ANSI/AHRI Standard 551/591-2023 (SI)

2023 Standard for

Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle

Approved American National Standard
ANSI

Approved by ANSI on 5 June 2023

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Note:

This standard supersedes AHRI Standard 551/591-2020 (I-P) (Addendum 1).
For SI ratings, see AHRI Standard 550/590-2023 (I-P).

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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.

2023 Edition

This edition of ANSI/AHRI 551/591 (SI), *Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle*, was prepared by Chiller Standards Technical Committee. The standard was approved by the Applied Standards Subcommittee on 6 February 2023. The standard was approved as an American National Standard (ANS) on 5 June 2023.

Origin and Development of AHRI Standard number

The initial publication was AHRI Standard 551/591-2011, *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle*. Subsequent revisions were:

ANSI/AHRI Standard 551/591 (SI) with Addendum 1-2012, *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle*

AHRI Standard 551/591 (SI)-2011 (with Addenda 1 and 2), *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle*

AHRI Standard 551/591 (SI)-2011 (with Addenda 1, 2 and 3), *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle*

AHRI Standard 551/591 (SI)-2015, *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle*

AHRI Standard 551/591 (SI)-2015 (with Errata), *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle (with Errata)*

AHRI Standard 551/591 (SI)-2015 (with Addendum 1), *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle (with Addendum 1)*

AHRI Standard 551/591 (SI)-2018, *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle*

AHRI Standard 551/591 (SI)-2018 (with Errata), *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle*

AHRI Standard 551/591 (SI)-2020, *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle*

AHRI Standard 551/591-2020 (SI) (Addendum 1), *Performance Rating of Water-chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle*

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Summary of Changes

ANSI/AHRI Standard 551/591-2023 (SI) contains the following update(s) to the previous edition:

- Revise current ANS to align with 2020 versions
- Incorporate Addendum 1 from AHRI 551/591-2020 (SI)
- Addresses three interpretations to AHRI 551/591-2020 (SI)
    - Interpretation to AHRI Standards 550/590 – 2020 (I-P) and 551/591 – 2020 (SI) – 1
    - Interpretation to AHRI Standards 550/590 – 2020 (I-P) and 551/591 – 2020 (SI) – 2
    - Interpretation to AHRI Standards 550/590 – 2020 (I-P) and 551/591 – 2020 (SI) – 3
- Editorial corrections and minor clarifications as needed
- Update references

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Chiller Standards Technical Committee Scope:

The Chiller Standards Technical Committee is responsible for the development and maintenance of AHRI standards and guidelines pertaining to Performance Rating of Liquid-Chilling and Heat Pump Liquid-Heating Packages using the Vapor Compression Cycle, Absorption Liquid Chilling and Liquid Heating Packages, Fouling Factor Applications related to Air Conditioning and Refrigeration, and Non-condensable Gas Purge Equipment for use with Low Pressure Centrifugal Liquid Chillers.

Out of scope for this STC are water-to-water heat pumps with a capacity less than 135,000 Btu/h as covered by ASHRAE/AHRI/ISO Standard 13256-2, and air-to-water units designed exclusively to heat potable water as covered by AHRI Standard 1300.

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The scope of the Applied Standards Subcommittee is standards and guidelines related to the end products that are part of the AHRI Applied Industry Sector. (The definition of and list of products associated with each sector are found on the AHRI website.

These lists represent the membership at the time the Standards Technical Committee and Standards Subcommittee were balloted on the final text of this edition. Since that time, changes in the membership may have occurred. Membership on these committees shall not in and of itself constitute an endorsement by the committee members or their employers of any document developed by the committee on which the member serves.

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PERFORMANCE RATING OF WATER-CHILLING AND HEAT PUMP WATER-HEATING PACKAGES USING THE VAPOR COMPRESSION CYCLE

Section 1. Purpose

1.1 *Purpose*. This standard establishes definitions, test requirements, rating requirements, minimum data requirements for Published Ratings, marking and nameplate data, conversions and calculations, nomenclature, and conformance conditions for Water-chilling and Heat Pump Water-heating Packages using the vapor compression cycle.

Section 2. Scope

2.1 *Scope*. This standard applies to factory-made Water-chilling and Water-heating Packages utilizing the vapor compression cycle as defined in Section 3. These Water-chilling and Water-heating Packages include:

2.1.1 Water-cooled, Air-cooled, or Evaporatively-cooled Condensers
2.1.2 Water-cooled heat recovery Condensers
2.1.3 Air-to-water heat pumps
2.1.4 Water-to-water heat pumps with a Capacity greater or equal to 40 kW.

2.2 *Exclusions.*

2.2.1 Water-to-water heat pumps with a Capacity less than 40 kW are covered by the latest edition of ASHRAE/ANSI/AHRI/ISO Standard 13256-2.

2.2.2 Air-to-water units designed exclusively to heat potable water as covered by the latest edition of ANSI/AHRI Standard 1300.

2.2.3 Water-chilling Packages are excluded when the Condenser is actively adiabatically-cooled. An adiabatically-cooled Condenser is an Air-cooled Condenser that uses evaporative cooling to pre-cool air before that air reaches the dry heat transfer surface.

2.2.4 Water-chilling or Water-heating packages with both an Air-cooled Condenser and a Water-cooled Condenser are outside the scope of this standard when operating in any mode (cooling, heating, heat recovery, or simultaneous heating and cooling) with the heat rejection split between the Air-cooled Condenser and Water-cooled Condenser.

2.2.5 Units with Evaporators or Condensers that use any liquid other than water are outside the scope of this standard.

Section 3. Definitions

All terms in this document follow the standard industry definitions in the *ASHRAE Terminology* website unless otherwise defined in this section.

3.1 *Expressions of Provision.* 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.

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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 *Auxiliary Power*. Power provided to devices that are not integral to the operation of the vapor compression cycle such as, but not limited to: oil pumps, refrigerant pumps, control power, fans and heaters.

3.2.2 *Bubble Point.* Refrigerant liquid saturation temperature at a specified pressure.

3.2.3 *Capacity*. A measurable physical quantity that characterizes the water side heat flow rate. Capacity is the product of the water mass flow rate and the change in water enthalpy entering and leaving the heat exchanger, measured at the point of the field connection. For this standard, the enthalpy change is approximated as the sensible heat transfer using specific heat and temperature difference.

3.2.3.1 *Net Heating Capacity.* The Capacity of the heating Condenser available for useful heating of the thermal load external to the Water-heating Package and is calculated using only the sensible heat transfer. (Refer to Equations 20 and 21.)

3.2.3.2 *Net Refrigerating Capacity*. The Capacity of the Evaporator available for cooling of the thermal load external to the Water-chilling Package and it is calculated using only the sensible heat transfer. (Refer to Equation 18.)

Note: The method of test referenced in Sections 4.1 and 4.2 defines and makes use of gross heating capacity and gross refrigerating capacity, which consider the energy associated with water-side pressure losses.

3.2.4 *Compressor Saturated Discharge Temperature.* For single component and azeotrope refrigerants, it is the saturated temperature corresponding to the refrigerant pressure at the compressor discharge measured downstream of any refrigerant circuit components like mufflers, oil separators and discharge valves at the point of field connection. For zeotropic refrigerants, it is the arithmetic average of the Dew Point and Bubble Point temperatures corresponding to refrigerant pressure at the compressor discharge.

3.2.5 *Condenser*. A refrigeration system component which condenses refrigerant vapor. Desuperheating and sub-cooling of the refrigerant can occur as well.

3.2.5.1 *Air-cooled Condenser.* A component which condenses refrigerant vapor by rejecting heat to air mechanically circulated over its heat transfer surface causing a rise in the air temperature.

3.2.5.2 *Evaporatively-cooled Condenser.* A component which condenses refrigerant vapor by rejecting heat to a water and air mixture mechanically circulated over its heat transfer surface, causing evaporation of the water and an increase in the enthalpy of the air.

3.2.5.3 *Remote Condenser.* Any Condenser that is installed as a separate assembly from the rest of the Water-chilling or Water-heating Package with field installed interconnecting piping.

3.2.5.4 *Water-cooled Condenser.* A component which utilizes refrigerant-to-water heat transfer means, causing the refrigerant to condense and the water to be heated.

3.2.5.5 *Water-cooled Heat Recovery Condenser.* A component or components which utilizes refrigerant-to-water heat transfer means, causing the refrigerant to condense and the water to be heated. This Condenser can be a separate Condenser, the same as, or a portion of the Water-cooled Condenser. The heat rejected can be done through a single or multiple heat exchangers, including desuperheaters as defined in ANSI/AHRI Standard 470.

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3.2.6 *Dew Point.* Refrigerant vapor saturation temperature at a specified pressure.

3.2.7 *Energy Efficiency.*

3.2.7.1 Cooling Energy Efficiency.

3.2.7.1.1 *Cooling Coefficient of Performance (COP_R).* A ratio of the Net Refrigerating Capacity to the Total Input Power at any given set of Rating Conditions. (Refer to Equation 14.)

3.2.7.2 Heating Energy Efficiency.

3.2.7.2.1 *Heating Coefficient of Performance (COP_H).* A ratio of the Net Heating Capacity to the Total Input Power at any given set of Rating Conditions. (Refer to Equation 15.)

3.2.7.3 Energy efficiency metrics for simultaneous heating and cooling operating modes.

3.2.7.3.1 *Heat Recovery Coefficient of Performance (COP_{HR}).* A ratio of the Net Heat Recovery Capacity plus the Net Refrigerating Capacity to the Total Input Power at any given set of Rating Conditions. COP_{HR} applies to units that are operating in a manner that uses either all or only a portion of heat generated during chiller operation, Q_{hrc}, to heat a load, while the remaining heat, Q_{cd}, if any, is rejected to the outdoor ambient. COP_{HR} takes into account the beneficial cooling Capacity, Q_{ev}, as well as the Heat Recovery Capacity, $Q_{hrc.}$ (Refer to Equation 16.)

3.2.7.3.2 *Simultaneous Heating and Cooling Coefficient of Performance (COP_{SHC}).* A ratio of the Net Heating Capacity plus the Net Refrigerating Capacity to the Total Input Power at any given set of Rating Conditions. COP_{SHC} applies to units that are operating in a manner that uses both the net heating and refrigerating capacities generated during operation. COP_{SHC} takes into account the beneficial Capacity, Q_{ev}, as well as the heating Capacity, Q_{cd},. (Refer to Equation 17.)

3.2.8 *Evaporator*. A refrigeration system component which evaporates refrigerant liquid. Superheating of the refrigerant can occur as well.

3.2.8.1 *Remote Evaporator.* Any Evaporator that is installed as a separate assembly from the rest of the Water-chilling or Water-heating Package with field installed interconnecting piping.

3.2.9 *Fouling Factor (R_{foul}).* The thermal resistance due to fouling accumulated on the water side or air side heat transfer surface.

3.2.9.1 *Fouling Factor Allowance ($R_{foul,sp}$).* A specified value for Published Ratings as a provision for anticipated thermal resistance due to water side or air side fouling during use, expressed in $m^2 \cdot K/kW$.

3.2.10 *Liquid Refrigerant Temperature*. The temperature of the refrigerant liquid leaving the Condenser but prior to the expansion device.

3.2.11 *Part-load Value (PLV).* A single number figure of merit expressing part-load efficiency for equipment on the basis of weighted operation at various partial load capacities for the equipment.

3.2.11.1 *Integrated Part-load Value (IPLV.SI).* A single number part-load efficiency figure of merit calculated per the method described in this standard at Standard Rating Conditions.

3.2.11.2 *Non-Standard Part-load Value (NPLV.SI).* A single number part-load efficiency figure of merit calculated per the method described in this standard referenced to conditions other than IPLV.SI conditions (i.e. for units that are not designed or selected to operate at Standard Rating Conditions).

3.2.12 *Percent Load (%Load).* The ratio of the part-load rated net Capacity to the Full Load Capacity, stated in decimal format (e.g.100% = 1.0).

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3.2.12.1 *Full Load (100% Load).* The highest Capacity at which the chiller has been rated at specific conditions. Corresponds to the 100% Load point utilized in IPLV.SI or NPLV.SI.

3.2.13 *Published Ratings*. A statement of the assigned values of those performance characteristics, under stated Rating Conditions, by which a unit can be chosen to fit its application. These values apply to all units of like nominal size and type (identification) produced by the same manufacturer. The term Published Rating 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.

3.2.13.1 *Application Rating.* A rating based on tests performed at Application Rating Conditions (other than Standard Rating Conditions).

3.2.13.2 *Standard Rating*. A rating based on tests performed at Standard Rating Conditions.

3.2.14 *Rating Conditions*. Any set of operating conditions under which a single level of performance results and which causes only that level of performance to occur.

3.2.14.1 *Appplication Rating Conditions*. A set of operating conditions within the range of Table 5 selected for a customer application (other than Standard Rating Conditions).

3.2.14.1 *Standard Rating Conditions*. A set of operating conditions used as the basis of comparison for performance characteristics, per Table 4.

3.2.15 *Significant Figure(s)*. Each of the digits of a number that are used to express it to the required degree of accuracy, starting from the first nonzero digit. (Refer to Sections 4.3 and 6.2.)

3.2.16 *Total Input Power (W_{input})*. Combined power input of all components of the unit, including Auxiliary Power and excluding integral pumps.

3.2.17 *Water-chilling or Water-heating Package.* A factory-made and prefabricated assembly (not necessarily shipped as one package) of one or more compressors, Condensers and Evaporators, with interconnections and accessories designed for the purpose of cooling or heating water. It is a machine specifically designed to make use of a vapor compression refrigeration cycle to remove heat from water and reject the heat to a cooling medium, usually air or water. The refrigerant Condenser can be an integral or separate part of the package.

3.2.17.1 *Heat Recovery Water-chilling Package*. A factory-made package designed for the purpose of chilling water and containing a Condenser for recovering heat. Where such equipment is provided in more than one assembly, the separate assemblies are to be designed to be used together, and the requirements of rating outlined in this standard are based upon the use of matched assemblies. It is a package specifically designed to make use of the refrigerant cycle to remove heat from the water source and to reject the heat to another fluid for heating use. Any excess heat can be rejected to another medium, usually air or water.

3.2.17.2 *Heat Pump Water-heating Package*. A factory-made package designed for the purpose of heating water. Where such equipment is provided in more than one assembly, the separate assemblies are to be designed to be used together, and the requirements of rating outlined in this standard are based upon the use of matched assemblies. It is a package specifically designed to make use of the refrigerant cycle to remove heat from an air or water source and to reject the heat to water for heating use. This unit can include valves to allow for reverse-cycle (cooling) operation.

3.2.17.3 *Condenserless Chiller*. A factory-made package designed for the purpose of chilling water but is not supplied with a Condenser. A separate air, water or evaporatively cooled Condenser interfaces with the Condenserless Chiller.

3.2.18 *Water Pressure Drop*. The reduction in static water pressure associated with the flow through a water-type heat exchanger.

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Section 4. Test Requirements

4.1 *Test Requirements*. Ratings shall be established at the Rating Conditions specified in Section 5. Testing to validate ratings shall be conducted in accordance with the test method and procedures described in this standard and ANSI/ASHRAE Standard 30. Where there are discrepancies between this standard and ANSI/ASHRAE Standard 30, this standard shall prevail.

4.2 Tests shall report measurement values and calculated results in accordance with methods and procedures described in ANSI/ASHRAE Standard 30. Refer to Appendix E for examples showing average data samples collected between each time stamp for the test data points in accordance with ANSI/ASHRAE Standard 30.

4.3 *Rounding.* Calculations shall use measurement values without rounding as defined below. Reported measurement data and calculated test results shall round values to a number of Significant Figures per Section 6. Energy balance and voltage balance shall be rounded to four (4) Significant Figures.

4.3.1 Numerical data are often obtained (or at least calculations can be made) with more digits than are justified by their accuracy or precision. For clarity, such data shall be rounded to the number of figures consistent with the confidence that can be placed in them when reported in final form. However, more digits shall be retained at intermediate stages of calculation to avoid compounding of rounding errors; retain no less than two additional Significant Figures than the final reported value, or as many digits as possible. The number of Significant Figures is the number of digits remaining when the data are rounded.

4.3.2 The rules for identifying Significant Figures when writing or interpreting numbers are as follows:

4.3.2.1 All non-zero digits are considered significant. For example, 91 has two Significant Figures (9 and 1), while 123.45 has five Significant Figures (1, 2, 3, 4 and 5).

4.3.2.2 Zeros appearing anywhere between two non-zero digits are significant. Example: 101.1203 has seven Significant Figures: 1, 0, 1, 1, 2, 0 and 3.

4.3.2.3 Leading zeros are not significant. For example, 0.00052 has two Significant Figures: 5 and 2.

4.3.2.4 Trailing zeros in a number containing a decimal point are significant. For example, 12.2300 has six Significant Figures: 1, 2, 2, 3, 0 and 0. The number 0.000122300 still has only six Significant Figures (the zeros before the 1 are not significant). In addition, 120.00 has five Significant Figures since it has three trailing zeros. This convention clarifies the precision of such numbers; for example, if a measurement precise to four decimal places (0.0001) is given as 12.23 then it can be misunderstood that only two decimal places of precision are available. Stating the result as 12.2300 makes clear that it is precise to four decimal places (in this case, six Significant Figures).

4.3.2.5 The significance of trailing zeros in a number not containing a decimal point can be ambiguous. For example, it is not always clear if a number like 1300 is precise to the nearest unit (and just happens coincidentally to be an exact multiple of a hundred) or if it is only shown to the nearest hundred due to rounding or uncertainty. One of the following conventions shall be used to address this issue:

4.3.2.5.1 Place a bar over the last Significant Figure; any trailing zeros following this are insignificant. For example, 1300 has three Significant Figures (and hence indicates that the number is precise to the nearest ten).

4.3.2.5.2 Underline the last Significant Figure of a number; for example, "2000" has two Significant Figures.

4.3.2.5.3 Place a decimal point after the number; for example, "100." indicates specifically that three Significant Figures are meant.

4.3.2.5.4 In the combination of a number and a unit of measurement, choose a suitable unit prefix. For example, the number of Significant Figures in a power measurement specified as 1300 W is ambiguous, while a power of 1.30 kW is not.

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4.3.2.5.5 Use scientific notation or exponential notation; for example, 1.30×10^3 W.

4.3.2.6 In multiplication and division, the operation with the least number of Significant Figures determines the numbers to be reported in the result. For example, the product 1256 x 12.2 = 15323.2 is reported as 15$\bar{3}$00. In addition and subtraction, the least number of figures to either the right or the left of the decimal point determines the number of Significant Figures to be reported. Thus, the sum of 120.05 + 10.1 + 56.323 = 156.473 is reported as 156.5 because 10.1 defines the reporting level. In complex calculations involving multiplications and additions, for example, the operation is done serially, and the final result is rounded according to the least number of Significant Figures involved. Thus: (1256 x 12.2) + 125 = 15323.2 + 125 =15$\bar{4}$00.

4.3.3 The following rules shall be used in rounding values:

4.3.3.1 When the digit next beyond the one to be retained is less than five, the retained figure is kept unchanged. For example: 2.541 becomes 2.5 to two Significant Figures.

4.3.3.2 When the digit next beyond the one to be retained is greater than or equal to five, the retained figure is increased by one. For example; 2.453 becomes 2.5 to two Significant Figures.

4.3.3.3 When two or more figures are to the right of the last figure to be retained, they are to be considered as a group in rounding decisions. Thus in 2.4(501), the group (501) is considered to be >5 while for 2.5(499), (499) is considered to be <5.

4.4 *Water Connections*. Ratings shall be established with a single entering and single leaving connection per water circuit as follows:

4.4.1 *Water-cooled Condensers.* Units with multiple Water-cooled Condenser heat exchangers shall be tested with all Water-cooled Condenser heat exchangers connected for the duration of the test.

4.4.2 *Water-cooled Heat Recovery Condenser*. Units with multiple Water-cooled Heat Recovery Condenser heat exchangers shall be tested with all Water-cooled Heat Recovery Condenser heat exchangers connected for the duration of the test.

4.4.3 *Evaporator*. Units with multiple Evaporator heat exchangers shall be tested with all Evaporator heat exchangers connected for the duration of the test.

4.5 *Refrigerant Tubing for Remote Condenser or Remote Evaporator*. The unit shall be installed with interconnecting refrigerant tubing. The equivalent length of that tubing shall be no less than the rated length per Section 5.9. All refrigerant tubing and components shall be installed within the same test room as all other parts of the tested equipment. Refrigerant tubing line sizes, insulation, and details of installation shall be in accordance with the manufacturer's published recommendation and shall be recorded prior to testing.

4.6 *Corrections.* This section defines fouling factor related adjustments to target temperature values, as well as corrections to test measurements for water-side pressure drop, and corrections to test results for atmospheric pressure.

4.6.1 *Method for Simulating Fouling Factor Allowance.* The calculations in this section apply to evaporators and Condensers using water, for full load and part load operating conditions. The resultant fouling factor correction, ΔT_{adj}, is added or subtracted to the target test water temperature as appropriate to simulate the fouled condition.

$$\Delta T_{range} = \left| T_{out,w} - T_{in,w} \right| \quad (1)$$

$$\Delta T_{small,sp} = \left| T_{sat,r} - T_{out,w} \right| \quad (2)$$

Where $T_{sat,r}$ is the saturated vapor temperature for single component or azeotrope refrigerants, or for zeotropic refrigerants T_{sat} is the arithmetic average of the Dew Point and Bubble Point temperatures, corresponding to refrigerant pressure.

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Calculate the Log Mean Temperature Difference (ΔT_{LMTD}) for the evaporator and/or Condenser using the following equation at the Fouling Factor Allowance (R_{foul}) specified by the rated performance, and the corresponding specified small temperature difference, $\Delta T_{small,sp}$.

$$\Delta T_{LMTD} = \frac{\Delta T_{range}}{\ln\left(1+\frac{\Delta T_{range}}{\Delta T_{small,sp}}\right)} \quad 3$$

Calculate the incremental log mean temperature difference (ΔT_{ILMTD}) using Equation 4:

$$\Delta T_{ILMTD} = R_{foul}\left(\frac{Q}{A_w}\right) \quad 4$$

Where Q is the rated net Capacity and A_w is the water-side heat transfer surface area for the heat exchanger, which is inside or outside surface area depending on the heat exchanger design.

The water temperature adjustment needed to simulate the additional fouling, ΔT_{adj}, can now be calculated:

$$Z = \frac{\Delta T_{range}}{\Delta T_{LMTD} - \Delta T_{ILMTD}} \quad 5$$

$$\Delta T_{small,clean} = \frac{\Delta T_{range}}{e^{Z}-1} \quad 6$$

$$\Delta T_{adj} = \Delta T_{small,sp} - \Delta T_{small,clean} \quad 7$$

Where $\Delta T_{small,sp}$ is the small temperature difference as rated at a specified Fouling Factor Allowance, and $\Delta T_{small,clean}$ is the small temperature difference as rated in a clean condition with no fouling.

ΔT_{adj} is used for both Evaporator and Condenser water temperature corrections and shall be calculated separately for each heat exchanger. ΔT_{adj} shall be added to the controlled target temperature for condensing heat exchangers and subtracted from the controlled target temperature for evaporating heat exchangers. Operating condition tolerance limits per Table 1 apply to the adjusted target temperature. The test requires control over one temperature and the flow rate in a heat exchanger; the uncontrolled, unadjusted temperature can vary.

Note: See informative Appendix F for calculation examples of Fouling Factor Allowances to correct temperature targets.

4.6.1.1 *Condensing heat exchangers in cooling mode.* The corrected water temperature target for condensing heat exchangers in cooling mode shall be calculated using Equation 8:

$$T_{in,adj} = T_{in,w} + \Delta T_{adj} \quad 8$$

4.6.1.2 *Evaporating heat exchangers in cooling mode.* The corrected water temperature target for evaporating heat exchangers in cooling mode shall be calculated using Equation 9:

$$T_{out,adj} = T_{out,w} - \Delta T_{adj} \quad 9$$

4.6.1.3 *Condensing heat exchangers in heating mode.* The corrected water temperature target for condensing heat exchangers in heating mode shall be calculated using Equation 10:

$$T_{out,adj} = T_{out,w} + \Delta T_{adj} \quad 10$$

4.6.1.4 *Evaporating heat exchangers in heating mode.* The corrected water temperature target for evaporating heat exchangers in heating mode shall be calculated using Equation 11:

$$T_{out,adj} = T_{out,w} - \Delta T_{adj} \quad 11$$

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4.6.1.5 *Special Consideration for Multiple Refrigerant Circuits.*

For units that have multiple refrigeration circuits for the evaporator or Condenser, and the following items are known for each heat exchanger: refrigerant saturation temperatures, inlet and outlet water temperatures, and water flow rates; an adjustment temperature $\Delta T_{adj,i}$ shall be computed for each heat exchanger and then combined into a single water temperature adjustment. For series water circuits, the intermediate water temperatures are calculated when measurement is not practical. For this purpose a weighted average for the $\Delta T_{adj,i}$ values shall be computed as follows:

$$\Delta T_{adj,weighted} = \frac{\Sigma(Q_i \cdot \Delta T_{adj,i})}{\Sigma(Q_i)} \quad (8)$$

Where 'i' is equal to the number of heat exchangers.

For this purpose, the weighted temperature adjustment, $\Delta T_{adj,weighted}$, shall be added to the condenser entering water temperature or subtracted from the evaporator leaving water temperature to simulate the additional fouling factor adjustment.

4.6.1.6 *Derivation of Log Mean Temperature Difference (LMTD).*

This derivation is included for reference only:

$$\begin{aligned}\Delta T_{LMTD} &= \frac{(T_{sat,r} - T_{in,w}) - (T_{sat,r} - T_{out,w})}{\ln\left[\frac{T_{sat,r} - T_{in,w}}{T_{sat,r} - T_{out,w}}\right]} \\ &= \frac{(T_{out,w} - T_{in,w})}{\ln\left[\frac{(T_{sat,r} - T_{out,w}) + (T_{out,w} - T_{in,w})}{T_{sat,r} - T_{out,w}}\right]} \\ &= \frac{(T_{out,w} - T_{in,w})}{ln\left[1 + \frac{(T_{out,w} - T_{in,w})}{T_{sat,r} - T_{out,w}}\right]} \\ &= \frac{\Delta T_{range}}{ln\left(1 + \frac{\Delta T_{range}}{\Delta T_{small,sp}}\right)}\end{aligned} \quad (9)$$

4.7 *Validation.* Measurement data validation shall be in accordance with ANSI/ASHRAE Standard 30 except as noted below.

4.7.1 *Redundant Voltage Measurement.* Where redundant voltage measurement is required, the average voltage shall not differ by more than 2% from either measurement.

4.7.2 *Operating Condition Tolerances and Stability Criteria.* Measured data shall be in accordance with Table 1.

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Table 1. Definition of Operating Condition Tolerances and Stability Criteria

Measurement or Calculation Result		Applicable Operating Mode(s)	Values Calculated from Data Samples		Operating Condition Tolerance Limits	Stability Criteria
			Mean	Standard Deviation		
Net Capacity (Cooling or Heating)		Cooling, Heating, Heat Recovery	$\bar{Q}$	-	Unit with Continuous Unloading: [1] Part Load test Capacity shall be within 2% of the target part-load Capacity [2] $\frac{\lvert \bar{Q} - Q_{target} \rvert}{Q_{100\%}} \leq 2.000\%$	No requirement
					Units with Discrete Capacity Steps: Part Load test points shall be taken at the capacity steps closest to the specified part-load rating points as stated in Table 6. If not within 2% of the target part-load Capacity[2] then interpolate per Section 5.4.3.2.	
Evaporator	Entering Water Temperature	Cooling	$\bar{T}$	s_T	No Requirement	$s_T \leq 0.10$ °C
	Leaving Water Temperature				$\lvert \bar{T} - T_{target} \rvert \leq 0.28$ °C	
Condenser	Entering Water Temperature					
	Leaving Water Temperature				No Requirement	
Condenser	Entering Air Mean Dry Bulb Temperature [3]	Cooling with fan cycling	$\bar{T}$	s_T	$\lvert \bar{T} - T_{target} \rvert \leq 0.56$ °C	$S_T \leq 0.42$ °C
	Entering Air Mean Wet Bulb Temperature [3]					
Evaporator	Entering Water Temperature [3]	Heating, Heat Recovery	$\bar{T}$	s_T	Heating portion: No requirement Defrost portion: $\lvert \bar{T} - T_{target} \rvert \leq 1.11$ °C	Heating portion: $s_T \leq 0.10$ °C Defrost portion: $s_T \leq 0.28$ °C
	Leaving Water Temperature [3]				Heating portion: $\lvert \bar{T} - T_{target} \rvert \leq 0.28$ °C Defrost portion: no requirement	Heating portion: $s_T \leq 0.10$ °C Defrost portion: no requirement
Condenser	Leaving Water Temperature				$\lvert \bar{T} - T_{target} \rvert \leq 0.28$ °C	$s_T \leq 0.10$ °C
	Entering Water Temperature				No Requirement	

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Table 1. Definition of Operating Condition Tolerances and Stability Criteria (continued)

Measurement or Calculation Result		Applicable Operating Mode(s)	Values Calculated from Data Samples		Operating Condition Tolerance Limits	Stability Criteria
			Mean	Standard Deviation		
Evaporator or Condenser	Entering Air Mean Dry Bulb Temperature [1]	Cooling, Heating (non-frosting)	$\overline{T}$	s_T	$\left\|\overline{T} - T_{target}\right\| \leq 0.56\ °C$	$s_T \leq 0.42\ °C$
		Heating (frosting) [4]			Heating portion: $\left\|\overline{T} - T_{target}\right\| \leq 1.11\ °C$	Heating portion: $s_T \leq 0.56\ °C$
					Defrost portion: no requirement for $\overline{T}$	Defrost portion: $s_T \leq 1.39\ °C$
	Entering Air Mean Wet Bulb Temperature [1]	Cooling, Heating (non-frosting)			$\left\|\overline{T} - T_{target}\right\| \leq 0.56\ °C$	$s_T \leq 0.28\ °C$
		Heating (frosting) [4]			Heating portion: $\left\|\overline{T} - T_{target}\right\| \leq 0.83\ °C$	Heating portion: $s_T \leq 0.42\ °C$
					Defrost portion: no requirement for $\overline{T}$	No requirement
Water Flow (Volumetric, Entering)		Cooling, Heating, Heat Recovery	$\overline{V}_w$	s_{Vw}	$\frac{\left\|\overline{V}_w - V_{w,target}\right\|}{V_{w,target}} \leq 5.000\%$	$\frac{s_{V_w}}{\overline{V}_w} \leq 0.750\%$
Voltage [5] (if multiphase, this is the average of all phases)		Cooling, Heating, Heat Recovery	$\overline{V}$	s_V	$\frac{\left\|\overline{V} - V_{target}\right\|}{V_{target}} \leq 10.00\%$	$\frac{s_V}{\overline{V}} \leq 0.500\%$
Frequency [5]		Cooling, Heating, Heat Recovery	$\overline{\omega}$	s_ω	$\frac{\left\|\overline{\omega} - \omega_{target}\right\|}{\omega_{target}} \leq 1.000\%$	$\frac{s_\omega}{\overline{\omega}} \leq 0.500\%$
Condenserless Refrigerant Saturated Discharge Temperature		Cooling	$\overline{T}$	s_T	$\left\|\overline{T} - T_{target}\right\| \leq 0.28\ °C$	$s_T \leq 0.14\ °C$
Condenserless Liquid Temperature		Cooling	$\overline{T}$	s_T	$\left\|\overline{T} - T_{target}\right\| \leq 0.56\ °C$	$s_T \leq 0.28\ °C$
Steam Turbine Pressure/Vacuum [6]		Cooling, Heating, Heat Recovery	$\overline{p}$	s_p	$\left\|\overline{p} - p_{rating}\right\| \leq 3.45\ kPa$	$s_p \leq 1.72\ kPa$
Gas Turbine Inlet Gas Pressure [6]						
Governor Control Compressor Speed [7]		Cooling, Heating, Heat Recovery	$\overline{n}$	s_n	$\frac{\left\|\overline{n} - n_{target}\right\|}{n_{target}} \leq 0.500\%$	$\frac{s_n}{\overline{n}} \leq 0.250\%$

Notes:

1. The target set point condenser entering temperatures (Table 6) are determined at the target part-load test point.
2. The ± 2.0% tolerance shall be calculated as 2.0% of the Full Load rated Capacity (ton_R). For example, a nominal 50.0% part load point shall be tested between 48.0% and 52.0% of the Full Load Capacity to be used directly for IPLV.SI and NPLV.SI calculations. Outside this tolerance, interpolation shall be used.
3. The "heat portion" shall apply when the unit is in the heating mode except for the first ten minutes after terminating a defrost cycle. The "defrost portion" shall include the defrost cycle plus the first ten minutes after terminating the defrost cycle.
4. When computing average air temperatures for heating mode tests, omit data samples collected during the defrost portion of the cycle.
5. For electrically driven machines, voltage and frequency shall be maintained at the nameplate rating values within tolerance limits and stability criteria on voltage and frequency when measured at the locations specified by ANSI/ASHRAE Standard 30. For dual nameplate voltage ratings, tests shall be performed at the lower of the two voltages.
6. For steam turbine and gas turbine drive machines the pressure shall be maintained at the nameplate rating values within the tolerance limits.
7. For speed-controlled compressors the speed shall be maintained at the nameplate rating value within the tolerance limits.

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4.8 *Air Temperature Measurement.* In addition to Table 1, air temperature measurement shall be in accordance with Table 2. For evaporatively-cooled units and heat pump chillers operating in heating mode, either wet-bulb temperature or dewpoint shall be measured. If dewpoint is measured, wet-bulb temperature shall be calculated and recorded.

Table 2. Temperature Measurement Requirements

Measurement	Measurement System Accuracy	Measurement Resolution	Selected, Installed, Operated, Maintained in Accordance with
Dry-Bulb and Wet-Bulb Temperatures[2]	Per ANSI/ASHRAE Standard 30	Per ANSI/ASHRAE Standard 30	ANSI/ASHRAE Standard 41.1
Air Sampling Tree Average Temperature[1]	Per ANSI/ASHRAE Standard 30	Per ANSI/ASHRAE Standard 30	
Dewpoint Temperature[3]	±0.2 K	≤ 0.05 K	

4.9 *Air Sampling Array Requirements.* The air sampling array is an alternative to utilizing a thermopile grid. measurement devices shall be positioned to measure at the four (4) locations shown in Figure 1 within 5% of overall width and height, where W and H are condenser air inlet nominal face area width and height.

Where the W or H dimension is less than or equal to 60 cm, at least one (1) temperature measurement shall be used in that dimension. For example, if W = 60 cm and H = 120 cm, at least two (2) temperature measurements shall be used for that area.

Table 3 criteria for air distribution and control of air temperature shall be met. For evaporatively-cooled units and heat pump chillers operating in heating mode, either wet-bulb temperature or dewpoint shall be measured. If dewpoint is measured, wet-bulb temperature shall be calculated and recorded. Wet-bulb temperature is not required for other unit types.

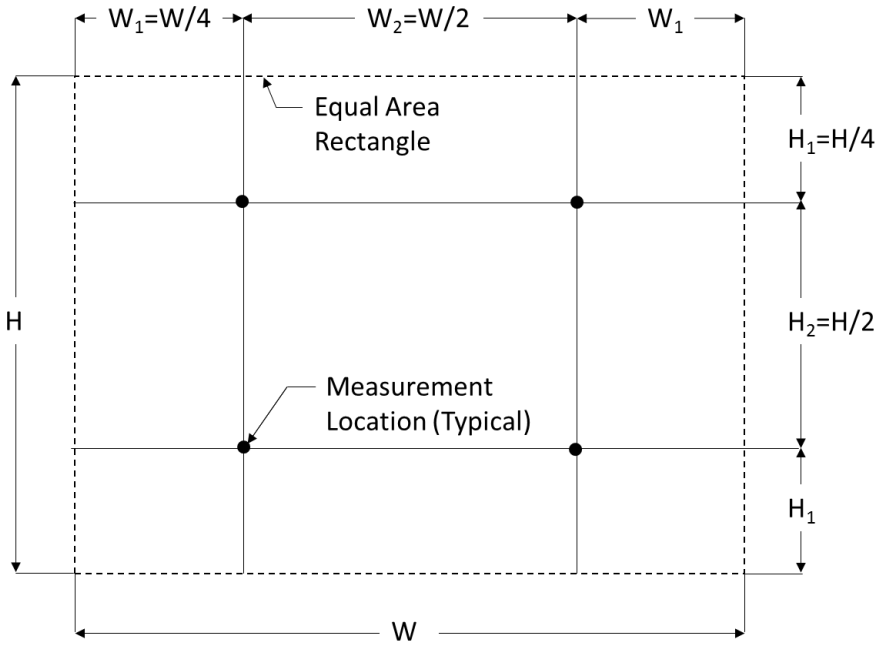


Figure 1. Air Sampling Array

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Table 3. Criteria for Air Distribution and Control of Air Temperature		
Item	Purpose	Deviation from Mean Value, °C
Dry-bulb Temperature		
Mean measurement of an Air Sampling Array	Uniform temperature distribution	±1.11 (≤700.0 kW)
		±2.22 (>700.0 kW)
Individual measurements in an Air Sampling Array	Uniform temperature distribution	±0.83
Condenser discharge air recirculation measurement as compared to associated Air Sampling Array.	Recirculation Check	±2.80
Wet-bulb Temperature		
Wet-bulb temperature at any individual temperature measurement station	Uniform humidity distribution	±0.56

Section 5. Rating Requirements

5.1 *Rating Metrics.*

5.1.1 *Cooling Energy Efficiency*. The general form of Cooling Energy Efficiency is shown in Equation 14. This term is calculated at both design point and at part load conditions.

Note: Refer to Section 5.4.3.2.7 for part load degradation factor adjustment and Appendix C for atmospheric pressure adjustment.

5.1.1.1 The Cooling Coefficient of Performance (COP_R), kW/kW, shall be calculated using Equation 14:

$$COP_R = \frac{Q_{ev}}{W_{input}} \quad 14$$

5.1.2 *Heating Energy Efficiency*. The general forms of the Heating Energy Efficiency terms are listed as Equations 15 through 17. These terms are calculated at both design point and at part load conditions.

Note: Refer to Section 5.4.2.3.7 for part load degradation factor adjustment and Appendix C for atmospheric pressure adjustment.

5.1.2.1 The Heating Coefficient of Performance (COP_H), kW/kW, shall be calculated using Equation 15:

$$COP_H = \frac{Q_{cd}}{W_{input}} \quad 15$$

5.1.2.2 The Heat Recovery Coefficient of Performance (COP_{HR}), kW/kW shall be calculated using Equation 16:

$$COP_{HR} = \frac{Q_{ev} + Q_{hrc}}{W_{input}} \quad 16$$

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5.1.2.3 The Simultaneous Heating and Cooling Coefficient of Performance (COP_{SHC}), kW/kW, shall be calculated using Equation 17:

$$COP_{SHC} = \frac{Q_{cd} + Q_{ev}}{W_{input}} \quad 17$$

5.1.3 *Net Refrigerating Capacity*. The Net Refrigerating Capacity, kW, 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 18:

$$Q_{ev} = m_w \cdot c_p \cdot (T_{in} - T_{out}) \quad 18$$

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 37). The volumetric flow rate shall be calculated using Equation 19:

$$V_w = \frac{m_w}{\rho_{in}} \quad 19$$

5.1.4 *Net Heating Capacity*. The Net Heating Capacity, KW, for either a heat rejection, or heat recovery Condenser, and other heat rejection devices (e.g. oil coolers, inverters, etc.), shall use the water temperatures, water flow rate, and water properties at the entering and leaving conditions and be calculated using Equations 20 or 21:

$$Q_{cd} = m_w \cdot c_p \cdot (T_{out} - T_{in}) \quad 20$$

$$Q_{hrc} = m_w \cdot c_p \cdot (T_{out} - T_{in}) \quad 21$$

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 Equations 19 and 37).

5.1.5 *Water Pressure Drop.* For this standard, the Water Pressure Drop shall include pressure losses due to nozzles, piping, or other interconnections included with the Water-chilling or Water-heating Package and shall include all pressure losses across the external unit connection points for water inlet and water outlet. For Published Ratings, this value is expressed in kPa at a reference water temperature of 15.6 ºC. For test measurements, this is a differential pressure expressed in kPa. For the calculation of Water Pressure Drop, Refer to ANSI/ASHRAE Standard 30. Note the requirements for a single inlet and single outlet as described in Section 4.4.

5.2 *Standard Ratings and Conditions.* Standard Ratings for all Water-chilling Packages shall be established at the Standard Rating Conditions. These packages shall be rated for cooling, heat recovery, or heating performance at conditions specified in Table 4. Standard Ratings shall include a water-side Fouling Factor Allowance as specified in the notes section of Table 4. Chiller packages consisting of multiple units and rated as a single package shall be tested as rated.

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Table 4. Standard Rating Conditions

Operating Category	Conditions	Cooling Mode Evaporator[2]			Cooling Mode Heat Rejection Heat Exchanger											
					Tower (Water Conditions)[3]			Heat/Recovery (Water Conditions)[4]		Evaporatively-cooled Entering Temperature[5, 7]		Air-cooled (AC) Entering Temperature[5, 7]		Without Condenser			
														Air-cooled Refrigerant Temperature		Water & Evaporatively Cooled Refrigerant Temperature	
		Entering Temperature, ºC	Leaving Temperature, ºC	Flow Rate, L/(s·kW)	Entering Temperature, ºC	Leaving Temperature, ºC	Flow Rate, L/(s·kW)	Entering Temperature, ºC	Leaving Temperature, ºC	Dry-Bulb, ºC	Wet-Bulb, ºC	Dry-Bulb, ºC	Wet-Bulb, ºC	SDT, ºC	LIQ, ºC	SDT, ºC	LIQ, ºC
All Cooling	Standard	12.00	7.00	Note - 8	30.00	35.00	Note - 9	--	--	35.00	24.00	35.0	--	52.0	41.0	41.00	37.00
AC Heat Pump High Heating[6]	Low	--	40.00	Note - 1	--	--	--	--	--	--	--	8.00	6.00	--	--	--	--
	Medium	--	50.00	Note - 1	--	--	--	--	--	--	--	8.00	6.00	--	--	--	--
	High	--	60.00	Note - 1	--	--	--	--	--	--	--	8.00	6.00	--	--	--	--
AC Heat Pump Low Heating[6]	Low	--	40.00	Note - 1	--	--	--	--	--	--	--	-8.00	-9.00	--	--	--	--
	Medium	--	50.00	Note - 1	--	--	--	--	--	--	--	-8.00	-9.00	--	--	--	--
	High	--	60.00	Note - 1	--	--	--	--	--	--	--	-8.00	-9.00	--	--	--	--
Water Cooled Heating	Low	--	7.00	Note - 8	--	--	--	35.00	40.00	--	--	--	--	--	--	--	--
	Medium	--	7.00	Note - 8	--	--	--	42.00	50.00	--	--	--	--	--	--	--	--
	High	--	7.00	Note - 8	--	--	--	50.00	60.00	--	--	--	--	--	--	--	--
	Boost	--	19.00	Note - 8	--	--	--	50.00	60.00	--	--	--	--	--	--	--	--
Heat Recovery	Low	--	7.00	Note - 8	24.00	--	Note - 9	35.00	40.00	4.00	3.00	4.00	3.00	--	--	--	--
	Medium	--	7.00	Note - 8	24.00	--	Note - 9	42.00	50.00	4.00	3.00	4.00	3.00	--	--	--	--
	Hot Water 1	--	7.00	Note - 8	24.00	--	Note - 9	32.00	60.00	4.00	3.00	4.00	3.00	--	--	--	--
	Hot Water 2	--	7.00	Note - 8	24.00	--	Note - 9	50.00	60.00	4.00	3.00	4.00	3.00	--	--	--	--

Notes:

1. The water flow rate used for the heating tests of reverse cycle air to water heat pumps shall be the flow rate determined during the cooling test.
2. The rating Fouling Factor Allowance for the cooling mode Evaporator or the heating Condenser for AC reversible cycles shall be R_{foul} = 0.0180 $m^2 \cdot K/kW$.
3. The rating Fouling Factor Allowance for tower heat exchangers shall be R_{foul} = 0.0440 $m^2 \cdot K/kW$.
4. The rating Fouling Factor Allowance for heating and heat recovery heat exchangers shall be R_{foul} = 0.0180 $m^2 \cdot K/kW$ for closed loop and R_{foul} = 0.0440 $m^2 \cdot K/kW$ for open loop systems.
5. Evaporatively cooled Condensers and Air-cooled Condensers shall be rated with a Fouling Factor Allowance of zero, R_{foul} = 0.00$\overline{0}$ $m^2 \cdot K/kW$.
6. A reversible cycle is assumed where the cooling mode Evaporator becomes the condenser circuit in the heating mode.
7. Air-cooled & evaporatively-cooled unit ratings are at standard atmospheric condition (sea level). Measured test data shall be corrected to an atmospheric pressure of 101.33 kPa per Appendix C.
8. Rated water flow is determined by the water temperatures at the rated Cooling Capacity.
9. Rated water flow is determined by the water temperatures at the rated Capacity and rated efficiency.

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5.3 *Application Rating Conditions.* Full and part-load Application Ratings shall include the range of Rating Conditions listed in Table 5 or be within the operating limits of the equipment. For guidance to the industry, designing to large Fouling Factors significantly impacts the performance of the chiller. It is best to maintain heat transfer surfaces by cleaning or maintaining proper water treatment to avoid highly fouled conditions and the associated efficiency loss. From a test perspective, highly fouled conditions are simulated with clean tubes by testing at decreased Evaporator water temperatures and increased Condenser water temperatures. High Fouling Factors can increase or decrease these temperatures to conditions outside test loop or equipment capabilities. For this test standard, the application range for the water side fouling shall be between clean (0.000) and 0.180 $m^2 \cdot K/kW$. Fouling Factors above these values are outside of the scope of this standard and shall be noted as such.

Table 5. Full and Part-load Application Rating Conditions

<table>
<tr><td></td><td colspan="3">Evaporator</td><td colspan="3">Condenser</td></tr>
<tr><td rowspan="15">Cooling</td><td colspan="3">Water Cooled</td><td colspan="3">Water Cooled</td></tr>
<tr><td>Leaving Temperature[1], °C</td><td>Temperature Difference Across Heat Exchanger[5], K</td><td>Fouling Factor Allowance, $m^2 \cdot K/kW$</td><td>Entering Temperature[2], °C</td><td>Flow Rate [5, 7], L/(s·kW)</td><td>Fouling Factor Allowance, $m^2 \cdot K/kW$</td></tr>
<tr><td rowspan="6">2.20 to 21.10</td><td rowspan="6">2.80 to 11.10</td><td rowspan="6">0.000 to 0.180</td><td>12.80 to 46.11</td><td>0.0179 to 0.1076</td><td>0.000 to 0.180</td></tr>
<tr><td colspan="3">Air-cooled</td></tr>
<tr><td colspan="2">Entering Air Dry Bulb[3], °C</td><td>Atmospheric Pressure[6], kPa</td></tr>
<tr><td colspan="2">12.8 to 52.0</td><td>79.70 to 104.8</td></tr>
<tr><td colspan="3">Evaporatively Cooled</td></tr>
<tr><td colspan="2">Entering Air Wet Bulb[4], °C</td><td>Atmospheric Pressure[6], kPa</td></tr>
<tr><td colspan="2">10.0 to 26.7</td><td>79.70 to 104.8</td></tr>
<tr><td rowspan="15">Heating</td><td colspan="3">Water Source Evaporator</td><td colspan="3">Water Cooled Condenser</td></tr>
<tr><td colspan="2">Entering Water Temperature[1], °C</td><td>Fouling Factor Allowance, $m^2 \cdot K/kW$</td><td>Leaving Water Temperature[2], °C</td><td>Temperature Difference Across Heat Exchanger[5], K</td><td>Fouling Factor Allowance, $m^2 \cdot K/kW$</td></tr>
<tr><td colspan="2">4.44 to 26.67</td><td>0.000 to 0.180</td><td rowspan="4">40.56 to 71.11</td><td rowspan="4">2.80 to 16.67</td><td rowspan="4">0.000 to 0.180</td></tr>
<tr><td colspan="3">Air Source Evaporator</td></tr>
<tr><td>Entering Air temperature, °C</td><td colspan="2">Atmospheric Pressure[6], kPa</td></tr>
<tr><td>-9.4 to 15.6</td><td colspan="2">79.70 to 104.8</td></tr>
</table>

Notes:
1. Evaporator water temperatures shall be published in rating increments of no more than 2.00 °C
2. Condenser water temperatures shall be published in rating increments of no more than 3.00 °C.
3. Entering air temperatures shall be published in rating increments of no more than 5.0 °C.
4. Air wet bulb temperatures shall be published in rating increments of no more than 1.5 °C.
5. Applies to design point only, not part-load points.
6. Rated altitude not exceeding 1980 m. Measured test data shall be corrected per Appendix C to the application rating atmospheric pressure.
7. The normalized flow rate is per unit of Evaporator Capacity.

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