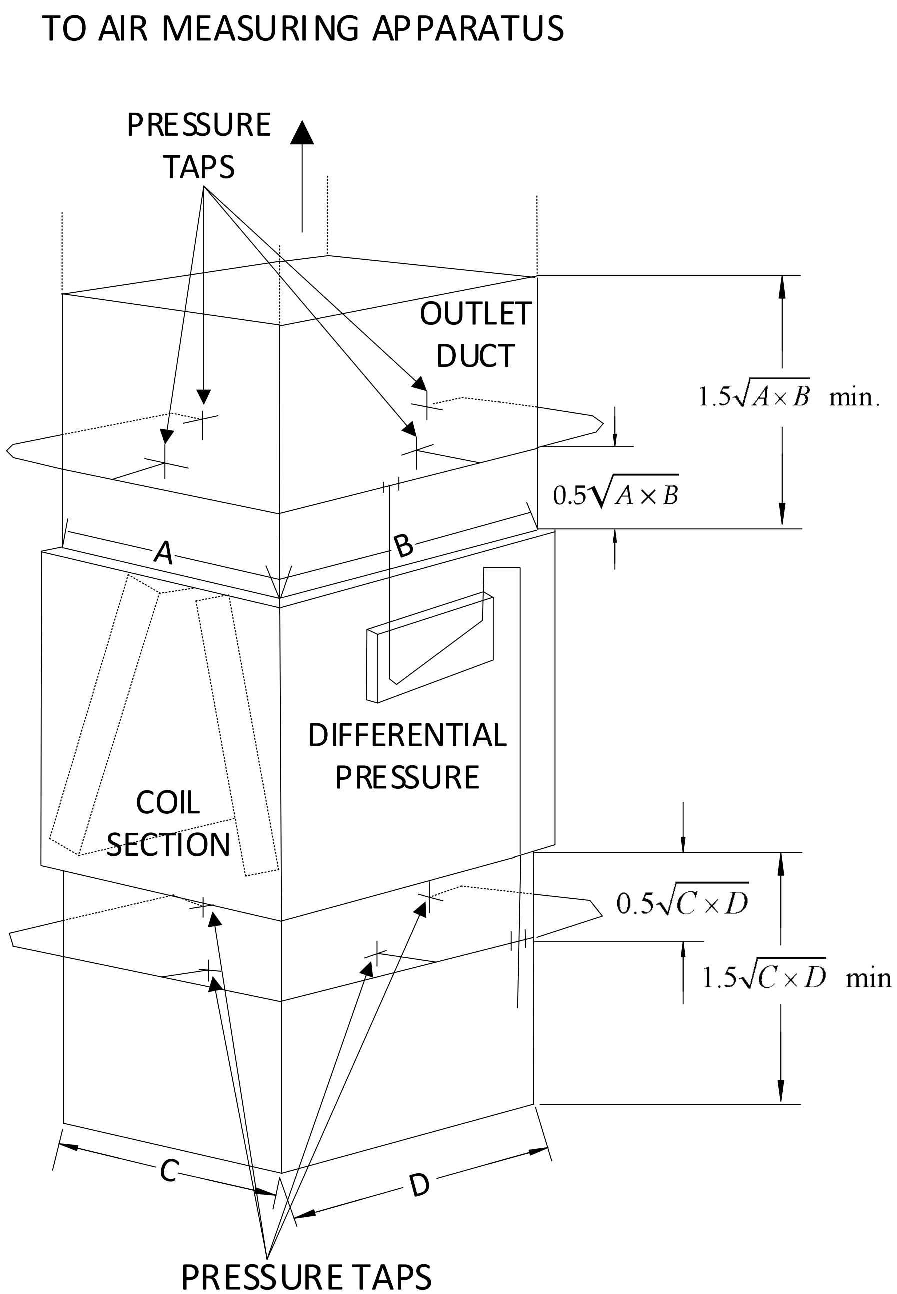
If the test room has sufficient space, use an inlet duct as described in Section 6.4.2.1.1. Otherwise, use an inlet duct as described in Section 6.4.2.1.2.

6.4.3.2.1 The outlet plenum shall have cross-sectional dimensions equal to the dimensions of the equipment outlet. It shall be fabricated as shown by the setup given in Figure 20 and discharge into the mixer (if used) prior to the air sampling section upstream of the airflow measurement device (see Figure 9 for reference).~~If space within the test room permits, a full outlet plenum shall be attached to the outlet of the discharge side of the equipment. This plenum shall have cross-sectional dimensions equal to the dimensions of the equipment outlet and if space allows, be fabricated as shown by the setup given in Figure 21 and shall discharge into the mixer (if used) prior to the air sampling section upstream of the airflow measurement device (see Figure 10 for reference).~~

The discharge plenum duct length shall be 1.5 equivalent diameters, $1.5 \cdot \sqrt{\frac{\pi D_o^2}{4}}$ for circular ducts, where D_o is the duct inner diameter or $1.5 \cdot \sqrt{A \cdot B}$ for rectangular ducts, where A and B are the interior cross-sectional dimensions of the duct.~~.~~

The static pressure measurement plane is located 0.5 equivalent diameters, $0.5 \cdot \sqrt{\frac{\pi D_o^2}{4}}$ for circular ducts or $0.5 \cdot \sqrt{A \cdot B}$ -for rectangular ducts downstream of the unit ~~inlet~~ outlet connection with a tolerance of ± 2.5% of this 2-equivalent-diameter dimension.~~of ± 10%~~.

6.4.3.2.2 If space within the test room does not permit the full outlet plenum connection, an alternative outlet duct connection shall be installed. A square elbow with turning vanes shall be attached to the outlet of the discharge side of the equipment. The orientation of the elbow shall be such that flow from inlet to outlet of the elbow follows the direction of rotation of the blower (see Figure 18)~~The orientation of the elbow shall be such that the discharge of the elbow is parallel to the flow of the air and flow from inlet to outlet of the elbow follows the direction of rotation of the blower (see Figure 19)~~. The dimensions of the duct connected to the outlet of the elbow and the location of the static measurement plane shall follow Section 6.4.3.2.1 using the outlet plane of the elbow as the starting reference point. The outlet duct shall discharge into the mixer (if used) prior to the air sampling section upstream of the airflow measurement device (see Figure 9 for reference).



<u>Figure 20</u> Air static pressure drop measurement for coil (without fan).

6.4.4 Units with Fans and Multiple Outlets or Multi-Evaporators

6.4.4.1 If space within the test room permits, a full outlet plenum shall be attached to the outlet of the discharge side of the equipment. Units with multiple discharge outlet duct connections or multi-evaporator systems shall have a plenum conforming to Figure 15 attached to each outlet. Each plenum shall discharge into a single common duct section for each respective test room. If air volume rate is to be measured directly, then this duct section shall discharge into an airflow measuring device. Where required for the purpose of achieving the static pressure in each plenum, an adjustable restrictor shall be located in the plane where each plenum enters the common duct section. External static pressure in each plenum shall be measured as specified in section 6.4.1.

6.4.4.2 Multiple blower units employing a single discharge duct connection flange shall be tested with a single outlet duct in accordance with Section 6.4.2.2~~.1.~~ Any other test plenum arrangements shall not be used except to simulate duct designs specified by the equipment manufacturer.

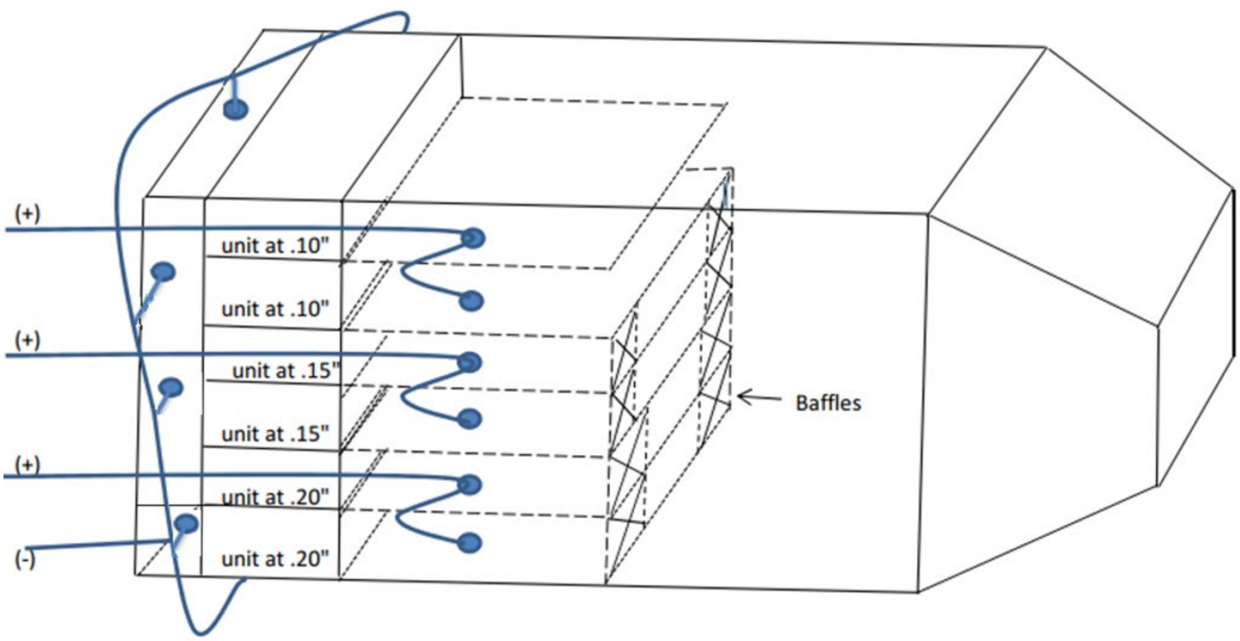


Figure 21 Example Indoor Units Installation Based on Different Static Pressures

6.4.4.3 If space within the test room does not permit the full outlet plenum, whether for a single or multiple outlets, follow the provisions of Sections 6.4.2.2.2 and 6.4.3.2.2 respective of indoor unit type for each plenum.

6.4.5 Small-duct, High-velocity Systems

6.4.5.1~~4.4~~ For Small-duct, High-velocity Systems, install an outlet plenum that has a diameter that is equal to or less than the value listed Table 3. The limit depends only on the Cooling Full-Load Air Volume Rate and is not dependent on the flange dimensions on the outlet of the unit (or an air supply plenum adapter accessory, if installed in accordance with the manufacturer's installation instructions).

TABLE 3: Maximum Diameter of Outlet Plenum

Cooling Full-Load Air Volume Rate Standard L/s (scfm)	Maximum Diameter* of Outlet Plenum cm (in)
≤ 236.0 (500)	15.24 (6)
236.4 (501) to 330.4 (700)	17.78 (7)
330.8 (701) to 424.8 (900)	20.32 (8)
425.2 (901) to 519.1 (1100)	22.86 (9)
519.6 (1101) to 660.7 (1400)	25.4 (10)
661.2 (1401) to 825.9 (1750)	27.94 (11)
*If the outlet plenum is rectangular, calculate its equivalent diameter using $(4A)/P$, where A is the area and P is the perimeter of the rectangular plenum, and compare it to the listed maximum diameter.	

6.4.5.2~~4.5~~ For Small-duct, High-velocity Systems, install an air damper to the end of the interconnecting duct, just prior to the transition to the airflow measuring apparatus. –To minimize air leakage, adjust this damper such that the pressure differential between the receiving chamber of the airflow measuring apparatus and the surrounding test room ambient is no more than 0.124 kPa (0.50 in. of water).~~To minimize air leakage, adjust this damper such that the pressure in the receiving chamber of the airflow measuring apparatus is no more than 0.124 kPa (0.5 in. of water) higher than the surrounding test room ambient.~~ Instead of installing a separate damper, it is acceptable to use the outlet air damper box if it allows variable positioning.

6.4.5.3 Apply ~~these~~ the steps in 6.4.5.2 to any conventional indoor blower unit that creates a static pressure within the receiving chamber of the airflow measuring apparatus that exceeds the test room ambient pressure by more than 0.124 kPa (0.5 in. of water).

6.4.~~5~~ 6 Non-ducted Units

6.4.~~5~~6.1 Outlet Plenum

6.4.~~5~~6.1.1 Indoor Leaving Plenum and Duct Requirements for Non-ducted Indoor Units. A plenum (enlarged duct box) shall be installed at the air outlet of ~~between~~ the ~~duct and the~~ indoor unit(s).~~–~~ The plenum must have a cross-sectional area at least 2 times the area of the indoor unit(s) combined outlet area. For all outlets, the plenum must extend for a distance of at least 3.5 times the square root of the cross-sectional area of the indoor unit(s) combined outlet area prior to any duct transitions, elbows, or Air Sampling Trees used for air condition measurement. Outlet Plenum Requirements are shown in Figure 22.

6.4.~~5~~6.1.2 If used, exit elbows connected to the end of the plenum shall have a centerline radius equal to at least 1.5 times the elbow duct width in the radial direction or have turning vanes. Air velocities calculated as measured volume flow divided by duct or plenum cross-sectional area shall not exceed 1.27 m/s (250 ft/min) inside the plenum and 2.54 m/s (500 ft/min) in the connecting duct at its connection to the plenum.

6.4.~~5~~6.1.3 Manifolded static pressure taps shall be installed in the plenum in at least four locations spaced uniformly around the plenum. The static pressure taps shall be located 2.8 times the square root of the cross-sectional area of the combined outlets from the indoor unit(s) distant from the indoor unit outlets.

6.4.~~5~~6.1.4 Air Sampling Trees used for indoor air leaving property measurement shall be placed in the duct between the airflow measurement apparatus and the ~~minimum required~~ plenum exit~~length~~.

6.4.~~5~~6.1.5 ~~The p~~The plenum shall be constructed such that the discharge air leaving the indoor unit does not impinge on the plenum wall, taking into consideration the discharge air throw angle ~~lenum shall not interfere with the non-ducted indoor discharge air throw angle~~ (see Figure 22).

~~**6.4.5.1.6** Outlet Plenum Requirements are shown in Figure 23. Air velocities calculated as measured volume flow divided by duct or plenum cross-sectional area shall not exceed 1.27 m/s (250 ft/min) inside the plenum.~~

6.4.~~5~~6.1.~~7~~ 6 Air Sampling Trees used for temperature measurement shall be placed in the duct between the airflow measurement apparatus and the minimum required plenum length.

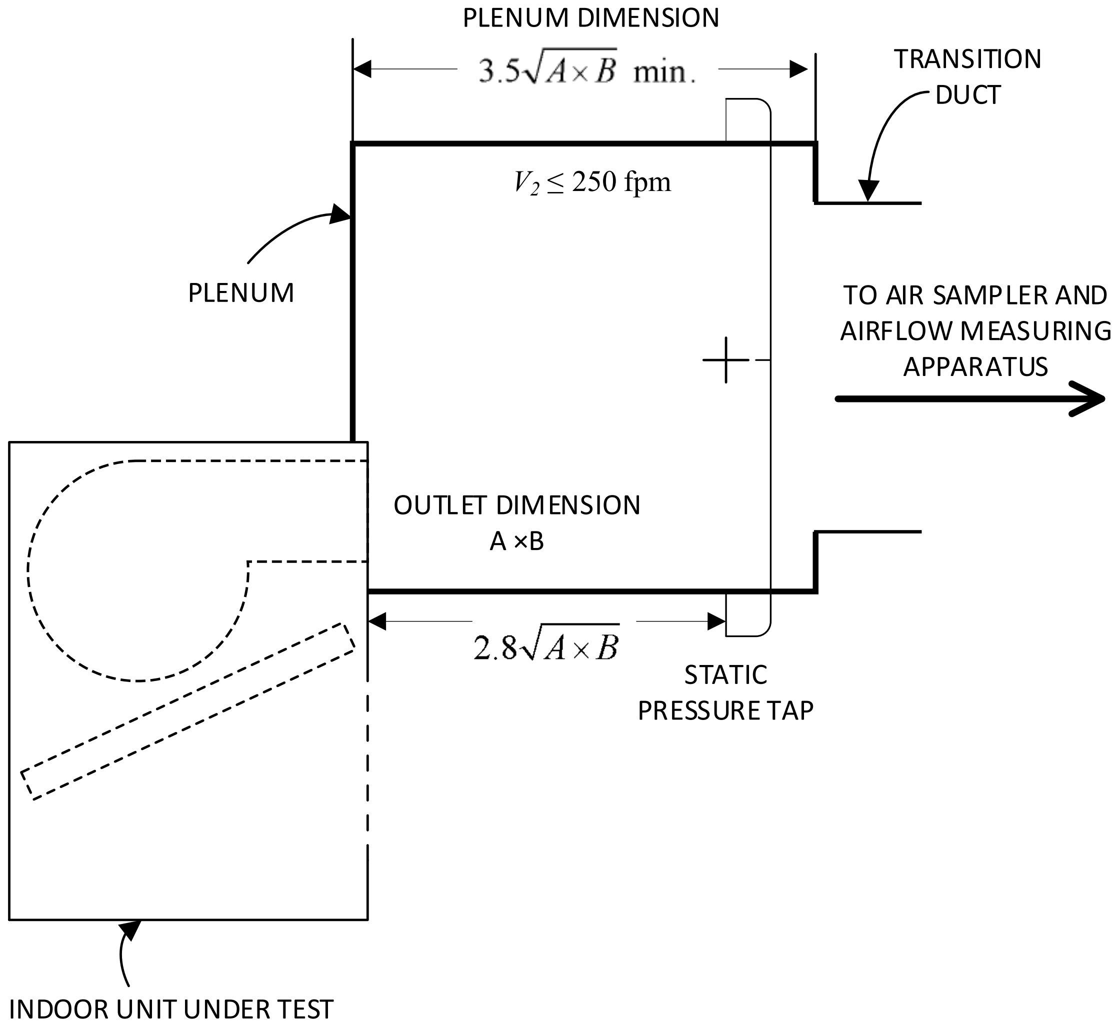


Figure 22. Example Setup for High Wall Mounted Indoor Units

6.4.~~5~~6.1.~~8~~ 7 External static pressure measurement shall be as defined in Section 6.4.1

6.4.~~5~~6.2 Inlet Plenum

6.4.~~5~~6.2.1 Except for Ceiling Cassettes, never use an inlet plenum when testing a non-ducted unit. If an inlet plenum is used for Ceiling Cassettes, the inlet plenum shall have a cross-sectional area at least 2 times the area of the Ceiling Cassette(s) combined inlet.

6.4~~.5~~.6.2.2 Plenum and Duct Requirements for Ceiling-mount Indoor Units are show in figures 23, 24, and 25.

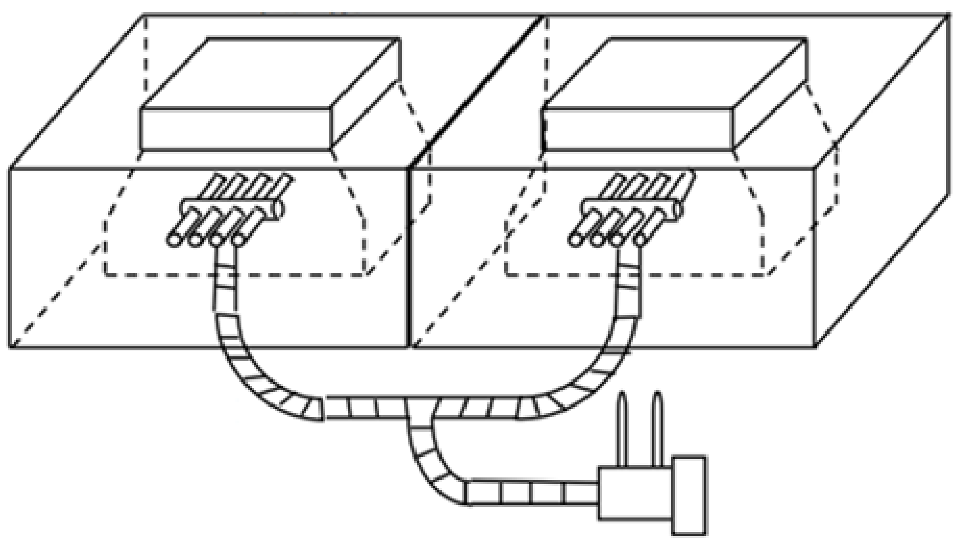


Figure 23 Example Return Air Measurement Setup For Non-Ducted Units, Sampling Tree at Unit

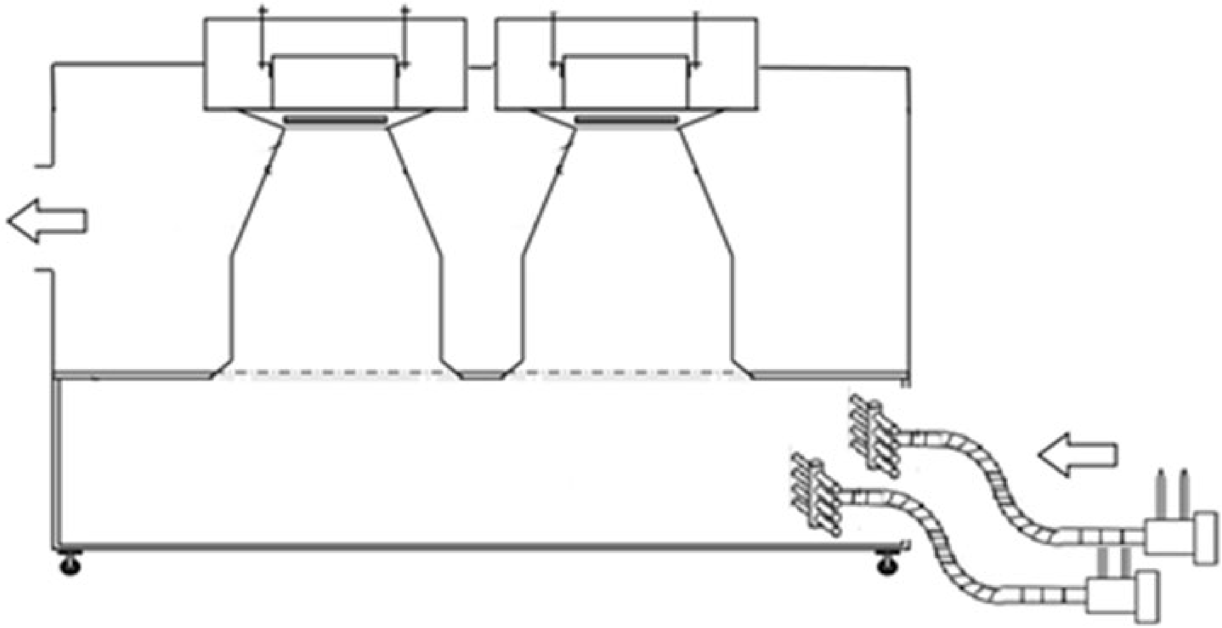


Figure 24 Example Return Air Measurement Setup For Non-Ducted Units, Sampling Tree Common

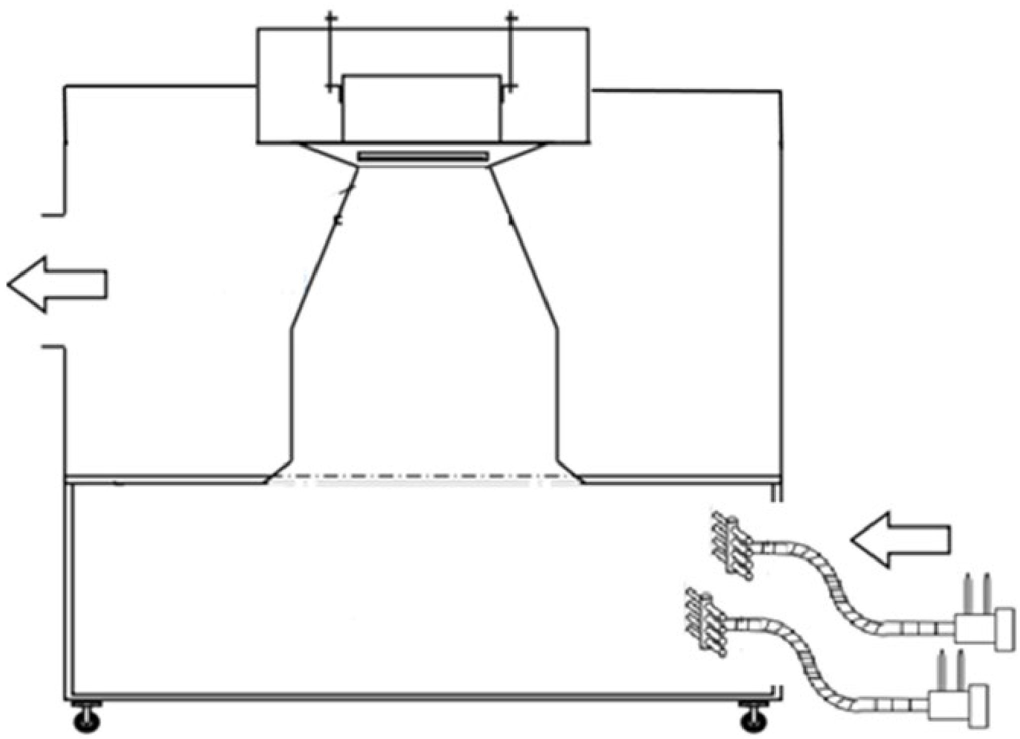


Figure 25. Example Return Air Measurement Setup for Ceiling Cassette

6.4.~~6~~ 7 Multi-split Units

6.4.~~6~~7.1 Outlet Plenum

6.4.~~6~~7.1.1 For systems having multiple indoor coils, or multiple indoor blowers within a single indoor section, attach a plenum to each indoor coil or blower outlet. Connect two or more outlet plenums to a single common duct so that ~~each indoor coil ultimately connects to~~ an airflow measuring apparatus measures the air flowing through all of the connected indoor units. If using more than one indoor test room, create one or more common ducts, each supplying a separate airflow measurement apparatus, within each test room that contains multiple indoor coils. At the plane where each plenum enters a common duct, install an adjustable airflow damper. U~~and u~~se the dampers ~~it~~ to equalize the static pressures in ~~each~~ all of the plenums. Each outlet air temperature grid and airflow measuring apparatus are located downstream of the inlet(s) to the common duct.

6.4.~~6~~7.1.2 External static pressure measurement shall be as defined in Section 6.4.1.

6.4.~~6~~7.1.3 Example arrangements for multiple indoor units are shown in Figures 26, 27, and 28

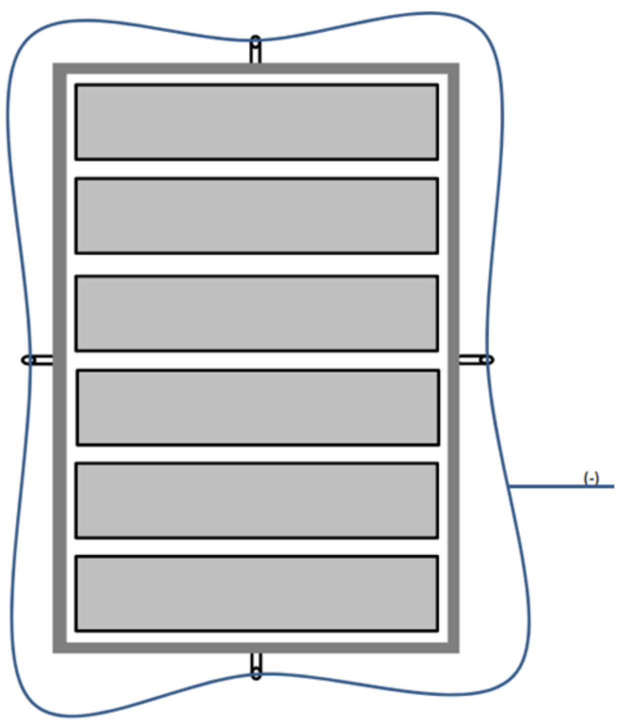


Figure 26. Example Indoor Units Installation for IDUs of Same Chassis Size

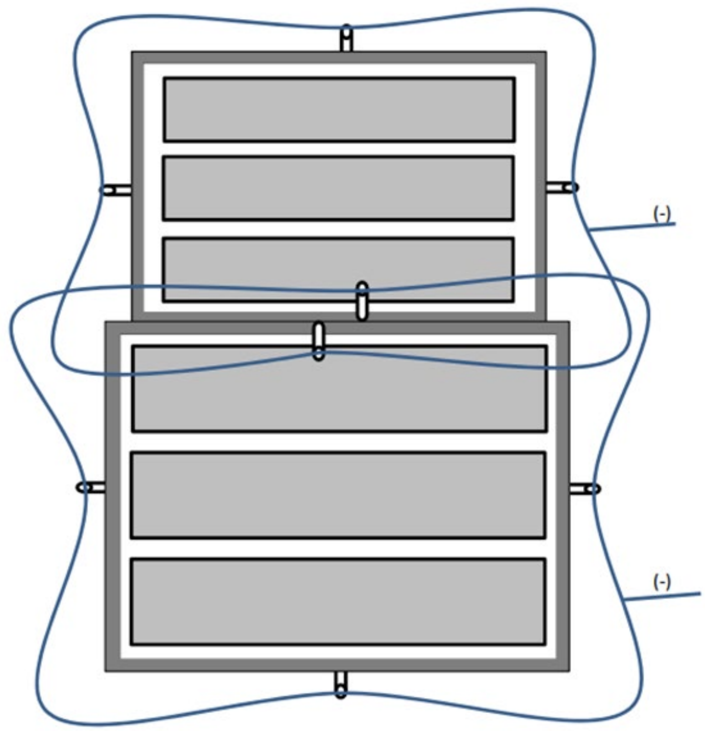


Figure 27. Example Indoor Units Installation for IDUs of Different Chassis Size

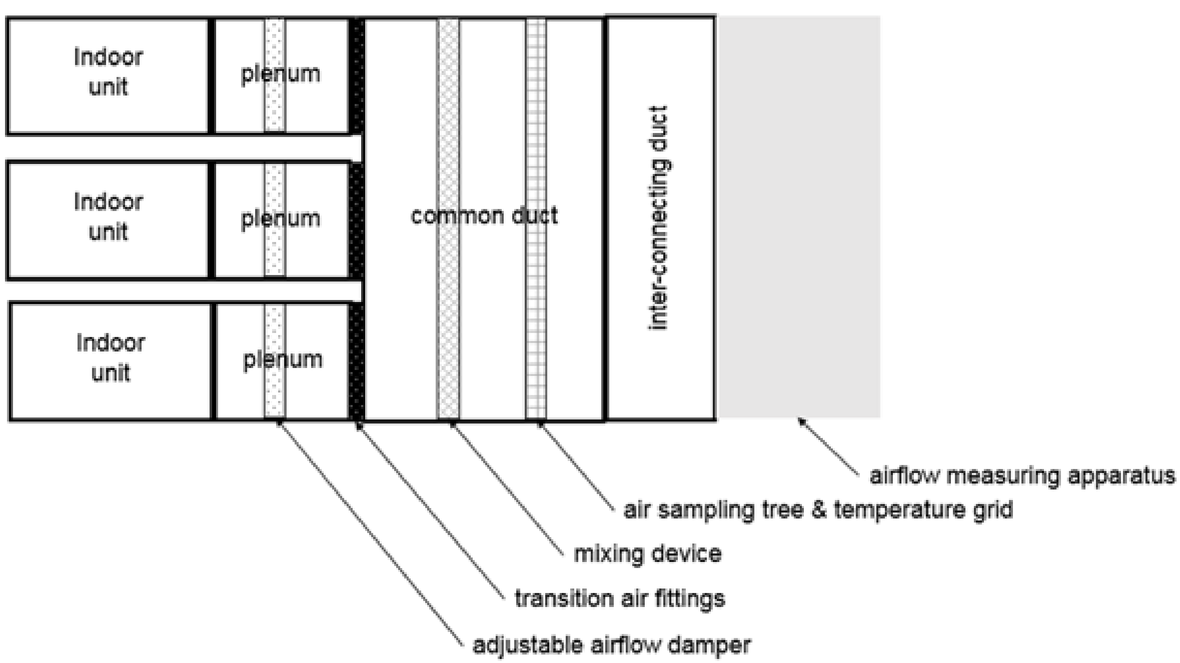


Figure 28 Schematic of Example Test Setup for Ducted Indoor Units with Common Duct

7. METHODS OF TESTING AND CALCULATION

7.1 Standard Test Methods. The following five test methods for measuring space conditioning capacity are covered in this standard:

(a) Indoor air enthalpy method (see 7.3)
(b) Outdoor air enthalpy method (see 7.3)
(c) Compressor calibration method (see 7.4)
(d) Refrigerant enthalpy method (see 7.5)
(e) Outdoor liquid coil method (see 7.6)

For all tests of equipment with a rated cooling capacity less than 40 kW (135,000 Btu/h), use the indoor air enthalpy method as the primary test method to determine the unit's space conditioning capacity.

For all tests of equipment with a rated cooling capacity greater than or equal to 40 kW (135,000 Btu/h), the alternative method described in Section 7.7.1.2 may be used as the primary test method. In this case, the use of In addition, an alternative to the method described in Section 5.6 for measuring indoor airflow rate is described in Section 7.7. Section 7.8, describes a method for measuring cooling condensate and determining latent cooling capacity, shall be used to measure latent capacity.

Simultaneous use of sections 7.7 and 7.8 is not required except when testing equipment having a rated cooling capacity of 40 kW (135,000 Btu/h) or greater where the indoor air enthalpy method is not used. For air-cooled single package equipment that does not reject condensate to the condenser coil with outdoor airflow rates greater than 4,250 Standard L/s (9,000 scfm), use the method described in of Section 7.8 may be used as the as an alternate secondary method.

7.2 Applicability of Test Methods

7.2.1 For all tests, , use the indoor air enthalpy method as the primary test method to determine the unit's space conditioning capacity as specified in Table 4, Group A. The procedure and data collected, however, differ slightly depending upon whether the test is a steady-state test, a cyclic test, or a frost accumulation test.

7.2.1.1 For the full-capacity cooling-mode test and, when testing a heat pump, the full-capacity heating-mode test, use one of the secondary methods specified in Table 4, Group B (with the corresponding section references) to determine the indoor space conditioning capacity. Calculate this secondary check of capacity according to section 10.1.2. The two capacity measurements must agree to within 6.0% of the primary measurement to constitute a valid test.

7.2.1.2 If testing an indoor unit without a fan, compare primary and secondary capacities before making the after-test fan heat adjustments described in Section 7.3.3.1 for cooling and 7.3.4.1 for heating. However, include the appropriate fan heat adjustments within the indoor air enthalpy method capacities used for the reported net capacity.

7.2.2 When testing equipment rated as having a total cooling capacity of 40 kW (135,000 Btu/h) or greater, at least one of the applicable methods from Table 4, Group A or Group B, except the Outdoor Air Enthalpy Method, shall be used. For cases where an air-source heat pump is to be tested and one or more heating capacity tests in the defrost region are to be conducted (see Section 8.8), the indoor air enthalpy method must be used. When the indoor air enthalpy method is not used, indoor airflow rate shall be determined from the space conditioning capacity test using the indirect method described in 7.7.1.2 and 7.7.3 and, for cooling tests, latent cooling capacity shall be determined by measuring condensate as described in 7.8.

Table 4 Applicable Test Methods

System Reference		Group A[a,b]	Group B[a,b]				
		7.3	7.3	7.4	7.5	7.6	7.7 & 7.8
Equipment Component Arrangement(s)	Method of Heat Rejection During Cooling Cycle	Indoor Air Enthalpy Method	Outdoor Air Enthalpy Method[c,d,i]	Compressor Calibration Method[e]	Refrigerant Enthalpy Method[e,f, j]	Outdoor Liquid Coil Method[g]	Cooling Condensate and Indirect Airflow Measurement
Single Package Unit	Air Cooled	P	S[k]	S[h,k]	S[l]		S
	Evaporatively Cooled	P		S[h,k]			S
	Water Cooled	P		S[h,k]		S	S
Remote Outdoor Heat Exchanger; Compressor within Conditioned Space	Air Cooled	P	S[k]	S[h,k]	S[h]		S
	Evaporatively Cooled	P		S[h,k]	S[h]		S
	Water Cooled	P		S[h,k]	S[h]	S	S
Remote Outdoor Heat Exchanger and Compressor	Air Cooled	P	S[k]	S	S		S
	Evaporatively Cooled	P		S	S		S
	Water Cooled	P		S	S		S
Remote Outdoor Heat Exchanger; Remote Compressor within Space	Air Cooled	P	S[k]	S[h,k]	S[l, h]		S
	Evaporatively Cooled	P		S[h,k]	S[l, h]		S
	Water Cooled	P		S[h,k]	S[l, h]	S	S

(a) For equipment having a rated cooling capacity less than 40 kW (135,000 Btu/h), capacity shall be determined using the indoor air enthalpy method and, except as noted in 8.8.3, using one of the applicable methods from Group B.
(b) For equipment having a rated cooling capacity of 40 kW (135,000 Btu/h) and greater, at least one prescribed method from Group A or Group B (unless the outdoor air enthalpy method is used as described in section 7.3.2) is required. For cases where the indoor airflow rate is not directly measured, the indoor air enthalpy method is not used, the requirements specified in 7.2.2 shall be invoked.
(c) Applicable only for equipment having a rated cooling capacity less than 40 kW (135,000 Btu/h).
(d) Test subject to 8.6.
(e) Not applicable for cooling capacity tests if the cooling mode expansion device is located remotely from the indoor coil(s).
(f) Test subject to 7.5.1 and 7.5.2.
(g) Test subject to 7.6.1.2. Not applicable if compressor is ventilated by outdoor air.
(h) Not applicable if uninsulated outdoor water coil is located in the indoor airstream, or if compressor is uninsulated and is ventilated by indoor air.
(i) Refer to 8.2.7 when compressor is ventilated independent of outdoor fan stream.
(j) Refer to 7.5 (sometimes referred to as volatile refrigerant flow method).
(k) Applicable only as a verification (heat balance) of the primary test method (indoor air enthalpy method) during steady-state tests. Not applicable during cyclic tests.
(l) Method allowed for use by manufacturers but shall not be used for certification testing.
P - primary test method
S - secondary test method

Informative Note: The methods described in this standard may be used to test unitary equipment not otherwise covered. However, proper consideration shall be given in the capacity calculations to adhere to energy balance principles.

7.3 Indoor and Outdoor Air Enthalpy Methods

7.3.1 Space conditioning capacity is determined by measuring airflow rate and the dry-bulb temperature and water vapor content of the air that enters and leaves the coil. Air enthalpies shall be determined in accordance with ANSI/ASHRAE Standard 41.6-1994 (RA 2006).

7.3.2 The use of the outdoor air enthalpy method is allowed when testing air cooled equipment that is rated as having a total cooling capacity less than 40 kW (135,000 Btu/h) and that does not use remote liquid chillers. Use of this method, however, is subject to the additional requirements and apparatus arrangement limitations specified in 8.6 and, if the equipment uses a remote outdoor coil(s), to the line loss adjustments described in 7.3.3.4 and 7.3.4.4.

7.3.3 Cooling Calculations

7.3.3.1 Total, sensible, and latent indoor cooling capacities, based on test data collected according to the indoor air enthalpy method, shall be calculated using the following equations:

$$q_{tci} = \frac{Q_{mi}(h_{a1} - h_{a2})}{v_n} - qs_{adj} = \frac{Q_{mi}(h_{a1} - h_{a2})}{v'_n(1 + W_n)} - qs_{adj}$$

$$\left[= \frac{60Q_{mi}(h_{a1} - h_{a2})}{v_n} - qs_{adj} = \frac{60Q_{mi}(h_{a1} - h_{a2})}{v'_n(1 + W_n)} - qs_{adj}\right]$$

$$q_{sci} = \frac{Q_{mi}\left(c_{p_{a1}}t_{a1} - c_{p_{a2}}t_{a2}\right)}{v_n} - qs_{adj} = \frac{Q_{mi}\left(c_{p_{a1}}t_{a1} - c_{p_{a2}}t_{a2}\right)}{v'_n(1 + W_n)} - qs_{adj}$$

$$\left[= \frac{60Q_{mi}\left(c_{p_{a1}}t_{a1} - c_{p_{a2}}t_{a2}\right)}{v_n} - qs_{adj} = \frac{60Q_{mi}\left(c_{p_{a1}}t_{a1} - c_{p_{a2}}t_{a2}\right)}{v'_n(1 + W_n)} - qs_{adj}\right]$$

where

$$cp_{a1} = 1005 + 1859W_1$$

$$[= 0.24 + 0.444W_1]$$

$$cp_{a2} = 1005 + 1859W_2$$

$$[= 0.24 + 0.444W_2]$$

qs_{adj} = fan capacity adjustment for indoor units, W [Btu/h]

where

For indoor units with a fan, $qs_{adj} = 0$
For indoor units with a fan but the blower off, $qs_{adj} = 3.412E_i$
For indoor units without a fan, $qs_{adj} = 3.412E_{id}$

E_{id} = default fan power

Informative note: For indoor units without a fan, reference Equations 11.17 or 11.18 in AHRI Standard 210/240-2023 for a method for calculating default fan power for establishing ratings.

$$q_{lci} = 2.47 \times 10^6 \frac{Q_{mi}(W_1 - W_2)}{v_n} = 2.47 \times 10^6 \frac{Q_{mi}(W_1 - W_2)}{v'_n(1 + W_n)}$$

$$\left[= (1061)(60) \frac{Q_{mi}(W_1 - W_2)}{v_n} = (1061)(60) \frac{Q_{mi}(W_1 - W_2)}{v'_n(1 + W_n)}\right]$$

Informative note: the latent indoor cooling capacity is a function of the latent heat of vaporization (h_{fg}) of water; in 7.3.3.1 equations for q_{lci}, the h_{fg} corresponding to 13°C (57°F) is used: 2.47×10^6 J/ kg (1061 Btu/lbm). Additionally, the energy associated with the leaving condensate is not included because its impact on net capacity is negligible.

7.3.3.2 Total indoor cooling capacity based on test data collected according to the outdoor air enthalpy method shall be calculated using one of the following equations:

$$q_{tco} = \frac{Q_{mo}(h_{a4} - h_{a3})}{v_n} - E_t = \frac{Q_{mo}(h_{a4} - h_{a3})}{v'_n(1 + W_n)} - E_t$$

$$\left[= \frac{60Q_{mo}(h_{a4} - h_{a3})}{v_n} - 3.412E_t = \frac{60Q_{mo}(h_{a4} - h_{a3})}{v'_n(1 + W_n)} - 3.412E_t\right]$$

or for air-cooled equipment that does not re-evaporate drained condensate from the indoor coil,

$$q_{tco} = \frac{Q_{mo}\left(c_{p_{a4}}t_{a4} - c_{p_{a3}}t_{a3}\right)}{v_n} - E_t = \frac{Q_{mo}\left(c_{p_{a4}}t_{a4} - c_{p_{a3}}t_{a3}\right)}{v'_n(1 + W_n)} - E_t$$

$$\left[= \frac{60Q_{mo}\left(c_{p_{a4}}t_{a4} - c_{p_{a3}}t_{a3}\right)}{v_n} - 3.412E_t = \frac{60Q_{mo}\left(c_{p_{a4}}t_{a4} - c_{p_{a3}}t_{a3}\right)}{v_n'(1+W_n)} - 3.412E_t\right]$$

where

$$cp_{a3} = 1005 + 1859W_3$$

$$[= 0.24 + 0.444W_3]$$

$$cp_{a4} = 1005 + 1859W_4$$

$$[= 0.24 + 0.444W_4]$$

7.3.3.3 When the indoor or outdoor air enthalpy method is used, the total and sensible cooling capacities shall be adjusted for duct losses. The duct loss adjustment shall be added to the total and sensible cooling capacities. The duct loss adjustment shall be calculated as follows:

If using the indoor air enthalpy test method and the equipment indoor section is located in the indoor test room, then

$$qloss_{IA} = (UA_{duct})_{2i}(t_{ai} - t_{a2})$$

If using the outdoor air enthalpy method and the equipment outdoor section is located in the outdoor test room, then

$$qloss_{OA} = (UA_{duct})_{4o}(t_{a4} - t_{ao})$$

If using the indoor air enthalpy test method and the equipment indoor section is located in an outdoor test room, then

$$qloss_{IA} = (UA_{duct})_{1o}(t_{ao} - t_{a1}) + (UA_{duct})_{2o}(t_{ao} - t_{a2}) + (UA_{duct})_{2i}(t_{ai} - t_{a2})$$

7.3.3.4 A line loss capacity adjustment shall be applied if using the outdoor air enthalpy method as the secondary method and if the adjustment is needed to obtain the energy balance specified in 10.1.2 (for equipment having a rated cooling capacity less than 40 kW [135,000 Btu/h]). The line loss capacity adjustment shall be added algebraically to the capacity determined using the outdoor air enthalpy method, q_{tco}. The adjustment shall be evaluated as follows:

(a) For bare copper tube,

$$q_l = (0.61 + 0.0053D_t^{0.75}\Delta t^{1.25} + 0.0798D_t\Delta t)L$$

$$[= (0.63 + 0.03D_t^{0.75}\Delta t^{1.25} + 1.17D_t\Delta t)L]$$

(b) For insulated lines,

$$q_l = (0.62 + 0.031(Th)^{-0.33} D_t^{0.75} \Delta t^{1.25})L$$

$$[= (0.64 + 0.06(Th)^{-0.33} D_t^{0.75} \Delta t^{1.25})L]$$

The temperature difference Δt is defined as the difference between the average refrigerant temperature and the surrounding ambient temperature.

7.3.3.5 Cooling—Cyclic. The following equations shall be used to determine the cyclic cooling capacity:

$$q'_{cyc} = 60 Q_{mi} c_{p_{a2}} \Gamma / [v'_n(1 + W_n)] - qs_{adj}[\theta_I - 0]$$

where Q_{mi}, c_{pa2}, v_n', and W_n shall be determined from a steady-state test at the same ambient conditions as for the cyclic test.

$$\Gamma = \int_0^{\Theta_I} [t_{ai}(\theta) - t_{a2}(\theta)] d\theta$$

where Θ_I is the length of the integration time within a cycle as defined in the specific test plan.

Informative note: Example of cycle times defined in a specific test plan include Section 5.2 of AHRI Standard 210/240-2023

In order to correct q_{cyc} for thermal storage effects (see 8.5.6), the following equations shall be used:

$$q_{cyc} = q'_{cyc} + q_{ts}$$

$$q_{ts} = mc_{pm}[t_m(0) - t_m(\Theta_I)]$$

where $t_m(0)$ is the temperature of the thermal storage device at the beginning of the cycle on period and $t_m(\Theta_I)$ is the temperature at the end of time Θ_I.

For units without an indoor fan and blower coil systems with fan disabled for cyclic tests,, q_{cyc} shall have a fan correction, qs_{adj}. The fan correction shall be for a time period Θ_I, whose definition source is indicated above. The fan-corrected q_{cyc} shall be the corrected capacity value to be used with the cyclic test.

7.3.4 Heating Calculations When Using the "S" Test Method of Section 8.8.2

7.3.4.1 The total heating capacity-based test data collected according to the indoor air enthalpy method shall be calculated using the following equation:

$$q_{thi} = \frac{Q_{mi}c_{p_{a2}}(t_{a2} - t_{a1})}{v_n} + qs_{adj} = \frac{Q_{mi}c_{p_{a2}}(t_{a2} - t_{a1})}{v'_n(1 + W_n)} + qs_{adj}$$

$$\left[= \frac{60Q_{mi}c_{p_{a2}}(t_{a2} - t_{a1})}{v_n} + qs_{adj} = \frac{60Q_{mi}c_{p_{a2}}(t_{a2} - t_{a1})}{v'_n(1 + W_n)} + qs_{adj}\right]$$

where c_{pa2} is calculated as specified in Section 7.3.3.1 and

$$W_n = W_1 = W_2$$

See Section 7.3.3.1 for values of qs_{adj}

7.3.4.2 The total heating capacity based on test data collected as described in the outdoor air enthalpy method shall be calculated using

$$q_{tho} = \frac{Q_{mo}(h_{a3} - h_{a4})}{v_n} + E_t = \frac{Q_{mo}(h_{a3} - h_{a4})}{v'_n(1 + W_n)} + E_t$$

$$\left[= \frac{60Q_{mo}(h_{a3} - h_{a4})}{v_n} + 3.412E_t = \frac{60Q_{mo}(h_{a3} - h_{a4})}{v'_n(1 + W_n)} + 3.412E_t\right]$$

where

$$W_n = W_4$$

7.3.4.3 When the indoor or outdoor air enthalpy method is used, the total heating capacity shall be adjusted for the duct losses. The duct loss adjustment shall be calculated as specified in 7.3.3.3 and then the absolute value of q_{loss} added algebraically to the heating capacity.

7.3.4.4 A line loss capacity adjustment shall be applied if using the outdoor air enthalpy method as the secondary method and if the adjustment is needed to obtain the energy balance specified in 10.1.2 (for equipment having a rated cooling capacity less than 40 kW [135,000 Btu/h]). The line loss capacity adjustment specified in 7.3.3.4 shall be subtracted algebraically (subtract the q_l's that are positive and add the q_l's that are negative) from the capacity determined using the outdoor air enthalpy method, q_{tho}.

7.3.5 Heating Calculations When Using the "T" Test Method of Section 8.8.3

7.3.5.1 For equipment required to perform defrost cycles, an average heating capacity corresponding to the total number of complete cycles shall be determined. If a defrost does not occur during the data collection interval, an average heating capacity shall be determined using data from the entire interval.

7.3.5.2 Average space heating capacity shall be determined as follows:

$$q_{thi} = \frac{Q_{mi} C_{p_{a2}} \Gamma}{(\tau_2 - \tau_1) v_n} + qs_{adj} = \frac{Q_{mi} C_{p_{a2}} \Gamma}{(\tau_2 - \tau_1) v'_n (1 + W_n)} + qs_{adj}$$

$$\left[= \frac{60 Q_{mi} C_{p_{a2}} \Gamma}{(\tau_2 - \tau_1) v_n} + qs_{adj} = \frac{60 Q_{mi} C_{p_{a2}} \Gamma}{(\tau_2 - \tau_1) v'_n (1 + W_n)} + qs_{adj} \right]$$

where c_{pa2} is calculated as specified in Section 7.3.3.1,

$$W_n = W_1 = W_2,$$

and

$$\Gamma = \int_{\tau_1}^{\tau_2} (t_{a2}(\tau) - t_{a1}(\tau)) \delta\tau$$

7.3.5.3 For heat pumps that automatically cycle off the indoor fan during a defrost cycle, the quantity $t_{a2}(\tau) - t_{a1}(\tau)$ shall be assigned as zero during the off interval. The elapsed time while the indoor fan is off shall be included as part of the total test time $(\tau_2 - \tau_1)$ that is used for evaluating average heating capacity.

7.3.5.4 Heating—Cyclic. The following equations shall be used to determine the cyclic heating capacity:

$$q'_{cyc} = \frac{60 Q_{mi} c_{p_{a2}} \Gamma}{[v'_n (1 + W_n)]} + qs_{adj} [\theta_I - 0]$$

where Q_{mi}, c_{pa2}, v_n', and W_n shall be determined from a steady-state test at the same ambient conditions as for the cyclic test.

$$\Gamma = \int_0^{\Theta_I} [t_{ai}(\theta) - t_{a2}(\theta)] d\theta$$

where Θ_I is the length of the integration time within a cycle as defined in the specific test plan.

Informative note: Example of cycle times defined in a specific test plan include Section 5.2 of AHRI Standard 210/240-2023

In order to correct q_{cyc} for thermal storage effects (see 8.5.6), the following equations shall be used:

$$q_{cyc} = q'_{cyc} + q_{ts}$$

$$q_{ts} = mc_{pm}[t_m(\Theta_I) - t_m(0)]$$

where $t_m(0)$ is the temperature of the thermal storage device at the beginning of the cycle on period and $t_m(\Theta_I)$ is the temperature at the end of time Θ_I.

For units without an indoor fan, q_{cyc} shall have a fan correction, qs_{adj}. The fan correction shall be for a time period for Θ_I, whose definition source is indicated above. The fan-corrected q_{cyc} shall be the correct capacity value to be used with the cyclic test.

7.3.6 Temperature

7.3.6.1 Temperature measurements shall be made with the equipment discussed in Section 5.1 and 6.2.2. Temperature measurements shall be taken at not less than nine locations at the center of equal segments of the cross-sectional area or with the use of -sampling and mixing devices. Consult ANSI/ASHRAE Standard 41.1-2013 for proper methods of achieving mixing in order not to exceed a 0.83°C (1.5°F) difference between all grid positions during steady state testing.

7.3.6.2 For non-steady-state temperature measurements, the velocity at any point in the cross-sectional area of the duct at the temperature-measuring location shall never be so low that the response time of temperature-measuring instrumentation is greater than 25 seconds at that velocity. Section 7.3.6.1 and this section will require flow mixers or straighteners or both if the requirements of these sections cannot be met without them.

7.4 Compressor Calibration Method

7.4.1 General Description

7.4.1.1 For the compressor calibration method, total cooling capacity or heating capacity is determined as follows:

(a) For cases where the superheat of the refrigerant leaving the evaporator is 3°C (5°F) or higher, capacity shall be evaluated by determining refrigerant flow rate and the change in refrigerant enthalpy between the inlet and outlet of the indoor section or indoor side of the equipment. Refrigerant flow rate shall be deduced based on prior or subsequent calibration of the compressor under identical operating conditions: the same compressor suction and discharge pressures and the same compressor suction temperature. As described in ANSI/ASHRAE Standard 23.1-2019, compressor calibration shall be achieved using either one of the calorimeter methods or one of the flow meter methods.

(b) For cooling mode tests where the superheat of the refrigerant leaving the evaporator is less than 3°C (5°F), cooling capacity shall be determined by conducting a separate evaporator-type calorimeter test where the compressor is operated under the same test conditions as encountered for the equipment test.
(c) For heating mode tests where the superheat of the refrigerant leaving the evaporator is less than 3ºC (5ºF), heating capacity shall be determined as described above in (a) with the additional stipulation that refrigerant flow rate shall be deduced based on compressor calibrations conducted using a condenser-type calorimeter.

7.4.2 Refrigerant Properties Measurement

7.4.2.1 With the equipment operating at the required test conditions, the temperature and pressure of the refrigerant leaving the indoor section or side, entering the indoor section or side (heating mode), entering the expansion device (cooling mode), and entering and leaving the compressor shall be measured. For cases where the indoor air enthalpy method and the compressor calibration method are both conducted, data used to calculate capacity according to the compressor calibration method and the indoor air enthalpy method shall be collected over the same intervals.

7.4.2.2 On equipment not sensitive to refrigerant charge, it is allowable to use pressure measuring instruments tapped into the refrigerant lines provided that the total charge is not affected by more than 0.5%.

7.4.2.3 On equipment sensitive to refrigerant charge, a preliminary test is required prior to connecting any pressure gauges or beginning the first official test. In preparation for this preliminary test, temperature sensors shall be attached to the equipment's indoor and outdoor coils. The sensors shall be located at points that are not affected by vapor superheat or liquid subcooling. For example, placed at the midpoint of the coil, at a return bend. The preliminary test shall be conducted as described in 8.7 with the additional requirement that the temperatures of the on-coil sensors be included with the regularly recorded data. After the preliminary test is completed, the refrigerant shall be removed from the equipment, and the needed pressure gauges shall be installed. The equipment shall be evacuated and recharged with refrigerant. The test shall then be repeated. Once steady-state operation is achieved, refrigerant shall be added or removed until, as compared to the average values from the preliminary test, the following conditions are achieved: (1) each on-coil temperature sensor indicates a reading that is within ±0.3°C (0.5°F), (2) the temperatures of the refrigerant entering and leaving the compressor are within ±2°C (3°F), and (3) the refrigerant temperature entering the expansion device is within ±0.5°C (1.0°F). Once these conditions have been achieved over an interval of at least 10 minutes, refrigerant charging equipment shall be removed and the first of the official tests shall be initiated.

7.4.2.4 Refrigerant temperatures shall be measured in accordance with Section 5 and the temperature measuring devices shall be attached to the lines at appropriate locations.

7.4.2.5 No instrumentation shall be removed, replaced, or otherwise disturbed during any portion of a complete capacity test.

7.4.2.6 Temperatures and pressures of the refrigerant vapor entering and leaving the compressor shall be measured at 20-30 cm (8-12 in.) from the compressor shell. If the reversing valve is included in the calibration, these measurements shall be taken on the lines to the coils at 20-30 cm (8-12 in.) from the reversing valve.

7.4.3 Compressor Flow Rate Calibration

7.4.3.1 Refrigerant flow rate shall be determined based on separate calibration tests conducted on the same compressor as used by the equipment under test. For cases where the superheat of the refrigerant leaving the evaporator is 3°C (5°F) or higher, the calibration tests shall be conducted using one of the applicable methods specified in ANSI/ASHRAE Standard 23.1-2019. For cases where the equipment is heating and the refrigerant superheat leaving the evaporator is less than 3°C (5°F), however, the condenser calorimeter method described in ANSI/ASHRAE Standard 23.1-2019 and ANSI/ASHRAE Standard 41.9-2018 shall be exclusively used to determine refrigerant flow rate. Refrigerant flow rate calibration tests are not applicable for cases where the equipment is cooling and the refrigerant superheat leaving the evaporator is less than 3°C (5°F) (see 7.4.4 instead).

7.4.3.2 Calibration tests shall be performed with the compressor and reversing valve (where used) at the same ambient temperature and air pattern as in the tested equipment.

7.4.4 Cooling Capacity Secondary Test for Equipment, When Tested, Having a Suction Superheat Less than 3°C (5°F)

7.4.4.1 For cooling mode tests where the superheat of the refrigerant leaving any evaporator is less than 3ºC (5ºF), a separate test using an evaporator-type calorimeter shall be conducted. The three evaporator-type calorimeters that shall be used are:

1. Secondary refrigerant calorimeter
2. Secondary fluid calorimeter
3. Primary refrigerant calorimeter

The separate calorimeter test shall be conducted as specified in ANSI/ASHRAE Standard 23.1-2019 and ANSI/ASHRAE Standard 41.9-2018. For these particular calorimeter tests, adherence to the requirements given in Sections 7.7.3, 7.7.4, 8.7.3, 8.7.4, 9.7.3, 9.7.4 of ANSI/ASHRAE Standard 41.9-2018 shall be waived.

7.4.4.2 In order to conduct the follow-up calorimeter test, knowledge of the following parameters from the original equipment test are required: the evaporator saturation temperature or pressure and refrigerant temperature leaving the evaporator. The condenser saturation temperature or pressure from the original equipment test shall be recorded.

7.4.4.3 Using the results from the evaporator-type calorimeter test, total cooling capacity shall be calculated as specified in 7.4.5.2.

7.4.5 Compressor Calibration Method Calculations— Cooling Capacity When the Equipment Suction Superheat Is 3°C (5°F) or Higher

7.4.5.1 If the evaporator superheat from the test is 3°C (5°F) or higher, total cooling capacity shall be calculated as follows:

$$q_{tc} = w_r(h_{r2} - h_{r1}) - E_i$$

$$[= w_r(h_{r2} - h_{r1}) - 3.412E_i]$$

where h_{r2}, h_{r1}, and E_i are measured during the equipment test, and w_r is determined based on prior or subsequent compressor calibration tests and refrigerant property measurements made during the equipment test.

$$w_r = \frac{[w_w c_{pw}(t_1 - t_2) + UA_a(t_c - t_a)]}{(h_{g2} - h_{f2})}$$

7.4.5.2 If the evaporator superheat from the test is less than 3°C (5°F), total cooling capacity shall be calculated as follows:

$$q_{tc} = q_e + UA_a(t_a - t_c) - E_i$$

$$[= q_e + UA_a(t_a - t_c) - 3.412E_i]$$

where E_i is measured during the original equipment test while q_e, UA_a, t_a, and t_c are all measured during the subsequent evaporator-type calorimeter test described in 7.4.4.

7.4.6 Compressor Calibration Method Calculations— Heating Capacity

7.4.6.1 Total heating capacity shall be calculated as follows:

$$q_{th} = w_r(h_{r1} - h_{r2}) + E_i$$

$$[= w_r(h_{r1} - h_{r2}) + 3.412E_i]$$

where h_{r1}, h_{r2}, and E_i are measured during the equipment test, and w_r is determined based on prior or subsequent compressor calibration tests and refrigerant property measurements made during the equipment test.

7.5 Refrigerant Enthalpy Method

7.5.1 General Description

7.5.1.1 In this method, capacity is determined from the refrigerant enthalpy change and flow rate. Enthalpy changes are determined from measurements of entering and leaving pressures and temperatures of the refrigerant, and the flow rate is determined in accordance with Section 5. With the equipment operating at the required test conditions, the temperature and pressure of the refrigerant leaving the indoor section or side and either entering the indoor section or side (heating mode) or entering the expansion device (cooling mode) shall be measured. For cases where the indoor air enthalpy method and the refrigerant enthalpy method are both conducted, data used to calculate capacity as described in the refrigerant enthalpy method and the indoor air enthalpy method shall be collected over the same intervals.

Informative Note: This method may be used for tests of equipment in which the refrigerant charge is not critical and where normal installation procedures involve the field connection of refrigerant lines.

7.5.1.2 This method shall not be used if during the test period the refrigerant liquid leaving the flow meter is subcooled less than 2°C (3°F) or if during the test period any instantaneous measurement of the superheat of the vapor leaving the indoor section is less than 3°C (5°F).

7.5.2 Refrigerant Flow Measurement

7.5.2.1 The refrigerant flow rate shall be measured with an integrating type flow meter connected in the liquid line upstream of the refrigerant control device. This meter shall be sized so that its pressure drop does not exceed the vapor pressure change that a 2°C (3°F) saturation temperature change produces. The mass flow rate measurements shall be measured in accordance with ANSI/ASHRAE 41.10-2020.
7.5.2.2 Temperature and pressure measuring instruments and a sight glass shall be installed immediately downstream of the meter to determine if the refrigerant liquid is subcooled. The refrigerant is subcooled if the liquid temperature is 2°C (3°F) below the bubble point of the refrigerant and there is an absence of any vapor bubbles in the liquid.

Informative Note: It is recommended that the meter be installed at the bottom of a vertical downward loop in the liquid line to take advantage of the static head of liquid thus provided.

7.5.2.3 At the end of the test, if a sample of the circulating refrigerant and oil mixture is taken from the equipment, the percentage of oil shall be measured in accordance with ANSI/ASHRAE Standard 41.4-2015. The total indicated flow rate shall then be corrected for the amount of circulating oil. When refrigerant oil mixture is not sampled a default value representing 1% oil shall be used.

7.5.3 Refrigerant Temperature and Pressure Measurement

7.5.3.1 The temperature and pressure of the refrigerant entering and leaving the indoor side of the equipment shall be measured with instruments in accordance with Section 5.1.

7.5.4 Refrigerant Enthalpy Method Calculations— Cooling Capacity

7.5.4.1 Total cooling capacity shall be calculated as follows:

$$q_{tci} = x\rho V_{ro}(h_{r2} - h_{r1}) - E_i = xw_{ro}(h_{r2} - h_{r1}) - E_i$$

$$[= x\rho V_{ro}(h_{r2} - h_{r1}) - 3.412E_i = xw_{ro}(h_{r2} - h_{r1}) - 3.412E_i]$$

7.5.5 Refrigerant Enthalpy Method Calculations— Heating Capacity

7.5.5.1 Total heating capacity shall be calculated as follows:

$$q_{thi} = x\rho V_{ro}(h_{r1} - h_{r2}) + E_i = xw_{ro}(h_{r1} - h_{r2}) + E_i$$

$$[= x\rho V_{ro}(h_{r1} - h_{r2}) + 3.412E_i = xw_{ro}(h_{r1} - h_{r2}) + 3.412E_i]$$

7.6 Outdoor Liquid Coil Method

7.6.1 General Description

7.6.1.1 In this method, total cooling or heating capacity is determined from measurements of the outdoor coil liquid temperature change and flow rate.

7.6.1.2 This method is intended for the test of equipment that uses a liquid (for example, water) as a heat sink or source, factory-assembled *packaged* system equipment, or equipment with a remote outdoor coil if the remote coil is insulated or if the manufacturer specifies insulating the coil with a material with insulating properties greater than or equal to that of 25 mm (1.0 in.) of glass fibrous insulation. This method shall only be used where the compressor is ventilated in the indoor airstream or is in an indoor closed compartment that is not ventilated or is insulated in the same manner as described above for the outdoor coil.

7.6.2 Liquid Flow Rate Measurement

7.6.2.1 The outdoor coil liquid flow rate shall be measured with a liquid quantity or flow meter in accordance with 5.1.

7.6.3 Temperature Measurement

7.6.3.1 Entering and leaving liquid temperatures shall be measured with instruments in accordance with 5.1 at the equipment connections.

7.6.4 Outdoor Liquid Coil Method Calculations— Cooling Capacity

7.6.4.1 Total cooling capacity shall be calculated as follows:

$$q_{tco} = w_l c_{pl}(t_{l4} - t_{l3}) - E_t$$

$$\left[= w_l c_{pl}(t_{l4} - t_{l3}) - 3.412E_t\right]$$

7.6.5 Outdoor Liquid Coil Method Calculations— Heating Capacity

7.6.5.1 Total heating capacity shall be calculated as follows:

$$q_{tho} = w_l c_{pl}(t_{l3} - t_{l4}) + E_t$$

$$\left[= w_l c_{pl}(t_{l3} - t_{l4}) + 3.412E_t\right]$$

7.6.6 Pump Power Considerations

7.6.6.1 The total power input term, Et, in the equations above (in Sections 7.6.4.1 and 7.6.5.1) shall include the measured power input to the pump only if the pump is located between the inlet (t_{l3}) and outlet water temperature sensors (t_{l4}).

7.6.7 Interconnecting Tubing Adjustment

7.6.7.1 For equipment with a remote outdoor coil, allowance shall be made in the capacity calculations for heat gains or losses through the interconnecting tubing (see 7.3.3.4).

7.7 Airflow Rate Measurement

7.7.1 Measurement Methods—According to Rated Cooling Capacity

7.7.1.1 For equipment having a rated cooling capacity less than 40 kW (135,000 Btu/h), the indoor airflow rate shall be measured using the nozzle airflow measuring apparatus described in Section 5.6 and pictured in Figure 3. The apparatus shall be used to measure the airflow rate through the outdoor coil if using the outdoor air enthalpy method to provide the secondary capacity measurement.

The airflow nozzle(s) that is used shall be selected and applied in accordance with section 5.6. The airflow rate shall be calculated as specified in section 7.7.2. ANSI/ASHRAE Standard 41.2-2018 shall be referred to for guidance on the placement of the static pressure taps and the position of the diffusion baffle (settling means) relative to the chamber inlet. Deviations from the specified test setup shall be allowed only if such deviations are described in ANSI/ASHRAE Standard 41.2-2018.

7.7.1.2 For equipment having a rated capacity of 40 kW (135,000 Btu/h) or higher, the indoor airflow rate shall be measured as described in 7.7.1.1. For cases where a Section 5.6 nozzle airflow measuring apparatus is not used and capacity is determined using one or more of the below listed test methods, airflow rate shall be determined indirectly. Indirect determination shall be achieved by using the calculated capacity or by measuring the dry-bulb temperature and water vapor content of the air that enters and leaves the indoor coil (see 7.7.3).

(a) Compressor calibration method
(b) Refrigerant enthalpy method
(c) Outdoor liquid coil method

As a fourth option, airflow rate is determined using the modified airflow measurement apparatus shown in Figure 30. For this fourth option, the airstream is heated by a measurable amount and the increase in air dry-bulb temperature is measured. The modified airflow measurement apparatus is located downstream of the static pressure taps, the dry-bulb temperature sensors, and the instrumentation used in determining the water vapor content of the outlet air. Airflow rate shall be calculated as specified in Section 7.7.4 when the modified airflow measurement apparatus is used.

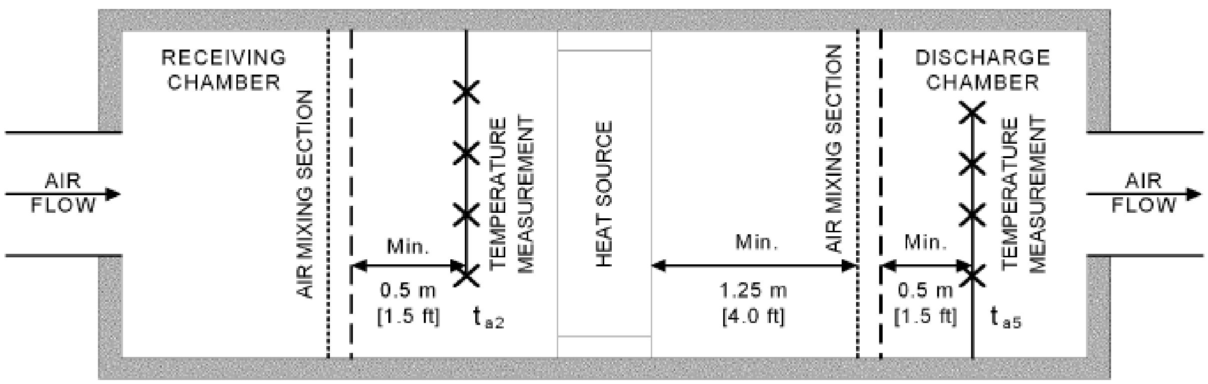


Figure 30 Modified airflow measurement apparatus.

Notes for Figure 30:
1. Air mixing and temperature measurement shall be in accordance with ANSI/ASHRAE Standard 41.1-2013
2. Heat loss from the enclosure shall be less than 1.0% of the heat input to the heat source.
3. Minimum temperature rise ($t_{a5} - t_{a2}$) across the heat source shall be 10°C (18°F).

7.7.2 Calculations—Nozzle Airflow Measuring Apparatus

7.7.2.1 The airflow rate through a single nozzle is calculated by the following equations:

$$Q_{mi} = CA_n\sqrt{2P_V v_n'}$$

$$\left[= 775.9CA_n\sqrt{2P_V v_n'} = 1097CA_n\sqrt{P_V v_n'}\right]$$

Where C is the nozzle coefficient of discharge calculated in Section 5.6.11 and,

$$v_n' = \frac{v_n}{1 + W_n} = \frac{101.325 v_{nsp}}{P_n(1 + W_n)}$$

$$\left[= \frac{v_n}{1 + W_n} = \frac{29.92 v_{nsp}}{P_n(1 + W_n)} \right]$$

7.7.2.2 When more than one nozzle is used, the total airflow rate is the sum of the flow rates of the individual nozzles calculated in accordance with 7.7.2.1.

7.7.2.3 Airflow rate, expressed in terms of standard air calculated using dry air specific volume v_n, shall be calculated as follows:

$$Q_s = \frac{Q_{mi}}{1.204 v_n} = \frac{Q_{mi}}{1.204 v_n'(1 + W_n)}$$

$$\left[= \frac{Q_{mi}}{0.075 v_n} = \frac{Q_{mi}}{0.075 v_n'(1 + W_n)} \right]$$

7.7.3 Calculations—Indirect Determination of Airflow Rate

7.7.3.1 When airflow rate is determined indirectly in accordance with 7.7.1.2, then airflow rate shall be evaluated using the following equations:

For Cooling:

$$Q_i = \frac{q_{tci} v_1}{h_{a1} - h_{a2}}$$

$$\left[= \frac{q_{tci} v_1}{60(h_{a1} - h_{a2})} \right]$$

For Heating:

$$Q_i = \frac{q_{thi} v_1}{h_{a2} - h_{a1}}$$

$$\left[= \frac{q_{thi} v_1}{60(h_{a2} - h_{a1})} \right]$$

7.7.3.2 Airflow rate, expressed in terms of standard air calculated using dry air specific volume v_n, (Q_s), shall be calculated as specified in 7.7.2.3, where v_n and W_n shall be evaluated based on the indoor coil entering air property measurements, assume $v_n = v_1$ and $W_n = W_1$.

7.7.4 Calculations—Modified Airflow Measurement Apparatus

7.7.4.1 When the modified airflow measurement apparatus described in 7.7.1.2 is used, airflow rate shall be calculated as follows:

$$Q_i = w_{ai} v_{ai}$$

$$\left[= \frac{w_{ai} v_{ai}}{60}\right]$$

where

$$w_{ai} = \frac{q_{sri}}{(1005 + 1859W_2)(t_{a5} - t_{a2})}$$

$$\left[= \frac{q_{sri}}{(0.24 + 0.444W_2)(t_{a5} - t_{a2})}\right]$$

The rate of energy added to the air, q_{sri}, shall be determined as follows:

(a) If electric reheat is used:

$$q_{sri} = \text{power input to heater(s)}$$

$$[= \text{power input to heater(s)} \times 3.412]$$

(b) If steam coil reheat is used:

$$q_{sri} = w_k(h_{k1} - h_{k2})$$

7.7.4.2 Airflow rate, expressed in terms of standard air calculated using dry air specific volume v_n, shall be calculated as follows:

$$Q_s = \frac{Q_i}{1.204 v_{ai}} = \frac{w_{ai}}{1.204}$$

$$\left[= \frac{Q_i}{0.075(60) v_{ai}} = \frac{w_{ai}}{4.5}\right]$$

7.8 Cooling Condensate Measurement

7.8.1 For equipment whose indoor airflow rate is determined indirectly in accordance with 7.7.1.2 and 7.7.3 during cooling mode tests, the latent cooling capacity of the equipment shall be determined from measurements of the condensate flow rate. The use of the cooling condensate measurement as a secondary measurement of latent capacity is allowed when used with the nozzle airflow measuring apparatus method. Cooling condensate mass shall be recorded at three equal intervals of 10 minutes during the 30-minute test period after equilibrium has been attained. The drain connection shall be trapped to stabilize condensate flow. The maximum deviation between any two cooling condensate mass measurements shall be less than 5%, with respect to the smaller of the two cooling condensate mass measurements. The total cooling condensate mass collected over the 30-minute period shall be multiplied by two to yield the condensate rate in kg/h (lb/hr) and shall be used as w_c when calculating latent capacity per Section 7.8.2.1 below. For the full load cooling test, latent cooling capacity calculated in Section 7.8.2.1 shall agree within 6.0% of the latent capacity calculated per Section 7.3.3.1.

> Informative note: During the test where a cooling condensate measurement test is being performed, one should ensure there's no condensate blow-off or leaks occurring.

7.8.2 Calculations

7.8.2.1 Latent cooling capacity shall be calculated as follows:

$$q_{lci} = 2.47 \times 10^6\ w_c$$

$$[= 1061\ w_c]$$

7.8.2.2 The sensible cooling capacity is then calculated as follows:

$$q_{sci} = q_{tci} - q_{lci}$$

where q_{tco} or q_{tc} shall be substituted for q_{tci} (refrigerant enthalpy method) when capacity is determined using either the outdoor liquid coil method (q_{tco}) or the compressor calibration method (q_{tc}).

8. TEST PROCEDURES

8.1 Test Room Requirements

8.1.1 One, two or multiple test rooms are required, depending upon the type of equipment to be tested and the manufacturer's installation instructions.

8.1.2 An indoor condition test room is always required.

> Informative Note: This may be any room or space in which the desired test conditions can be maintained within the prescribed tolerances. It is recommended that air velocities in the vicinity of the equipment under test do not exceed 2.54 m/s (500 fpm).

8.1.3 An outdoor condition test room or space is required for tests of air and evaporatively cooled equipment and for tests of remote water-cooled equipment. This test room shall a volume such that the circulated conditioned air -does not change the -air circulating pattern of the equipment under test. It shall be of dimensions such that the distance from any room surface to any equipment surface wherefrom air is discharged is not less than 1.8 m (6 ft) and the distance from any other room surface to any other equipment surface is not less than 0.9 m (3 ft), except for floor or wall relationships required for equipment installation.

Informative Note: The room conditioning apparatus should handle air at a rate not less than the outdoor airflow rate and preferably should take this air from the direction of the equipment air discharge and return it at the desired conditions, distributed uniformly, and at reduced velocities ~~and at low velocities~~..

8.1.4 Air Distribution

If used, mixing fans shall be oriented such that the fans are pointed away from the air intake so that the mixing fan exhaust cannot be directed at or away from the air entrance to the ~~condenser~~ outdoor air inlet. Particular attention shall be given to prevent recirculation of ~~condenser~~ outdoor fan exhaust air back through the unit.

Informative Note: To ensure adequate air distribution, thorough mixing, and uniform air temperature, it is important that the room and test setup is properly designed and operated. Air distribution at the test facility point of supply to the unit should be reviewed and may require remediation prior to the beginning of testing.

Multiple individual reading thermocouples (at least one per sampling tree location) shall be installed around the unit outdoor air discharge perimeter so that the thermocouples are below the plane of outdoor fan exhaust and just above the top of the outdoor coil(s). These thermocouples shall not indicate a temperature difference greater than 2.78°C (5.0°F) from the average inlet air. This provision does not apply to single package vertical units where outdoor air discharge is on the same plane as outdoor air inlet.

To check for uniformity of outdoor inlet air, the deviation from the mean air dry-bulb temperature grid to the air dry-bulb temperature at any individual temperature measurement location shall not exceed 1.11°C (2.0°F).

If more than one outdoor air sampler serves a given psychrometer, the difference between time-averaged dry-bulb temperature measured with air sampler tree and with Aspirating Psychrometer shall not exceed 0.83°C (1.5°F). If the average of the air sampling tree measurements differs from the psychrometer or conduit dry-bulb temperature sensor measurement by more than 0.28°C (0.5°F), use air-sampler exit dry-bulb temperature sensors. For this case, the uniformity requirement is based on comparison of each of the air-sampler exit measurements with the average of these measurements. When not using psychrometers, this 0.83°C (1.5°F) tolerance applies to either (a) the dry-bulb temperature measurement in a single common air conduit serving one or more air samplers or (b) the average of the dry-bulb temperature measurements made separately for each of the air samplers served by a single air sampler fan.

8.2 Equipment Installation

8.2.1 The equipment to be tested shall be installed in the test room(s) in accordance with the manufacturer's installation instructions. Equipment that is intended to be installed indoors shall be located entirely within the indoor test room; equipment that is intended to be installed outdoors shall be located entirely within the outdoor test room. ~~*Single-packaged, air-source equipment*~~*Packaged system* equipment shall be located in or adjacent to an opening in the wall or partition separating the test rooms. In all cases, the manufacturer's installation requirements shall be followed.

8.2.2 No alterations to the equipment shall be made except for the attachment of required test apparatus and instruments in the prescribed manner.

8.2.3 Where necessary, equipment shall be evacuated and charged with the type and amount of refrigerant specified in the manufacturer's published instructions.

8.2.4 Interconnecting tubing shall be as furnished or prescribed by the manufacturer. In the absence of other instructions, 7.~~5~~62 m (25 ft) of tubing shall be employed, at least 3 m (10 ft) of the tubing shall be located in the outdoor test room.

8.2.5 If pressure measuring instruments are used, said instruments shall be connected to the equipment only through short lengths of small diameter tubing and shall be located so that the readings are not influenced by fluid head in the tubing.

8.2.6 No change shall be made in fan speed or system resistance to correct for barometric variations.

8.2.7 If the compressor in the equipment under test is ventilated independently of the outdoor airstream, the calorimeter air enthalpy arrangement (see Figure 6) must be employed to account for compressor shell heat losses.

8.3 Airflow Measurements

8.3.1 The airflow measuring device shall provide measurements in accordance with the provisions of 7.7.

8.4 External Static ~~Resistance~~ Pressure Measurement

8.4.1 External static pressure ~~resistances~~ shall be measured in accordance with the provisions of Section 6.4~~.1~~. ~~Connections to equipment outlets shall comply with the provisions of Section 6.4.1~~

8.5 Temperature Measurement

8.5.2 In-duct, outlet temperature measurements shall be taken at not less than nine locations at the centers of equal segments of the cross-sectional area, or alternatively using sampling and mixing devices. Example mixing and sampling devices are illustrated in ANSI/ASHRAE Standard 41.1-2013.

8.5.3 Indoor inlet dry-bulb temperature measurements shall be taken at not less than nine positions equally spaced over the equipment inlet area. For units without an inlet duct connection or enclosure, the dry-bulb temperature and water vapor content measuring instruments or sampling devices shall be located 15-30 cm (6-12 in) from the equipment inlet opening or openings.

8.5.4 Outdoor inlet air dry-bulb temperature and water vapor content shall be measured at locations such that the following conditions are fulfilled:

(a) The measured dry-bulb temperature and water vapor content shall be representative of the conditions surrounding the outdoor section and simulate the conditions encountered in an actual application.
(b) At the point of measurement, the psychrometric properties of the air must not be affected by the air discharged from the outdoor section. This makes it mandatory that the air property measurements be made upstream of any recirculation produced.

> Informative note: It is intended that the ambient conditions surrounding the outdoor section under test shall simulate as nearly as possible a normal installation operating at ambient air conditions identical with the specified test conditions.

8.5.6 For non-steady-state measurements, the measured capacity shall be corrected to account for thermal storage effects of all connections, all flow mixers, all flow straighteners, and all other devices located between the measured points. This correction shall be made in either of two ways:

(a) Measure the temperature of all devices at the beginning and end of the capacity measuring time. Determine the change in internal energy of each device and either add or subtract this from the capacity. See 7.3.3.5 and 7.3.5.4.
(b) Make the total thermal storage capacity of all devices less than 1% of the total measured capacity. The total thermal storage capacity shall be calculated using the temperature difference between the indoor room and steady-state outlet temperature of the coils.

8.6 Additional Requirements for the Outdoor Air Enthalpy Method

8.6.1 When using the outdoor air enthalpy method as the secondary method for capacity measurement (except for Double-duct Systems), first conduct a test without the outdoor air-side test apparatus connected to the outdoor unit and then attach the outdoor air-side test apparatus and conduct a test with the apparatus connected to the outdoor unit. Use measurements from the free outdoor air test (the indoor air enthalpy method capacity measurements and power input) as the applicable measurements for determination of efficiency metrics. For Double-duct Systems, do not conduct a free outdoor air test, and use measurement from the ducted outdoor air test as the applicable measurements for determination of efficiency metrics.

8.6.1.1 Free Outdoor Air Test. For the free outdoor air test, connect the indoor air-side test apparatus to the indoor coil; do not connect the outdoor air-side test apparatus. Allow the test room reconditioning apparatus and the unit being tested to operate for at least 1 hour. After attaining equilibrium conditions, measure the following quantities at equal intervals of 30 seconds or less: (1) The evaporator and condenser temperatures or pressures; (2) Parameters required according to the indoor air enthalpy method (as specified in Section 7.3). To measure evaporator and condenser pressures, attach a thermocouple onto a return bend located at the midpoints of each coil or at points not affected by vapor superheat or liquid subcooling. Alternatively, if the test unit is not sensitive to the refrigerant charge, install pressure gauges to the access valves or to ports created from tapping into the suction and discharge lines according to Sections 7.4.2.2 and 8.2.5. The alternative approach shall be used when testing a unit charged with a zeotropic refrigerant having a temperature glide greater than 0.6°C (1.0°F) at the specified test conditions. For the free outdoor air test to constitute a valid test for determination of efficiency metrics, the following conditions shall be met: (1) For the ducted outdoor test, the capacities determined using the outdoor air enthalpy method and the indoor air enthalpy method shall agree within 6.0% of the primary method. (2) The capacity determined using the indoor air enthalpy method from the ducted outdoor air test and the capacity determined using the indoor air enthalpy method from the free outdoor air test shall agree within 2% of the test used to determine the efficiency metric (as specified in Section 7.2.1).

8.6.1.2 Ducted Outdoor Air Test. After collecting 30 minutes of steady-state data during the free outdoor air test, (if applicable) connect the outdoor air-side test apparatus to the unit for the ducted outdoor air test. Adjust the exhaust fan of the outdoor air-side test apparatus until averages for the evaporator and condenser temperatures, or the saturated temperatures corresponding to the measured pressures, agree within ± 0.28°C (0.5 °F) of the averages achieved during the free outdoor air test (if applicable). Collect 30 minutes of steady-state data where the applicable test tolerances are satisfied. During the ducted outdoor air test, at intervals of 30 seconds or less, measure the parameters required according to the indoor air enthalpy method and the outdoor air enthalpy method for the prescribed 30 minutes. For cooling mode ducted outdoor air tests, calculate capacity based on outdoor air enthalpy measurements as specified in Sections 7.3.3.2 and 7.3.3.3. For heating mode ducted tests, calculate Heating Capacity based on outdoor air enthalpy measurements as specified in Sections 7.3.4.2 and 7.3.4.3. Adjust the outdoor-side capacity according to Section 7.3.3.4 to account for line losses when testing *split systems*. Use the outdoor airflow rate as measured during the ducted outdoor air test to calculate capacity for checking the agreement with the capacity calculated using the indoor air enthalpy method during the ducted outdoor test. When the outdoor airflow rate is adjusted as described in this section, the adjusted airflow rate is employed in the capacity calculation. In such cases, however, the outdoor fan power input observed during the applicable preliminary test shall be used for rating purposes.

8.7 Test Procedure for Steady State Cooling Capacity Tests

8.7.1 The test room reconditioning apparatus and the equipment under test shall be operated until steady-state performance that is consistent with the test tolerances specified in Table 5 is attained before cooling capacity test data are recorded.

8.7.2 Data used in evaluating cooling capacity shall then be recorded at equal intervals that span 30 seconds or less until readings over a period of 30 minutes are within the tolerances prescribed in Table 5.

8.7.3 When the outdoor air enthalpy method is used, the requirements in Section 8.7.1 and Section 8.7.2 apply to both the preliminary test specified in 8.6 and test itself. When the compressor calibration method is employed, the above requirements apply to both the equipment test and the compressor calibration test.

8.8 Test Operating Procedure for Steady State and Defrost Heating Capacity Tests

8.8.1 General

8.8.1.1 When evaluating the heating performance of a heat pump when operating at conditions that are conducive to frost accumulation on the outdoor coil, the manufacturer shall have the option of first trying to use the "S" test procedure of Section 8.8.2. If the requirements of the "S" test procedure cannot be achieved, then the heating capacity test shall be conducted using the "T" test procedure described in Section 8.8.3.

8.8.1.2 Except as noted, overriding of automatic defrost controls shall be prohibited. The controls shall only be overridden when manually initiating a defrost cycle is permitted.

8.8.1.3 For heat pumps that use a time-adaptive defrost control system, where defrost initiation depends on the length of previous defrost cycles, the defrost controls of the heat pump shall be defeated during the official data collection interval of all heating capacity tests. When the defrost controls are defeated, defrost cycles (if any) shall be manually induced in accordance with the manufacturer's instructions.

8.8.1.4 Any defrost cycle, whether automatically or manually initiated, that occurs while conducting a heating capacity test shall always be terminated by the action of the heat pump's defrost controls.

8.8.1.5 Defrost termination shall be defined as occurring when the controls of the heat pump actuate the first change in converting from defrost operation to heating operation. Whether automatically or manually initiated, defrost initiation shall be defined as occurring when the controls of the heat pump first alter its heating operation in order to eliminate accumulations of frost on the outdoor coil.

8.8.2 "S" Test Steady State Procedure

8.8.2.1 For heat pumps having a rated cooling capacity that is less than 40 kW (135,000 Btu/h), a secondary measurement of heating capacity shall be made in accordance with Section 7.2.1.1.

8.8.2.2 The dry-bulb temperature of the air entering the indoor-side and the dry-bulb temperature and water vapor content of the air entering the outdoor-side shall then be recorded at equal intervals that span 30 seconds or less throughout the preconditioning and data collection periods.

Over these same periods, all other applicable Table 5 non-frosting parameters used in evaluating equilibrium shall be recorded at equal intervals that span 30 seconds or less. All data collected over the respective periods, except for parameters sampled between a defrost initiation and 10 minutes after the defrost termination, shall be used to evaluate compliance with the test tolerances specified in Table 5.

8.8.2.3 The test room reconditioning apparatus and the equipment under test shall be operated until equilibrium conditions are attained, but for not less than 1 hour, before test data are recorded. One or more defrost cycles are allowed at t any time during the preconditioning period, if automatically initiated by its own controls. The preconditioning period is allowed to end with a defrost cycle either automatically or manually initiated. If a defrost does occur, the heat pump shall operate in the heating mode for at least 10 minutes after defrost termination prior to resuming or beginning the data collection described in Section 8.8.2.2 and Section 8.8.2.4, respectively.

Informative Note: Ending the preconditioning period with a defrost cycle is especially recommended for heating capacity tests at low outdoor temperatures.

8.8.2.4 Once the preconditioning described in Section 8.8.2.3 is completed, the data required for the specified or chosen test method(s) of 7.1 and 7.2 shall be collected. These data shall be sampled at equal intervals that span 30 seconds or less. The difference between the dry-bulb temperature of the air leaving and entering the indoor coil, $\Delta t_{ai}(\tau)$, shall be evaluated at equal intervals that span 30 seconds or less. The temperature difference evaluated at the start of the data collection period, $\Delta t_{ai}(\tau = 0)$, shall be saved for purposes of evaluating Section 8.8.2.5.1 or Section 8.8.2.6.1 compliance.

8.8.2.5 Test Procedures If the Pre-Conditioning Period Ends with a Defrost Cycle

8.8.2.5.1 Data collection shall be suspended immediately if any of the following conditions occur prior to completing a 30-minute interval where the Table 5 non-frosting test tolerances are satisfied:

(a) if the heat pump undergoes a defrost;
(b) if the indoor-side dry-bulb temperature difference degrades such that the ratio $[\Delta t_{ai}(\tau = 0) - \Delta t_{ai}(\tau)] / \Delta t_{ai}(\tau = 0)$ exceeds 0.025; or
(c) if one or more of the applicable Table 5 non-frosting test tolerances are exceeded.

8.8.2.5.2 If the “S” test procedure is suspended because of condition “a” of Section 8.8.2.5.1, then the “T” test procedure described in Section 8.8.3 shall be used.

8.8.2.5.3 If the “S” test procedure is suspended because of condition “b” of Section 8.8.2.5.1, then the “T” test procedure described in Section 8.8.3 shall be used.

8.8.2.5.4 If the "S" test procedure is suspended because of condition "c" of Section 8.8.2.5.1, then another attempt at collecting data in accordance with Section 8.8.2 and the "S" test procedure shall be made as soon as steady performance is attained. An automatic or manually initiated defrost cycle is allowed to occur prior to making this subsequent attempt. If a defrost does occur, the heat pump shall operate in the heating mode for at least 10 minutes after defrost termination prior to beginning the data collection described in Section 8.8.2.4. The preconditioning requirements in Section 8.8.2.3 are not applicable when making this subsequent attempt.

8.8.2.5.5 If the "S" test procedure is not suspended in accordance with Section 8.8.2.5.1, then the sampling specified in Section 8.8.2.4 shall be terminated after 30 minutes of data collection. The test shall be designated as a completed steady-state heating capacity test if the Table 5 test tolerances for non-frosting are met.

8.8.2.6 Test Procedure If the Pre-Conditioning Period Does Not End with a Defrost Cycle

8.8.2.6.1 Data collection shall be suspended immediately if any of the following conditions occur prior to completing a 30-minute interval where the Table 5 non-frosting test tolerances are satisfied:

(a) if the heat pump undergoes a defrost;
(b) if the indoor-side dry-bulb temperature difference degrades such that the ratio $[\Delta t_{ai}(\tau = 0) - \Delta t_{ai}(\tau)] / \Delta t_{ai}(\tau = 0)$ exceeds 0.025; or
(c) if one or more of the applicable Table 5 non-frosting test tolerances are exceeded.

8.8.2.6.2 If the "S" test procedure is suspended because of condition "a" of Section 8.8.2.6.1, then another attempt at collecting data in accordance with Section 8.8.2.4 and Section 8.8.2.5 shall be made beginning 10 minutes after the defrost cycle is terminated. The preconditioning requirements of Section 8.8.2.3 are not applicable when making this subsequent attempt.

8.8.2.6.3 If the "S" test procedure is suspended because of condition "b" of Section 8.8.2.6.1, then another attempt at collecting data in accordance with Section 8.8.2.4 and Section 8.8.2.5 shall be made. This subsequent attempt shall be delayed until 10 minutes after the heat pump completes a defrost cycle.

Informative Note: This defrost cycle should be manually initiated, if possible, in order to avoid the delay of having to otherwise wait for the heat pump to automatically initiate a defrost.

8.8.2.6.4 If the "S" test procedure is suspended because of condition "c" of Section 8.8.2.6.1, then another attempt at collecting data in accordance with Section 8.8.2 and the "S" test procedure shall be made as soon as steady performance is attained. An automatic or manually initiated defrost cycle is allowed to occur prior to making this subsequent attempt. If a defrost does occur, the heat pump shall operate in the heating mode for at least 10 minutes after defrost termination prior to beginning the data collection described in Section 8.8.2.4. The preconditioning requirements in Section 8.8.2.3 are not applicable when making this subsequent attempt.

8.8.2.6.5 If the "S" test procedure is not suspended in accordance with Section 8.8.2.6.1, then the sampling specified in Section 8.8.2.4 shall be terminated after 30 minutes of data collection. The test shall be designated as a completed steady-state heating capacity test if the Table 5 test tolerances for non-frosting are met.

8.8.3 "T" Test Transient Procedure

8.8.3.1 Average heating capacity shall be determined using the indoor air enthalpy method. The outdoor air enthalpy method shall not be used and its associated outdoor-side measurement apparatus, if used in the previous test, shall be disconnected from the heat pump. In all cases, the outdoor-side airflow of the equipment shall not be disturbed. Use of a secondary test method is not required.

8.8.3.2 No changes in the airflow settings of the heat pumps shall be made. If the heat pump turns the indoor fan off during the defrost cycle, forced airflow through the indoor coil shall cease and the outlet duct shall be blocked while the fan is off.

8.8.3.3 The test tolerance given in Table 5, "heat with frost," shall be satisfied when conducting heating capacity tests using the "T" test procedure. As listed in Table 5, the test tolerances are specified for two sub-intervals. "Heat portion" consists of data collected during each heating interval, excluding the first 10 minutes after defrost termination. "Defrost portion" consists of data collected during each defrost cycle plus the first 10 minutes of the subsequent heating interval. The test tolerance parameters in Table 5 shall be sampled throughout the preconditioning and data collection periods. For the purpose of evaluating compliance with the specified test tolerances, the dry-bulb temperature of the air entering the indoor-side and the outdoor-side shall be sampled at least every 30 seconds during the heat portion and at least every 10 seconds during the defrost portion. The water vapor content of the air entering the outdoor side shall be sampled at least every 30 seconds. All other Table 5 "heat with frost" parameters shall be sampled at equal intervals that span 30 seconds or less.

All data collected during each interval, heat portion and defrost portion, shall be used to evaluate compliance with the Table 5 "heat with frost" tolerances. Data from two or more heat portion intervals or two or more defrost portion intervals shall not be combined and then used in evaluating Table 5 "heat with frost" compliance. Compliance is based on evaluating data for each interval separately.

8.8.3.4 The test room reconditioning apparatus and the equipment under test shall be operated until equilibrium conditions are attained, but for not less than 1 hour. Elapsed time associated with a failed attempt using the "S" test procedure of Section 8.8.2 is allowed to be counted in meeting the minimum requirement for 1 hour of operation. Prior to obtaining equilibrium and completing 1 hour of operation, the heat pump is allowed to undergo a defrost(s) cycle if automatically initiated by its own controls.

8.8.3.5 Once the preconditioning described in Section 8.8.3.4 is completed, a defrost cycle shall occur before data are recorded.

Informative Note: This defrost cycle should be manually initiated, if possible, in order to avoid the delay of having to otherwise wait for the heat pump to automatically initiate a defrost.

Data collection shall begin at the termination of the defrost cycle and shall continue until one of the following criteria is met. If, at an elapsed time of 3 hours, the heat pump has completed at least one defrost cycle and a defrost cycle is not presently underway, then data collection shall be immediately terminated. If, at an elapsed time of 3 hours, the heat pump is conducting a defrost, the cycle shall be completed before terminating the collection of data. If three complete cycles are concluded prior to 3 hours, data collection shall be terminated at the end of the third cycle. A complete cycle consists of a heating period and a defrost period, from defrost termination to defrost termination. For a heat pump where the first defrost cycle is initiated after 3 hours but before 6 hours have elapsed, data collection shall cease when this first defrost cycle terminates. Data collection shall cease at 6 hours if the heat pump does not undergo a defrost cycle within 6 hours.

8.8.3.6 In order to constitute a valid test, the test tolerances in Table 5 “heat with frost” shall be satisfied during the applicable Section 8.8.3.5 test period.

Informative Note: Because the test begins at defrost termination and may end at a defrost termination, the first defrost portion interval will only include data from the first 10 minute heating interval while the last defrost portion interval could potentially include data only from the last defrost cycle.

8.8.3.7 Except for the deviations noted for the dry-bulb temperatures, the data required for the indoor air enthalpy test method shall be sampled at equal intervals that span 10 seconds or less. The dry-bulb temperature of the air entering and leaving the indoor-side or, if a thermopile is used, the difference between these two dry-bulb temperatures shall be sampled at least every 10 seconds during

1. defrost cycles and
2. the first 10 minutes after a defrost termination (includes the first 10 minutes of the data collection interval).

8.8.3.8 Average heating capacity shall be calculated in accordance with Section 7.3.5 using data from the total number of complete cycles that are achieved before data collection is terminated. In the event that the equipment does not undergo a defrost during the data collection interval, the entire 6 hour data set shall be used for the calculations in Section 7.3.5.

8.9 Test Procedure for Air Enthalpy Method—Indoor Side, Cyclic Dry-Coil Performance Test, Cooling and Heating Tests

8.9.1 The room reconditioning apparatus and the equipment under test shall be operated until cyclic equilibrium conditions are attained but not for less time than it takes to perform two complete on/off cycles.

8.9.2 In this test, the unit shall be cycled at an on/off rate as defined in the test plan. When cyclic equilibrium is reached, one additional on/off cycle is conducted where data shall be recorded according to Section 9 within the tolerances prescribed by Table 5.

Informative note:
Example of cycle times defined in a specific test plan include Section 5.2 of AHRI Standard 210/240-2023

8.9.2.1 Cycle equilibrium shall be defined as three or more consecutive cycles where the ΔT for the ON portion of the cycle does not vary by more than ±0.16°C (±0.3°F) and the total power for the complete ON/OFF cycle does not vary by more than 10 Watts. This cyclic dry-coil performance test shall be conducted by cycling the unit on and off through the control circuitry connected to the thermostat.

Table 5 Test Tolerances

Test Tolerances: SI Units (I-P)		Test Operating Tolerance (Total Observed Range)				Test Condition Tolerance (Variation of Average from Specified Test Conditions)			
		Cooling	Non-Frosting	Heat with Frost[a]		Cooling	Non-Frosting	Heat with Frost[a]	
				Heat Portion	Defrost Portion			Heat Portion	Defrost Portion
Outdoor Dry-Bulb Temperature - ºC (ºF)	Entering	1.0 (2.0)	1.0 (2.0)	1.7(3.0)	5.6(10)	0.3(0.5)[b]	0.3(0.5)[b]	0.5(1.0)	N/A
Outdoor Wet-Bulb Temperature - ºC (ºF)	Entering	0.5 (1.0)	0.5 (1.0)	0.9(1.5)	N/A	0.2(0.3)[bd]	0.2(0.3)[b]	0.3(0.5)	N/A
Indoor Dry-Bulb Temperature - ºC (ºF)	Entering	1.0 (2.0)	1.0 (2.0)	1.7/3.0	2.2(4.0)[d]	0.3(0.5)[b]	0.3(0.5)[b]	0.5(1.0)	N/A[c]
Indoor Wet-Bulb Temperature - ºC (ºF)	Entering	0.5 (1.0)	0.5 (1.0)	N/A	N/A	0.2(0.3)[b]	N/A	N/A	N/A
Condenser Cooling Liquid Temperature - ºC (ºF)		0.3(0.5)	0.3(0.5)	N/A	N/A	0.1(0.2)[b]	0.1(0.2)	N/A	N/A
Saturated Refrigerant Temperature Corresponding to the Measured Indoor Side Pressure - ºC (ºF)		1.7(3.0)	1.7(3.0)	N/A	N/A	0.3(0.5)	0.3(0.5)	N/A	N/A
Make up Water temperature - ºC (ºF)		0.3(10)	NA	N/A	N/A	0.1(5.0)	N/A	N/A	N/A
External Resistance to Airflow - Pa(inches of H2O)	Ducted	12.5(0.05)	12.5(0.05)	N/A	N/A	N/A~~N/A~~	N/A ~~N/A~~	N/A	N/A
	Non-ducted	12.5(0.05)	12.5(0.05)	N/A	N/A	5.0(0.02)	5.0(0.02)	N/A	N/A
Electrical Voltage (% of reading)		2	2	2	N/A	N/A	N/A	N/A	N/A
Liquid Flow Rate (% of reading)		2	2	N/A	N/A	N/A	N/A	N/A	N/A
Nozzle Pressure Drop (% of Reading)		2	2	N/A	N/A	N/A	N/A	N/A	N/A

a. The "heat portion" shall apply when the unit is in the heating mode except for the first 10 minutes after terminating a defrost cycle. The "defrost portion" shall include the defrost cycle plus the first 10 minutes after terminating the defrost cycle.
b. Determine slope of least squares linear regression over the time of the test. Absolute value of total test time times slope shall not exceed 1/2 Test Condition Tolerance.
c. Applies only when using the outdoor air enthalpy method.

d. When these data are sampled within the defrost portion of the cycle, this data shall be omitted when computing average temperatures for the tests.
e. Applicable only when the testing equipment that rejects condensate to the outdoor coil and when testing package systems where the indoor coil is located in the outdoor chamber.
f. Not applicable if the indoor fan is stopped.
g. Tolerance applies only for the compressor calibration and refrigerant enthalpy methods: the saturation temperature, in this case, shall be evaluated based on the pressure transducer located between the indoor coil and the compressor for the given operating mode, heating or cooling.

9. DATA TO BE RECORDED

9.1 Table 5 shows the data to be recorded during a test. Items indicated by an "x" under the test method columns are required when that test method is employed.

9.2 Test Tolerances

9.2.1 All tests shall comply with the Test Operating Tolerance and Test Condition Tolerance, both listed in Table 5. Test Tolerances are for steady state and transient, respectively. Additionally, measurement accuracies shall comply with those in Table 1 Instrument Accuracy of Section 5. Instruments and Measurement Apparatus.

9.2.2 Variations greater than those prescribed or accuracies less than those prescribed shall invalidate the test.

Table 6 Data to be Recorded

Item	Indoor Air Enthalpy Method	Outdoor Air Enthalpy Method	Compressor Calibration Method	Refrigerant Flow Method	Outdoor Liquid Coil Method	Cooling Condensate and Indirect Airflow Measurement
Date	X	X	X	X	X	X
Observer(s)	X	X	X	X	X	X
Barometric pressure, kPa [in. Hg]	X	X	X	X	X	X
Equipment nameplate data	X	X	X	X	X	X
Test interval times, minutes	X	X	X	X	X	X
Power input to equipment, W (a)	X	X	X	X	X	X
Applied Voltage(s), V	X	X	X	X	X	X
Frequency, Hz	X	X	X	X	X	X
External resistance to airflow, Pa [in. H_2O]	X	X	X	X	X	X
Fan speed(s), setting, rpm	X	X	X	X	X	X
Dry-bulb temperature of air entering equipment, indoor side, °C [°F]	X	X	X	X	X	X
Wet-bulb temperature of air entering equipment, indoor side, °C [°F]	X	X	X	X	X	X
Dry-bulb temperature of air leaving equipment, indoor side, °C [°F]	X					X
Wet-bulb temperature of air leaving equipment, indoor side, °C [°F]	X					X
Dry-bulb temperature of air entering equipment, outdoor side, °C [°F]	X	X	X	X		
Wet-bulb temperature of air entering equipment, outdoor side, °C [°F]	X	X	X	X		
Dry-bulb temperature of air leaving equipment, outdoor side, °C [°F]		X				
Wet-bulb temperature of air leaving equipment, outdoor side, °C [°F]		X				
Throat diameter of nozzle(s), mm [in.]	X	X				
Velocity pressure at nozzle throat or static pressure difference across nozzle(s), Pa [in. H_2O]	X	X				
Temperature at nozzle throat, °C [°F]	X	X				
Pressure at nozzle throat, Pa [in. H_2O]	X	X				
Condensing pressure or temperature, kPa [psig] or °C [°F]			X	X		
Evaporating pressure or temperature, kPa [psig] or °C [°F]			X	(c)		
Temperature of refrigerant vapor entering compressor, °C [°F]			X			
Temperature of refrigerant vapor leaving compressor, °C [°F]			X			
Temperature of high side refrigerant vapor leaving reversing valve, °C [°F]			X			
Refrigerant or surface temperature used for leakage coefficient determination, °C [°F]			X			
Refrigerant-oil flow rate, kg/s [lb_m/h]				X		
Refrigerant volume in refrigerant-oil mixture, m^3/m^3 [ft^3/ft^3]				X		
Outdoor coil water flow rate, kg/s [lb_m/h]					X	
Temperature of outdoor water entering equipment, °C [°F]					X	
Temperature of outdoor water leaving equipment, °C [°F]					X	
Rate of condensate collection, kg/s [lb_m/h]						X

Refrigerant liquid temperature, indoor side, °C [°F]		(d)	X	X		
Refrigerant liquid temperature, outdoor side, °C [°F]		(d)	(d)	(d)		
Refrigerant vapor temperature, indoor side, °C [°F]		(d)	X	X		
Refrigerant vapor temperature, outdoor side, °C [°F]		(d)	(d)	(d)		
Refrigerant vapor pressure, indoor side, kPa [psig]			X	X		
Additional data			(e)	(f)		

(a) Total power input and, where required, input to equipment components.
(b) Not required for dry-coil operation.
(c) Required only during cooling capacity.
(d) Required only for line loss adjustment.
(e) Additional data required, subsection 7.6.
(f) Additional data required, subsection 7.7.

10. TEST RESULTS

10.1 Capacity Test Requirements

10.1.1 The results of a capacity test shall express quantitatively the effects produced upon air by the equipment tested. For given test conditions, the capacity test results shall include each of the following quantities that are applicable to cooling or heating and to the type of equipment tested:

(a) total cooling capacity, W [Btu/h]
(b) sensible cooling capacity, W [Btu/h]
(c) latent cooling capacity, W [Btu/h]
(d) heating capacity, W [Btu/h]
(e) indoor side airflow rate, standard air calculated using dry air specific volume v_n, m^3/s [cfm]
(f) external resistance to indoor airflow, Pa [in. H_2O]
(g) total power input to equipment or power inputs to all equipment components, W [Watts]

> ***Informative Note:*** The capacities and power inputs may not include additional fan power required to move the air.

10.1.2 When two test methods are required, the total cooling or heating (except frosting) capacity shall be the indoor side capacity of the two simultaneously conducted methods of test and these two capacities shall agree within 6.0%. When the compressor calibration method is employed, “simultaneously conducted” shall be construed to mean that the needed refrigerant property measurements are made during the capacity test while either a prior or subsequent compressor calibration test is used in determining refrigerant flow rate or, for cases described in Section 7.4.1.1(b), in determining cooling capacity.

10.1.3 When two test methods for cooling are required, the sensible and latent cooling capacities shall be those determined using the indoor air enthalpy method.

10.1.4 Heating capacity under conditions of equipment cycling due to defrost cycles shall be determined using the indoor air enthalpy method. Heating capacity shall be based on airflow and the indoor air temperature rise (or drop when defrosting) averaged with respect to time for the entire test period. In the event the indoor air fan stops during defrosting, the capacity during this interval shall be zero; but this elapsed period of time must be included in the total test period for obtaining the average temperature rise for the indoor airstream. The net result for units where defrost does not occur is the integrated capacity for the total test period. For units where defrost occurs, the net result is the integrated capacity for the total number of complete cycles during the test period. A complete cycle consists of a heating period and a defrost period from defrost termination to defrost termination.

10.1.5 Test results shall be used to determine capacities without adjustment for permissible variations in test conditions.

10.1.6 Air enthalpies used in calculating space conditioning capacities shall be evaluated for the measured ambient conditions: dry-bulb temperature, water vapor content measurements, and barometric pressure.

11. SYMBOLS USED IN EQUATIONS

11.1 The significance of terms used in this standard is provided in Table 7.

TABLE 7 Symbols

A_n = nozzle area, m^2 [ft^2]
c_{pa1} = specific heat of air entering the indoor side, J/kg$_{da}$·°C [Btu/lbm$_{da}$·°F]
c_{pa2} = specific heat of air leaving the indoor side, J/kg$_{da}$·°C [Btu/lbm$_{da}$·°F]
c_{pa3} = specific heat of air entering the outdoor side, J/kg$_{da}$·°C [Btu/lbm$_{da}$·°F]
c_{pa4} = specific heat of air leaving the outdoor side, J/kg$_{da}$·°C [Btu/lbm$_{da}$·°F]
c_{pl} = specific heat of the liquid (water), J/kg$_{da}$·°C [Btu/lbm$_{da}$·°F]
c_{pm} = specific heat of thermal storage device J/kg·°C [Btu/lbm·°F]
c_{pw} = specific heat of water J/kg·°C [Btu/lbm·°F]
C = nozzle coefficient of discharge, dimensionless
D = nozzle throat diameter, mm [in.]
D_i = Inlet plenum circular duct diameter, m [in]
D_o = Outlet plenum circular duct diameter, m [in]
D_t = diameter of refrigerant tubing, mm [in. (OD)]
E_i = power input, indoor side, W [Watts]
E_{id} = default fan power, W [Watts]
E_t = power input, total, W [Watts]
h_{a1} = enthalpy, air entering indoor side, J/kg$_{da}$ [Btu/lbm$_{da}$]
h_{a2} = enthalpy, air leaving indoor side, J/kg$_{da}$ [Btu/lbm]
h_{a3} = enthalpy, air entering outdoor side, J/kg$_{da}$ [Btu/lbm$_{da}$]
h_{a4} = enthalpy, air leaving outdoor side, J/kg$_{da}$ [Btu/lbm$_{da}$]
h_{f2} = enthalpy of refrigerant liquid leaving the condenser, J/kg [Btu/lbm]
h_{g2} = enthalpy of refrigerant vapor entering condenser, J/kg [Btu/lbm]
h_{k1} = enthalpy, steam entering calorimeter evaporator, J/kg [Btu/lbm]
h_{k2} = enthalpy, fluid leaving calorimeter evaporator, J/kg [Btu/lbm]
h_{r1} = enthalpy, refrigerant entering indoor side, J/kg [Btu/lbm]
h_{r2} = enthalpy, refrigerant leaving indoor side, J/kg [Btu/lbm]
L = length of refrigerant line, m [ft]
m = thermal storage device mass, kg [lbm]

P_n = pressure at nozzle throat, kPa [in. Hg]
P_v =velocity pressure at nozzle throat or static pressure difference across nozzle, Pa [in. H_2O]
q_{cyc} = total integrated (cyclic) capacity, J [Btu]
q'_{cyc} = net integrated (cyclic) capacity, J [Btu]
q_e = heat input to calorimeter evaporator, W [Btu/h]
q_l = line loss, interconnecting tubing, W [Btu/h]
q_{lci} = latent cooling capacity, indoor side data, W [Btu/h]

$qloss_{IA}$ = duct loss correction for the indoor air enthalpy method, W [Btu/h]
$qloss_{OA}$ = duct loss correction for the outdoor air enthalpy method, W [Btu/h]
q_{sci} = sensible cooling capacity, indoor side data, W [Btu/h]
q_{sri} = sensible reheat capacity, indoor side data, W [Btu/h]
q_{tc} = total cooling capacity, compressor data, W [Btu/h]
q_{tci} = total cooling capacity, indoor side data, W [Btu/h]
qs_{adj} = evaporator fan capacity adjustment, indoor side data, W [Btu/h]
q_{tco} = total cooling capacity, outdoor side data, W [Btu/h]
q_{th} = total heating capacity, compressor data, W [Btu/h]
q_{thi} = total heating capacity, indoor side data, W [Btu/h]
q_{tho} = total heating capacity, outdoor side data, W [Btu/h]
q_{ts} = thermal storage device capacity, J [Btu]
Q_i = airflow, indoor, calculated, m3/s [cfm]
Q_{mi} = airflow, indoor, measured, m3/s [cfm]
Q_{mo} = airflow, outdoor, measured, m3/s [cfm]
Q_s = airflow, standard air calculated using dry air specific volume v_n, m3/s [cfm]
Re = Reynolds number
t_a = temperature, ambient air, dry-bulb, °C [°F]
t_{a1} = temperature, air entering indoor side, dry-bulb, °C [°F]
$t_{a1}(\tau)$ = dry-bulb temperature of air entering the indoor coil at elapsed time τ, °C [°F]; only recorded when indoor airflow is occurring
t_{a2} = temperature, air leaving indoor side, dry-bulb, °C [°F]
$t_{a2}(\tau)$ = dry-bulb temperature of air leaving the indoor coil at elapsed time τ, °C [°F]; only recorded when indoor airflow is occurring
t_{a3} = temperature, air entering outdoor side, dry-bulb, °C [°F]
t_{a4} = temperature, air leaving outdoor side, dry-bulb, °C [°F]
t_{a5} = temperature, air leaving reheat coil, dry-bulb, °C [°F]
t_{ai} = temperature, air temperature within the indoor test room, dry-bulb, °C [°F]
t_{ao} = temperature, air temperature within the outdoor test room, dry-bulb, °C [°F]
t_c = temperature, surface, calorimeter condenser, °C [°F]
t_m = temperature, thermal storage device mass, °C [°F]
t_{l3} = temperature, liquid entering outdoor side, °C [°F]
t_{l4} = temperature, liquid leaving outdoor side, °C [°F]
t_1 = temperature, water entering calorimeter condenser, °C [°F]
t_2 = temperature, water leaving calorimeter condenser, °C [°F]
Th = insulation thickness, interconnecting tubing, mm [inch]
UA_a = product of the overall condenser-to-air heat transfer coefficient and the outside surface area of the condenser, as determined from the separate evaporator-type calorimeter test method (see 7.4.4), W/°C [Btu/h °F]
$(UA_{duct})_{1o}$ = product of the overall heat transfer coefficient and surface area for the indoor coil inlet duct that is located in the outdoor test room, W/°C [Btu/h °F]
$(UA_{duct})_{2i}$ = product of the overall heat transfer coefficient and surface area for the indoor coil outlet duct that is located in the indoor test room, W/°C [Btu/h°F]
$(UA_{duct})_{2o}$ = product of the overall heat transfer coefficient and surface area for the indoor coil outlet duct that is located in the outdoor test room, W/°C [Btu/h °F]

$(UA_{duct})_{4o}$ = product of the overall heat transfer coefficient and surface area for the outdoor coil outlet duct that is located in the outdoor test room, W/°C [Btu/h °F]
v_{ai} = specific volume of air leaving indoor side, m^3/ kg_{da} [ft^3/lbm_{da}]
v_{i1} = specific volume of air, entering indoor side, m^3/kg_{da} [ft^3/lbm_{da}]
v_n = specific volume of the dry air portion of the mixture evaluated at the dry-bulb temperature and barometric pressure at the nozzle exit, and the vapor content evaluated at the leaving conditions, m^3/kg_{da} [ft^3/lbm_{da}]
v_{nsp} = specific volume of the dry air portion of the mixture evaluated at the dry-bulb temperature at the nozzle exit and the vapor content evaluated at the leaving conditions, but at standard barometric pressure, m^3/kg_{da} [ft^3/lbm_{da}]
v'_n = specific volume of air at the nozzle, m^3/kg [ft^3/ lbm] of air-water vapor mixture
V = velocity of air, at nozzle, m/s [fpm]
V_{ro} = volume flow rate, refrigerant-oil mixture, m^3/s [ft^3/h]
w_{ai} = mass flow rate, indoor dry air, kg_{da}/s [lbm_{da}/h]
w_c = mass flow rate, indoor coil condensate, kg/s [lbm/h]
w_k = mass flow rate, fluid condensate (steam), kg/s [lbm/h]
w_r = mass flow rate, refrigerant, kg/s [lbm/h]
w_l = mass flow rate, liquid, kg/s [lbm/h]
w_{ro} = mass flow rate, refrigerant oil mixture, kg/s [lbm/h]
w_w = mass flow rate, water, kg/s [lbm/h]
W_1 = humidity ratio, air entering indoor side, kg water vapor per kg of dry air [lbm_{wv}/lbm_{da}]
W_2 = humidity ratio, air leaving indoor side, kg water vapor per kg of dry air [lbm_{wv}/lbm_{da}]
W_3 = humidity ratio, air entering outdoor side, kg water vapor per kg of dry air [lbm_{wv}/lbm_{da}]
W_4 = humidity ratio, air leaving outdoor side, kg water vapor per kg of dry air [lbm_{wv}/lbm_{da}]
W_n = humidity ratio at the nozzle, kg water vapor per kg of dry air [lbm_{wv}/lbm_{da}]
W_1 = humidity ratio, air entering indoor side, kg_{wv}/kg_{da} [lbm_{wv}/lbm_{da}]
W_2 = humidity ratio, air leaving indoor side, kg_{wv}/kg_{da} [lbm_{wv}/lbm_{da}]
W_3 = humidity ratio, air entering outdoor side, kg_{wv}/kg_{da} [lbm_{wv}/lbm_{da}]
W_4 = humidity ratio, air leaving outdoor side kg_{wv}/kg_{da} [lbm_{wv}/lbm_{da}]
W_n = humidity ratio at the nozzle, kg_{wv}/kg_{da} [lbm_{wv}/lbm_{da}]
x = mass ratio, refrigerant to refrigerant-oil mixture
ρ = density of refrigerant, kg/m^3 [lbm/ft^3]
Δt = temperature difference, °C [°F]
Γ = the integrated (with respect to elapsed time) air temperature difference across the indoor coil, °C·h [°F·h]
θ = time (cyclic tests), h
Θ_1 = for ducted systems, the elapsed time when airflow is initiated through the Indoor coil; for non-ducted systems, the elapsed time when the compressor is on, h
μ = dynamic air viscosity, kg/m·s [lbm/ft·s]
τ = time (defrost tests), h
τ_1 = the elapsed time when the defrost termination occurs that begins the official test period, h
τ_2 = the elapsed time when the last defrost termination occurs, h; if no defrost cycles occur during the data collection interval, τ2 equals the elapsed time for the total data collection interval

12. REFERENCE PROPERTIES AND DATA

12.1 Thermodynamic Properties of Dry and Moist Air. The thermodynamic properties of dry and moist air shall be obtained from ASHRAE Research Project RP-1485[a].

12.2 Thermodynamic Properties of Liquids. The thermodynamic properties of liquids shall be obtained from NIST Standard Reference Database 23 (*REFPROP*)[b] or from the source of the liquid and shall be recorded in the test report.

12.3 Thermodynamic Properties of Refrigerants. The thermodynamic properties of refrigerants shall be obtained from NIST Standard Reference Database 23 (*REFPROP*)[b] or from the source of the refrigerant and shall be recorded in the test report.

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a. Herrmann, S., H.-J. Kretzschmar, and D.P. Gatley, ASHRAE RP-1485, *Thermodynamic Properties of Real Moist Air, Dry Air, Steam, Water, and Ice*, 2008, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.

b. NIST Standard Reference Database 23: *NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP) Version 10,* National Institute of Standards and Technology, Gaithersburg, MD.

13. REFERENCES

[1]*ANSI/ASHRAE Standard 41.1-2013, Standard Method for Temperature Measurement*, American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

[2]*ANSI/ASHRAE Standard 41.6-2014, Standard Method for Measurement of Moist Air Properties*, American Society of Heating, Refrigerating, and Air- Conditioning Engineers.

[3]*ANSI/ASHRAE Standard 41.3-2014, Standard Method for Pressure Measurement*, American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

[4]*ANSI/ASHRAE Standard 41.11-2020, Standard Methods for Power Measurement,* American Society of Heating, Refrigerating, and Air-Conditioning Engineers

[5]*ANSI/ASHRAE Standard 41.2-2018, Standard Method for Air Velocity and Airflow Measurement*, American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

[6]Bohanon, H.R., "Fan Test Chamber-Nozzle Coefficients," *ASHRAE Transactions*, Vol. 81, Part 1 (formerly ASHRAE paper No. 2334, 1975), American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA 30329 USA.

[7]*ASHRAE Standard 23.1-2019, Methods for Performance Testing Positive Displacement Refrigerant Compressors and Condensing Units that Operate at Subcritical Pressure of the Refrigerant*, American Society of Heating, Refrigerating and Air-Conditioning Engineers.

[8]*ANSI/ASHRAE Standard 41.9-2018, Standard Methods for Refrigerant Mass Flow Measurements Using Calorimeters,* American Society of Heating, Refrigerating, and Air-Conditioning Engineers

[9]*ANSI/ASHRAE Standard 41.4-2015, Standard Method for Measuring the Proportion of Lubricant in Liquid Refrigerant,* American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

[10] *2017 ASHRAE Handbook—Fundamentals,* American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

[11]*AHRI Standard 210/240-2017 with Addendum 1, Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment*, AHRI, 2311 Wilson Boulevard, Suite 400, Arlington, VA 22203

[12]*ANSI/ASHRAE Standard 41.10-2020, Standard Methods for Refrigerant Mass Flow Measurements Using Flowmeters,* American Society of Heating, Refrigerating, and Air-Conditioning Engineers

[13]*ANSI/ASHRAE Standard 41.8-2016 (RA 2019), Standard Methods for Liquid Flow Measurement,* American Society of Heating, Refrigerating, and Air-Conditioning Engineers