AHRI Standard 551/591 (SI)

2020 Standard for

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

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IMPORTANT

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Note:

This 2020 standard supersedes AHRI Standard 551/591 (SI)-2018 (with Errata).
For I-P ratings, see AHRI Standard 550/590 (I-P)-2020.

Accompanying this standard is an Excel Spreadsheet including all example calculations shown in the standard (http://www.ahrinet.org/site/686/Standards/HVACR-Industry-Standards/Search-Standards).

AHRI CERTIFICATION PROGRAM PROVISIONS

The current scope of the Air-cooled Chiller (ACCL) and Water-cooled Chiller (WCCL) Certification Programs can be found on AHRI website www.ahrinet.org. The scope of the Certification Programs should not be confused with the scope of the standard, as the standard also includes ratings for products that are not covered by a certification program.

Foreword:

The standard has been updated to include the following main revisions:

- Update to the scope of the standard for adiabatic and heat pump chillers.
- Reference ANSI/ASHRAE Standard 30 as the method of test.
- Define full-load for any published rating.
- Update part-load rating interpolation test and calculation methods.
- Clarify standard rating conditions for water-cooled water-heating chillers.
- Increase the application rating scope.
- Clarify published rating requirements for all chiller types.

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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*. The purpose of this standard is to establish for Water-chilling and Heat Pump Water-heating Packages using the vapor compression cycle: definitions; test requirements; rating requirements; minimum data requirements for Published Ratings; marking and nameplate data; conversions and calculations; nomenclature; and conformance conditions.

1.1.1 *Intent.* This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, efficiency regulators, contractors and users.

1.1.2 *Review and Amendment.* This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 *Scope*. This standard applies to factory-made vapor compression refrigeration Water-chilling and Water-heating Packages including one or more compressors. 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 which uses evaporative cooling to pre-cool air before that air reaches the dry heat transfer surface.

Section 3. Definitions

All terms in this document follow the standard industry definitions in the *ASHRAE Terminology* website (https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology) unless otherwise defined in this section.

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

3.3 *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, and in some calculations also the energy associated with water-side pressure losses.

3.3.1 *Net Heating Capacity.* The Capacity of the heating Condenser available for useful heating of the thermal load

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external to the Water-heating Package and is calculated using only the sensible heat transfer. (Refer to Equations 16 and 17.)

3.3.2 *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 14.)

3.4 *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.

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

3.5.1 *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.

3.5.2 *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.

3.5.3 *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.

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

3.5.5 *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 may 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.

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

3.7 *Energy Efficiency.*

3.7.1 *Cooling Energy Efficiency.*

3.7.1.1 *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 10.)

3.7.2 *Heating Energy Efficiency.*

3.7.2.1 *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 11.)

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

3.7.3.1 *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 12.)

3.7.3.2 *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

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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 13.)

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

3.8.1 *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.

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

3.9.1 *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 $m^2 \cdot K/kW$.

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

3.11 *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.

3.11.1 *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.

3.11.2 *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).

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

3.12.1 *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.

3.13 *Published Ratings*. A statement of the assigned values of those performance characteristics, under stated Rating Conditions, by which a unit may 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.

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

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

3.14 *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.

3.14.1 *Standard Rating Conditions*. Rating Conditions used as the basis of comparison for performance characteristics.

3.15 *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.)

3.16 *"Shall" or "Should".* "Shall" or "should" shall be interpreted as follows:

3.16.1 *Shall*. Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

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3.16.2 *Should,* "Should" is used to indicate provisions which are not mandatory but which are desirable as good practice.

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

3.18 *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 may or may not be an integral part of the package.

3.18.1 *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 may be rejected to another medium, usually air or water.

3.18.2 *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.

3.18.3 *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 will be supplied to interface with the Condenserless Chiller.

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

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).

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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 might 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, $1\bar{3}00$ 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, "2$\underline{0}$00" 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.

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:

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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.

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:

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

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

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

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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.

The calculation of ΔT_{adj} is used for both evaporator and condenser water temperature corrections. The correcting water temperature difference, ΔT_{adj}, is then added to the condenser entering water temperature or subtracted from the evaporator leaving water temperature to simulate the additional Fouling Factor.

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

4.6.1.2 *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 5.4.2.2.	
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)	$\bar{T}$	s_T	$\lvert\bar{T} - T_{target}\rvert \leq 0.56\ °C$	$s_T \leq 0.42\ °C$
		Heating (frosting) [4]			Heating portion: $\lvert\bar{T} - T_{target}\rvert \leq 1.11\ °C$	Heating portion: $s_T \leq 0.56\ °C$
					Defrost portion: no requirement for $\bar{T}$	Defrost portion: $s_T \leq 1.39\ °C$
	Entering Air Mean Wet Bulb Temperature [1]	Cooling, Heating (non-frosting)			$\lvert\bar{T} - T_{target}\rvert \leq 0.56\ °C$	$s_T \leq 0.28\ °C$
		Heating (frosting) [4]			Heating portion: $\lvert\bar{T} - T_{target}\rvert \leq 0.83\ °C$	Heating portion: $s_T \leq 0.42\ °C$
					Defrost portion: no requirement for $\bar{T}$	No requirement
Water Flow (Volumetric, Entering)		Cooling, Heating, Heat Recovery	$\bar{V}_w$	s_{Vw}	$\frac{\lvert\bar{V}_w - V_{w,target}\rvert}{V_{w,target}} \leq 5.000\%$	$\frac{s_{V_w}}{\bar{V}_w} \leq 0.750\%$
Voltage [5] (if multiphase, this is the average of all phases)		Cooling, Heating, Heat Recovery	$\bar{V}$	s_V	$\frac{\lvert\bar{V} - V_{target}\rvert}{V_{target}} \leq 10.00\%$	$\frac{s_V}{\bar{V}} \leq 0.500\%$
Frequency [5]		Cooling, Heating, Heat Recovery	$\bar{\omega}$	s_ω	$\frac{\lvert\bar{\omega} - \omega_{target}\rvert}{\omega_{target}} \leq 1.000\%$	$\frac{s_\omega}{\bar{\omega}} \leq 0.500\%$
Condenserless Refrigerant Saturated Discharge Temperature		Cooling	$\bar{T}$	s_T	$\lvert\bar{T} - T_{target}\rvert \leq 0.28\ °C$	$s_T \leq 0.14\ °C$
Condenserless Liquid Temperature		Cooling	$\bar{T}$	s_T	$\lvert\bar{T} - T_{target}\rvert \leq 0.56\ °C$	$s_T \leq 0.28\ °C$
Steam Turbine Pressure/Vacuum [6]		Cooling, Heating, Heat Recovery	$\bar{p}$	s_p	$\lvert\bar{p} - p_{rating}\rvert \leq 3.45\ kPa$	$s_p \leq 1.72\ kPa$
Gas Turbine Inlet Gas Pressure [6]						
Governor Control Compressor Speed [7]		Cooling, Heating, Heat Recovery	$\bar{n}$	s_n	$\frac{\lvert\bar{n} - n_{target}\rvert}{n_{target}} \leq 0.500\%$	$\frac{s_n}{\bar{n}} \leq 0.250\%$

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.

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	

Notes:
1. If a thermopile is used for this measurement, then the thermocouple wire shall have special limits of error and all thermocouple junctions shall be made from the same spool of wire; thermopile junctions are wired in parallel.
2. The accuracy specified is for the temperature indicating device and does not reflect the operation of the aspirating psychrometer.
3. Dewpoint may be measured and wet-bulb temperatures calculated and recorded as required for evaporatively-cooled units and heat pump chillers operating in the heating mode.

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, only one (1) temperature measurement is required in that dimension. For example, if W = 60 cm and H = 120 cm, only two (2) temperature measurements are required for that area.

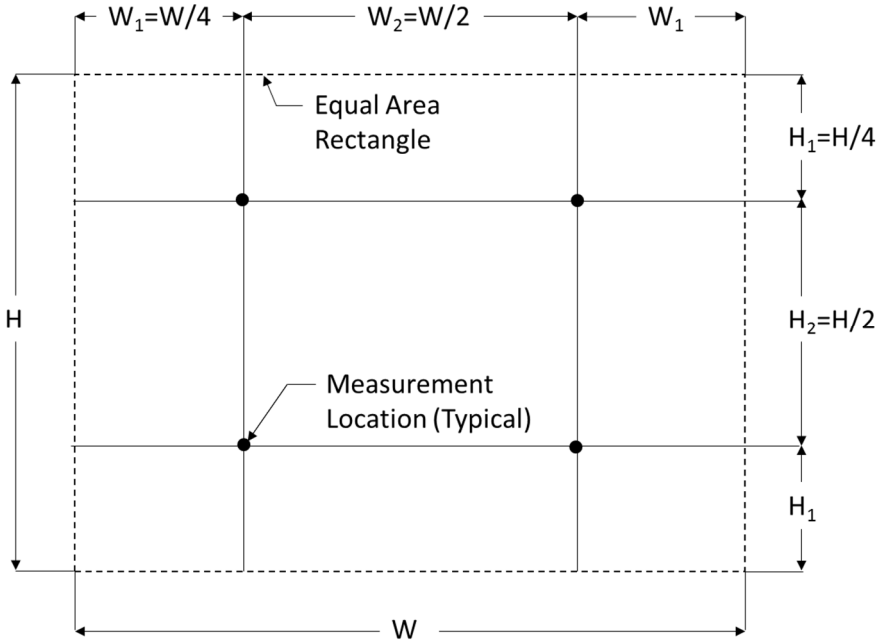


Figure 1. Air Sampling Array

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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 [1,2]		
Wet-bulb temperature at any individual temperature measurement station	Uniform humidity distribution	±0.56
Notes: 1. Wet-bulb temperature measurement is only required for evaporatively-cooled units and heat pump chillers operating in the heating mode. 2. Dewpoint may be measured, and wet-bulb temperatures calculated and recorded.		

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 10. This term is calculated at both design point and at part load conditions.

Note: Refer to Section 5.4.2.2.7 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 10:

$$COP_R = \frac{Q_{ev}}{W_{input}} \quad (10)$$

5.1.2 *Heating Energy Efficiency*. The general forms of the Heating Energy Efficiency terms are listed as Equations 11 through 13. These terms are calculated at both design point and at part load conditions.

Note: Refer to Section 5.4.2.2.7 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 11:

$$COP_H = \frac{Q_{cd}}{W_{input}} \quad (11)$$

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5.1.2.2 The Heat Recovery Coefficient of Performance (COP_{HR}), kW/kW shall be calculated using Equation 12:

$$COP_{HR} = \frac{Q_{ev} + Q_{hrc}}{W_{input}} \quad 12$$

5.1.2.3 The Simultaneous Heating and Cooling Coefficient of Performance (COP_{SHC}), kW/kW, shall be calculated using Equation 13:

$$COP_{SHC} = \frac{Q_{cd} + Q_{ev}}{W_{input}} \quad 13$$

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 14:

$$Q_{ev} = m_w \cdot c_p \cdot (T_{in} - T_{out}) \quad 14$$

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 33). The volumetric flow rate shall be calculated using Equation 15:

$$V_w = \frac{m_w}{\rho_{in}} \quad 15$$

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 16 or 17:

$$Q_{cd} = m_w \cdot c_p \cdot (T_{out} - T_{in}) \quad 16$$

$$Q_{hrc} = m_w \cdot c_p \cdot (T_{out} - T_{in}) \quad 17$$

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 15 and 33).

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} = 0.000 $m^2 \cdot K/kW$.
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 will 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">0.00$\overline{0}$ to 0.180</td><td>12.80 to 46.11</td><td>0.0179 to 0.1076</td><td>0.00$\overline{0}$ 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="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>0.00$\overline{0}$ to 0.180</td><td rowspan="3">40.56 to 71.11</td><td rowspan="3">2.80 to 16.67</td><td rowspan="3">0.00$\overline{0}$ 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>Heating</td><td>-9.4 to 15.6</td><td colspan="2">79.70 to 104.8</td><td colspan="3"></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 will 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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5.3.1 For the purpose of this standard, published Application Ratings shall use a standardized relationship between rated geometric altitude (Z_H) above mean sea level and atmospheric pressure (p_{atm}). The intent is to allow chiller Application Ratings to be published based on the nominal altitude at the installation location without consideration of local weather variations on atmospheric pressure. Test data however shall be corrected on the basis of atmospheric pressure at the time of the test. See Section 7 and Appendix C.

5.4 *Part-load Ratings.* Water-chilling Packages shall be rated at 100%, 75%, 50%, and 25% load relative to the full-load rating Net Refrigerating Capacity at the conditions defined in Table 6. For chillers capable of operating in multiple modes (cooling, heating, and /or heat recovery), part-load ratings are only required for cooling mode operation.

5.4.1 *Part-load Rating Points.* Cooling mode Part-load rating points shall be presented in one of the three following ways:

5.4.1.1 IPLV.SI. Based on the conditions defined in Table 6 and method defined in Section 5.4.2. Providing individual part-load data point(s) suitable for calculating IPLV.SI as defined in Table 6 is permissible.

5.4.1.2 NPLV.SI. Based on the conditions defined in Table 6 and method defined in Section 5.4.2. Providing individual part-load data point(s) suitable for calculating NPLV.SI as defined in Table 6 is permissible. NPLV.SI is not required when Table 8, Note 5 applies.

5.4.1.3 Other part-load points, within the application rating limits of Table 5 and method defined in Section 5.4.3, that do not meet the requirements of Table 6, Notes 3, 4, 5, or 6 (i.e. variable water flow rates or other entering condenser water temperatures). Neither IPLV.SI nor NPLV.SI shall be calculated for such points and shall not be a requirement for publication per Section 6.

Note: Heat Pump Water-heating Packages and Heat Recovery Water-chilling Packages are permitted to be rated at individual part load points. Neither IPLV.SI nor NPLV.SI shall be calculated for such points.

5.4.2 *Determination of Part-load Performance*. For Water-chilling Packages covered by this standard, the IPLV.SI or NPLV.SI shall be calculated as follows:

Determine the Part-load energy efficiency at 100%, 75%, 50%, and 25% load points at the conditions specified in Table 6.

Use Equation 18 to calculate the IPLV.SI or NPLV.SI for units rated with COP_R.

$$\text{IPLV.SI or NPLV.SI} = 0.01 \cdot A + 0.42 \cdot B + 0.45 \cdot C + 0.12 \cdot D \quad (18)$$

For COP_R where:

A = COP_R at 100% load
B = COP_R at 75% load
C = COP_R at 50% load
D = COP_R at 25% load

5.4.2.1 For a derivation of Equation 18, and an example of an IPLV.IP or NPLV.IP calculation, see Appendix D. The weighting factors have been based on the weighted average of the most common building types and operations using average weather in 29 U.S. cities, with and without airside economizers.

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Table 6. Part-load Conditions for Rating

	IPLV.SI	NPLV.SI
Evaporator (All Types)		
All loads LWT[2], ºC	7.0 0	User defined LWT
Flow Rate[3] (L/s per kW)	Per Table 4	Per Table 4[3]
R_{foul}., $m^2 \cdot K/kW$	0.018	User defined
Water-cooled Condenser[1,2]		
100% load EWT, ºC	30.00	User defined EWT
75% load EWT, ºC	24.50	Note[4]
50% load EWT, ºC	19.00	Note[4]
25% load EWT , ºC	19.00	Note[4]
Flow rate, L/s per kW[3]	Note[3]	User defined flow rate
R_{foul} $m^2 \cdot K/kW$	0.044	User defined
Air-cooled Condenser[1,7]		
100% load EDB, ºC	35.0	User defined EDB
75% load EDB, ºC	27.0	Note[5]
50% load EDB, ºC	19.0	Note[5]
25% load EDB, ºC	13.0	Note[5]
R_{foul}, $m^2 \cdot K/kW$	0.000	User defined
Evaporatively-cooled Condenser[1,7]		
100% load EWB, ºC	24.00	User defined EWB
75% load EWB, ºC	20.50	Note[6]
50% load EWB, ºC	17.00	Note[6]
25% load EWB, ºC	13.50	Note[6]
R_{foul}, $m^2 \cdot K/kW$	0.000	User defined
Air-cooled Without Condenser		
100% load SDT, ºC	52.00	User defined SDT
75% load SDT, ºC	42.00	Note[6]
50% load SDT, ºC	32.00	Note[6]
25% load SDT, ºC	22.00	Note[6]
R_{foul}, $m^2 \cdot K/kW$	0.000	User defined
Water-cooled or Evaporatively-cooled Without Condenser		
100% load SDT, ºC	41.00	User defined SDT
75% load SDT, ºC	35.50	Note[6]
50% load SDT, ºC	30.00	Note[6]
25% load SDT, ºC	24.50	Note[6]
R_{foul}, $m^2 \cdot K/kW$	0.000	User defined

Notes:

1. If the unit manufacturer's recommended minimum temperatures are greater than those specified in Table 6, then those shall be used in lieu of the specified temperatures. If head pressure control is active below the rating temperature, then tests shall be run per the Section 5.8 test procedure.
2. Correct for Fouling Factor Allowance by using the calculation method described in Section 4.6.
3. The flow rates are to be held constant at full-load values for all part-load conditions as per Table 4.
4. For part-load entering condenser water temperatures, the temperature shall vary linearly from the user defined EWT at 100% load to 19.00 ºC at 50% loads, and fixed at 19.00 ºC for 50% to 0% loads. See Equation 20.
5. For part-load EDB, the temperature should vary linearly from the user defined EDB at 100% load to 13.0 ºC at 33.3% load, and fixed at 13.0 ºC for 33.3% to 0% loads. See Equation 19.
6. For part-load EWB or SDT, the temperature should vary linearly from the user defined EWB or SDT at 100% load to the following temperatures at 0% load for each respective system type.
   - 6.1 – 10.00 °C EWB for Evaporatively-cooled Condenser. See Equation 21.
   - 6.2 – 12.00 °C SDT for Air-cooled Without Condenser. See Equation 22.
   - 6.3 – 19.00 °C SDT for Water-cooled or Evaporatively-cooled Without Condenser. See Equations 23 and 24.
7. Air-cooled and evaporatively-cooled unit ratings are at standard atmospheric condition (sea level). Measured data shall be corrected to standard atmospheric pressure of 101.33 kPa per Appendix C.

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