AHRI Standard 365-2024 (SI/I-P)

Performance Rating of Commercial and Industrial Unitary Air-conditioning Condensing Units

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ICS Codes: 23.120, 27.080

Note:

This standard supersedes AHRI Standard 365-2009 (I-P) and AHRI Standard 366-2009 (SI).

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Intent

This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors, and users.

Review and Amendment

This standard is subject to review and amendment as technology advances.

2024 Edition

This edition of AHRI Standard 365-2024 (SI/I-P), *Performance Rating of Commercial and Industrial Unitary Air-conditioning Condensing Units*, was prepared by the Commercial Unitary Standards Technical Committee. The standard was approved by the Standards Committee on 25 November 2024.

Origin and Development of AHRI Standard 365

The initial publication was ARI Standard 365-1987, *Commercial and Industrial Unitary Air-Conditioning Condensing Units*. Subsequent revisions were:

- ARI Standard 365-1994, *Commercial and Industrial Unitary Air-Conditioning Condensing Units*
- ARI Standard 365-2002, *Commercial and Industrial Unitary Air-Conditioning Condensing Units*
- AHRI Standard 365 (I-P)-2009, *Performance Rating of Commercial and Industrial Unitary Air-Conditioning Condensing Units*
- AHRI Standard 366 (SI)-2009, *Performance Rating of Commercial and Industrial Unitary Air-Conditioning Condensing Units*

Summary of Changes

AHRI Standard 365-2024 (SI/I-P) contains the following updates to the previous edition:

- Remove IPLV references
- Minor non-technical changes
- Revision to the *IEER* test procedure to align with AHRI 340/360 test and rating procedure for condenser temperatures
- Consolidate with AHRI Standard 366 (SI) to publish a joint unit standard

Committee Personnel

Standards Work Group (SWG)-365 and 1365

Company/Organization	Participant	Voting Role
Voting Organizations		
Trane Technologies Inc	Beth Braddy (Chair)	Alternate voter
	Lane Liudahl	Primary voter
	Richard Pulfer	Alternate voter
Aaon	Harold Dubensky	Alternate voter
	Kevin Teakell	Primary voter
Allied Air Enterprises, LLC Lennox	Guru Ravi	Primary voter
Carrier	Richard Lord	Alternate voter
	Patrick Riley	Alternate voter
	Nick Schinner	Primary voter
Daikin Industries Goodman Manufacturing Company	Henry Ernst	Primary voter
	Jeff Whitelaw	Alternate voter
GD Midea Air-Conditioning Equipment Co., Ltd.	Edison Shen	Primary voter
U.S. Department of Energy	Lily Byer	Alternate voter
	Cortney Cavanaugh	Primary voter
	Sean Faltermeier	Alternate voter
	Anish Odhav	Alternate voter
Intertek	Tyler Stiles	Primary voter
Kentuckiana Curb Co., Inc.	Matthew Lea	Alternate voter
	Kevin Muldoon	Primary voter
Rheem Sales Company	Scott Creamer	Primary voter
Antonio Romeo		AHRI Staff Liaison

Standards Work Group (SWG)-365 and 1365 Scope:

This SWG is responsible for the revision of AHRI 365 and AHRI 1365.

Commercial Unitary Standards Technical Committee

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Voting Organizations		
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	Richard Lord	Alternate voter
2050 Partners	John Bade	Primary voter
Aaon	Kevin Teakell	Primary voter
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	Beth Braddy	Alternate voter
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United CoolAir	Brad Dunn	Primary voter
Antonio Romeo		AHRI Staff Liaison

Commercial Unitary Standards Technical Committee (STC) Scope:

The Commercial Unitary STC is responsible for the development and maintenance of AHRI standards and guidelines pertaining to Commercial & Industrial Unitary Air-conditioning and Heat Pump Equipment including split systems, remote condensing units, and packaged equipment.

Out of scope: Unitary Small Equipment, Packaged Terminal AC/HP, Furnaces, Variable Refrigerant Systems (VRF), Geothermal and Water Source HP, Single Package Vertical Unit (SPVU), Performance Rating of Zoning products, DX-Dedicated Outdoor Air System Units (DOAS) Demand response and smart grid interface

Standards Committee

Company/Organization	Participant	Voting Role
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Daikin Applied Americas Inc.	Henry Ernst, Vice Chair	Primary
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Danfoss	Justin Prosser	Primary
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Nailor Industries	Gus Faris	Primary
Rheem Sales Company, Inc.	Sachin Nehete	Primary
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These lists represent the membership at the time the Standards Work Group, Standards Technical Committee, and Standards Committee were balloted on the final text of this edition. Since that time, changes in the membership may have occurred. Membership on these groups shall not in and of itself constitute an endorsement by the group's members or their employers of any document developed by the group on which the member serves.

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PERFORMANCE RATING OF COMMERCIAL AND INDUSTRIAL UNITARY AIR-CONDITIONING CONDENSING UNITS

Section 1. Purpose

This standard establishes definitions, classifications, test requirements, rating requirements, minimum data requirements for *published ratings*, operating requirements, marking and nameplate data, and conformance conditions for *commercial and industrial unitary air-conditioning condensing units*.

Section 2. Scope

2.1 Scope

This standard applies to factory-made *commercial and industrial unitary air-conditioning condensing units* greater than or equal to 135,000 Btu/h or 40.0 kW as defined in Section 3.2.

2.2 Exclusions

This standard does not apply to the testing and rating of condensing units for refrigeration purposes, as described in AHRI 520.

Section 3. Definitions

All terms in this document follow the standard industry definitions in the ASHRAE Terminology website unless otherwise defined Section 3.2. The standard-specific defined terms are italicized throughout the standard.

3.1 Expression of Provisions

Terms that provide clear distinctions between requirements, recommendations, permissions, options, and capabilities.

3.1.1 "Can" or "cannot"

Express an option or capability.

3.1.2 "May"

Signifies a permission expressed by the document.

3.1.3 "Must"

Indication of unavoidable situations and does not mean that an external constraint referred to is a requirement of the document.

3.1.4 "Shall" or "shall not"

Indication of mandatory requirements to strictly conform to the standard and where deviation is not permitted.

3.1.5 "Should" or "should not"

Indication of recommendations rather than requirements. In the negative form, a recommendation is the expression of potential choices or courses of action that is not preferred but not prohibited.

3.2 Standard-specific Definitions

3.2.1 Air Sampling Device(s)

A combination of *air sampling tree(s)*, conduit, fan and *aspirating psychrometer* or *dew-point hygrometer* used to determine dry-bulb temperature and moisture content of an air sample from critical locations.

3.2.2 Aspirating Psychrometer

An instrument used to determine the humidity of air by simultaneously measuring both the wet-bulb and dry-bulb temperatures. The difference between these temperatures is referred to as the wet-bulb depression.

3.2.3 Bubble Point

Refrigerant liquid saturation temperature at a specified pressure.

3.2.4 Coefficient of Performance (COP_C)

A ratio of the *cooling capacity* in kW to the power input in kW at any given set of *rating conditions*.

3.2.5 Commercial and Industrial Unitary Air-conditioning Condensing Unit

A factory-made assembly of refrigeration components designed to compress and liquefy a specific refrigerant that consists of one or more refrigerant compressors, refrigerant condensers (air-cooled, evaporatively-cooled, or water-cooled, or a combination thereof), condenser fans and motors (where used), and factory-supplied accessories.

3.2.6 Cooling Capacity

The capacity in Btu/h (kW) obtained at specific conditions, equal to the increase in total enthalpy between the liquid refrigerant entering the expansion valve and superheated return gas multiplied by the mass flow rate of the refrigerant.

3.2.7 Dew Point

Refrigerant vapor saturation temperature at a specified pressure.

3.2.8 Dew-point Hygrometer

An instrument used to determine the humidity of air by detecting visible condensation of moisture on a cooled surface.

3.2.9 Energy Efficiency Ratio (EER)

A ratio of the *cooling capacity* in Btu/h to the power input value in watts at any given set of *rating conditions* expressed in Btu/(W·h).

3.2.9.1 Standard Energy Efficiency Ratio

A ratio of the capacity to power input value obtained at *standard rating conditions*.

3.2.10 Integrated Coefficient of Performance ($ICOP_C$)

A single number part-load efficiency figure of merit calculated in accordance with the method described in this standard expressed in W/W.

3.2.11 Integrated Energy Efficiency Ratio (IEER)

A weighted calculation of mechanical cooling efficiencies at full load and part load *standard rating conditions* expressed in Btu/W·h.

3.2.12 Manufacturer Instructions

3.2.12.1 Manufacturer's Installation Instructions (MII)

Manufacturer's documents that come packaged with or appear in the labels applied to the unit(s).

3.2.13 Makeup Water

The water supplied to an evaporative cooled condenser to compensate for the water evaporated.

3.2.14 Published Rating

A statement of the assigned values of those performance characteristics, under stated *rating conditions*, where a unit can be chosen to fit the application. These values apply to all units of the same nominal size and type (identification) produced by the same manufacturer. This includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated *rating conditions*.

3.2.14.1 Application Rating

A rating based on tests performed at rating conditions other than *standard rating conditions*.

3.2.14.2 Standard Rating

A rating based on tests performed at *standard rating conditions*.

3.2.15 Rating Conditions

Any set of operating conditions where a single level of performance results and causes only that level of performance to occur.

3.2.15.1 Application Rating Condition

Rating conditions other than *standard rating conditions* that are within the scope of the standard.

3.2.15.2 Standard Rating Condition

Rating conditions used as the basis of comparison for performance characteristics.

3.2.16 Single Number Rating

The *cooling capacity* and *EER* (COP_C) determined by the results of the tests at *rating condition* No. 1 for air-cooled and evaporatively-cooled condensing units and at *rating condition* No. 3 for water-cooled condensing units (see Section 6).

Section 4. Classifications

Equipment covered within the scope of this standard shall be classified as shown in Table 1.

Table 1 Classifications of Commercial and Industrial Air-conditioning Condensing Units

Designation	AHRI Type[1]	Condenser Type	Arrangement
Remote Condensing Unit (RCU)	RCU-A	Air	COMP COND
	RCU-E	Evaporatively	
	RCU-W[2]	Water	

Notes:

1. "-A" indicates air-cooled condenser, "-E" indicates evaporatively-cooled (does not apply to evaporative pre-cooled) condenser, and "-W" indicates water-cooled condenser.
2. For water-cooled products, outdoor arrangement can move from outdoor side to indoor side.

Section 5. Test Requirements

5.1 Standard Ratings

All *standard ratings* shall be verified by tests conducted in accordance with ASHRAE 23, ASHRAE 37, and ASHRAE 30 with the test methods and procedures as described in this standard and modified in Appendix C and Appendix D.

An alternate method of verification can be by tests conducted in accordance with ASHRAE 37 provided that the suction *dew point* temperature and the return gas superheat temperature are determined from the procedures in this standard.

5.2 Instruction Priority

Units shall be installed in accordance with the *MII*. In the event of conflicting instructions regarding the set-up of the unit under test, priority shall be given to installation instructions that appear on the unit's label over installation instructions that are shipped with the unit.

5.3 Break-in

Conduct a compressor break-in period prior to conducting the test if there is a *manufacturer-specified* break-in period. Conduct the break-in period using the *manufacturer-specified* duration and conditions; however, the duration shall not exceed twenty hours and the outdoor temperature shall not exceed 115°F or 46°C. When there is a *manufacturer-specified* break-in period, each compressor of the unit shall undergo this break-in period. Testing shall not commence until the *manufacturer-specified* break-in period is completed.

5.4 Head Pressure Control

For units with condenser head pressure controls, the head pressure controls shall be enabled and operated in automatic mode. Set head pressure controls as specified by the *MII*. If such instructions are not provided, use the as-shipped setting. If this results in unstable operation, meaning outside test tolerances in Section 8.3, and testing requirements cannot be met, then the procedures in Section D.6 shall be used.

5.5 Refrigerant Charging

Use the test or operating conditions specified in the *MII* for charging. If the *MII* do not specify a test or operating conditions for charging or *MII* are not provided, charging shall be conducted at *standard rating*. If the *MII* contain two sets of refrigerant charging criteria, one for field installation and one for lab testing, use the field installation criteria. Charging of refrigerant blends shall be performed with refrigerant in the liquid state.

5.5.1 Manufacturer-specified Range for Charging Parameter

If the *MII* give a *manufacturer-specified* range for a charging parameter, for example, superheat, subcooling, or refrigerant pressure, the average of the range shall be used to determine the refrigerant charge.

5.5.2 Parameters and Target Values not Provided

If *MII* are not provided or the *MII* do not provide parameters and target values, or both, set superheat to a target value of 12°F or 6.7°C for fixed orifice systems or set subcooling to a target value of 10°F or 5.5°C for expansion valve systems.

5.5.3 Conflicting Information

In the event of conflicting information between charging instructions, use the instruction priority order indicated in Section 5.2. Conflicting information is defined as multiple *manufacturer-specified* conditions given for charge adjustment where all *manufacturer-specified* conditions cannot be met. If such instances of conflicting information occur within the highest-ranking set of instructions where refrigerant charging instructions are provided, follow the hierarchy in Table 2, as applicable, unless the manufacturer specifies a different priority in the outdoor unit installation instructions.

Table 2 Tolerances for Charging Hierarchy

Expansion Valve		
Priority	**Parameter**	**Tolerance**
1	Subcooling	± 2.0°F (± 1.1°C)
2	High side pressure or saturation temperature	± 4.0 psi (± 27.5 kPa) or ± 1.0°F (± 0.59°C)
3	Low side pressure or saturation temperature	± 2.0 psi (± 13.8 kPa) or ± 0.8°F (± 0.44°C)
4	Approach temperature[1]	± 1.0°F (± 0.59°C)
5	Charge weight	± 2.0 oz (56 g)
Note: 1. Approach temperature means the refrigerant temperature at the outdoor liquid service port minus the outdoor ambient temperature.		

5.6 Test Unit Location

5.6.1 Air-cooled, and Evaporatively-cooled Equipment

The condensing unit shall be located in the outdoor test room.

5.6.2 Water-Cooled Equipment

The unit, including both units for split systems, shall be located in the indoor test room.

5.7 Variable Speed Units

When testing air conditioners that have a variable speed drive, an induction watt-hour meter shall not be used.

5.8 Instrumentation Accuracy

In addition to the instrument accuracy requirements specified in Section 5 of ASHRAE 37, measurements shall be made in accordance with the provisions in Section 5.8.1 and Section 5.8.2.

5.8.1 Atmospheric Pressure

Atmospheric pressure measuring instruments shall be accurate to within ± 0.5% of the reading.

5.8.2 Electrical Frequency

Measurement devices used to measure electrical frequency shall be accurate to within ± 0.2 Hz.

Section 6. Rating Requirements

6.1 Standard Ratings

Standard ratings shall be obtained at one or more of the *standard rating conditions* as shown in Table 3 and Table 4. Power input shall be the total power input to the compressor(s), fan(s), controls, and any other components included as part of the condensing unit.

6.1.1 Air-cooled and Evaporatively-cooled Condensing Units

For air-cooled and evaporatively-cooled condensing units, the manufacturer shall record the liquid temperature and pressure leaving the condensing unit in the unit's ratings. The wet-bulb temperature is required for evaporatively-cooled condensing units only.

6.1.2 Water-cooled Units

Standard ratings of water-cooled units shall not include allowance for cooling tower fan motor and circulating water pump motor power.

Note: AHRI 340/360 requires that products less than 135,000 Btu/hr are rated with power allowance of 10.0 W per 1000 Btu/h *cooling capacity*, but this is not required by AHRI 365 test procedures.

Standard ratings for water-cooled equipment shall be based on a fouling factor of 0.0000 hr·ft2·°F/Btu.

Table 3 Standard Rating Conditions (I-P)

Air-cooled and Evaporatively-cooled Condensing Units				
Rating Condition	**Air Temperature Entering and Surrounding Unit**		**Refrigerant Temperature Entering Condensing Unit**	
—	**Dry-bulb Temperature, °F**	**Wet-bulb Temperature, °F**	**Suction *Dew Point* Temperature, °F**	**Return Gas Superheat Temperature, °F**
1[1]	95.0	75.0	45.0	15.0
2	80.0	67.0	45.0	15.0
Water-cooled Condensing Units				
Rating Condition	**Water Temperature Entering, °F**	**Water Temperature Leaving, °F**	**Suction *Dew Point* Temperature, °F**	**Return Gas Superheat Temperature, °F**
3[1]	85.0	95.0	45.0	15.0
4	75.0	Same water flow rate as established in *rating condition* 3	45.0	15.0

Note:

1. The *single number ratings* are determined by the results of the tests at *rating condition* No. 1 or at *rating condition* No. 3.

Table 4 Standard Rating Conditions (SI)

Air-cooled and Evaporatively-cooled Condensing Units				
Rating Condition	**Air Temperature Entering and Surrounding Unit**		**Refrigerant Temperature Entering Condensing Unit**	
—	**Dry-bulb Temperature, °C**	**Wet-bulb Temperature, °C**	**Suction *Dew Point* Temperature, °C**	**Return Gas Superheat Temperature, °C**
1[1]	35.0	23.8	7.2	8.3
2	26.7	19.4	7.2	8.3
Water-cooled Condensing Units				
Rating Condition	**Water Temperature Entering, °C**	**Water Temperature Leaving, °C**	**Suction *Dew Point* Temperature, °C**	**Return Gas Superheat Temperature, °C**
3[1]	29.4	35.0	7.0	8.3
4	23.9	Same water flow rate as established in *rating condition* 3	7.0	8.3

Note:

1. The *single number ratings* are determined by the results of the tests at *rating condition* No. 1 or at *rating condition* No. 3.

6.1.3 Values of Standard Cooling Capacity Ratings

These ratings shall be expressed only in terms of thousands of Btu/h (in terms of watts) in multiples of 2000 Btu/h or 500 W for units with *standard ratings* equal to or less than 400,000 Btu/h or 117,000 W. For units with *standard ratings* greater than 400,000 Btu/h or 117,000 W, the ratings shall be expressed in multiples of 5000 Btu/h or 1500 W.

6.1.4 Values of Standard Efficiency Ratings

EER, in Btu/(W·h), and *IEER* shall be expressed in multiples of 0.1. COP_C, in W/W, and $ICOP_C$ shall be expressed in multiples of 0.01.

6.1.5 Single Number Ratings

The recorded values shall be determined by the results obtained at rating condition No. 1 or at rating condition No. 3.

6.1.6 Electrical Conditions

Standard rating tests shall be performed at the nameplate rated voltage(s) and frequency.

For condensing units with dual nameplate voltage ratings, *standard rating* tests shall be performed at both voltages, or at the lower of the two voltages, if only a single *standard rating* is published.

6.1.7 Condenser Airflow Rate

All *standard ratings* for condensing units shall be determined at the condenser airflow rate specified by the manufacturer where the fan drive is adjustable. Where the fan drive is direct-connected, *standard ratings* shall be determined at the condenser airflow rate established when the condensing unit is operated with all of the associated inlet louvers and any duct work and attachments determined by the manufacturer. Once established, the airflow circulation rate of the condensing unit shall remain unchanged throughout all tests prescribed herein, except as altered by automatic controls.

6.2 Part-load Rating

All equipment rated in accordance with this standard shall include an *IEER* rating, even if there is one stage of *cooling capacity* control.

6.2.1 Measurement of Merit

The *IEER* ($ICOP_C$) is intended to be a measure of merit for the part load performance of the unit. Each building can have different part load performance due to local occupancy schedules, building construction, building location, and ventilation requirements.

Note: For specific building energy analysis, an hour-by-hour analysis program should be used.

6.2.2 Integrated Energy Efficiency Ratio (IEER)/Integrated Coefficient of Performance ($ICOP_C$)

For equipment covered by this standard, the *IEER* ($ICOP_C$) shall be calculated using tests, derived data, and Equation 1 or Equation 2.

$$IEER = 0.020 \cdot A + 0.617 \cdot B + 0.238 \cdot C + 0.125 \cdot D \tag{1}$$

$$ICOP_C = 0.020 \cdot A + 0.617 \cdot B + 0.238 \cdot C + 0.125 \cdot D \tag{2}$$

Where:

A = *EER* (COP_C) at 100% capacity at design conditions, (Btu/h)/W (W/W)

B = *EER* (COP_C) at 75% capacity and reduced condenser conditions (see Table 5 and Table 6), (Btu/h)/W (W/W)

C = *EER* (COP_C) at 50% capacity and reduced condenser conditions (see Table 5 and Table 6), (Btu/h)/W (W/W)

D = *EER* (COP_C) at 25% capacity and reduced condenser conditions (see Table 5 and Table 6), (Btu/h)/W (W/W)

Note: Adjust condenser airflow as required by the unit controls for head pressure control.

The *IEER* and $ICOP_C$ ratings require that the unit efficiency be determined at 100 percent load, 75 percent load, 50 percent load, and 25 percent load at the conditions specified in Table 5 and Table 6.

Condenser airflow shall be adjusted, if required, in accordance with Section 5.4.

At 100 percent load, the condenser water flow rate shall be equal to the flow rate determined for the standard rating condition for cooling, described in Table 3 and Table 4.

Table 5 IEER Part-Load Rating Conditions (I-P)

Conditions	**Condition**
Refrigerant temperature entering condensing unit Return gas dewpoint	45.0°F[1] 15.0°F
Air-cooled condenser Entering dry-bulb temperature (OAT) Condenser airflow rate, cfm	100 percent load = 95.0°F 75 percent load = 81.5°F 50 percent load = 68.0°F5 25 percent load = 65.0°F
Water-cooled condenser Entering condenser water temperature (EWT) Condenser water flow rate, gpm	100 percent load = 85.0°F 75 percent load = 73.5°F 50 percent load = 62.0°F 25 percent load = 55.0°F
Evaporatively-cooled condenser Entering air wet-bulb/air dry-bulb/*makeup water* temperature (EWB/DB/MW)	100 percent load = 75.0°F/95.0°F/85.0°F 75 percent load = 66.2°F/81.5°F/77.0°F 50 percent load = 57.5°F/68.0°F/77.0°F 25 percent load = 52.8°F/65.0°F/77.0°F

Note:

1. For refrigerants with a glide, the mid-point saturated suction temperature is the average of the *bubble point* and *dew point*.

Table 6 $ICOP_C$ Part-Load Rating Conditions (SI)

Conditions	Condition
Refrigerant temperature entering condensing unit Return gas dewpoint	7.0°C[1] 8.3°C
Air-cooled condenser Entering dry-bulb temperature (OAT) Condenser airflow rate, cfm	100 percent load = 35.0°C 75 percent load = 27.5°C 50 percent load = 20.0°C 25 percent load = 18.3°C
Water-cooled condenser Entering condenser water temperature (EWT) Condenser water flow rate, gpm	100 percent load = 29.4°C 75 percent load = 23.1°C 50 percent load = 16.7°C 25 percent load = 12.8°C
Evaporatively-cooled condenser Entering air wet-bulb/air dry-bulb/*makeup water* temperature (EWB/DB/MW)	100 percent load = 23.9°C/35.0°C/29.4°C 75 percent load = 19.0°C/27.0°C/25.0°C 50 percent load = 14.2°C/20.0°C/25.0°C 25 percent load = 11.6°C/18.3.0°C/25.0°C
Note: 1. For refrigerants with a glide, the mid-point saturated suction temperature is the average of the *bubble point* and *dew point*.	

6.2.3 Rating Adjustments

Testing shall be performed at the four load points and condenser conditions as defined in Table 5 and Table 6. If the unit is not capable of running at any of the 75 percent load, 50 percent load, or 25 percent load points then Section 6.2.5 shall be followed to determine the *EER* rating at the required load.

6.2.4 Interpolation

If the units cannot run at any of the 75 percent load, 50 percent load, or 25 percent load points within a tolerance of ± 3% but is capable of running at load above and below the percent load of 75, 50, or 25, interpolation of the test points shall be used to determine the *EER* at the required load.

6.2.5 Degradation

If the unit cannot be unloaded to the 75 percent load, 50 percent load, or 25 percent load then the unit shall be run at the minimum step of unloading and the rated indoor airflow at the condenser conditions defined for each of the percent load points listed in Table 5 and Table 6 and then the part-load *EER* shall be adjusted for cyclic performance using Equation 3 or Equation 4.

$$EER = \frac{\mathrm{LF} \cdot \mathrm{Capacity}}{\mathrm{LF} \cdot (\mathrm{C_D} \cdot (\mathrm{P_C} + \mathrm{P_{CF}})) + \mathrm{P_{CT}}} \quad (3)$$

$$COP_C = \frac{\mathrm{LF} \cdot \mathrm{Capacity}}{\mathrm{LF} \cdot (\mathrm{C_D} \cdot (\mathrm{P_C} + \mathrm{P_{CF}})) + \mathrm{P_{CT}}} \quad (4)$$

Where:

Capacity = Measured capacity at the lowest machine unloading point operating at the selected part load rating condition, Btu/h (W)

PC = Compressor power at the lowest machine unloading point operating at the selected part load rating condition, W

P_{CD} = Condenser fan power, if applicable, at the minimum step of unloading at the selected part load rating condition, W

P_{CT} = Control circuit power and any auxiliary loads, W

C_D = Degradation coefficient to account for cycling of the compressor for capacity less than the minimum step of capacity

Note: C_D should be determined using Equation 5.

$$C_D = (-0.13 \cdot LF) + 1.13 \quad (5)$$

Where:

LF = Fractional on time for last stage at the selected load point as shown in Equation 6:

$$LF = \frac{\left(\frac{\%Load}{100}\right) \cdot (\text{Full Load Unit Capacity})}{\text{Part Load Unit Capacity}} \quad (6)$$

Where:

%Load = *Standard rating* point of either 75%, 50%, or 25%

6.2.6 Example Calculations

This section provides examples and calculations for *IEER* and $ICOP_C$.

6.2.6.1 Example 1

For this example, the condensing unit has proportional capacity control and can be run at the 75% rating point, 50% rating point, and 25% rating point.

The data in Table 7 and Table 8 is from actual unit measurements:

Table 7 Example 1 Data (I-P)

Stage	Ambient (°F)	Actual % Load (Capacity)	Saturated Suction (°F)	Capacity Btu/h	Compressor (P_C) W	Condenser Fan (P_{CF}) W	Control (P_{CT}) W	*EER* Btu/(W·h)
4	95.0	100	45	481,866	43,535	2100	100	10.54
3	81.5	75	45	361,397	28,731	2100	100	11.68
2	68.0	50	45	240,933	17,791	2100	100	12.05
1	65.0	25	45	120,464	9491	2100	100	10.30

$$IEER = (0.02 \cdot 10.54) + (0.617 \cdot 11.68) + (0.238 \cdot 12.05) + (0.125 \cdot 10.30) = 11.58$$

Table 8 Example 1 Data (SI)

Stage	Ambient (°C)	Actual % Load (Capacity)	Saturated Suction (°C)	Capacity W	Compressor (P_C) W	Condenser Fan (P_{CF}) W	Control (P_{CT}) W	COP_C W/W
4	35.0	100	7	141,187	43,535	2,100	100	3.09
3	27.5	75	7	105,889	28,731	2,100	100	3.42
2	20.0	50	7	70,593	17,791	2,100	100	3.53
1	18.3	25	7	35,296	9,491	2,100	100	3.02

$$ICOP_C = (0.02 \cdot 3.09) + (0.617 \cdot 3.42) + (0.238 \cdot 3.53) + (0.125 \cdot 3.02) = 3.39$$

6.2.6.2 Example 2

For this example, the condensing unit has a single stage of capacity.

The data in Table 9 and Table 10 is from actual unit measurements.

Table 9 Example 2 Data (I-P)

Stage	Ambient (°F)	Actual % Load (Capacity)	Saturated Suction (°F)	Capacity Btu/h	Compressor (P_C) W	Condenser Fan (P_{CF}) W	Control (P_{CT}) W	*EER* Btu/(W·h)
1	95.0	100	45	481,866	43,535	2100	100	10.54
1	81.5	98.8	45	476,245	38,877	2100	100	11.59
1	68.0	100.3	45	483,502	35,261	2100	100	12.91
1	65.0	98.7	45	475,813	35,475	2100	100	12.63

Table 10 Example 2 Data (SI)

Stage	Ambient (°C)	Actual % Load (Capacity)	Saturated Suction (°C)	Capacity W	Compressor (P_C) W	Condenser Fan (P_{CF}) W	Control (P_{CT}) W	*EER* W/W
1	35.0	100	7	141,187	43,535	2100	100	3.09
1	27.5	98.8	7	139,540	38,877	2100	100	3.40
1	20.0	100.3	7	141,666	35,261	2100	100	3.78
1	18.3	98.7	7	139,413	35,475	2100	100	3.70

The unit cannot unload to the 75% point, 50% point, or 25% point; therefore, tests have the compressor on at the ambient temperatures specified for 75%, 50%, and 25%.

Using this data, the load factor (LF) and the C_D factors can be calculated, followed by calculating the adjusted performance for the 75% point, 50% point, and 25% point, and finally calculating the *IEER* as shown in Table 11 and Table 12.

Table 11 Example 2 Calculations (I-P)

Stage —	Ambient (°F)	Actual % Load (Capacity)	Capacity Btu/h	Compressor (P_C) W	Condenser Fan (P_{CF}) W	Control (P_{CT}) W	*EER* Btu/(W·h)	C_D —	LF —
1	95.0	100.0	481,866	43,535	2100	100	10.54	—	—
1	81.5	98.8	476,245	38,877	2100	100	11.59	—	—
—	—	75.0	—	—	—	—	11.23	1.031	0.759
1	68.0	100.3	483,502	35,261	2100	100	12.91	—	—
		50.0	—	—	—	—	12.09	1.065	0.498
1	65.0	98.7	475,813	35,475	2100	100	12.63	—	—
—	—	25.0	—	—	—	—	11.43	1.097	0.253

Table 12 Example 2 Calculations (SI)

Stage —	Ambient (°C)	Actual % Load (Capacity)	Capacity W	Compressor (P_C) W	Condenser Fan (P_{CF}) W	Control (P_{CT}) W	COP_C W/W	C_D —	LF —
1	95.0	100.0	481,866	43,535	2100	100	10.54	—	—
1	81.5	98.8	476,245	38,877	2100	100	11.59	—	—
—	—	75.0	—	—	—	—	11.23	1.031	0.759
1	68.0	100.3	483,502	35,261	2100	100	12.91	—	—
—	—	50.0	—	—	—	—	12.09	1.065	0.498
1	65.0	98.7	475,813	35,475	2100	100	12.63	—	—
—	—	25.0	—	—	—	—	11.43	1.097	0.253

The following is an example of the C_D calculation for the 50% point (I-P):

$$LF = \frac{\left(\frac{50}{100}\right) \cdot 481{,}866}{483{,}502} = 0.498$$

$$C_D = (-0.13 \cdot 0.498) + 1.13 = 1.065$$

$$EER_{50\%} = \frac{0.498 \cdot 483{,}502}{0.498 \cdot [1.065 \cdot (35{,}261 + 2{,}100)] + 100}$$

The *IEER* can be calculated using these types of calculations for the 75%, 50%, and 25% points:

$IEER = (0.02 \cdot 10.54) + (0.617 \cdot 11.23) + (0.238 \cdot 12.09) + (0.125 \cdot 11.43) = 11.45$

The following is an example of the C_D calculation for the 50% point (SI):

$$LF = \frac{\left(\frac{50}{100}\right) \cdot 141{,}187}{141{,}666} = 0.498$$

$$C_D = (-0.13 \cdot 0.498) + 1.13 = 1.065$$

$$COP_{C,50\%} = \frac{0.498 \cdot 141{,}666}{0.498 \cdot [1.065 \cdot (35{,}261 + 2{,}100)] + 100}$$

The $ICOP_C$ can be calculated using these types of calculations for the 75%, 50%, and 25% points:

$ICOP_C = (0.02 \cdot 3.09) + (0.617 \cdot 3.29) + (0.238 \cdot 3.54) + (0.125 \cdot 3.35) = 3.35$

6.2.6.3 Example 3

For this example, the condensing unit has two stages of capacity.

The data in Table 13 and Table 14 are from actual unit measurements.

Table 13 Example 3 Data (I-P)

Stage	Ambient (°F)	Actual % Load (Capacity)	Saturated Suction (°F)	Capacity Btu/h	Compressor (P_C) (W)	Condenser Fan (P_{CF}) (W)	Control (P_{CT}) (W)	*EER* Btu/(W·h)
2	95.0	100	45.0	481,866	43,535	2100	100	10.54
2	81.5	114.8	45.0	553,300	42,746	2100	100	12.31
1	81.5	66.6	45.0	320,914	22,442	2100	100	13.02
1	68.0	53.2	45.0	256,400	17,125	2100	100	13.27
1	65.0	53.5	45.0	257,600	16,250	2100	100	13.96

Table 14 Example 3 Data (SI)

Stage	Ambient (°C)	Actual % Load (Capacity)	Saturated Suction (°C)	Capacity (W)	Compressor (P_C) (W)	Condenser Fan (P_{CF}) (W)	Control (P_{CT}) (W)	COP_C W/W
2	35.0	100	7.0	141,095	43,535	2100	100	3.09
2	27.5	114.8	7.0	162,012	42,746	2100	100	3.61
1	27.5	66.6	7.0	93,967	22,442	2100	100	3.82
1	20.0	53.2	7.0	75,077	17,125	2100	100	3.89
1	18.3	53.5	7.0	75428	16,250	2100	100	4.09

The 66.6% point and 114.8% point can be used to interpolate for the 75% point; however, the C_D factor is calculated for the 50% point and 25% point as shown in Table 15 and Table 16.

Table 15 Example 3 Calculations (I-P)

Stage	Ambient (°F)	Actual % Load (Capacity)	Capacity (Btu/h)	Compressor (P_C) (W)	Condenser Fan (P_{CF}) (W)	Control (P_{CT}) (W)	*EER* Btu/(W·h)	C_D	LF
2	95.0	100.0	481,866	43,535	2100	100	10.54	—	—
2	81.5	114.8	553,300	42,746	2100	100	12.31	—	—
—	—	75.0	—	—	—	—	12.90	—	—
1	81.5	66.6	320,914	22,442	2100	100	13.02	—	—
1	68.0	53.2	356,808	19,466	2100	100	16.47	—	—
—	—	50.0	—	—	—	—	15.77	1.042	0.675
1	65.0	53.5	257,600	16,250	2100	100	13.96	—	—
—	—	25.0	—	—	—	—	12.99	1.069	0.468

Using the above calculations, the *IEER* can be calculated as follows:

$IEER = (0.02 \cdot 10.54) + (0.617 \cdot 12.90) + (0.238 \cdot 15.77) + (0.125 \cdot 12.99) = 13.55$

Table 16 Example 3 Calculations (SI)

Stage	Ambient (°C)	Actual % Load (Capacity)	Capacity (W)	Compressor (P_C) (W)	Condenser Fan (P_{CF}) (W)	Control (P_{CT}) (W)	COP_C W/W	C_D	LF
2	35.0	100.0	141,095	43,535	2100	100	3.09	—	—
2	27.5	114.8	162,012	42,746	2100	100	3.61	—	—
—	—	75.0	—	—	—	—	3.78	—	—
1	27.5	66.6	93,967	22,442	2100	100	3.82	—	—
1	20.0	53.2	104,477	19,466	2100	100	4.83	—	—
—	—	50.0	—	—	—	—	4.62	1.042	0.675
1	18.3	53.5	104,709	16,250	2100	100	4.09	—	—
—	—	25.0	—	—	—	—	3.81	1.069	0.468

Using the above calculations, the $ICOP_C$ can be calculated as follows:

$$ICOP_C = (0.02 \cdot 3.09) + (0.617 \cdot 3.78) + (0.238 \cdot 4.62) + (0.125 \cdot 3.81) = 3.91$$

6.3 Tolerances

To comply with this standard, measured test results shall not be less than 95% of *published ratings* for *cooling capacity* and *EER* (*COP_C*). Results shall not be less than 90% of *published ratings* for *IEER* (*$ICOP_C$*).

Section 7. Minimum Data Requirements for Published Ratings

As a minimum, *published ratings* shall include all *standard ratings*. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with AHRI Standard 365 (SI/I-P)". All claims to ratings outside the scope of this standard shall include the statement "Outside the scope of AHRI Standard 365 (SI/I-P)". *Application ratings* within the scope of the standard shall include a statement of the conditions under which the ratings apply.

As a minimum, published ratings shall consist of the following information:

1) *Single number rating cooling capacity*, Btu/h (kW)
2) *Single number Standard Efficiency EER*, Btu/(W·h) or *single number rating COP_C* (W/W)
3) *IEER* (Btu/W h) or *$ICOP_C$* (W/W)

Section 8. Operating Requirements

8.1 Operating Requirements

To comply with this standard, any production *commercial and industrial unitary air-conditioning condensing unit* shall meet the requirements detailed herein.

8.2 Maximum Operating Conditions Test

Commercial and industrial unitary air-conditioning condensing units shall be designed and produced to pass the following maximum operating conditions tests. For multi-capacity units, these tests shall be conducted with the unit's controls set for maximum capacity.

8.2.1 Temperature Conditions

For all units:	
Air temperature surrounding unit	115°F dry-bulb temperature or 46.0°C dry-bulb temperature. For units or portions thereof intended to be installed only indoors, this temperature can be reduced to 95.0°F dry-bulb temperature or 35.0°C dry-bulb temperature.
Refrigerant entering condensing unit:	
Suction *dew point* temperature	50.0°F or 10.0°C
Return gas superheat	15.0°F or 8.3°C
For water-cooled units:	
Water temperature entering condenser	90.0°F or 32.0°C
Water temperature leaving condenser	100°F or 38.0°C
For air-cooled units:	
Outside air temperature	115°F dry-bulb temperature or 46.0°C dry-bulb temperature, and 75.0°F wet-bulb temperature or 24.0°C wet-bulb temperature when condensate is rejected to the condenser air stream at the standard condenser airflow rate specified and stated by the manufacturer.
For evaporatively-cooled units:	
Outside air temperature	100.0°F dry-bulb temperature or 38.0°C dry-bulb temperature
	80.0°F wet-bulb temperature or 27.0°C wet-bulb temperature
Make-up water temperature	90.0°F or 32.0°C

8.2.2 Voltages

Tests shall be conducted at the Range B minimum and maximum utilization voltages from Table 1 of AHRI 110 based on the unit's nameplate rated voltage(s). These voltages shall be supplied at the unit's service connection and at rated frequency. A lower minimum or a higher maximum voltage shall be used if listed on the nameplate.

8.2.3 Procedure

The condensing unit shall be operated continuously for two hours at the temperature conditions and voltage(s) specified. All power to the condensing unit shall be interrupted for a long enough period to cause the compressor to stop (not to exceed five seconds) and then be restored.

8.2.4 Requirements

During both tests, the condensing unit shall operate without failure of any of the unit's parts. The unit shall resume continuous operation within one hour of restoration of power and shall then operate continuously for one hour.

Note: Operation and resetting of safety devices prior to establishment of continuous operation is permitted.

Units with water-cooled condensers shall operate at maximum conditions with a water-pressure drop not to exceed 15.0 psi (100 kPa), measured across the unit.

8.3 Tolerances

The conditions for the tests outlined in Section 8.2 are average values subject to tolerances of ± 1.0°F or ± 0.6°C for air wet-bulb temperature and dry-bulb temperature, ± 0.5°F or ± 0.3°C for water temperatures, and ± 1.0% of the readings for specified voltages.

Section 9. Marking and Nameplate Data

As a minimum, the nameplate shall include the manufacturer's name, model designation, refrigerant designation in accordance with ASHRAE 34, and electrical characteristics.

Nameplate voltages for 60 Hz systems shall include one or more of the equipment nameplate voltage ratings shown in Table 1 of AHRI 110. Nameplate voltages for 50 Hz systems shall include one or more of the utilization voltages shown in Table 2 of AHRI 110.

Section 10. Conformance Conditions

While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard's Purpose (Section 1) and Scope (Section 2) unless such product claims meet all of the requirements of the standard and all of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard shall not reference, state, or acknowledge the standard in any written, oral, or electronic communication.

APPENDIX A. REFERENCES – NORMATIVE

This appendix lists all standards, handbooks, and other publications essential to the development and implementation of the standard. All references in this appendix are part of the standard.

A.1 ANSI/AHRI Standard 110-2024 (SI/I-P), *Air-Conditioning, Heating and Refrigerating Equipment Nameplate Voltages*, 2024, Air-Conditioning, Heating, and Refrigeration Institute, 2311 Wilson Blvd., Suite 400, Arlington, VA 22201, USA.

A.2 AHRI Standard 520-2004, *Performance Rating of Positive Displacement Condensing Units*, 2004, Air-Conditioning, Heating, and Refrigeration Institute, 2311 Wilson Blvd., Suite 400, Arlington, VA 22201, USA.

A.3 ASHRAE Standard 23-2022, *Methods for Performance Testing Positive Displacement Refrigerant Compressors and Compressor Units*, 2022, ASHRAE, 180 Technology Parkway, Peachtree Corners, Georgia 30092, USA.

A.4 ANSI/ASHRAE Standard 37-2009 (RA2019), *Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment*, 2019, ASHRAE, 180 Technology Parkway, Peachtree Corners, Georgia 30092, USA.

A.5 ASHRAE Terminology. Accessed November 28, 2023. https://www.ashrae.org/technical-resources/authoring-tools/terminology.

A.6 ANSI/ASHRAE 30-2019 *Method of Testing Liquid Chillers*, 2019, ASHRAE, 180 Technology Parkway, Peachtree Corners, Georgia 30092, USA.

A.7 ANSI/ASHRAE 41.1-2020 *Standard Methods for Temperature Measurement*, 2020, ASHRAE, 180 Technology Parkway, Peachtree Corners, Georgia 30092, USA.

APPENDIX B. REFERENCES – INFORMATIVE

This appendix lists standards, handbooks, and other publications not essential but that provide useful information and background. References in this appendix are not part of the standard.

None.

APPENDIX C. OUTDOOR AIR CONDITION MEASUREMENT – NORMATIVE

C.1 Purpose

This appendix includes modifications to the test stand setup and instrumentation as defined in ASHRAE 23, ASHRAE 37, and ASHRAE 30, and shall be used to be compliant with this standard.

C.2 General

Measure outdoor air entering dry-bulb temperature and water vapor content conditions that are required to be controlled for the test in accordance with the requirements in Section C.3. Maintain test operating and test condition tolerances and uniformity requirements as described in Section C.3.7.

C.3 Outdoor Air Entering Conditions

For cooling tests of both evaporatively-cooled equipment and air-cooled equipment that uses condensate obtained from the evaporator to enhance condenser cooling, measure the water vapor content as provided in Section C.3.2. For heating tests of all air-source heat pumps, measure water vapor content as provided in Section C.3.2.2.

C.3.1 Temperature Measurements

Measure temperatures in accordance with ASHRAE 41.1 and follow the requirements of Table 17. The specified accuracies shall apply to the full instrument systems including read-out devices. When using a grid of individual thermocouples rather than a thermopile, follow the thermopile temperature requirements of Table 17.

When measuring dry-bulb temperature for sampled air within the sampled air conduit rather than with the psychrometer as discussed in Section C.3.4, use a temperature sensor and instrument system, including read-out devices, with accuracy of ≤ ± 0.2°F or 0.2°C and display resolution of ≤ 0.1°F or 0.1°C.

Table 17 Temperature Measurement Requirements

Measurement	Accuracy, °F (°C)	Display Resolution, °F (°C)
Dry-bulb and wet-bulb temperatures[1]	≤ ± 0.2 (0.1°C)	≤ 0.1 (0.1°C)
Thermopile temperature	≤ ± 1.0 (0.5°C)	≤ 0.1 (0.5°C)

Note:

1. The accuracy specified is for the temperature indicating device and does not reflect the operation of the *aspirating psychrometer*.

To meet the requirements of Table 17, thermocouple wire shall have special limits of error and all thermocouple junctions in a thermopile shall be made from the same spool of wire; thermopile junctions are wired in parallel.

C.3.2 Psychrometer or Hygrometer Requirements

If measurement of water vapor is required, use one of the following two methods.

C.3.2.1 Aspirating Psychrometer

The *aspirating psychrometer* consists of a flow section and a fan to draw air through the flow section and measures an average value of the sampled air stream. The flow section shall be equipped with two dry-bulb temperature probe connections, one shall be used for the facility temperature measurement, and one shall be provided to confirm this measurement using an additional or a third-party's temperature sensor probe. For applications where the humidity is required for testing of evaporatively cooled units or heat pump unitary products in heating mode, the flow section shall be equipped with two wet-bulb temperature probe connection zones, and one shall be used for the facility wet-bulb measurement, and one shall be provided to confirm the wet-bulb measurement using an additional or a third-party's wet-bulb sensor probe. The *aspirating psychrometer* shall include a fan that can either be adjusted manually or automatically to maintain the required velocity of 1,000 fpm ± 200 fpm across the sensors. An example configuration for the *aspirating psychrometer* is shown in Figure 1.

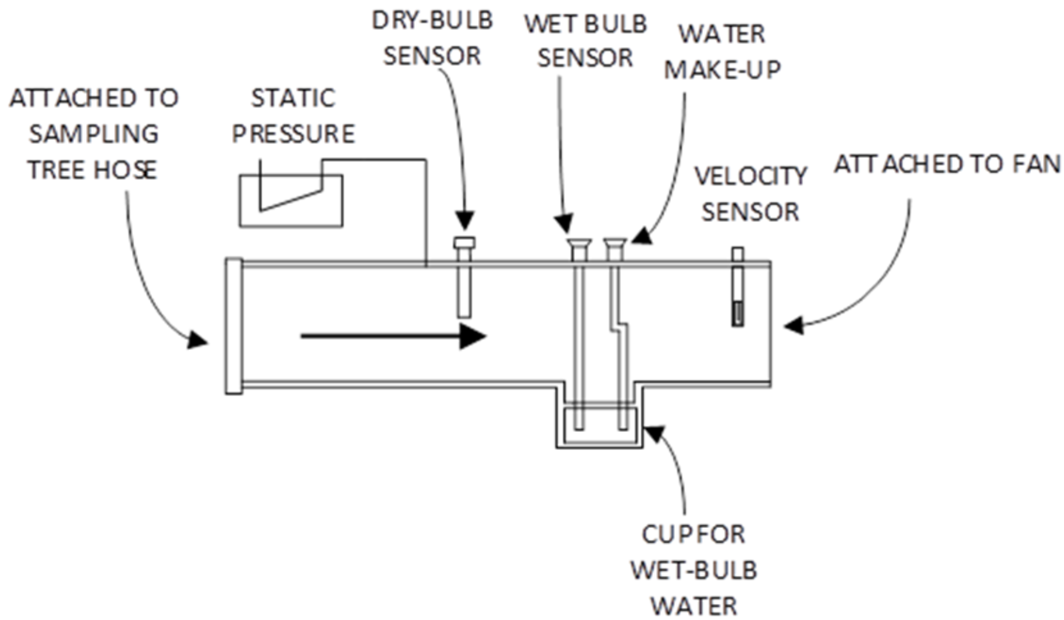

Figure 1 Aspirating Psychrometer

C.3.2.2 Dew-point Hygrometer

Measure *dew point* temperature using a *dew-point hygrometer* as specified in Section 4, Section 5, Section 6, Section 7.1, and Section 7.4 of ASHRAE 41.6 with an accuracy of within ± 0.4°F (±0.2°C). Use a dry-bulb temperature sensor within the sampled air conduit and locate the *dew-point hygrometer* downstream of the dry-bulb temperature sensor, and upstream of the fan.

C.3.3 Air Sampling Tree Requirements

The *air sampling tree* is intended to draw a uniform sample of the airflow entering the air-cooled or evaporatively-cooled outdoor section. An example configuration for the *air sampling tree* is shown in Figure 2 for a tree with overall dimensions of 4 ft by 4 ft or 10 cm by 10 cm sample.

Other sizes and rectangular shapes shall be permitted and shall be scaled accordingly as long as the aspect ratio (width to height) of not greater than 2 to 1 is maintained.

The *air sampling tree* shall be constructed of stainless steel, plastic, or other, durable materials and shall have a main flow trunk tube with a series of branch tubes connected to the trunk tube. The branch tubes shall have holes spaced and sized to provide equal airflow through all the holes by increasing the hole size as you move further from the trunk tube to account for the static pressure regain effect in the branch and trunk tubes. A minimum hole density of six holes per square foot of area to be sampled is required. The minimum average velocity through the *air sampling tree* holes shall be 2.5 ft/s or 0.76 cm/s as determined by evaluating the sum of the open area of the holes as compared to the flow area in the *aspirating psychrometer*. The assembly shall have a tubular connection to allow a flexible tube to be connected to the *air sampling tree* and to the *aspirating psychrometer*.

The outdoor inlet air sampling tree shall be equipped with a thermocouple thermopile grid or individual thermocouples to measure the average temperature of the airflow over the *air sampling tree*. Angled or wrap-around *air sampling trees* shall have a thermocouple thermopile grid or a grid of individual thermocouples to separately measure the average temperature for each plane, (such as each set of co-planar air sampling holes, of the *air sampling tree*. The *air sampling trees* shall be placed within 6-12 in or 15-30 cm from the unit to minimize the risk of damage to the unit while ensuring that the *air sampling trees* are measuring the air going into the unit rather than the room air around the unit. Confirm that that sampling holes are not pulling in the discharge air leaving the outdoor section of the unit under test. Any sampler holes directly exposed to the outdoor coil discharge air shall be blocked to prevent sampling. Blocking holes does not necessarily prevent thermal transfer on *air sampling tree* tubes, therefore portions of the *air sampling tree* tubes directly exposed to the outdoor coil discharge air shall be thermally shielded with a material with an R-value of 4-6 ft^2·°F·hr/Btu or 8-11 K/W.

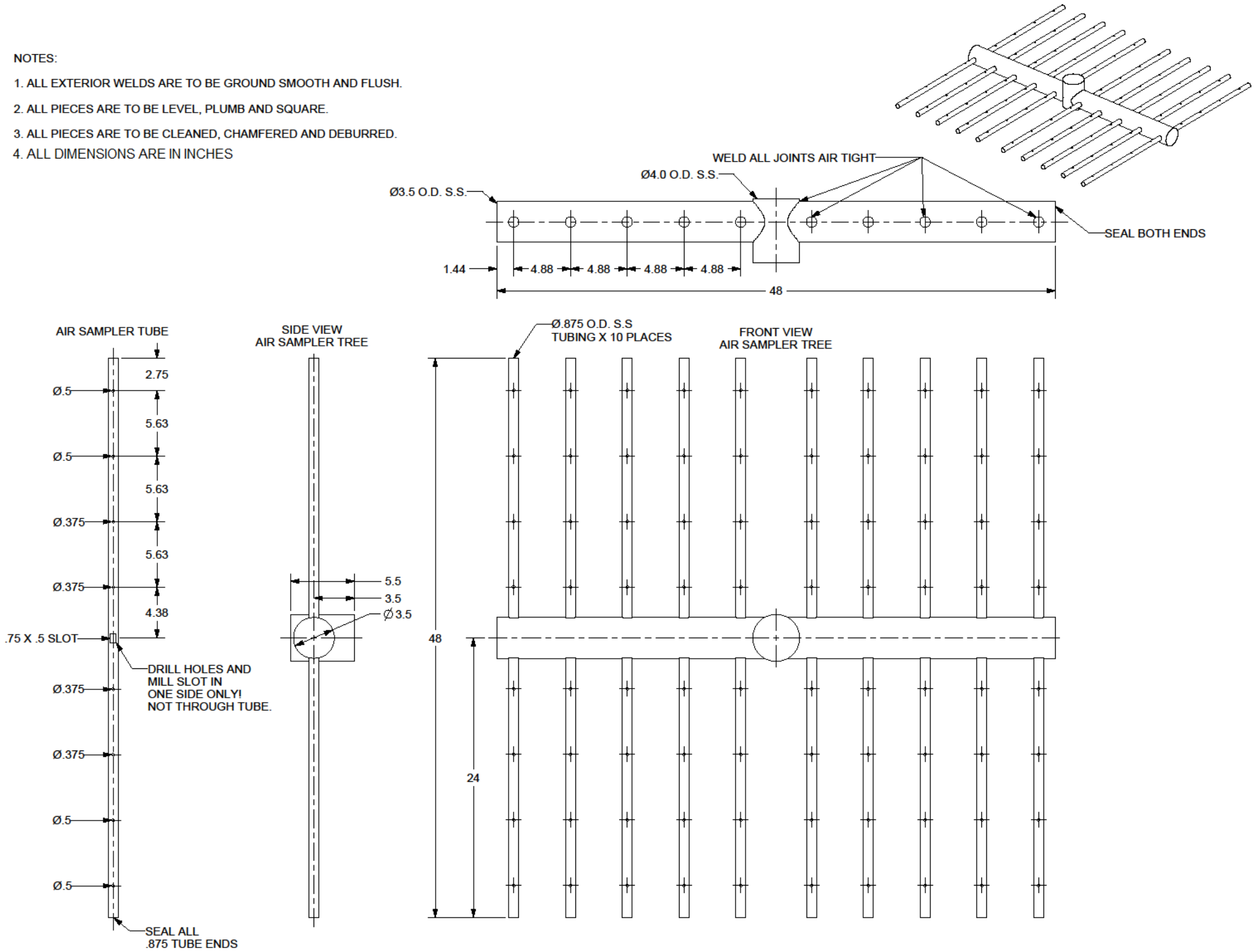

Figure 2 Example Air Sampling Tree (Informative)

Note: The 0.75 in by 0.50 in or 1.27 cm by 1.91 cm slots referenced in Figure 2 are cut into the branches of the *air sampling tree* and are located inside of the trunk of the *air sampling tree*. The slots are placed to let air be pulled into the main trunk from each of the branches.

C.3.3.1 Test Setup Description

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

The nominal face area can extend beyond the outdoor coil depending on coil configuration and orientation and shall include all regions where air enters the unit.

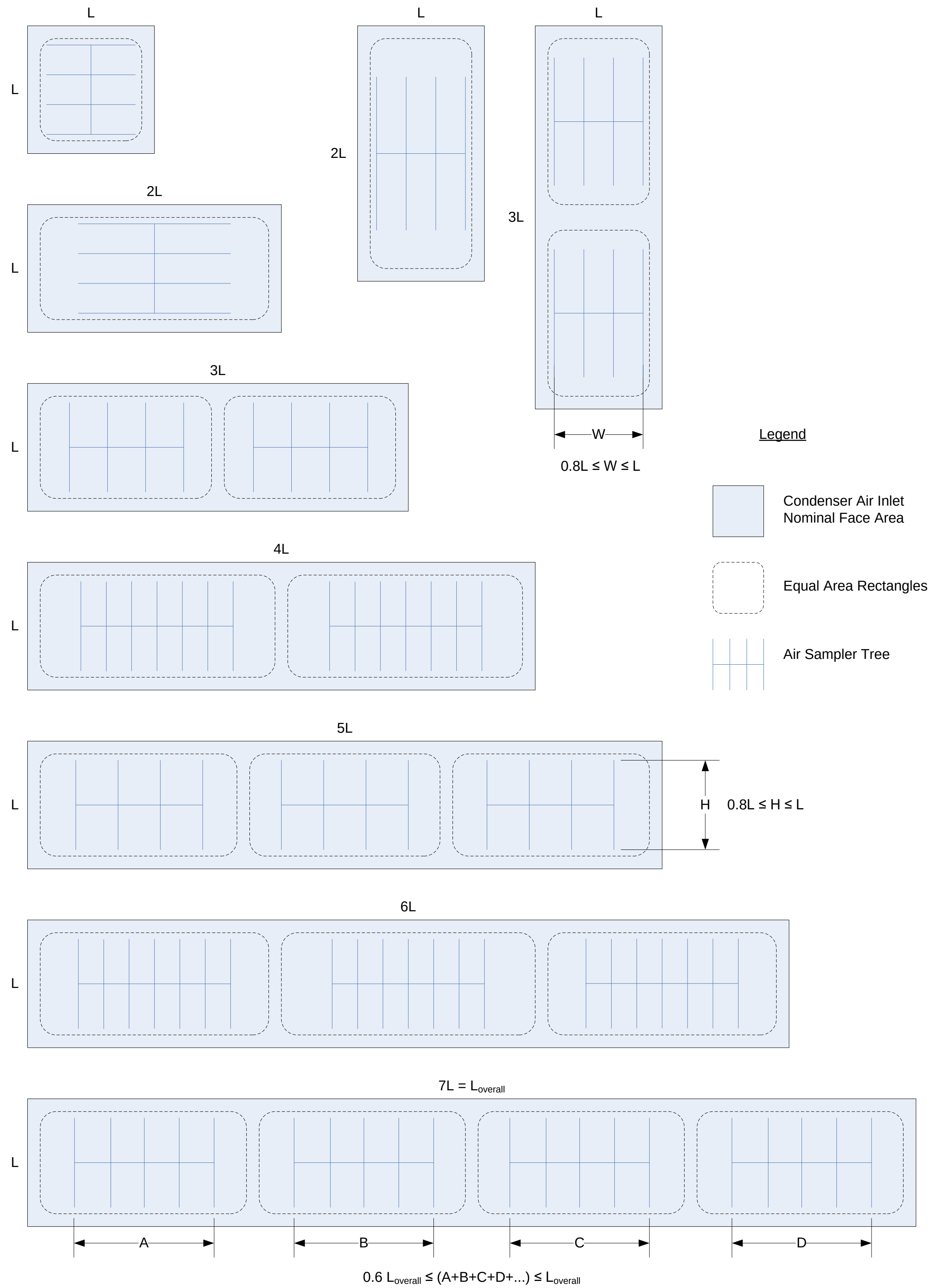

Figure 3 Determination of Measurement Rectangles and Required Number of Air Sampling Trees

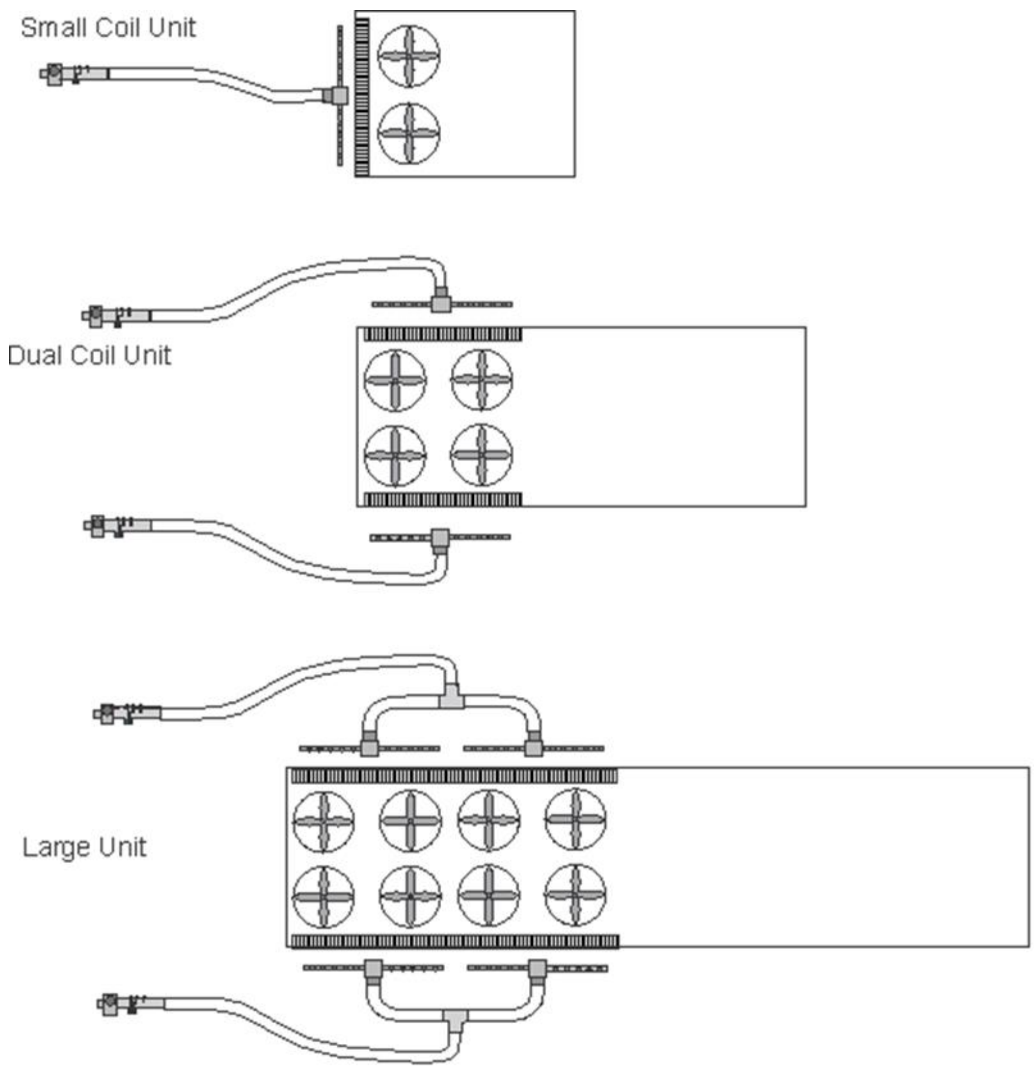

Figure 4 Example Test Setup Configurations (Informative)

A minimum of one *aspirating psychrometer* or *dew-point hygrometer* per side of a unit shall be used except for units with three or more sides. For units with three or more sides, two sampling *aspirating psychrometers* shall be used but shall require a separate *air sampling tree* for the third side. For units that have air entering the sides and the bottom of the unit, additional *air sampling trees* shall be used. For units that require more than eight *air sampling trees*, install a thermocouple thermopile grid or individual thermocouples on each rectangular area where an *air sampling tree* is not installed.

The *air sampling trees* shall be located at the geometric center of each rectangle; either horizontal or vertical orientation of the branches can be used. The *air sampling trees* shall cover at least 80% of the height and 60% of the width of the air entrance to the unit (for long horizontal coils) or shall cover at least 80% of the width and 60% of the height of the air entrance (for tall vertical coils). If the *air sampling trees* extend beyond the face of the air entrance area, block all branch inlet holes that extend beyond that area. Refer to Figure 3 for examples of how an increasing number of *air sampling trees* are required for longer outdoor coils.

C.3.4 Dry-bulb Temperature Measurement

Measure dry-bulb temperatures using the psychrometer dry-bulb sensors, or, if not using psychrometers, use dry-bulb temperature sensors with accuracy as described in Section C.3.1. Measure the dry-bulb temperature within the conduit at a location between the air sampler exit to the conduit and the air sampler fan. When a fan draws air through more than one air sampler, the dry-bulb temperature can be measured separately for each air sampler or for the combined set of air sampler flows. If dry-bulb temperature is measured at the air sampler exit to the conduit, the use of a thermocouple thermopile grid or a grid of individual thermocouples for duplicate measurement of dry-bulb temperature is not required—instead use the air-sampler-exit measurement when checking temperature uniformity.

C.3.5 Wet-Bulb or Dew Point Temperature Measurement to Determine Air Water Vapor Content

Measure wet-bulb temperatures using one or more psychrometers or measure *dew point* temperature using one or more hygrometers. If using hygrometers, measure *dew point* temperature within the conduit conducting air sampler air to the air-sampling fan at a location downstream of the dry-bulb temperature measurement. When a fan draws air through more than one air sampler, the *dew point* temperature can be measured separately for each air sampler or for the combined set of air sampler flows.

When more than one air sampler feeds a single water vapor content measurement instrument, measure relative humidity as required in Section C.3.1 to allow assessment of water vapor content uniformity.

C.3.6 Monitoring and Adjustment for Air Sampler Conduit Temperature Change and Pressure Drop

If dry-bulb temperature is measured at a distance from the air sampler exits, determine average conduit temperature change as the difference in temperature between the remote dry-bulb temperature and the average of thermopiles or thermocouple measurements of all air samplers collecting air that is measured by the remote dry-bulb temperature sensor. If this difference is greater than 0.5°F or 0.2°C, measure dry-bulb temperature at the exit of each air sampler, as described in Section C.3.4, and use these additional sensors to determine average indoor entering air dry-bulb temperature.

Measure gauge pressure at the sensor location of any instrument measuring water vapor content. If the pressure differs from room pressure by more than 2 in H_2O or 5 cm H_2O, use this gauge pressure measurement to adjust the atmospheric pressure used to calculate the humidity ratio (in units of pounds of moisture per pound of dry air) at the measurement location.

If either the 0.5°F temperature difference threshold or the 2 in H_2O or 0.5 kPa H_2O pressure difference threshold are exceeded, use a two-step process to calculate adjusted air properties, (for example, wet-bulb temperature or enthalpy, for the one or more affected air samplers. First, calculate the moisture level (pounds water vapor per pound dry air) at the humidity measurement location(s) using either the psychrometer dry-bulb and wet-bulb temperature measurements or the hygrometer *dew point* measurement, using for either approach the adjusted pressure, if it differs from the room atmospheric pressure by 2 in H_2O or 0.5 kPa or more. Then calculate the air properties for the air sampler location based on the moisture level, the room atmospheric pressure, and the dry-bulb temperature at the air sampler location. If the air sampler fan or *aspirating psychrometer* serves more than one air sampler, and the 0.5°F or 0.3°C threshold was exceeded, the dry-bulb temperature used in this calculation shall be the average of the air sampler exit measurements. For multiple air samplers, if humidity is measured using multiple hygrometers, the moisture level used in this calculation shall be the average of the calculated moisture levels calculated in the first step.

C.3.7 Temperature Uniformity

To guarantee air distribution, thorough mixing, and uniform air temperature, the room and test setup shall be designed and operated as described in this section. The room conditioning equipment airflow shall be set such that recirculation of outdoor discharged air is circumvented except as can naturally occur from the equipment. To check for the recirculation of outdoor discharged air back into the outdoor coil(s) the following method shall be used:

- Multiple individual reading thermocouples (at least one per air sampling tree location) shall be installed around the unit air discharge perimeter so that the thermocouples are below the plane of outdoor fan exhaust and just above the top of the outdoor coil(s).
- These thermocouples shall not indicate a temperature difference greater than 5.0°F from the average inlet air.
- Air distribution at the test facility, at the point of supply to the unit, shall be reviewed to determine if the air distribution requires remediation prior to beginning testing.

Mixing fans can be used to provide air distribution in the test room. If used, mixing fans shall be pointed away from the air intake so that the mixing fan exhaust direction is at an angle of 90°-270° to the air entrance to the outdoor air inlet. Pay particular attention to prevent recirculation of outdoor fan exhaust air back through the unit.

When not using psychrometers, the "psychrometer dry-bulb temperature measurement" of Table 18 refers to either (a) the dry-bulb temperature measurement in a single common air conduit serving one or more air samplers or (b) the average of the dry-bulb temperature measurements made separately for each of the air samplers served by a single air sampler fan. Similarly, "wet-bulb temperature" refers to calculated wet-bulb temperatures based on *dew point* measurements.

Adjust measurements if required by Section C.3.6 prior to checking uniformity.

The 1.5°F dry-bulb temperature tolerance in Table 18 between the air sampler thermopile (thermocouple) measurements and psychrometer measurements only applies when more than one air sampler serves a given psychrometer. See Note 2 in Table 18.

The uniformity requirements apply to test period averages rather than instantaneous measurements.

A valid test shall meet the criteria for air distribution and control of air temperature as shown in Table 18.

Table 18 Uniformity Criteria for Outdoor Air Temperature and Humidity Distribution

Uniformity Criterion[1]	Purpose	Maximum Variation, °F (°C)
Deviation from the mean air dry-bulb temperature to the air dry-bulb temperature at any individual temperature measurement station	Uniform dry-bulb temperature distribution	± 2.0 (1.1)
Difference between dry-bulb temperature measured with *air sampler tree* thermopile and with *aspirating psychrometer*[2]	Uniform dry-bulb temperature distribution	± 1.5 (0.8)
Deviation from the mean wet-bulb temperature and the individual temperature measurement stations[3]	Uniform humidity distribution	± 1.0 (0.46)

Notes:

1. The uniformity requirements apply to test period averages for each parameter rather than instantaneous measurements. Each measurement station represents a single *aspirating psychrometer*. The mean temperature is the mean of temperatures measures from all measurement stations.
2. Applies when multiple air samplers are connected to a single psychrometer or conduit dry-bulb temperature sensor. If the average of the thermopile measurements differs from the psychrometer or conduit dry-bulb temperature sensor measurement by more than 0.5°F or .3°C, use air-sampler exit dry-bulb temperature sensors. For this case, the uniformity requirement is based on comparison of each of the air-sampler exit measurements with the average of these measurements.
3. The wet-bulb temperature measurement is used for outdoor entering air for evaporatively-cooled units and heat pump units operating in heating mode.

APPENDIX D. METHOD OF TESTING AIR CONDITIONING CONDENSING UNIT PRODUCTS – NORMATIVE

D.1 Purpose

This appendix prescribes the test procedures used for testing commercial and industrial condensing units. The testing of AHRI 365 products shall comply with ASHRAE 23, ASHRAE 37, and ASHRAE 30 with the additional requirements described in this appendix.

D.2 Atmospheric Pressure

Test data is only valid for tests conducted when the atmospheric pressure is greater than 13.700 psia.

D.3 Outdoor Air Temperature Measurement

The outdoor air temperature, as applicable shall be measured using the procedures defined in Appendix C.

D.4 Minimum Data Collection Requirements

Either power (in W) or integrated power (in W·h) shall be measured. Units with digitally modulating compressors shall have either of the following:

1) an integrated power measurement
2) power measurements recorded at intervals no longer than one second.

D.5 Test Methods for Capacity Measurement

Because this standard is only for rating the condensing unit, an indoor heat exchanger shall be used. For ease of testing, a refrigerant to water heat exchanger and a chiller water test loop shall be used following the testing procedure outlined in ASHRAE 30 for chiller water systems.

There are no requirements for secondary tests other than the use of redundant flow meters for water flow measurements as defined in ASHRAE 30.

D.5.1 Net Refrigerating Capacity

The net refrigerating capacity, Btu/h, for the evaporator shall use the water temperatures, water mass flow rate and water properties at the evaporator entering and leaving conditions and be calculated using Equation 7.

$$Q_{ev} = m_w \cdot c_p \cdot (T_{in} - T_{out}) \qquad 7$$

Where:

Q_{ev} = Net capacity of evaporator, Btu/h (kW)

m_w = Mass flow rate, water lb/hr (kg/s)

c_p = Specific heat at constant pressure, Btu/lb °F (J/kg K)

T_{in} = Entering water temperature (°C)

T_{out} = Leaving water temperature (°C)

Specific heat c_p is taken at the average of entering and leaving water temperatures. When expressing water flow rate in volumetric terms for ratings, the conversion from mass flow rate shall use water density corresponding to entering water temperature. Refer to Equation 8.

D.5.2 Waterside Properties Calculation Methods

One of the following calculation methods shall be utilized. In both cases, the value of the water temperature or pressure to be used as input is dependent on the context of the calculation using the density and specific heat terms. This standard shall be used where discrepancies exist between these methods and those prescribed by ASHRAE 30.

Method 1. Use NIST REFPROP software version 10.0 or later to calculate physical properties density and specific heat, as a function of both pressure and temperature.

Method 2. Use polynomial Equation 8 and Equation 9 respectively to calculate density and specific heat of water as a function of temperature only.

$$\rho = (\rho_4 \cdot T^4) + (\rho_3 \cdot T^3) + (\rho_2 \cdot T^2) + (\rho_1 \cdot T) + \rho_0 \qquad \textbf{8}$$

Where:

ρ_0	=	62.227 lb_m/ft^3 (1000.2 kg/m^3)
P_1	=	$1.2164 \cdot 10^{-2}$ lb_m/ft^3 ($4.6734 \cdot 10^{-2}$ kg/m^3)
ρ_2	=	$-1.8846 \cdot 10^{-4}$ lb_m/ft^3 ($-7.3948 \cdot 10^{-3}$ kg/m^3)
ρ_3	=	$5.2643 \cdot 10^{-7}$ lb_m/ft^3 ($4.0229 \cdot 10^{-5}$ kg/m^3)
ρ_4	=	$-7.4704 \cdot 10^{-10}$ lb_m/ft^3 ($-1.2556 \cdot 10^{-7}$ kg/m^3)
T	=	Water temperature (32 to 212) °F (0 to 100) °C

$$c_p = (c_{p5} \cdot T^5) + (c_{p4} \cdot T^4) + (c_{p3} \cdot T^3) + (c_{p2} \cdot T^2) + (c_{p1} \cdot T) + c_{p0} \qquad \textbf{9}$$

Where:

C_{p0}	=	1.0295 Btu / $lb_m \cdot °F$ (4.2160 kJ/kg·K)
C_{p1}	=	$-1.0677 \cdot 10^{-3}$ Btu / $lb_m \cdot °F$ ($-3.1103 \cdot 10^{-3}$ kJ/kg·K)
C_{p2}	=	$1.4071 \cdot 10^{-5}$ Btu / $lb_m \cdot °F$ ($9.4433 \cdot 10^{-5}$ kJ/kg·K)
C_{p3}	=	$-9.2501 \cdot 10^{-8}$ Btu / $lb_m \cdot °F$ ($-1.3901 \cdot 10^{-6}$ kJ/kg·K)
C_{p4}	=	$3.1031 \cdot 10^{-10}$ Btu / $lb_m \cdot °F$ ($1.0770 \cdot 10^{-8}$ kJ/kg·K)
C_{p5}	=	$-4.0739 \cdot 10^{-13}$ Btu / $lb_m \cdot °F$ ($-3.2220 \cdot 10^{-11}$ kJ/kg·)
T	=	Water temperature 32 to 21)°F or 0 to 100°C)

Note: Density and specific heat polynomial equations are curve fit from data generated by NIST REFPROP v10.0, see Appendix A, at 100 psia or 689.5 kPa and using a temperature range of 32°F to 212°F or 0°C to 100°C. The 100 psia or 689.5 kPa value used for the water property curve fits is a representative value to calculate water side properties as a function of temperature only. This eliminates the complexity of measuring and calculating water side properties as a function of both temperature and pressure. This assumption, in conjunction with a formulation for capacity that does not make explicit use of enthalpy values, provides a mechanism for computing heat exchanger capacity for fluids other than pure water where specific heat data are generally known but enthalpy curves are not provided.

D.6 Head Pressure Control for Air-cooled, Water-cooled, and Evaporatively-cooled Units

For units that have condenser head pressure control to maintain the flow of refrigerant through the expansion valve during low condenser temperature conditions, the head pressure controls shall be enabled and operate in automatic control mode. The setting shall be set at the factory settings or as defined in the *MII*.

If the head pressure control is engaged by the control logic during part-load cooling tests, then use the following steps. For all part-load cooling tests for water-cooled units, the water flow rate shall not exceed the value for the full-load cooling test.

D.6.1 Control Logic

The control logic shall control the operation of the unit. If the unit can be run and stable conditions are obtained, meaning the test tolerances in Table 10 are met, then a standard part-load cooling test shall be run.

D.6.2 Head Pressure Control Time Average Test

If the head pressure control results in unstable conditions, such as test tolerances in Table 19 cannot be met), then a series of two steady-state one-hour tests shall be run. Prior to the first one-hour test, the condenser entering temperature, meaning outdoor air dry-bulb temperature or condenser water temperature), described in Table 6 and Table 7 shall be approached from at least a 10°F or 5.5°C higher temperature until the tolerances specified in Table 19 are met. Prior to the second one-hour test, the condenser entering temperature defined by Table 6 and Table 7 shall be approached from at least a 5°F or 2.8°C lower temperature until the tolerances specified in Table 19 are met. For each test, once all tolerances in Table 19 are met, the one-hour test shall be started and test data shall be recorded every five minutes for one hour, resulting in twelve test measurements for each test parameter. During each one-hour test, the tolerances specified in Table 19 shall be met.

Table 19 Tolerances for Head Pressure Control Time Average Test

Measured Value		Operating Tolerance	Condition Tolerance
Outdoor air dry-bulb temperature °F (°C)	Entering	3.0 (1.7)	1.0 (0.59)
	Leaving	—	—
Outdoor air wet-bulb temperature °F (°C)	Entering	1.5 (0.83)	0.5 (0.28) [1]
	Leaving	—	—
Water serving outdoor coil temperature °F (°C)	Entering	0.75 (0.42)	0.3 (0.17)
	Leaving	0.75 (0.42)	—
Voltage		2%	1%

Note:

1. Applies only for air-cooled systems that evaporate condensate, evaporatively-cooled systems, and single package units that have the indoor coil located in the outdoor chamber

If the tolerances in Table 19 are met, the tests results for both one-hour steady-state test series shall then be averaged to determine the capacity and efficiency that is then used for the *IEER* calculation.

D.6.3 Meeting Tolerances

If the tolerances in Table 19 cannot be met for the head pressure control time average test, *STI* shall be used to determine the settings required to stabilize operation. However, if *STI* do not provide guidance for stable operation or operation in accordance with *STI* results in a condensing (liquid outlet) pressure corresponding to a *bubble point* temperature less than 75°F or 24°C, proceed to the next step.

D.6.4 Stable Operation

If *STI* are not used to provide stable operation, the fan(s) for air-cooled and evaporatively-cooled units or valve(s) for water-cooled units causing the instability shall be set manually at a speed, operating state (on/off), or position to achieve a condensing (liquid outlet) pressure corresponding to a *bubble point* temperature as close to 85°F or 29°C as achievable while remaining not lower than 85°F or 29°C.

D.7 Setup Provisions for Evaporatively Cooled Units

D.7.1 Makeup Water Temperature

For evaporatively cooled units the *makeup water* shall be maintained at the temperatures specified in Table 6. This can be done using one of the following options:

- Turn the *makeup water* off during the test and use just the water in the evaporatively cooled condenser sump.
- Heat or cool the *makeup water* to the ambient outdoor air dry-bulb temperature or feed the makeup water from an external tank that is exposed to the outdoor air dry-bulb test temperature.

D.7.2 Blow-down Water

Any blow-down water used for control of material byproducts of evaporation shall be turned off during the test.

D.7.3 Purge Water Settings

For evaporatively-cooled systems that purge sump water to reduce mineral and scale buildup on the condenser heat exchanger, the purge water settings shall be set in accordance with manufacturer's instructions.

Note: If the manufacturer's instructions give multiple options for purge rate, such as for hard water or soft water, or indicate a range of values for the purge rate, the median of the listed purge rates should be used.

If the median of the listed purge rates cannot be achieved, the next highest purge rate above the median that can be achieved shall be used. If the manufacturer's instructions regarding the purge rate are not given, the factory settings for the purge rate shall be used.