Public Review Draft

Methods of Test for Determining Application Data of Overhead Circulator Fans


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FOREWORD

This standard was created to provide standardized design data for the application of overhead circulation fans in indoor spaces. The test data can be used for occupant thermal comfort calculations and to demonstrate compliance with the thermal comfort requirements of ASHRAE Standard 55.

1. PURPOSE

The purpose of this standard is to specify the instrumentation, facilities, test installation methods, and procedures to determine circulator fan application data for occupant thermal comfort in a space.

2. SCOPE

2.1 This standard applies to overhead circulator ceiling fans.

3. DEFINITIONS

air density ($\rho_a$): the mass per unit volume of the air.

air density, standard ($\rho_0$): the density of air at standard conditions, 0.075 lbm/ft³ (1.20 kg/m³), which approximates dry air at a temperature of 70°F (21.1°C) and a barometric pressure of 29.92 in. Hg (101.3 kPa).

air speed ($V$): the rate of air movement at a point, without regard to direction.

air speed, average ($V_{a,m}$): the average air speed at a test position or test point. The average is with respect to location and time. The height of the test points above the floor are 4, 24, and 43 in. (0.1, 0.6, and 1.1 m) for determining the average air speed for seated occupants; and 4, 43, and 67 in. (0.1, 1.1, and 1.7 m) for determining the average air speed for standing occupants. The air speed is averaged over a minimum interval of 3 minutes.

barometric pressure, ambient ($B_a$): the pressure of the atmosphere relative to zero absolute pressure (a perfect vacuum).

blade height: the vertical distance from the lowest point on the fan blades to the floor.

comfort, thermal: the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

current, input ($I$): measured movement or flow of charge in an electrical circuit.

fan size ($D$): total diameter of a circle measured at the blade tips.

fan speed ($N$): the rotational speed of the impeller.
humidity, relative (ϕ): ratio of the partial pressure or density of water vapor to the saturation pressure or density, respectively, at the same dry-bulb temperature and ambient barometric pressure.

overhead circulator ceiling fan: a non-ducted, fixed fan that is suspended from the ceiling and has no provision for connection to ducting or separation of impeller inlet from its outlet, designed to be used for the circulation of air.

power, input (P): the electrical power required to drive the fan and any elements which are considered a part of the fan.

temperature, air dry-bulb (t_{db}): temperature of air indicated by an ordinary thermometer shielded from solar and long wave radiation.

temperature, air wet-bulb(t_{wb}): the temperature indicated when a thermometer bulb is covered with a water saturated wick over which air is caused to flow at approximately 900 fpm (4.5 m/s) to reach the equilibrium temperature of water evaporating into the air when the heat of vaporization is supplied by the sensible heat of the air, motion.

test sampling duration: Length of time that air speeds are sampled at each test position.

test point: a point at a given height at a test position where measurements are taken.

test position (TP): the location of a set of vertically spaced test points.

voltage (E): electric potential or potential difference.

4. SYMBOLS AND UNITS

4.1 For the purposes of this document, the symbols and primary units given in Table 1 for the parameters listed apply.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>IP Unit</th>
<th>SI Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>B_{a}</td>
<td>Ambient barometric pressure</td>
<td>In. Hg</td>
<td>Pa</td>
</tr>
<tr>
<td>CC</td>
<td>Cooling coverage fraction</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>CE</td>
<td>Cooling effect from air speed</td>
<td>°F</td>
<td>°C</td>
</tr>
<tr>
<td>CFE</td>
<td>Cooling Fan Efficiency</td>
<td>°F/W</td>
<td>°C/W</td>
</tr>
<tr>
<td>D</td>
<td>Fan size (diameter)</td>
<td>ft</td>
<td>m</td>
</tr>
<tr>
<td>DR</td>
<td>Draft risk fraction</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>d</td>
<td>Distance</td>
<td>ft</td>
<td>m</td>
</tr>
<tr>
<td>E</td>
<td>Voltage</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>f</td>
<td>Frequency</td>
<td>Hz</td>
<td>Hz</td>
</tr>
<tr>
<td>I</td>
<td>System input current</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>N</td>
<td>Fan speed</td>
<td>rpm</td>
<td>rpm</td>
</tr>
<tr>
<td>P</td>
<td>System input power</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>p_{b}</td>
<td>Corrected barometric pressure</td>
<td>in. Hg</td>
<td>Pa</td>
</tr>
<tr>
<td>p_{s}</td>
<td>Saturated vapor pressure</td>
<td>in. Hg</td>
<td>Pa</td>
</tr>
<tr>
<td>p_{w}</td>
<td>Partial vapor pressure</td>
<td>in. Hg</td>
<td>Pa</td>
</tr>
<tr>
<td>R</td>
<td>Gas constant</td>
<td>ft•lb/lb-m•°R</td>
<td>J/kg•K</td>
</tr>
</tbody>
</table>
### Additional Subscript

<table>
<thead>
<tr>
<th>Subscript</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5r</td>
<td>2.5 times the fan radius from center</td>
</tr>
<tr>
<td>m</td>
<td>Mean value</td>
</tr>
<tr>
<td>max</td>
<td>Maximum value</td>
</tr>
<tr>
<td>min</td>
<td>Minimum value</td>
</tr>
<tr>
<td>n</td>
<td>Number in general</td>
</tr>
<tr>
<td>room</td>
<td>Referring to the test room</td>
</tr>
<tr>
<td>s</td>
<td>Spacing from test position zero to test position one</td>
</tr>
<tr>
<td>seated</td>
<td>Test point heights relevant for a seated occupant</td>
</tr>
<tr>
<td>standing</td>
<td>Test point heights relevant for a standing occupant</td>
</tr>
<tr>
<td>0</td>
<td>Zero, starting, minimum or null value</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit 1</th>
<th>Unit 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>Radius of the fan size (diameter)</td>
<td>ft</td>
<td>m</td>
</tr>
<tr>
<td>$t_{db}$</td>
<td>Temperature, air dry-bulb</td>
<td>°F</td>
<td>°C</td>
</tr>
<tr>
<td>$t_{wb}$</td>
<td>Temperature, air wet-bulb</td>
<td>°F</td>
<td>°C</td>
</tr>
<tr>
<td>TP</td>
<td>Test position</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$V_a$</td>
<td>Air speed</td>
<td>fpm</td>
<td>m/s</td>
</tr>
<tr>
<td>U</td>
<td>Uniformity</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>WF</td>
<td>Weighting factor</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\rho_a$</td>
<td>Density, air</td>
<td>lb/ft³</td>
<td>kg/m³</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Humidity, relative</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>
5. INSTRUMENTS AND APPARATUS

5.1 Measurement Criteria. The measuring instrumentation used shall meet the minimum requirements for measurement range and accuracy given in Table 2. Air dry-bulb temperature sensors shall be shielded from radiation exchange with the surroundings.

Table 2 - Minimum Requirements for Instrumentation Measurement Range and Accuracy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measuring Range</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature, dry-bulb</td>
<td>50°F–105°F (10°C–40°C)</td>
<td>± 0.5°F (± 0.2°C)</td>
</tr>
<tr>
<td>Length</td>
<td>-</td>
<td>± 0.0625 in (±1 mm)</td>
</tr>
<tr>
<td>Power</td>
<td>0W-3,000W</td>
<td>± 1.0%</td>
</tr>
<tr>
<td>Voltage</td>
<td>0V – 600V</td>
<td>± 1.0%</td>
</tr>
<tr>
<td>Frequency</td>
<td>40Hz – 80Hz</td>
<td>± 1.0%</td>
</tr>
<tr>
<td>Current</td>
<td>0A – 50A</td>
<td>± 0.5%</td>
</tr>
<tr>
<td>Air Speed</td>
<td>30 fpm to 950 fpm (0.15 m/s to 4.8 m/s)</td>
<td>± 5% or 10 fpm (0.05m/s), whichever is greater</td>
</tr>
<tr>
<td>Fan Speed</td>
<td>0 RPM - 1000 RPM</td>
<td>± 0.5%</td>
</tr>
<tr>
<td>Barometric Pressure</td>
<td>20 in. Hg to 32.5 in. Hg (67 kPa to 110 kPa)</td>
<td>±0.1 in. Hg (±340 Pa)</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>10% - 90%</td>
<td>2%</td>
</tr>
</tbody>
</table>

5.2 All equipment used to measure parameters listed in Table 2 shall be calibrated over the range of values to be encountered during testing against a meter with a calibration by an ISO 17025 accredited calibration laboratory that is traceable to the National Institute of Standards and Technology (NIST) or other national physical measures recognized as equivalent by NIST.

6. TEST CONDITIONS AND GENERAL PROCEDURES

6.1 Test Conditions.

6.1.1 Steady State Air Speed Conditions. Measurements shall be done under steady state conditions. For the purpose of this standard, steady-state conditions are achieved when the absolute difference between the mean of the first half of the test sampling duration and the mean of the second half of the test sampling duration is less than either 10% or 10 fpm (0.05m/s). If steady state conditions are not met at the minimum test sampling duration, the test sampling duration shall increase in 180 second increments until steady state conditions are achieved, up to a maximum of 720 seconds, at which steady state conditions are assumed to have been met.

6.1.2 Space Conditions. The test space air temperature and humidity shall be maintained at 70±10°F (21.0±5.5°C) and 50±10% relative humidity during testing.

6.1.3 Extraneous Airflow. Air speed in the test chamber not generated by the test fan shall not exceed 30 fpm (0.15 m/s) prior to, during, and after the test. Air speed measurements shall be taken at test position 0, as defined in Section 7.2.2. Measurements shall be taken immediately before the fan is turned on and at least three minutes after the fan has been powered off after completion of all testing to ensure this condition is met.

6.2 General Test Procedure.
6.2.1 Fan Operational Parameters. The fan shall be run at the test speed for at least 15 minutes before measuring fan operating parameters. Input current, input power, frequency, voltage, and fan speed shall be measured for 100 seconds at a sampling interval of one sample per second. Measure input current, input power, frequency, and voltage at a point that includes all power-consuming components of the fan and fan controller (but without any attached light kit or heater energized). Measure power consumption at the rated voltage that represents normal (intended) operation. If the ceiling fan operates on multi-phase input power, measure the active (real) power in all phases simultaneously.

6.2.2 Space Psychrometric Parameters. Measure the air dry-bulb temperature, relative humidity, and ambient barometric pressure at the start of each test session. These measured values shall be used to calculate air density and for input into air speed collection software (if required). Air dry-bulb temperature and relative humidity shall be measured continuously, at a sampling interval of 2 samples per minute, to verify compliance with Section 6.1.2. Air dry-bulb temperature, relative humidity, and ambient barometric pressure sensors shall be located within the test room; and sensors mounted on interior walls shall be installed in a manner that minimizes thermal bridging from the exterior environment.

7. AIR SPEED MEASUREMENTS AND MEASUREMENT LOCATIONS

7.1 Test Chamber and Fan Mounting Height Requirements

7.1.1 Test Chamber Dimensions. Fans shall be tested within a test chamber comprised of a solid floor, ceiling, and four walls with the dimensions prescribed in Table 3. The test chamber shall be fully bounded and prevent air movement between the interior and exterior of the test chamber. The test chamber openings (doors, dampers, windows, etc.), shall be closed during data collection.

7.1.2 Fan location. The fan shall be tested in the chamber specified in Table 3. The fan shall be centered on the horizontal axes within the test chamber (±0.25 ft, ±0.076 m). The fan shall be assembled in accordance with the manufacturer’s published installation manual. The required fan blade height shall be determined using Table 3 and shall be measured when the fan is stationary.

<table>
<thead>
<tr>
<th>Fan size, ft (m)</th>
<th>Test chamber size Width x Length x Height, ft (m)</th>
<th>Blade height*, ft (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D ≤ 7 (2.1)</td>
<td>20x20x11 ±0.75 (6.1x6.1x3.4 ±0.23)</td>
<td>8 ±0.083 (2.4 ±0.025)</td>
</tr>
<tr>
<td>7 (2.1) &lt; D ≤ 16 (4.9)</td>
<td>50x50x22 ±1.5 (15.2x15.2x6.7 ±0.46)</td>
<td>15 ±0.167 (4.6 ±0.051)</td>
</tr>
<tr>
<td>D &gt; 16 (4.9)</td>
<td>80x80x32 ±2.0 (24.4x24.4x9.8 ±0.61)</td>
<td>21 ±0.25 (6.4 ±0.076)</td>
</tr>
</tbody>
</table>

*Additional testing performed at mounting heights not specified in Table 3 shall be clearly labeled as non-compliant with the mounting height requirements of this standard.

7.1.3 Space Conditioning. Turn off all forced-air and radiant environmental conditioning equipment in the chamber (e.g., air conditioning, radiant heaters), close all doors, and wait 3 minutes prior to starting a test.
session. Environmental conditioning equipment shall remain off during active testing but may be used between test sessions to maintain environmental conditions required in Section 6.1.2.

7.2 Air Speed Testing

7.2.1 Air Speed Instrumentation. Air speeds shall be measured using omnidirectional anemometers.

7.2.2 Test Position Locations. Test positions shall fall along one radial line, running from the center of the fan to the corner of the test space, as shown in Figure 1.

![Figure 1 - Diagram of Representative Test Positions](image)

Test positions shall be measured from the center of the fan as determined by the fan size. The distribution of test positions shall be determined by set increments that are dependent on the size of the room, as described in Table 4. Increments shall be consistent from fan center to the radius of the fan size (r), from r to a distance twice the radius of the fan (2r) and from 2r to the corner of the room. If a test position does not align with r or 2r, the smaller increments shall be used until the distance from the fan center exceeds r or 2r, respectively. The farthest test position from the center of the fan shall be no closer than 2 ft (0.61 m) from the corner of the room. After all test positions are determined, a test position at 2.5 times the fan radius (2.5r) shall be added, if not included in the positions determined using Table 4. No adjustment to the other test positions should be made due to the addition of the 2.5r test position.
Table 4 - Distribution of Test Positions

<table>
<thead>
<tr>
<th>Test Chamber Dimensions</th>
<th>Test Position Spacing Increments</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft (m)</td>
<td>0 to r, in (cm)</td>
</tr>
<tr>
<td>20x20x11 (6.1x6.1x3.4)</td>
<td>3 ±0.25 (7.62 ±0.6)</td>
</tr>
<tr>
<td>50x50x22 (15.2x15.2x6.7)</td>
<td>6 ±0.25 (15.2 ±0.6)</td>
</tr>
<tr>
<td>80x80x32 (24.4x24.4x9.8)</td>
<td>12 ±0.5 (30.5 ±1.3)</td>
</tr>
</tbody>
</table>

7.2.3 Test Point Heights. At each test position, air speed measurements shall be taken concurrently at four heights; 4, 24, 43, and 67 in. (0.1, 0.6, 1.1, and 1.7 m) above the floor as described in ASHRAE Standard 55. Measurement height shall be ±0.25 in. (±0.006 m) of the specified test point heights.

7.2.4 Test Position Number. Each test position shall be assigned a number for reference. The first test position will remain constant, positioned directly underneath the fan, and labeled position 0 (TP0). All test positions extending out from test position 0 shall be numbered in increments of 1. The test position farthest from the test position zero shall be labeled test position max (TPmax).

7.3 Measurement Frequency and Duration

7.3.1 Test Sampling Duration. At each test point, the air speed shall be recorded for a minimum period of 180 seconds or longer based on steady state requirements in Section 6.1.1. The results are to be used to determine average air speed.

7.3.2 Average Air Speed Sampling Frequency. To determine the average air speed, the sampling interval shall be a minimum of one sample every two seconds.

8. CALCULATIONS

8.1 Air Density. The air density (ρₐ) shall be determined from measurements, taken in the test chamber at the start of each test session, of ambient dry-bulb temperature (tdb), ambient wet-bulb temperature (twb), and ambient barometric pressure (Ba) using the following equations:

\[ p_w = 3.25t_{wb}^2 + 18.6t_{wb} + 692 \]  

\[ p_w = 0.000296t_{wb}^2 - 0.0159t_{wb} + 0.41 \]  

\[ p_s = p_w - B_a \left( \frac{t_{db} - t_{wb}}{1500} \right) \]  

\[ p_s = p_w - B_a \left( \frac{t_{db} - t_{wb}}{2700} \right) \]  

(Eq 8.1 IP)  

(Eq 8.1 SI)  

(Eq 8.2 IP)  

(Eq 8.2 SI)
where
\( B_a \) = Ambient barometric pressure
\( p_s \) = Saturated vapor pressure, in. Hg (Pa)
\( p_w \) = Partial vapor pressure, in. Hg (Pa)
\( R \) = Gas constant for air 53.35 ft•lb/lbm•°R (287.1J/kg•K)
\( t_{db} \) = Ambient dry-bulb temperature, °F (°C)
\( t_{wb} \) = Ambient wet-bulb temperature, °F (°C)
\( \rho_a \) = Air density, lb/ft³ (kg/m³)

It is permissible to calculate ambient wet-bulb temperature from relative humidity measurements using psychrometric equations.

8.2 Fan Operational Parameters. The mean of the measured values for input current, input power, voltage, and fan speed, collected per Section 6.2.1, shall be calculated using Equation 8.4.

\[
\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i
\]  

(Eq 8.4)

where
\( n \) = Number of measured values
\( \bar{x} \) = Sample mean
\( x_i \) = ith measured value

8.3 Weighting Factors. Calculate the weighting factor (WF) corresponding to each sensor test position defined in Section 7.2. As both TP₀ and TP_max have only one adjacent test position, these weighting factors are calculated using unique equations. Weighting factors are a ratio of the area represented by a test position to the total area.

For TP₀, the weighting factor is:

\[
WF_0 = \left( \frac{\bar{x}}{d_{max}} \right)^2
\]  

(Eq 8.5)

where
\( d_{max} \) = Distance from test position closest to corner to TP₀, ft (m)
\( d_i \) = Distance from TP₀ to test position 1: 0.25 ft (0.0762 m) for the small test chamber, 0.5 ft (0.152 m) for the medium test chamber, and 1.0 ft (0.305 m) for the large test chamber
WF₀ = Weighting factor for TP₀

For the furthest test position from the center of the room (TPₘₐₓ), the weighting factor is:

\[
WF_{max} = \frac{(d_{max})^2 - \left(\frac{d_{max} + d_{max-1}}{2}\right)^2}{(d_{max})^2}
\]

(Eq 8.6)

where
\[
d_{max-1} = \text{Distance from test position second closest to corner to test position 0, ft (m)}
\]
\[
WF_{max} = \text{Weighting factor for test position max}
\]

For all other test positions, the weighting factor is:

\[
WF_{n} = \frac{\left(\frac{d_{n}+d_{n+1}}{2}\right)^2 - \left(\frac{d_{n}+d_{n-1}}{2}\right)^2}{(d_{max})^2}
\]

(Eq 8.7)

where
\[
n = \text{Test position number}
\]
\[
d_{n} = \text{Distance from test position n to TP₀, ft (m)}
\]
\[
d_{n-1} = \text{Distance from test position n minus 1 to TP₀, ft (m)}
\]
\[
d_{n+1} = \text{Distance from test position n plus 1 to TP₀, ft (m)}
\]
\[
WF_{n} = \text{Weighting factor for test position n}
\]

**Table 8.1 - Sample Test Position and Weighting Factors for 2 Foot Diameter Ceiling Fan**

<table>
<thead>
<tr>
<th>Test Position Number</th>
<th>Spacing - ft (m)</th>
<th>Distance from TP₀ - ft (m)</th>
<th>Weighting Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0.000109</td>
</tr>
<tr>
<td>1</td>
<td>0.25 (0.0762)</td>
<td>0.25 (0.0762)</td>
<td>0.000868</td>
</tr>
<tr>
<td>2</td>
<td>0.25 (0.0762)</td>
<td>0.50 (0.152)</td>
<td>0.001736</td>
</tr>
<tr>
<td>3</td>
<td>0.25 (0.0762)</td>
<td>0.75 (0.229)</td>
<td>0.002604</td>
</tr>
<tr>
<td>4</td>
<td>0.25 (0.0762)</td>
<td>1.0 (0.305)</td>
<td>0.005534</td>
</tr>
<tr>
<td>5</td>
<td>0.50 (0.152)</td>
<td>1.5 (0.457)</td>
<td>0.010417</td>
</tr>
<tr>
<td>6</td>
<td>0.50 (0.152)</td>
<td>2.0 (0.610)</td>
<td>0.013889</td>
</tr>
<tr>
<td>7</td>
<td>2.5r</td>
<td>2.5 (0.762)</td>
<td>0.017361</td>
</tr>
</tbody>
</table>
8.4 Average Air Speed. The average (mean) air speed shall be calculated for each test point and test position specified in Section 7.2. The levels of the test points are 4, 24, and 43 in. (0.1, 0.6, and 1.1 m) for determining the seated average air speed for a test position \( \left( V_{a,m,seated} \right) \); and 4, 43, and 67 in. (0.1, 1.1, and 1.7 m) for determining the standing average air speed for a test position \( \left( V_{a,m,standing} \right) \).

8.5 Maximum Average Air Speed. The maximum value for the seated average air speed \( \left( V_{a,m,seated,max} \right) \) and the standing average air speed \( \left( V_{a,m,standing,max} \right) \) shall be determined from average air speeds determined per Section 8.4.

8.6 Minimum Average Air Speed. The minimum value for the seated average air speed \( \left( V_{a,m,seated,min} \right) \) and the standing average air speed \( \left( V_{a,m,standing,min} \right) \) shall be determined from average air speeds determined per Section 8.4.

8.7 Uniformity. The uniformity shall be calculated from the seated average air speed and the standing average air speed determined per Section 8.4. The test positions with the largest and smallest average air speeds shall be eliminated, and the second highest and second lowest average air speeds shall be used to calculate uniformity. A uniformity value of 1.0 indicates that the average air speed is identical at all test positions. A uniformity value approaching zero indicates a large difference between the Maximum and Minimum Average Air Speed.

\[
U_{seated} = 1 - \left( \frac{V_{a,m,seated,max-1} - V_{a,m,seated,min+1}}{V_{a,m,seated,max-1}} \right) \quad (\text{Eq 8.8})
\]

\[
U_{standing} = 1 - \left( \frac{V_{a,m,standing,max-1} - V_{a,m,standing,min+1}}{V_{a,m,standing,max-1}} \right) \quad (\text{Eq 8.9})
\]

where
\( U_{seated} = \text{Uniformity for seated occupants} \)
\( U_{standing} = \text{Uniformity for standing occupants} \)
\( V_{a,m,seated,max-1} = \text{Second largest seated average air speed, fpm (m/s)} \)
\( V_{a,m,standing,max-1} = \text{Second largest standing average air speed, fpm (m/s)} \)
\( V_{a,m,seated,min+1} = \text{Second smallest seated average air speed, fpm (m/s)} \)
\( V_{a,m,standing,min+1} = \text{Second smallest standing average air speed, fpm (m/s)} \)

8.8 Room Average Air Speed. The mean of the air speeds measured at each test position specified in Section 8.3. Room Average Air Speed shall be calculated for both seated and standing occupants.
where

\[ V_{a,m,seated,n} = \text{Seated average air speed at test position } n, \text{ fpm (m/s)} \]

\[ V_{a,m,standing,n} = \text{Standing average air speed at test position } n, \text{ fpm (m/s)} \]

\[ V_{a,m,seated,room} = \text{Seated room average air speed, fpm (m/s)CFE} \]

\[ V_{a,m,standing,room} = \text{Standing room average air speed, fpm (m/s)} \]

8.9 Room Average Cooling Effect. The Average Air Speed at each test position shall be used with the following assumed space conditions to determine a room average cooling effect. The cooling effect at each test position is determined based on the change in Standard Effective Temperature (SET) as described in ASHRAE Standard 55. Equations 8.12 and 8.13 shall be used to determine the Average Cooling Effect for seated and standing occupants, respectively.

<table>
<thead>
<tr>
<th>Comfort Conditions</th>
<th>Baseline</th>
<th>Elevated Air Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Dry-Bulb Temperature</td>
<td>80°F (26.7°C)</td>
<td>80°F (26.7°C)</td>
</tr>
<tr>
<td>Mean Radiant Temperature</td>
<td>80°F (26.7°C)</td>
<td>80°F (26.7°C)</td>
</tr>
<tr>
<td>Humidity Ratio</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>Metabolic Rate</td>
<td>1.1 met</td>
<td>1.1 met</td>
</tr>
<tr>
<td>Clothing Insulation</td>
<td>0.5 clo</td>
<td>0.5 clo</td>
</tr>
<tr>
<td>Air Speed</td>
<td>20 fpm (0.1m/s)</td>
<td>Room Average Air Speed</td>
</tr>
</tbody>
</table>

\[ CE_{a,m,seated,room} = \sum_{n=0}^{\text{max}} WF_n \times 2.754 \times \ln (V_{a,m,seated,n}) - 8.351 \]  
\[ \text{(Eq 8.12 IP)} \]

\[ CE_{a,m,seated,room} = \sum_{n=0}^{\text{max}} WF_n \times 1.530 \times \ln (V_{a,m,seated,n}) + 3.444 \]  
\[ \text{(Eq 8.12 SI)} \]

\[ CE_{a,m,standing,room} = \sum_{n=0}^{\text{max}} WF_n \times 2.754 \times \ln (V_{a,m,standing,n}) - 8.351 \]  
\[ \text{(Eq 8.13 IP)} \]
BSR/ASHRAE Standard 216P, Methods of Test for Determining Application Data of Overhead Circulator Fans
Second Public Review Draft

\[ CE_{a,m,standing,room} = \sum_{n=0}^{\max} WF_{n} \times 1.530 \times \ln (V_{a,m,standing,n}) + 3.444 \]  
(Eq 8.13 SI)

where

\( CE_{a,m,seated,room} \) = Seated Room Average Cooling Effect, °F (°C)

\( CE_{a,m,standing,room} \) = Standing Room Average Cooling Effect, °F (°C)

8.10 2.5r Cooling Effect. The 2.5r cooling effect shall be determined using the same methodology and assumptions used to calculate room average cooling effect in Section 8.8, except the air speed at a distance from the center of the fan equal to 2.5 times the fan radius (1.25 times the diameter) shall be utilized.

\[ CE_{a,m,seated,2.5r} = 2.754 \times \ln (V_{a,m,seated,2.5r}) - 8.351 \]  
(Eq 8.14 IP)

\[ CE_{a,m,standing,2.5r} = 1.530 \times \ln (V_{a,m,standing,2.5r}) + 3.444 \]  
(Eq 8.14 SI)

\[ CE_{a,m,standing,2.5r} = 2.754 \times \ln (V_{a,m,standing,2.5r}) - 8.351 \]  
(Eq 8.15 IP)

\[ CE_{a,m,standing,2.5r} = 1.530 \times \ln (V_{a,m,standing,2.5r}) + 3.444 \]  
(Eq 8.15 SI)

where

\( CE_{a,m,seated,2.5r} \) = Seated Cooling Effect at test position 2.5r, °F (°C)

\( CE_{a,m,standing,2.5r} \) = Standing Cooling Effect at test position 2.5r, °F (°C)

\( V_{a,m,seated,2.5r} \) = Seated average air speed at test position 2.5r, fpm (m/s)

\( V_{a,m,standing,2.5r} \) = Standing average air speed at test position 2.5r, fpm (m/s)

8.11 Cooling Coverage Fraction. The fraction of the area where the Average Air Speed is greater than or equal to 85 feet per minute (0.43 m/s). 85 feet per minute (0.43 m/s) results in a cooling effect of approximately 4°F (2.2°C) at the comfort conditions defined in Section 8.9.

\[ CC_{seated} = \sum_{n=0}^{\max} WF_{n} \times Y_{n,seated} \]  
(Eq 8.16)

\[ CC_{standing} = \sum_{n=0}^{\max} WF_{TPn} \times Y_{n,standing} \]  
(Eq 8.17)

where

\( CC_{seated} \) = Seated Cooling Coverage Fraction

\( CC_{standing} \) = Standing Cooling Coverage Fraction

\( Y_{n,seated} = 0 \) if the seated average air speed is less than 85 fpm (0.43 m/s) at test position n, 1 if the seated average air speed is greater than or equal to 85 fpm (0.43 m/s) at test position n

\( Y_{n,standing} = 0 \) if the standing average air speed is less than 85 fpm (0.43 m/s) at test position n, 1 if the standing average air speed is greater than or equal to 85 fpm (0.43 m/s) at test position n

8.12 Heating Draft Risk Fraction. The fraction of the area where the Average Air Speed is greater than 40 feet per minute (0.2 m/s). This metric is only applicable for fans operating in spaces where conditions would meet the criteria for unwanted local cooling of the body (draft). Section 5 of ASHRAE Standard 55
defines draft as air speeds above 40 feet per minute (0.2 m/s) when the operative temperature is below 73.4°F (23.0°C).

\[
DR_{\text{seated}} = \sum_{n=0}^{\text{max}} WF_n \times Z_{n,\text{seated}}
\]  
(Eq 8.18)

\[
DR_{\text{standing}} = \sum_{n=0}^{\text{max}} WF_n \times Z_{n,\text{standing}}
\]  
(Eq 8.19)

where

\(DR_{\text{seated}}\) = Seated Draft Risk Fraction

\(DR_{\text{standing}}\) = Standing Draft Risk Fraction

\(Z_{n,\text{seated}} = 0\) if the seated average air speed is less than or equal to 40 fpm (0.2 m/s) at test position n, 1 if the seated average air speed is greater than 40 fpm (0.2 m/s) at test position n

\(Z_{n,\text{standing}} = 0\) if the standing average air speed is less than or equal to 40 fpm (0.2 m/s) at test position n, 1 if the standing average air speed is greater than 40 fpm (0.2 m/s) at test position n

8.13 Cooling Fan Efficiency (CFE). Ratio of the cooling effect to the input power of the fan. CFE shall only be calculated for test conditions where the Cooling Coverage Fraction is greater than or equal to 90%. For any test condition where the Cooling Coverage Fraction is less than 90%, then the test report shall not include a value for CFE.

\[
CFE_{\text{seated}} = \frac{CE_{a,m,\text{seated},2.5r}}{P}
\]  
(Eq 8.20)

\[
CFE_{\text{standing}} = \frac{CE_{a,m,\text{standing},2.5r}}{P}
\]  
(Eq 8.21)

where

\(P\) = System Input power, W

**Informative Note:** CFE is only directly comparable for fans that have the same diameter and that are tested in the same size test chamber.

**9. REPORT AND RESULTS OF TEST**

9.1 Report. The report of a laboratory overhead circulator ceiling fan test shall at a minimum include the following data:

**General Test Information:**
Laboratory name
Laboratory address
Date of testing
Test number
Personnel performing testing
Title of test personnel
Test chamber dimensions (L x W x H)
Photograph of test setup (Showing fan under test)
Fan size
Fan manufacturer
Fan model number
Fan serial number
Fan drive type
Motor model number
Motor nameplate data
VSD model (if applicable)
VSD model number (if applicable)
Nominal system input voltage, phase, frequency

Test Data:
Air speeds for each test point
Ambient dry-bulb temperature
Ambient wet-bulb temperature
Ambient barometric pressure
Extraneous airflow - before test
Extraneous airflow - after test
Fan speed
System input current
System input frequency
System input power
System input voltage
Direction of operation (forward or reverse flow)

Calibration information (per instrument):
Manufacturer
Model number
Serial number
Scale range
ISO 17025 calibration laboratory
Date of last calibration
Date of next required or scheduled calibration

Calculated values:
Air density
Average system input power
Average air speed at each test point
Average air speed at each test position (seated)
Average air speed at each test position (standing)
Cooling Fan Efficiency (seated)
Cooling Fan Efficiency (standing)
Room average air speed (seated)
Room average air speed (standing)
Maximum air speed at a test position (seated)
Maximum air speed at a test position (standing)
Minimum air speed at a test position (seated)
Minimum air speed at a test position (standing)
Uniformity (seated)
Uniformity (standing)
Room average cooling effect (seated)
Room average cooling effect (standing)
2.5r cooling effect (seated)
2.5r cooling effect (standing)
Cooling coverage fraction (seated)
Cooling coverage fraction (standing)
Heating draft risk fraction (seated)
Heating draft risk fraction (standing)
10. NORMATIVE REFERENCES

Section numbers indicate where the reference occurs in this document.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Organization for Standardization (ISO)</td>
<td>ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories</td>
<td>5.6</td>
</tr>
</tbody>
</table>
INFORMATIVE APPENDIX A: USE OF FAN TEST DATA FOR CALCULATION OF EQUIVALENT STANDARD EFFECTIVE TEMPERATURE

![Figure A-1 Thermal comfort test room configuration.](image)

This appendix provides an example of how to use the ASHRAE Standard 55 Analytical Comfort Zone Method to establish thermal comfort factors that approximate Predicted Mean Vote (PMV), Predicted Percentage of Dissatisfied (PPD), and Standard Equivalent Temperature (SET) using elevated air speeds that are equivalent to a still air baseline condition.

Baseline Conditions:

- Floor Area: 20 x 20 ft (6.1 x 6.1 m)
- Ceiling height = 11 ft (3.4 m)
- Occupants: 4 seated workers, one per workstation each 7 ft (2.1 m) from the center of the fan
- Baseline thermal comfort factor airs with still air:

<table>
<thead>
<tr>
<th>Thermal Comfort Factor</th>
<th>Baseline Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor cooling set-point, air dry-bulb</td>
<td>75°F (23.9°C)</td>
</tr>
<tr>
<td>Mean radiant temperature</td>
<td>75°F (23.9°C)</td>
</tr>
</tbody>
</table>
Design cooling humidity ratio | 0.0093 lb_w/lb_d (0.0093 kg_w/kg_d)
Metabolic rate | 1.1 met
Clothing level | 0.57 clo
Air speed | 20 fpm (0.10 m/s)

The ASHRAE Thermal Comfort Tool can be used to calculate the PMV, PPD, and SET of the baseline cooling design.

![Thermal comfort calculation results](image)

**Figure A-2 Thermal comfort calculation results for a typical cooling condition without the use of elevated air speed CBE Thermal Comfort Tool)**

Section 5.3.3 (Elevated Air Speed) of Standard 55-2017 requires the use of equal skin heat loss computed by the SET model when utilizing elevated air speed. A baseline SET of 75.1°F (24°C) has been determined for still air.

A design that uses elevated air speed as the first stage of comfort cooling has been proposed. In this design, a circulator fan will be used to maintain occupant thermal comfort until the adjusted (increased) indoor air temperature setpoint has been reached. Once the air temperature exceeds
that adjusted set-point value, the air conditioning system will operate in conjunction with circulator fan to maintain occupant thermal comfort. In the elevated air speed design, four occupants are seated approximately 7 ft (2.1 m) from the center of a six-speed, 60-inch (1.52-m) ceiling fan. There is a local air speed control provided to the occupants.

Performance data for the 60-inch ceiling fan at maximum speed in a 20x20x11 ft (LxWxH; 6.1x6.1x3.4 m) space is shown in the chart below. Average air speed at each test position is plotted against the distance from the center of the fan (Figure A-3).

![Figure A-3](image)

**Figure A-3** The average of the air speed as measured at 4, 24, and 43 in. (0.1, 0.6, and 1.1 m) above the finished floor relative is plotted relative to the horizontal distance from the center of the fan

The average air speed surrounding a representative occupant is the average of three heights above the floor, as specified in the definition of average air temperature in ASHRAE Standard 55. For a seated occupant, the ankle level, the waist level, and the head level are 4, 24, and 43 in. (0.1, 0.6, and 1.1 m) above the floor. The average air speed in the space is the average of all measured air speeds. When using the data in Figure A-3, the average air speed is 120 fpm (0.61 m/s).

Standard 55-2017, Section 5.3.3 requires compliance with either Section 5.3.3.3 (Limits to Average Air Speed with Occupant Control) or Section 5.3.3.4 (Limits to Average Air Speed without Occupant Control).

Section 5.3.3.3 includes the following requirements:

- Control directly accessible to 6 or fewer occupants or 900 ft² (84 m²) less;
- At least one control for each space in multioccupant spaces

Section 5.3.3.4 includes the following requirements:

- No local control of air speed;
- Air speed less than or equal to 160 fpm (0.8 m/s) for operative temperatures above 77.9°F (25.5°C).

Section 5.3.3.3 is applicable because one local air speed control is provided to the four occupants.

For each seated occupant (seated 7 ft [2.1 m] from the center of the fan), the average air speed is 110 fpm (0.56 m/s) as shown in Figure A-4. To determine the conditions at which 110 fpm (0.56 m/s) of elevated air speed would provide acceptable thermal comfort, equal skin heat loss to the baseline conditions must be determined. This condition is expressed as the SET in °F (°C).

![Figure A-4 Determination of the average air speed at a horizontal distance of 7 ft (2.1 m) from the center of the fan](image)

The baseline inputs to the CBE Thermal Comfort Tool are used, but the still air (20 fpm [0.1 m/s]) is replaced with the elevated air speed of 110 feet per minute (0.56 m/s). The cooling effect of elevated air speed allows the air dry bulb setpoint to be increased, reducing the mechanical cooling required.
Figure A-5 Thermal comfort calculations show that increasing the air speed alone without changing any other thermal comfort criteria results in a PMV lower than allowed by Standard 55 (CBE Thermal Comfort Tool).

Increasing the air speed alone results in a lower SET. To achieve the baseline SET value (75.1°F [24°C]), the air temperature and the mean radiant temperature are increased in small, equal increments until the baseline SET is met.
Figure A-6 When using elevated air speed the dry-bulb air temperature and the mean radiant temperature are increased to achieve an equivalent SET as that established with low air speed. (CBE Thermal Comfort Tool.)

As illustrated in Figure A-6, the dry bulb air temperature and mean radiant temperature must be increased to 79.9°F (26.6°C) to achieve an SET equivalent to the baseline SET. The resulting cooling effect of increasing average air speed by 110 fpm (0.56 m/s) is therefore 4.8°F (79.9°F-75.1°F) or 2.7°C (26.6°C-23.9°C).

A side-by-side presentation of the baseline thermal comfort conditions relative to the adjusted conditions is as follows:

<table>
<thead>
<tr>
<th>Thermal Comfort Factor</th>
<th>Baseline Value</th>
<th>Adjusted Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor cooling set-point, air dry-bulb</td>
<td>75.0°F (23.9°C)</td>
<td>79.9°F (26.6°C)</td>
</tr>
<tr>
<td>Mean radiant temperature</td>
<td>75.0°F (23.9°C)</td>
<td>79.9°F (26.6°C)</td>
</tr>
<tr>
<td>Design cooling humidity ratio</td>
<td>0.0093 lbw/lba (kgw/kga)</td>
<td>0.0093 lbw/lba (kgw/kga)</td>
</tr>
<tr>
<td>Metabolic rate</td>
<td>1.1 met</td>
<td>1.1 met</td>
</tr>
<tr>
<td>----------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Clothing level</td>
<td>0.57 clo</td>
<td>0.57 clo</td>
</tr>
<tr>
<td>Air speed</td>
<td>20 fpm (0.10 m/s)</td>
<td>110 fpm (0.56 m/s)</td>
</tr>
</tbody>
</table>

**Calculation Results**

<table>
<thead>
<tr>
<th>PPD</th>
<th>7%</th>
<th>8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMV</td>
<td>-0.34</td>
<td>-0.35</td>
</tr>
<tr>
<td>SET</td>
<td>75.1°F (25.0°C)</td>
<td>75.1°F (25.0°C)</td>
</tr>
</tbody>
</table>
INFORMATIVE APPENDIX B: INFORMATIVE REFERENCES

This appendix contains informative references for the convenience of users of this standard and to acknowledge source documents when appropriate.


INFORMATIVE APPENDIX C: EXAMPLE TEST FORMS

Consumer Cut Sheet

![Table and diagrams showing air speed vs. distance from fan center]
Test Summary

---

<table>
<thead>
<tr>
<th>Test Information</th>
<th>Ceiling Fan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test #</td>
<td>3</td>
</tr>
<tr>
<td>Test Date: 10/18/2016</td>
<td></td>
</tr>
<tr>
<td>Test Personnel: Joe Tester</td>
<td></td>
</tr>
</tbody>
</table>

### Fan Information

- Fan Manufacturer: Ceiling Fan Co.
- Fan Model: Ceiling Fan
- Fan Serial #: 12345
- Fan Type: Ceiling Fan
- Fan Drive Type: -
- Fan Diameter: 28.8 in
- Fan Speed (RPM): 1000 RPM
- Fan Test Direction: Forward

### Laboratory Information

- Laboratory Name: John Doe Labs
- Laboratory Address: 123 Big Way, NY 45678

### Motor Information

- Motor Manufacturer: -
- Motor Type: -
- Motor Model #: 78900
- Motor Serial #: 123456
- Motor Nameplate can be found in images

### Test Room Dimensions

- Ceiling Height: 52.0 ft
- Wall Length: 80.0 ft
- Wall Width: 80.0 ft

### Gear Reducer Information

- Gear Manufacturer: -

### Electrical Information

- Nom. Input Voltage: 240
- Input Phase: 30
- Frequency: 60

---

**Average Air Speed vs. Distance From Fan Center**

---

<table>
<thead>
<tr>
<th>signature</th>
<th>signature</th>
<th>signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tester</td>
<td>Reviewer</td>
<td>Reviewing Manager</td>
</tr>
<tr>
<td>Joe Tester</td>
<td>Ted Reviewer</td>
<td>Mike Manager</td>
</tr>
</tbody>
</table>
Test Info

| Test Number | 2 |
| Test Date   | 10/10/2016 |
| Test Person | Joe Tester |

Test Space

- Ceiling Height (ft): 32.0
- Wall Length (ft): 80.0

Electrical Information

- Nominal Input Voltage: 240 V
- Input Phase: 3φ
- Frequency: 60.0 Hz

Fan Information

- Fan Model: Ceiling Fan
- Fan Diameter (in): 20.0
- Fan Diameter (ft): 240.0
- Fan Serial #: 128458
- Fan Type: Ceiling Fan
- Fan Drive Type: -
- Fan Speed (RPM): 100.0
- Fan Test Direction: Forward

Motor Information

- Motor Manufacturer: -
- Motor Type: -
- Motor Model #: 76500
- Motor Serial #: 112233

VSD Information

- VSD Manufacturer: -
- VSD Model: -
- VSD Model #: VSD12345

Gear Reducer Information

- Gearbox Model: -

Environmental Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Bulb Temp. (°F)</td>
<td>83.3</td>
</tr>
<tr>
<td>Wet Bulb Temp. (°F)</td>
<td>74.7</td>
</tr>
<tr>
<td>Saturated Vapor Pressure (in Hg)</td>
<td>0.9</td>
</tr>
<tr>
<td>Partial Vapor Pressure (in Hg)</td>
<td>0.8</td>
</tr>
<tr>
<td>Air Density (slpm/ft³)</td>
<td>0.070</td>
</tr>
<tr>
<td>Barometric Pressure (in Hg)</td>
<td>29.1</td>
</tr>
<tr>
<td>Ext. Airflow - before test (ft/min)</td>
<td>32.0</td>
</tr>
<tr>
<td>Ext. Airflow - after test (ft/min)</td>
<td>33.0</td>
</tr>
</tbody>
</table>

Test Setup Images:

- Fan Tested

Test Data

[Data table with various test results and measurements]
Test Metrics

Equipment List

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Manufacturer</th>
<th>Model No.</th>
<th>Equipment No.</th>
<th>Last Calibration</th>
<th>Calibration Labs</th>
<th>Equipment Scale Range</th>
<th>Equipment Serial #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multidirectional Anemometer</td>
<td>sensor-electronic</td>
<td></td>
<td>1-Jan-16</td>
<td></td>
<td>31-Dec-17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type Measure</td>
<td></td>
<td></td>
<td>1-Jan-15</td>
<td></td>
<td>6-Jun-16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>