BSR/ASHRAE Standard 40-2014R

Public Review Draft

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

First Public Review (September 2024)
(Complete Draft for Full Review)

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).

The appearance of any technical data or editorial material in this public review document does not constitute endorsement, warranty, or guaranty by ASHRAE of any product, service, process, procedure, or design, and ASHARE expressly disclaims such.

ASHRAE, 180 Technology Parkway, Peachtree Corners, GA 30092

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

This revision of the 2014 version is a substantial update of the standard. Additionally, this new version meets ASHRAE's mandatory language requirement.

PURPOSE

1.1 This standard provides test methods for determining the heating and cooling output capacities and energy inputs of unitary air-conditioning and heat pump equipment that is heat-operated (see Section 3, "Definitions").

1.2 These test methods may be used as a basis for rating such equipment, but it is not the purpose of this standard to specify methods of establishing ratings.

SCOPE

2.1 This standard applies to heat-operated unitary air conditioners and heat pumps consisting of one or more assemblies, including engine-driven systems. Where such equipment is provided in more than one assembly, the separate assemblies are designed to be used together.

2.2 Equipment within the scope of this standard may be classified as follows:

a. Component arrangements:
    1. factory-assembled equipment employing heat-operated or mechanical refrigeration cycle or cycles (e.g., a packaged unit)
    2. equipment employing a heat-operated or mechanical refrigeration cycle with indoor and outdoor sections in separate assemblies (e.g., a split system)
    3. equipment employing a heat-operated or mechanical refrigeration cycle as a liquid chiller with cooling coil in separate assembly (e.g., chiller)
    4. equipment employing refrigeration cycles and heating functions (e.g., chiller/heater)
b. Method of providing air circulation through indoor section:
    1. with circulating fan incorporated with indoor assembly
    2. without circulating fan, for use with separate fan or air handler, or with heating equipment incorporating a fan
c. Medium for heat transfer to or from the outdoors:
    1. air
    2. water (or brine)
    3. evaporatively cooled condenser (cooling only)

2.3 This standard does not include methods of testing the following types of equipment:

a. heat-operated absorption and engine-driven liquid chillers not part of a unitary air conditioner or heat pump
b. electrically driven unitary air conditioners or heat pumps
c. refrigerating systems employing the Peltier effect
d. desiccant-based cooling systems

3. DEFINITIONS AND SYMBOLS

accuracy: the degree of conformity of an indicated value to the corresponding *true value*.

equivalent diameter: the diameter of a circle having the same area as a rectangular area.

error: the difference between the observed value of the measurand and its corresponding *true value*.

random error: the portion of the total error that varies randomly in repeated measurements of the *true value* throughout a test process.

systematic error: the portion of the total error that remains constant in repeated measurements of the true value throughout a test process.

true value: the unknown, error-free value of a test result.

uncertainty: the limits of error within which the *true value* lies.

unit under test (UUT): equipment that is the subject of performance testing.

4. CLASSIFICATIONS

4.1 Heat-operated unitary air-conditioning and heat pump equipment within the scope of this standard are classified as follows:

4.1.1 Operating Principles

a. Continuous cycle
b. Batch process cycle

4.1.2 Component Arrangements

a. factory-assembled equipment employing heat-operated or mechanical refrigeration cycle or cycles (for example, a packaged unit)
b. equipment employing a heat-operated or mechanical refrigeration cycle with indoor and outdoor sections in separate assemblies (for example, a split system)
c. equipment employing a heat-operated or mechanical refrigeration cycle as a liquid chiller with cooling coil in separate assembly (for example, a chiller)
d. equipment employing refrigeration cycles and heating functions (for example, a chiller/heater)

4.1.3 Method Of Providing Air Circulation Through Indoor Section

a. with circulating fan incorporated with indoor assembly
b. without circulating fan, for use with separate fan or air handler, or with heating equipment incorporating a fan

4.1.4 Medium For Heat Transfer To Or From The Outdoors

a. air
b. water (or brine)
c. evaporatively cooled condenser (cooling only)

4.2 This Standard Does Not Include Methods Of Testing The Following Types Of Equipment:

a. heat-operated absorption and engine-driven liquid chillers not part of a unitary air conditioner or heat pump
b. electrically driven unitary air conditioners or heat pumps
c. refrigerating systems employing the Peltier effect
d. desiccant-based cooling systems

5. INSTRUMENTS AND MEASUREMENTS

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

5.2 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.

5.3 Instruments shall be applied and used in accordance with the following standards:

a. Temperature – ASHRAE Standard 41.1-2024[1] for dry-bulb temperatures except use ASHRAE Standard 41.1-2013[15] Sections 5.3.2 through 5.3.7 for air mixing methods.

b. Air Velocity and Airflow – ASHRAE Standard 41.2-2022[2]

c. Pressure – ASHRAE Standard 41.3-2022[3]

d. Humidity – ASHRAE Standard 41.6-2021[4] for wet-bulb temperatures

e. Gas Flow – ASHARAE Standard 41.7-2021[8]

f. Liquid Flow – ASHRAE Standard 41.8-2019[5]

g. Refrigerant Flow – ASHRAE Standard 41.10-2024[6]

h. Power – ASHRAE Standard 41.11-2023[7]

i. Fuel Higher Heating Value - ASHRAE Standard 41.13-2023[16]

5.4 Instrument Accuracy Requirements and Measurement Methods. Measuring instruments shall be selected to meet or exceed the instrument accuracy or measurement uncertainty listed in Table 5-1 for each type of measurement. Instruments and measurement methods shall comply with the ASHRAE measurement standards listed in Table 5-1.

Table 5-1: Test instrument requirements and measurement methods

Type of Measurement	Purpose	Required Accuracy	Standard
Temperature	Air Dry-bulb, Steady	±0.1 ºC (0.2 ºF)	ASHRAE 41.1[1]

	Air Dry-bulb, Cyclic	±0.16 ºC (0.3 ºF)[1]	
	Refrigerant	±0.6 ºC (1 ºF)	
	Water and Coolants	±0.1 ºC (0.2 ºF)	
Wet-bulb Temperature	Water Vapor Content	±0.1 ºC (0.2 ºF)	ASHRAE 41.6[4]
Dew Point Temperature	Water Vapor Content	±0.2 ºC (0.4 ºF)	
Relative Humidity	Water Vapor Content	±1.2% RH	
Pressure	Barometric Pressure	±100 pa (0.030 in. Hg)	ASHRAE 41.3[3]
	Refrigerant and Liquid	±1.0% of the reading, or 0.5 psig if greater	
	Nozzle pressure difference and nozzle exit velocity pressure	±1% of reading	
	Air duct static pressure	±2.5 Pa (±0.01 in. of water)	
Power Input: -Electrical Power Input -Shaft Power Input	System components	±1% of reading	ASHRAE 41.11[17]
	Standby power for measurements less than 50W	± 0.5 W	
	Heaters and apparatus furnishing heat loads	±1% of reading	
	Total System Power Input	±1.0% of reading	
Voltage	Equipment Input Voltage	±1.0% of reading	
Velocity	Air Velocity	±3% of reading or ±0.015 m/s (±3 ft/min) if greater	ASHRAE 41.2[2]
Flow	Airflow	±1.0% of reading	ASHRAE 41.2[2]
	Refrigerant Flow	±1.0% of reading	ASHRAE 41.10[6]
	Gaseous Flow	±1.0% of reading	ASHRAE 41.7[8]
	Liquid Flow	±1.0% of reading	ASHRAE 41.8[5]

Rotational Speed	Fan Speed	±1.0% of reading	Not Applicable
Time	Any	±0.1% of the elapsed time measured	Not Applicable
Mass	Condensate	±1.0% of the reading, or 22.68 g (0.05 lb_m) if greater	Not Applicable
Higher Heating Value	Fuel	±2%of reading	ASHRAE 41.13[16]

Total System Output Capacity – note (a)	Example: Where total system output capacity is secondary liquid heating loop wpg*cpl*(twss-twsr)	±2.5% of reading	Where parameters wpg, cpl, twss, twsr are each compliant with all ASHRAE 41 requirements per 5.3
Total System Input Power - note (b)	Gas + Electric	+/- 1.75% of reading	Where parameters Gas flow, HHV, & electric power consumption are each compliant with all ASHRAE 41 requirements per 5.3
System Efficiency: COP total – note (c) Total System Output Capacity (BTU) / Total System Input Power	Total System Output Capacity / Total System Input Power	+/- 4.25% (+/- 4.4% @95% confidence)	Select all parameter measurement devices to measure COP with 95% confidence interval

Notes:
a. reference 11.1 Symbols used in equations
b. reference subparagraph 8.6.3 for input power equations
c. compliance to all ASHRAE 41 standards, Section 8 uncertainty calculation, requirement, & analysis shall be applicable to all direct or indirect system capacity calculations conducted per Section 7 of this standard.

5.5 Fluid Properties

5.5.1 Thermodynamic Properties of Air. The thermodynamic properties of the dry air and moist air shall be obtained from ASHRAE RP-1485[12].

(Informative Note: Software based upon ASHRAE RP-1485[A3] is available.)

5.5.2 Air Dynamic Viscosity. Calculate the dynamic viscosity of air behaving as an ideal gas at moderate pressures and temperatures using Equation 5-1 for SI units or Equation 5-2 for IP units.

$$\mu = (17.23 + 0.048\ t_1) \times 10^{-6} \quad (5\text{-}1)$$

where

μ = dynamic viscosity, kg/(m-s)

t_1 = nozzle inlet temperature, °C

$$\mu = (11.00 + 0.018\ t_1) \times 10^{-6} \quad (5\text{-}2)$$

where

μ = dynamic viscosity, lb_m/(ft-s)

t_1 = nozzle inlet temperature, °F

5.5.3 Refrigerant Properties. Refrigerant properties shall be obtained from *NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP)*[13] or from the refrigerant supplier if a constituent of the refrigerant being tested is not included in REFPROP.

5.6 Fuel Higher Heating Values. Apply ASHRAE 41.13[16] to obtain the higher heating value for fuels including natural gas, commercial propane, manufactured gas, and bio-derived gas.

5.7 Air Sampling Tree Requirements. An example of an air sampling tree is shown in Figure 5-1. The air sampling tree shall be constructed of plastic, stainless steel, or other rigid materials. The air sampling tree 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. Sizes for the air sampling tree shall be scaled accordingly with the following requirements:

1. Minimum hole density of 6 holes per 0.92 m^2 (1 ft^2) of area to be sampled
2. Sampler branch tube spacing = 60 ± 7.62 mm (2.36 ± 0.30 in.)
3. Manifold trunk to branch diameter ratio having a minimum of 3:1 ratio
4. Hole spacing shall be equally distributed over the branch. Use 1/2 hole spacing from the closed end to the nearest hole.
5. Nominal individual hole-to-branch diameter ratio of 1:2 and maximum individual hole-to-branch diameter ratio of 1:3.

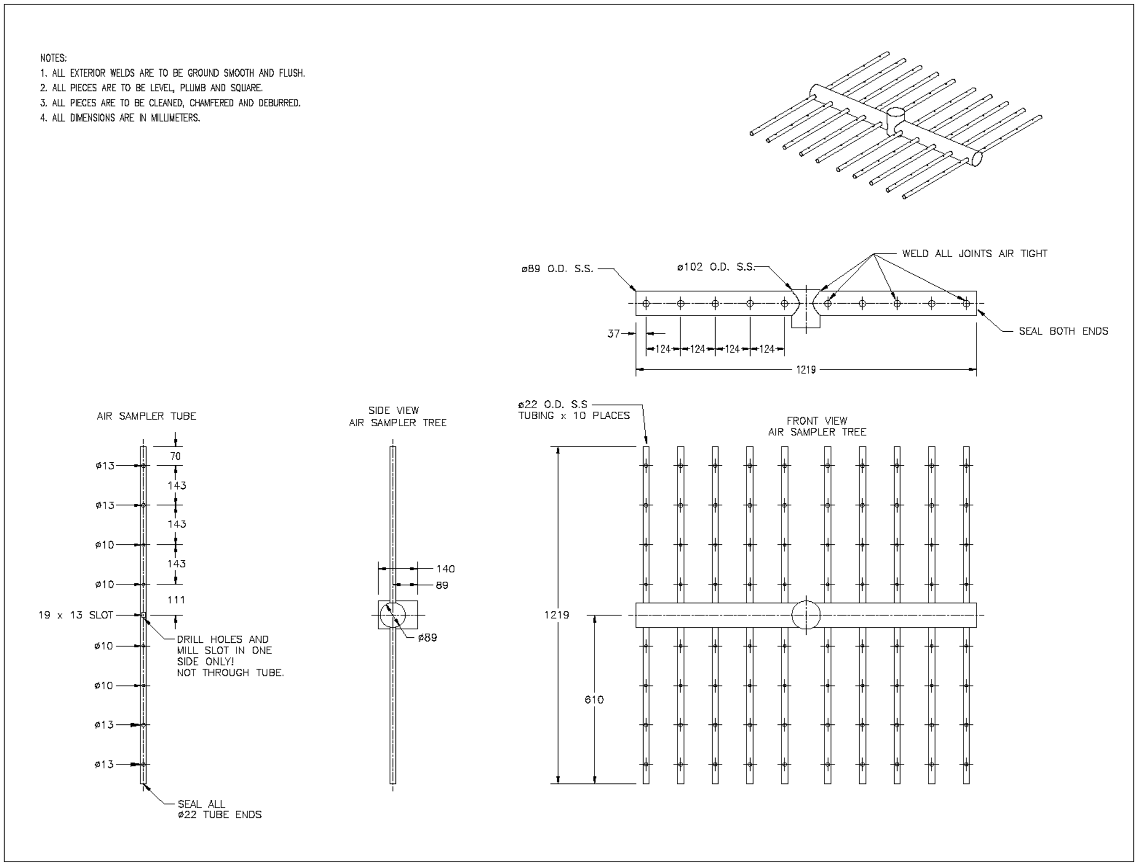

Figure 5-1 An Example of an Air Sampling Tree

The minimum average velocity through the air sampling tree holes shall be 0.762 m/s (2.5 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.

5.8 Aspirating Psychrometer Requirements. The inlet of the aspirating psychrometer is connected to the air sampling tree outlet. The aspirating psychrometer consists of a flow section and a fan to draw air through the flow section and instruments to measure the static pressure, wet-bulb temperature, and dry bulb temperature of the sampled air stream. An example of an aspirating psychrometer is shown in Figure 5-2.

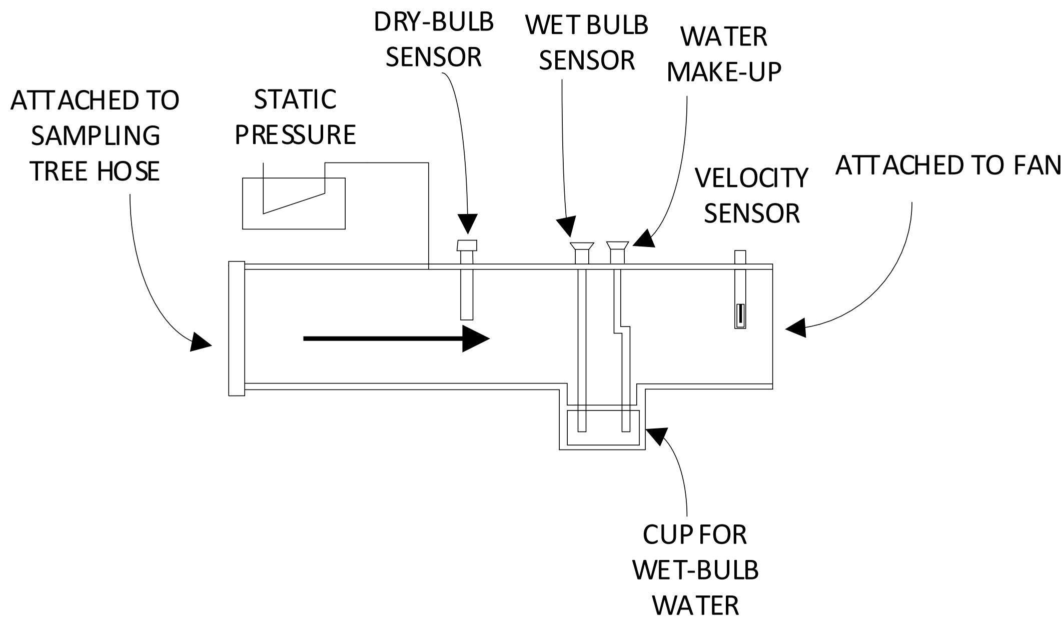

Figure 5-2 An Example of an Aspirating Psychrometer

If the wet-bulb psychrometer is designed in accordance with Section 7.1 of ASHRAE Standard 41.6[4], the wet-bulb temperatures shall be read only when the air velocity is 3.5±0.18 m/s (690±50 ft/min) over the wet-bulb sensor, and only when evaporative equilibrium of the sensor has been attained.

If the wet-bulb psychrometer is not designed in accordance with Section 7.1 of ASHRAE Standard 41.6[4], the wet-bulb temperatures shall be read only when the air velocity is 3.56 to 10 m/s (700 to 2000 ft/min) over the wet-bulb sensor, and only after evaporative equilibrium of the sensor has been attained.

The aspirating psychrometer shall be made from plastic, aluminum, or other rigid materials. Outside diameters range from 50.8 mm (2 in) diameter to 152.4 mm (6 in.).

The air drawn through the aspirating psychrometer shall be returned to the UUT airstream downstream of the air sampling tree.

5.9 Static Pressure Taps. Static pressure taps shall be constructed as defined in Figure 5-3 and shall be located around the duct perimeter in a measurement plane with (a) one pressure tap located on each surface of a rectangular duct and centered within ±10% of the width of the surface, or (b) four pressure taps shall be located with one pressure tap at each 90 degrees of circumference within ±10 degrees.

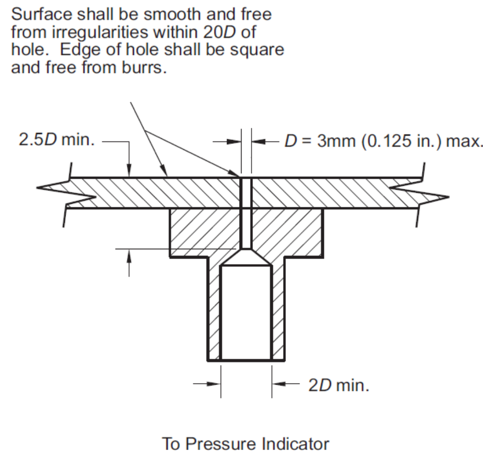

Figure 5-3 Static pressure tap construction requirements

5.10 Piezometer Ring

5.10.1 Piezometer Ring Requirements. Piezometer ring is the name given to the static pressure manifolds that provide an average static pressure at a given measurement plane. Piezometer rings shall be installed as illustrated in Figure 5-4 with the following constraints:

a. The four tubing segments (A + B) shall have equal lengths within ±10%.

b. The four tubing segments C shall have equal lengths within ±10%.

c. The tubing segments (D + E) and (F + G) shall have equal lengths within ±10%.

d. The tubing segments (H + J) and (K + L) shall have equal lengths within ±10%.

e. The four tubing segments M shall have equal lengths within ±10%.

f. The four tubing segments N shall have equal lengths within ±10%.

g. Tubing shall be made from metal or plastic with a pressure rating not less than 1480 kPa (200 psig) to pass the installed piezometer ring pressure leak test procedures prescribed in Section 5.12.2.

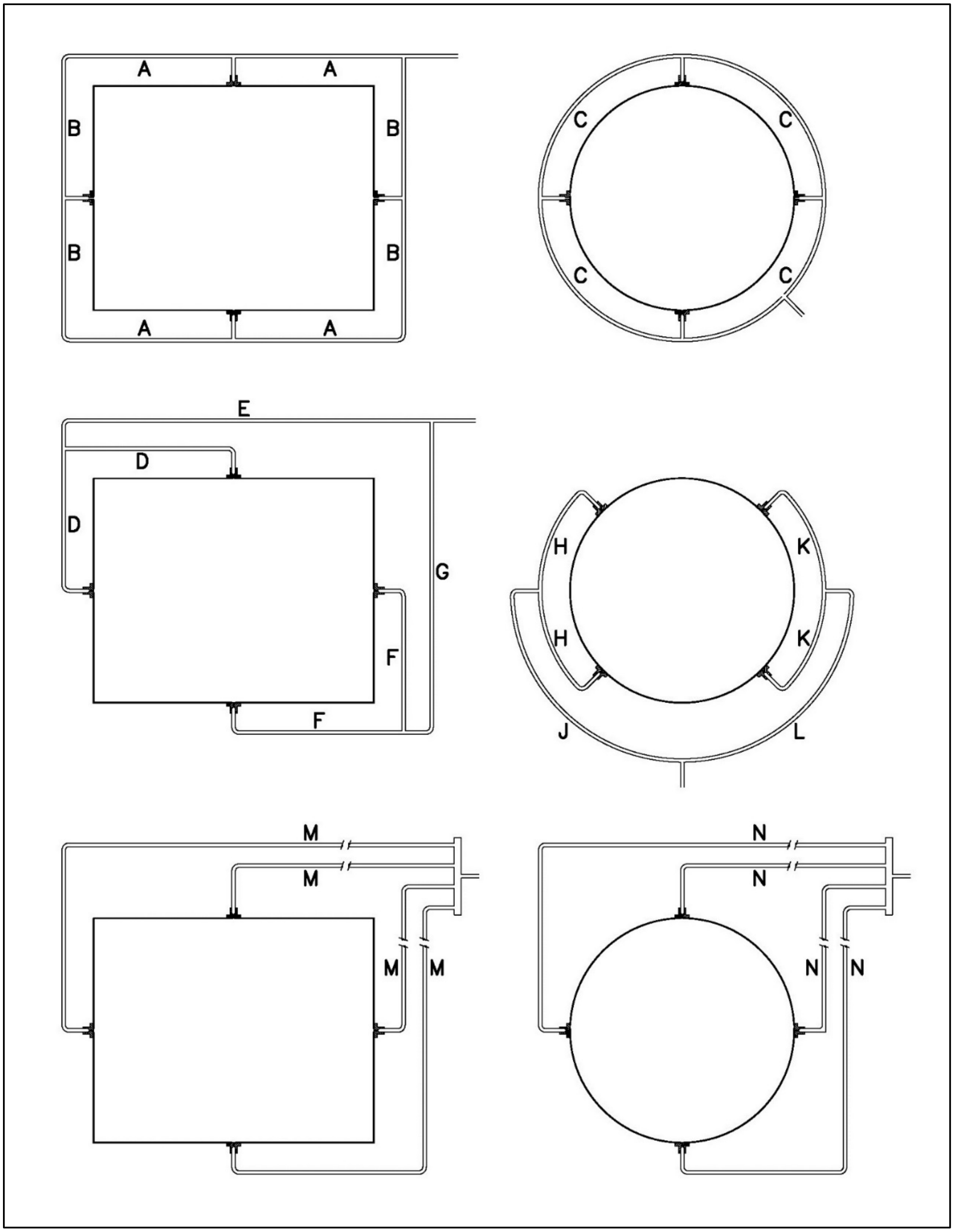

Figure 5-4 Piezometer ring connection alternatives

5.10.2 Piezometer Ring Leak Test Procedures.

5.10.2.1 Disconnect each barometric pressure sensor and each differential pressure sensor in the installed piezometer ring assembly. Use one of the open tube ends to pressurize the assembly in compliance with Figure 5-5. Plug the remaining open tube ends.

5.10.2.2 Connect the open end of the tube into a source of regulated compressed air or compressed nitrogen as illustrated in Figure 5-5 that has (a) an integral pressure gauge at the connection and (b) a dew point temperature no more than -40°C (-40°F) at a pressure not less than 136 kPa (5 psig) and not more than 170 kPa (10 psig).

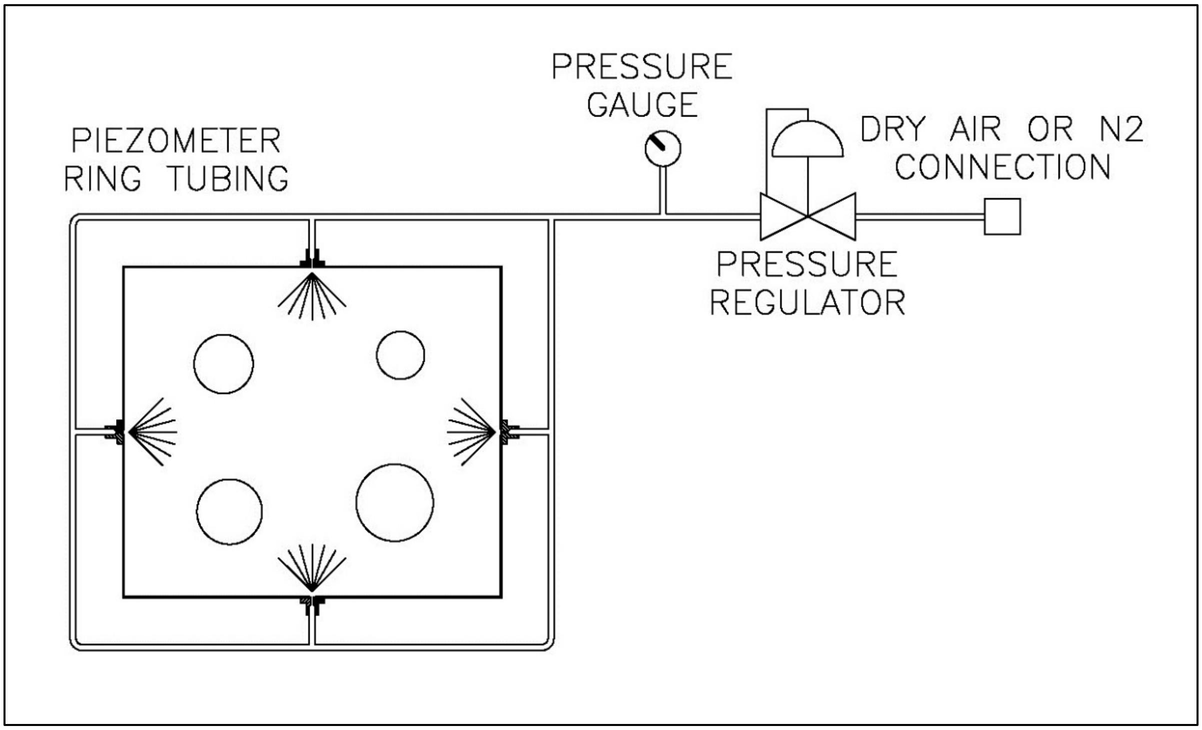

Figure 5-5 Piezometer leak test setup illustration

5.10.2.3 Apply a leak test liquid solution to the perimeter of each tubing connection and fitting in the installed piezometer assembly. Bubbles in the leak test solution indicate leaks. Repair the installed piezometer assembly to eliminate the leaks that are found using this procedure, and repeat this leak test procedure until the installed piezometer ring assembly is leak-free.

5.10.2.4 Release the leak test pressure, disconnect the source of compressed air or compressed nitrogen, and re-install each barometric pressure sensor and each differential pressure sensor.

5.11 Equivalent Diameter. The unit under test (UUT) ducts are either round or rectangular. For round ducts, the equivalent diameter D_E is equal to the interior diameter D. For rectangular ducts with interior width and height dimensions equal to a and b respectively, the equivalent diameter shall be obtained from Equation 5-1.

$$D_E = \sqrt{\frac{4ab}{\pi}} \qquad (5\text{-}1)$$

where

D_E = equivalent diameter, dimensionless
a = interior width, m (ft)
b = interior height, m (ft)

5.12 Enthalpy and Pressure Measurement Apparatus. Example 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 pressure drop shall be provided.

5.12.1 Indoor Apparatus Overall Construction and Implementation

5.12.1.1 The test apparatus for air distribution is a physical arrangement of dampers, mixers, thermopile or thermocouple grids, nozzles, sampling trees, and ducts. Dampers, bends, sampling trees, and transitions shall be located outside pressure-measuring locations, as shown in Figures 5-11, 5-12, and 5-13 in both the inlet and outlet air ducts.

5.12.1.2 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), when a negative pressure of 0.25 kPa (1 in. of water) is maintained at the apparatus exit location.

5.12.1.3 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-h)/Btu). For coil-only units not employing an enclosure, the coil shall be tested with an enclosure constructed of 25.4 mm (1 in.) fiberglass duct board. Any extra insulating or sealing shall not be employed for units with enclosures or cabinets. Duct losses shall be calculated using proper conduction factors, inside air and outside ambient temperature difference, and the total duct surface area between the unit and the temperature measurement location. Ducts that are exposed to multiple ambient temperatures shall be divided into zones and each zone calculated separately.

5.12.2 Air Sampling Requirements

5.12.2.1 The nominal face area of the airflow shall be divided into a number of equal area sampling rectangles with aspect ratios not greater than 2 to 1. Each rectangular area shall have one air sampling tree.

5.12.2.2 The air sampler trees shall be located at the geometric center of each equal area sampling rectangle; either horizontal or vertical orientation of the branches is allowed. A maximum of four (4) air sampling trees shall be connected to each aspirating psychrometer.

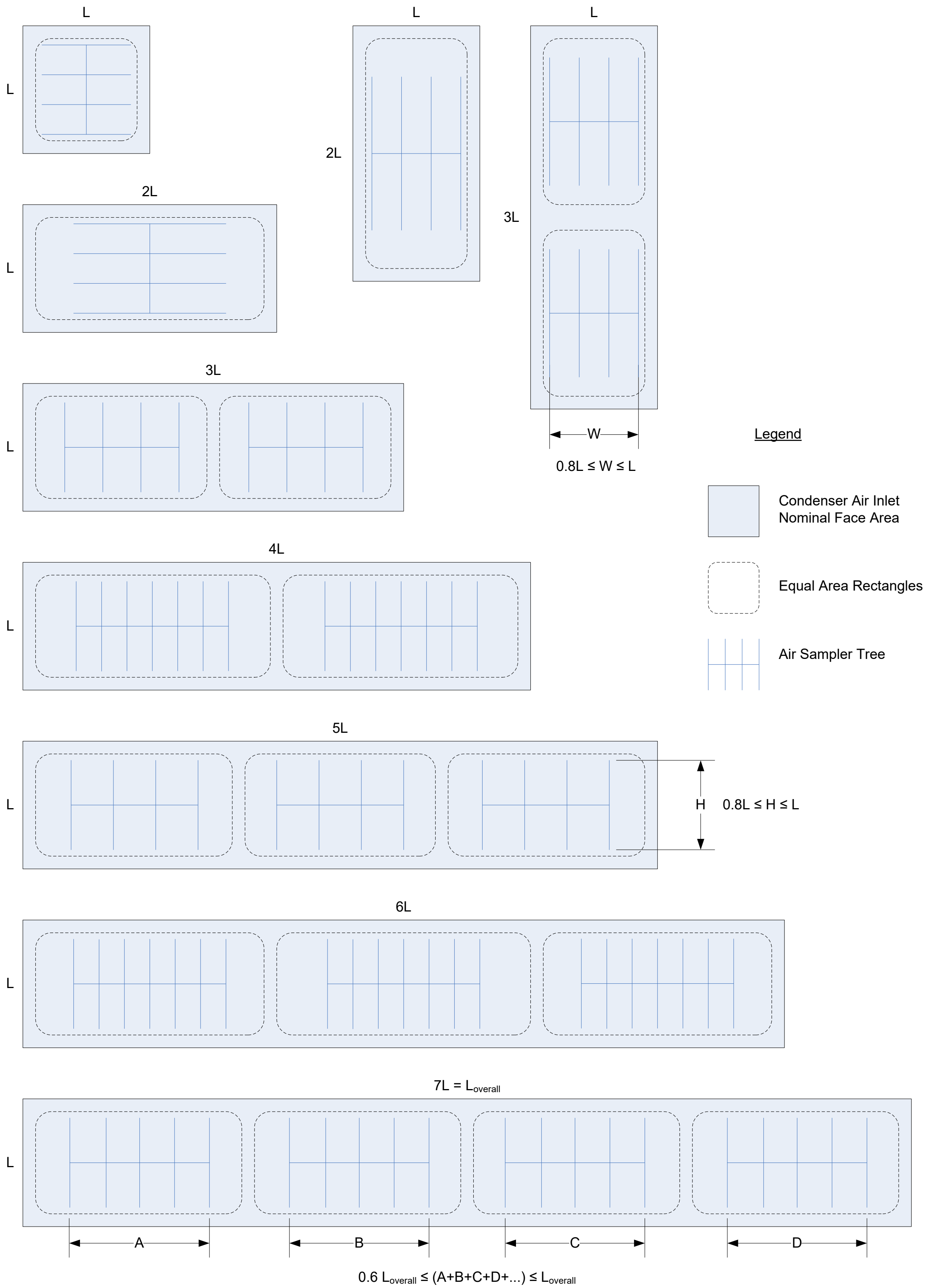

Figure 5-6 Determination of measurement rectangles and required number of air sampling trees

5.12.2.3 Outdoor Inlet Air Sampling Requirements

5.12.2.3.1 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-K)/W (4 ft^2-°F-h)/Btu) and shall not come within 50.8 mm (2 in.) of the chamber floor.

5.12.2.3.2 For the outdoor air inlet location, multiple temperature measurements shall be used to determine air distribution and the mean air temperature.

5.12.2.3.3 The outdoor air inlet air sampling tree shall be equipped with a thermocouple 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 152.4 - 609.6 mm (6-12 in) of the unit to minimize the risk of damage to the unit while making certain that the air sampling tubes are measuring the air going into the unit rather than the room air around the unit, and measures shall be taken to assure that the upper sampling holes are not pulling in the discharge air leaving the outdoor section of the unit under test. Any sampler holes directly exposed to condenser discharge air shall be blocked to prevent sampling.

5.12.2.3.4 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 shall cover at least 80% of the width and 60% of the height of the air entrance (for tall vertical coils). The air sampler tree is permitted to be larger than the face area of the side being measured. 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 aspirated psychrometers shall meet the velocity, temperature, and pressure measurement requirements specified in Section 5.10. Install a thermopile or thermocouple grid on each rectangular area where an air sampling tree is not installed.

For units with a nominal air inlet face area less than or equal to 6 m^2 (64.6 ft^2) and with one to four air sampling trees, a minimum of one aspirating psychrometer shall be used. 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 aspirated psychrometers shall be used. If the number of equal area sampling rectangles require more than eight (8) air sampling trees, additional aspirating psychrometers shall be used. Alternatively, eight (8) air sampling trees shall be used on the largest rectangular areas, provided air sampling tree(s) are used on each side of test unit that has air inlets, and the aspirated psychrometers are connected to air sampling tree(s) on opposing sides.

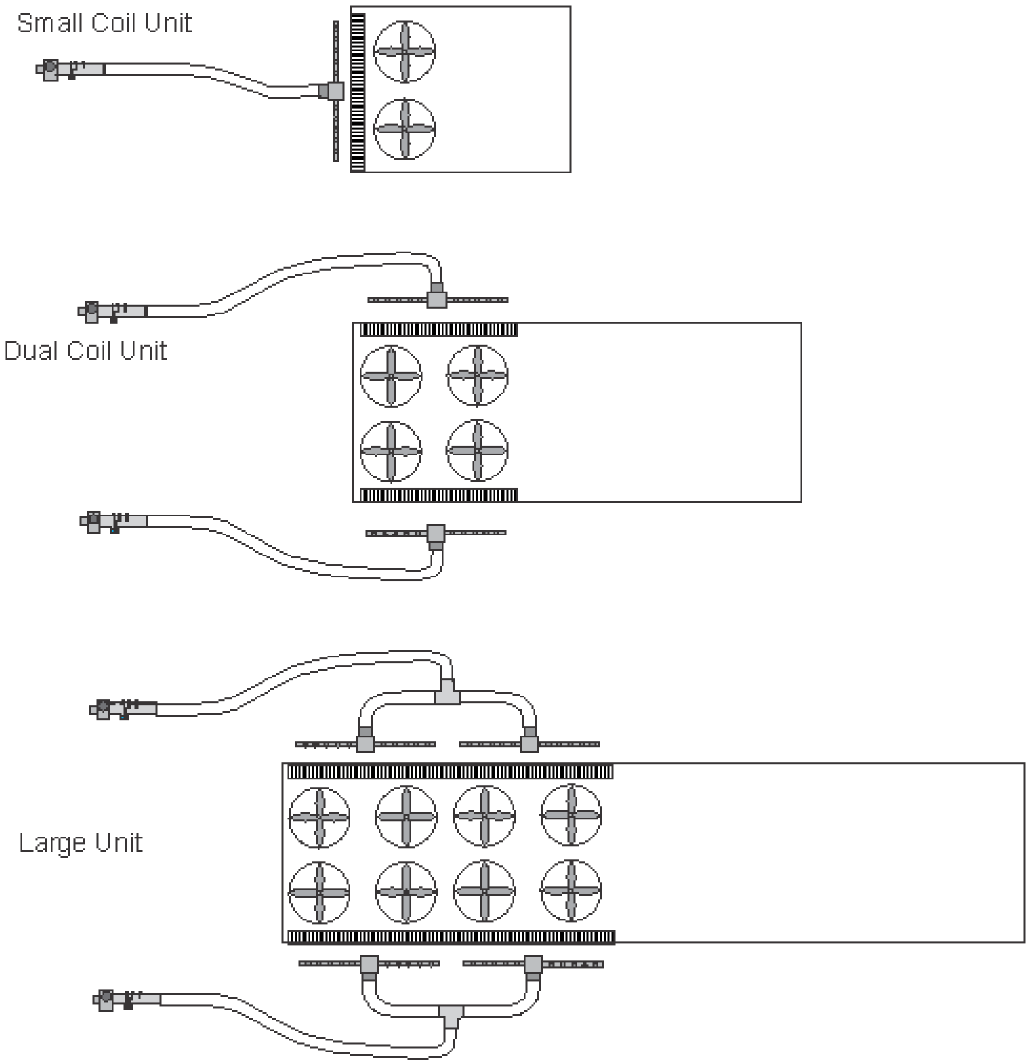

Figure 5-7 Example Test Setup Configurations

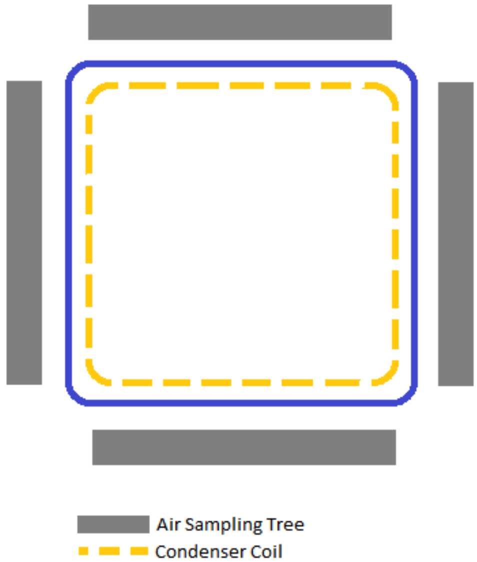

Figure 5-8 Single Module Air Sampling Tree Placement Example

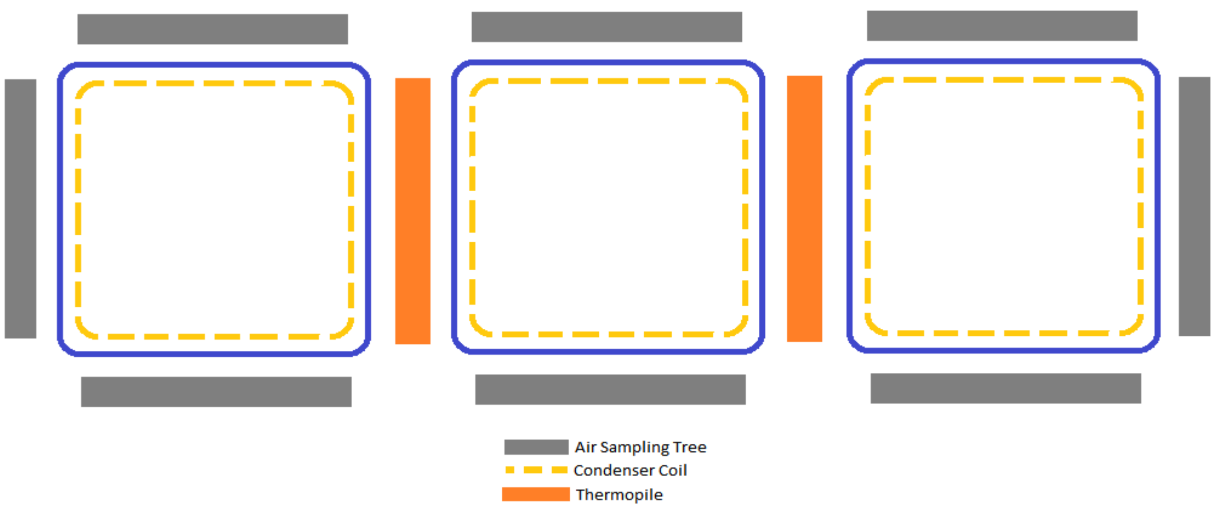

Figure 5-9 Multiple Module Air Sampling Tree Placement Example

5.12.3 Indoor Inlet Air Sampling Requirements

Follow the requirements for outdoor inlet air sampling requirements as described in Section 5.13.1, except for the following:

a. 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.

b. 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 dry-bulb temperature measurement 152.4 ± 25.4 mm (6 ± 1 in.) upstream from the inlet of each indoor coil that is being sampled.

5.12.3.1 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 152.4 ± 25.4 mm (6 ± 1 in.) from the inlet of each indoor coil.

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

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

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

5.12.3.5 Inlet air aspirated psychrometer 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. Locations of thermocouple grids and air samplers for measuring temperatures are shown in Figures 5-4, 5-5, 5-6, 5-7, 5-8, and 5-9.

5.13 Cyclic Damper (Optional)

5.13.1 Use an inlet and outlet air damper box or airflow prevention device when conducting cyclic tests on ducted systems. Use an outlet air damper box or airflow prevention device when testing heat pumps, both ducted and non-ducted, that cycle the indoor fan off during defrost cycles unless there are other means for preventing natural or forced convection through the indoor unit when the indoor fan is off.

5.13.2 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 a short transition duct section to connect the damper box with the 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..

5.13.3 Cyclic 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 5 seconds after the aspirated psychometer is de-energized. The air pressure difference (ΔP) at the nozzle shall be within 2% of steady ΔP within 15 seconds from the time the aspirated psychometer is reenergized.

5.13.4 An outlet air damper box, if used, shall be installed within the interconnecting duct at a location upstream of the location where air from the aspirated psychrometer 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 566.3369 L/min (20 cfm) when a negative pressure of 248.84 pa (1.0 in. of water) is maintained at the outlet.

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

5.14.1 Inlet Plenum

5.14.1.1 If space within the test room permits, a full inlet duct connection shall be installed. If used, the inlet duct shall have cross-sectional dimensions equal to those of the equipment and a length of 1.5 equivalent diameters, $1.5\sqrt{\frac{\pi D_i^2}{4}}$ for circular ducts or $1.5\sqrt{C \times D}$. The static pressure measurement plane is located 0.5 equivalent diameters, $0.5\sqrt{\frac{\pi D_i^2}{4}}$ for circular ducts or $0.5\sqrt{C \times D}$ upstream of the unit inlet connection with a tolerance of ±10%. The length of the inlet duct, $1.5\sqrt{C \times D}$, is a minimum dimension. For more precise results, use $4\sqrt{C \times D}$ if the test room permits.

5.14.1.2 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 152.4 mm (6 inches). Four static pressure taps shall be located in the center of each face with a tolerance of ±10%. This inlet duct shall be connected directly to the inlet of the unit.

5.14.2 Outlet Plenum

5.14.2.1 If space within the test room permits, a full outlet plenum shall be attached to the outlet of the discharge side of the equipment. This plenum shall have cross-sectional dimensions equal to the dimensions of the equipment outlet and fabricated as shown by the setups given in Figures 5-11, 5-12, and 5-13, and discharges into the mixer, if used, prior to the air sampling section upstream of the airflow measurement device.

The discharge plenum duct shall be 2.5 equivalent diameters, $2.5\sqrt{\frac{\pi D_o^2}{4}}$ for circular ducts, or $2.5\sqrt{A \times B}$.

The static pressure measurement plane is located 2.0 equivalent diameters,
$2.0\sqrt{\frac{\pi D_o^2}{4}}$ or circular ducts or $2.0\sqrt{A \times B}$ downstream of the unit inlet connection with a tolerance of ±10%.

5.14.2.2 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 as shown in Figure 5-14. The dimensions of the duct connected to the outlet of the elbow and the location of the static measurement plane are as shown in Figure 5-14 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.

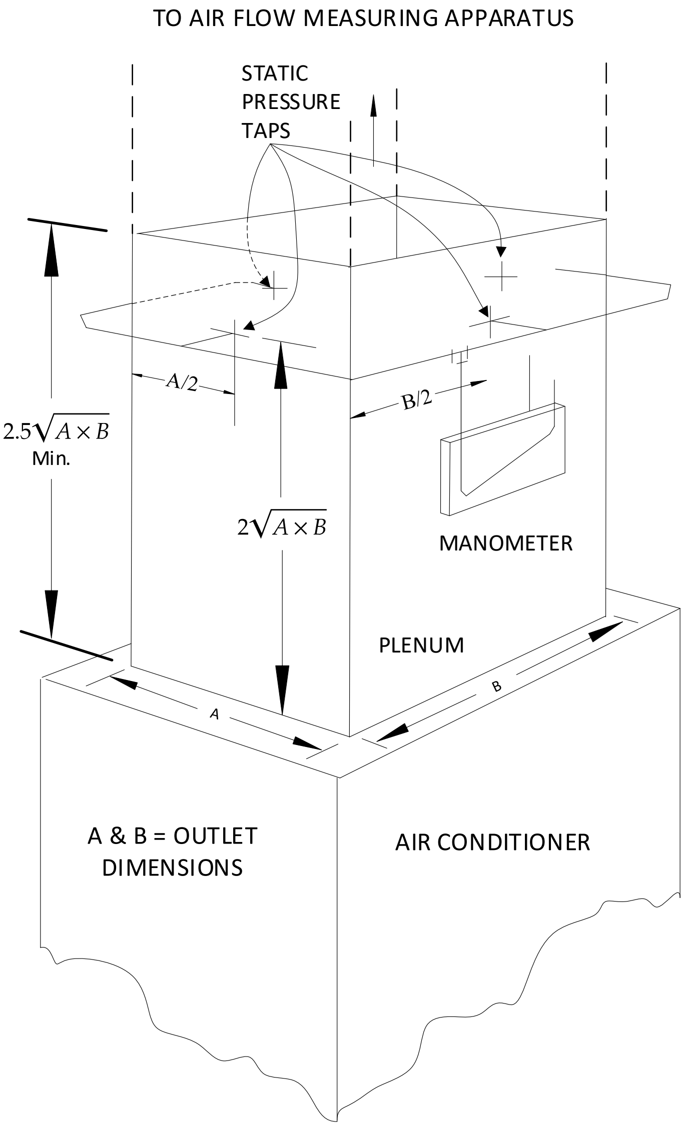

Figure 5-11 External static pressure measurement.

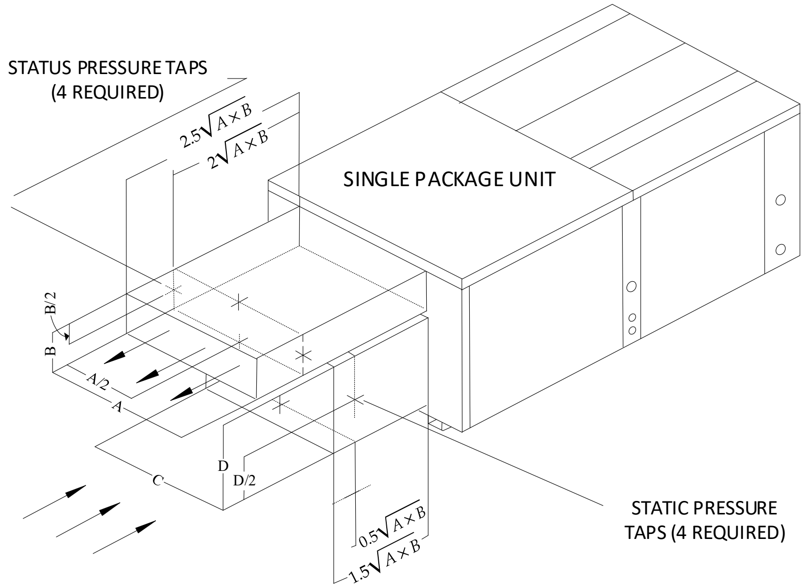

Figure 5-12 External static pressure measurement.

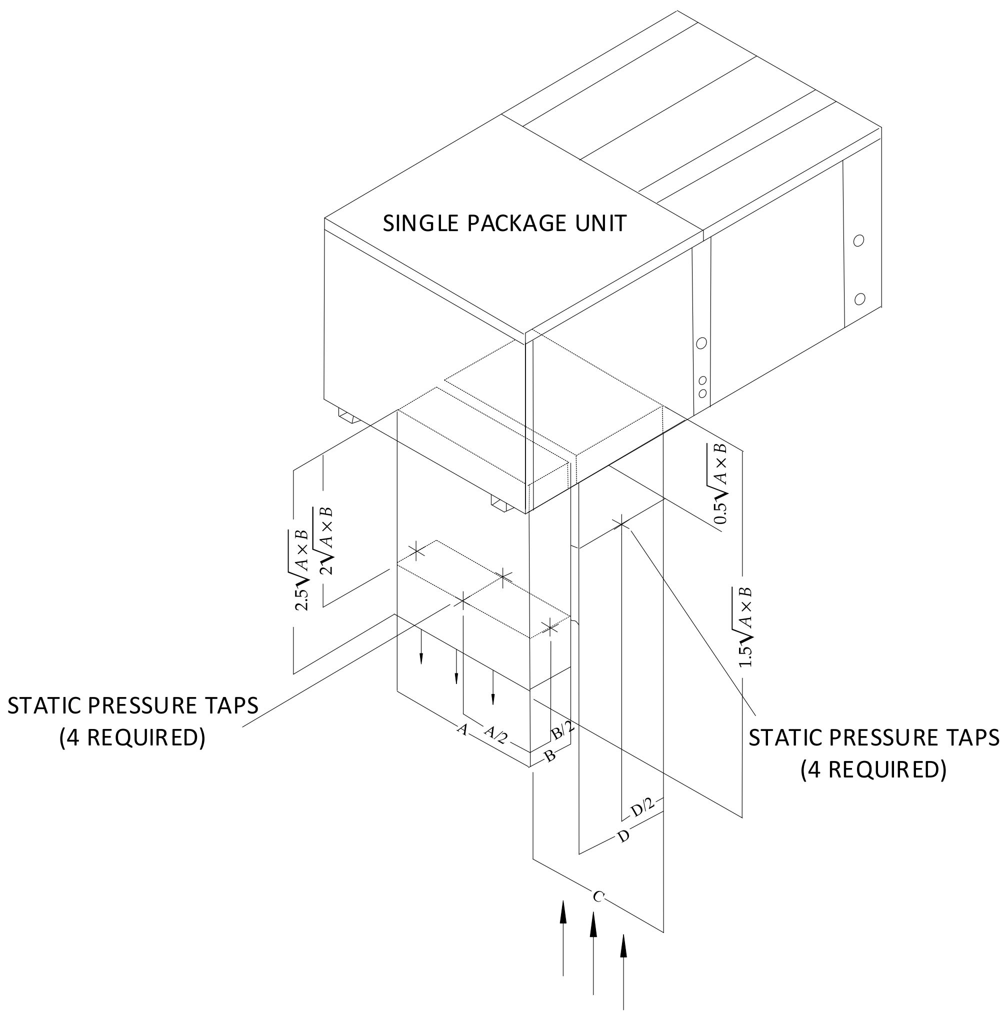

Figure 5-13 External static pressure measurement.

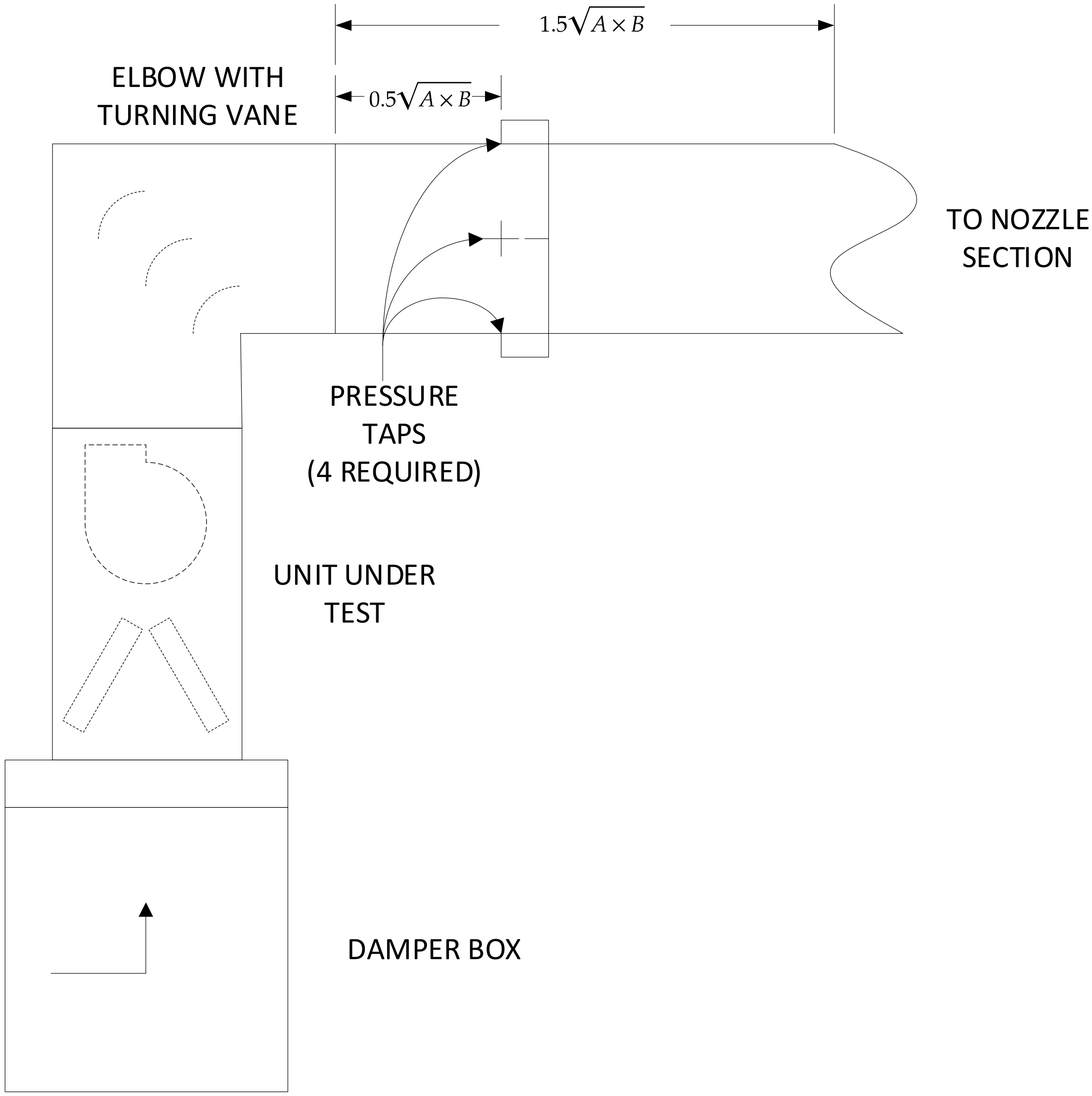

Figure 5-14 Alternate Ductwork from RP-1581

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

5.15.1 Inlet Plenum

5.15.1.1 If space within the test room permits, a full inlet duct connection shall be installed. If used, the inlet duct shall have cross-sectional dimensions equal to those of the equipment and a length of 1.5 equivalent diameters, $1.5\sqrt{\frac{\pi D_i^2}{4}}$ for circular ducts or $1.5\sqrt{C \times D}$. The static pressure measurement plane is located 0.5 equivalent diameters, $0.5\sqrt{\frac{\pi D_i^2}{4}}$ for circular ducts or $0.5\sqrt{C \times D}$ upstream of the unit inlet connection with a tolerance of ±10%. The length of the inlet duct, $1.5\sqrt{C \times D}$, is a minimum dimension. For more precise results, use $4\sqrt{C \times D}$ if the test room space permits.

5.15.1.2 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 152.4 mm (6 in.). Four static pressure taps shall be located in the center of each face with a tolerance of ±10%. This inlet duct shall be connected directly to the inlet of the unit.

5.15.2 Outlet Plenum

5.15.2.1 If space within the test room permits, a full outlet plenum shall be attached to the outlet of the discharge side of the equipment. This plenum shall have cross-sectional dimensions equal to the dimensions of the equipment outlet and fabricated as shown by the setups given in Figures 5-11, 5-12, and 5-13, and discharges into the mixer, if used, prior to the air sampling section upstream of the airflow measurement device.

The discharge plenum duct shall be 2.5 equivalent diameters, $2.5\sqrt{\frac{\pi D_o^2}{4}}$ for circular ducts, or $2.5\sqrt{A \times B}$.

The static pressure measurement plane is located 2.0 equivalent diameters,
$2.0\sqrt{\frac{\pi D_o^2}{4}}$ or circular ducts or $2.0\sqrt{A \times B}$ downstream of the unit inlet connection with a tolerance of ±10%.

5.15.2.2 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 as shown in Figure 5-14. The dimensions of the duct connected to the outlet of the elbow and the location of the static measurement plane as shown in Figure 5-15 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.

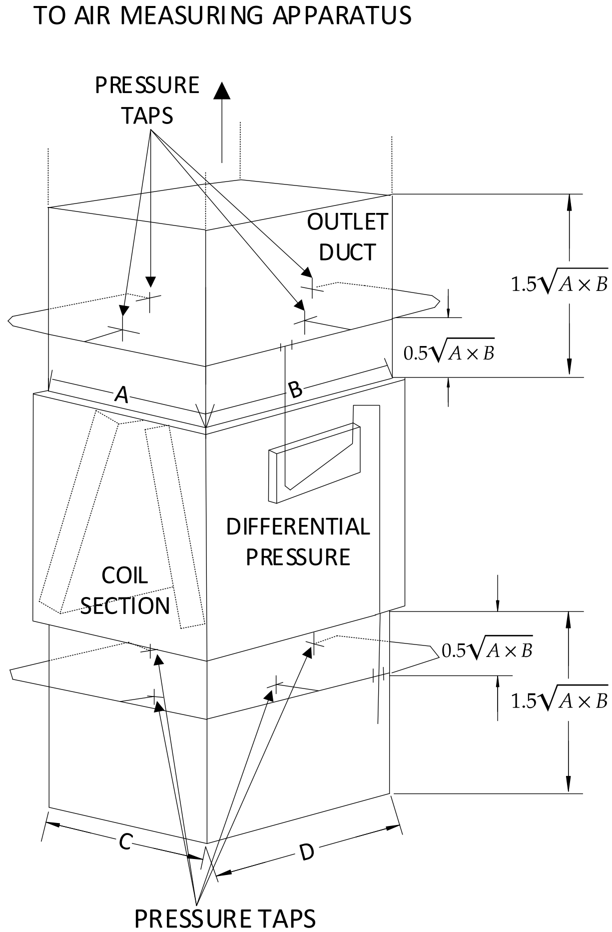

Figure 5-15 Air static pressure drop measurement for coil without fan

5.16 Units with Fans and Multiple Outlets or Multi-Evaporators

5.16.1 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 5-16 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 Figure 5-11.

5.16.2 Multiple blower units employing a single discharge duct connection flange shall be tested with a single outlet duct in accordance with Figure 5-17. Any other test plenum arrangements shall not be used except to simulate duct designs specifically selected by the equipment manufacturer.

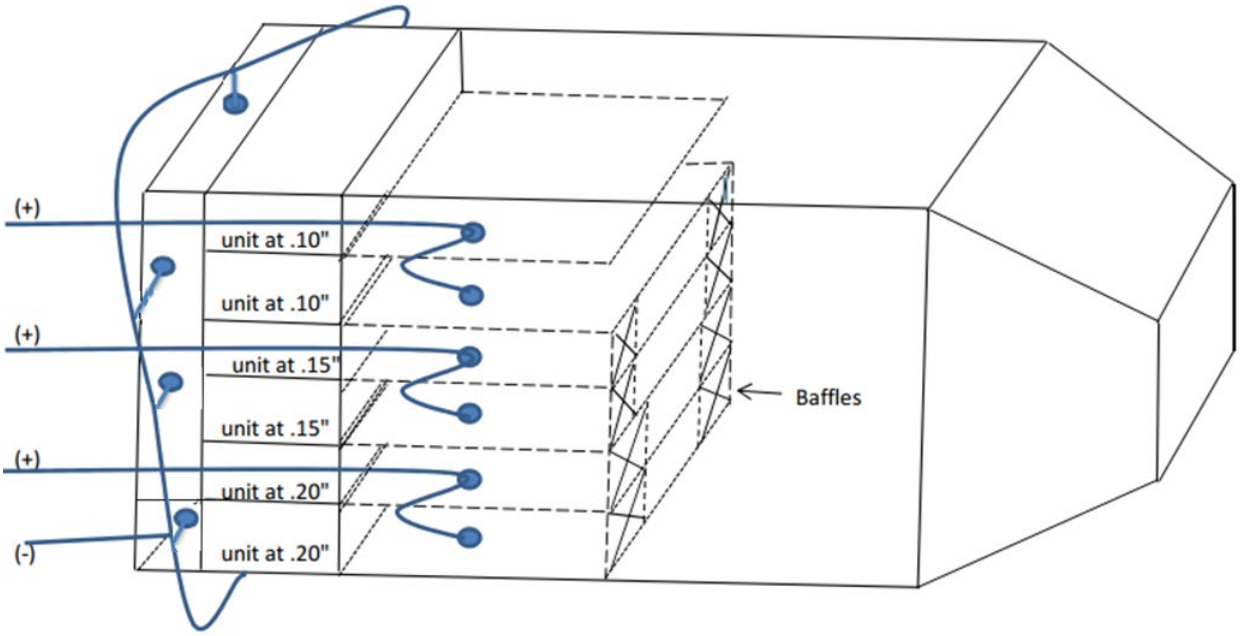

Figure 5-17 Example Indoor Units Installation Based on Different Static Pressures

5.16.3 If space within the test room does not permit the full outlet plenum, follow the provisions of Sections 5.14.1.2 or 5.15.1.2.

5.16.4 For small-duct, high-velocity systems, install an outlet plenum that has a diameter that is equal to or less than the value listed in Table 5-2. This limit depends only on the cooling full-load air volume rate and works regardless of (a) the flange dimensions on the outlet of the unit, or (b) an air supply plenum adapter accessory, if installed in accordance with the manufacturer's installation instructions.

TABLE 5-2 Maximum Diameter of Outlet Plenum

Cooling Full-Load Air Volume Rate Standard L/s (scfm)	Maximum Diameter* of Outlet Plenum mm (in.)
≤ 236.0 (500)	152.4 (6)
236.4 (501) to 330.4 (700)	177.8 (7)
330.8 (701) to 424.8 (900)	203.2 (8)
425.2 (901) to 519.1 (1100)	228.6 (9)
519.6 (1101) to 660.7 (1400)	254 (10)
661.2 (1401) to 825.9 (1750)	279.4 (11)
*If the outlet plenum is rectangular, calculate the equivalent diameter using *(4A)/P*, where *A* is the cross-sectional area and *P* is the perimeter of the rectangular plenum, and	

compare the equivalent diameter to the listed maximum diameter.

5.16.5 For small-duct, high-velocity systems, install an air damper close 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 in the receiving chamber of the airflow measuring apparatus is not more than 0.124 kPa (0.5 in. of water) higher than the surrounding test room ambient. Instead of installing a separate damper, use the outlet air damper box if the outlet air damper box allows variable positioning. Apply these steps 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).

5.17 Non-ducted Units

5.17.1 Outlet Plenum

5.17.1.1 Indoor leaving plenum and duct requirements for non-ducted indoor units. A plenum shall be installed 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. 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 prior to any duct transitions, elbows, or air sampling trees used for air condition measurement.

5.17.1.2 If used, elbows connected to the end of the plenum shall have a centerline radius equal to at least 1.5 times the 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 the plenum connection.

5.17.1.3 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 2.8 times the square root of the cross-sectional area of the combined outlets from the indoor unit(s).

5.17.1.4 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 length.

5.17.1.5 The plenum shall not interfere with the throw angle.

5.17.1.6 Outlet plenum requirements per Section 5.18.1. 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.

5.17.1.7 Air sampling trees used for temperature measurement shall be placed in the duct between the airflow measurement apparatus and the minimum required plenum length.

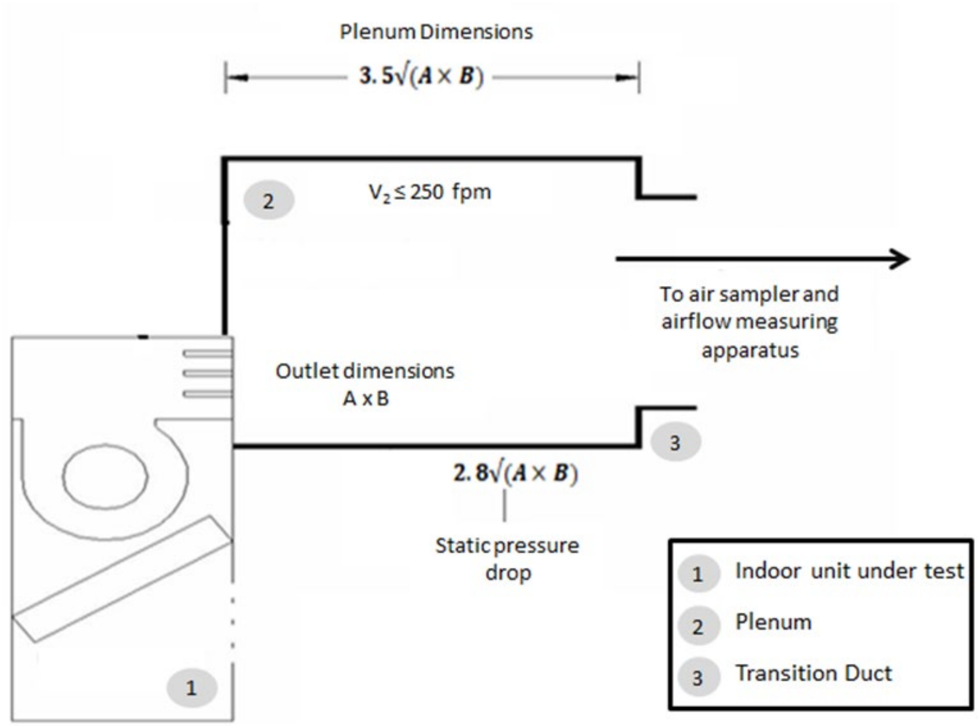

Figure 5-18 Example Setup for High Wall Mounted Indoor Units

5.17.1.8 External static pressure measurement shall be as defined in Figure 5-11.

5.17.2 Inlet Plenum

5.17.2.1 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 cassettes combined inlet.

5.17.2.2 Plenum and duct requirements for ceiling-mount indoor units are shown in Figures 5-19, 5-20, and 5-21.

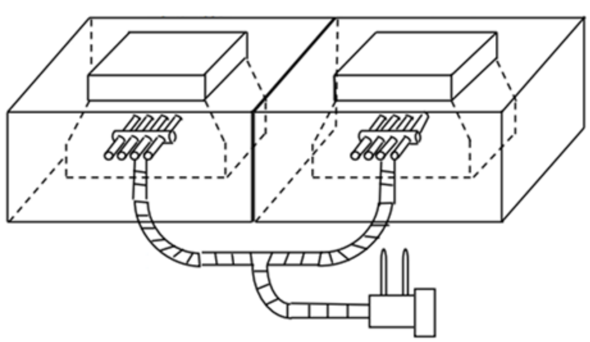

Figure 5-19 Example Return Air Measurement Setup For Non-Ducted Units, Sampling Tree at Unit

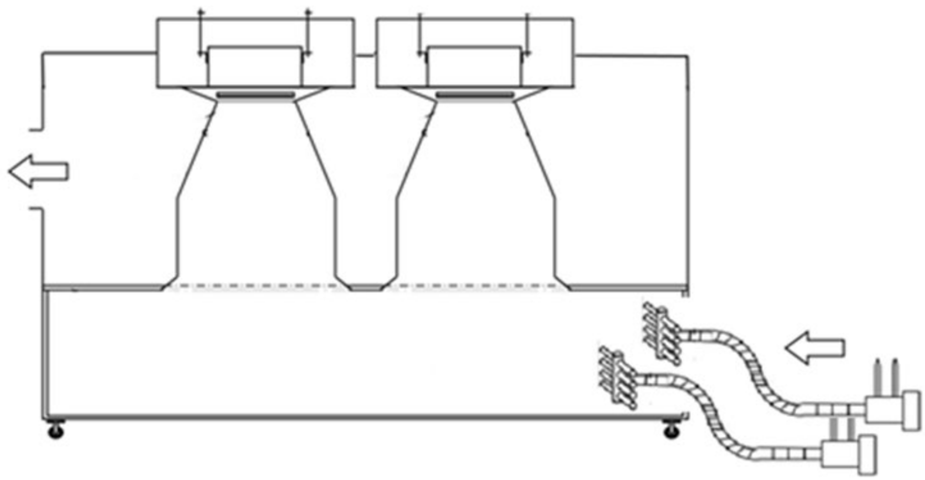

Figure 5-20 Example Return Air Measurement Setup For Non-Ducted Units, Sampling Tree Common

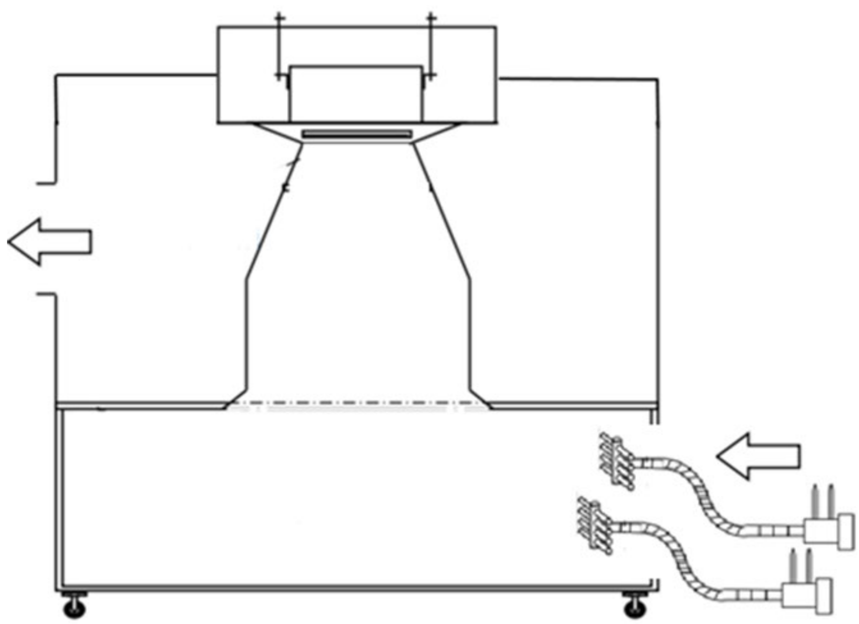

Figure 5-21 Example Return Air Measurement Setup For Ceiling Cassette

5.18 Multi-split Units

5.18.1 Outlet Plenum

5.18.1.1 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. If using more than one indoor test room, take the same steps, creating one or more common ducts within each test room that contains multiple indoor coils. At the plane where each plenum enters a common duct, install an adjustable airflow damper and adjust the damper to equalize the static pressure in each plenum. Each outlet air temperature grid and airflow measuring apparatus are located downstream of the inlet(s) to the common duct.

5.18.2 External static pressure measurement shall be as defined in Figure 5.11.

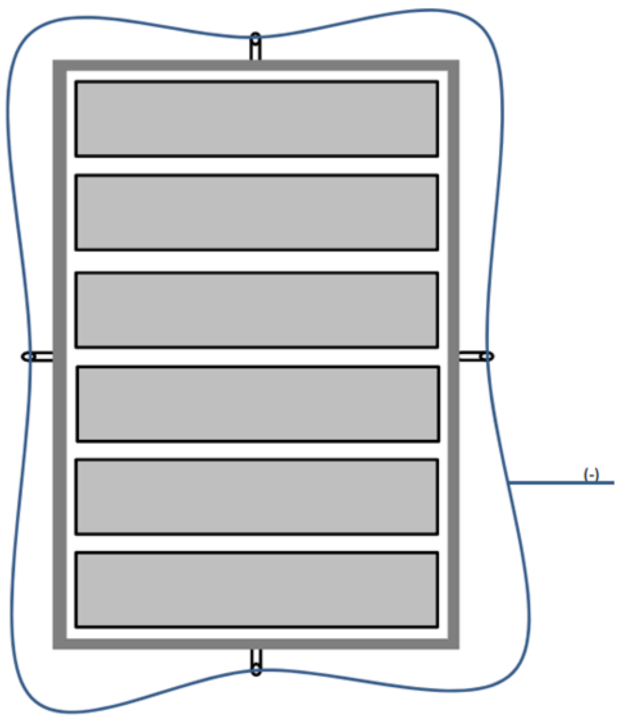

Figure 5-22. Example Indoor Units Installation for IDUs of Same Chassis Size

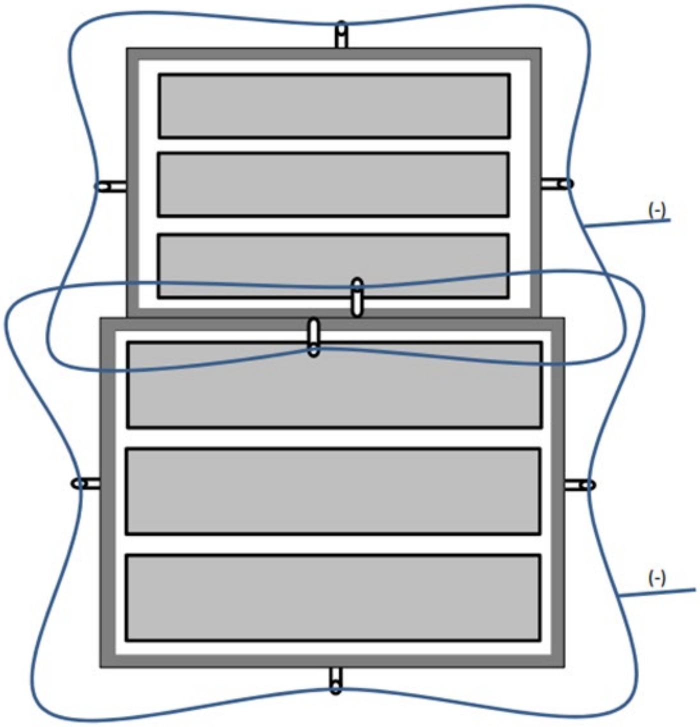

Figure 5-23. Example Indoor Units Installation for IDUs of Different Chassis Size

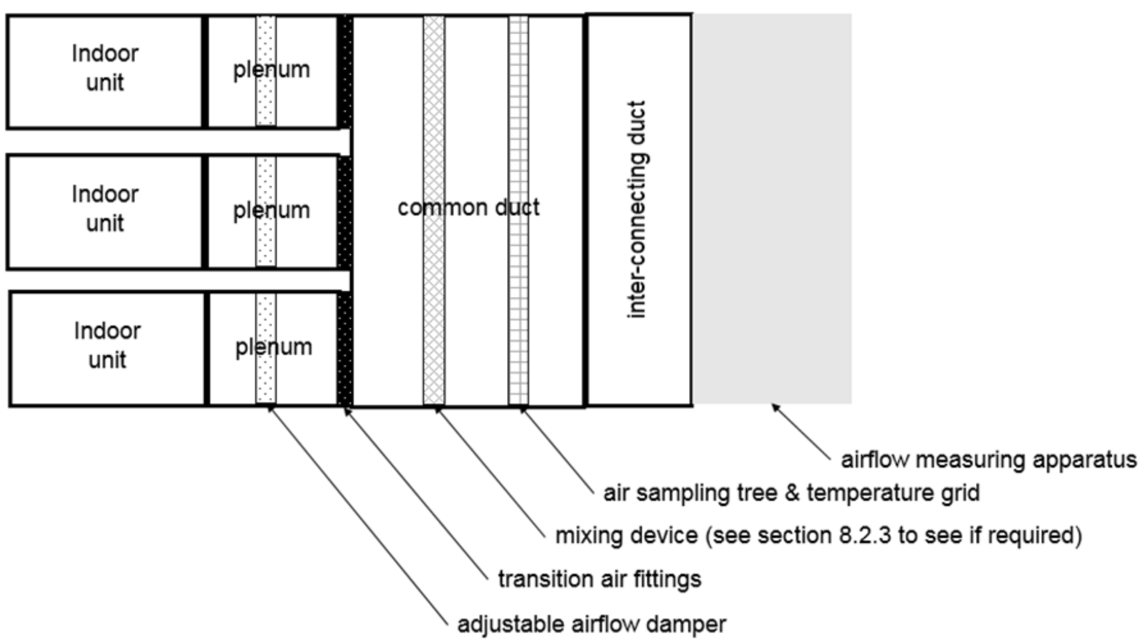

Figure 5-24 Schematic of a Test Setup for Ducted Indoor Units with Common Duct

6. TEST FACILITY ARRANGEMENTS

6.1 Test facility arrangements

The test facility arrangements shown in Figures 6-1 through 6-9 illustrate potential testing configurations and do not represent specific requirements for all types of equipment.

6.1.1 The tunnel air-enthalpy arrangement is illustrated in Figure 6-1. The equipment to be tested is to be located in a test room or rooms (see Section 7). 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 that is to be provided with a means for: maintaining the air entering the unit at the target wet- and dry-bulb temperatures, measuring the wet- and dry-bulb temperatures of the air entering and leaving the unit, and the internal resistance. Refer to ASHRAE Standard 41.1[1], ASHRAE Standard 41.6[4], ASHRAE Standard 41.2[2], ASHRAE Standard 41.3[3], ASHRAE 41.10[6], ASHRAE 41.7[8], and ASHRAE 41.13[16].

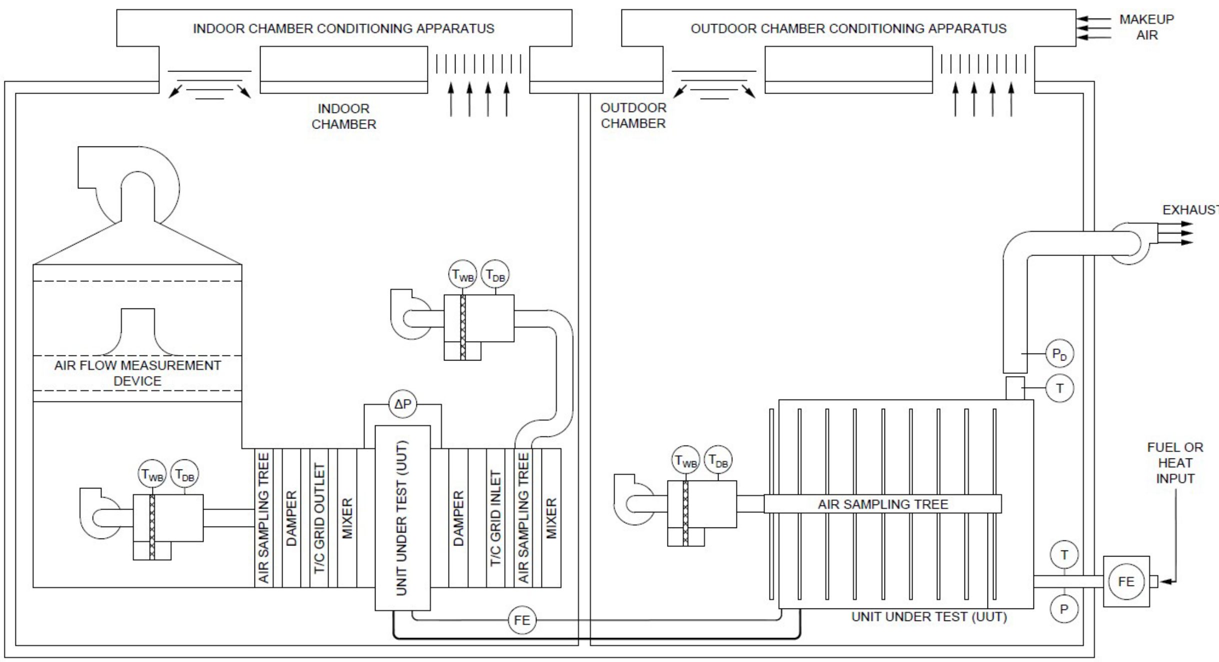

Figure 6-1 Tunnel air enthalpy arrangement (air-to-air heat pump)

6.1.2 Two versions of the liquid enthalpy arrangement for air-to-liquid heat pumps are illustrated in Figures 6-2 and 6-3. These arrangements depict the use of liquid enthalpy measurements for air-to-liquid heat pumps where the unit under test that supplies conditioned liquid is split from the outdoor heat exchanger (Figure 6-2) or the unit under test is a fully packaged system meant for outdoor installations (Figure 6-3). In both cases, the outdoor heat exchanger or the packaged system is to be located in a test room (see Section 7). An air-measuring device shall be attached to the air inlet or outlet of the equipment (as applicable). In both configurations, the unit under test that supplies the conditioned water shall be connected to a heat sink or source such as a heat exchanger. This device shall be provided with a means for: circulating the liquid if not furnished as part of the unit under test, maintaining target liquid temperature returning to the unit under test, measuring liquid flow, measuring supply and return temperatures, and measuring internal resistance. Refer to ASHRAE Standard 41.1[1], ASHRAE Standard 41.6[4], ASHRAE Standard 41.2[2], ASHRAE Standard 41.3[3], ASHRAE 41.10[6], ASHRAE 41.7[8], ASHRAE 41.8[5], and ASHRAE 41.13[16].

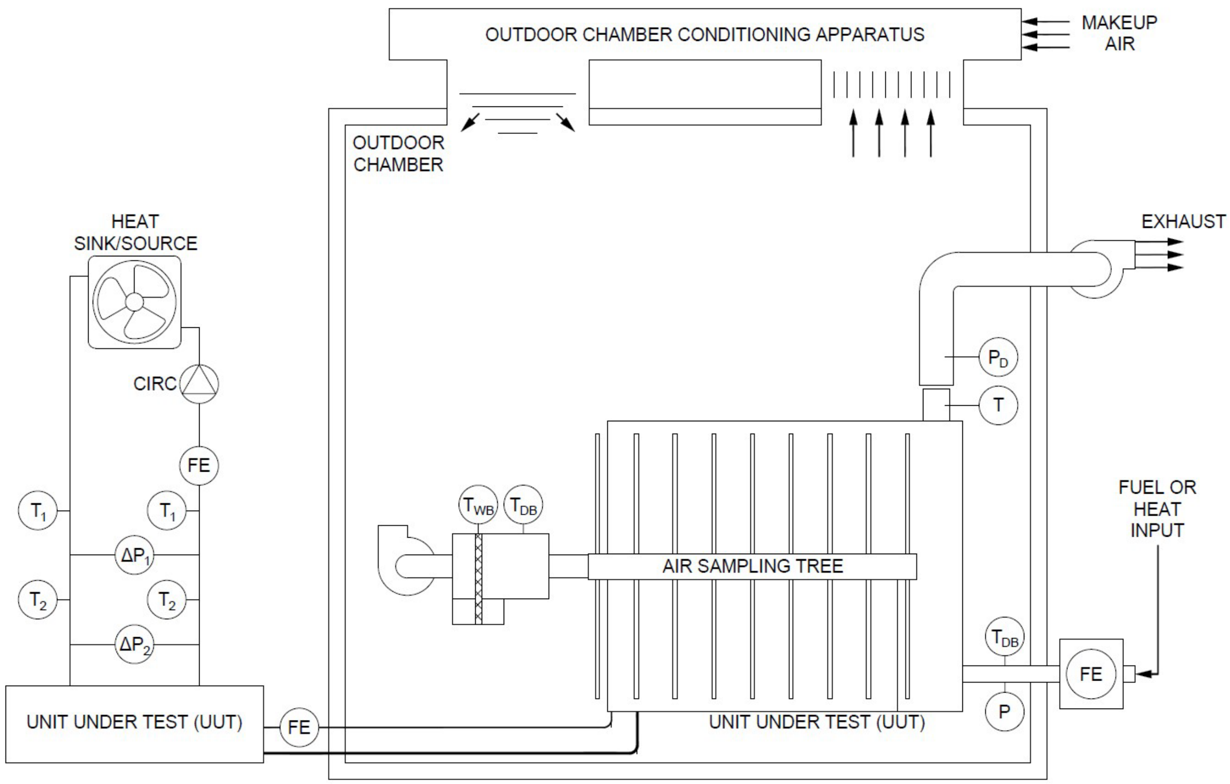

Figure 6-2 Liquid enthalpy arrangement (air-to-liquid heat pump)

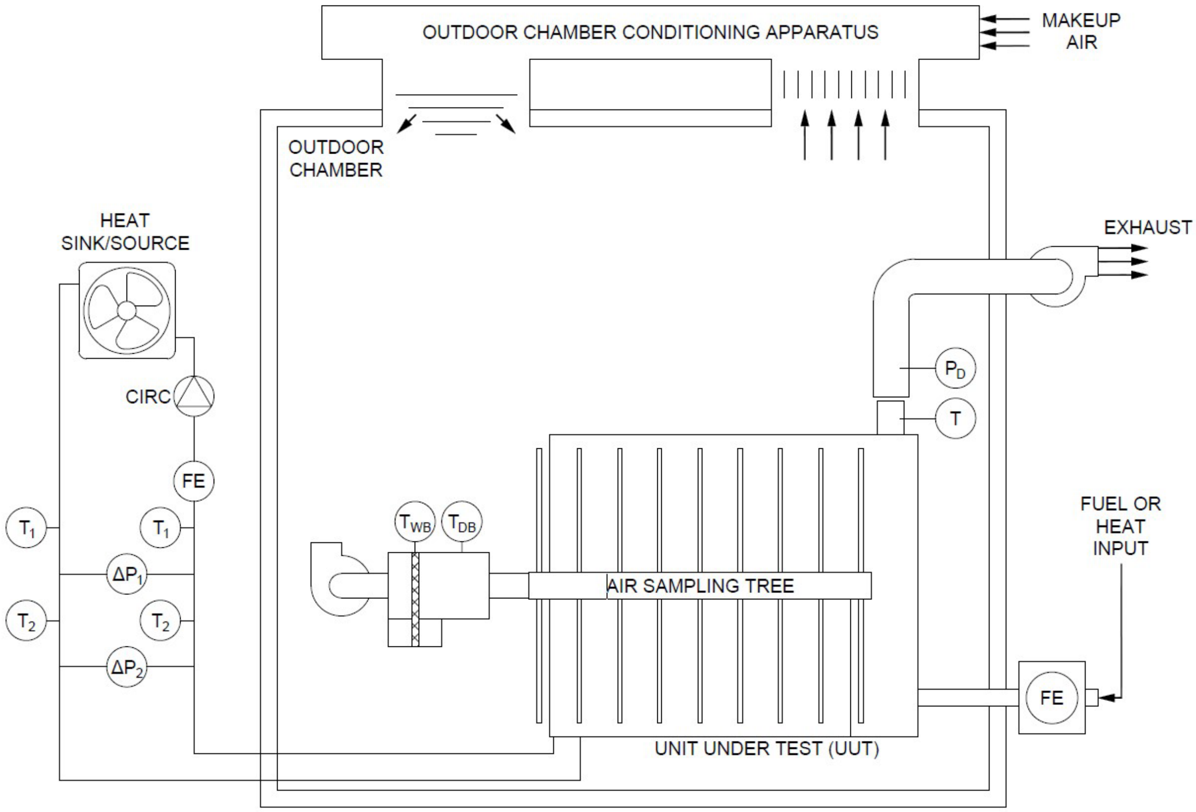

Figure 6-3 Liquid enthalpy arrangement (air-to-liquid heat pump)

6.1.3 Figures 6-4 and 6-5 show tunnel-air enthalpy configurations for energy transfer from a liquid source such as a ground-source or water-source heat pump. In Figure 6-4, fuel is supplied to the outdoor section of the unit under test. Figure 6-5 shows a system with fuel supplied to the indoor unit. Refer to ASHRAE Standard 41.1[1], ASHRAE Standard 41.6[4], ASHRAE Standard 41.2[2], ASHRAE Standard 41.3[3], ASHRAE 41.10[6], ASHRAE 41.7[8], and ASHRAE 41.13[16].

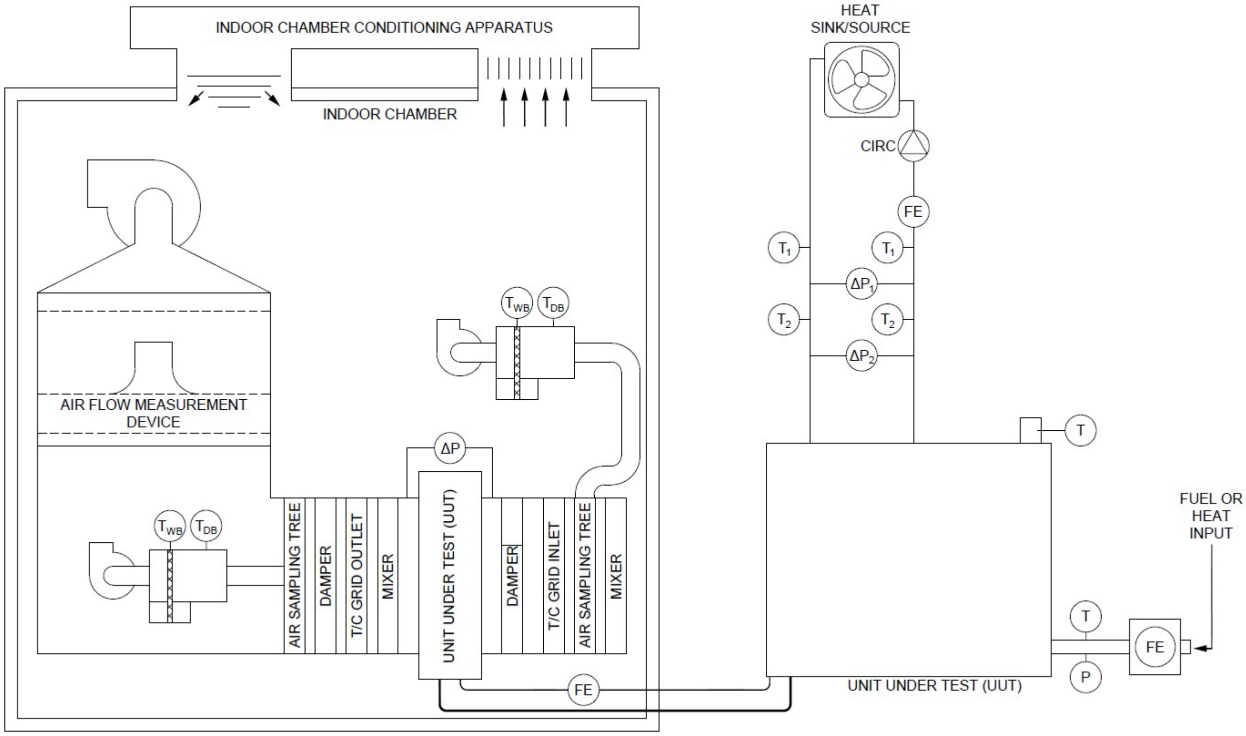

Figure 6-4 Tunnel air enthalpy arrangement (liquid-to-air heat pump)

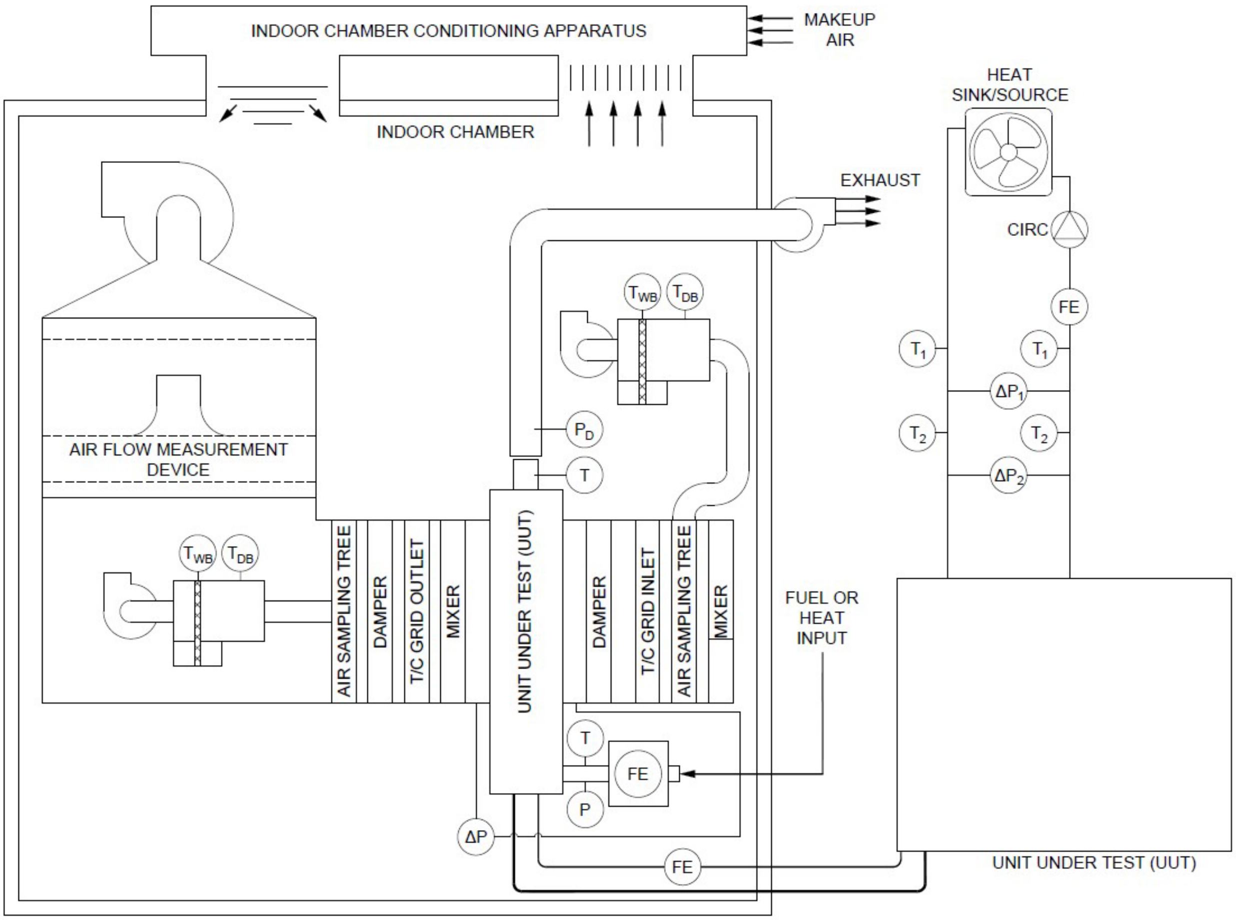

Figure 6-5 Tunnel air enthalpy arrangement (liquid-to-air heat pump)

6.1.4 The configuration illustrated in Figure 6-6 represents a liquid-to-liquid heat pump unit. This example shows a configuration with redundant temperature measurement to ensure accurate results. The heat source and heat sink are reversed depending on the heating or cooling operating mode. Refer to ASHRAE Standard 41.1[1], ASHRAE Standard 41.6[4], ASHRAE Standard 41.2[2], ASHRAE Standard 41.3[3], ASHRAE 41.10[6], ASHRAE 41.7[8], and ASHRAE 41.13[16].

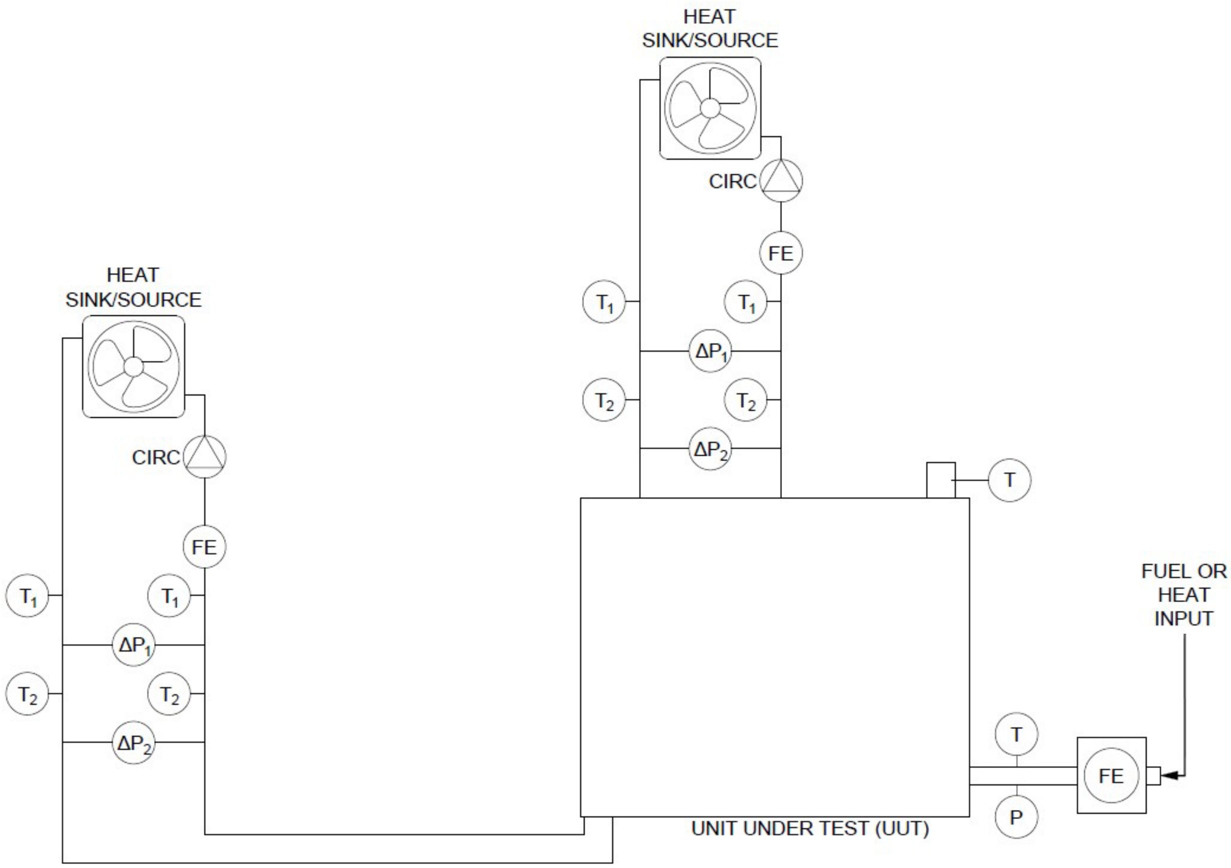

Figure 6-6 Liquid enthalpy arrangement (liquid-to-liquid heat pump)

6.1.5 Loop air-enthalpy arrangement is illustrated in Figure 6-2. This arrangement differs from the tunnel arrangement in that discharge of the air-measuring device shall be connected to 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. Maintain the dry-bulb temperature within the test room within ±2.7°C (±5.0°F) of the required dry-bulb temperature test condition for the air entering the indoor unit. Dewpoint shall be within 1.1°C (2°F) of the required inlet conditions. Refer to ASHRAE Standard 41.1[1], ASHRAE Standard 41.6[4], ASHRAE Standard 41.2[2], ASHRAE Standard 41.3[3], ASHRAE 41.10[6], ASHRAE 41.7[8], and ASHRAE 41.13[16].

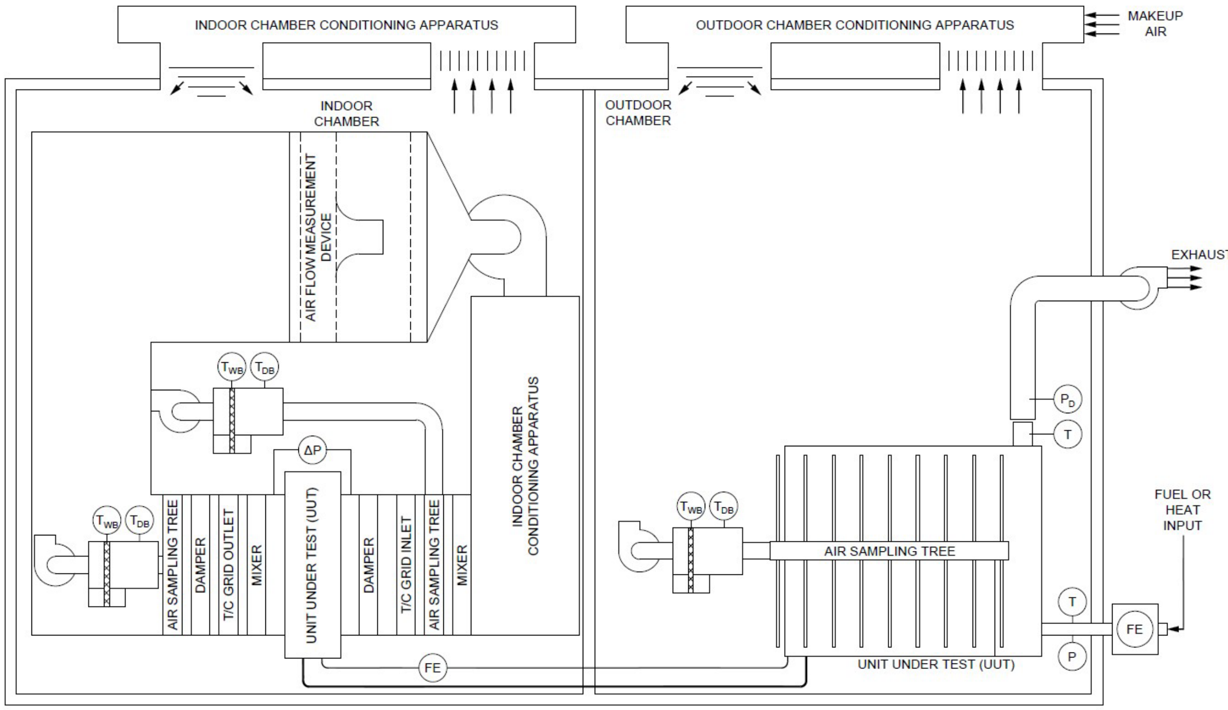

Figure 6-7 Loop air enthalpy arrangement (air-to-air heat pump)

6.1.6 The room air-enthalpy arrangement is shown in Figure 6-8. 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 reconditioning equipment. The discharge air from the reconditioning apparatus maintains wet- and dry-bulb temperatures where air-sampling devices and pressure sensor(s) measure wet- and dry-bulb temperatures and external resistance as required. Refer to ASHRAE Standard 41.1[1], ASHRAE Standard 41.6[4], ASHRAE Standard 41.2[2], ASHRAE Standard 41.3[3], ASHRAE 41.10[6], ASHRAE 41.7[8], and ASHRAE 41.13[16].

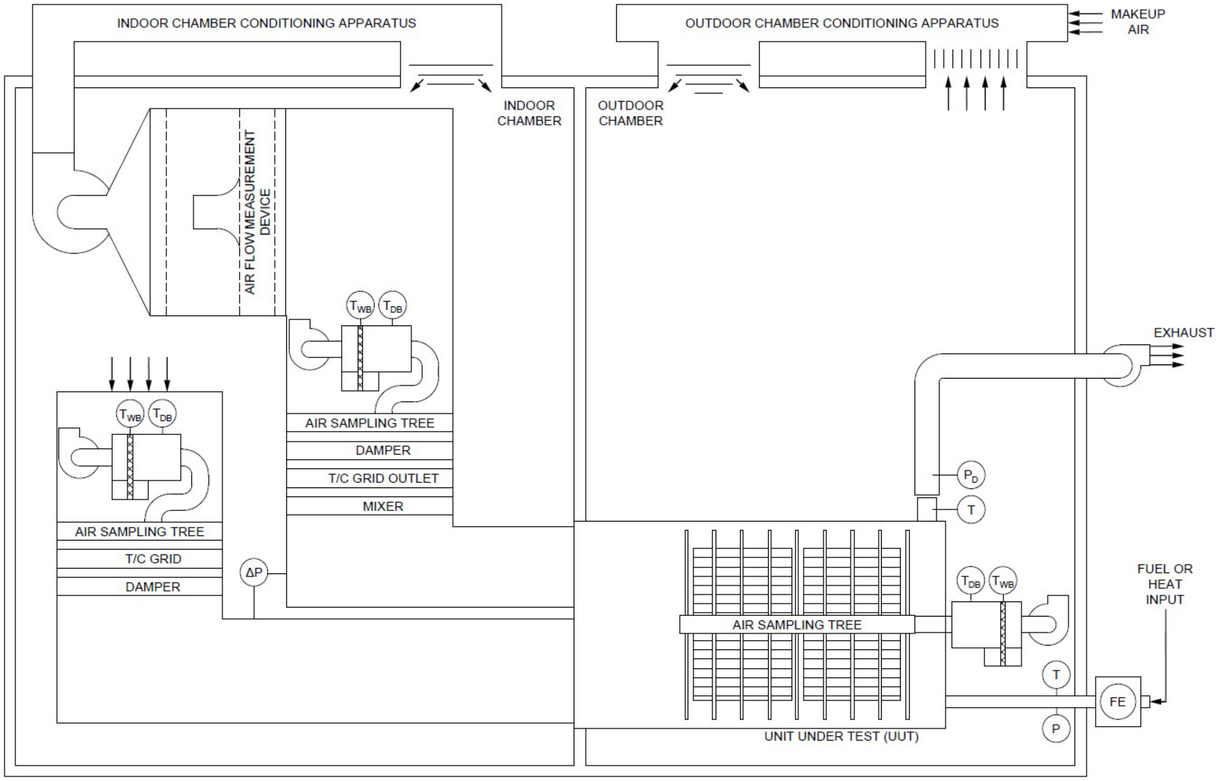

Figure 6.8 Room air enthalpy arrangement (air-to-air heat pump)

6.1.7 A multi-split, multiroom arrangement to facilitate variable refrigerant flow (VRF) is shown in Figure 6-9. Refer to ASHRAE Standard 41.1[1], ASHRAE Standard 41.6[4], ASHRAE Standard 41.2[2], ASHRAE Standard 41.3[3], ASHRAE 41.10[6], ASHRAE 41.7[8], and ASHRAE 41.13[16].

7. METHODS OF TESTING AND CALCULATIONS

7.1 Standard Test Methods

The following three test methods for measuring space conditioning capacity are covered in this standard:

(a) Indoor air enthalpy method (see 7.3)
(b) Liquid coil method (see 7.4)
(c) Refrigerant enthalpy method (see 7.5)

7.2 Applicability of Test Methods

7.2.1 For all tests, two test methods shall be performed simultaneously to calculate the space conditioning capacity; one is designated as the primary test method and the other is designated as secondary test method for validation. The calculated secondary capacity must agree to within 6% of the calculated primary capacity to constitute a valid test.

7.2.2 When using the liquid coil method as the primary measurement method, if implementing a secondary method is impractical to validate energy balance, concurrent redundant instrumentation per 7.2.3 shall be used to measure temperatures, flows, and energy inputs.

7.2.3 When using redundant measurement data to substantiate the validity of each test point, the redundant instrument measurements shall be within the limitation below:

7.2.3.1 Entering liquid temperature measurements shall not differ by more than 0.1 K (0.2°F).

7.2.3.2 Leaving liquid temperature measurements shall not differ by more than 0.1K (0.2°F).

7.2.3.3 Flow measurements shall not differ by more than 2%.

7.2.3.4 Energy input measurements shall not differ by more than 2%.

7.2.4 For air-delivery (air-to-air and water-to-air) equipment of rated cooling capacity of less than 40 kW (135,000 Btu/h) or rated heating capacity of 66 kW (225,000 Btu/h), the indoor air enthalpy shall be used as the primary test method and either the refrigerant enthalpy method or the liquid coil method shall be used as the secondary test method as applicable (Refer to Table 7-1).

For liquid-delivery (air-to-liquid and liquid-to-liquid) equipment of rated cooling capacity of less than 40 kW (135,000 Btu/h) or 66 kW (225,000 Btu/h) rated heating capacity, the liquid coil method shall be used as the primary test method and either the liquid coil method used as the secondary test method by performing energy balance on both sides of the heat exchanger, or redundant measurements shall be used per 7.2.3. (Refer to Table 7-1).

Table 7-1. Proposed Standard 40 Applicable Test Methods

Equipment Component Arrangement(s)	Delivery Type	Indoor Air Enthalpy Method	Refrigerant Enthalpy Method	Liquid Coil Method	Redundant Measurement
Packaged Unit	Air delivery	P	S	S	
	Liquid delivery	S		P/S	S
Split System	Air delivery	P	S	S	
	Liquid delivery	S	S	P/S	S

P: primary test method
S: secondary test method

7.2.5 For air-source equipment of rated cooling capacity of 40 kW (135,000 Btu/h) or greater, equipment shall be tested using one of the applicable methods in Section 7.1. 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, the indoor-air enthalpy method (Section 7.3) shall be used in all heating-capacity tests. 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 (Section 7.6), and for cooling tests, latent cooling capacity shall be determined by measuring condensate mass flow rate and temperature as described in Section 7.7.

7.2.6 If testing an indoor unit without a fan, compare primary and secondary capacities before making the after-test fan heat adjustments described in Section 7.3.2.1. However, include the appropriate fan heat adjustments within the indoor air enthalpy method capacities used for the reported net capacity.

7.2.7 Test procedure and data collected shall be in accordance with Section 8 (Test Procedure) and Section 9 (Test Results).

7.3 Indoor Air-Enthalpy Test Method

7.3.1 In the indoor air-enthalpy method, space conditioning capacity is calculated from measurements of flow rate, dry-bulb temperature, and water vapor content of the air that enters and leaves the indoor coil. Air enthalpies shall be determined in accordance with ANSI/ASHRAE Standard 41.6-2021.

7.3.2 Cooling Calculations

7.3.2.1 Steady-state total, sensible, and latent indoor cooling capacities, based on test data collected in accordance with the indoor-air enthalpy method, shall be calculated using the following equations.

$$q_{tci} = \frac{K_1 Q_{mi}(h_{a1} - h_{a2})}{v_n} - qs_{adj} = \frac{K_1 Q_{mi}(h_{a1} - h_{a2})}{v'_n(1 + W_n)} - qs_{adj}$$

$$q_{sci} = \frac{K_1 Q_{mi}\left(c_{p_{a1}} t_{a1} - c_{p_{a2}} t_{a2}\right)}{v_n} - qs_{adj} = \frac{K_1 Q_{mi}\left(c_{p_{a1}} t_{a1} - c_{p_{a2}} t_{a2}\right)}{v'_n(1 + W_n)} - qs_{adj}$$

$$q_{lci} = K_4 \frac{Q_{mi}(W_1 - W_2)}{v_n} = K_4 \frac{Q_{mi}(W_1 - W_2)}{v'_n(1 + W_n)}$$

where

$$c_{p_{a1}} = K_2 + K_3 W_1$$

$$c_{p_{a2}} = K_2 + K_3 W_2$$

qs_{adj} is the fan capacity adjustment for indoor units, W (Btu/h)

where

$$qs_{adj} = \begin{cases} 0, & \text{for indoor units with a fan} \\ 3.412 \cdot E_i, & \text{for indoor units with a fan but the blower off} \\ 3.412 \cdot E_{id}, & \text{for indoor units without a fan} \end{cases}$$

7.3.2.2 When the indoor 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 the equipment indoor section is located in the indoor test room, then

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

If parts of the equipment indoor section are located in the outdoor test room, then

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

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

$$q'_{cyc} = K_1 Q_{mi} c_{p_{a2}} \Gamma / [v'_n(1 + W_n)] - qs_{adj}[\Theta_I - 0]$$

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.

(Informative Note: When performing numerical integration, it is recommended to use the Trapezoidal Rule or another method that minimizes integration error.)

(Informative note: Cycle time as defined in specific test procedures such as ANSI/CSA Z21.40.4.

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, 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.

7.3.3 Heating Calculations

7.3.3.1 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 7.3.2.1 and

$$W_n = W_1 = W_2$$

See Section 7.3.2.1 for values of qs_{adj}

7.3.3.2 When the indoor 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 7.3.2.2 and then the absolute value of q_{loss} added algebraically to the heating capacity.

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

7.3.4.1 For equipment where defrosting occurs or for equipment that operates in batch mode, 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.

7.3.4.2 Average space heating capacity shall be determined as follows:

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

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

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

$$W_n = W_1 = W_2 ,$$

and

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

Informative Note: When performing numerical integration, it is recommended to use the Trapezoidal Rule or another method that minimizes integration error.

7.3.4.3 For heat pumps that automatically cycle off the indoor fan during a defrost cycle or for those that operate in batch mode, 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 (for example, $\tau_2 - \tau_1$) that is used for evaluating average heating capacity.

7.3.4.4 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.

$$\boldsymbol{\Gamma} = \int_{\mathbf{0}}^{\boldsymbol{\Theta_I}} [\boldsymbol{t_{ai}(\theta) - t_{a2}(\theta)}]\boldsymbol{d\theta}$$

(Informative Note: When performing numerical integration, it is recommended to use the Trapezoidal Rule or another method that minimizes integration error.

where Θ_I is the length of the integration time within a cycle.

(Informative Note: Cycle time as defined in specific test procedures such as ANSI/CSA Z21.40.4.)

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.

7.3.5 Temperature

7.3.5.1 Temperature measurements in accordance with ASHRAE Standard 41.1[1] for dry-bulb temperatures and ASHRAE Standard 41.6[4] shall be made with the equipment discussed in 5.1 and 6.2.2 at the accuracies specified in Table 5-1. Temperature measurements shall be taken at not less than nine locations at the center of equal segments of the cross-sectional area. Consult ASHRAE Standard 41.1[15] Sections 5.3.2 through 5.3.7 for proper mixing methods in order not to exceed a 0.83°C (1.5°F) difference between grid positions during steady state testing.

7.3.5.2 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 7.3.5.1 and this section will require flow mixers or flow straighteners or both.

7.4 Liquid Coil Method

7.4.1 Overview

7.4.1.1 This method shall be used as the primary test method for liquid delivery (air-to-liquid and liquid-to-liquid equipment) to measure both the total cooling and heating capacity, or as a secondary method to measure the total cooling or heating capacity.

7.4.2 Liquid Flow Rate Measurement

7.4.2.1 The coil liquid flow rate shall be measured in accordance with ASHRAE Standard 41.8[5] with a liquid quantity or flow meter in accordance with the accuracy requirements in Table 5-1.

7.4.3 Temperature Measurement

7.4.3.1 Entering and leaving liquid temperatures shall be measured with instruments in accordance with ASHRAE Standard 41.1[1] at the accuracies specified in Table 5-1 at the equipment connections.

7.4.4 Liquid Coil Method Calculations— Cooling Capacity

7.4.4.1 Total cooling capacity shall be calculated as follows:

$$q_{tco} = w_l c_{p1}(t_{l4} - t_{l3}) - E_t$$

$$\left[= w_l c_{p1}(t_{l4} - t_{l3}) - 3.412E_t\right]$$

7.4.5 Liquid Coil Method Calculations— Heating Capacity

7.4.5.1 Total heating capacity shall be calculated as follows:

$$q_{tho} = w_l c_{p1}(t_{l3} - t_{l4}) + E_t$$

$$\left[= w_l c_{p1}(t_{l3} - t_{l4}) + 3.412 E_t\right]$$

7.4.6 Pump Power Considerations

7.4.6.1 The total power input term, *Et*, in the equations above (in Sections 7.4.4.1 and 7.4.5.1) shall include the measured power input to the pump only if the pump is located between the inlet and outlet water temperature sensors t_{l3} and t_{l4}.

7.4.7 Interconnecting Tubing Adjustment

7.4.7.1 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 7.3.2.3).

7.5 Refrigerant Enthalpy Method

7.5.1 Overview

7.5.1.1 In this method, capacity is determined from the refrigerant enthalpy change and flow rate for equipment with accessible refrigerant lines. Enthalpy changes are determined from measurements of entering and leaving pressures and temperatures of the refrigerant, and the flow rate is determined by airflow meter in the liquid line. With the equipment operating at the specified 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 is conducted simultaneously, 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.

7.5.1.2 This method shall be used for tests of equipment where the refrigerant charge is not critical and where installation procedures involve the field connection of refrigerant lines.

7.5.1.3 This method shall not be used for tests where the refrigerant liquid leaving the flow meter is subcooled less than 2°C (3°F) or for tests where 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 ASHRAE Standard 41.10[6] at the accuracy specified in Table 5-1.

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. Subcooling not less than 2°C (3°F) and the absence of any vapor bubbles in the liquid is required. Install the flow meter 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 For equipment where oil is circulated with the refrigerant, at the end of the test, a sample of the circulating refrigerant and oil mixture shall be taken from the equipment and the percentage of oil measured in accordance with ASHRAE Standard 41.4-2015[14]. 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 in accordance with ASHRAE Standards 41.1[1] and 41.3[3] at the accuracies specified in Table 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 Airflow Rate Measurement

7.6.1 Measurement Methods—According to Rated Cooling Capacity

7.6.1.1 For equipment having a rated cooling capacity less than 40 kW (135,000 Btu/h), the indoor airflow rate shall be measured according to ASHRAE 41.2-2022.

7.6.1.2 For equipment having a rated capacity of 40 kW (135,000 Btu/h) or higher, the indoor airflow rate shall be measured by one of these options: (a) according to ASHRAE 41.2-2022, or (b) using the indirect method defined in Section 7.6.3 for cases where capacity is determined using the Refrigerant Enthalpy Method or the Liquid Coil Method 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.

7.6.2 Calculations—Indirect Determination of Airflow Rate

7.6.2.1 When airflow rate is determined indirectly in accordance with 7.6.1.2, 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:

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

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

7.6.2.2 Airflow rate, expressed in terms of standard air (Q_s), shall be calculated as follows:

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

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

where v_n and W_n shall be evaluated based on the indoor coil entering air property measurements, for example, assume $v_n = v_1$ and $W_n = W_1$.

7.7 Cooling Condensate Measurement

7.7.1 For equipment whose indoor airflow rate is determined indirectly in accordance with 7.6.1.1 and 7.6.2.2 during cooling mode tests, the latent cooling capacity of the equipment shall be determined from measurements of the condensate flow rate. The nozzle airflow measuring apparatus method shall use the cooling condensate measurement as a secondary measurement of latent capacity. The drain connection shall be trapped to stabilize condensate flow.

7.7.2 Calculations

7.7.2.1 Latent cooling capacity shall be calculated as follows:

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

$$[= 1061 \, w_c]$$

7.7.2.2 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) if capacity is determined using either the outdoor liquid coil method or the compressor calibration method.

8. TEST PREPARATION AND PERFORMANCE

8.1 Test Room Requirements

8.1.1 Either one or two adjacent test rooms are required, depending upon the type of equipment to be tested and the manufacturer's installation instructions. A single test room shall be used if

a) the equipment is packaged equipment designed to be installed entirely indoors or entirely outdoors (see Section 8.2.1), and
b) the test apparatus is capable of supplying air (using the loop air-enthalpy test apparatus) or coolant to the equipment at specified test conditions that are other than those established for the single test room where the equipment is installed.

8.1.1.1 Appendix A shall be consulted and applied, when appropriate, to the design and construction of test rooms for equipment covered by this standard.

8.1.2 The indoor test room, when required, shall be any room or space where the specified test conditions are maintained within the prescribed test condition and test operating tolerances. Air velocities in the vicinity of the equipment under test shall not exceed 2.5 m/s (500 fpm).

8.1.3 The outdoor test room, when required, shall be any room or space where the specified test conditions are maintained within the prescribed test condition and test operating tolerances. This test room shall be of large enough volume and shall circulate air in a manner such that the enclosure does not change the air-circulating pattern of the equipment under test. The room shall be of dimensions such that the distance from any room surface to any equipment surface where 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 installations. The room-conditioning apparatus shall provide air at a rate not less than the outdoor airflow rate and shall take this air from the direction of the equipment air discharge and return it at the specified conditions uniformly and at low velocities (see Section 8.1.4).

8.1.4 Test Room Uniformity

8.1.4.1 Air dry-bulb temperature variations in the vicinity of the outdoor coil shall not exceed 0.5°C (1.0°F) or shall not exceed the allowed variation in test room temperature as specified in Table 8-1, whichever is greater.

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 using manufacturer's installation procedures and accessories. Self-contained, water-cooled equipment shall be located entirely within the test room. Indoor equipment or indoor sections shall be located in the indoor test room. Outdoor equipment or outdoor sections shall be located in the outdoor test room.

Air and evaporatively cooled, self-contained (single packaged) equipment shall be located in or adjacent to an opening in the wall or partition separating the test rooms in accordance with the manufacturer's specifications. In all cases, the manufacturer's specifications with respect to distances from adjacent walls, and amount of extension through walls 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 and other fluids specified on the nameplate or as prescribed in the manufacturer's published instructions for field installations.

8.2.4 Interconnecting tubing or piping shall be installed as furnished or as prescribed in the manufacturer's published installation instructions for field installations. If no specific instructions are provided from the manufacturer, 8 m (25 ft) of tubing or piping shall be used, where at least 3 m (10 ft) are located in the outdoor test room. The line sizes, insulation, and details of installation shall be in accordance with the manufacturer's published specification.

8.2.5 Pressure-measuring instruments, where used, 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 the fluid or fluid-head in the tubing.

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

8.2.7 For heat balance purposes, measurements of heat losses from components not otherwise captured by the procedures specified in this standard shall be made according to accepted engineering principles. The approach used to capture these heat losses shall be documented and maintained with the recorded test data.

8.3 Airflow Measurements

8.3.1 Airflow measurements shall be performed in accordance with ANSI/ASHRAE 41.2[2].

(Informative Note: Section 8.4 contains requirements that are copied from ANSI/ASHRAE 41.2[2] as a convenience for the user.)

8.4 External Pressure Measurement

8.4.1 Static Pressure Taps. Static pressure taps shall be constructed as defined in Figure 8-1 and shall be located around the duct perimeter in a measurement plane with (a) one pressure tap located on each surface of a rectangular duct and centered within ±10% of the width of the surface, or (b) four pressure taps shall be located with one pressure tap at each 90 degrees of circumference within ±10 degrees.

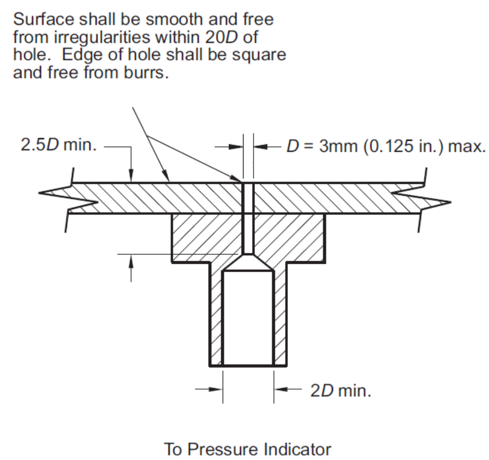

FIGURE 8-1. Static pressure tap construction requirements

8.4.2 Piezometer Ring

8.4.2.1 Piezometer Ring Requirements. Piezometer ring is the name given to the static pressure manifolds that provide an average static pressure at a given measurement plane. Unless otherwise specified in the test plan in Section 5.1, piezometer rings shall be installed as illustrated in Figure 8-2 with the following constraints:

a. The four tubing segments (A + B) shall have equal lengths within ±10%.

b. The four tubing segments C shall have equal lengths within ±10%.

c. The tubing segments (D + E) and (F + G) shall have equal lengths within ±10%.

d. The tubing segments (H + J) and (K + L) shall have equal lengths within ±10%.

e. The four tubing segments M shall have equal lengths within ±10%.

f. The four tubing segments N shall have equal lengths within ±10%.

g. Tubing shall be made from metal or plastic with a pressure rating not less than 1480 kPa (200 psig) to pass the installed piezometer ring pressure leak test procedures prescribed in Section 8.3.2.

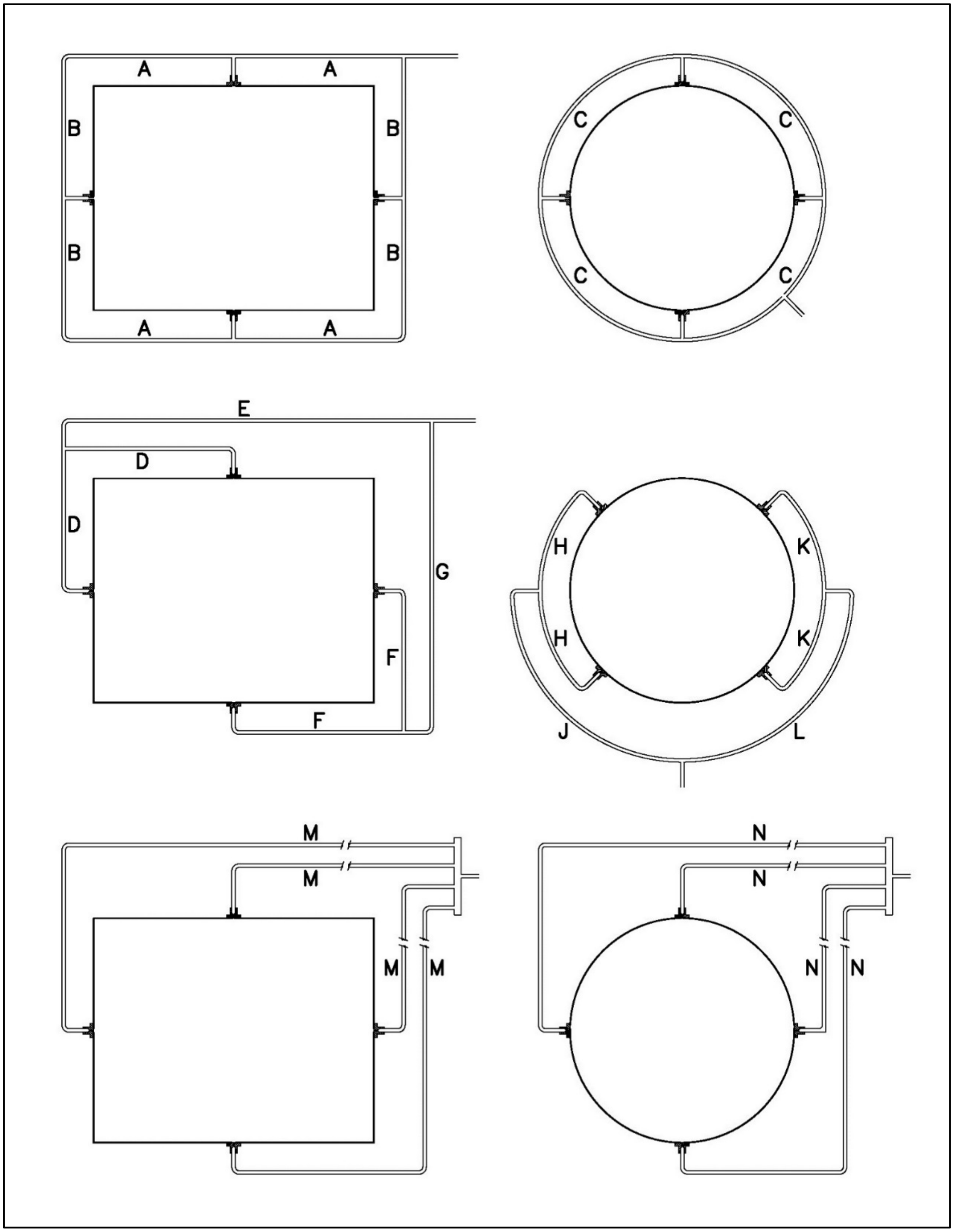

FIGURE 8-2. Piezometer ring connection alternatives

8.4.2.2 Piezometer Ring Leak Test. Leak test each installed piezometer ring assembly as prescribed in Section 8.4.2.2.1 through Section 8.4.2.2.4.

8.4.2.2.1 Disconnect each barometric pressure sensor and each differential pressure sensor in the installed piezometer ring assembly. Use one of the open tube ends to pressurize the assembly in compliance with 8.4.2.3 and 8.4.2.4. Plug the remaining open tube ends.

8.4.2.2.2 Connect the open end of the tube into a source of regulated compressed air or compressed nitrogen as illustrated in Figure 8-3 that has (a) an integral pressure gauge at the connection and (b) a dew point temperature no more than -40°C (-40°F) at a pressure not less than 136 kPa (5 psig) and not more than 170 kPa (10 psig).

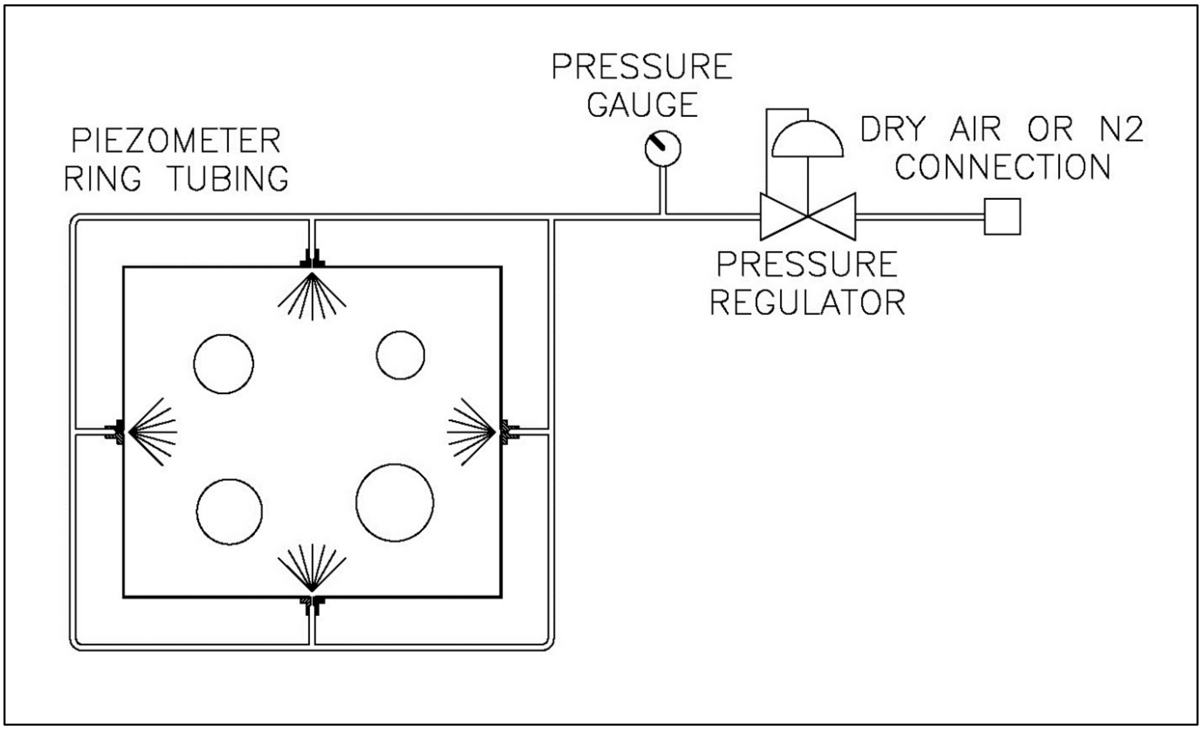

FIGURE 8-3 Piezometer leak test setup illustration

8.4.2.2.3 Apply a leak test liquid solution to the perimeter of each tubing connection and fitting in the installed piezometer assembly. Bubbles in the leak test solution indicate leaks. Repair the installed piezometer assembly to eliminate the leaks that are found using this procedure, and repeat this leak test procedure until the installed piezometer ring assembly is leak-free.

8.4.2.2.4 Release the leak test pressure, disconnect the source of compressed air or compressed nitrogen, and re-install each barometric pressure sensor and each differential pressure sensor.

8.5 Temperature Measurement

8.5.1 Temperature measurements shall be made in accordance with ANSI/ASHRAE Standard 41.1-2024 and 41.6-2021 (wet-bulb temperature methods).

8.5.2 In-duct, outlet temperature and water vapor contact measurements shall be taken at not less than three locations at the center of equal segments of the cross-sectional area, or the centers of equal segments of the cross-sectional area. Sampling or mixing devices giving comparable results shall be provided. ANSI/ASHRAE Standard 41.2-2024 describes air mixing devices. Connection to the equipment shall be insulated between the place of measurement and the equipment so that heat leakage through all the connections does not exceed 1.0% of the capacity.

8.5.3 Indoor inlet dry-bulb temperature and water vapor content measurements shall be taken at not less than three positions equally spaced over the equipment inlet area, or comparable sampling means provided. 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 150 mm ± 25 mm (6 in. ±1 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. It is intended that the ambient conditions surrounding the outdoor section under test shall simulate an installation operating at ambient air conditions identical with the specified test conditions.

8.5.5 Wet-bulb measurements shall be conducted in accordance with ASHRAE Standard 41.6[6].

8.5.6 To minimize the thermal storage effect with water delivery equipment, interconnecting tubes shall be at least 25 ft (7.6 m) long but not exceeding 30 ft (9.1 m) of the manufacturer specified diameter tubing. For packaged systems with an outdoor unit, at least 10 ft (3 m) of each interconnecting tube shall be exposed to the outdoor conditions. Insulation shall be per manufacturer specifications. No buffer tanks shall be used on the supply loops unless furnished by the manufacturer as part of the packaged system.

8.6 Measured Energy Input Parameters

8.6.1 Fuel

8.6.1.1 When conducting the tests specified herein, fuel gases with characteristics referenced in ASHRAE 41.13-2020 shall be used. The manufacturer is to specify the gases that the equipment is designed for.

8.6.1.2 Measure and record the gas input rate, including primary usage, pilot gas, and auxiliary usage corrected to standard temperature and pressure conditions. Measurement error shall be no greater than that specified in Section 5.4.

8.6.2 Electricity

8.6.2.1 Measure electrical input power in accordance with ANSI/ASHRAE Standard 41.11[7].

8.6.2.2 Maintain the electrical supply to the equipment within 1% of the nameplate voltage for the duration of the test. If a dual voltage is used for nameplate voltage, maintain the electrical supply within 1% of the higher voltage.

8.6.2.3 Measure and record the steady-state electric power to the equipment under test (for example: fans, blowers, pumps, burners, and other ancillary equipment). The error shall be no greater than that specified in Section 5.4.

8.6.2.4 Electrical input voltage, frequency, power, and energy shall be measured by digital power instruments. Voltages shall be measured at the equipment terminals.

8.6.2.5 If using an integrating (Wh) measurement instrument, measurements shall be recorded at intervals specified in Section 8.7

8.6.2.6 If using a non-integrating (W) measurement instrument, apply the steady-state criteria in ASHRAE Standard 41.11 to obtain the power for power measurement. If unsteady power measurements are required, apply Section 5.3.5 of ASHRAE Standard 41.11.

8.6.3 Indirectly Heated Systems

8.6.3.1 For indirectly heated systems (for example: waste heat driven and steam driven), the input energy shall be calculated using the equations below and the heating load maintained within ±2% of the manufacturer's rated input capacity for the duration of the test.

(***Informative Note***: The rated input capacity might be found on the product's serial plate, user/installation manual, or in combination thereof.)

For systems employing noncombustible heating fluids involving phase change (for example: steam), use the following equation to determine the input energy:

$$q_i = w_H(h_{H,in} - h_{H,out}) \qquad \text{W (Btu/h)}$$

where
q_i = heat input energy to the system, W (Btu/h),
w_H = heating fluid flow rate, kg/s (lb/h)
$h_{H,in}$ = enthalpy of the heating fluid entering the equipment, J/kg (Btu/lb)
$h_{H,out}$ = enthalpy of the heating fluid exiting the equipment, J/kg (Btu/lb)

Otherwise, for single-phase fluids (for example: hot water), use

$$q_i = w_H c_{p,H}(t_{H,in} - t_{H,out}) \qquad \text{W (Btu/h)}$$

where
q_i = heat input energy to the system, W (Btu/h)
w_H = heating fluid flow rate, kg/s (lb/h)
$c_{p,H}$ = specific heat of the heating fluid, J/kg/K (Btu/lb/F)
$t_{H,in}$ = temperature of the heating fluid entering the equipment, J/kg (Btu/lb)
$t_{H,out}$= temperature of the heating fluid exiting the equipment, J/kg (Btu/lb)

8.7 Test Operating Procedure

8.7.1 The test room reconditioning apparatus and the equipment under test shall be operated until equilibrium conditions are attained before capacity test data are recorded. Equilibrium means compliance with Tables 8.1 and 8.2 of test tolerances.

8.7.1.1 Continuous. Data used in evaluating capacity shall be recorded at equal intervals that span 5 minutes or less until readings over a period of one-half hour or more are within the tolerances prescribed in Section 10 and Table 8-1.
8.7.1.2 Batch Process. The appropriate data acquisition interval for continuous yet transient processes shall not be less than once every 10 seconds for a period specified by the manufacturer. In no case shall the period be less than one hour or four consecutive complete cycles. For batch processes, individual observations

shall vary within a cycle as long as the cycle-to-cycle averaged variations are within the tolerances specified in Section 10 and Table 8-2.

TABLE 8-1 Test Tolerances for steady-state tests

Measurement Item	Test Operating Tolerance (Total Observed Range) Max-to-Min Range	Test Condition Tolerance (Variation of Average from Specified Test Condition) Average over a Cycle
All air temperatures, indoor and outdoor		
Dry-Bulb, °C (°F)	1.0 (2.0)	0.3 (0.5)
Wet Bulb, °C (°F)	0.5 (1.0)	0.2 (0.3)
Heat-transfer fluid temperatures, °C (°F)	0.3 (0.5)	0.1 (0.2)
External resistance to airflow, Pa (in. H_2O)	12.5 (0.05)	6.25 (0.025)
Electrical Voltage, %	2.0	--
Fluid mass flow rate, %	2.0	--
Nozzle pressure drops, % of reading	2.0	--

TABLE 8-2 Test Tolerances for transient tests (including batch processes, cyclic testing, and defrosting)

Measurement Item	Test Operating Tolerance (Total Observed Range) Max-to-Min Range	Test Condition Tolerance (Variation of Average from Specified Test Condition) Average over a Cycle
All air temperatures, indoor and outdoor		
Dry-Bulb, °C (°F)	1.7 (3.0)	0.5 (1)
Wet Bulb, °C (°F)	0.9 (1.5)	0.3 (0.5)
Heat-transfer fluid temperatures, °C (°F)	0.5	0.2
External resistance to airflow, Pa (in. H_2O)	--	--
Electrical Voltage, %	4.0	4.0
Fluid mass flow rate, %	5.0	2.0
Nozzle pressure drops, % of reading	--	--

8.8 Test Operating Procedure for Heating Capacity Tests

8.8.1 Introduction

8.8.1.1 Heating capacity tests used to evaluate the heating performance of a heat pump when operating at conditions that are conducive to frost accumulation on the outdoor coil or of a heat pump operating in batch-mode shall be conducted using the "T" test procedure described in Section 8.8.3. Otherwise, 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" procedure are not achievable, 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 stated, overriding of automatic defrost controls shall be prohibited. The controls shall only be over-ridden 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. When automatically or manually initiated, defrost initiation shall be defined as occurring when the controls of the heat pump first alter its operation in order to eliminate any accumulations of frost on the outdoor coil.

8.8.2 "S" Test 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.

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 side entering the outdoor-side shall be sampled at equal intervals that span one minute or less throughout the pre-conditioning and data collection periods. Over these same periods, all other applicable Table 8-1 steady state parameters used in evaluating equilibrium shall be sampled at equal intervals that span five minutes or less. All data collected over the respective periods, except for parameters sampled between a defrost initiation and ten minutes after the defrost termination, shall be used to evaluate compliance with the test tolerances specified in Table 8-1.

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 one hour, before test data are recorded. If a defrost occurs, the heat pump shall operate in heating mode for at least ten minutes after defrost termination prior to resuming or beginning the data collection described in 8.8.2.2 and 8.8.2.4, respectively. End the pre-conditioning period with a defrost cycle for heating capacity tests at low outdoor temperatures.

8.8.2.4 Once the pre-conditioning described in 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 five minutes or less.

The difference between the dry-bulb temperature of the air leaving and entering the indoor coil shall be evaluated at equal intervals that span five minutes or less. The temperature difference evaluated at the start of the data collection period shall be saved for purposes of evaluating 8.8.2.5.1 or 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 8-1 steady state 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 8-1 steady state test tolerances are exceeded

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

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

8.8.2.5.4 If the “S” test procedure is suspended because of condition “c” of 8.8.2.5.1, then another attempt at collecting data in accordance with 8.8.2 and the “S” test procedure shall be made as soon as steady performance is attained. If a defrost cycle occurs, the heat pump shall operate in the heating mode for at least ten minutes after defrost termination prior to beginning the data collection described in 8.8.2.4. The pre-conditioning requirements in 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 8.8.2.5.1, then the sampling specified in 8.8.2.4 shall be terminated after 30 minutes of data collection. The test, where Table 8-1 test tolerances for steady state apply, shall be designated as a completed steady-state heating capacity test.

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 8-1 steady state 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 8-1 steady state test tolerances are exceeded.

8.8.2.6.2 If the “S” test procedure is suspended because of condition “a” of 8.8.2.6.1, then another attempt at collecting data in accordance with 8.8.2.4 and 8.8.2.5 shall be made beginning ten minutes after the defrost cycle is terminated. The pre-conditioning requirements of 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 8.8.2.6.1, then another attempt at collecting data in accordance with 8.8.2.4 and 8.8.2.5 shall be made. This subsequent attempt shall be delayed until ten minutes after the heat pump completes a defrost cycle. This defrost cycle shall be manually initiated, if practical, so that there is no 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 8.8.2.6.1, then another attempt at collecting data in accordance with 8.8.2 and the “S” test procedure shall be made as soon as steady performance is attained. If a defrost does occur, the heat pump shall operate in the heating mode for at least ten minutes after defrost termination prior to beginning the data collection described in 8.8.2.4. The pre-conditioning requirements in 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 8.8.2.6.1, then the sampling specified in 8.8.2.4 shall be terminated after 30 minutes of data collection. The test, where the Table 8-1 test tolerances for steady state apply, shall be designated as a completed steady-state heating capacity test.

8.8.3 “T” Test Procedure

8.8.3.1 Average heating capacity shall be determined using the indoor air enthalpy method. Use of a secondary test method is not required.

8.8.3.2 No changes in the airflow setting 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 8-2 shall be satisfied when conducting heating capacity tests using the "T" test procedure. The test tolerance parameters in Table 8-2 shall be sampled throughout the pre-conditioning 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 20 seconds. The water vapor content of the air entering the outdoor-side shall be sampled at least every minute. All other Table 8-2 parameters shall be sampled at equal intervals that span five minutes or less.

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 one hour. Elapsed time associated with a failed attempt using the "S" test procedure of 8.8.2 shall be counted in meeting the minimum requirement for one hour of operation.

(Informative Note: Prior to obtaining equilibrium and completing one hour of operation, the heat pump may undergo a defrost(s) cycle if automatically initiated by its own controls.)

8.8.3.5 Once the pre-conditioning described in 8.8.3.4 is completed, a defrost cycle shall occur before data are recorded. Manually initiate this defrost cycle if practical, instead 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 three 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 the elapsed time of three 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 the three 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 three hours but before six hours have elapsed, data collection shall cease when this first defrost cycle terminates. Data collection shall cease at six hours if the heat pump does not undergo a defrost cycle within six hours.

8.8.3.6 For a valid test, the test tolerances in Table 8-2 shall be satisfied during the applicable 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 ten-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 stated allowable deviations for the dry-bulb temperatures, the data required for the indoor air-enthalpy test method shall be sampled at equal intervals that span five minutes 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 ten seconds during:

1. defrost cycles

2. the first ten minutes after a defrost cycle termination (including the first ten minutes of the data collection interval)

8.8.3.8 Average heating capacity shall be calculated in accordance with Section 7.3.4 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 six-hour data set shall be used for the calculation in 7.3.4.

9. DATA TO BE RECORDED

9.1 Table 9-1 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 test observations shall be within the tolerances specified in Tables 8-1 and 8-2, as appropriate to the test methods and type of equipment. Additionally, measurement accuracies shall comply with those in Table 5-1.

9.2.2 The maximum permissible variation of any observation during the capacity test is listed under "Test Operating Tolerance" in Tables 8-1 and 8-2. This represents the greatest permissible difference between maximum and minimum instrument observations during the test. When expressed as a percentage, the maximum allowable variation is the specified percentage of the arithmetic average of the observations.

For batch processes, individual observations are permitted to vary within a cycle as long as the cycle-to-cycle averaged variations are within the specified tolerances in Table 8-2. See Section 8.7.1.2.

9.2.3 The maximum permissible variations of the average of the test observations from the standard or selected conditions are shown in Tables 8-1 and 8-2.

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

Table 9-1 Data to be Recorded

Item	Indoor Air Enthalpy Method	Outdoor Liquid Coil Method	Refrigerant Enthalpy Method	Airflow Measurement Approach	
				Nozzle	Modified Airflow Apparatus
Date	X	X	X		
Observer(s)	X	X	X		
Barometric pressure, kPa [in. Hg]	X	X	X		
Equipment nameplate data	X	X	X		
Test interval times, minutes	X	X	X		
Power input to system components, W	(a)	(a)	(a)		
Standby power, W	(a)	(a)	(a)		
Power for heaters and apparatus furnishing heat loads, W	(a)	(a)	(a)		
Total power input to equipment, W	(a)	(a)	(a)		
Applied Voltage(s), V	X	X	X		
Frequency, Hz	X	X	X		
External resistance to airflow, Pa [in. H_2O]	X				
Fan speed(s), setting, rpm	X				

Dry-bulb temperature of air entering equipment, indoor coil, °C [°F]	X				
Wet-bulb temperature of air entering equipment, indoor coil, °C [°F]	X				
Dry-bulb temperature of air leaving equipment, indoor coil, °C [°F]	X				
Wet-bulb temperature of air leaving equipment, indoor coil, °C [°F]	X				
Indoor duct heat transfer, UA_{duc}, W/°C [Btu/°F]	X				
Dry-bulb temperature of air entering equipment, outdoor coil, °C [°F]	X				
Wet-bulb temperature of air entering equipment, outdoor coil, °C [°F]	X				
Dry-bulb temperature of air leaving equipment, outdoor coil, °C [°F]	X				
Wet-bulb temperature of air leaving equipment, outdoor coil, °C [°F]	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			
Power input of pump if located between the inlet and outlet water temperature sensors, W		X			
Heat losses for interconnecting tubing for remote outdoor coil if present,		(c)			
Refrigerant or surface temperature used for leakage coefficient determination, °C [°F]			X		
Refrigerant mass flow rate in liquid line, kg/s [lb_m/h]			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		
Refrigerant liquid temperature, indoor side, °C [°F]			X		
Refrigerant vapor temperature, indoor side, °C [°F]			X		
Refrigerant vapor pressure, indoor side, kPa [psig]			X		
Throat diameter of nozzle(s), mm [in.]				X	
Velocity pressure at nozzle throat or static pressure difference across nozzle(s), Pa [in. H_2O]				X	
Temperature at nozzle throat, °C [°F]				X	
Pressure at nozzle throat, Pa [in. H_2O]				X	
Input to electric reheat or steam coil reheat, W					X
Rate of condensate collection, kg/s [lb_m/h]				(b)	(b)
Additional data					
- Total power input and, where required, input to equipment components. - Required only for latent capacity. - Required only for line loss adjustment.					

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, if the system is an air delivery heating design utilizing an air handler. The results of a capacity test shall express quantitatively the effect produced upon water by the equipment tested, if the system is a radiant heat delivery design. For given test conditions, the capacity test results shall include each of the following quantities that are applicable to cooling or heating or domestic hot water (DHW), 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) total heating capacity, W [Btu/h]
(e) indoor side airflow rate, m^3/s standard air [cfm]
(f) external resistance to indoor airflow, Pa [in. H_2O]
(g) total power input to equipment and power inputs to all equipment components, W [W]

(h) indoor room and outdoor ambient dry bulb and wet bulb conditions [°F]
(i) DHW capacity (Btu/h)
(j) DHW hydronic heated supply and return water temperatures[°F]
(k) DHW potable water inlet makeup water temperature and outlet supply water temperature [°F]
(l) hydronic type equipment's primary loop warm and cold supply and return temperatures [°F], and secondary loops if applicable
(m) ambient temperature of equipment operating location[°F]
(n) hydronic type equipment's primary loop water flow rates (gpm), and secondary loop if applicable
(o) total energy input, gas combustion power (Btu/h), if applicable
(p) hydronic system propylene glycol % used in each water loop (%)
(q) hydronic water flow pressure (psig) and flows (gpm) and head loss (psig)
(r) lambda -fuel/air ratio mixture established
(s) atmospheric pressure and % O2 level maintained for combustion
(t) heat addition from operating hydronic pumps W(Btu/h)

The capacity and energy inputs reported shall be those associated with the primary test method (see Section 7.2).

(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 defrosting) or DHW capacity shall be the indoor side capacity of the two simultaneously conducted methods of test and these two capacities shall agree within 6.0%.

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 recorded as 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 no defrost occurs 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. Radiant capacity results are determined from supply and return water solution delivered at measured flow rates with no adjustment from humidity conditions.

11. SYMBOLS USED IN EQUATIONS

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 (for example: 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]
cppg = specific heat of propylene glycol
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_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_{f1} = enthalpy of refrigerant liquid at a saturation temperature corresponding to the pressure of refrigerant vapor leaving the compressor, J/kg [Btu/lbm]
h_{f2} = enthalpy of refrigerant liquid leaving the condenser, J/kg [Btu/lbm]
h_{g1} = enthalpy of refrigerant vapor entering compressor under conditions specified, 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]
Lambda = fuel/air ratio, unitless
m = thermal storage device mass*, kg [lbm]*
P_a = pressure, barometric, kPa [in. Hg]
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]
Ppp = pressure of primary water pump
Psp = pressure of secondary water pump
q = compressor capacity as determined in accordance with ASHRAE Standard 23-1993,
W [Btu/h]
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]
$(q_{loss})_{IA}$ = duct loss correction for the indoor air enthalpy method, W [Btu/h]
qlosswp = water pressure head loss
qlosswt = water temperature loss in hydronic system
q_{sc} = sensible cooling capacity, 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]
qhpri = total primary loop heating capacity
qhsec = total secondary loop heating capacity
qcpri = total primary loop cooling capacity
qcsec = total secondary loop cooling capacity
qdhw = total dhw capacity
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, m3/s [cfm]
Qrm = radiant measured, standard dT and water flow capacity delivered
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_{r2} = temperature, refrigerant at outdoor unit, °C [°F]
t_s = temperature, saturated refrigerant, °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]
twps. = temperature, warm primary loop supply
twpr = temperature, warm primary loop return
tcps = temperature, cold primary loop supply
tcpr = temperature, cold primary loop return
twss = temperature, warm secondary loop supply
twsr = temperature, warm secondary loop return
tcss = temperature, cold secondary loop supply
tcsr = temperature, cold secondary loop return
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]
wpg = mass flow rate, propylene glycol solution
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[12].

12.2 Thermodynamic Properties of Liquids. The thermodynamic properties of liquids shall be obtained from NIST Standard Reference Database 23 (*REFPROP*)[13] 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*)[13] or from the source of the refrigerant and shall be recorded in the test report.

13. REFERENCES

1. ANSI/ASHRAE Standard 41.1-2024, *Standard Methods for Temperature Measurement*, ASHRAE Atlanta.
2. ANSI/ASHRAE Standard 41.2-2022, *Standard Methods for Air Velocity and Airflow Measurement*, ASHRAE Atlanta.
3. ANSI/ASHRAE Standard 41.3-2022, *Standard Methods for Pressure Measurement*, ASHRAE Atlanta.
4. ANSI/ASHRAE Standard 41.6-2021, *Standard Methods for Humidity Measurement*, ASHRAE Atlanta.
5. ANSI/ASHRAE Standard 41.8-2023, *Standard Methods for Liquid Flow Measurement*, ASHRAE Atlanta.
6. ANSI/ASHRAE Standard 41.10-2024, *Standard Methods for Temperature Measurement*, ASHRAE Atlanta.
7. ANSI/ASHRAE Standard 41.11-2023, *Standard Methods for Refrigerant Mass Flow Measurement using Flowmeters*, ASHRAE Atlanta.
8. ANSI/ASHRAE Standard 41.7-2021, *Standard Methods for Gas Flow Measurement*, ASHRAE Atlanta.
9. ASTM D1826-94 (2017), *Standard Test Method for Calorific (Heating) Value of Gases in Natural Gas Range by Continuous Recording Calorimeter*, American Society for Testing and Materials, West Conshohocken, PA
10. ASTM D3588-20, *Standard Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels, American Society for Testing and Materials*, West Conshohocken, PA.
11. ASHRAE RP-1581 Final Report, *Develop Alternate Setup Guidelines for Unitary Air Conditioners Which Cannot Adhere to ASHRAE 37/ASHRAE 116 Specified Duct Dimensions and External Pressure Tap Locations*, 2013, ASHRAE Atlanta.
12. 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, Atlanta: ASHRAE.
13. NIST Standard Reference Database 23: NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP) Version 10, National Institute of Standards and Technology, Gaithersburg, MD.
14. ANSI/ASHRAE Standard 41.4-2015, *Standard Method for Measuring the Proportion of Lubricant in Liquid Refrigerant,* ASHRAE, Atlanta.
15. ANSI/ASHRAE Standard 41.1-2013, Standard Methods for Temperature Measurement, ASHRAE Atlanta.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX A ENVIRONMENTAL CHAMBER DESIGN CONSIDERATIONS FOR TESTING HEAT-ACTUATED COOLING EQUIPMENT

A1. GENERAL OBSERVATIONS

Environmental chambers used to test electrically driven air conditioners and heat pumps are often not suitable for testing thermally activated or engine-driven systems. The airtight nature of environmental chambers for electrical equipment, in combination with vent gases produced by thermally activated equipment, results in significant differences in chamber designs.

Since thermally activated air-conditioning systems require combustion air and reject more heat to the environmental chamber than electric equipment, environmental chambers intended to test heat-activated or engine equipment must have larger room-conditioning equipment and more sophisticated controls systems.

Thermally activated heat pumps are often designed to continue to pump heat at relatively cold outdoor air temperatures (e.g., –27°C [–17°F]), lower than the limiting temperatures of electric heat pumps. In addition, some thermally activated heat pumps have backup heating systems in the outdoor unit, as opposed to the indoor strip heaters used by electric heat pumps. Therefore, an environmental chamber for testing thermally activated heat pumps should be capable of operating at very low temperatures, depending on the type of equipment being tested.

Temperatures down to –30°C (–20°F) may be required. The environmental chamber should have sufficient cooling capacity to both control low temperatures and to pull the chamber down to these temperatures in a reasonable time period. Humidity control, given makeup air requirements, may often require the use of a desiccant system to operate the chamber at these colder temperatures.

A2. CHAMBER CONDITIONS UNIFORMITY

Carefully design the air-supply system to deliver constant-temperature air into the chambers. Use of diffuser-panel ceilings and/or walls is recommended. For example, temperature differences as little as ±0.5°C (1°F) can turn one side of an absorber coil into a generator when testing absorption machines. This can, therefore, cause very misleading results. Figure A2-1 shows one possible layout for an environmental chamber. Consideration needs to be given to obtaining temperature uniformity across the face of the coils. Figure A2-2 shows an arrangement where the equipment has a separate venting system for flue products. Figure A2-3 shows a generic flow chart layout for adaptation to other equipment configurations.

Air returns are best located in the center of the ceiling, not along the perimeter. Duct face velocities should be about 500 fpm for uniformity and control.

A3. TEST EQUIPMENT HANDLING

A3.1 Design Chambers with "High" Ceilings. Generally, chambers are built from modular standard panels and come with standard 1.75 m or 2.5 m (6 ft or 8 ft) ceilings. At least a 3 m (10 ft) ceiling is recommended. This feature will greatly facilitate installation and removal of equipment into and out of the chamber.

A3.2 Design the Chamber(s) with a Floor That Will Allow One to Move in "Heavy" (up to 450 kg [1000 lb]) Test Units. The chamber floors should be able to support a load brought into the chamber with a forklift truck. Ideally, the roof should have an access for insertion/removal of components using an internal or external hoist.

Alternatively, either the door access to the chamber can be level with the floor or a ramp used to move wheeled vehicles in and out of the chamber through a more conventional door-lip. These requirements add to the complexity of designing a sealed chamber.

A4. REFRIGERANT CONSIDERATION

Provide floor drains and wall curbs for containment, collection, and cleanup of fluid spills. Leaks of hydronic solutions, oil, antifreeze, refrigerants, aqueous lithium bromide, or aqueous ammonia solutions may occur during testing of heat-actuated equipment. The drains provide not only a flow path for these fluids but allow for easy wash down and cleanup of spills.

Consideration should also be given to the installation of dedicated spill collection/testing tanks connected to these drains, since some solutions in heat-activated heat pumps may be legally classified as hazardous wastes.

The designer should provide for the remote addition/ removal/control of fluids, air, air/fuel controls, and samples to the test unit to minimize the time(s) needed to physically enter the chamber. This will greatly increase the time available to collect steady-state data and minimize personnel exposure to potential hazards. Manual filling and draining of refrigerants such as ammonia in an enclosed test chamber can pose a hazard.

A5. COMBUSTION AND MAKEUP AIR CONSIDERATIONS

Makeup air to the environmental chamber is needed for the following:

a. Combustion supply air.
b. Exhaust bleed air (a) to maintain safe conditions within the chamber and (b) supply air to the exhaust hood.
c. Safety venting or purge air to clear the chamber in the event of a loss of refrigerant (e.g., ammonia) charge.

Combustion air should be taken directly from the environmental chamber. This provides combustion air at outdoor air conditions as required for a realistic test. The combustion air needed for a 17 kW (5-ton, 60,000 Btu/h) system is approximately 0.01 m^3/s (20 scfm) for an absorption system.

The makeup air requirements increase the level of the latent load in the chamber. This increases the complexity of the chamber humidity control. A desiccant system may be required to control humidity for low ambient test conditions.

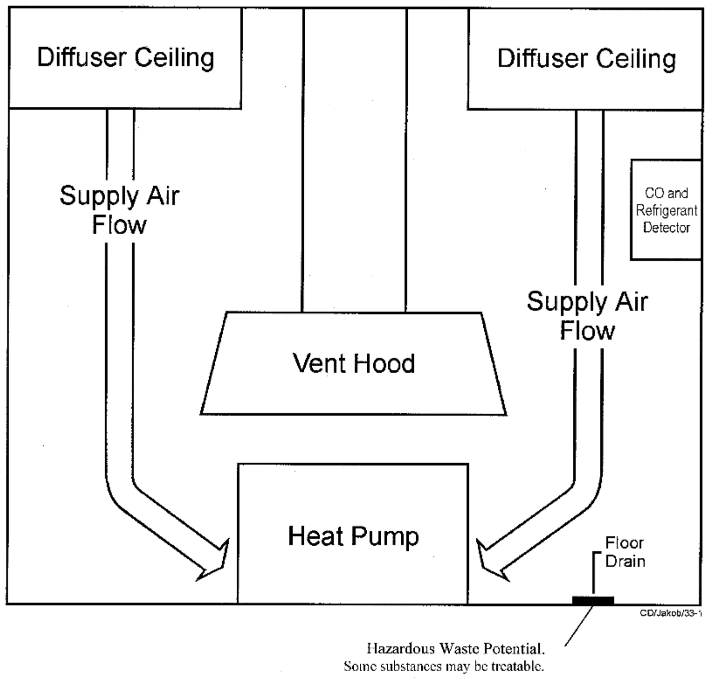

FIGURE A2-1 One suggested layout for an environmental chamber for use with fuel-fired heat pumps. The exhaust hood may be replaced by a ceiling return directly above the heat pump. The operator should be located outside of chamber space with an observation window. Chamber walls and door are typically pre-insulated aluminum panels in structure, with door gaskets and closures typical of a walk-in cooler. Combustion air must come from within the environmental chamber.

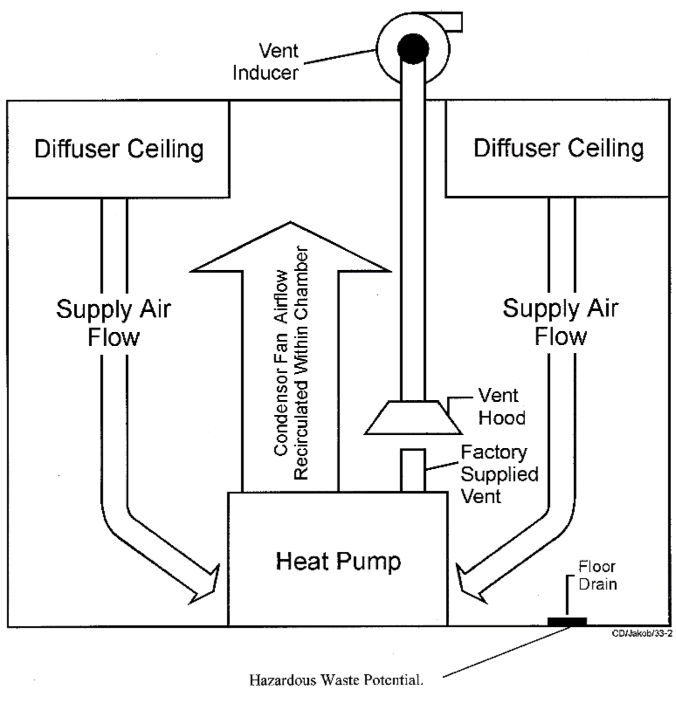

FIGURE A2-2 Suggested layout for an environmental chamber for use with heat-activated heat pump with a small-diameter, factory-supplied vent. Combustion of the small-diameter vent line will allow proper venting without large-scale disturbance of the uniform in-chamber temperature

distribution. Note that the draft hood is located such that the heat pump vent system will operate as it would in an actual outdoor installation. Also, the vent inducer is located outside the environmental chamber. This forces the vent line to operate at negative pressure throughout the environmental chamber, thereby discouraging leakage into the closed chamber.

A6. COMBUSTION VENT PRODUCTS CONSIDERATIONS

Heat-activated heat pumps may discharge vent gases in either of two ways:

a. Some heat pumps, in particular, engine heat pumps, may be designed to discharge vent gases through a small-diameter flue. For such devices, the environmental chamber venting may be performed by a small-diameter vent pipe. In general, a small draft hood should be located at the end of the vent line supplied with the heat pump. A vent draft inducer should be used to power the vent line beyond the draft hood. In this way, the factory-supplied venting system within the heat pump package will see back pressure identical to that seen in a realistic outdoor installation.
b. More typically, the heat pump may be designed to mix vent gases with the overall condenser coil airflow. Proper venting may then be suggested by the large draft hood, covering the entire appliance. This configuration is illustrated in Figure A2-1.

A7. ENVIRONMENTAL CHAMBER CONTROL SYSTEMS

Heat-actuated cooling equipment adds considerable load and complexity of controls to an environmental chamber design when compared with more familiar electric-based chambers. For example, a 5-refrigerant ton (RT) gas heat pump can have heat rejection rates in the outdoor chamber of up to 60 kW (200,000 Btu/h). In one sample chamber designed to test up to 17 kW (5-ton, 60,000 Btu/h) fuel-fired heat pump systems, the environmental chamber is controlled by four condensing units having a total of 90 kW (25.5 ton, 306,000 Btu/h) cooling capabilities in addition to a proportionately large desiccant unit for humidity control.

The HVAC system serving the chamber must be controllable enough to provide tight temperature and humidity control and yet be powerful enough to change chamber temperature quickly enough to allow running multiple tests in a typical workday. Chamber conditioning is best achieved with precooling, desiccation, and post cooling of the airstreams.

Testing fuel-fired heat pumping at low temperatures may dictate that the environmental chamber be capable of running tests at temperatures as low as –30°C (–20°F). This will require a suitable refrigeration-type cooling system capable of lowering chamber temperature over an acceptable time period. Once in heat-pumping mode, the system must be able to supply heat to this low-temperature chamber to keep conditions stable during heat pump testing. This may eliminate use of any available heating hot water supply due to coil freezing concerns.

Generally, an environmental chamber is moved to an operating temperature, and then the hardware to be tested is started. At this point, dramatic departures from the chamber temperature setpoint can be observed due to the heat rejected or absorbed by the equipment. Generally, the control system, as well as the chamber conditioning equipment, ought to be designed/sized to bring the room back to the setpoint within 30 to 60 minutes. This usually requires the HVAC equipment that is controlling the chamber environment to be significantly larger than the total heat rejection of the system to be tested.

A8. SAFETY CONTROLS

Control strategies should also be able to sense solution and refrigerants leaks, as well as the buildup of combustion/exhaust products in the chamber. Sensors and detectors need to be checked for temperature dependency when running cold/heating tests and hot/cooling tests. If excessive levels of emissions are indicated, the controls should either sound a warning to the operator or automatically shut down the chamber according to predetermined procedures. Means should be provided to purge the chamber of vapors and combustion products. Manual purge, panic purge, and emergency shutdown buttons should be provided in the chamber.

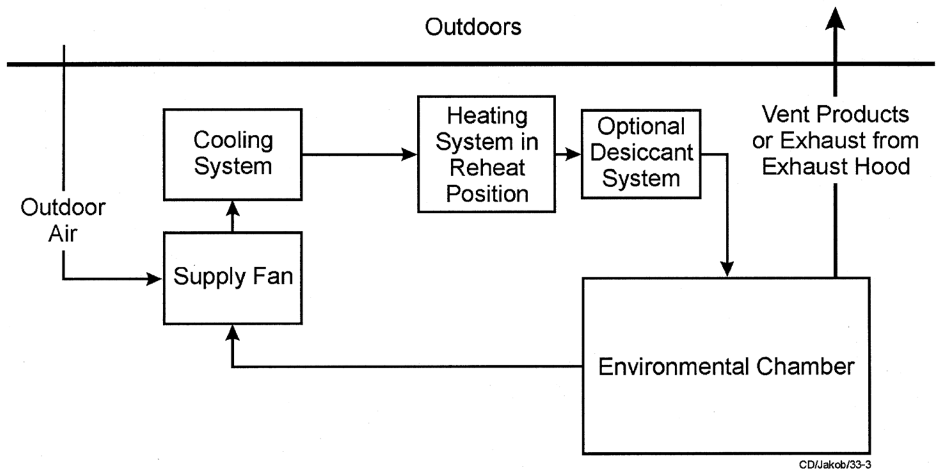

FIGURE A2-3 Possible layout for environmental chamber equipment.
In Figure A2-3, ultimate test conditions should dictate the type of equipment used. Heating coil in the reheat position may aid in controlling environmental chamber humidity. The cooling system may be required to provide refrigerated air for heat-pump testing.