BSR/ASHRAE Standard 133-2015R

Public Review Draft

Method of Testing Direct Evaporative Air Coolers

First Public Review (July 2022)
(Complete Draft for Full Review)

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ASHRAE, 180 Technology Parkway NW, Peachtree Corners GA 30092
1. PURPOSE: This standard establishes a uniform method of laboratory testing for rating packaged and component direct evaporative air coolers.

2. SCOPE

2.1 The scope of this standard covers a method of testing for rating saturation effectiveness, airflow rate, and total power of packaged and component direct evaporative air coolers.

2.2 Covered tests include the methods for measuring the static pressure differential of the direct evaporative air cooler, density of the air, and speed of rotation of the fan.

2.3 This standard requires that packaged and component direct evaporative air coolers be simultaneously tested for airflow, total power, and saturation effectiveness.

2.4 The ratings resulting from application of this standard are intended for use by manufacturers, specifiers, installers, and users of evaporative air-cooling apparatus for residential, commercial, agricultural, and industrial ventilation; air cooling applications; and for commercial, industrial, and agricultural processing applications.

3. DEFINITIONS AND ACRONYMS

**appurtenance device power:** the electric power to drive accessories — not including fans, pumps, or rotary devices — that are supplied as a standard component of the production model of the direct evaporative air cooler (DEC). Appurtenance device power includes water metering devices, conductivity controllers, timers, dump cycle pumps, solenoids, and transformers providing low voltage to control mechanisms and freeze protection devices.

**boundaries:** direct evaporative air cooler (DEC) inlet and outlet boundaries are defined as the interface between the cooling unit and the remainder of the system, and these boundaries are at a plane perpendicular to the airstream where it enters or leaves the DEC. Various appurtenances, such as filter media assemblies, inlet boxes, inlet vanes, inlet cones, silencers, screens, rain hoods, dampers, discharge cones, and eaves, that are supplied as standard components to the unit shall be included as a part of the cooling unit between the inlet and outlet boundaries.

**component direct evaporative cooler:** an unpackaged direct evaporative cooler that does not include a fan, and may have a pump or rotary wetting device, and may also have its media wetted down by a laboratory source. An example of a component DEC is shown in Informative Appendix B, Figure B-2.

**determination:** a complete set of measurements for a particular point of operation of a DEC. The measurements shall be used to determine all DEC performance variables as defined in this standard.

**direct evaporative air cooling:** water evaporates directly into the airstream, thereby reducing the dry-bulb temperature of the air and increases the humidity level.

**DEC airflow rate:** the mass airflow rate or volumetric airflow rate at the test conditions.

**DEC outlet area:** the total inside area measured in the plane(s) of the outlet opening(s).

**DEC static pressure differential:** the static pressure differential measured across the DEC and its appurtenances.

**DEC water flow rate:** the flow rate of water distributed within the DEC from the reservoir to the media by a pump. This is not to be confused with water provided to make up for water evaporated by the DEC.

**design temperature:** the design dry-bulb temperature for the space being cooled by the DEC shall be 32.2°C (90°F).

**fan power:** the power required to drive the fan and any drive train elements that are part of the fan.

**fan speed:** the rotational speed of the impeller. If a fan has more than one impeller, fan speeds are the rotational speeds of each
impeller.

**free delivery:** the point of operation where the external static gauge pressure is zero.

**geometrically equivalent diameter:** the diameter of a circle having the same area as a rectangle.

**media:** a collection of sheets, fibers, or similar that, when wetted, provide wet surface area for enhanced water evaporation. In this standard, it is considered an isothermal heat exchanger with a surface temperature that is the wet bulb temperature of the air passing through it.

**media saturation effectiveness:** the dry-bulb temperature reduction achieved by the wetted media divided by the entering wet-bulb depression.

**packaged direct evaporative cooler:** a self-contained unit, including a fan, media, reservoir, a pump, or rotary device and may contain various appurtenances. An example of a DEC is shown in Informative Appendix B, Figure B-1.

**point of operation:** the relative position on the cooling unit characteristic curve corresponding to a particular airflow rate. It is controlled during a test by adjusting the position of the throttling device, by changing flow nozzles or auxiliary fan characteristics, or by doing any combination of these.

**pump or rotary device power:** the electric power to drive the pump or rotary device used to distribute water in the DEC.

**shutoff:** the point of operation where the airflow rate is zero.

**standard air:** dry air with a density of 1.202 kg/m³ (0.075 lbm/ft³).

**test:** a series of determinations for various points of operation that satisfy the stability criteria.

**type A DEC**, a packaged DEC that does not include a fan and a pump upstream of the media.

**type B DEC**, a packaged DEC that includes a fan and a pump upstream of the media.

**wet-bulb depression:** the temperature difference between the dry-bulb temperature and wet-bulb temperatures of an airstream.

### 4. SYMBOLS AND SUBSCRIPTS

#### 4.1 Symbols

- **ED** geometric equivalent diameter, m (ft)
- **Nn** nominal constant fan speed, rad/s (rpm)
- **N** DEC fan speed as measured, rad/s (rpm)
- **n** number of readings, dimensionless
- **Pn** standard air pressure at nominal constant fan speed, Pa (in. of water)
- **Psx** static pressure at plane x, Pa (in. of water)
- **Pstd** static pressure at standard air density, Pa (in. of water)
- **pb** ambient barometric pressure, Pa (in. Hg)
- **ΔP** pressure differential, Pa (in. of water)
- **ΔPDEC** pressure differential across DEC, Pa (in. of water)
- **ΔPnozzle** nozzle pressure differential, Pa (in. of water)
- **ΔPstd** pressure differential corrected to standard air density, Pa (in. of water)
- **ρx** air density at plane x, kg/m³ (lbm/ft³)
- **ρstd** standard air density, kg/m³ (lbm/ft³)
- **qstd** DEC Sensible cooling capacity, W (Btu/h)
- **Qn** volumetric airflow rate at nominal constant fan speed, m³/s (cfm)
- **QW** DEC water flow rate, L/s (gpm)
- **tdux** dry-bulb temperature at plane x, °C (°F)
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\( t_{wx} \)  
\text{wet-bulb temperature at plane } x, \ ^\circ \mathrm{C} (\ ^\circ \mathrm{F})

\( W_E \)  
\text{total of all the input power for devices completely within the air upstream of the media section except the fan, } W (W)

\( W_L \)  
\text{total of all the input power for devices completely within the air downstream of the media section except the fan, } W (W)

\( W_{FE} \)  
\text{input power for fan if completely within the air upstream of the media section, } W (W)

\( W_{FL} \)  
\text{input power for fan if completely within the air downstream of the media section, } W (W)

\( W_{ex} \)  
\text{total of all the input power for devices outside and thermally isolated from the airstream of the DEC, } W (W)

\( W_{total} \)  
\text{total DEC input power, } W (W)

4.2 Subscripts

\( E \)  
plane E (entering air face of media), means upstream of media

\( ex \)  
denotes an area that is completely external to the DEC airstream

\( L \)  
plane L (leaving air face of media), means downstream of media

\( test \)  
refers to quantities determined from test

\( x \)  
plane \( x \), where \( x = 0, 1, 2, E, \) and \( L \)

\( 0 \)  
plane 0 (DEC inlet)

\( 1 \)  
plane 1 (pressure tap station)

\( 2 \)  
plane 2 (temperature measurement station)

\( n \)  
nominal

\( std \)  
standard air density

5. REQUIREMENTS

5.1 Determinations. The number of determinations required to establish the performance of a direct evaporative air cooler (DEC) over the range from shutoff to free delivery shall be established depending on the shapes of the various characteristic curves. Plans shall be made to vary the opening of the throttling device to evenly space the test points. For smooth characteristics, at least eight determinations shall be required to define curves that are not smooth. When performance at only one point of operation is required, at least three determinations shall be made to define a short curve that includes that point.

5.2 Test Data Processing. Data point measurements collected during the duration of the testing period shall be processed to calculate sample mean and sample standard deviation.

Equation 5-1 is the number of successive samples:

\[ n \geq 30 \]  \hspace{1cm} (5-1)

Equation 5-2 is the sample mean:

\[ \bar{x} = \frac{1}{n} \sum_{j=1}^{n} (x_j) \]  \hspace{1cm} (5-2)

Equation5-3 3 is the sample standard deviation:

\[ \sigma_x = \sqrt{\frac{1}{n-1} \sum_{j=1}^{n} (x_j - \bar{x})^2} \]  \hspace{1cm} (5-3)

Equation 5-4 is the sample stability ratio:

\[ S_x = \frac{\sigma_x}{\bar{x}} \]  \hspace{1cm} (5-4)
Equation 5-5 is the sample stability criteria:

\[ S_x \leq 1.0\% \quad (5-5) \]

Recorded test data shall be valid only when all of the stability criteria in Table 1 or in Table 2 are simultaneously satisfied where the cooling capacity is stated in Equation 5-6 or Equation 5-7.

\[ q = 1.21 Q_{std} (t_{d0} - t_{d2}) \quad \text{SI} \quad (5-6) \]
\[ q = 1.08 Q_{std} (t_{d0} - t_{d2}) \quad \text{IP} \quad (5-7) \]

### TABLE 1: Stability Criteria for Data Recording for Packaged DECs

<table>
<thead>
<tr>
<th>Measurement or Calculation Result</th>
<th>Values Calculated from Data Samples</th>
<th>Stability Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling capacity</td>
<td>( \bar{q} ) ( \sigma_q )</td>
<td>( S_{d_{std}} \leq 0.05 )</td>
</tr>
<tr>
<td>Total Input Power</td>
<td>( W_{total} ) ( \sigma_{W_{total}} )</td>
<td>( S_{W_{total}} \leq 0.05 )</td>
</tr>
</tbody>
</table>

### TABLE 2: Stability Criteria for Data Recording for Component DECs

<table>
<thead>
<tr>
<th>Measurement or Calculation Result</th>
<th>Values Calculated from Data Samples</th>
<th>Stability Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Static Pressure Ratio</td>
<td>( \bar{\Delta P}<em>{std} ) ( \sigma</em>{\Delta P_{std}} )</td>
<td>( S_{\Delta P_{std}} \leq 0.05 )</td>
</tr>
<tr>
<td>Saturation Effectiveness:</td>
<td>( \varepsilon ) ( \sigma_{\varepsilon} )</td>
<td>( S_{\varepsilon} \leq 0.05 )</td>
</tr>
</tbody>
</table>

5.3 **Temperature and Humidity at Test Conditions.** Inlet plenum dry-bulb temperature \( t_{d0} \) shall be 46°C (115°F) maximum, the wet-bulb temperature \( t_{w0} \) shall be 5°C (41°F) minimum, and the wet-bulb depression shall be 11°C (20°F) minimum during the testing period. After correcting for device heat, the upstream wet-bulb temperature \( t_{w0} \) shall differ from the downstream wet-bulb temperature \( t_{w2} \) by no more than 1°C (2°F) during the test for the test results to be valid.

5.4 **Water Conductivity.** Conductivity of the water shall be measured using a conductivity meter compensated for temperature. The conductivity of the water supplied to the distribution header shall be between 350 and 3500 microsiemens (µS).

5.5 **Entrainment Verification.** Water entrainment shall not occur in equipment being tested for rating. Water entrainment will affect temperature measurements; consequently, any water entrainment shall invalidate test results. A sensitive paper that changes color when water touches the paper or a different means shall be used to monitor the plenum airflow measuring station for wetness.

5.6 **Thermodynamic Properties of Air.** Dry and moist air properties shall be obtained from or agree with ASHRAE RP-1485.

*(Informative Note: Software based upon ASHRAE RP-1485 is available. Refer to Informative Appendix A, Section A5 of this standard.)*

5.7 **Airflow Leakage Requirement:** Measured airflow leakage into or out of the test apparatus shall not be greater than 0.25% of the airflow at the leak test pressure that is equal to the maximum operating pressure.

6 **INSTRUMENTS AND MEASUREMENT METHODS**

6.1 **Instrument Calibrations.** Measurements from the instruments shall be traceable to primary or secondary standards calibrated by
the National Institute of Standards and Technology (NIST) or to the Bureau International des Poids et Mesures (BIPM) if a National Metrology Institute (NMI) other than NIST is used. In either case, the indicated corrections shall be applied to meet the uncertainty stated in subsequent sections. Instruments shall be recalibrated on regular intervals that do not exceed the intervals prescribed by the instrument manufacturer, and calibration records shall be maintained. Instruments shall be installed in accordance with the instrument manufacturer’s requirements. If not, the manufacturer’s accuracy shall not apply.

6.2 Instrument Accuracy Requirements and Measurement Methods. Measuring instruments shall be selected to meet or exceed the instrument accuracy listed in Table 3 for each type of measurement. Instruments and measurement methods shall comply with the ASHRAE measurement standards listed in Table 3.

### TABLE 3: Test instrument requirements and measurement methods

<table>
<thead>
<tr>
<th>Measurement Parameter</th>
<th>Accuracy</th>
<th>Maximum Resolution</th>
<th>ASHRAE Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air dry-bulb temperature</td>
<td>±0.05°C (±0.1°F)</td>
<td>±0.05°C (±0.1°F)</td>
<td>41.1²</td>
</tr>
<tr>
<td>Air wet-bulb temperature</td>
<td>±0.05°C (±0.1°F)</td>
<td>0.05°C (0.1°F)</td>
<td>41.6³</td>
</tr>
<tr>
<td>Other temperatures</td>
<td>±0.3°C (±0.5°F)</td>
<td>0.1°C (0.2°F)</td>
<td>41.1²</td>
</tr>
<tr>
<td>Barometric pressure</td>
<td>±34 Pa (±0.01 in. Hg)</td>
<td>2 Pa (0.005 in. Hg)</td>
<td>41.3⁴</td>
</tr>
<tr>
<td>Other pressures</td>
<td>±1.0 percent of reading</td>
<td>±0.5 percent of reading</td>
<td>41.3⁴</td>
</tr>
<tr>
<td>Wattmeter</td>
<td>±1.0 percent of reading</td>
<td>±0.5 percent of reading</td>
<td>41.1¹</td>
</tr>
<tr>
<td>Water flow rate</td>
<td>±0.5 percent of reading</td>
<td>±0.2 percent of reading</td>
<td>41.8⁵</td>
</tr>
<tr>
<td>Water conductivity</td>
<td>±10 percent of reading</td>
<td>±0.5 percent of reading</td>
<td>N/A</td>
</tr>
<tr>
<td>Fan Speed</td>
<td>±1.0 percent of reading</td>
<td>±0.5 percent of reading</td>
<td>N/A</td>
</tr>
<tr>
<td>Time</td>
<td>±0.5% of the elapsed time measured</td>
<td>±0.1% of the elapsed time measured</td>
<td>N/A</td>
</tr>
</tbody>
</table>

6.3 Airflow Measurement. Apply ASHRAE Standard 41.2² to measure volumetric airflow and standard volumetric airflow using a single- or multiple-nozzle test chamber.

6.4 Static Pressure Measurement in Ducts or Chambers. Static pressure in ducts or chambers shall be measured in accordance with the static pressure tap geometry and the piezometer ring specifications in Section 8 of ASHRAE Standard 41.2²

6.5 Air Inlet Temperature Sampling Apparatus. Use an air sampling apparatus and a wet-bulb psychrometer that is constructed as illustrated in Figure 1 to obtain the air inlet dry-bulb and wet-bulb temperature. The sample tree shall sample at least nine equal areas.

6.5.1 If the wet-bulb psychrometer is designed in accordance with Section 7.1 of ASHRAE Standard 41.6³, the wet-bulb temperatures shall be read only when the air velocity is 3.5±0.18 m/s (690±50 ft/min) over the wet-bulb sensor, and only when evaporative equilibrium of the sensor has been attained.

6.5.2 If the wet-bulb psychrometer is not designed in accordance with Section 7.1 of ASHRAE Standard 41.6³, the wet-bulb temperatures shall be read only when the air velocity is 3.56 to 10 m/s (700 to 2000 ft/min) over the wet-bulb sensor, and only when evaporative equilibrium of the sensor has been attained.
FIGURE 1 Example of an airflow sampling tree assembly that includes a wet-bulb psychrometer
7 TEST SETUP AND EQUIPMENT

7.1 Type A Packaged DEC Test Setup and Equipment

1. ED is equal to the geometrically equivalent diameter of the DEC outlet port as defined in Std. 41.2 Section 9.3.3.1

2. Aspirated discharge airflow shall flow back into the airstream upstream of the nozzle plane in the airflow measuring system. If not completely contained within the outlet duct, the entrance and exit duct penetrations shall be airtight.

3. DEC shown has only on inlet side; however, figure also applies to DECs with multi-sided inlet.

4. Test duct transition pieces per Std. 41.2 Section 8.5 are permitted.

5. Up discharge DECs have mirrored outlet ducts.

6. For component DECs, watt metered power source for fan will not be included.

FIGURE 2 Test Setup Schematic for Type A Packaged DEC with Up or Down Discharge
1. ED is equal to the geometrically equivalent diameter of the DEC outlet port as defined in Std. 41.2 Section 9.3.3.1
2. Aspirated discharge airflow shall flow back into the airstream upstream of the nozzle plane in the airflow measuring system. If not completely contained within the outlet duct, the entrance and exit duct penetrations shall be airtight.
3. DEC shown has only on inlet side; however, figure also applies to DECs with multi-sided inlet
4. Test duct transition pieces per Std. 41.2 Section 8.5 are permitted.
5. For component DECs, watt metered power source for fan will not be included.

FIGURE 3 Test Setup Schematic for Type A Packaged DEC with Horizontal Discharge
7.2 Type B Packaged DEC Test Setup and Equipment

1. ED is equal to the geometrically equivalent diameter of the DEC outlet port as defined in Std. 41.2 Section 9.3.3.1
2. Aspirated discharge airflow shall flow back into the airstream upstream of the nozzle plane in the airflow measuring system. If not completely contained within the outlet duct, the entrance and exit duct penetrations shall be airtight.
3. DEC shown has only on inlet side; however, figure also applies to DECS with multi-sided inlet
4. Test duct transition pieces per Std. 41.2 Section 8.5 are permitted.
5. Up discharge DECS have mirrored outlet ducts.
6. For component DECS, watt metered power source for fan will not be included.

FIGURE 4 Test Setup Schematic for Type B Packaged DEC with Up or Down Discharge
8. TEST DATA TO BE RECORDED

8.1 Test DEC. The description of the test direct evaporative air cooler (DEC) shall be recorded. The nameplate data shall be copied. Dimensions shall be checked against a drawing and a copy of the drawing attached to the data.

8.2 Test Setup. The description of the test setup, including specific dimensions, shall be recorded. The instruments and apparatus used in the test shall be listed. Names, model numbers, serial numbers, scale ranges, and proof of calibration shall be recorded.

8.3 Test Data. Test data for each determination shall be recorded at each point of operation that satisfies the stability criteria. Readings shall be made simultaneously.

a. DEC inlet dry-bulb temperature \( t_{d0} \), °C (°F)
b. DEC inlet wet-bulb temperature \( t_{w0} \), °C (°F)
c. Ambient barometric pressure \( p_b \), Pa (in. Hg)
d. DEC downstream dry-bulb temperature \( t_{d2} \), °C (°F)
e. DEC downstream wet-bulb temperature \( t_{w2} \), °C (°F)
f. Average fan speed for each fan \( N \), rad/s (rpm)
g. The following power inputs, if applicable: \( W_{Pe}, W_{Fl}, W_{ex}, W_{E}, W_{L} \) W (W)
h. Static pressure \( P_{s0} \), Pa (in. of water)
i. Static pressure \( P_{s1} \), Pa (in. of water)
j. Nozzle inlet airflow density \( \rho \), kg/m³ (lbm/ft³)
k. All information required by ASHRAE Standard 41.2 to calculate the DEC volumetric airflow rate \( Q \), m³/s (cfm) and the standard volumetric airflow rate \( Q_{std} \), m³/s (scfm)
l. Water conductivity, (µS)
m. If a component DEC is not supplied with a pump or rotary device, record water flow to the DEC \( Q_w \), m³/s (ft³/s)
9. CALCULATIONS

9.1 DEC Standard Airflow Rate. Apply ASHRAE Standard 41.2 to calculate the direct evaporative air cooler (DEC) standard volumetric airflow rate $Q_{std}$, m$^3$/s (cfm).

9.2 DEC Applicability. The calculations in this section apply to (a) a Type A packaged DEC, (b) a Type B packaged DEC, and (c) a component DEC noting that:

- A Type A packaged DEC does not include a fan or a pump upstream of the media, so $WF_E = 0$ and $W_E = 0$.
- A Type B packaged DEC includes a fan and a pump upstream and downstream of the media.
- A component DEC does not include a fan, a pump, or other devices upstream of the media, so $WF_E = 0$, $WF_L = 0$.

(Informative Note: While there are several potential variations of DECs, the Type A and Type B variations are described here for the purpose of illustrating the basis for the power parameters that are included or are not included in the calculations that follow. The user should delete any power parameter that does not apply to the unit under test.)

9.3 DEC Power Input at Test Conditions. The total power input to the test unit is the sum of fan and pump or rotary device power and appurtenance device power.

$$W_{total} = WF_E + WF_L + W_{ex} + W_E + W_L \quad W (W) \quad SI/IP \quad (9-1)$$

9.4 DEC Media Saturation Effectiveness. Apply Equation 9-2 to determine the DEC media saturation effectiveness at each point of operation that satisfies the stability criteria.

$$\varepsilon = \left(\frac{(t_{dE} - t_{dL})}{(t_{dE} - t_{wL})}\right) \times 100\%, \quad \text{dimensionless} \quad SI/IP \quad (9-2)$$

9.4.1 For Type A Packaged DECs:

$$t_{dE} = t_{d0} \quad SI/IP \quad (9-3)$$

$$t_{wE} = t_{w0} \quad SI/IP \quad (9-4)$$

$$t_{dL} = t_{d2} + \left(\frac{W_L + WF_L}{1.21Q_{std}}\right) \quad SI \quad (9-5)$$

$$t_{dL} = t_{d2} + \left(\frac{W_L + WF_L}{1.08Q_{std}}\right) \quad IP \quad (9-6)$$

$$t_{wL} = t_{w2} \quad SI/IP \quad (9-7)$$

9.4.2 For Type B Packaged DECs:

$$t_{dE} = t_{d0} + \left(\frac{W_E + WF_E}{1.21Q_{std}}\right) \quad SI \quad (9-8)$$

$$t_{dE} = t_{d0} + \left(\frac{W_E + WF_E}{1.08Q_{std}}\right) \quad IP \quad (9-9)$$

Obtain $t_{wE}$ from $t_{w0}$ and $t_{dE}$ using techniques in ASHRAE RP-1485$^1$.

$$t_{dL} = t_{d2} + \left(\frac{W_L + WF_L}{1.21Q_{std}}\right) \quad SI \quad (9-10)$$

$$t_{dL} = t_{d2} + \left(\frac{W_L + WF_L}{1.08Q_{std}}\right) \quad IP \quad (9-11)$$
9.5 DEC Static Pressure Differential
The DEC static pressure differential, the static pressure differential between plane 0 and plane 1, is obtained using Equation 9-13.

\[ \Delta P_{DEC} = P_{s0} - P_{s1} \]  

(9-13)

9.6 DEC Standard Sensible Cooling Capacity

\[ q_{std} = 1.21 Q_{std} (t_{d0} - t_{d2}) \]  

SI  (9-14)

\[ q_{std} = 1.08 Q_{std} (t_{d0} - t_{d2}) \]  

IP  (9-15)

9.6.1 For Type A Packaged DECs:

\[ t_{dE} = t_{d0} \]  

SI/IP  (9-16)

\[ t_{wE} = t_{w0} \]  

SI/IP  (9-17)

9.6.2 For Type B Packaged DECs:

\[ t_{dE} = t_{d0} - \left( \frac{W_{E}+W_{F}}{1.21 Q_{std}} \right) \]  

SI  (9-18)

\[ t_{dE} = t_{d0} - \left( \frac{W_{E}+W_{F}}{1.21 Q_{std}} \right) \]  

IP  (9-19)

Obtain \( t_{wE} \) from \( t_{w0} \) and \( t_{dE} \) using techniques in ASHRAE RP-14851.

9.7 DEC Coefficient of Performance (COP) and Energy Efficiency Ratio (EER)

\[ COP = \frac{q}{W_{total}}, \text{ dimensionless} \]  

SI  (9-20)

\[ EER = \frac{q}{W_{total}}, \text{ Btu/(W-h)} \]  

IP  (9-21)

9.8 DEC Standard Airflow
The ratio of the input volumetric airflow to the standard airflow shall be obtained from the Standard 41.2 test results as shown in Equation 9-22.

\[ \left( \frac{Q_{std}}{Q} \right) = \left( \frac{\rho}{\rho_{std}} \right) \]  

SI/IP  (9-22)

9.9 Fan Speed at Standard Conditions
Fan speed at standard conditions shall be calculated from the fan laws using Equation 9-23.

\[ \left( \frac{N_{std}}{N} \right) = \left( \frac{Q_{std}}{Q} \right) = \left( \frac{\rho}{\rho_{std}} \right) \]  

SI/IP  (9-23)

9.10 DEC Standard Static Pressure Differential
From the fan laws and Equation 9-23, the standard static pressure differential of the DEC shall be calculated using Equation 9-24.

\[ \Delta P_{std} = \Delta P_{DEC} \times \left( \frac{N_{std}}{N} \right)^2 = \Delta P_{DEC} \times \left( \frac{\rho}{\rho_{std}} \right)^2 \]  

SI/IP  (9-24)
9.11 Fan Power at Standard Conditions
Calculate the fan power at standard conditions using Equation 9-25.

\[(W_E + WF_L)_{std} = (WF_E + WF_L) \times \left(\frac{\rho}{\rho_{std}}\right)^3\]  
SI/IP  (9-25)

9.12 Total Fan Power at Standard Conditions
Use Equation 9-26 to calculate the total fan power at standard conditions.

\[W_{std} = (W_E + WF_L)_{std} + W_{ex} + W_E + W_L\]  
SI/IP  (9-26)

9.13 Correction to Nominal Fan Speed at Standard Density
Apply Equations 9-27, 9-28, and 9-29 to convert test data to test data at nominal fan speed.

\[Q_n = Q_{std} \times \left(\frac{N_n}{N}\right)\]  
SI/IP  (9-27)

\[P_n = P_{std} \times \left(\frac{N_n}{N}\right)^2\]  
SI/IP  (9-28)

\[W_{fn} = W_{std} \times \left(\frac{N_n}{N}\right)^3\]  
SI/IP  (9-29)

10 TEST REPORT
The report of a laboratory direct evaporative air cooler (DEC) test shall include test data and descriptions of the DEC, including the inlet and outlet boundaries, appurtenances, test setup, and test instruments. The laboratory shall be identified by name and location.

10.1 Performance data shall be provided in a spreadsheet. If the DEC is not supplied with a pump or rotary device, a description of the method of supplying the water and the flow rate of water delivered to the DEC shall be included.

10.2 Performance Curves.
The following DEC test results shall be presented as performance curves:

- DEC standard volumetric airflow rate, \(Q_{std}\), SI or IP
- DEC standard total power input, \(W_{std}\), SI or IP
- DEC standard static pressure differential, \(\Delta P_{std}\), SI or IP
- DEC media saturation effectiveness, \(\varepsilon\), dimensionless
- DEC standard sensible cooling capacity, \(q_{std}\), SI or IP
- DEC overall performance, COP dimensionless. (EER, Btu/(W-h))

10.2.1 Test Points. The results for each determination shall be shown on the performance curve as a series of circled points, one performance curve for each variable plotted as the ordinate.

10.2.2 Curve-Fitting. Curves for each performance variable shall be using the test points for reference. The equations for each of those curves shall have an R\(^2\) value greater than 0.95.

10.2.4 Coordinates for Packaged DEC Performance Curves. Performance curves shall be drawn with DEC standard airflow rate as abscissa. If all results were recorded at or converted to a nominal speed, that speed shall be listed; otherwise, an additional curve with fan speed as ordinate shall be drawn.

11 REFERENCES
3. ANSI/ASHRAE Standard 41.6-2021 Standard Methods for Humidity Measurement, Atlanta: ASHRAE.
4. ANSI/ASHRAE Standard 41.3-2022, Standard Methods for Pressure Measurement, Atlanta: ASHRAE.
INFORMATIVE APPENDIX A BIBLIOGRAPHY
A5 ASHRAE LibHuAirProp software, Atlanta: ASHRAE
INFORMATIVE APPENDIX B ADDITIONAL FIGURES

FIGURE B-1 Illustration of a packaged direct evaporative air cooler (DEC).
FIGURE B-2 Illustration of a component direct evaporative air cooler (DEC).