BSR/ASHRAE Standard 200-2018R

Public Review Draft

Methods of Testing Chilled Beams

First Public Review (December 2023)

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NOTE

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FOREWORD

ASHRAE Standard 200 was written at the request of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) to provide test instrumentation and facilities, installation methods, and procedures for determining the capacity and related performance of chilled beams. Procedures provided in this standard apply to active chilled beams.

This standard was prepared in cooperation with the AHRI Chilled Beams Section, and it is referenced in AHRI Standards 1240 (I-P) and 1241 (SI), Performance Rating of Active Chilled Beams, as the method of test for the AHRI Active Chilled Beam (ACB) certification program.

Changes from the 2015 edition of the standard include clarifications/revisions to the acoustical testing requirements, as well as verified test methods for induction ratio and water pressure drop.

1. PURPOSE

1.1 To define laboratory methods of testing chilled beams to determine performance.

2. SCOPE

2.1 Defines laboratory methods of testing chilled beams to determine performance.

2.2 Specifies test instrumentation, facilities, installation methods, and procedures for determining the performance of chilled beams.

3. DEFINITIONS AND SYMBOLS

3.1 Definitions

active chilled beam: an air induction and diffusion device that introduces and conditions air for the purpose of temperature and/or humidity control. Primary air is delivered through a series of nozzles, which induces and conditions secondary air through a unit-mounted coil.

induced air: the flow of secondary air into a chilled beam resulting from a pressure differential within the beam, distributed and circulating through the coil.

octave band: a frequency band of sound with an upper limit that is twice the frequency of the lowest limit. The center frequency of an octave band is the geometric mean of its upper and lower limits. Table 1 shows octave bands 1 through 8.

passive chilled beam: a cooled element or coil fixed in, above, or below a ceiling that sensibly cools through natural convection using buoyancy-driven airflow. The cooling media in the coil is water.

<table>
<thead>
<tr>
<th>Octave Band</th>
<th>Center Frequency, Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63</td>
</tr>
<tr>
<td>2</td>
<td>125</td>
</tr>
<tr>
<td>3</td>
<td>250</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
</tr>
<tr>
<td>5</td>
<td>1000</td>
</tr>
<tr>
<td>6</td>
<td>2000</td>
</tr>
<tr>
<td>7</td>
<td>4000</td>
</tr>
<tr>
<td>8</td>
<td>8000</td>
</tr>
</tbody>
</table>

radiation shielded sensor: resistive temperature devices (RTDs) designed to measure dry-bulb air temperatures are susceptible to radiation heat transfer, and therefore the total temperature measured is the sum of the air temperature and the radiation component generated by a heat source or heat sink where present. Radiant shields must be attached to the RTD to minimize the effect of radiant heat transfer. The radiant shield must be designed such that the incoming radiation is deflected while not obstructing air currents. The maximum surface emissivity for the shield is 0.09. The shield must be made of a thin conductive film or metal with high thermal conductivity greater than 87 Btu*ft/(h*ft²*°F) (150 W/m-K). The inside of the shield must be designed to absorb incident radiation that may enter the shield through air vents, and interior emissivity must be greater than 0.75. (Informative Note: See Informative Appendix D for more information.)

sound power: in a specified frequency band, the rate at which sound energy is radiated by a noise source, expressed in watts (W).

sound power level (Lw): ten times the logarithm to the base ten of the ratio of the sound power radiated by the source to a reference sound power, expressed in decibels (dB). The reference sound power used in this standard is 10⁻¹² W.

sound pressure: in a specified frequency band, a fluctuating pressure superimposed on the static pressure by the presence of sound.

sound pressure level (Lp): twenty times the logarithm to the base ten of the ratio of the sound pressure radiated by the noise source under test to a reference sound pressure of 20 μPa, expressed in decibels (dB).

(Informative Note: For terms not defined above, refer to definitions on the ASHRAE Terminology website.)

3.2 Symbols

a empirical coefficient (different for I-P and SI units)

a' empirical coefficient (different for I-P and SI units)

Aφ coil-free cross-sectional area perpendicular to direction of induced airflow, ft² (m²)

b empirical coefficient (different for I-P and SI units)

b₃ center distance between thermal simulators (between 4 and 6 ft [1.2 and 1.8 m])

ANSI/ASHRAE Standard 200-2018
This foreword is not a 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.

This is a revision of Standard 200-2018. This standard was prepared under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). It may be used, in whole or in part, by an association or government agency with due credit to ASHRAE. Adherence is strictly on a voluntary basis and merely in the interests of obtaining uniform standards throughout the industry.

The changes made for the 2023 revision were:

- References were updated.
4. INSTRUMENTATION AND FACILITIES

4.1 All instruments shall have been calibrated in the range of use within the past year to a NIST-traceable or equivalent organization standard.

4.2 Temperature and moist air properties measuring instruments shall meet the requirements of ASHRAE Standard 41.1 \(^1\) and ASHRAE Standard 41.5 \(^2\) and the following subsections.

4.2.1 Accuracy of the temperature measuring and moist air properties instruments shall be within the following limits:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>±0.2°F (0.1°C)</td>
</tr>
<tr>
<td>Water temperature</td>
<td>±0.2°F (0.1°C)</td>
</tr>
<tr>
<td>Temperature differential</td>
<td>±0.1°F (0.05°C)</td>
</tr>
<tr>
<td>(sensors calibrated as a pair)</td>
<td></td>
</tr>
<tr>
<td>Room dew-point temperature</td>
<td>±1.0°F (0.6°C)</td>
</tr>
</tbody>
</table>

4.2.2 Accuracy of the water pressure measuring instruments shall be within the following limits:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water pressure</td>
<td>±0.05% full scale or 0.2 psi (0.1 kPa)</td>
</tr>
</tbody>
</table>

4.3 Pressure measuring instruments shall meet the requirements of ANSI/ASHRAE Standard 41.3 \(^3\) and the requirements of Section 4.3.1.

4.3.1 For air pressure, the maximum scale intervals shall not be greater than the characteristics listed below for the accompanying range of pressure indicating device.

<table>
<thead>
<tr>
<th>Range</th>
<th>Maximum Scale Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.004 to 0.10 in. (1.0 to 25 Pa)</td>
<td>0.001 in. (0.25 Pa)</td>
</tr>
<tr>
<td>0.10 to 1.00 in. (25 to 250 Pa)</td>
<td>0.010 in. (2.5 Pa)</td>
</tr>
<tr>
<td>1.00 to 2.00 in. (250 to 500 Pa)</td>
<td>0.020 in. (5.0 Pa)</td>
</tr>
<tr>
<td>&gt;2.00 in. (&gt;500 Pa)</td>
<td>0.100 in. (25 Pa)</td>
</tr>
</tbody>
</table>
4.3.2 Calibrations standards shall be used as indicated in the following subsections.

4.3.2.1 For instruments with the range 0.005 to 0.100 in. of water (1.25 to 25 Pa), a micromanometer or another instrument calibrated to ±0.0005 in. of water (0.125 Pa) shall be used.

4.3.2.2 For instruments with the range 0.1 to 2.0 in. of water (25 to 500 Pa), a micromanometer or another instrument calibrated to ±0.01 in. of water (2.5 Pa) shall be used.

4.3.2.3 For instruments with a range greater than 2.0 in. of water (500 Pa), a manometer or another instrument calibrated to ±0.1 in. of water (25 Pa) shall be used.

4.3.3 Barometric Pressure. The barometric pressure shall be obtained by means of a barometer located in the general test area and have accuracy within ±0.05 in. Hg (169 Pa).

4.3.4 For water pressure measurement, use ASHRAE Standard 41.3.

4.4 Primary Airflow Measurement

4.4.1 Airflow meters shall have an accuracy of ±5.0% of primary airflow reading.

4.4.2 The device for airflow measurement shall be calibrated to provide the accuracies listed in Section 4.3.1. (Informative Note: For more information on airflow measurement methods is in Informative Appendix B).

4.4.3 Airflow measurement devices shall be checked at intervals as appropriate, but not exceeding 12 months. This check shall take a form indicated in one of the following subsections.

4.4.3.1 A calibration check over the full range using the original method employed for the original calibration of flowmeters calibrated in situ.

4.4.3.2 Airflow meters shall be checked in situ by means described in ASHRAE Standards 41.2 or 41.7 or in Informative Appendix B.

4.4.4 Air temperature shall be maintained to within ±0.4°F (0.2°C) during airflow measurements.

4.4.5 Ductwork between the reference airflow measuring device and the device under test shall be sealed per SMACNA duct class A at 3 in. of water (747.3 Pa), seal class zero.

4.5 Water Flow Rate Measurement

4.5.1 The water flow rate through the test object shall be measured with a flowmeter calibrated to an uncertainty of 1% (±0.5%) or less.

4.5.2 In any calibration method that removes water from the system, the method shall not allow air to enter the system or shall provide means for its removal.

4.6 Sound Power Measurement

4.6.1 Sound Power Determination. Sound power levels shall be determined for the octave band center frequencies from 125 to 4000 Hz according to AHRI Standard 220 as modified below. Sound power levels in additional octave band center frequencies above and below this range shall be determined only where the reverberation room has been qualified in those ranges. AHRI Standard 220 specifies the instrumentation, test facilities, sound power calculation method, required data, reference sound source (RSS) requirements, and reverberation room qualification procedures.

4.6.2 Reverberation Room Qualification. Units are required to be tested in a reverberation room that meets the broadband requirements of AHRI Standard 220. It is not necessary to test units in a reverberation room that meets the discrete frequency requirements of ANSI/AHRI Standard 220.

4.6.3 Sound Data Requirements. Sound measurements shall be performed in one-third octave band levels from 100 to 5000 Hz center frequencies. Sound power levels in additional octave band center frequencies above and below this range shall be determined only where the reverberation room has been qualified in those ranges. Corrections for background noise and for the computation of the one-third octave band sound power levels shall be per AHRI Standard 220.

4.7 Discharge Air Jet Performance Measurement. Used for throw measurements (see Section 5.7.5).

4.7.1 Instruments used for discharge air jet velocity measurement shall meet the accuracy levels shown in ASHRAE Standard 70.

4.8 Water-Side Cooling Capacity Measurement

4.8.1 The water-side cooling capacity of the test object shall be determined from measurements of the cooling water flow rate and cooling water temperature rise under steady-state condition. The water-side cooling capacity shall be presented as a function of the primary airflow rate and the temperature difference between the reference air temperature and the mean cooling water temperature.

4.8.2 The measurements shall be performed in an airtight room, per the requirements of Section 4.8.3, with temperatures on the inside surfaces not varying by more than 3°F (1.7°C).

4.8.2.1 Internal Heat Supply Method

4.8.2.1.1 The perimeter of the room shall be insulated and have negligible heat flow through it. The perimeters shall be insulated in such a way that during the test the average heat flow through these surfaces is less than 0.13 Btu/h/ft² (0.40 W/m²).

4.8.2.1.2 To balance the cooling capacity of the test object, heating is supplied in the test room by means of several electric heated person simulators (such as dummies) as described in Informative Appendix C. The dummies are placed on the floor inside the test room. To obtain reproducible results, the dummies shall be placed in determined positions as described in Section 5.10.2. For location of beams relative to the dummies, see Section 5.10.2.

4.8.2.2 External Heat Supply Method

4.8.2.2.1 To balance the cooling capacity of the test object, heating is supplied to the test room, distributed evenly through the walls and the floor. The ceiling shall be insulated in such a way that during the test the heat flow through the ceiling is less than 0.13 Btu/h/ft² (0.4 W/m²). The temperature of the inner walls and floor of the test room shall be controlled and maintained uniform at any level necessary to sustain the desired room temperature. The maximum tem-
temperature difference between any point of the inner walls and floor during the test shall be less than 2°F (1.1 K).

4.8.3 Test Room

4.8.3.1 The floor area of the test room shall be between 108 and 600 ft² (10 and 55.7 m²).

4.8.3.2 The ratio of width to length of the test room shall be not less than 0.5, and the inside height shall be between 9 and 10 ft (2.7 and 3 m).

4.8.3.3 The test room shall be sufficiently tight to minimize flow from the ambient air outside, which shall not exceed 0.16 cfm/ft² (0.8 L/s m²) of the perimeter surface (including floor, walls, and ceiling) at a pressure difference of 0.2 in. of water (50 Pa).

4.8.3.4 The outside of the room or outer room, as appropriate, shall be insulated. Heat loss to the outside shall be determined by preliminary calibration (without test object cooling) to demonstrate compliance with either Section 4.8.1 or 4.8.2 as appropriate.

4.8.3.5 The fixed temperature sensors shall be installed on the inside surface of each test room wall and floor.

4.8.3.6 The radiation emissivity of the inner surfaces of the room shall be at least 0.9.

4.8.3.7 The primary air shall be provided by either Section 4.8.3.7.1 or 4.8.3.7.2.

4.8.3.7.1 The primary air shall be ducted to the test object through an insulated duct from the outside of the test room. The exhaust opening shall be placed in the ceiling or in a wall adjacent to the ceiling in a place outside the main total air current from the test object and have a velocity at the exhaust opening no greater than 200 fpm (1 m/s).

4.8.3.7.2 An alternative method is to take air from inside the test room by using a fan inside the test room to create a full recirculatory system, which will simplify the heat balance checks. In this case, the fan power has to be considered part of the load. The fan inlet duct shall be placed adjacent to the ceiling but outside of the main air current from the test object and have a velocity at the intake opening no greater than 200 fpm (1 m/s).

4.8.3.8 Instrumentation for the Internal Heat Supply Method

4.8.3.8.1 To balance the cooling of the test object (and the cooling from the primary air in the nonisothermal tests), heating is supplied in the test room by means of a number of electric heated person simulators (such as dummies) placed on the floor inside the test room as described in Section 5.3.3.2. The effective electric power to the dummies shall be measured over the test period with wattmeter plus calibrated timer or an integrating watt-hour meter with an uncertainty of 1% or less.

4.8.3.9 Instrumentation for the External Heat Supply Method

4.8.3.9.1 To balance the cooling of the test object (and the cooling from the primary air in the nonisothermal tests), heating is supplied into the test room, distributed evenly over the walls and floor by means of one of the methods in the following subsections.

4.8.3.9.2 Water Panels with Circulating Warm Water. The heat supplied shall be determined from measurements of the water flow rate and water temperature difference for the actual panels. To obtain the necessary temperature difference, this shall be measured in a primary circuit feeding water to the panels.

4.8.3.9.3 Several electric heating elements placed in the outer room that cover all walls and the floor of the inside test room. Use fans for forced air circulation in the outer room. The effective electric power to the heating elements and circulation fans shall be measured over the test period with wattmeter plus calibrated timer or an integrating watt-hour meter with an uncertainty of 1% or less.

4.8.3.10 Other Instrumentation

4.8.3.10.1 Air temperatures shall be measured by radiant shielded sensors (as described in Informative Appendix D) with an uncertainty equal to 0.4°F (±0.2°C) or less.

4.8.3.10.2 Surface temperatures shall be measured by sensors fixed to small metal plates glued to the surface and painted to match the wall surface emissivity, or with other types of surface temperature sensors, with an uncertainty of 0.4°F (0.2°C) or less.

4.8.3.10.3 Globe temperature shall be measured with a sensor calibrated to give an accuracy of 0.4°F (0.2°C) or less, placed in the center of a black globe with diameter 2.36 to 5.9 in. (60 to 150 mm), per ISO 7726.

4.8.3.10.4 The temperature of the water into and out of the test object shall be measured by sensors placed in the water flow immediately before and after the test object, calibrated with an accuracy of 0.2°F (0.1°C) or less. Where temperature differences are required, pairs of sensors shall be calibrated to give an accuracy of the cooling water temperature rise (\(t_w_{2} - t_w_{1}\)) of ±0.04°F (±0.02°C) or less. The reference air temperature sensor shall be calibrated together with the water temperature probes to give an accuracy of measurement of the temperature difference between the reference air temperature and the inlet and outlet water temperatures of ±0.02°C or less.

4.8.3.10.5 The water flow rate through the test object shall be measured with a flowmeter calibrated to an accuracy of 1% (±0.5%) or less. In any calibration method that removes water from the system, the method shall not allow air to enter the system or shall provide means for its removal.

4.8.3.10.6 The primary airflow rate to the test object shall be measured using instruments in accordance with Informative Appendix B.

4.8.3.10.7 The dew point of the test room air shall be measured with an instrument that has the necessary accuracy to confirm that the dew point is at least 3.6°F (2°C) lower than the water inlet temperature.

5. TEST METHODS

5.1 Acoustics

5.1.1 Sound power level determination requires that the device be installed in the reverberant room, as appropriate for the installation style of device under test.
5.1.2 Combined Radiant and Discharge Sound Test

5.1.2.1 The unit shall be installed in accordance with Figure 1. This test method is used to determine the combined radiant and discharge sound power.

5.1.2.2 Mounting of Equipment for Testing. Equipment shall be mounted in a way that is representative of a design application of the product.

5.1.2.2.1 Position A (Figure 1)—mounted away from wall.

5.1.2.2.2 Position B (Figure 1)—mounted against or through the wall with the bottom of equipment on the floor. The equipment shall be mounted at the minimum manufacturer recommended projection into the room.

5.1.2.2.3 Position C (Figure 1)—mounted against or through the wall, but the bottom of the equipment is not on the floor. The equipment shall be mounted at the minimum manufacturer’s recommended projection into the room.

5.1.2.2.4 Position D (Figure 1)—ceiling-mounted equipment shall be suspended from the sound room ceiling or from a frame device or mounted on rails supported by concrete blocks.

5.1.2.2.5 All equipment shall be mounted according to the manufacturer’s installation instructions. If any deviations from these instructions are necessary, the deviations shall be made in such a manner that the acoustic performance of the equipment will not be affected.

5.1.2.2.6 These installation conditions shall be described in the test report.

5.1.3 Sound power levels generated from air outlets and air inlets shall be determined for third octave bands in accordance with Section 4.6.

5.1.4 The air outlet or air inlet test unit shall be installed in accordance with Figure 1 or as recommended by the manufacturer. Ductwork attached to the unit under test shall be the same size as the connection and straight for at least 5 diameters from the unit. Any duct elbows used to route air to or from the unit under test shall be full radius type. Air shall be supplied to or from the installed test unit and the airflow rate shall be measured in accordance with Section 4.4. All ductwork leading to the test unit must be lagged with a sound barrier material to prevent the breakout of sound, which influences the sound generation measurement of the test unit.

5.2 Physical Requirements for Water-Side Cooling Capacity

5.2.1 The test chamber shall be configured for the following test methodologies.

5.2.1.1 An internal heat supply method enables the use of a single enclosure (hence referred to as the “test room” or “chamber”) whose heat escape is limited by the chamber surface’s insulation.

5.2.1.2 The room height must be between 9 and 10 ft (2.7 and 3 m).

5.2.1.3 An external heat supply method requires an enclosure that allows for the inner walls and floor to provide controlled and evenly distributed heat flow to maintain the test room temperature. The ceiling shall be insulated.

5.2.2 Room Characteristics

5.2.2.1 Leakage shall be minimized to keep chamber room pressure above ambient but no greater than 0.05 in. of water (12.4 Pa).

5.2.2.2 If the internal heat supply method is used, all surfaces must be insulated to confirm that the average heat flux through the surfaces does not exceed 0.13 Btu/h/ft² (0.4 W/m²).

5.2.2.3 The outside of the room or outer room shall be insulated as appropriate. The heat loss to the outside shall be determined by preliminary calibration (without test object cooling) to demonstrate compliance with either Section 4.8.2.1 or 4.8.2.2, as appropriate. If the chamber walls are not controlled, then the outer room temperature must be documented during calibration and maintained for all subsequent data collection.

5.3 Test Setup Requirements

5.3.1 The following sections describe the location of (and qualification requirements for) the test sample, heat sources, and measurements required by the standard.

5.3.2 Heat-Source Qualifications and Location

5.3.2.1 Internal Heat Supply Method

5.3.2.1.1 Heat sources (such as dummies) must be used to provide internal heat supply (see Informative Appendix C).

5.3.2.1.2 Heat sources (such as dummies) shall be placed in determined positions as specified in Section 5.3.3.2.

5.3.2.2 External Heat Supply Method

5.3.2.2.1 Heat shall be supplied by hot-water panels or electric heaters covering the surfaces of all four walls and the floor.
5.3.2.2.2 Heat must be supplied evenly through all four walls and the floor. Temperatures at any point on these five (5) surfaces must remain within 1.8°F (1°C) of each other throughout the test.

5.3.2.2.3 Other heat sources (such as dummies) shall not be used for this method.

5.3.3 Test Sample Qualifications and Location

5.3.3.1 This test setup and installation procedure details the requirements for installing an active chilled beam within an environmental test chamber with qualities closely approaching a perfect adiabatic box. The setup covers installation procedures for one-way, two-way, and four-way air discharge products. Although test conditions remain identical for each type of discharge pattern, location of internal loads will change, and the throw characteristics of the product must be accounted for.

5.3.3.2 The location of the internal loads will change depending on the number of discharge slots of the product being tested. Figures 2, 3, and 4 are the recommended installation positions for three such cases, as described in the following subsections.

5.3.3.2.1 The one-way units require a slightly different installation procedure than the two-way and four-way units. In contrast to a symmetric installation, the test object must be placed along one of the interior walls (Figure 2). This is required because the negative pressure region generated on the opposing side of the discharge slot favors recirculation in a symmetric installation and will cause inefficiencies in testing.

5.3.3.2.2 The two-way installation (Figure 3) requires that the test object be located symmetrically in the space so that the center of the test object is located at (A/2, B/2). Internal heat loads must be placed symmetrically along the length of the discharge slot.

5.3.3.2.3 A four-way installation (Figure 4) is similar to a two-way installation in that the center of the test object must be at coordinates (A/2, B/2). If the four-way unit is a rectangle, then the internal loads must be proportionally increased along its length.

5.3.3.3 Suspend test object from ceiling and attach air/hydraulic components to the chilled beam. Confirm that all air has been evacuated from the coil by purging the coil with a heat-transfer medium. Temperature measurements must be taken in the supply and return pipe connections to the test object.

5.3.3.4 If the test object is intended for installation in a recessed ceiling where the throw is dependent on the Coanda effect, a perimeter of no less than 18 in. (46 cm) must be built around the discharge columns to allow attachment of the discharge air column to the ceiling.

5.3.3.5 Three temperature sensors are installed lengthwise across the face of the test object, spaced evenly across the length and along the beam’s center line as shown in the two-way test object in Figure 5.

5.3.3.6 These three temperature sensors must be shielded with radiant deflectors to mitigate radiant effects from the hydronic coil.

5.3.3.7 For both internal and external methods, a visualization test of the test object is necessary to confirm that the discharge air from the test object adheres to the ceiling.

Informativ Note: The conditions required for this are those most likely to cause detachment of the air column from the ceiling and result in recirculation of discharge air through the return of the test object, as listed in the following subsections.

5.3.3.7.1 Airflow is set to minimum airflow or static pressure.

5.3.3.7.2 Water flow is set to maximum water flow rate.

5.3.3.7.3 Entering water temperature is set to coldest condition.

5.3.3.7.4 After the (Mean Water – Average Return Air Temperature) has stabilized to less than 0.2 K for 10 minutes, a vaporized base smoke shall be injected into the airstream. With the air pattern at operating conditions, the discharge air column must adhere to the ceiling to confirm performance of the test object.

5.3.3.8 Test sample water-cooling capacity must be at least equal to 4.75 Btu/h/ft² (15 W/m²) of the test chamber floor area.

5.3.3.9 If the sample relies on induction from above, the distance from the sample’s induction face to the ceiling of the chamber must be representative of field installations and noted on the test report.

5.3.3.10 Primary air is supplied to the sample through an insulated duct.

5.3.3.11 The number of simulators in each row shall be calculated from the following equation:

\[ n_r = l_r / b_s \]

where

\[ n_r \] = number of simulators in each row
\[ l_r \] = room length
\[ b_s \] = center distance between each simulator, between 4 and 6 ft (1.2 and 1.8 m)

5.3.4 Measurement Requirements and Locations

5.3.4.1 The following measurements (and their measurement location) are required by the standard.

5.3.4.1.1 Test room static pressure \( P_{test} \) for reference (measured relative to the pressure outside the test chamber).

5.3.4.1.2 Test room barometric pressure \( P_{bar} \).

5.3.5 Temperature Measurements

5.3.5.1 Induced air temperature \( t_p \) is an average of air temperatures of the induced air on the inlet side of the cooling coils, measured with radiation-shielded sensors in three positions in each induced air opening, two centrally at the quarter points and one at the central point of the opening, at 1 in. (2.54 cm) from the induced air opening. It shall remain constant (±1°C or ±1.8°F) between 72°F and 82°F (22°C and 27°C) throughout the test.

5.3.5.2 Room (ambient) air temperature \( t_a \) shall be measured with radiation-shielded sensors at heights of 4, 42, and 67 in. (0.1, 1.1, and 1.7 m) above the floor at the center of the room.
5.3.5.3 The return air temperature $t_a$ shall be measured in the exhaust duct upstream of any air-moving device.

5.3.5.4 Primary air temperature $t_p$ shall be measured in the primary duct just ahead of the test sample.

5.3.5.5 Surface temperatures of all inside walls $t_{sw}$ through $t_{sw4}$, floor $t_f$, and ceiling $t_c$ shall be measured at the center of the surface.

5.3.5.6 Water supply temperature $t_{w1}$ shall be measured immediately before entry into the sample.

5.3.5.7 Water return temperature $t_{w2}$ shall be measured immediately exit from the sample.

5.3.5.8 The room dew-point temperature $t_{dp}$ must be measured and recorded using an instrument that has the necessary accuracy to confirm that the dew point is at least 2°F (1°C) lower than the supply water temperature $t_{w1}$ entering the test sample.

5.3.6 Volume Flow Rate Measurements

5.3.6.1 The primary airflow rate $q_p$ to the test sample shall be measured in the primary air duct.

5.3.6.2 Water flow rate $q_w$ to the test sample shall be measured either upstream or downstream of the test sample.
5.3.6.3 The chilled beam's plenum static pressure shall be measured for a particular given primary airflow rate in accordance with manufacturer's instruction.

5.3.7 Power and Heat Flow Measurements

5.3.7.1 Measure heating contribution $P_z$ from dummies to determine the watt-hour value of power supplied to the dummies.

5.4 Testing Requirements

5.4.1 Test Battery 1 (three tests) involves testing of the sample at three prescribed primary airflows (min, max, and mid). The water flow rate, inlet water temperature, primary air temperature, and reference temperature shall be maintained constant throughout this battery of tests.

5.4.2 Test Battery 2 (three tests) involves testing of the sample at three prescribed inlet water temperatures (min, max, and mid). The primary airflow rate shall be defined as midrange as in Test Battery 1. The primary airflow rate and temperature, water flow rate, and reference temperature shall remain constant and at the same values as Test Battery 1 (Section 5.4.1) throughout this battery of tests.

5.4.3 Test Battery 3 (three tests) involves testing of the sample at three prescribed chilled-water flow rates $q_w$ (min, max, and mid). The primary air temperature, inlet water temperature, and reference temperature shall remain constant and at the same values as Test Battery 1 (Section 5.4.1) throughout this battery of tests.

Run the test battery at constant nominal primary airflow rate (midway between manufacturer-specified min and max airflow rate).

5.4.4 Room dew-point temperature $t_{dp}$ is to be maintained at least 2°F (1°C) below the chilled-water supply temperature $t_{w1}$.

5.4.5 Primary air temperature shall remain constant within ±0.4°F (±0.2°C) throughout tests.

5.4.6 Induction Coefficient Determination

5.4.6.1 Use the procedure described in Normative Appendix E for the range of primary airflow rates recommended by the manufacturer for a given beam configuration.

5.4.7 Uncertainty of Test Results

5.4.7.1 The uncertainty of each test's results is calculated using the Cumulative Error Law and the standard deviations of all of the listed measurement parameters:

$$r = \left( r_1^2 + r_2^2 + r_3^2 + r_4^2 + r_5^2 \right)^{0.5}$$
5.4.7.2 Cooling water flow rate: \( q_w \) (% of specified value), uncertainty \( r_1 \).

5.4.7.3 Cooling water temperature rise: \( t_{w2} - t_{w1} \) (±5°F or ±5°C), uncertainty \( r_2 \).

5.4.7.4 Temperature differential \( \Delta t \) between induced air and mean water (±5°F or ±5°C), uncertainty \( r_3 \).

5.4.7.5 Primary airflow rate: \( q_p \) (% of specified value), uncertainty \( r_4 \).

5.4.7.6 Test room configuration, uncertainty \( r_5 \) (assume to be 3%).

5.4.7.7 The cumulative error \( r \) shall not exceed ±6% at the nominal flow rates and \( \Delta t_{NW} = 115°F \) (8°C).

5.5 Test Procedures

5.5.1 Test measurements shall only be made when the conditions in the following subsections are satisfied.

5.5.1.1 The sum cooling provided by the test sample(s) is at least 4.8 Btu/h/ft² (15 W/m²).

5.5.1.2 The induced air temperature is between 72°F and 82°F (22°C and 27°C).

5.5.1.3 The chamber dew-point temperature \( t_{dp} \) is at least 2°F (1°C) lower than the supply water temperature \( t_{w1} \) entering the test sample.

5.5.1.4 Only after steady-state conditions (see Section 5.6) have been recorded over a period of at least 60 minutes (minimum one measurement per minute).

5.5.1.5 Upon verifying steady-state conditions (see Section 5.6), test measurements must include at least twenty (20) recordings (1 per minute) under steady-state conditions.

5.6 Definition of Steady State

5.6.1 The standard establishes steady-state conditions as those in which the standard deviation of all of the measurement parameters is within the ranges of the following subsections.

5.6.1.1 Reference temperature \( t_r \) (std. dev.), is less than 0.09°F (0.05°C).

5.6.1.2 Interior room surface temperatures \( t_{sw1,2,3,4} \), \( t_s \), and \( t_c \) (std. dev.) are less than 0.9°F (0.5°C).

5.6.1.3 Inlet water temperature (std. dev.) is less than 0.09°F (0.05°C).

5.6.1.4 Cooling water flow rate \( q_w \) (std. dev.) is less than 1% of the specified value.

5.6.1.5 Primary air temperature \( t_p \) (std. dev.) is within 0.4°F (0.2°C) of the specified value.

5.6.2 Primary airflow rate \( q_p \) (std. dev.) is within 1.5% of the specified value.

5.7 Calculations and Expression of Results

5.7.1 Calculations

5.7.1.1 The parameters in the following subsections are determined directly by calculations using measured test data.

5.7.1.1.1 Water temperature rise \( \Delta t_w = t_{w2} - t_{w1} \).

5.7.1.1.2 Mean water temperature \( t_w = 0.5 \times (t_{w1} + t_{w2}) \).

5.7.1.1.3 Induced air to mean water temperature differential \( \Delta t = t_r - t_w \).

5.7.1.4 Induced air to primary air temperature differential \( \Delta t_p = t_r - t_p \).

5.7.1.5 Cooling capacity of primary air \( P_a = m_p \times c_{pa} (t_r - t_p) \).

5.7.1.6 Cooling capacity of water coil \( P_w = m_w \times c_{pw} (t_{w2} - t_{w1}) \).

5.7.1.7 For the internal heat supply method, the heat transfer through all of the room surfaces is to be calculated and summed with the heat removal by the primary air and water passing through the test chamber. This value shall not differ from the total power added to the chamber by more than 5%.

5.7.2 Plot of Results

5.7.2.1 Upon verification of the heat balance, the plots in the following subsections shall be performed.

5.7.2.1.1 Maintaining the air to mean water temperature differential \( \Delta t \) (at 14.4°F [8°C] in the example), the water-side cooling capacity is plotted versus the three primary airflow rates used in Test Battery 1 (Figure 6).

5.7.2.1.2 Plot water-side cooling capacity \( P_w \) versus the air to mean water temperature differential \( \Delta t \) for the three values of inlet water temperature (min, mid, and max) used in Test Battery 2.

5.7.2.1.3 Maintaining the air to mean water temperature differential \( \Delta t \) at 14.4°F (8°C), the water-side cooling capacity is plotted versus the three water flow rates per Test Battery 3 (Figure 8).

5.7.2.2 The best fit curves of the plots are then used to determine the constants that describe the water-side cooling performance.

5.7.3 Throw-Testing Conditions

5.7.3.1 Throw testing shall be performed in accordance with ANSI/ASHRAE Standard 70, Method of Testing the Performance of Air Outlet and Air Inlets.

5.7.3.2 It is recommended that a visualization technique, such as theatrical smoke or a fog machine, be used to ascertain performance before testing.

6. REPORTING

The test report shall include the following information:

a. Name and address of the testing laboratory
b. Identification number of the test report
c. Name and address of the manufacturer or supplier of the test object
d. Name or identification codes of the test object
e. Detailed description of the test object, including relevant materials and dimensions (including coil cooling length, inside pipe diameter, number of pipe rows, and fin spacing)
f. Description of the installation of the test objects in the test room (including clearance above beam to roof of test room)
g. Description and identification of the test equipment and instruments used
Figure 6 Example best-fit curve for water-side cooling capacity vs. three primary airflow rates (I-P).

Figure 7 Example of best-fit curve for water-side cooling capacity vs. three temperature differentials (I-P).
Figure 8  Example of best-fit curve for water-side cooling capacity vs. three water flow rates (I-P).

Figure 9  Example best-fit curve for water-side cooling capacity vs. three primary airflow rates (SI).
Figure 10  Example of best-fit curve for water-side cooling capacity vs. three temperature differentials (SI).

Figure 11  Example of best-fit curve for water-side cooling capacity vs. three water flow rates (SI).
h. Test results for each measuring point (as described in Section 5.7) and including primary air and water-side pressure drop
i. Test results for each test series, including the constants and diagrams (as described in Section 7.2)
j. Nominal cooling/heating capacities (if applicable)
k. Induction coefficient
l. Sketches of airflow pattern direction near the test object, drawn from smoke tests
m. Throw distance for 150, 100, and 50 fpm (0.75, 0.5, and 0.25 m/s).

n. Octaves 2 through 7 sound power data in decibels
o. A sample sheet of measurements and results
p. Date and authorization

In addition, each page of the test report shall have a page number and the total number of pages. It is recommended there be a footnote on each page stating that it is not allowed to copy single pages of the report.

7. NORMATIVE REFERENCES


(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
GOVERNING EQUATIONS FOR CHILLED BEAMS

A1. TOTAL COOLING CAPACITY

Chilled-beam total cooling capacity is a combination of cooling capacity provided by primary air and the cooling capacity of the chilled-beam coil.

\[ P = P_a + P_w \]  
(A-1)

The following equation is used to calculate the cooling capacity of primary air.

\[ P_a = m_p c_p \theta_a(t_p - t_r) \]  
(A-2)

A2. COIL-COOLING CAPACITY

The following system of equations describes coil heat transfer under steady-state conditions, assuming no condensation on the coil surface.

\[ P_w = m_w c_p \theta_a(t_w2 - t_w1) \]  
(A-3)

\[ P_w = K A_f \Delta t \]  
(A-4)

\[ P_w = m_i c_p \theta_a(t_i1 - t_i2) \]  
(A-5)

It is not uncommon in design practice to see the chilled-beam water-side cooling capacity estimated using Equation A-3. Often, the water temperature difference is assumed to be 4°F to 6°F (2.2°C to 3.3°C), and the other two equations affecting coil cooling capacity (Equations A-1 and A-2) are neglected. It is important to understand that the temperature of water leaving the coil \( t_w2 \) is a function of several parameters, including the temperature and velocity of induced air traveling across the coil, as well as the temperature and velocity of the water passing through it. For a given coil, heat-transfer coefficient \( K \) is a function of all of the above-mentioned parameters, and it should be calculated but never assumed. The effectiveness of the active beam design is defined by its heat-transfer coefficient and coil heat-transfer surface area.

A3. COIL HEAT-TRANSFER COEFFICIENT

Coil heat-transfer coefficient \( K \) for a given chilled-beam design depends on the following:

a. Mass velocity (velocity times density or mass airflow divided by free cross-sectional area of the coil) of induced air traveling across the coil \( \nu_p \)

b. Velocity of water (liquid media) in the coil \( \omega \)

Coil heat-transfer coefficient is governed by equations of forced convection for air passing through the coil with water (or other cooling media circulating inside the coil) and is described by the following empirical equation:

\[ K = a' (\nu_p)^{n_1} \omega^{n_2} \]  
(A-6)

Convective heat-transfer coefficient from the water to the pipe is significantly higher than that from the coil fins to induced air passing through the coil. That is why \( \nu_p \) has a dominant effect in Equation A-6. (Informative Note: This statement assumes turbulent flow conditions in the pipes, which is always the case as long as water flow is above 0.5 gpm [0.03 L/s] for a 1/2 in. [12.7 mm] pipe.) Previous measurements show that power factor \( n_1 \) is 3 to 4 times higher than \( n_2 \).

Because coil heat-transfer area is constant for a given active beam, a similar equation is used to calculate heat-transfer coefficient times the coil surface area or coil cooling output per degree of temperature difference \( \Delta t \).

\[ K' = K A_f = a' (\nu_p)^{n_1} \omega^{n_2} \]  
(A-7)

The velocity of induced air \( \nu \), which is defined by induced airflow per unit length of coil and coil cross-sectional area, depends on primary airflow \( q_p \), beam induction coefficient \( K_{im} \), and temperature difference \( \Delta t \). The first two parameters take into account active beam induction force, and the second takes into account buoyancy force acting on non-isothermal air moving in vertical direction across the coil. For example, if warm induced air moves up across the coil, it cools down, and buoyancy force slows its motion. On the contrary, if active beam design deploys downward movement of induced air, this buoyancy force will accelerate the air movement across the coil when in cooling mode.

\[ \nu = \frac{K_m q_p + b \Delta t}{A_f} \]  
(A-8)

Combining Equations A-7 and A-8, and taking into consideration that \( A_f \) is constant for a given beam design, we can derive the equation defining coil heat-transfer coefficient as a function of temperature difference \( \Delta t \), velocity of water in the pipes \( \omega \), and primary airflow \( q_p \).

\[ K' = a[(c \Delta t^n + K_{im} q_p)^{n_1} \omega^{n_2} \]  
(A-9)

In active beams with induced air moving horizontally across the coil, coefficient \( b \) in Equation A-8 becomes 0, because velocity across the coil is not affected by buoyancy force, and Equation A-9 is reduced to the following:

\[ K' = a(K_{im} q_p)^{n_1} \omega^{n_2} \]  
(A-10)

Equation A-10 can also be used to define the heat-transfer coefficient for passive beams, where airflow through the coil is determined by convection forces only as represented by the following equation:

\[ K' = a(\Delta t^n q_p)^{n_1} \omega^{n_2} \]  
(A-11)

Equation A-9 and its derivatives are important for understanding what parameters affect coil cooling or heating output. They provide sufficient information to simulate any active beam in energy simulation software. All empirical coefficients \( a, c, n, n_1, n_2 \) and \( K_{im} \) are constant for a given beam design and can be derived from the manufacturer's
cooling and heating (when testing active beams for heating) capacity tests. The test sequence, along with the calculation procedure to determine these coefficients, can be part of the method of tests for active beams currently being developed by ASHRAE. This would help integration of active beam systems into the energy simulation software.

Based on our measurement data, we found that power factor $n_1$ in these equations is 3 to 4 times higher than power factor $n_2$.

Equation A-9 also contains induced air density, which allows for calculating a correction factor for the coil heat-transfer coefficient when designing active beam systems for high elevations above sea level. Assuming the manufacturer’s coil heat-transfer data is measured and presented at sea level, the correction factor to account for higher elevation above sea level is as follows:

$$k_{air} = (1 - 6.875 \times 10^{-6}z)^{4.256/n_1} \quad [\text{I-P}] \quad (A-12)$$

$$k_{air} = (1 - 2.256 \times 10^{-5}z)^{4.256/n_1} \quad [\text{SI}] \quad (A-13)$$

where $z$ is the elevation above sea level in feet (I-P) or metres (SI).

**A.4. MEASURING INDUCTION COEFFICIENT, $K_{IN}$**

Energy and mass flow balance for a beam shown in Figure A-1 is represented by the following equations:

$$q_p \rho_p f_p + q_i \rho_i f_i = q_s \rho_s f_s \quad (A-14)$$

$$q_p \rho_p + q_i \rho_i = q_s \rho_s \quad (A-15)$$

These two equations allow solving for the induction coefficient $K_{IN}$ as a function of primary air temperature, supply (or discharge) air temperature, and induced air temperature measured after the cooling coil.

$$K_{IN} = \frac{q_i}{q_p} = \left(\frac{t_s - t_i}{t_{12} - t_i}\right) \frac{\rho_p}{\rho_i} \quad (A-16)$$

When the beam is working within the design range of primary airflows, the coefficient of induction is typically constant as long as induced airflow across the cooling coil is not
affected by buoyancy force. Buoyancy effect is minimal when induced air temperature is close to the average surface temperature of the coil or when induced air moves in horizontal direction across the coil. When there is a significant temperature difference between induced air and the coil surface temperature, and induced air is moving vertically across the coil, buoyancy force may begin to affect induced airflow. Kin shall be measured at a minimum value of $\Delta t$ and at maximum primary airflow when the effect of buoyancy force on induced airflow is negligible.

A5. MEASUREMENT OF THE INDUCTION COEFFICIENT BY THE ZERO-PRESSURE METHOD

Induction airflow rates can also be measured directly using the test setup shown in Figure A-2. A tightly sealed connection chamber is connected securely to the induction opening of the beam. The connection chamber shall consist of adequate flow-equalizing devices to prevent velocity variations across the induction inlet. Care shall also be taken to ensure that the induction section is isolated from any air that might discharge from the supply elements of the beam.

A variable-speed compensation fan delivers air into the connection chamber through a duct that is fitted with a calibration nozzle or orifice plate. The primary airflow rate to the beam is established and measured by techniques described in Sections 4.2.1 and 4.4 of this standard.

The compensation fan speed is then adjusted until zero pressure difference across the connection is established; then the delivered fan airflow rate is recorded. At least three (3) time-averaged measurements shall be taken, allowing at least 3 minutes to elapse between measurements. The beam's induction rate is then calculated with equation A-16.

$$K_{in} = \frac{q_i}{q_p}$$  \hfill (A-17)
INFORMATIVE APPENDIX B
PRIMARY AIRFLOW MEASUREMENT

B1. PRIMARY AIRFLOW MEASUREMENT

B1.1 Airflow rate shall be measured in accordance with ASHRAE Standard 41.2H-1. Alternative airflow rate measurement methods may be used if calibrated with a certified standard to the required accuracy.

B2. ORIFICE METERS

B2.1 Orifice meters shall be constructed in accordance with ASME Performance Test Code 19.5H-2 and shall be sized for a throat velocity not less than 3000 fpm (15 m/s) or more than 7000 fpm (35 m/s).

B3. MULTIPLE NOZZLE CHAMBER METER

B3.1 Multiple nozzle chamber meters shall be constructed in accordance with ANSI/ASHRAE Standard 51 (ANSI/AMCA 210)H-3.

B4. VANE ANEMOMETER
FLOW MEASURING SYSTEM

B4.1 One method of accurately measuring airflow rates with low pressure drop is to use a vane anemometer that has been calibrated in situ against a certified standard to the required accuracy.

B4.2 The vane anemometer flow measuring system consists of a straight length of duct with a propeller anemometer, humidity measuring instruments, and a temperature probe inside (see Figure B-1). The duct has five diameters of inlet length, a flow straightener, and three diameters of discharge length. Optionally, a backpressure regulating device can be installed in the discharge of the precision flow station. A properly calibrated vane anemometer flowmeter can be accurate to ±2% over an extremely wide flow range. Following is a list of components for a vane anemometer flow measuring system (see Figure B-1):

a. Item 1 is a section of straight duct to allow the airflow to stabilize in the duct.

b. Item 2 is the propeller anemometer.

c. Item 3 is the center section of duct where all of the instruments are mounted.

d. Item 4 is the humidity sensor.

e. Item 5 is the temperature probe.

f. Item 6 is the discharge duct.

g. Item 7 is the discharge transition.

h. Item 8 is the optional backpressure damper.

i. Item 9 is a flow straightener consisting of at least a grid of 0.5 in. (12.7 mm) squares deeper than two times the grid size.

j. Item 10 is an in-duct static pressure probe mounted 1 diameter behind the front of the propeller.

k. Not shown is an atmospheric pressure transducer.

B4.3 Vane Anemometer Flowmeter Calibration Procedure

B4.3.1 Because the propeller anemometer is most commonly used for outdoor wind speed measurement, and, because in this measurement approach, the anemometer is mounted in a duct, the factory calibration will not be valid. The most convenient and accurate method of calibration is to calibrate it in place using a flow standard such as a NIST-traceable venture flowmeter. Figure B-2 shows a partial numbered list of components for a vane anemometer flowmeter calibration procedure.

B4.3.2 Depending on the purpose of the propeller flow station, several flow ranges will be needed to fully calibrate the unit.

B4.3.3 The anemometer flow station must be constructed solidly to minimize the potential for leakage at high static pressures. Verify that the flowmeter and calibrating venture are concentric, straight, and level. Misalignment will result in lower than anticipated accuracy.

B4.3.4 When constructing the anemometer flowmeter, take care to locate the anemometer within 0.16 equivalent diameters of the center of the duct as shown in Figure B-3.

B4.3.5 The target of the calibration is to create an empirical mathematic equation that relates frequency output from the anemometer to flow rate. The finished anemometer will have an extremely wide flow range, 8 to 3400 cfm for a 12 in. (4 to 1605 L/s for a 30.5 cm) diameter duct. Several venturi will be needed to cover the entire range. Larger ducts will have a higher minimum and higher maximum; similarly, smaller ducts will have a lower minimum and lower maximum.

a. Start with the smallest venturi first and calibrate through its range. Gradually increase and then decrease the flow rate from the lowest practical value for that size venturi to the highest practical value in small steps, recording the flow rate and frequency every few seconds.

b. Repeat with the next size larger venturi until the required flow range is covered. Ensure that the range of each venturi overlaps the range of adjacent sizes.

c. Use standard statistical analysis to determine the relationship between flow and frequency.

b. Use the data to refine the flow rate and frequency relationship.

B4.3.6 Venturi flowmeters automatically correct for atmospheric density, but anemometer flowmeters do not. The solution to this is to use the barometric pressure transducer and the static pressure transducer, along with the humidity and temperature probes, to correct for atmospheric density changes. The anemometer flowmeter will then give readings in standard cubic feet per minute (standard cubic metres per second).

Note: The anemometer flowmeter can be inside any size or shape duct and still be very accurate over an extremely wide flow range because of the calibrate-in-place procedure.
Figure B-1 Vane anemometer flow measuring system.

Figure B-2 Vane anemometer flowmeter calibration procedure.

Figure B-3 Correct positioning of anemometer in flowmeter.
INFORMATIVE APPENDIX C
ELECTRIC HEATED PERSON SIMULATORS

C1. PURPOSE

An internal heat supply to the test room can be provided by means of a number of electrically heated person simulators (i.e., dummies) placed on the floor inside the test room for chilled-beam and chilled-floor tests. The following is loosely based on EN 14240-2004[4-5].

C2. SIMULATOR CONSTRUCTION

The exterior surfaces of the simulator shall be opaque and nonreflective. The emission rate of the inner and outer surface of the simulator casing should be at least 0.9.

Figure C-1 shows a drawing of a recommended simulator. The simulator contains three incandescent light bulbs placed along its vertical centerline. The lights are placed 7 in. (17.8 cm) apart with the lowest being 8 in. (20.3 cm) from the floor.

The simulator is a cylinder with a diameter of 1 ft and height of 3 ft 7 3/8 in. (1.1 m) supported by 3 ft (0.91 m) evenly distributed. The top of the simulator is enclosed, while the bottom is open. There are four evenly distributed holes of 3 in. (7.6 cm) diameter near the top to permit convective heat transfer.

Figures C-2 and C-3 show a fabrication of a recommended simulator.

C3. TEST ROOM PLACEMENT OF SIMULATORS

The simulators shall be located in two rows symmetrically along the longest center line of the room. The distance between the rows shall be half of the room width. The center-to-center distance of each simulator in a row shall be between 3.5 and 4.5 ft (1.0 and 1.4 m).

The distance from the end of the walls to the center of the nearest simulator shall be 1.7 to 2.3 ft (0.5 to 0.7 m).

The number of simulators in each row shall be calculated from Equation C-1:

\[ n_r = \frac{l_r}{b_s} \]  \hspace{1cm}  (C-1)

where

- \( n_r \) = number of simulators in each row
- \( l_r \) = room length
- \( b_s \) = center distance between each simulator, which shall be between 4 and 6 ft (1.2 m and 1.8 m)

Typical examples are shown in Figure C-4.

---

Figure C-1  Heat load simulator.
Table C-1 Suggested Supply Power for Various Simulations

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>70 W</td>
</tr>
<tr>
<td>Computer</td>
<td>25 to 150 W</td>
</tr>
<tr>
<td>Equipment</td>
<td>Varies</td>
</tr>
</tbody>
</table>

C4. INTERNAL HEAT LOAD SELECTION

Each simulator shall illuminate three 60 W incandescent light bulbs or contain a heat source that can supply 0 and 180 W of sensible heat and must be continuously adjustable, for example, with a variable voltage transformer or thyristor. Table C-1 shows the recommended electric power to be supplied for various applications. For more information, refer to ASHRAE Handbook—Fundamentals.¹⁻⁵

Key
1. Inner surface
2. Thermal insulation
3. Fan and heat exchanger
4. Measuring point of air temperature
5. Measuring point of globe temperature
6. Cooling load simulator (dummy)
7. Local thermal insulation
8. Measuring point of the temperature below insulation

Figure C-4 Plan view of test room and heat load simulator placement.
INFORMATIVE APPENDIX D
RADIANT SHIELDED TEMPERATURE SENSOR

D1. PURPOSE
The purpose of shielding a resistive temperature device (RTD) is to mitigate the effects of radiant heat transfer on the sensor and to measure only the dry-bulb air temperature. When an RTD is placed directly underneath a water coil, as typically found in an induction driven product, the radiant effects of the coil can have a significant impact on the measured air temperature.

D2. DESIGN CONSIDERATIONS
The shield should cover as much of the sensor as possible while still permitting sufficient air to pass over the sensor head. To allow the air to circulate within, the shield should not be air-tight. To minimize radiant heat transfer, several design considerations should be taken into account:

a. Material Selection. The material of the shield should be selected to have high thermal conductivity in order to minimize the effects of thermal storage and should not be thicker than 1 mm (0.04 in.).
   Materials such as aluminum, copper, and brass are ideal candidates, but care should be taken to prevent their oxidation.

b. Construction. The shield should completely encase the RTD. The shield should have ventilation slots notched out to allow for air to pass over the RTD. Figure D-1 gives an example of a cylindrical design with a single notched vent.

c. Viewing Angle. The viewing angle is the view to which the RTD sensor head will be directly exposed if placed in front of a radiant source as seen in Figure D-2. The view angle should be between 20 and 30 degrees.
(This appendix is part of this standard. It is normative and contains requirements necessary for conformance to the standard. It has been processed according to the ANSI requirements for a standard.)

NOMINATIVE APPENDIX E
LABORATORY MEASUREMENT OF
INDUCED AIRFLOW RATES AND
CALCULATION OF INDUCTION RATIOS

Active beam induced airflow rates shall be measured by either of two methods: measurement and calculation using the induction velocity method or by a thermal balance method. The induction ratio \( K_{in} \) of the beam is the ratio of the induced-to-primary airflow rates of the beam.

E1. MEASUREMENT BY THE
INDUCTION VELOCITY METHOD

E1.1 Induced Air Velocity Measurement

E1.1.1 Induction ratio shall be calculated by measuring the average induced air velocity at isothermal conditions.

E1.1.2 Induced air velocity measurement instruments shall meet the requirements of ANSI/ASHRAE Standard 70, Method of Testing the Performance of Air Outlets and Air Inlets and the following subsections.

E1.1.3 The range of the velocity measurement device shall fall within the specified range of 20 to 200 ft/min (0.1 to 1 m/s).

E1.1.4 The velocity measurement device shall be calibrated to an accuracy of no more than \( \pm 10\% \) of the reading within the specified measurement range.

E1.2 Test Sample Qualification and Locations

E1.2.1 The test sample shall be installed in a test chamber that meets the requirements of ANSI/ASHRAE Standard 70, Method of Testing the Performance of Air Outlets and Air Inlets and the following subsections.

E1.2.2 The water coil shall be disconnected or shut-off from a chilled water supply.

E1.2.3 A supply-air duct attached to the test sample shall have cross-sectional dimensions equal to the nominal inlet size of the device under test. The duct shall be straight for a minimum length of three equivalent diameters, with any required flow straightener at least three diameters from the test sample’s air inlet.

E1.2.4 The test sample shall be mounted in a way that does not obstruct the discharge and induction air paths of the test sample.

E1.3 Measurement Requirements and Locations

E1.3.1 The chilled beam’s plenum static pressure shall be measured and recorded for each primary airflow rate in accordance with the manufacturer’s instruction.

E1.3.2 The temperature of the test unit supply air shall be measured in the center of the test duct at the plane of measurement.

E1.3.3 The induced air temperature \( T_r \) shall be measured as per Section 5.3.5.1.

E1.3.4 Velocity measurements shall be taken at eight (8) points located 1 in. (25 mm) away from the induced-air face of the beam (or water coil if no face exists) according to the layout in Figure E-1.

E1.4 Testing Requirements

E1.4.1 The induction ratio shall be measured at three (3) prescribed airflow rates (minimum, maximum, and medium). The medium airflow shall be measured at a plenum static pressure of 0.5 in. of water (125 Pa). The maximum airflow shall be measured as per the manufacturer specifications. The minimum airflow shall be determined as the lowest airflow that meets all of the following conditions.

E1.4.1.1 Has an average velocity of 30 ft/min (0.15 m/s) or higher at one of the eight measurement locations.

E1.4.1.2 Has a plenum static pressure of 0.2 in. of water (50 Pa) or higher.

E1.5 Test Procedures

E1.5.1 Test measurements shall only be made when all of the following conditions are satisfied.

E1.5.1.1 The induced air temperature is between 72°F and 82°F (22°C and 27°C).

E1.5.1.2 The primary airflow rate shall not vary by more than \( \pm 5\% \) or 1 cfm (0.5 L/s), whichever is greater.

E1.5.1.3 The primary air temperature shall not vary by more than \( \pm 1^\circ F \) (0.5°C).

E1.5.1.4 The temperature difference between the test unit supply air temperature and the induced air temperature during the period of air velocity measurement shall not exceed 1°F (0.5°C).

E1.5.2 Velocity measurements shall be made with a single sensor that is moved to each measurement location described in Section E1.3.4, or a sensor grid that measures all locations simultaneously.

E1.5.3 Test measurements shall include at least thirty (30) velocity recordings (1 per second) at each measurement point.

E1.6 Calculation and Expression of Results

E1.6.1 The induced air velocity \( V_r \) shall be calculated as the arithmetic average of the velocity readings at all eight (8) measurement points.

E1.6.2 For test units with an induction face covering the coil, the induction \( A_r \) area shall be taken as the total projected area of the induction face perpendicular to the direction of airflow.

E1.6.3 For test units with a completely exposed coil, the induction area \( A_r \) shall be taken as the total projected area of the coil (not counting pipe stub-outs or u-bends) perpendicular to the direction of airflow.

E1.6.4 The induced air flow rate shall be calculated by multiplying the induced air velocity by the induction area.

\[
q_r = V_r A_r
\]

(E-1)

E1.6.5 The induction ratio shall be calculated by dividing the induced air flow rate by the primary airflow rate.

\[
K_{in} = \frac{q_r}{q_p}
\]

(E-2)
E2. MEASUREMENT BY THE THERMAL BALANCE METHOD

E2.1 Temperature Measurement of Induced Air after Leaving the Cooling Coil

E2.1.1 Induction ratio shall be calculated by measuring the temperature of induced air after leaving the cooling coil under steady state while the active chilled-beam system is operating.

E2.1.2 Energy balance between the chilled-beam coil and the induced air allows for solving the induced air flow rate. The following equations explain the heat transfer procedure when the induced air passes the chilled-beam coil under the steady-state condition, assuming no condensation on the chilled-beam coil surface.

\[ m_w \times c_{pw} \times (t_{w2} - t_{w1}) = m_i \times c_{pa} \times (t_{i1} - t_{i2}) \]  \hspace{1cm} (E-3)

\[ m_i = \frac{m_w \times c_{pw} \times (t_{w2} - t_{w1})}{c_{pa} \times (t_{i1} - t_{i2})} \]  \hspace{1cm} (E-4)

\[ m_i = \rho_i \times q_i \]  \hspace{1cm} (E-5)

\[ q_i = \frac{m_w \times c_{pw} \times (t_{w2} - t_{w1})}{\rho_i \times c_{pa} \times (t_{i1} - t_{i2})} \]  \hspace{1cm} (E-6)
E2.2 Measurement Requirements and Locations

E2.2.1 The chilled beam’s plenum static pressure shall be measured and recorded for each primary airflow rate in accordance with manufacturer’s instruction.

E2.2.2 All temperature measurements shall conform to Section 5.3.5 of this standard.

E2.2.3 Measurement of the primary airflow and water flow rate shall conform to Section 4.4 of this standard.

E2.2.4 Measurement of the water flow rate shall conform to Section 4.5 of this standard.

E2.2.5 The temperature of the induced air entering the coil \( t_{1l} \) shall be measured at three (3) points as per Section 5.3.5.1.

E2.2.6 The temperature measurements of the induced air leaving the cooling coil \( t_{2l} \) shall be taken at eight (8) points located no more than 1 in. (25mm) above the face of the coil. The detailed sensor layout is shown in Figure E-2.

E2.3 Testing Requirements

E2.3.1 The induction ratio shall be measured at three (3) prescribed airflows (minimum, maximum and medium). The medium airflow shall be measured at a plenum static pressure of 0.5 in. of water (125 Pa). The maximum airflow shall be measured as per the manufacturer specifications. The minimum airflow shall have a plenum static pressure of 0.2 in. of water (50 Pa).

E2.4 Test Procedures

E2.4.1 Test measurements shall only be made when all of the following conditions are satisfied.

E2.4.1.1 The induced air temperature is between 72°F and 82°F (22°C and 27°C).

E2.4.1.2 The primary airflow rate shall not vary by more than ±5% or 1 cfm (0.5 L/s), whichever is greater.

E2.4.1.3 The primary air temperature shall not vary by more than ±0.4°F (0.2°C).

E2.4.1.4 Steady-state conditions, as defined in Section 5.6 have been recorded over a period of at least 60 minutes (1 measurement per minute).

E2.4.2 Test measurements shall conform to Section 5.5.1.5 once steady-state conditions have been established for each primary airflow.

E2.5 Calculation and Expression of Results

E2.5.1 The temperature of the induced air entering the coil \( t_{1l} \) shall be calculated as the arithmetic average of the three (3) temperature probes below the coil. (Refer to the reference temperature in Section 5.3.5.1.)

E2.5.2 The temperature of the induced air leaving the coil \( t_{2l} \) shall be calculated as the arithmetic average of the temperature readings at all eight (8) measurement points below the coil (Figure E-2).

E2.5.3 The induced airflow rate shall be calculated using Equation E-6.

E2.5.4 The induction ratio shall be calculated by dividing the induced airflow rate by the primary airflow rate.

\[
\eta_{in} = \frac{q_i}{q_p}
\]  
(E-7)
(This appendix is part of this standard. It is normative and contains requirements necessary for conformance to the standard. It has been processed according to the ANSI requirements for a standard.)

NORMATIVE APPENDIX F
METHOD OF TESTING WATER PRESSURE DROP

F1. METHOD OF TESTING WATER PRESSURE DROP

F1.1 The temperatures and pressures of water entering and leaving the chilled beam shall be measured by the apparatus as illustrated in Figure F-1. The connecting piping shall be the same size as the chilled-beam supply and return connections.

F1.2 Temperature measuring instruments shall be placed so as to measure the temperature of the water entering and leaving the beam. The liquid lines shall be insulated at and adjacent to the temperature measuring instruments. Appropriate insulation having an R-value of 4.5 ft²·°F·h/Btu (RSI of 0.79 m²·K/W) or greater shall be applied from the unit under test to at least 6 in. (150 mm) upstream of the inlet temperature sensor and 6 in. (150 mm) downstream of the outlet temperature sensor. Temperature sensor stems shall be insulated. To minimize temperature stratification, appropriate mixers, such as static mixers, shall be inserted in the inlet and outlet liquid lines upstream from the temperature measuring instruments. Alternatively, two close-coupled 90 degree elbows just upstream of the temperature measuring instruments serve as mixers, provided the water velocity at the mixing section is not below 1 ft/s (0.3 m/s).

F1.3 Appropriate means shall be provided for determining the liquid absolute pressure entering the beam and the liquid pressure drop through the beam and measurement apparatus, as shown in Figure F-1. The piezometer rings shall be located and constructed in accordance with the dimensions shown in Figure F-1. Pressure taps are an alternative to piezometer rings. The test setup measurement of pressure drop between piezometer rings or pressure taps shall be reduced by the pressure drop of the total length of pipe between the piezometer rings or pressure taps and the beam. The piping loss shall be determined by calibration of the measurement apparatus.

F1.4 The pressure drop in the test measurement apparatus, including any pipe between the beam and the measuring devices, at the test flow shall be calculated and subtracted from the measurement. This piping loss shall be determined by calibration of the test apparatus or by calculation of pressure drop based on type of material used for the pipe.
Figure F-1 Water pressure drop measurement apparatus.
NOMINATIVE APPENDIX G
WATER-SIDE PRESSURE DROP MEASUREMENT PROCEDURE

G1. PURPOSE
The purpose of this appendix is to prescribe a measurement method for water pressure drop and a correction method to compensate for friction losses associated with external piping measurement sections. The measurement method only applies to pipe of circular cross section.

G2. BACKGROUND
The water-side pressure drop needs to be determined by test with acceptable measurement uncertainty. The measured pressure drop, per this standard, will be determined by using static pressure taps external to the unit in upstream and downstream piping. When using external piping, adjustment factors are allowed to compensate the reported pressure drop measurement. Numerous studies conclude that the determination of a calculated correction term for these external components may contain significant sources of error, and, therefore, the use of external correction factors will be restricted to limit the magnitude of these potential errors. For units with small connection sizes, it is feasible that straight pipe sections be directly connected to the units with adequate length to obtain static pressure measurements with acceptable systematic errors due to instrument installation location.

G3. MEASUREMENT LOCATIONS
Static pressure taps shall simultaneously meet all of the following requirements.

G3.1 Static pressure taps may be in either the unit connections (i.e., nozzles) or in additional external piping provided for the purpose of test measurements.

G3.2 If using additional external piping, the piping arrangement shall use rigid pipe and may include fittings such as elbows, reducers, or enlargers between the pressure tap locations and the unit connections. Flexible hose is prohibited between the unit connections and the pressure taps.

G3.3 Static pressure taps shall maintain the lengths of cylindrical straight pipe in the flow path adjacent to each pressure tap location as shown in Table G-1.

a. The water pressure measurement apparatus shall be constructed in accordance with the length requirements outlined in Table G-1.

b. Construct the water pressure measurement apparatus using a material suitable for the rated pressure of the beam being tested. Ends shall be threaded or have flanges. Table G-2 provides an example for schedule 40 SS piping.

c. Straight length upstream of pressure taps: Minimum of 10 inside diameters or 6 in. (15 cm), whichever is greater. The 6 in. minimum is required for wrench clearance.

d. Straight length downstream of pressure taps: Minimum of 3 inside diameters or 6 in. (15 cm), whichever is greater. The 6 in. minimum is required for wrench clearance.

G4. STATIC PRESSURE TAPS
Static pressure taps will be in a piezometer ring or piezometer manifold arrangement with a minimum of three taps located circumferentially around the pipe, all taps at equal angle spacing. To avoid introducing measurement errors from recirculating flow within the piezometer ring, each of the pipe tap holes shall have a flow resistance that is greater than or equal to five times the flow resistance of the piezometer ring piping connections between any pair of pressure taps. A triple-tee manifold arrangement using four pipe tap holes is the preferred arrangement but is not required if the flow resistance requirement is met.

G4.1 For design or evaluation purposes, flow resistance may be estimated by resistance coefficient K-factor calculation methods, as found in Crane Technical Paper No. 410. Generally, manifold tubing or piping can be evaluated using the K-factor, and pressure tap holes can be evaluated using orifice flow equations.

G4.2 Provisions shall be made to bleed air out of the lines connected to pressure measurement devices. These provisions shall take into consideration the orientation of pressure taps and manifold connections.

G5. CORRECTION METHOD
Measured water pressure drop values shall be adjusted to subtract additional static pressure drop due to external piping. The additional static pressure drop shall be the sum of all losses between the unit connections and the location of static pressure taps. Record the original measured value, the calculated adjustment value, and the final calculated result for water pressure drop.

G5.1 The adjustment shall not exceed 10% of the measured water pressure drop.

G5.2 The general form of the adjustment equations use the methods in Crane Technical Paper No. 410. A Darcy friction factor is determined using the Swanee-Jain equation.

\[ f = 0.25 / \{ \log_{10}(\varepsilon / 3.7 \times D) + (5.74 / \text{Re}^{0.8}) \}^2 \]  \hspace{1cm} (G-1)

where

\[ \varepsilon = \text{absolute roughness, 0.00015 ft (0.045 mm) for purposes of this standard} \]

\[ D = \text{internal pipe diameter, ft (mm)} \]

\[ \text{Re} = \text{Reynolds number for the flow in the pipe} \]

The pressure drop \( h_f \) associated with a flow component or fitting may be calculated using the friction factor, as detailed above, or the equation may use a K-factor. These are shown in Equation G-2.

\[ h_f = f \times (L/D) \times (V^2/2g) \]  \hspace{1cm} (G-2)

when the Darcy friction factor is used for straight pipe sections, where

\[ L = \text{pipe length, ft (mm)} \]

\[ D = \text{internal diameter, ft (mm)} \]
### Table G-1 Water Pressure Measurement Apparatus (SPL PMA) Design

<table>
<thead>
<tr>
<th>Unit Connection Nominal Pipe Size, in. (mm)</th>
<th>Straight Length in Flow Path</th>
<th>Upstream of Pressure Tap</th>
<th>Downstream of Pressure Tap</th>
</tr>
</thead>
</table>
| ≤3 (75)                                   | Minimum 10 × D,
|                                          | Minimum 3 × D,
| 4, 5, or 6 (100, 125, or 150)             | Minimum 6 × D,
|                                            | Minimum 2 × D,
| ≥8 (200)                                  | Minimum 3 × D,
|                                            | Minimum 1 × D,

**Notes:**
1. Static pressure taps may be made with piezometer rings (annulus) or by manifolding three or four taps together with tubing.
2. Static pressure tap construction (annulus, braze joints, tubing, etc.) shall be strong enough to withstand 1.5 times maximum tube side water pressure without leaking.
3. The upstream and downstream distances from the pressure tap shall be no less than 6 in. (150 mm).

### Table G-2 Example SPL PMA Sizing for 40S SS Piping

| Nominal Pipe Size (NPS), in. | Schedule Number | Pipe Outside Diameter D,
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>40S</td>
<td>0.54</td>
</tr>
<tr>
<td>0.375</td>
<td>40S</td>
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</tr>
<tr>
<td>0.50</td>
<td>40S</td>
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</tr>
<tr>
<td>0.75</td>
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</tr>
<tr>
<td>1.00</td>
<td>40S</td>
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</tr>
<tr>
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</tr>
<tr>
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<tr>
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<td>2.88</td>
</tr>
<tr>
<td>3.00</td>
<td>40S</td>
<td>3.50</td>
</tr>
<tr>
<td>3.50</td>
<td>40S</td>
<td>4.00</td>
</tr>
</tbody>
</table>

| Wall Thickness t,
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<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
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<td>0.11</td>
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<tr>
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<tr>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>0.23</td>
<td>0.23</td>
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</tbody>
</table>

| Pipe Inside Diameter D,
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<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>0.36</td>
</tr>
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<tr>
<td>3.54</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Min. Length Upstream of Pressure Tap, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.00</td>
</tr>
<tr>
<td>6.00</td>
</tr>
<tr>
<td>6.22</td>
</tr>
<tr>
<td>8.24</td>
</tr>
<tr>
<td>10.49</td>
</tr>
<tr>
<td>13.80</td>
</tr>
<tr>
<td>16.10</td>
</tr>
<tr>
<td>20.67</td>
</tr>
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<td>35.40</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Min. Length Downstream of Pressure Tap, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.00</td>
</tr>
<tr>
<td>6.00</td>
</tr>
<tr>
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<td>6.00</td>
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<tr>
<td>6.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Min. Total Length SPL PMA, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.00</td>
</tr>
<tr>
<td>12.00</td>
</tr>
<tr>
<td>12.22</td>
</tr>
<tr>
<td>14.24</td>
</tr>
<tr>
<td>16.49</td>
</tr>
<tr>
<td>19.80</td>
</tr>
<tr>
<td>22.10</td>
</tr>
<tr>
<td>26.87</td>
</tr>
<tr>
<td>32.10</td>
</tr>
<tr>
<td>39.88</td>
</tr>
<tr>
<td>46.02</td>
</tr>
</tbody>
</table>

### G5.3
An Excel® spreadsheet is available from AHRI for computation of the pressure drop adjustment factors.

### G6. PRESSURE MEASUREMENT PIPE CALIBRATION

The pressure measurement pipes shall be calibrated by conducting the following test and comparing the measurements to calculated adjustment values.

**G6.1** Connect the entering beam pressure measurement pipe exit (minimum straight length downstream of taps = 3 × D, or 6 in. [150 mm], whichever is greater) to the leaving beam pressure measurement pipe entrance (minimum straight length upstream of taps = 10 × D, or 6 in. [150 mm], whichever is greater). The coupling shall have the same nominal pipe size as the pressure measurement pipes. Connect the pipes to a water flow source.

**G6.2** The instrumentation for the test shall consist of the following:

- Water temperature entering beam pressure measurement pipe, °F (°C)
- Water absolute pressure entering beam pressure measurement pipe, psi (kPa)
- Water temperature leaving beam pressure measurement pipe, °F (°C)
- Water pressure drop through entering beam and leaving beam pressure measurement pipes, psi (kPa)
- Water mass flow rate, lbm/h (kg/s)
- Pressure measurement pipe material
- Water type (water, aqueous solution, etc.)
- Aqueous solution composition by mass, % (if not water)
- Water temperature entering beam pressure measurement pipe, °F (°C)
- Water absolute pressure entering beam pressure measurement pipe, psi (kPa)
- Water temperature leaving beam pressure measurement pipe, °F (°C)
j. Water pressure drop through entering beam and leaving beam pressure measurement pipes, psi (kPa)
k. Water mass flow rate, lbm/h (kg/s)

G6.4 Conduct the water pressure drop test with at least four different water velocities inside pressure measurement pipe covering the range of 1 to 14 ft/s (0.3 to 4.25 m/s) in approximately equally spaced velocity increments on a logarithmic scale. The water temperature and flow rate shall be in steady state. Variance of more than ±1°F (0.6°C) or ±5% flow rate or 1 gpm (0.06 L/s), whichever is greater, make the test results invalid and they must be repeated.

G6.5 Record the test data continuously for at least 30 minutes (every 1 minute) after steady-state condition has been achieved. Average the rounds to determine each run’s test values. Wait for steady-state conditions before testing at the next water velocity.

G6.6 Use the following input data and the AHRI spreadsheet to calculate water pressure drop through entering beam and leaving beam pressure measurement pipes at the test input conditions.

a. Pressure measurement pipe inside diameter, in. (mm).
b. Entering beam pressure measurement pipe straight length downstream of pressure taps, in. (mm).

c. Leaving beam pressure measurement pipe straight length upstream of pressure taps, in. (mm).
d. Pressure measurement pipe material.
e. ε = pressure measurement pipe absolute roughness. Start with 0.00015 ft (0.045 mm).
f. Water type (water, aqueous solution, etc.).
g. Aqueous solution composition by mass, % (if not water).
h. Water temperature entering beam pressure measurement pipe, °F (°C).
i. Water absolute pressure entering beam pressure measurement pipe, psi (kPa).
j. Water temperature leaving beam pressure measurement pipe, °F (°C).
k. Water mass flow rate, lbm/h (kg/s).

G6.7 The measurement shall not exceed the calculated adjustment by more than 10%; otherwise, additional corrections shall be applied and noted.

G6.8 If the pressure measurement pipes are made from a non-corroding material, and the water under test is soft, the pipe’s absolute roughness should not change as a function of time.

G6.9 The laboratory shall conduct an annual calibration of the pressure measurement pipes.
INFORMATIVE APPENDIX H

INFORMATIVE REFERENCES


H-7. ASHRAE. 2016. ANSI/ASHRAE Standard 130, Laboratory Methods of Test for Air Terminal Units. Atlanta: ASHRAE.


(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 I
ADDENDA DESCRIPTION INFORMATION

ANSI/ASHRAE Standard 200-2018 incorporates ANSI/ASHRAE Standard 200-2015 and Addenda a and b to ANSI/ASHRAE Standard 200-2015. Table I-1 lists each addendum and describes the way in which the standard is affected by the change. It also lists the ASHRAE and ANSI approval dates for each addendum.

Table I-1  Addenda to ANSI/ASHARE Standard 200-2015

<table>
<thead>
<tr>
<th>Addendum</th>
<th>Section(s) Affected</th>
<th>Description of Changes*</th>
<th>Approval Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>4.2; 4.4.3.2; 4.5; 4.6.1; 4.6.2; 4.6.3; 4.8.3.10.3; 7; Informative Appendix H</td>
<td>Addendum a updates the normative references and adds a new Informative Appendix H, “Informative References.”</td>
<td>June 30, 2015</td>
</tr>
<tr>
<td>b</td>
<td>4.2.1; 4.2.5; 7; Normative Appendix F; Normative Appendix G</td>
<td>Addendum b includes a method of test for water pressure drop, revisions to the normative references, and an update to the dew-point temperature tolerances. Addendum b modifies changes made by Addendum a.</td>
<td>March 31, 2017</td>
</tr>
</tbody>
</table>

* These descriptions may not be complete and are provided for informative purposes only.
ASHRAE is concerned with the impact of its members’ activities on both the indoor and outdoor environment. ASHRAE’s members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE’s short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its Handbook, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system’s intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE’s primary concern for environmental impact will be at the site where equipment within ASHRAE’s scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.
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