Method of Testing for Rating Ceiling Panels for Sensible Heating and Cooling

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(Complete Draft for Full Review)

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ASHRAE, 1791 Tullie Circle, NE, Atlanta GA 30329-2305
ASHRAE Standards Project Committee 138
Cognizant TC: 6.5, Radiant and In-Space Convective Heating and Cooling
SPLS Liaison: Roger L. Hedrick

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CONTENTS

ANSI/ASHRAE Standard 138-2013 (RA 2016),
Method of Testing for Rating Ceiling Panels for
Sensible Heating and Cooling

SECTION PAGE
Foreword ................................................................. 2
1 Purpose ..................................................................... 2
2 Scope ........................................................................ 2
3 Units of Measurement .................................................. 2
4 Symbols ...................................................................... 3
5 Definitions ................................................................... 5
6 Instruments and Measuring Standards ......................... 5
7 Standard Test Setup and the Equipment ............... 6
8 Method of Conducting a Standard Test .................. 10
9 Processing Test Data ................................................... 12
10 Acceptance Criteria for the Standard Test ............ 13
11 Reporting Standard Test Results ......................... 13
12 References ............................................................. 15
Normative Annex A—Adjustment of Panel Heat Flux .... 16
Normative Annex B—Line Fitting by the Method of Least Squares ...... 17
Informative Annex C—Uncertainty Analysis of Panel Heat Flux .................. 18
Informative Annex D—Calculating the Approximate Thermal Efficiency of the Test Panel .... 19
Informative Annex E—Provisions for Electric Panels and Calibration of the Test Chamber ...... 20

NOTE
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FOREWORD

Standard 138 establishes uniform methods of laboratory testing for rating the thermal performance of ceiling panels manufactured for radiant panel heating and cooling of indoor spaces. This standard covers steady-state testing of ceiling panels at panel surface temperatures from 24°C to 65°C (75°F to 149°F) for nonmetal heat transfer elements in the ceiling panel or from 24°C to 150°C (75°F to 302°F) for metal heat transfer elements in the ceiling panel. Sensible cooling ceiling panels are tested from 14°C to 24°C (57°F to 75°F). This standard provides correction factors with respect to defined test conditions for the size of the test room, barometric pressure in the test location, and average air velocity in the vicinity of the test panels in order to ensure repeatable test results.

This is a reaffirmation of Standard 138-2013. This standard was prepared under the auspices of 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 interest of obtaining uniform guidelines throughout the industry. This version of the reaffirmation has no changes.

1. PURPOSE

This standard establishes uniform methods of laboratory testing for rating steady-state thermal performance of ceiling panels used in indoor spaces for sensible heating, sensible cooling, or both. The objective is to rate ceiling panels under repeatable conditions.

2. SCOPE

2.1 This standard specifies procedures, apparatus, and instrumentation for rating thermal performance of ceiling panels in a specific indoor configuration and thermal conditions.

2.2 Thermal performance of a ceiling panel is measured in terms of heat delivered or heat removed by the ceiling panel as a function of the average fluid temperature of the heat transfer medium in the ceiling panel and the temperatures characterizing the surrounding indoor space.

2.3 This standard covers testing of ceiling panels in the following effective panel surface high and low temperature range limits:

- Sensible Heating Ceiling Panels: from 24°C to 65°C (75°F to 149°F) for nonmetal heat transfer elements in the ceiling panel or from 24°C to 150°C (75°F to 302°F) for metal heat transfer elements in the ceiling panel.

- Sensible Cooling Ceiling Panels: from 14°C to 24°C (57°F to 75°F).

2.4 This standard does not cover the following ceiling panels:

a. Hybrid (combined thermal radiation and forced-convection: load-sharing) ceiling panels.

b. Ceiling panels that are embedded into the ceiling, wall, or floor structure.

c. Test methods for design, production, or field-testing of ceiling panels.

3. UNITS OF MEASUREMENT

3.1 System of Units. In this standard, the International System of Units (SI) is used. Inch-pound (I-P) units are shown parenthetically. Values shall be based on the National Institute of Standards and Technology (NIST) values, which, in turn, are based on the fundamental values of the International Bureau of Weights and Measures.

3.2 Basic Units. The unit of length is the meter, designated m (foot or inch, designated ft or in.). The unit of mass is the kilogram, designated kg (pound, designated lb), and the unit of time is second or hour, designated s or h. The unit of temperature is degree Celsius, designated °C (degree Fahrenheit, designated °F), or kelvin, designated K (degree rankine, designated °R). The unit of force is the newton, designated N (pound-force, designated lbf).

3.3 Derived Units

3.3.1 Velocity and Acceleration. The unit of velocity is m/s (ft/s). The unit of acceleration is m/s² (ft/s²).

3.3.2 Surface Area. The unit of surface area is m² (ft²).

3.3.3 Volume Flow Rate. The unit of volume flow rate is cubic meter (foot) per second, m³/s (ft³/s).

3.3.4 Pressure. The unit of pressure is pascal, designated Pa, or kilopascal, kPa (pound-force per square foot, designated lbf/ft²).

3.3.5 Energy, Work, and Power. The unit of energy and work is joule, designated J (British thermal unit, designated Btu). The unit of power is watt, designated W (British thermal unit per hour, designated Btu/h).

3.3.6 Heat Flux. The unit of heat flux is W/m² (Btu/ [h·ft²]).

3.3.7 Thermal Resistance. The unit of thermal resistance is m²·K/W (h·ft²·°F/Btu).

3.3.8 Mass Density. The unit of mass density is kilogram per cubic meter, kg/m³ (pound per cubic foot, lb/ft³).

3.3.9 Dynamic Viscosity and Kinematic Viscosity. The unit of dynamic viscosity is Pa·s (lbf·s/ft²). The unit of kinematic viscosity is m²/s (ft²/s).

3.3.10 Specific Heat. The unit of specific heat is J/(kg·K) (Btu/[lb·°F]).
(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.)

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The changes made for the 2021 revision were:
• References were updated
• Informative Annex E3 Reference was updated
• Section 7.2.5 Reference to Standard 119 changed to ASHRAE Standard 119
4. SYMBOLS

\( A_c \) = sum of the surface area of the test chamber ceiling that is not obstructed by the ceiling panels, \( m^2 (ft^2) \)

\( A_{ce} \) = sum of the surface area of the test chamber ceiling that is directly exposed to thermally effective surfaces of ceiling panels (if ceiling panels are detached from the ceiling surface), \( m^2 (ft^2) \)

\( A_e \) = interior surface area of the simulated exterior wall of the test chamber, \( m^2 (ft^2) \)

\( A_p \) = sum of the thermally effective panel surface area of a test panel (projected surface area shall be used if the surface is heat transfer augmented, such as with fins or corrugation), \( m^2 (ft^2) \)

\( A_{po} \) = sum of the thermally effective surface area of a test panel that is directly exposed to the walls and the floor of the test chamber, \( m^2 (ft^2) \)

\( A_r \) = sum of the area of the interior surfaces of the test chamber to which the thermally effective panel surfaces are directly exposed, \( m^2 (ft^2) \)

\( A_{tc} \) = net ceiling (floor) surface area of the test chamber (measured from the inside of the test chamber), \( m^2 (ft^2) \)

\( \text{AUST} \) = area-weighted average temperature of the interior surfaces of the test chamber to which the thermally effective surfaces of ceiling panels are exposed (Equation 7), \(^\circ\text{C} (^\circ\text{F})\)

\( C_{he} \) = characteristic performance coefficient of the ceiling panel in sensible heating, based on \((t_w-t_c)\) (Equation 13), \( W/(m^2 \cdot {^\circ}\text{C}_{\text{he}}) \) (Btu/[hr \cdot \text{ft}^2 \cdot {^\circ}\text{F}_{\text{he}}])

\( C_{co} \) = characteristic performance coefficient of the ceiling panel in sensible cooling, based on \((t_w-t_c)\) (Equation 14), \( W/(m^2 \cdot {^\circ}\text{C}_{\text{co}}) \) (Btu/[hr \cdot \text{ft}^2 \cdot {^\circ}\text{F}_{\text{co}}])

\( C_{he}' \) = characteristic performance coefficient of the ceiling panel in sensible heating, based on \((t_w-t_c)\) (Equation 15), \( W/(m^2 \cdot {^\circ}\text{C}_{\text{he}'}(t_p-t_c)) \) (Btu/[hr \cdot \text{ft}^2 \cdot {^\circ}\text{F}_{\text{he}'}])

\( C_{co}' \) = characteristic performance coefficient of the ceiling panel in sensible cooling, based on \((t_w-t_c)\) (Equation 16), \( W/(m^2 \cdot {^\circ}\text{C}_{\text{co}'}(t_p-t_c)) \) (Btu/[hr \cdot \text{ft}^2 \cdot {^\circ}\text{F}_{\text{co}'}])

\( C_{he}'' \) = characteristic performance coefficient of the ceiling panel in sensible heating, based on \((t_p-t_c)\) (Equation 17), \( W/(m^2 \cdot {^\circ}\text{C}_{\text{he}''}) \) (Btu/[hr \cdot \text{ft}^2 \cdot {^\circ}\text{F}_{\text{he}''}])

\( C_{co}'' \) = characteristic performance coefficient of the ceiling panel in sensible cooling, based on \((t_p-t_c)\) (Equation 18), \( W/(m^2 \cdot {^\circ}\text{C}_{\text{co}''}) \) (Btu/[hr \cdot \text{ft}^2 \cdot {^\circ}\text{F}_{\text{co}''}])

\( C_p \) = specific heat, \( J/(kg \cdot \text{K}) \) (Btu/[lb \cdot {^\circ}\text{F}])

\( d \) = hydraulic diameter of heat transfer element in the ceiling panel or control panel, \( m \) (ft)

\( D_c \) = equivalent diameter describing the size of a ceiling panel \((4 \times \text{surface area}/\text{perimeter})\), \( m \) (ft)

\( e_p \) = surface area-weighted average thermal emittance of the thermally effective surfaces of a test panel, dimensionless

\( e_r \) = area-weighted average thermal emittance of interior surfaces of the test chamber to which the thermally effective surfaces of the ceiling panel are directly exposed, dimensionless

\( F_c \) = radiation exchange factor, dimensionless

\( F_{p-r} \) = radiation angle factor between the active panel surface(s) and the unconditioned interior surface(s) of the test chamber, dimensionless

\( g \) = gravitational acceleration, \( 9.81 \text{m/s}^2 (32.18 \text{ft/s}^2) \)

\( h \) = elevation of the test chamber above sea level, \( m \) (ft)

\( L \) = surface plate thickness of the fast-response control panels that control the interior surface temperatures of the test chamber, \( m \) (ft)

\( M \) = heat transfer element spacing in the ceiling panel, on centers, \( m \) (ft)

\( m \) = number of identical test panels simultaneously tested in the test chamber, dimensionless

\( \text{min} \) = subscript denoting a minimum value

\( nhe \) = characteristic performance exponent in sensible heating, based on operative temperature, \( t_o \) (Equation 13), dimensionless

\( nco \) = characteristic performance exponent in sensible cooling, based on operative temperature, \( t_o \) (Equation 14), dimensionless

\( nhe' \) = characteristic performance exponent in sensible heating, based on average dry-bulb air temperature, \( t_a \) (Equation 15), dimensionless

\( nco' \) = characteristic performance exponent in sensible cooling, based on average dry-bulb air temperature, \( t_a \) (Equation 16), dimensionless

\( nhe'' \) = characteristic performance exponent in sensible heating, based on \( t_p - t_c \) (Equation 17), dimensionless

\( nco'' \) = characteristic performance exponent in sensible cooling, based on \( t_p - t_c \) (Equation 18), dimensionless

\( P_b \) = measured barometric pressure in the test chamber, \( \text{Pa} \) (lb/ft²)

\( P_i \) = measured pressure of the heat transfer fluid at the inlet of the ceiling panel, \( \text{Pa} \) (lb/ft²)

\( P_r \) = measured pressure of the heat transfer fluid at the exit of the ceiling panel, \( \text{Pa} \) (lb/ft²)

\( P_s \) = standard atmospheric pressure (sea level, at 20°C [68°F]), 101.325 kPa (2115.34 lb/ft²)

\( Q \) = thermal power of the ceiling panel in sensible heating or sensible cooling, \( W \) (Btu/h)
\[ q = \text{heat flux delivered to or removed from thermally effective surfaces of a ceiling panel, W/m}^2 \text{/(Btu/ft}^2\text{)} \]
\[ q_{ad} = \text{adjusted heat flux delivered to or removed from thermally effective ceiling panel surfaces, W/m}^2 \text{/(Btu/ft}^2\text{)} \]
\[ q_{cor} = \text{predicted heat flux of the ceiling panel at the actual site of installation, W/m}^2 \text{/(Btu/ft}^2\text{)} \]
\[ r = \text{exponent of barometric pressure adjustment factor (Table A2 in Normative Annex A), dimensionless} \]
\[ R_a = \text{thermal resistance of the ceiling panel between the heat transfer fluid and the medium next to the thermally ineffective panel surface (if the medium is an open space, combined and linearized thermal resistance of natural convection and thermal radiation at that surface is included), m}^2 \text{K/W (h-ft}^2\text{.°F/Btu)} \]
\[ R_{be} = \text{thermal conduction resistances of the back and edge insulation of the finished ceiling panel as shipped for general sales and provided by the manufacturer for testing, m}^2 \text{K/W (h-ft}^2\text{.°F/Btu)} \]
\[ R_c = \text{thermal conduction resistance of the exterior insulation of the test chamber ceiling, m}^2 \text{K/W (h-ft}^2\text{.°F/Btu)} \]
\[ R_e = \text{Reynolds number (Equation 1), dimensionless} \]
\[ R_f = \text{thermal conduction resistance of the bottom and edge insulation of the floor of the test chamber, m}^2 \text{K/W (h-ft}^2\text{.°F/Btu)} \]
\[ R_i = \text{thermal conduction resistance of the immediate back insulation of the control panel, m}^2 \text{K/W (h-ft}^2\text{.°F/Btu)} \]
\[ R_w = \text{thermal resistance of the ceiling panel between the heat transfer fluid and the indoor space next to the thermally effective panel surface, m}^2 \text{K/W (h-ft}^2\text{.°F/Btu)} \]
\[ R_{we} = \text{thermal conduction resistance of the exterior insulation of the test chamber wall, which is simulated as exterior wall, m}^2 \text{K/W (h-ft}^2\text{.°F/Btu)} \]
\[ R_{wi} = \text{thermal conduction resistance of the exterior insulation of the test chamber walls, which are simulated as interior walls, m}^2 \text{K/W (h-ft}^2\text{.°F/Btu)} \]
\[ s = \text{exponent of panel surface area (size) factor (Table A2 in Normative Annex A), dimensionless} \]
\[ st = \text{subscript denoting a standard value or expression} \]
\[ t_a = \text{average dry-bulb air temperature in the test chamber, °C (°F)} \]
\[ t_b = \text{dry-bulb air temperature measured in the test chamber between the ceiling and ceiling panels (in Installation Method B only, Section 7.3.3.2), °C (°F)} \]
\[ t_c = \text{area-weighted average surface temperature of the test chamber ceiling that is not directly obstructed by ceiling panels, °C (°F)} \]
\[ t_{ce} = \text{area-weighted average surface temperature of the test chamber ceiling to which the thermally effective surfaces of the ceiling panels are directly exposed, °C (°F)} \]
\[ t_e = \text{average interior surface temperature of the simulated exterior wall of the test chamber, °C (°F)} \]
\[ t_i = \text{fluid temperature measured at the inlet of a test panel, °C (°F)} \]
\[ t_m = \text{calculated average fluid temperature circulating in a test panel (Equation 5), °C (°F)} \]
\[ t_{nr} = \text{mean radiant temperature in the test chamber (Equation 8), °C (°F)} \]
\[ t_o = \text{dry-bulb air temperature in the vicinity of the thermally ineffective panel surface (such as in the ceiling plenum or neighboring space), °C (°F)} \]
\[ t_r = \text{fluid temperature measured at the exit of a test panel, °C (°F)} \]
\[ t_o = \text{operative temperature in the test chamber (Equation 9), °C (°F)} \]
\[ t_p = \text{area-weighted average temperature of the thermally effective surfaces of a test panel (Section 8.3.1.1.1), °C (°F)} \]
\[ t_{po} = \text{average temperature of the thermally effective surfaces of a test panel that are directly exposed to the walls and the floor of the test chamber, °C (°F)} \]
\[ \Delta p = \text{pressure drop of the heat transfer fluid in a test panel (Equation 19), Pa (lb/ft}^2\text{)} \]
\[ \Delta t = \text{temperature difference, °C (°F)} \]
\[ \nu = \text{volume flow rate, m}^3/\text{s (ft}^3/\text{s)} \]
\[ \nu_a = \text{indoor air velocity, m/s (ft/s)} \]
\[ \rho = \text{mass density, kg/m}^3 \text{ (lb/ft}^3\text{)} \]
\[ \mu = \text{dynamic viscosity, Pa·s (lb-ft/ft-s)} \]
\[ \beta = \text{adjustment factor for heat flux, } q_{ad} = q_\beta \text{ (Equation 6), dimensionless} \]
\[ \nu = \text{kinematic viscosity, } \nu = \mu/\rho, \text{ m}^2/\text{s (ft}^2/\text{s)} \]
\[ \varepsilon = \text{uncertainty in a measured variable (Normative Annex B), dimensionless} \]
\[ X = \text{thermal efficiency of a ceiling (test) panel, dimensionless} \]
\[ z = \text{number of test points recorded in a test, dimensionless} \]
5. DEFINITIONS

average dry-bulb air temperature in the test chamber: arithmetic average of three readings of dry-bulb air temperature at specified locations in the test chamber (Section 8.3.1.2.2).

average fluid temperature in the ceiling (test) panel: arithmetic average of temperature readings of the heat transfer fluid at the inlet and exit of the test panel (Equation 5).

combined panel: a complete ceiling panel that is designed and can be independently installed and operated for both sensible cooling and sensible heating of an indoor space through heat transfer between the thermally effective panel surfaces and the occupants and/or the indoor space by thermal radiation and natural convection.

heat transfer fluid: the fluid that is circulating in the heat transfer elements of a test panel and the testing apparatus that delivers heat to or removes heat from test panels.

interior surface temperature of the test chamber: the area-weighted average temperature of the interior surfaces of the test chamber (AUST) that are directly exposed to the thermally effective surfaces of test panels during the test. Interior surfaces that are not directly exposed to thermally effective panel surfaces are excluded from the calculation (Equation 7).

interior surface temperature control panels: fast-response combined panels that are integral to every wall and the floor of the test chamber. During a test, they control the interior surface temperatures of the walls and the floor as a function of the measured average dry-bulb air temperature. In this standard, the term “control panel” shall be used to refer to interior surface temperature control panels.

mean radiant temperature in the test chamber: the surface area-weighted average interior surface temperature of the walls and the floor of the test chamber and the part of the ceiling and effective test panel surfaces that are directly exposed to the walls and the floor (Equation 8).

operative temperature in the test chamber: the arithmetic average of the mean radiant temperature and the average dry-bulb air temperature in the test chamber (Equation 9).

pressure drop in the test panel: difference between the fluid pressure at the inlet and exit of a test panel (Equation 19).

return fluid temperature: temperature of the heat transfer fluid at the exit of a test panel.

Reynolds number: a dimensionless number, designated Re, that indicates whether the fluid flow is laminar or turbulent (Equation 1).

sensible cooling panel: a complete panel that is designed and can be independently installed and operated for sensible cooling of an indoor space through heat transfer to the thermally effective panel surfaces from the occupants and/or indoor space by thermal radiation and natural convection.

sensible heating panel: a complete panel that is designed and can be independently installed and operated for sensible heating of an indoor space through heat transfer from the thermally effective panel surfaces to the occupants and/or indoor space by thermal radiation and natural convection.

supply fluid temperature: temperature of the heat transfer fluid at the inlet of a test panel.

temperature-controlled surfaces of the test chamber: interior surfaces of four walls and the floor of the test chamber are temperature controlled by control panels. Three walls are simulated as “interior” walls, and the fourth wall is simulated as the “exterior” wall.

test panel: any sensible cooling, sensible heating, or combined ceiling panel that is subjected to test in the test chamber according to this standard.

test point: a test condition uniquely characterized by the average fluid temperature in the test panel that is controlled during the test. All test variables are measured and recorded at every test point during the test. Section 8.1.2.1 gives the minimum number of test points required for completing a test.

thermal emittance: a surface property of a material governing the emission of thermal radiation relative to that emitted by a perfect emitter, or black body, at the same surface temperature.

thermally effective panel surface: any exterior surface of a panel that is intended to transfer heat between the panel and the occupants and/or the indoor space.

thermally effective panel surface area: area of a thermally effective panel surface, which shall be calculated by using the outer dimensions of the panel minus the exterior insulation thickness and the casing of the panel. If any side of the thermally effective panel surface, excluding the insulation and casing, extends more than 2 M from the centerline of the nearest hydronic panel heat transfer element, that section of the surface shall be excluded from surface area calculation. If the surface is heat transfer augmented (such as with fins or corrugation) or the surface has a curvature, then the projection of the surface shall be used to calculate or measure the thermally effective panel surface area.

thermally effective panel surface temperature: the area-weighted average temperature of the thermally effective surfaces of a panel.

thermally ineffective panel surface: any exterior surface of a panel that is not intended to transfer heat between the panel and the occupants and/or the indoor space.

thermal power of the test panel: the thermal power delivered or removed from the test panel under steady-state conditions at a test point. It is the product of the heat flux and the thermally effective panel surface area. If thermal energy meter readings are taken, then the thermal power of the test panel is the ratio of the thermal energy measured during unit time at a test point, under steady-state conditions.

6. INSTRUMENTS AND MEASURING STANDARDS

6.1 Accuracy and Precision. Instruments and methods of measurement that are described in the following sections are subject to accuracy and precision specifications as shown in...
7. STANDARD TEST SETUP AND THE EQUIPMENT

7.1 Test Room. The testing facility shall be equipped with an air-conditioned test room capable of accommodating the test chamber and carrying out the tests. The test room shall also accommodate the necessary testing, recording, and measuring instruments, other testing and operating ancillaries (excluding heating and cooling equipment such as boiler and chiller), and test personnel. All electrical devices and electronic instruments and equipment shall be properly insulated and grounded.

7.2 Test Chamber. Test panels shall be subjected to test in a test chamber that is located in the test room. The test chamber shall satisfy the following requirements.

7.2.1 General Features. According to the scope of this standard, thermally effective panel surfaces may exchange heat only by natural convection and thermal radiation. Avoiding any forced-convection heat transfer during a test shall satisfy this condition. Therefore, the test chamber shall not be subjected to air conditioning during a test. Instead, the test chamber shall be passively air conditioned prior to each test by detaching its two opposing walls and exposing it to the air-conditioning system of the test room. The air-conditioning system shall maintain the test room at an average dry-bulb air temperature at 22°C ± 4°C (71.6°F ± 7.2°F) and at 35% ± 15% RH. When the required thermophysical conditions to start a test are established (see Section 8.1.1.1), the detached walls shall be tightly closed and completely sealed. At the center of each wall, and at eye-level, there shall be 0.1 × 0.1 m (4 × 4 in.) double-glazed observation windows with insulated covers.

Provided that the conduction resistance of the thermal insulation on each side of the test chamber as required in this standard (Sections 7.2.4.1, 7.2.4.2, and 7.2.5) is increased by 25%, the test chamber may be installed in any indoor facility that may not have an air-conditioning system. In this case, the air-conditioning system shall directly serve the test chamber without any invasion or ductwork in the test chamber. All diffusers shall be flush with the interior surfaces to which they

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**TABLE 1** Specifications about the Accuracy and Precision of Measuring Instruments

<table>
<thead>
<tr>
<th>Measured Quantity</th>
<th>Accuracy</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid temperature (individual sensors)</td>
<td>0.05°C (0.1°F)</td>
<td>0.05°C (0.1°F)</td>
</tr>
<tr>
<td>Fluid temperature (differential sensors)</td>
<td>0.1°C (0.2°F)</td>
<td>0.1°C (0.2°F)</td>
</tr>
<tr>
<td>Indoor air temperature (dry bulb)</td>
<td>0.2°C (0.4°F)</td>
<td>0.2°C (0.4°F)</td>
</tr>
<tr>
<td>Surface temperature</td>
<td>0.2°C (0.4°F)</td>
<td>0.2°C (0.4°F)</td>
</tr>
<tr>
<td>Indoor air velocity</td>
<td>0.05 m/s (0.15 ft/s)</td>
<td>0.05 m/s (0.15 ft/s)</td>
</tr>
<tr>
<td>Time</td>
<td>0.05 s</td>
<td>0.05 s</td>
</tr>
<tr>
<td>Fluid pressure</td>
<td>0.5 kPa (10 lb/ft²)</td>
<td>0.5 kPa (10 lb/ft²)</td>
</tr>
<tr>
<td>Volume flow rate</td>
<td>0.1% of measured value</td>
<td>0.1% of measured value</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>±2% RH</td>
<td>±2% RH</td>
</tr>
</tbody>
</table>
are attached and shall be capable of being completely sealed off by forming a solid surface during all tests.

7.2.2 Physical Dimensions and Geometry. The test chamber shall be composed of four planar, vertical, solid walls; a planar, horizontal, solid ceiling; and a planar, horizontal, solid floor. All surfaces shall be perpendicular (90°± 1°) to each other. Three walls shall each be simulated as an interior wall. The remaining wall shall be simulated as the exterior wall. The interior net dimensions of the test chamber shall not be less than 4.0 m (13.1 ft) in length, 4.0 m (13.1 ft) in width, and 3.0 m (9.8 ft) in height. The interior dimensions of the test chamber shall not be greater than 6 m (19.7 ft) in length, 6 m (19.7 ft) in width, and 4.5 m (14.7 ft) in height. The width-to-length ratio of the test chamber shall be between 1.0 and 0.90. The height of the test chamber shall not exceed the width of the test chamber. Two interior walls, which are on opposite sides of the test chamber, shall be detachable from the test chamber to render a clearance of at least 2 m (6.56 ft). If the test chamber is directly served by an air-conditioning system according to Section 7.2.1, detachable walls are not required except for a sufficiently sized and positioned, fully sealing access door for general purposes such as maintenance, instrumentation, and test preparation.

7.2.3 Thermophysical Properties. The test chamber shall meet the Leakage Class A requirements of ANSI/ASHRAE Standard 119, Air Leakage Performance for Detached Single-Family Residential Buildings. All hydronic piping in the test chamber and in the test room shall be thermally insulated with an insulation material having a minimum thickness of 0.006 m (0.02 ft) and a maximum thermal conductivity of 0.030 W/(m·K) (0.017 Btu/[h·ft·°F]).

7.2.4 Temperature-Controlled Interior Surfaces. Every interior surface of the test chamber except the ceiling shall be independently temperature controlled within the ranges given in Sections 8.1.2.3 and 8.1.2.4 by control panels such as those shown for a hydronic system in Figure 1. The standard test factor regarding AUST must also be satisfied (Table A1 in Normative Annex A). An air panel system or an electric panel system (only for heating tests) may be used, provided that all initial steady-state test conditions and all test conditions specified in this standard are satisfied and the design factors specified in Section 7.2.4.3 are maintained.

7.2.4.1 Walls

7.2.4.1.1 Interior Walls. All interior walls shall be thermally insulated from the exterior. $R_{w}$ shall be at least 1.5 m²·K/W (8.5 ft²·°F·h/Btu).

7.2.4.1.1.1 Fixed Interior Wall. The subscript 3 shall identify the interior wall that faces the exterior wall on the longer side of the test panel. Associated variables shall bear the same subscript, e.g., $t_{3}$.

7.2.4.1.2 Detachable Interior Walls. (If applicable under provisions of Section 7.2.1) The subscripts 1 and 2 shall identify the two of the three interior walls that can be detached. Associated variables shall bear the same subscript, e.g., $t_{1}$ and $t_{2}$. Detachable interior walls shall accommodate loading and unloading of test panels, repair and maintenance work, passive air conditioning, and inspection of the test chamber between tests.

7.2.4.1.2 Exterior Wall. The subscript $e$ identifies the exterior wall and associated variables, e.g., $t_{e}$. This wall must be on the longer side (width) of the test chamber (if the width and the length of the test chamber are unequal). Thermal resistance of the thermal insulation on the exterior surface, $R_{w}$, shall be at least 2 m²·K/W (22.7 ft²·°F·h/Btu).

7.2.4.2 Floor. The subscript 4 shall identify the floor. Thermal resistance of the exterior thermal insulation, $R_{w}$, shall be at least 2 m²·K/W (22.7 ft²·°F·h/Btu).

7.2.4.3 Control Panels. Fast-response control panels shall be integrated to the interior surfaces of the four walls and the floor. Control panels shall have a smooth, flat-painted finish with a thermal emittance of 0.9 or higher. To achieve a short thermal response time, control panels shall adhere to the design factors in Table 2. The term $Δt_{c}$ defines the time constant of the panel. $L$ is the panel thickness. The temperature difference between the supply and return heat transfer fluid, $Δt_{c}$, needs to be small, and the volume flow rate, $V_{c}$, shall be above a minimum in order to minimize the surface temperature variations and to maintain a turbulent flow. To satisfy these parameters, panel material preferably should be metal, which shall be mounted with sufficient clearance between panels in order to compensate for thermal expansion. Gaps between panels shall be thermally and physically insulated with proper filler material.

If a hydronic system is used, then the heat transfer element spacing $M$ shall be 0.2 m (8 in.). $M$ shall be 0.15 m (6 in.) for the exterior wall and the floor. Depending upon the actual dimensions of a wall or floor, more than one closed-loop, two-pipe-type hydronic circuit may be required. Under these circumstances, hydronic circuits shall have common supply and return manifolds and run parallel. If multiple circuits in parallel are used, they shall be piped in reverse return or have balancing valves to ensure even flow through all

Figure 1 Typical interior surface temperature control panels (hydronic).
circuit. No circuit shall have a heat transfer element length more than 61 m (200 ft). Hydronic circuitry shall permit easy and fast connection and disconnection without any air entrapment or loss of heat transfer fluid.

The electronic measuring and recording instruments and their connections shall be of types enabling easy connection and disconnection and shall be properly grounded.

7.2.5. Ceiling. The ceiling is not surface-temperature controlled. The ceiling shall be externally insulated with a minimum thermal conduction resistance of $R_c = 3 \text{ m}^2\text{K} / \text{W} (17 \text{ ft}^2\text{°F- h} / \text{Btu})$. This insulation shall extend to the exterior surfaces of the vertical walls by 0.5 m (1.64 ft) from the top of the test chamber. This extension shall minimize unintentional losses/gains to the test room from the back and edges of test panels and the ceiling of the test chamber. The insulated ceiling of the test panel shall have a sufficiently sized and resealable opening to accommodate air tightness tests, according to Standard 119.5.

7.2.6. Equipment and Apparatus

7.2.6.1. Panel Testing Equipment and Apparatus

A fluid circulation system shall be composed of a primary closed loop that connects the heat generation/dissipation equipment (such as a boiler or chiller) to the hydronic testing apparatus in the test chamber. All hydronic circuits shall be drained by gravity drain only.

Each test panel shall be served by separate two-pipe-type secondary closed loops that are attached to the primary closed loop by a heat exchanger that is located outside the test chamber. If there is more than one test panel in the test, test panels shall be plumbed in parallel. Each two-pipe-type secondary closed-loop circuit shall have adequate instruments to individually control the supply fluid temperature and the volume flow rate. A circulation pump shall be installed at the exit of the test panel. Each circulation pump shall be capable of controlling the volume flow rate in increments equal to the accuracy requirement defined in Table 1.

Secondary two-pipe-type, closed-loop circuits shall be connected to common supply and return manifolds. Every two-pipe-type secondary closed-loop circuit shall be designed and instrumented according to the design guidelines described in ASHRAE Handbook—HVAC Systems and Equipment, Chapter 6, and as recommended by the panel manufacturer. Static pressure in the secondary closed-loop circuits and test panels connected to them shall be 150 kPa gage (3132 lbf/ft²), unless specified by the manufacturer or required to be higher in order to avoid boiling at average fluid temperatures higher than 90°C (194°F), up to 150°C (302°F). Steam may not be used for sensible heating tests. Design provisions for a safe and reliable hydronic circuitry must be made according to the ASHRAE Handbook—HVAC Systems and Equipment, Chapter 12.

The volume flow rate of the heat transfer fluid in the test panels shall be adjusted such that the following constraint is satisfied in each test panel in the test chamber during the test:

$$Re = \frac{4 \rho V / \pi d u}{4 V / \pi v} \left( Re > 10,000 \right)$$  \hspace{1cm} (1)

The mass density and the viscosity of the heat transfer fluid shall be calculated at the average fluid temperature at that test point.

7.2.6.2. Interior Surface Temperature Control Equipment and Apparatus. Every control panel in the test chamber shall be independently controlled by two-pipe-type closed-loop circuits (if the system is hydronic) that are separated by a heat exchanger from the primary loop.

7.2.6.3. Heat Transfer Fluid Circulation System. Pumps shall be connected to the exit of control panel circuits. Volume flow, supply fluid temperature, and thermally effective control panel surface temperature shall be continuously controlled throughout the test as a function of $t_s$ (Section 8.1.2.3).

7.2.6.4. Heat Delivery/Extraction Equipment. The heat delivery/extraction capacity of each interior wall shall be at least 0.6 kW (2047 Btu/h). The heat delivery/ extraction capacity of the exterior wall shall be 1.3 kW (4435 Btu/h). The heat delivery/extraction capacity of the floor shall be at least 1.0 kW (3412 Btu/h).

7.2.6.5. Type and Composition of the Heat Transfer Fluid. If a hydronic system is used, then plain water shall be used.

7.2.7. Other Features of the Test Chamber and Requirements. During tests, no sensible or latent heat or cold source, including artificial lighting, may be functioning in the test chamber. All electronic instrumentation and electrical connections in the test room and the test chamber must conform to all applicable American National Standards Institute (ANSI), Underwriters Laboratories (UL), and National Fire Protection Association (NFPA) standards as well as to local codes where the test facility is located.
All fluid flow rate and fluid temperature control apparatus shall be the proportional control type. On-off type control apparatus may not be used under any circumstances.

7.2.8 Calibration, Testing, and Maintenance of the Test Chamber. An airtightness test shall be repeated after 40 tests or every six months, whichever comes first. All measuring and recording instruments shall be calibrated in the same period, according to their specifications. After calibrations, an overall evaluation may be made by the method described in Informative Annex E, Section E2.

7.3 Installation of Test Panels in the Test Chamber

7.3.1 Minimum Thermally Effective Panel Surface Area and the Minimum Number of Test Panels in the Test Chamber. For sensible heating and sensible cooling tests, the total thermally effective panel surface area installed in the test chamber shall not be less than 19% of the indoor ceiling area of the test chamber.

The minimum number of identical test panels that must be installed in the test chamber for any given sensible heating or sensible cooling test ($m_{min}$) is calculated from Equation 2. The result shall be rounded to the nearest integer number.

$$m_{min} = \frac{A_P}{A_p} \times 0.19 \quad (2)$$

7.3.2 General Layout and Arrangement. All test panels to be installed in the test chamber shall be of identical types and shall be installed in an identical manner at the same height in the test chamber. Test panels shall be installed as they are shipped for general sales with factory-recommended insulation as shown or described in the manufacturer's product literature with $R_{eq}$ (back and edge insulation) values between 0.45 and 0.6 m²·K/W (2.5 and 3.4 ft²·°F/Btu). Additional insulation, extra surface paint, or other material may not be applied to the test panels. However, if the manufacturer’s installation instructions recommend the field installation of insulation on the panel, such insulation as recommended may be applied. Test panels shall be installed such that their longitudinal axis shall be parallel to the exterior wall (the longer side of the test chamber). No test panel may be placed closer than 0.3 m (1 ft) to the edge of the ceiling. If there is a single test panel, it shall be installed on an axis at the geometric center of the exterior wall and no closer than 0.30 m (1 ft) to the exterior wall. If there is more than one test panel, the panels shall be installed at locations symmetric with the center of the exterior wall with a minimum of 0.30 m (1 ft) clearance between adjacent test panels and the exterior wall. Test panels shall be installed with a minimum clearance of 0.3 m (1 ft) in both lengthwise and widthwise directions.

A manufacturer may request additional tests with specific arrangements and test conditions provided that all of these test results are published under a separate heading, “Other Tests,” in the standard test report (Section 11) and provided that the data are processed within the same guidelines given in Sections 9 and 10. Specific test arrangements and test conditions of these additional tests shall also be reported. The manufacturer may publish other test results in any literature or post them on the Internet only under a separate heading, “Other Tests,” in the same document containing the standard test results. Other test results may not be incorporated into the standard test data and the standard test graph (Figure 2) and may not be published separately in any literature or posted on the Internet.

7.3.3 Test Panel Installation Methods. According to the manufacturer’s specifications, test panels may be either attached flat to the ceiling (Method A: ceiling-attached panel), suspended from the ceiling (Method B: suspended panel), or installed in a different position and arrangement (Method C). In any test, Installation Method B shall be used if it does not conflict with the manufacturer’s specifications for the intended use of the test panel.

7.3.3.1 Installation Method A: Ceiling-Attached Test Panel. Test panels shall be attached to the ceiling using the attachments provided by the manufacturer according to Section 7.3.1.

Figure 2 Standard test graph.
7.3.3.2 Installation Method B: Suspended Test Panel. A height- and position-adjustable T-grid shall be present in the test chamber such that thermally effective panel surface(s) observing the floor of the test chamber shall be at the same level, which is 2.44 m (8 ft) above the floor or 0.5 m (1.64 ft), whichever gives the maximum clearance between the suspended panels and the ceiling below the ceiling of the test chamber. The T-grid must be easily removable to permit testing of ceiling-attached panels. Test panels shall be attached to the T-grid according to Section 7.3.1.

7.3.3.3 Installation Method C: Other Methods. Method C allows the test panel to be installed in configurations other than those specified in Methods A and B upon the request of the manufacturer under “Other Tests.” A test panel intended for use in a vertical position is an example. If there is more than one identical vertical test panel, they shall be installed in-line along the diagonal of the test chamber so that they shall not face each other.

Only one of the above installations shall be used in a given test. Test panels shall be randomly selected from a group of identical panels that the manufacturer shall provide. The number provided shall be at least three times the number of test panels to be simultaneously subjected to test.

8. METHOD OF CONDUCTING A STANDARD TEST

8.1 Test Requirements. Several conditions are required in order to start, conduct, and complete a successful test. All conditions must be satisfied to consider a test successful.

8.1.1 Requirements for Starting a Test

8.1.1.1 Preparations to Test (Pretest Phase). If there is a separate test room outside the test chamber, then prior to a test, the detachable walls of the test chamber shall be opened wide with a minimum clearance of 2 m (6.56 ft) from the test chamber. The air-conditioning system either serving the test room or directly serving the test chamber as described in Section 7.2.1 shall be operating to establish average dry-bulb air temperature and relative humidity of 20°C ± 0.2°C (68°F ± 0.4°F) and 35% RH, respectively, for a sensible heating test. For a sensible cooling test, average dry-bulb air temperature shall be 24°C ± 0.2°C (75°F ± 0.4°F) and the relative humidity shall be 35% RH. For a sensible cooling test, indoor air relative humidity shall be 5% RH less than the relative humidity for a saturation temperature equal to the lowest supply fluid temperature selected for that test. Then, the detachable walls shall be closed tight and sealed if there is a test room outside the test chamber.

8.1.1.2 Initial Settings. Next, all control panels shall start to operate with an initial average thermally effective surface temperature of 18°C ± 0.5°C (64.4 ± 0.9°F) in a sensible heating test and 26°C ± 0.5°C (78.8 ± 0.9°F) in a sensible cooling test, respectively. At the same time, test panels shall start to operate at a supply fluid temperature of 24°C ± 0.5°C (75.2°F ± 0.9°F) in a sensible heating test. Test panels shall start to operate at a supply fluid temperature of 22°C ± 0.2°C (71.6°F ± 0.4°F) in a sensible cooling test. This operation shall continue until the test chamber comes to an initial thermal equilibrium. If thermal equilibrium is not achieved within three hours of operation, the supply fluid temperature for the test panels may be increased by 0.5°C (0.9°F) increments in a sensible heating test and decreased by 0.5°C (0.9°F) increments in a sensible cooling test until the thermal equilibrium is achieved.

8.1.1.3 Initial Steady-State Condition. Prior to a sensible heating test, while the system is operating at initial settings, the average dry-bulb air temperature shall remain at a range of 20°C ± 3°C (68°F ± 5.4°F) and stay steady within a tolerance of ±0.5°C (±0.9°F) for at least 1800 s (0.5 h). Prior to a sensible cooling test, while the system is operating at initial settings, the average dry-bulb air temperature shall remain in a range of 24°C ± 2°C (75.2°F ± 3.6°F) and stay steady within a tolerance of ±0.5°C (±0.9°F) for at least 1800 s (0.5 h). After this period, the test may proceed to the first test point by adjusting the average temperature and the flow rate of the heat transfer fluid in each test panel as selected for that test point.

8.1.2 Requirements for Conducting a Test

8.1.2.1 Minimum Number of Test Points. The minimum number of test points (n) required for completion of a test depends on the type of the test.

8.1.2.1.1 In a Sensible Heating Test. A sensible heating test shall include at least five test points uniquely characterized by five different average fluid temperatures of the test panel. These test points shall be evenly spaced over the operating temperature range that is specified by the manufacturer. The first and last test points shall include the lowest and highest operating average fluid temperatures, respectively, that are specified by the manufacturer. If they are not specified, high and low temperature range limit values as defined in Section 2.3 shall be used unless the panel or heat transfer element material temperature endurance limit under continuous operation is exceeded. In this case, the last test point shall be selected 5°C (9°F) below the maximum allowable temperature for the test panel or heat transfer element material under continuous operation. The minimum difference between the average fluid temperatures of two consecutive test points shall be 5°C (9°F) in a sensible heating test.

8.1.2.1.2 In a Sensible Cooling Test. A sensible cooling test shall include at least four test points at four different average fluid temperatures being evenly distributed over the operating temperature range specified by the manufacturer. The first and last test points shall include the highest and lowest operating average fluid temperatures, respectively. If these temperatures are not specified, 21°C (69.8°F) and 12°C (53.6°F) shall be used, respectively, unless the latter temperature gives a thermally effective panel surface temperature below 14°C (57°F).

8.1.2.2 Steady-State Condition. During testing at every test point, the test chamber must be in thermal equilibrium. Prior to each test point, all readings, except the average dry-bulb air temperature, shall remain at their values required by that test point and within their test tolerances (as shown in Table) 1 for at least 300 s to allow the completion of all measurements for that test point. After the measurements are completed, the test may proceed to the next test point by adjusting the average temperature and the flow rate of the heat transfer fluid in each test panel for that test point.
8.1.2.3 Controlled Interior Surface Temperatures During a Sensible Heating Test. Interior surface temperature of the exterior wall shall be maintained at $t_e - 5.5^\circ C \pm 0.5^\circ C$ ($t_e - 9.9^\circ F \pm 0.9^\circ F$). All other test chamber interior surfaces, excluding the ceiling, shall be maintained at $t_e - 0.5^\circ C \pm 0.5^\circ C$ ($t_e - 0.9^\circ F \pm 0.9^\circ F$). The average dry-bulb air temperature measured every 60 s shall be used to electronically control these temperatures. During the test the average dry-bulb air temperature must remain within $20^\circ C \pm 3^\circ C$ ($68^\circ F \pm 5.4^\circ F$). In order to satisfy this condition, average effective surface temperatures of the control panels as required in this section may be neglected.

8.1.2.4 Controlled Interior Surface Temperatures During a Sensible Cooling Test. The interior surface temperature of the exterior wall of the test chamber shall be maintained at $t_e + 5.5^\circ C \pm 0.5^\circ C$ ($t_e + 9.9^\circ F \pm 0.9^\circ F$). All other test chamber interior surfaces, excluding the ceiling, shall be maintained at $t_e + 0.5^\circ C \pm 0.5^\circ C$ ($t_e + 0.9^\circ F \pm 0.9^\circ F$). The average dry-bulb air temperature measured every 60 s shall be used to electronically control these temperatures. During the test the average dry-bulb air temperature must remain within $24^\circ C \pm 2^\circ C$ ($75.2^\circ F \pm 3.6^\circ F$). In order to satisfy this condition, average thermally effective surface temperatures of the interior surface temperature control panels as required in this section may be neglected.

8.1.2.5 Standard Test Factors. Table A1 in Normative Annex A lists standard test factors governing radiant and convective heat flux in the test chamber. If actual test conditions are different from these factors, heat flux calculations shall be adjusted (Section 9.1.1).

8.2 Starting a Test. A sensible heating test shall start from the test point with the lowest average fluid temperature determined for the given test (Section 8.1.2.1.1). A sensible cooling test shall start from the test point with the highest average fluid temperature determined for the given test (Section 8.1.2.1.2). All doors, openings, and diffusers (if the test chamber is directly connected to an air-conditioning system) must be sealed and closed prior to the test.

8.3 Conducting a Test. Tests shall be conducted by taking measurements at all test points successfully. All steady-state measurements at a test point shall be completed within a time period not to exceed 300 s. The test shall proceed from the first test point to the last test point (unless the test is interrupted for any reason as listed in Section 8.4.2). Test conditions for every test point shall be established by adjusting the corresponding average fluid temperature. After steady-state conditions are established for a test point, all measurements and recordings shall be made. This procedure shall be repeated until testing at the last test point is successfully completed.

8.3.1 Collecting Test Data. Test data shall be collected for every test point. The following readings shall be made at each test point.

8.3.1.1 Data for Test Panels

8.3.1.1.1 On the Thermally Effective Panel Surfaces. Calculate the thermally effective panel surface temperature, $t_{pe}$, as the area-weighted average of surface temperature measurements taken from at least six different points and obtained from suitable surface temperature sensors located at the approximate geometric center of six surface areas evenly distributed on each thermally effective panel surface. The sensor should not be located directly at a heating/cooling element position if the interior surface temperature control panels are of hydronic type. The sensor shall be located such that the distance from the nearest heating/cooling element shall be one-fourth of the heating/cooling element spacing. If some of the thermally effective panel surfaces are not directly exposed to the walls and the floor, $t_{pe}$ is calculated similarly with the exception that these surfaces are omitted.

8.3.1.1.2 In the Heat Transfer Fluid. Supply and return fluid temperatures, $t_s$ and $t_r$, respectively, shall be measured within 0.03 m (1.2 in.) of the test panel entry and exit points. Measure the supply and return fluid pressures, $p_s$ and $p_r$, respectively. Measurements shall be taken from hydronic pipes having the same hydraulic diameter. Distance between temperature and pressure measurement points shall not exceed 0.1 m (4 in.). Volume flow rate, $V$, shall be measured at the inlet of the test panel.

8.3.1.2 Data for the Test Chamber. Measure and record all interior surface temperatures, air velocity, dry-bulb air temperatures, barometric pressure, and the moisture content of the indoor air as explained in Sections 8.1.2.3, 8.3.1.2.1, 8.3.1.2.2, 8.3.1.2.3, and 8.3.1.2.4.

8.3.1.3 Uncontrolled Interior Surface Temperatures in the Test Chamber. Interior surface temperature of the uncontrolled ceiling of the test chamber shall be the arithmetic average of six readings obtained from suitable surface temperature sensors located at the geometric center of every approximately equal six surface areas. The geometric center of each surface area of the ceiling that is not obstructed by test panels shall be recorded and these areas shall be surface area-weighted to calculate the average ceiling surface temperature, $t_c$. If portions of the ceiling are directly exposed to any thermally effective panel surface, then the surface temperature of these surfaces shall also be recorded and surface area-weighted in a similar fashion to calculate $t_{pe}$. Infrared cameras that meet accuracy and precision requirements given in Table 1 may duplicate surface temperature measurements.

8.3.1.2.2 Dry-Bulb Air Temperatures in the Test Chamber. The average dry-bulb air temperature in the test chamber is not controlled, but it shall be measured and recorded every 60 s during the entire test, including the pretest phase. In Installation Methods A and C, use three shielded temperature sensors along the vertical centerline of the test chamber at heights of 0.75 and 1.5 m (2.46 and 4.92 ft) above the floor and 0.75 m (2.46 ft) below the ceiling. Then, arithmetic averaging of these readings shall give the average dry-bulb air temperature, $t_d$, for that set of three measurements. In Installation Method B, shielded temperature sensors shall be along the vertical centerline of the test chamber at heights of 0.75 and 1.5 m (2.46 and 4.92 ft) above the floor and 0.50 m (1.64 ft) below the plane of thermally effective panel surfaces. In no case shall any temperature sensor be closer than 0.30 m (1 ft) to any thermally effective panel surface. In Installation Method B, a fourth temperature sensor shall be placed along the same vertical centerline at 0.20 m (8 in.)
below the ceiling. This air temperature shall be measured simultaneously with other air temperature measurements, recorded, and processed similarly to calculate \( t_b \).

8.3.1.2.3 Air Velocity in the Test Chamber. Air velocity shall be measured using a temperature-compensated hot-wire or hot-film anemometer located 1.5 m (4.9 ft) above the floor on the same vertical centerline of temperature-measuring sensors.

8.3.1.2.4 Barometric Pressure and Moisture Content of Air in the Test Chamber. At every test point, the barometric pressure in the test chamber shall be measured. Relative humidity shall be recorded at the geometric center of the test chamber.

8.4 Ending a Test

8.4.1 Successful Completion of a Test. When all the test point measurements are completed successfully, the test ends. The primary closed loop, secondary closed loops, and hydronic (and/or air and/or electric) circuits for controlling the interior surfaces of the test chamber are shut down. Then, the detachable walls (or the service door if the test chamber is directly served by an air-conditioning system prior to test) shall be opened. Inlet valves of the test panels are shut down while the fluid in the heat delivery/extraction circuits is drained by gravity. After this operation, exit valves of every test panel are also closed. If the same test panels are not going to be subjected to another test, all the test panels shall be uninstalled. If the same test panels are going to be tested in a different installation method, their installation is altered according to the method of the next installation. Test data shall be compiled, and calculations shall be made. A visual inspection of the test panels and the test chamber completes the test.

8.4.2 Termination of a Test Prior to Completion. A test shall be terminated if any one of the following conditions occurs during the test. Then the test shall be restarted by going to the pretest phase as described in Section 8.1.1.1.

1. If initial steady-state conditions prior to a test cannot be established within 5400 s (1.5 h) or cannot be maintained in the test chamber for at least 1800 s (0.5 h) prior to test.
2. If steady-state conditions at a test point cannot be established within 3600 s (1 h) in the test chamber.
3. If steady-state conditions at a test point cannot be maintained for at least 300 s to complete the measurements at that test point.
4. If, during any sensible heating panel test, the average dry-bulb air temperature of the test chamber exceeds 23°C (73.4°F).
5. If a power failure occurs that lasts more than 600 s. If the power failure is less than 600 s, the test may be resumed by repeating the last test point. If the power failure is less than 120 s, the test may be continued from the point of interruption.
6. If the Reynolds number in any test panel drops to a value that is less than 10,000 at any stage of the test.
7. If the indoor air velocity exceeds 0.4 m/s (1.31 ft/s).
8. If, during a sensible cooling test, visible surface condensation occurs on the test panels or if the saturation temperature exceeds any test panel supply fluid temperature by 1°C (1.8°F). In either of these cases, check the hydronic (and/or air cooling or electric heating) system for any possible fluid leaks as well as the tightness of the test chamber.
9. If the relative humidity in the test chamber exceeds 60% RH in a sensible heating test.
10. If any thermally effective panel surface temperature exceeds 80°C (176°F) for test panels with thermoplastic tubing or exceeds 150°C (302°F) for test panels with metal piping.
11. If any mechanical failure occurs that renders the test inoperable, unsafe, or unreliable.
12. If the static liquid pressure in the secondary closed loops drops below 125 kPa gage (2610 lb/ft²) or a visible fluid leakage is observed. In this case, investigate the source and cause of the fluid leak and make up the fluid if necessary.

9. PROCESSING TEST DATA

The capacity of the test panel is defined in terms of the heat flux at the thermally effective panel surfaces. The capacity of the test panels shall be calculated from data obtained from all test points.

9.1 Heat Flux at the Thermally Effective Panel Surface(s). Heat flux at the thermally effective panel surface(s) shall be calculated at every test point.

9.1.1 Calculating the Heat Flux. Because unintentional heat losses/gains through thermally ineffective panel surfaces are contained in the test chamber due to heavy ceiling insulation, heat flux at the thermally effective panel surfaces of a test panel is equated to the heat-flux measurements in the hydronic circuit of the same test panel. Heat flux measured through the hydronic circuit is calculated by the following equations.

Sensible Heating Test

\[
q = \sum_{i=1}^{m} \frac{p V C_p (t_i - t_r)}{\sum_{i=1}^{m} A_p} (3a)
\]

Sensible Cooling Test

\[
q = \sum_{i=1}^{m} \frac{p V C_p (t_r - t_i)}{\sum_{i=1}^{m} A_p} (3b)
\]

If a thermal energy meter directly measures thermal energy \( \mathcal{Q} \) delivered or removed, then \( q \) for sensible heating or sensible cooling shall both be calculated from Equation 4.

\[
q = \sum_{i=1}^{m} \frac{\mathcal{Q}}{\sum_{i=1}^{m} A_p} (4)
\]

Mass density and the specific heat of the heat transfer fluid shall be calculated at the average fluid temperature for each test point, which is calculated by Equation 5.

\[
t_m = \frac{t_f + t_r}{2} (5)
\]

9.1.2 Adjusting the Heat-Flux Calculations. Calculated \( q \) values at each test point shall be adjusted if one or more of the actual test conditions deviate from the standard test conditions by more than the permissible amounts listed in
Table A1 in Normative Annex A. \( \beta \) is calculated from Equation A2 in Normative Annex A.

\[
q_{ad} = q\beta
\]  

(6)

9.2 Calculation of AUST in the Test Chamber. Calculate AUST by including all interior surfaces of the test chamber exposed directly to thermally effective panel surfaces.

\[
AUST = \frac{A_1l_1 + A_2l_2 + A_3l_3 + A_4l_4 + A_e l_e + A_{ce} l_{ce}}{A_1 + A_2 + A_3 + A_4 + A_e + A_{ce}}
\]  

(7)

9.3 Calculation of the Mean Radiant Temperature in the Test Chamber. Calculate \( t_{mr} \) in terms of interior surface temperatures of the walls and the floor, portion(s) of the ceiling surfaces that are not obstructed by test panel(s), and temperatures of the thermally effective test panel surfaces directly exposed to the walls and the floor of the test chamber.

\[
t_{mr} = \frac{A_1l_1 + A_2l_2 + A_3l_3 + A_4l_4 + A_e l_e + A_{ce} l_{ce} + \sum_{j=1}^{m} A_{po}l_{po}}{A_1 + A_2 + A_3 + A_4 + A_e + A_{ce} + \sum_{j=1}^{m} A_{po}}
\]  

(8)

9.4 Calculation of Operative Temperature in the Test Chamber, \( t_o \). Calculate \( t_o \) as the arithmetic average of \( t_a \) and \( t_{mr} \).

\[
t_o = \frac{1}{2} (t_a + t_{mr})
\]  

(9)

9.5 Calculation of the Characteristic Performance Coefficients of the Test Panel. Three characteristic performance equations shall be determined for three separate definitions of the temperature difference, \( \Delta t \). Negative signs designate the sensible cooling test. Coefficients and exponents, designated \( C_{he}, C_{co}, C_{he}', C_{co}', C_{nhe}, C_{nhe}' \), \( nhe, nco, nhe', nco' \), and \( nhe'', nco'' \), shall be determined by using the method of least squares (Normative Annex B).

\[
\Delta t = \pm (t_m - t_o)
\]  

(10)

\[
\Delta t' = \pm (t_m - t_{a})
\]  

(11)

\[
\Delta t'' = \pm (t_p - t_a)
\]  

(12)

\[
q_{ad} = C_{he}\Delta t^{nhe} \quad \text{(sensible heating)}
\]  

(13)

\[
q_{ad} = C_{co}\Delta t^{nco} \quad \text{(sensible cooling)}
\]  

(14)

\[
q_{ad} = C_{he}'\Delta t^{nhe'} \quad \text{(sensible heating)}
\]  

(15)

\[
q_{ad} = C_{co}'\Delta t^{nco'} \quad \text{(sensible cooling)}
\]  

(16)

\[
q_{ad} = C_{nhe}'\Delta t^{nhe''} \quad \text{(sensible heating)}
\]  

(17)

\[
q_{ad} = C_{nco}'\Delta t^{nco''} \quad \text{(sensible cooling)}
\]  

(18)

9.6 Pressure Drop in the Test Panel. At a given test point, pressure drop in the heat transfer fluid circulating in the test panels shall be recorded for documentation purposes only. Pressure drop is the difference between the fluid pressure measurements at the inlet and at the exit of the test panel:

\[
\Delta p = (p_1 - p_o)
\]  

(19)

9.7 Graphical Representation of Test Results. Processed test data shall be presented on a logarithmic graph with temperature differences on the abscissa and \( q_{ad} \) on the ordinate. Information boxes shall provide information about every test point. Test points start from the highest average fluid temperature in sensible cooling tests and from the lowest average fluid temperature in sensible heating tests.

9.8 Calculation of the Panel Thermal Resistance. Thermal resistance of a test panel between the fluid of the test panel and the indoor space shall be calculated by using Equation 20.

\[
R_{u} = \frac{1}{[C'_{co}\Delta t^{nco'-1}]} \quad \text{(20)}
\]

If the same test panel is subjected to the sensible cooling test in the same test chamber, then the above calculation shall be repeated:

\[
R_{u} = \frac{1}{[C'_{co}\Delta t^{nco'-1}]} \quad \text{(21)}
\]

10. ACCEPTANCE CRITERIA FOR THE STANDARD TEST

The following criteria shall be used to accept a standard test:

1. If the characteristic performance exponent \( nhe'' \) or \( nco'' \) obtained from a sensible heating or sensible cooling test satisfies the condition \( 1.0 \leq nhe'' \leq 1.3 \) or \( 1.0 \leq nco'' \leq 1.4 \), respectively.

2. If the same panel is subjected to both sensible heating and sensible cooling tests in the same test chamber, then values obtained from Equations 20 and 21 shall agree with each other within 20%, based on the arithmetic average of the two results.

11. REPORTING STANDARD TEST RESULTS

11.1 Standard Test Report. After the successful completion and acceptance of a test, a written test report is prepared. If the test was not successfully completed, a short report with reason(s) for terminating the test shall be prepared. If the test was successfully completed but not found acceptable according to Section 10, a report similar to a successful and acceptable test report shall be prepared and the reason(s) for rejection shall be stated.

11.2 Content of the Standard Test Report. The test report for a successful test shall describe the objective, descriptions of the test panel, number of identical test panels, test data, calculations, results, uncertainty of the test results, and any deviations from this standard. Table 3 provides an outline of the content of the test report that shall be prepared.
### TABLE 3  Content of the Standard Test Report

<table>
<thead>
<tr>
<th>Testing Facility</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of testing organization</td>
<td></td>
</tr>
<tr>
<td>Dimensions of test chamber, $A_C, A_P, A_{1,2,3,4}$, length, width, height, etc.</td>
<td></td>
</tr>
<tr>
<td>Thermophysical properties of the test chamber, $e_r$, surface paint of interior surfaces</td>
<td></td>
</tr>
<tr>
<td>Thermal conductance resistance (R-value) of the wall, ceiling, and floor insulation, etc.</td>
<td></td>
</tr>
<tr>
<td>Date, starting and ending times of test (any interruptions during test and their duration shall be reported)</td>
<td></td>
</tr>
<tr>
<td>Date of the last air leakage test performed for the test chamber and its results</td>
<td></td>
</tr>
<tr>
<td>Capacity of fluid heating and cooling equipment used to test panels</td>
<td></td>
</tr>
<tr>
<td>Location of the testing facility, altitude above sea level, and persons conducting the test</td>
<td></td>
</tr>
<tr>
<td>List of all applicable standards and codes regarding design, operation, maintenance, and safety of the test facility (provide certification)</td>
<td></td>
</tr>
<tr>
<td>A copy of the current ISO Standard 9001, Quality Management Systems—Requirements, certification of the facility or certificate of a similar accreditation from any national or international organization</td>
<td></td>
</tr>
<tr>
<td>Details about the interior surface temperature control system</td>
<td></td>
</tr>
</tbody>
</table>

### Instruments, Equipment, and Testing Apparatus

- Name, model and serial number, measuring range, accuracy, precision and type of all measuring, recording, and data processing instruments and equipment, including calibration data (may be kept available in a separate file and listed as “available upon request”)
- Specification of the circulation pumps, control systems, heat exchangers, manifolds valves, and all other ancillaries

### Test Panel Information

- Sampling method used for test panels
- Manufacturer
- Model information (trade name, make, model and serial number, and similar information)
- Type of test panel (sensible heating, sensible cooling, or combined panel)
- Number of identical test panels plumbed in parallel in the test chamber
- Test panel dimensions (external dimensions, heat transfer element size, connection type and size of hydronic connections), thermally effective panel surfaces, $A_p, e_p$ and panel surface finish (shall be provided by the manufacturer and verified before the test if necessary)
- Panel material
- Heat transfer fluid used (if different from plain water, give exact composition or trade name of the heat transfer fluid and provide temperature-dependent properties such as mass density, specific heat, and viscosity in the test range)

### Test Conditions

- Exact test panel installation locations (illustrated with figures)
- Complete details and installation figures if Installation Method C is used
- Indoor test conditions prior to test (average dry-bulb air temperature, relative humidity)
- Area-weighted average emittance of the interior test chamber surfaces directly exposed to test panels, test specific dimensions such as $A_{po}, A_C, A_{ce}$

### Test Results

- Test data (all recorded temperatures, flow rates, pressure drop, etc.)
- Number of test points, all calculations and results, including heat flux at each test point
- Figure 2 with all information boxes filled for each test point
- Uncertainty in panel output at each test point
- Characteristic performance coefficients and exponents

### Comments

- Any information regarding unexpected operation or measurement or any other unusual test conditions that may alter the results and recommendations
12. REFERENCES

NOMARATIVE ANNEX A—
ADJUSTMENT OF PANEL HEAT FLUX

When actual test conditions deviate from factors of the standard test shown in Table A1 by more than permissible amounts, heat flux calculated at every test point shall be adjusted. This adjustment involves correction factors for radiative and convective components of the heat transfer on thermally effective panel surfaces.

\[ q_{ad} = q^\beta \]  \hspace{1cm} (A1)
\[ \beta = 0.87a/F_c + (1 - a) \times abc \]  \hspace{1cm} (A2)
\[ \alpha = \frac{1 \pm k[t_a - \text{AUST}]_{st}}{1 \pm k[t_a - \text{AUST}]_{st}} \times (q_r/q) \]  \hspace{1cm} (A3)

The term \((q_r/q)\) is the average ratio of radiative heat flux to total heat flux at a given test point as calculated according to information given in ASHRAE Handbook—HVAC Systems and Equipment, Chapter 6. For cooling, \(k\) is 0.1 and the negative (\(-\)) sign is used. For cooling, \(k\) is 0.02 and the positive sign (\(+\)) is used. The variable \([t_a - \text{AUST}]_{st}\) is the standard difference between the average dry-bulb air temperature and AUST given in Table A1. The variable \([t_a - \text{AUST}]_{st}\) is the temperature difference during actual test at a given test point. If \(F_c\) is different from 0.87, a correction is required with three factors. With a base value of \(e_r = 0.90,\)

\[ F_c = \{1/F_{p-r} + [1/0.9 - 1] + [1/e_r - 1]A_{p}/A_r\}^{-1} \] \hspace{1cm} (A4)

\(F_{p-r}\) approaches unity if the panels are flat, horizontal, and flush with the finished ceiling. For other selected configurations, \(F_{p-r}\) may be calculated from related figures and tables in ASHRAE Handbook—Fundamentals, Chapter 4. Area-weighted average thermal emittance of the interior surfaces of the test chamber, \(\varepsilon_f\), shall be measured or obtained from ASHRAE Handbook—Fundamentals, Table 5 in Chapter 4.

The second term in Equation A2 adjusts the convective heat flux component according to the following factors:

- a. Size effect. The standard equivalent diameter, \(D_{eq}\), is given in Table A1, and \(D_p\) is the actual equivalent diameter of a single test panel.
- b. Mass density of air (altitude) effect.
- c. Indoor air velocity effect.

### TABLE A1 Standard Test Factors and Permissible Deviations

<table>
<thead>
<tr>
<th>Test Factor</th>
<th>SI Units</th>
<th>I-P Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>([t_a - \text{AUST}]_{st})</td>
<td>(\pm 1.5^\circ \text{C} \pm 0.5^\circ \text{C}) in cooling</td>
<td>(\pm 2.7^\circ \text{F} \pm 0.9^\circ \text{F}) in cooling</td>
</tr>
<tr>
<td>(D_{eq})</td>
<td>4.90 \pm 0.5 m</td>
<td>16.1 \pm 1.5 ft</td>
</tr>
<tr>
<td>(F_c)</td>
<td>0.87 \pm 0.05</td>
<td>0.87 \pm 0.05</td>
</tr>
<tr>
<td>(F_{p-r})</td>
<td>1 \pm 0.05</td>
<td>1 \pm 0.05</td>
</tr>
<tr>
<td>(e_r)</td>
<td>0.9 \pm 0.03</td>
<td>0.9 \pm 0.03</td>
</tr>
<tr>
<td>(p_{st})</td>
<td>101.32 \pm 10 kPa</td>
<td>2115.34 \pm 20 lb/ft^2</td>
</tr>
<tr>
<td>(h_{st})</td>
<td>0 \pm 500 m</td>
<td>0 \pm 1640 ft</td>
</tr>
<tr>
<td>(A_{p}/A_{r}(1/e_r - 1))</td>
<td>(\leq 0.02)</td>
<td>(\leq 0.02)</td>
</tr>
</tbody>
</table>

### TABLE A2 Adjustments to Natural Convection Heat Flux

<table>
<thead>
<tr>
<th>Convective Coefficients</th>
<th>SI Units</th>
<th>I-P Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>((D_p/D_{eq})^b)</td>
<td>((D_p/D_{eq})^b)</td>
</tr>
<tr>
<td>(b)</td>
<td>((\rho_{st}/\rho_f)^c)</td>
<td>((\rho_{st}/\rho_f)^c)</td>
</tr>
<tr>
<td>(c)</td>
<td>((\nu_f/0.15)^{0.8})</td>
<td>((\nu_f/0.5)^{0.8})</td>
</tr>
</tbody>
</table>

*See definitions of symbols \(r\) and \(s\) in Section 4.

Note:
The following relationships may also make the altitude correction:
\[ b = \left((1 - 0.67 \times 10^{-10}h_f)/(1 - 2.22 \times 10^{-10}h_f)\right)^{0.5} \]
\[ b = \left((1 - 0.67 \times 10^{-10}h_f)/(1 - 0.67 \times 10^{-10}h_f)\right)^{0.5} \]
\[ D_p = 4 \times \text{area/volume of the test chamber, in (ft)} \]
\[ \nu_f = \text{air velocity measured in the test chamber, m/s (ft/s)} \]
\[ r = 0.52 \times 5.254 \text{ for ceiling cooling and 0.50 \times 5.254 for ceiling heating} \]
\[ s = 0.08 \text{ for ceiling cooling and 0.25 for ceiling heating} \]
NORMATIVE ANNEX B—
LINE FITTING BY THE
METHOD OF LEAST SQUARES

The following method of least squares shall be used to determine the relationship given in Equations 13 through 18 in Section 9.5. Since the characteristic performance coefficient equation is a power function, taking the natural logarithm of each term in the equation makes that equation linear. For example:

\[
\ln(q_{ad}) = \ln(C_{he}) + nhe \ln(\Delta t)
\]

(B1)

\[
\ln(q_{ad}) = \ln(C_{co}) + nco \ln(\Delta t)
\]

(B2)

with the residual defined as

\[
\varepsilon_r^2 = \sum_{i=1}^{z} (y_i - y_{fitted,i})^2
\]

(B3)

which can be minimized by Equation B4:

\[
\varepsilon_r^2 = \sum_{i=1}^{z} [y_i - (A + Bx_i)]^2
\]

(B4)

where

\[
y_i = \ln(q_{ad})_i
\]

\[
x_i = \ln(\Delta t)_i
\]

A = ln(C_{he}) ln(C_{co})

B = nhe or nco

z = number of test points

With the appropriate sums, coefficients A and B in the linear fit can be solved:

\[
\Sigma y_i = \Sigma \ln(q_{ad})_i
\]

(B6)

\[
\Sigma x_i = \Sigma \ln(\Delta t)_i
\]

\[
\Sigma x_i^2 = \Sigma (\ln(q_{ad})_i)^2
\]

\[
\Sigma x_i y_i = \Sigma \ln(q_{ad})_i \ln(\Delta t)_i, \quad i = 1 \text{ to } z
\]

Then

\[
A = \left[ z \sum_{i=1}^{z} y_i - B \sum_{i=1}^{z} x_i \right] / z
\]

(B7)

\[
B = \left[ z \sum_{i=1}^{z} x_i y_i - \left( \sum_{i=1}^{z} x_i \right) \left( \sum_{i=1}^{z} y_i \right) \right] / \left[ z \sum_{i=1}^{z} x_i^2 - \left( \sum_{i=1}^{z} x_i \right)^2 \right]
\]

(B8)

and

\[
C_{he} \text{ or } C_{co} = e^A \text{ (intercept with ordinate in Figure 2)}
\]

(B9)

\[
nhe \text{ or } nco = B \text{ (slope of the lines in Figure 2)}
\]

(B10)

The same procedure shall be repeated to calculate \( C'_{he} \) or \( C'_{co} \) and \( nhe' \) or \( nco' \), \( C''_{he} \) or \( C''_{co} \) and \( nhe'' \) or \( nco'' \) by replacing \( \Delta t \) in Equations B1 to B6 with \( \Delta t' \) and \( \Delta t'' \). Also, A shall be replaced with \( A' \) and \( A'' \), and B shall be replaced with \( B' \) and \( B'' \).
(This annex 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 ANNEX C—UNCERTAINTY ANALYSIS OF PANEL HEAT FLUX

Rating of a sensible heating or sensible cooling panel depends on a number of measurements that each contains systematic and random errors. Without careful calibrations, these errors can result in large uncertainties. This annex gives the uncertainty analysis of the heat flux. According to Equation 3a, uncertainties primarily in volume flow rate and temperature difference influence the result. Since the equation is multiplicative, the following method can be used to estimate the uncertainty in heat flux for a single test panel (m = 1). Here, it is assumed that ε and ∆t are precisely known.

\[
\varepsilon_q^2 = \left( \frac{\partial q}{\partial V} \right)^2 \varepsilon_v^2 + \left( \frac{\partial q}{\partial C_p} \right)^2 \varepsilon_{C_p}^2 + \left( \frac{\partial q}{\partial \Delta t} \right)^2 \varepsilon_{\Delta t}^2 \quad (C1)
\]

\[
\varepsilon_q^2 = C_p^2 \Delta T^2 \varepsilon_v^2 + \nu^2 \Delta T^2 \varepsilon_{C_p}^2 + \varepsilon_{\Delta t}^2 \quad \Delta t \quad (C2)
\]

Here, \( \Delta t \) is the temperature difference of the heat transfer fluid between inlet and exit points of the test panel. After dividing Equation C2 by \( q^2 \),

\[
\left( \frac{\varepsilon_q}{q} \right)^2 = \frac{\varepsilon_q^2}{(V^2 C_p^2 \Delta T^2)} = \left( \frac{\varepsilon_v}{V} \right)^2 + \left( \frac{\varepsilon_{C_p}}{C_p} \right)^2 + \left( \frac{\varepsilon_{\Delta t}}{\Delta t} \right)^2 \quad (C3)
\]

If \( m \) is greater than 1, then:

\[
\left( \frac{\varepsilon_q}{q} \right)^2 = \sum_{j=1}^{m} \left( \frac{\varepsilon_v}{V}_j \right)^2 + \left( \frac{\varepsilon_{C_p}}{C_p}_j \right)^2 + \left( \frac{\varepsilon_{\Delta t}}{\Delta t}_j \right)^2 \quad \sum_{j=1}^{m} \left( V^2 C_p^2 \Delta T^2 \right)_j \quad (C4)
\]
(This annex 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 objections on informative material are not offered the right to appeal at ASHRAE or ANSL.)

INFORMATIVE ANNEX D—
CALCULATING THE APPROXIMATE THERMAL EFFICIENCY OF THE TEST PANEL

A test chamber is configured such that unintentional heat transfer at thermally ineffective surfaces of a test panel is contained in the test chamber. This leads to a test panel thermal efficiency to be very close to one. In practice, depending upon actual physical and thermohydraulic conditions, heat transfer at thermally ineffective surfaces of the panel becomes its unintentional heat losses or gains to or from the neighboring space. In this case, the designer might need to increase the required heat flux by using thermal efficiency $X$, which is approximated by Equation D1:

$$ X \approx \left[1 + \frac{R_d}{R_a} \left( t_m - t_d \right) \left( t_m - t_a \right)^{-1} \right] \quad \{X \leq 1\} \quad (D1) $$

If there is more than one thermally effective panel surface or more than one thermally ineffective panel surface in the same test panel, $R_d$ and $R_a$, each shall be surface-area-averaged. If the anticipated actual conditions where the test panel shall be installed are different from the standard test conditions given in Table A1, performance corrections may be made according to $\beta^*$, which is calculated now with respect to anticipated actual operating conditions. Here, $q_{cor}$ is the predicted (corrected) heat flux at the actual installation site.

$$ q_{cor} = q_{ad} X \beta^* = q_\beta X \beta^* \quad (D2) $$
(This annex 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 objections on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX E—
PROVISIONS FOR ELECTRIC PANELS
AND CALIBRATION OF THE TEST CHAMBER

E1. EVALUATING TEST PANELS

Although it is not part of this standard, the test facility may accommodate thermal evaluation of electric ceiling panels with the following provisions and restrictions:

- Calculate $q$ from Equation 4 by replacing the term $[Q]_e$ with the term $VI$. Here $V$ (volt) is the electric potential difference measured across the electrical terminals of the panel during operation at a test point. $I$ (amp) is the electrical current measured in the electrical circuit of the panel during operation at a test point.
- Electrical measurement and recording devices shall have sufficient accuracy and precision such that the same or better certainty and accuracy regarding $q$ shall be obtained when compared with hydronic panel tests as described in this standard.
- All electrical connections, wiring, and safety measures must conform to NFPA 70-99, National Electrical Code,1 or its most current edition, all other applicable ANSI and UL standards, as well as applicable local electrical codes. Electrical power supply capacity to the test chamber shall be at least 4 kW (13,657.6 Btu/h).
- Installed electric test panels may not have a combined heating capacity higher than 4 kW (13,657.6 Btu/h).
- Installed electric test panels may not have exposed electric wiring for heating purposes.
- Installed electric panels must be UL certified.
- During tests, electric panels may not be controlled by on/off controls. Electric power control shall be performed with a variable voltage supply of sufficient capacity and accuracy.
- All electrical devices, including electric panels, shall be properly and securely grounded.

E2. CALIBRATION TESTING OF THE TEST CHAMBER

A reference electrical panel may be used to evaluate the test chamber and determine whether it is fit to accurately simulate the required test environment for sensible heating tests when a calibration or airtightness test is completed. For this purpose, eight identical reference panels each with $1 \times 1 \text{ m } (3.28 \times 3.28 \text{ ft})$ thermally effective panel surface dimensions shall be installed in the test chamber. Four of these reference panels shall be attached to the ceiling, side by side, around the center of the ceiling. Each of the remaining four reference panels shall be attached to the ceiling at the corners of the ceiling by leaving 0.3 m (1 ft) clearance between the edges of the test chamber ceiling. Each reference panel shall have 500 W (1707.2 Btu/h) heating capacity. The back and exposed edges of reference panels shall be insulated with a minimum thermal resistance of $3 \text{ m}^2\text{K/W} (17 \text{ ft}^2\cdot{\circ}{\text{F}}/{\text{h}}/{\text{Btu}})$. Reference panels shall be operated in such a manner that a calibration curve similar to Figure 2 shall be prepared by using only $\Delta t'$. Then $t_p$ shall be varied between $30^\circ\text{C}$ and $100^\circ\text{C} (212^\circ\text{F} and 86^\circ\text{F})$, with $10^\circ\text{C} (50^\circ\text{F})$ increments. All applicable clauses of this standard may be used to conduct the test. Calculated performance coefficients $C_{he}$ and $nhe$ should be $4.75 \pm 0.1 \text{ W/(m}^2\cdot{\circ}{\text{C}}{\text{h}^{-1}}$/Btu) and $1.17 \pm 0.03 \text{ (1.17} \pm 0.03)$, respectively.

E3. REFERENCES

POLICY STATEMENT DEFINING ASHRAE’S CONCERN
FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

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.
About ASHRAE

ASHRAE, founded in 1894, is a global society advancing human well-being through sustainable technology for the built environment. The Society and its members focus on building systems, energy efficiency, indoor air quality, refrigeration, and sustainability. Through research, Standards writing, publishing, certification and continuing education, ASHRAE shapes tomorrow’s built environment today.

For more information or to become a member of ASHRAE, visit www.ashrae.org.

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ASHRAE offers its Standards and Guidelines in print, as immediately downloadable PDFs, on CD-ROM, and via ASHRAE Digital Collections, which provides online access with automatic updates as well as historical versions of publications. Selected Standards and Guidelines are also offered in redline versions that indicate the changes made between the active Standard or Guideline and its previous version. For more information, visit the Standards and Guidelines section of the ASHRAE Bookstore at www.ashrae.org/bookstore.

IMPORTANT NOTICES ABOUT THIS STANDARD

To ensure that you have all of the approved addenda, errata, and interpretations for this Standard, visit www.ashrae.org/standards to download them free of charge.

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