AHRI Standard 560-2023 (I-P)

2023 Standard for

Performance Rating of Water-cooled Lithium Bromide Absorption Water-chilling and Water-heating Packages

AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE

we make life better®

2311 Wilson Boulevard, Suite 400
Arlington, VA 22201, USA
www.ahrinet.org
PH 703.524.8800
FX 703.562.1942

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This standard supersedes AHRI Standard 560-2000.

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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 AHRI Standard 560, *Performance Rating of Water-cooled Lithium Bromide Absorption Water-chilling and Water-heating Packages*, was prepared by the Chiller Standards Technical Committee. The standard was approved by the Applied Standards Subcommittee on 28 November 2023.

Origin and Development of AHRI Standard 560

The initial publication was ARI Standard 560-1992, *Absorption Water Chilling and Water Heating Packages*. Subsequent revisions include:

AHRI Standard 560-2000 (SI/I-P), *Absorption Water Chilling and Water Heating Packages*

Summary of Changes

AHRI Standard 560 (I-P) contains the following update(s) to the previous edition:

- Reference ASHRAE 182-2020 as method of test
- Align definitions and requirements with AHRI 550/590 and 551/591 where possible
- Remove scope exclusion for air-cooled applications
- Update title to "Performance Rating of Water-cooled Lithium Bromide Absorption Water-chilling and Water-heating Packages"

Committee Personnel

Chiller Standards Technical Committee

Participant	Interest Category Classification	Voting Member Role	State / Country
Frank Giunta Trane U.S. Inc.	Product Manufacturer	Chair	WI, USA
Darrin Anderson Multistack LLC	Product Manufacturer	Primary Voter	WI, USA
Azzeddine Aoune Smardt Chiller Group Inc.	Product Manufacturer	Primary Voter	QC, Canada
John Bade 2050 Partners	General Interest	Primary Voter	CA, USA
John Cummings LG Electronics, Inc.	Product Manufacturer	Primary Voter	GA, USA
Dana Fischer Mitsubishi Electric	Product Manufacturer	Primary Voter	GA, USA
Chandra Gollapudi Samsung Electronics Co., Ltd.	Product Manufacturer	Primary Voter	South Korea
Tim Hammond WaterFurnace International, Inc.	Product Manufacturer	Primary Voter	IN, USA
Phillip Johnson Daikin Applied Americas Inc.	Product Manufacturer	Primary Voter	VA, USA
Richard Lord Carrier Corporation	Product Manufacturer	Primary Voter	TN, USA
Mustafa Yanik Danfoss Turbocor Compressors	Component Manufacturer	Primary Voter	PA, USA
Stephen Zardus Johnson Controls, Inc.	Product Manufacturer	Primary Voter	PA, USA
Yunqian Zhang Chongqing Midea General Refrigeration Equipment Co., Ltd.	Product Manufacturer	Primary Voter	China
Alireza Behfar Carrier Corporation	Product Manufacturer	Alternate to Richard Lord	NC, USA
Ben Dingel Trane U.S. Inc.	Product Manufacturer	Alternate to Frank Giunta	WI, USA
Ray Good Danfoss Turbocor Compressors	Product Manufacturer	Alternate to Mustafa Yanik	FL, USA
Natasha Helsper Trane U.S. Inc.	Product Manufacturer	Alternate to Frank Giunta	WI, USA
Ryan Holdmeyer Trane U.S. Inc.	Product Manufacturer	Alternate to Frank Giunta	WI, USA
David Ritter Johnson Controls, Inc.	Product Manufacturer	Alternate to Stephen Zardus	PA, USA
Brad Schafer Multistack LLC	Product Manufacturer	Alternate to Darrin Anderson	WI, USA
George Singh Trane U.S. Inc.	Product Manufacturer	Alternate to Frank Giunta	WI, USA
Doug Tucker Mitsubishi Electric Cooling & Heating	Product Manufacturer	Alternate to Dana Fischer	GA, USA
Michael Zamalis Johnson Controls, Inc.	Product Manufacturer	Alternate to Stephen Zardus	PA, USA
Jaime Yeh	AHRI Staff Liaison		

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 13256-2, and air-to-water units designed exclusively to heat potable water as covered by AHRI 1300.

Product definitions are as defined on the AHRI website Applied Sector page.

Applied Standards Subcommittee

Participant	Interest Category Classification	Voting Member Role	State / Country
Patrick Marks (Chair) Johnson Controls, Inc.	Product Manufacturer	Chair	PA, USA
Jeff deRoos Carrier Corporation	Product Manufacturer	Primary Voter	FL, USA
Henry Ernst Daikin Applied Americas Inc.	Product Manufacturer	Primary Voter	MN, USA
Craig Burg Desert Aire Corp.	Product Manufacturer	Primary Voter	WI, USA
Armin Hauer ebm-papst Inc.	Product Manufacturer	Primary Voter	CT, USA
Jennifer Butsch Emerson Commercial and Residential Solutions	Product Manufacturer	Primary Voter	OH, USA
Brandon Bates Energistics Laboratory	Testing Laboratory	Primary Voter	TX, USA
Eric Sakal GE Appliances, a Haier Company	Product Manufacturer	Primary Voter	KY, USA
Jeff Whitelaw Mitsubishi Electric Cooling & Heating	Product Manufacturer	Primary Voter	GA, USA
Tom McDermott Swegon North America Inc.	Product Manufacturer	Primary Voter	ON, Canada
Darcy Lee Trane U.S. Inc.	Product Manufacturer	Primary Voter	GA, USA
Karl Best	AHRI Staff Liaison		

Applied Standards Subcommittee Scope:

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-COOLED LITHIUM BROMIDE ABSORPTION WATER-CHILLING AND WATER-HEATING PACKAGES

Section 1. Purpose

This standard establishes definitions, test requirements, rating requirements, minimum data requirements for *published ratings*, marking and nameplate data, and conformance conditions for *water-cooled lithium bromide absorption water-chilling and water-heating packages*.

Section 2. Scope

2.1 Scope

This standard applies to lithium bromide water-cooled *single-effect* steam and hot water operated water-chilling units, water-cooled *double-effect* steam and hot water operated water-chilling units, and *double-effect direct-fired* (natural gas, oil, LP gas) water-chilling/heating units. Water is the refrigerant and LiBr (lithium bromide) the absorbent. See definitions in Section 3.

2.2 Exclusions

This standard does not apply to heat pump applications, exhaust gas fired applications, and non-standard units.

Section 3. Definitions

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

Common conversion factors are defined in Section 7 and are referred to in equations using K1, K2, K3, and K4.

3.1 Expression of Provisions

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

3.1.1 "Can" or "cannot"

Express an option or capability.

3.1.2 "May"

Signifies a permission expressed by the document.

3.1.3 "Must"

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

3.1.4 "Shall" or "shall not"

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

3.1.5 "Should" or "should not"

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

3.2 Standard Specific Definitions

3.2.1 Absorber

A component included in *absorption packages* where a concentrated solution absorbs refrigerant and becomes dilute, while rejecting heat from the cycle.

3.2.2 Auxiliary Power

Power provided to devices that are not inherent elements of the refrigerating and heating cycles including, but not limited to: burners, refrigerant pumps, solution pumps, control power, fans, and heaters.

3.2.3 Capacity

The rate heat is added to or removed from a liquid stream of an *absorption package*. This is the useful product of an *absorption package* and 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* calculated as the sensible heat transfer of water heated either in what is the *evaporator* in cooling mode (acting as a *condenser* in *heating mode*, two-pipe system) or in a separate hot-water heat exchanger (four-pipe system) that is available for useful heating of the thermal load external to the *absorption package*.

3.2.3.2 Net Refrigerating Capacity

The *capacity* calculated as the sensible heat transfer produced by the *evaporator* that is available for useful cooling of the thermal load external to the *absorption package*.

3.2.4 Condenser

A refrigeration system component that condenses refrigerant vapor.

3.2.4.1 Water-cooled Condenser

A component that utilizes refrigerant-to-water heat transfer means, causing the refrigerant to condense and the water to be heated for rejection to ambient.

3.2.5 Energy Efficiency

3.2.5.1 Cooling Energy Efficiency

3.2.5.1.1 Cooling Coefficient of Performance (COP_R)

A ratio of the *net refrigerating capacity* to the *thermal energy input* at any given set of *rating conditions*.

3.2.5.1.2 MBH/ton_R

Thermal energy input per unit *capacity*. The cooling efficiency expressed as a ratio of *thermal energy input* divided by the *net refrigerating capacity* using the following units of measure: MBH for *thermal energy input* and ton_R for *net refrigerating capacity*.

3.2.5.2 Heating Energy Efficiency

3.2.5.2.1 Heating Coefficient of Performance (COP_H)

A ratio of the *net heating capacity* to the *thermal energy input* at any given set of *rating conditions*.

3.2.6 Evaporator

A refrigeration system component that evaporates refrigerant liquid.

3.2.7 Fouling Factor

The thermal resistance due to fouling accumulated on the water side heat transfer surface.

3.2.7.1 Fouling Factor Allowance

A specified value for *published ratings* as a provision for anticipated thermal resistance due to water side fouling during use, expressed in $h \cdot ft^2 \cdot {}^{\circ}F/Btu$

3.2.8 Generator

A component of *absorption packages* that utilizes heat from an external source to desorb refrigerant from dilute solution to create a more concentrated solution.

3.2.9 Higher Heating Value (HHV)

The amount of heat produced per unit of fuel when complete combustion takes place at constant pressure. The products of combustion are cooled to the initial temperature of the fuel and air, and the vapor formed during combustion is condensed, Btu/lb or Btu/ft^3 for gaseous fuel, or Btu/lb or Btu/gal for liquid fuel.

3.2.10 Part-load Value (PLV)

A single number figure of merit expressing part-load efficiency for equipment based on weighted operation at various partial load capacities for the equipment.

3.2.10.1 Integrated Part-load Value (IPLV.IP)

A single number part-load efficiency figure of merit calculated per the method described in this standard at *standard rating conditions*.

3.2.10.2 Non-standard Part-load Value (NPLV.IP)

A single number part-load efficiency figure of merit calculated per the method described in this standard referenced to conditions other than *IPLV.IP* conditions.

3.2.11 Percent Load

The ratio of the part-load net *capacity* to the *full load* rated net *capacity*, stated in decimal format. (For example, 100% = 1.0).

3.2.11.1 Full Load (100% Load)

The highest *capacity* the *absorption package* has been rated at specific conditions. Corresponds to the *100% load* point utilized in *IPLV. IP* or *NPLV.IP*.

3.2.12 Published Ratings

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

3.2.12.1 Application Rating

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

3.2.12.2 Standard Rating

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

3.2.13 Rating Conditions

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

3.2.13.1 Application Rating Conditions

A set of operating conditions within the range of Table 2 selected for a customer application (other than *standard rating conditions*).

3.2.13.2 Standard Rating Conditions

A set of operating conditions used as the basis of comparison for performance characteristics, per Table 1.

3.2.14 Significant Figure

Each of the digits of a number that are used to express the required degree of accuracy, starting from the first nonzero digit (Refer to Appendix C).

3.2.15 Thermal Energy Input

The heat content of the fuel, steam or hot heat transfer fluid excluding the electrical input.

3.2.15.1 Direct-fired Energy Input

The gross heating content of the fuel based on the *HHV* in MBH in *direct-fired* systems.

3.2.15.2 Indirect-fired Energy Input

The heat content of the steam or hot water in MBH in *indirect-fired* systems.

3.2.16 Water-cooled Lithium Bromide Absorption Water-chilling and Water-heating Package (Absorption Package)

A factory-designed and prefabricated assembly used for chilling water, heating water, or both that consists of an *evaporator*, *absorber*, *water-cooled condenser*, *generator(s)*, and solution heat exchanger(s), with interconnections and accessories.

3.2.16.1 Direct-fired and Indirect-fired Absorption Packages

Absorption packages can be further subdivided into the following two categories:

3.2.16.1.1 Direct-fired

Uses thermal energy derived from natural gas, LP gas, oil, or other fuel, combusted within the *absorption package*.

3.2.16.1.2 Indirect-fired

Uses thermal energy from steam, hot water, hot heat-transfer fluids, or a hot gas stream not resulting from combustion within the *absorption package*.

3.2.16.2 Single-effect and Double-effect Absorption Packages

Utilizes a mixture of at least two components. The more volatile component is the refrigerant, and the less volatile substance with high affinity for the refrigerant is the absorbent. Either single or multiple reconcentration of an absorbent solution, known as effects, can be used as follows:

3.2.16.2.1 Double-effect

Employs a two-step reconcentration of the absorbent using a high-temperature *generator*. The refrigerant released in the high-temperature *generator* (first effect) is used to drive release of additional refrigerant in the low-temperature *generator* (second effect).

3.2.16.2.2 Single-effect

Employs a one-step reconcentration of the absorbent in the *generator*. Refrigerant vapor is released when thermal energy is introduced into the *generator*. The concentrated absorbent is returned to the *absorber* and absorbs refrigerant vapor flashed off in the *evaporator*, and the cycle repeats.

3.2.16.3 Operational Modes

Absorption packages can be operated in the following modes:

3.2.16.3.1 Cooling Only Mode

Cooling is delivered through the *evaporator*.

3.2.16.3.2 **Heating Mode**

Heat is delivered from an external source through the *evaporator* or another heat exchanger.

Note: Simultaneous heating and cooling can be provided where cooling is delivered through the *evaporator* and heat is simultaneously delivered from an external source through another heat exchanger.

3.2.17 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. All ratings shall be based on tests conducted in accordance with the test method and procedures described in ASHRAE 182.

4.2 Test Documentation

Test documentation shall record measurement values and calculated results in accordance with methods and procedures described in ASHRAE 182.

4.3 Calculations and Published Data

Calculations and published data shall comply with the requirements of ASHRAE 182.

Section 5. Rating Requirements

5.1 Standard Rating Metrics

5.1.1 Cooling Energy Efficiency

The forms of the *cooling energy efficiency* terms are listed as Equation 1 and Equation 2. These terms are calculated at both *full load* and part-load conditions.

5.1.1.1 Cooling Coefficient of Performance (COP_R)

The COP_R, Btu/h/Btu/h, shall be calculated using Equation 1.

$$COP_R = \frac{K1 \cdot Q_{ev}}{Q_{input}} \quad (1)$$

5.1.1.2 Thermal Energy Input per Capacity, MBH/ton_R

The *thermal energy input* per *capacity*, MBH/ton_R, shall be calculated using Equation 2.

$$MBH/ton_R = \frac{K2 \cdot Q_{input}}{Q_{ev}} \quad (2)$$

5.1.2 Heating Energy Efficiency

The COP_H, Btu/h/Btu/h, shall be calculated using Equation 3.

$$COP_H = \frac{Q_{ht}}{Q_{input}} \quad (3)$$

5.1.3 Net Refrigerating Capacity

The *net refrigerating capacity*, Btu/h, for the *evaporator* shall use the water temperatures, water mass flow rate and water properties at the *evaporator* entering and leaving conditions and be calculated using Equation 4:

$$Q_{ev} = m_w \cdot c_p \cdot (T_{in} - T_{out}) \quad (4)$$

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 20).

The volumetric flow rate shall be calculated using Equation 5.

$$V_w = \frac{m_w}{\rho_{in}} \cdot K3 \quad (5)$$

5.1.4 Net Heating Capacity

The *net heating capacity*, Btu/h, for a hot water heater shall use the water temperatures, water flow rate, and water properties at the entering and leaving conditions and be calculated using Equation 6.

$$Q_{ht} = m_w \cdot c_p \cdot (T_{out} - T_{in}) \quad (6)$$

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 20).

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 *absorption 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 ft H_2O at a reference water temperature of 60°F. For test measurements, this is a differential pressure expressed in psid. *Water pressure drop* shall be calculated using Equation 7.

$$\Delta p_{corrected} = \Delta p_{test} - \Delta p_{adj} \quad (7)$$

5.2 Standard Ratings and Conditions

Standard ratings for all *absorption packages* shall be established at the *standard rating conditions*. These packages shall be rated for one or more of the following: *cooling only mode* performance, *heating only mode* performance, or simultaneous heating and cooling performance at conditions specified in Table 1. *Standard ratings* shall include a water-side *fouling factor allowance* as specified in Table 1.

Table 1 Standard Ratings Conditions

	Single-effect Indirect-fired	***Double-effect Indirect-fired***	***Double-effect Direct-fired***
Absorber / *condenser* water			
Entering water temperature	85.00°F	85.00°F	85.00°F
Water flow rate	3.6 gpm/ton$_R$	4.0 gpm/ton$_R$	4.0 gpm/ton$_R$
Rating fouling allowance (water-side)	0.000250 h·ft^2·°F/Btu	0.000250 h·ft^2·°F/Btu	0.000250 h·ft^2·°F/Btu
Evaporator			
Leaving water temperature	44.00°F	44.00°F	44.00°F
Water flow rate	2.4 gpm/ton$_R$	2.4 gpm/ton$_R$	2.4 gpm/ton$_R$
Rating *fouling factor allowance*	0.000100 h·ft^2·°F/Btu	0.000100 h·ft^2·°F/Btu	0.000100 h·ft^2·°F/Btu
Energy input			
Fuel heat content	—	—	*HHV*
Steam pressure[1]	Note 2	Note 2	—
Rating *fouling factor allowance* (steam)	Note 2	Note 2	—
Hot water entering temperature	Note 2	Note 2	—
Hot water leaving temperature	Note 2	Note 2	—
Rating *fouling factor allowance* (water-side)	0.000100 h·ft^2·°F/Btu	0.000100 h·ft^2·°F/Btu	—

Notes:

1. After energy control valve at inlet flange of chiller.
2. Manufacturer specified conditions.

5.3 Application Rating Conditions

Application ratings shall include the range of *rating conditions* listed in Table 2 or be within the operating limits of the equipment. For guidance to the industry, designing to large *fouling factors* impacts the performance of the chiller. Heat transfer surfaces are best maintained by cleaning or maintaining proper water treatment to mitigate 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 0.00100 h·ft^2·°F/Btu. *Fouling factors* above these values are outside of the scope of this standard and shall be indicated as such.

Table 2 Application Rating Conditions

Rating Value	*Rating Conditions*
Evaporator	
Leaving *evaporator* water temperature	40.00°F to 70.00°F in increments of 2.00°F
Water temperature difference	8.00°F to 15.00°F
Fouling factor allowance	0.000 to 0.00100 h·ft^2 ·°F/Btu
Water cooled *absorber* / *condenser*	
Entering *absorber* water temperature	70.00°F to 95.00°F in increments of 5.00°F
Water flow rate limit	2.8 to 6.0 gpm/ton$_R$
Fouling factor allowance	0.000 to 0.00100 h·ft^2·°F/Btu
Input steam pressure at steam valve or inlet header	
Single stage unit	0 psig to 15.0 psig in increments of 2.0 psi
Two stage unit	0 psig to 125 psig in increments of 15.0 psi
Heating mode (*double-effect*)	
Hot water (to *generator*) temperature	180.00°F to 400.00°F
Heating water flow rate	Manufacturer's standard gpm/ton$_R$

Note: Applies to *full load* only and not part load ratings

5.4 Part-load Ratings

Double-effect (*indirect-fired* and *direct-fired*) 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 3. Part load ratings are not required for *single-effect absorption packages*.

5.4.1 Cooling Only Mode Part-load rating points

Cooling only mode part-load rating points shall be presented in one or more of the following four ways:

5.4.1.1 IPLV.IP

Based on the conditions defined in Table 3 and method defined in Section 5.4.2.

5.4.1.2 NPLV.IP

Based on the conditions defined in Table 3 and method defined in Section 5.4.2.

5.4.1.3 Individual Part-load Data Point(s)

Individual part-load data point(s) used for calculating *IPLV.IP* or *NPLV.IP* as defined in Table 3.

5.4.1.4 Other Part-load Points

Other part-load points, within the *application rating* limits of Table 2 and method defined in Section 0, that do not meet the requirements of notes (3) and (4) in Table 3 such as variable water flow rates or other entering *condenser* water temperatures. Neither *IPLV.IP* nor *NPLV.IP* shall be calculated for such points and shall not be required for publication per Section 6.

5.4.2 Determination of Part-load Performance

For Water-chilling Packages covered by this standard, the *IPLV.IP* or *NPLV.IP* shall be calculated as follows:

5.4.2.1 Determine the Part-load Energy Efficiency

Determine the part-load *energy efficiency* at 100%, 75%, 50%, and 25% load points at the conditions specified in Table 3.

5.4.2.2 Calculate the IPLV.IP or NPLV.IP for Units Rated with COP_R

Use Equation 8 to calculate the *IPLV.IP* or *NPLV.IP* for units rated with COP_R.

$$IPLV.IP \text{ or } NPLV.IP = 0.01 \cdot A + 0.42 \cdot B + 0.45 \cdot C + 0.12 \cdot D \quad (8)$$

Where:

A = *COP*COP_R at *100% load*

B = COP_R at 75% load

C = COP_R at 50% load

D = COP_R at 25% load

5.4.2.3 Calculate the IPLV.IP or NPLV.IP for Units Rated with MBH/ton$_R$

Use Equation 9 to calculate the *IPLV.IP* or *NPLV.IP* for units rated with *MBH/ton$_R$*.

$$IPLV.IP \text{ or } NPLV.IP = \frac{1}{\frac{0.01}{A} + \frac{0.42}{B} + \frac{0.45}{C} + \frac{0.12}{D}} \quad (9)$$

Where:

A = *Thermal energy input* per *capacity*, *MBH/ton$_R$* at *100% load*

B = *Thermal energy input* per *capacity*, *MBH/ton$_R$* at 75% load

C = *Thermal energy input* per *capacity*, *MBH/ton$_R$* at 50% load

D = *Thermal energy input* per *capacity*, *MBH/ton$_R$* at 25% load

Table 3 Part-load Conditions for Rating

	IPLV.IP	*NPLV.IP*
Evaporator		
All loads T_{out}, °F [2]	44.00	Selected T_{out}
Flow rate, gpm/ton$_R$ [3]	Per Table 1	Per Table 1[3]
R_{foul}, h·ft²·°F/Btu	0.000100	As specified
Water-cooled condenser [1,2]		
100% load T_{in}, °F	85.00	Selected T_{in}
75% load T_{in}, °F	75.00	Note 4
50% load T_{in}, °F	70.00	Note 4
25% load T_{in}, °F	70.00	Note 4
Flow rate, gpm/ton$_R$ [3]	Note 3	Selected flow rate
R_{foul}, h·ft²·°F/Btu	0.000250	As specified

Notes:

1. If the unit manufacturer's minimum temperatures are greater than those specified in Table 3, then the manufacturer's minimum temperatures can be used in place of the specified temperatures. If head pressure control is active below the rating temperature, then tests should be run at a temperature where head pressure control is activated.
2. Correct for *fouling factor allowance* by using the calculation method described in ASHRAE 182.
3. The flow rates are held constant at *full load* values for all part-load conditions as per Table 1.
4. For part-load entering *condenser* water temperatures, the temperature should vary linearly from the selected T_{in} at *100% load* to 70.00°F at 50% loads and fixed at 70.00°F for 50% to 0% loads.

5.4.2.4 Determine IPLV.IP or NPLV.IP Rating at Percent Load Rating Points

The *IPLV.IP* or *NPLV.IP* rating requires that the unit efficiency be determined at 100%, 75% 50% and 25% *percent load* rating points at the conditions specified in Table 3.

If a unit cannot run at the required *percent load* rating point within ± 2% but can run at a *percent load* less than the required *percent load* rating point, then the interpolation procedures defined in Section 5.4.2.4.1 shall be used to determine the *IPLV.IP* or *NPLV.IP*.

If unit cannot run at a *percent load* within ± 2% and cannot run at a *percent load* less than the rating *percent load*, then the degradation procedures of Section 5.4.2.4.2 shall be used to determine the *IPLV.IP* or *NPLV.IP*.

5.4.2.4.1 Interpolation

If the unit cannot run at any of the 75%, 50% or 25% *percent load* points within a tolerance of ± 2% but is capable of running at load above and below the rating *percent load* of 75%, 50% or 25% then interpolation of the test points shall be used to determine the part load efficiency rating at the required rating load points using the *condenser* water conditions defined for the part load *percent load* ratings point.

For example, if a unit can run at 66% *percent load* and 33% *percent load* then for the 50% *percent load* rating one rating point shall be run at 66% *capacity* with a *condenser* water temperature of 70°F and then a second test run at 33% *capacity* at 70°F *condenser* water and interpolation used to determine the rating at 50%. The *capacity* step closest to the rating point shall be used. For example, if a unit can run at 45% and 33% *capacity* then the 45% point shall be used for interpolating the 50% rating point and not the 33% *capacity* point.

Calculations shall use Equation 10 and Equation 11 when interpolating between two efficiency values η_1 and η_2 at different load points to determine an intermediate efficiency value η_{int} at another load point.

Point 1: $(\%Load_1, \eta_1)$

Point 2: $(\%Load_2, \eta_2)$

Interpolated point: $(\%Load_{int}, \eta_{int})$

$$\text{exponent} = \log(\eta_1) + (\%Load_{int} - \%Load_1) \cdot \frac{[\log(\eta_2) - \log(\eta_1)]}{(\%Load_2 - \%Load_1)} \qquad \textbf{10}$$

$$\eta_{int} = 10^{(\text{exponent})} \qquad \textbf{11}$$

Where:

η is any one of the *energy efficiency* metrics (such as, *COP*$_R$ or *MBH/ton*$_R$)

$\%Load$ is the decimal form of *percent load* (such as, 0.75 for 75% load)

Table 4 shows an example of interpolation for a unit that has the follow discrete steps of *capacity* for a nominal 200 ton$_R$ *full load capacity* unit.

Table 4 Unit Part-load Ratings

Operating Point	***Percent Load***	**Refrigeration Capacity**	***Thermal Energy Input***	***Absorber /Condenser*** **T$_{in}$**	***COP$_R$***
—	%	ton$_R$	Btu/h	°F	Btu/h / Btu/h
6	100%	200.0	2400000	85.00	1.000
5	83%	166.0	1994000	75.00	0.999
4-1	66%	132.0	1530000	75.00	1.035
4-2	68%	136.0	1496000	70.00	1.091
3	45%	90.00	976600	70.00	1.106
2	33%	66.00	722000	70.00	1.097
1	22%	44.00	567400	70.00	0.931

Table 5 shows the interpolation calculations that are required for the 75%, 50% and 25% *IPLV.IP* rating points.

Table 5 Unit IPLV.IP Calculation

***IPLV.IP* Point**	**Required Load**	**Operating Point**	**Actual Load**	***Absorber /Condenser* T_{in}**	***COP_R***	***IPLV.IP* Point (*COP_R*)**
-	%	-	%	°F	Btu/h / Btu/h	Btu/h / Btu/h
A	100%	6	100%	85.00	1.000	1.000
B	75%	5	83%	75.00	0.9990	1.016
		4-1	66%	75.00	1.035	
		interpolate	75%	75.00	1.016	
C	50%	4-2	68%	70.00	1.091	1.103
		3	45%	70.00	1.106	
		interpolate	50%	70.00	1.103	
D	25%	2	33%	70.00	1.097	0.9736
		1	22%	70.00	0.9310	
		interpolate	25%	70.00	0.9736	
—	—	—	—	—	*IPLV.IP*	1.050

5.4.2.4.2 Degradation

If a unit cannot be unloaded to the 25%, 50%, or 75% *percent load* point, then the unit shall be run at the minimum step of unloading at the *condenser* entering water temperature based on Table 3 for 25%, 50% or 75% rating *percent load* points as required. The efficiency shall then be determined by using Equation 12 or Equation 13.

$$\mathrm{COP_{R,CD}} = \frac{\mathrm{COP_{R,Test}}}{\mathrm{C_D}} \qquad (12)$$

$$\left(\frac{\mathrm{MBH}}{\mathrm{ton_R}}\right)_{CD} = \left(\frac{\mathrm{MBH}}{\mathrm{ton_R}}\right)_{Test} \cdot \mathrm{C_D} \qquad (13)$$

$COP_{R,Test}$, and $(MBH/ton_R)_{Test}$ are the efficiency at the test conditions and C_D is a degradation factor to account for cycling of the compressor for capacities less than the minimum step of *capacity*.

C_D shall be calculated using the Equation 14.

$$\mathrm{C_D} = (-0.13 \cdot \mathrm{LF}) + 1.13 \qquad (14)$$

Where LF is the load factor calculated using the Equation 15.

$$\mathrm{LF} = \frac{(\%\mathrm{Load})\,(\mathrm{Q_{ev\ 100\%}})}{(\mathrm{Q_{ev\ min\%Load}})} \qquad (15)$$

Part-load unit *capacity* is the measured or calculated unit *capacity* where *standard rating* points are determined using the method above.

The following is an example calculation for degradation:

The chiller has a *full load capacity* of 200 ton_R but can only run at a minimum *percent load* of 33% with the following part load performance.

Rated *full load* performance:

Full load capacity	=	200 ton_R
Minimum *percent load*	=	33%
Minimum *capacity*	=	66 ton_R
Minimum step efficiency at a *condenser* T_{in} of 70°F	=	1.097 Btu/h / Btu/h

$$LF = \frac{(\%Load)\ (Q_{ev\ 100\%})}{(Q_{ev\ min\%Load})} = \frac{25\% \cdot\ 200}{66} = 0.758$$

$$C_D = (-0.13 \cdot LF) +\ 1.13 = (-0.13\ \cdot 0.758) + 1.13 = 1.13 = 1.031$$

$$COP_{R,CD} = \frac{COP_R}{C_D} = \frac{1.097}{1.031} = 1.064\ \text{Btu/h / Btu/h}$$

5.5 Fouling Factor Allowances

Published ratings shall include *fouling factors* as specified in Table 1. Additional ratings, or means of determining those ratings, at other *fouling factor allowances* can be published if the *fouling factor* is within the ranges defined in Table 2.

Testing shall be conducted in accordance with the method outlined in ASHRAE 182 to establish the performance of the unit at the rated water-side fouling conditions. Tests conditions shall reflect *fouling factors* of zero (0.000) $h \cdot ft^2 \cdot °F/Btu$.

5.6 Tolerances

5.6.1 Tolerance Limit

The tolerance limits for *capacity*, *full load* and part load *energy efficiency*, and *water pressure drop* shall be determined from Equation 16, Equation 17, and Equation 18 per Table 6. The tolerance limit shall be rounded to the number of *significant figures* in Section 6 prior to comparison with a test result rounded to the same number of *significant figures*.

The tolerance limits are intended to be used when testing a unit to verify and confirm performance and take the following into account:

5.6.1.1 Uncertainty of Measurement

There are variations that result from instrumentation accuracy and installation effects, as well as test facility stability when testing a unit.

5.6.1.2 Uncertainty of Test Facilities

The tested performance of the same unit tested in multiple facilities can vary due to setup variations. This can cause variations in performance.

5.6.1.3 Uncertainty Due to Manufacturing

During the manufacturing of units, there are variations due to manufacturing production tolerances that can impact the performance from unit to unit.

5.6.1.4 Uncertainty of Performance Prediction Models

Due to the large complexity of options, manufacturers can use performance prediction models to determine ratings.

To comply with this standard, any test per Section 4 to verify published values shall be in accordance with Table 6.

Table 6 Definition of Tolerances

<table>
<tr><th colspan="2">-</th><th>Limits</th><th colspan="2">Related Tolerance Equations[2]</th></tr>
<tr><td rowspan="2">Capacity</td><td>Cooling or heating capacity for units with continuous unloading[1]</td><td>Minimum:
100% - Tol_1
Maximum:
100% + Tol_1</td><td rowspan="4">$$Tol_1 = 0.105 - (0.07 \cdot \%Load) + \left(\frac{0.15}{\Delta T_{FL} \cdot \%Load}\right)$$
See Figure 1 for graphical representation of the Tol_1 tolerance.</td><td rowspan="4">16</td></tr>
<tr><td>Cooling or heating capacity for units with discrete capacity steps</td><td>Minimum:
100% - Tol_1
Maximum: no limit
(Full load shall be at the maximum stage of capacity)</td></tr>
<tr><td rowspan="5">Efficiency</td><td>MBH/ton$_R$</td><td>Maximum of:
(100% + Tol_1) (rated MBH/ton$_R$)</td></tr>
<tr><td>COP$_R$</td><td>Minimum of:
(rated COP$_R$) / (100% + Tol_1)</td></tr>
<tr><td>IPLV.IP
NPLV.IP
(COP$_R$)</td><td>Minimum of:
(rated COP$_R$) / (100% + Tol_2)</td><td rowspan="3">$$Tol_2 = 0.065 + \left(\frac{0.35}{\Delta T_{FL}}\right)$$
See Figure 2 for graphical representation of the Tol_2 tolerance.</td><td rowspan="3">17</td></tr>
<tr><td>IPLV.IP
NPLV.IP
(MBH/ton$_R$)</td><td>Maximum of:
(100%+ Tol_2)·(rated MBH/ton$_R$)</td></tr>
<tr><td>IPLV.IP
NPLV.IP
(COP$_R$)</td><td>Minimum of
(rated COP$_R$) / (100% + Tol_2)</td></tr>
<tr><td colspan="2">Water pressure drop</td><td>$\Delta p_{corrected} \leq Tol_3$</td><td>$$Tol_3 = \max\begin{cases} 1.15 \cdot \Delta p_{rated} \\ \Delta p_{rated} + 2\ ft \cdot H_2O \end{cases}$$</td><td>18</td></tr>
<tr><td colspan="5">Notes:
1. The target set point condenser entering water temperatures for continuous unloading units are determined at the target part load test point.
2. %Load, Tol_1 and Tol_2 are in decimal form.</td></tr>
</table>

Figure 1 is a graphical representation of the related tolerance equation for *capacity* and efficiency as indicated in Table 6.

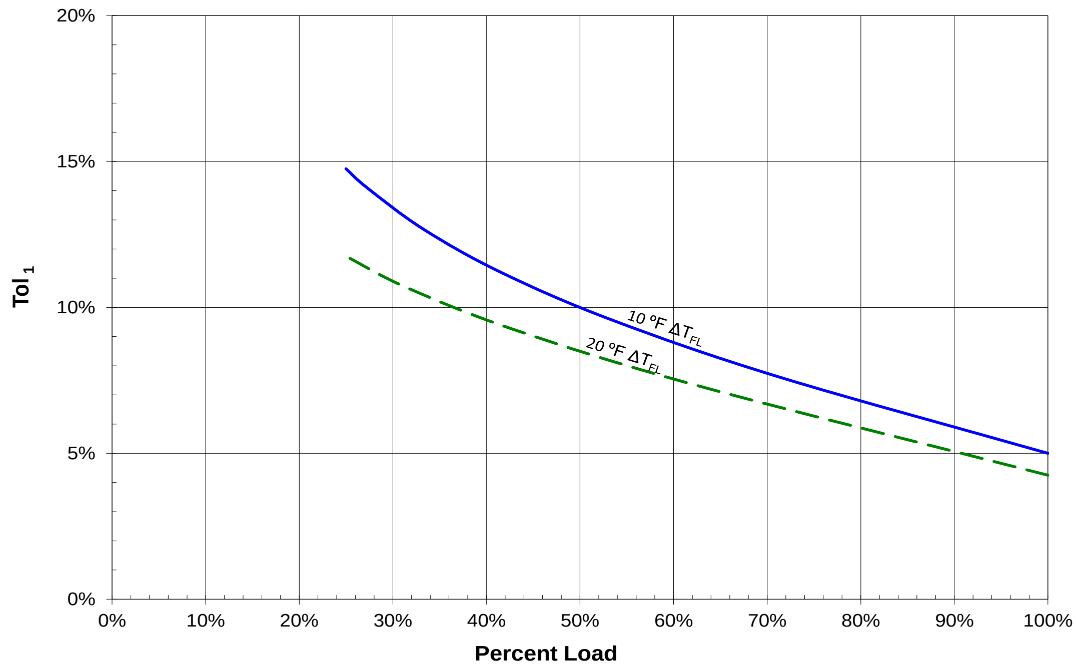

Figure 1 Allowable Tolerance (Tol_1) Curves for Full and Part-load Points

Figure 2 is a graphical representation of the related tolerance equation for *IPLV.IP and NPLV.IP* as indicated in Table 6. The *PLV* line shown can represent either *IPLV.IP* or *NPLV.IP* depending on use.

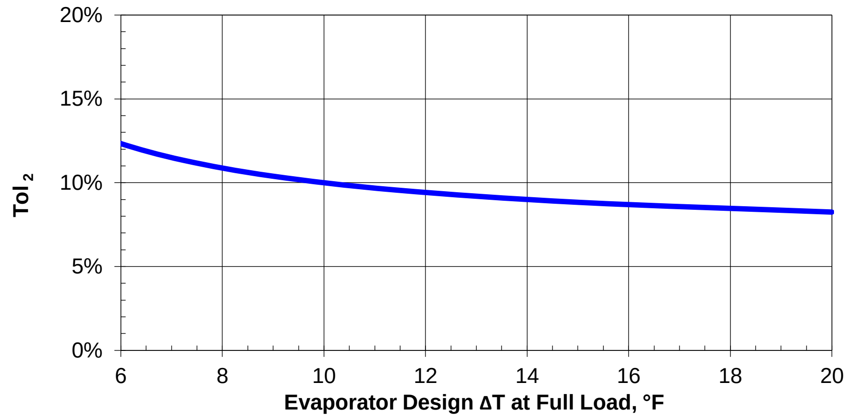

Figure 2 IPLV.IP and NPLV.IP Tolerance (Tol_2) Curve

5.6.2 Full Load Tolerance Examples

The tolerance limit on *full load capacity* and efficiency shall be determined from Section 5.6.1.

5.6.2.1 Full Load Example in COP_R

Rated *full load* performance:

Rated *capacity*	=	200.0 ton_R
Rated *thermal energy input*	=	378,700 Btu/h
Cooling ΔT_{FL}	=	10.00°F

$$COP_R = \frac{200 \text{ ton}_R \cdot K1}{378{,}700 \text{ Btu/h}} = 6.337 \ \frac{\text{Btu/h}}{\text{Btu/h}}$$

$$\text{Tolerance Limit} = \text{Tol}_1 = 0.105 - (0.07 \cdot 1.00) + \left(\frac{0.15}{10.00 \cdot 1.00}\right) = 0.05000$$

$$\text{Minimum Allowable } \mathit{Capacity} \ (\text{ton}_R) = (1.00 - 0.05) \cdot 200.0 \text{ ton}_R = 190.0 \text{ ton}_R$$

$$\text{Minimum Allowable } COP_R \left(\frac{\text{Btu/h}}{\text{Btu/h}}\right) = \frac{6.337}{1.00 + 0.05} = 6.035 \left(\frac{\text{Btu/h}}{\text{Btu/h}}\right)$$

5.6.2.2 Full Load Example in MBH/ton$_R$

Rated *full load* performance:

Rated *capacity*	=	200.0 ton$_R$
Rated *thermal energy input*	=	2400 MBH
Cooling ΔT_{FL}	=	10.00 °F

$$\text{Tolerance Limit} = \text{Tol}_1 = 0.105 - (0.07 \cdot 1.00) + \left(\frac{0.15}{10.00 \cdot 1.00}\right) = 0.05 = 0.05000$$

$$\text{Min. Allowable } \mathit{Capacity} = (1.00 - 0.05) \cdot 200.0 \text{ ton}_R = 190.0 \text{ ton}_R$$

$$\text{Max. Allowable MBH/ton}_R = (1.00 + 0.05) \cdot 12.00 \text{ MBH/ton}_R = 12.60 \text{ MBH/ton}_R$$

5.6.3 Part-load Tolerance Examples

The tolerance on part-load *COP$_R$* and *MBH/ton$_R$* shall be the tolerance as determined from Section 5.6.1.

5.6.3.1 Part-load Example in COP$_R$

Rated part-load performance:

Full load capacity	=	200.0 ton$_R$
Rated *thermal energy input* at 68% rated *capacity*	=	1,496,000 Btu/h
68% rated *capacity*	=	136.0 ton$_R$
Cooling ΔT_{FL}	=	10.00°F

$$COP_R = \frac{136.0 \text{ ton}_R \cdot K1}{1{,}496{,}000 \text{ Btu/h}} = 1.091 \ \frac{\text{Btu/h}}{\text{Btu/h}}$$

$$\text{Tolerance Limit} = \text{Tol}_1 = 0.105 - (0.07 \cdot 0.68) + \left(\frac{0.15}{10.00 \cdot 0.68}\right) = 0.07946$$

$$\text{Minimum Allowable } COP_R = \frac{1.091}{1.00 + 0.07946} = 1.012 \ \frac{\text{Btu/h}}{\text{Btu/h}}$$

5.6.3.2 Part-load Example in MBH/ton$_R$

Rated part-load performance:

Full load capacity	=	200.0 ton$_R$
Rated *thermal energy input* at 45% rated *capacity*	=	976.5 MBH
45% rated *capacity*	=	90.00 ton$_R$
Cooling ΔT_{FL}	=	10.00°F

$$\frac{\text{kW}}{\text{ton}_R} = \frac{976.5 \text{ MBH}}{90.00 \text{ ton}_R} = 10.85 \text{ MBH/ton}_R$$

$$\text{Tolerance Limit} = \text{Tol}_1 = 0.105 - (0.07 \cdot 0.45) + \left(\frac{0.15}{10.00 \cdot 0.45}\right) = 0.1068$$

$$\text{Maximum Allowable MBH/ton}_\text{R} = (1.00 + 0.1068) \cdot 10.85 = 12.01\text{MBH/ton}_\text{R}$$

Section 6. Minimum Data Requirements for Published Ratings

6.1 Minimum Data Requirements for Published Ratings

As a minimum, *published ratings* shall include either *standard ratings* or *application ratings*. Metrics at *standard rating conditions* shall be per Section 5.1 and Section 5.2. *Application rating conditions* shall adhere to Section 5.3 using the water-side *fouling factor allowance* per Table 1 unless the specified application states that a different *fouling factor allowance* value shall be used. Rated *capacity* $Q_{100\%}$, for *absorption packages* is the net *capacity* at the specified *full load rating conditions*.

All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with AHRI Standard 560 (I-P)". All claims to ratings outside the scope of this standard shall include the statement "Outside the scope of AHRI Standard 560 (I-P)". *Application ratings* within the scope of the standard shall include a statement of the conditions under which the ratings apply.

6.2 Published Ratings

Published ratings shall include a statement of all the following and shall be rounded to the specified number of *significant figures* (sf) or decimal places (dp).

6.2.1 General

1) Model number designations providing identification of the *absorption packages* to which the ratings shall apply.
2) *Net refrigerating capacity* (4 sf), ton_R.
3) Total energy input to the chiller (4 sf), MBH.
    a) *Direct-fired Energy Input*, MBH based on *HHV*.
    b) *Indirect-fired Energy Input*, MBH.
4) Chiller efficiency (4 sf), COP_R or MBH/ton_R.
5) *Evaporator fouling factor* (3 sf), as stated in Table 1.
6) Chilled water entering and leaving temperatures (2 dp), °F (as stated in Table 1), or leaving water temperature and temperature difference (2 dp), °F.
7) *Evaporator water pressure drop* (inlet to outlet) (3 sf), psi or ft H_2O.
8) Chilled water flow rate (4 sf), gpm.
9) Average electrical *auxiliary power* consumption (4 sf), kW for all auxiliary components including solution and refrigerant pumps, purge, control panel, burner fan, burner controls. Power required by system water pumps shall be excluded.
10) *Absorber / condenser water pressure drop* (inlet to outlet) (3 sf), psi or ft H_2O (at 60°F).
11) Any two of the following: Entering *absorber / condenser* water temperature (2 dp), °F. Leaving *absorber / condenser* water temperature (2 dp), °F. Water temperature rise through the *absorber / condenser* (2 dp), °F.
12) *Absorber / condenser* water flow rate (4 sf), gpm.
13) *Absorber / condenser fouling factors*, as stated in Table 1 (3 sf).

6.2.2 Hot Water Heating Option

1) *Net heating capacity* (4 sf), MBH.
2) Heating *water pressure drop* (3 sf), psi or ft H_2O (at 60°F)
3) Entering and leaving water temperatures (2 dp), °F (stated in Table 1).
4) Heating water flow rate (4 sf), gpm.

5) *Fouling factor*, as stated in Table 1 (3 sf).

Section 7. Conversions and Calculations

7.1 Conversions

For units that require conversion the following factors listed in Table 7 shall be utilized:

Table 7 Conversion Factors

To Convert From	Factor Name	To	Multiply By
ton of refrigeration (ton_R)	K1	British thermal unit per hour (Btu/h)	12,000
thousand British thermal units per hour (MBH)	K2	British thermal unit per hour (Btu/h)	1,000
cubic feet per hour $\left(\frac{ft^3}{h}\right)$	K3	Gallon per minute (gpm)	0.124675
foot of water at 60°F (ft H_2O (at 60°F))	K4	pound-force per square inch (psi)	0.43310

Notes:

- For *water pressure drop*, the conversion from water column "ft H2O" to "psi" is per ASHRAE Fundamentals Handbook. 60°F is used as the reference temperature for the density of water in the manometer.
- The British thermal unit (Btu) used in this standard is the International Table Btu. The Fifth International Conference on the Properties of Steam (London, July 1956) defined the calorie (International Table) as 4.1868 J. Therefore, the exact conversion factor for the Btu (International Table) is 1.05505585262 kJ.

7.2 Water Side Properties Calculation Methods

One of the following calculation methods shall be utilized. In both cases, the value of the water temperature or pressure to be used as input is dependent on the context of the calculation using the density and specific heat terms.

7.2.1 Method 1

Use a formulation of liquid water properties that is based on or consistent with IAPWS R7, such as NIST's REFPROP, to calculate physical properties such as density, volume expansivity, specific heat, and enthalpy as a function of both pressure and temperature.

7.2.2 Method 2

Use polynomial Equation 19 and Equation 20 to calculate density, volume expansivity, and specific heat of water as a function of temperature only.

$$\rho(T) = \rho_6\,T^6 + \rho_6\,T^5 + \rho_4\,T^4 + \rho_3 T^3 + \rho_2 T^2 + \rho_1 T + \rho_0 \quad \textbf{19}$$

$$c_p(T) = c_{p7}T^7 + c_{p6}T^6 + c_{p5}T^5 + c_{p4}T^4 + c_{p3}T^3 + c_{p2}T^2 + c_{p1}T + c_{p0} \quad \textbf{20}$$

Where:

T	=	$32 \sim 400°F$
ρ_6	=	$-2.37585 \cdot 10^{-15}\ \mathrm{lbm/(ft^3 \cdot °}R^6)$
ρ_5	=	$3.5568 \cdot 10^{-12}\ \mathrm{lbm/(ft^3 \cdot °}R^5)$
ρ_4	=	$-2.2802 \cdot 10^{-9}\ \mathrm{lbm/(ft^3 \cdot °}R^4)$

ρ_3 = $8.1558 \cdot 10^{-7}$ lbm/(ft$^3 \cdot {}^\circ R^3$)

ρ_2 = $-2.1479 \cdot 10^{-4}$ lbm/(ft$^3 \cdot {}^\circ R^2$)

ρ_1 = $1.3283 \cdot 10^{-2}$ lbm/(ft$^3 \cdot {}^\circ R$)

ρ_0 = 62.2097 lbm/ft^3

c_{p7} = $-9.98516 \cdot 10^{-19}$ Btu/(lbm $\cdot {}^\circ R^8$)

c_{p6} = $1.76843 \cdot 10^{-15}$ Btu/(lbm $\cdot {}^\circ R^7$)

c_{p5} = $-1.29636 \cdot 10^{-12}$ Btu/(lbm $\cdot {}^\circ R^6$)

c_{p4} = $5.1114 \cdot 10^{-10}$ Btu/(lbm $\cdot {}^\circ R^5$)

c_{p3} = $-1.1556 \cdot 10^{-7}$ Btu/(lbm $\cdot {}^\circ R^4$)

c_{p2} = $1.5435 \cdot 10^{-5}$ Btu/(lbm $\cdot {}^\circ R^3$)

c_{p1} = $-1.1068 \cdot 10^{-3}$ Btu/(lbm $\cdot {}^\circ R^2$)

c_{p0} = 1.0306 Btu/(lbm $\cdot {}^\circ R$)

Note: Density and specific heat polynomial equations are curve fits to values generated by NIST REFPROP v10 covering a temperature range of 32°F to 400°F. The applied pressure is taken as the larger of 100 psia and the saturation pressure corresponding to the temperature plus 60 psid. The 100 psia value is representative of system pressures used to allow for the calculation of water-side properties as a function of temperature only.

Section 8. Symbols and Subscripts

The symbols and subscripts used are defined in Table 8:

Table 8 Symbols and Subscripts

Symbol		Description	Unit Name	Unit Symbol
A	=	Efficiency at *100% load*	—	COP_R or MBH/ton_R
B	=	Efficiency at 75% load	—	COP_R or MBH/ton_R
C	=	Efficiency at 50% load	—	COP_R or MBH/ton_R
C_D	=	Degradation factor	dimensionless	—
COP_H	=	*Heating coefficient of performance*	dimensionless	—
COP_R	=	*Cooling coefficient of performance*	dimensionless	—
$COP_{R,CD}$	=	Efficiency, *cooling coefficient of performance*, corrected with degradation factor	dimensionless	—
$COP_{R,Test}$	=	Efficiency, *cooling coefficient of performance*, test value	dimensionless	—
c_p	=	Specific heat at constant pressure	British thermal unit (IT) per pound degree Fahrenheit	Btu/(lb·°F)
ρ	=	Density at constant pressure	pound (avoirdupois) per cubic foot	lb/ft^3
D	=	Efficiency at 25% load	—	COP_R or MBH/ton_R
%Load	=	*Percent load*	dimensionless	%
HHV	=	*Higher heating value*	Btu per hour, Btu per cubic foot, Btu per pound, or Btu per gallon	Btu/lb or Btu/ft^3 for gaseous fuel, or Btu/lb or Btu/gal for liquid fuel
IPLV.IP	=	Efficiency, *integrated part load value* when calculated and recorded in accordance with AHRI 560 (I-P)	—	COP_R or MBH/ton_R
K1 – K4	=	Refer to Table 7	—	varies
MBH/ton_R	=	*Cooling energy efficiency*	MBH per ton of refrigeration	MBH/ton_R
$\left(\frac{\mathrm{MBH}}{\mathrm{ton_R}}\right)_{CD}$	=	Efficiency, power input per *capacity*, corrected with degradation factor	MBH per ton of refrigeration	MBH/ton_R

Symbol		Description	Unit Name	Unit Symbol
$\left(\frac{\mathrm{MBH}}{\mathrm{ton_R}}\right)_{Test}$	=	Efficiency, power input per *capacity*, test value	MBH per ton of refrigeration	MBH/ton_R
LF	=	Load factor	dimensionless	—
LP	=	Liquefied petroleum	dimensionless	—
m_w	=	Mass flow rate, water	pound (avoirdupois) per hour	lb/h
NPLV.IP	=	Efficiency, *non-standard part load value* when calculated and recorded in accordance with AHRI 560 (I-P)	—	COP_R or MBH/ton_R
Q_{ht}	=	*Net heating capacity*	Btu per hour	Btu/h
Q_{ev}	=	*Net refrigerating capacity*	Btu per hour	Btu/h
ton_R	=	*Net refrigerating capacity*	ton	ton
$Q_{ev\%Load}$	=	Test results for unit net *capacity* at test point	Btu per hour	Btu/h
$Q_{ev100\%}$	=	Test results for unit net *capacity* at *100% load* point	Btu per hour	Btu/h
$Q_{evmin\%Load}$	=	The measured or calculated unit net *capacity* at the minimum step of *capacity*	Btu per hour	Btu/h
R_{foul}	=	*Fouling factor*	hour-foot squared-degree Fahrenheit per Btu	$h \cdot ft^2 \cdot °F/Btu$
$R_{foul,sp}$	=	*Fouling factor allowance*	hour-foot squared-degree Fahrenheit per Btu	$h \cdot ft^2 \cdot °F/Btu$
T	=	Temperature	degree Fahrenheit	°F
T_{in}	=	Entering water temperature	degree Fahrenheit	°F
Tol_1	=	Tolerance 1, performance tolerance limit	dimensionless	—
Tol_2	=	Tolerance 2, IPLV and NPLV performance tolerance limit	dimensionless	—
Tol_3	=	Tolerance 3, Tolerance on water side pressure drop	foot of water	ft H_2O (at 60°F)
T_{out}	=	Leaving water temperature	degree Fahrenheit	°F
V_w	=	Volumetric flow rate	gallon per minute	gpm
Q_{input}	=	*Thermal energy input*	Btu per hour	Btu/h
$\Delta p_{corrected}$	=	Tested result for liquid pressure drop	pound force per square inch, or foot of water	psid or ft H_2O (at 60°F)
Δp_{adj}	=	Calculated liquid pressure drop adjustment, refer to ASHRAE 182	pound force per square inch, or foot of water	psid or ft H_2O (at 60°F)

Symbol		Description	Unit Name	Unit Symbol
Δp_{rated}	=	Rated liquid pressure drop (inlet to outlet)	pound force per square inch, or foot of water	psid or ft H_2O (at 60°F)
ΔT_{FL}	=	Temperature differential, at rated *full load* design conditions	degree Fahrenheit	°F
ρ_{in}	=	Density corresponding to the entering water temperature	pound (avoirdupois) per cubic foot	lb/ft^3

Section 9. Marking and Nameplate Data

9.1 Marking and Nameplate Data

As a minimum, the nameplate shall display the following:

1) Manufacturer's name and location
2) Model number designation providing performance-essential identification
3) Refrigerant designation (in accordance with ASHRAE 34)
4) Voltage, phase, and frequency
5) Serial number

9.2 Nameplate Voltage

Where applicable, nameplate voltages for 60 Hz systems shall include one or more of the equipment nameplate voltage ratings shown in Table 1 of AHRI 110-2016. Where applicable, nameplate voltages for 50 Hz systems shall include one or more of the utilization voltages shown in Table 1 of IEC 60038.

Section 10. Conformance

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

APPENDIX A. REFERENCES – NORMATIVE

Listed here are all standards, handbooks, and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of the standard.

A.1. AHRI Standard 110 2016, *Air-Conditioning, Heating and Refrigerating Equipment Nameplate Voltages*, 2016, Air-Conditioning, Heating and Refrigeration Institute, 2311 Wilson Boulevard, Suite 400, Arlington, VA 22201, USA.

A.2. ANSI/ASHRAE Standard 182-2020, *Method of Testing Absorption Water-Chilling and Water-Heating Packages*, 2020, ASHRAE, 180 Technology Parkway NW, Peachtree Corners, Georgia 30092 USA.

A.3. ANSI/ASHRAE Standard 34-2022 with Addenda, *Designation and Safety Classification of Refrigerants*, ASHRAE, 180 Technology Parkway NW, Peachtree Corners, Georgia 30092 USA.

A.4. ASHRAE *Fundamentals Handbook*, 2021, ASHRAE, 180 Technology Parkway NW, Peachtree Corners, GA 30092 USA.

A.5. ASHRAE Terminology. ASHRAE. Accessed December 15, 2021. https://www.ashrae.org/technical-resources/free-resources/ashrae-terminology.

A.6. IEC Standard 60038, *IEC Standard Voltages*, 2009, International Electrotechnical Commission, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

A.7. International Association for the Properties of Water and Steam (IAPWS) R7, *The International Association for the Properties of Water and Steam*, 2012, International Association for the Properties of Water and Steam, http://www.iapws.org.

A.8. Lemmon, E.W., Bell, I.H., Huber, M.L., McLinden, M.O. NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties-REFPROP, Version 10.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, 2018. doi: https://doi.org/10.18434/T4/1502528.

APPENDIX B. REFERENCES – INFORMATIVE

Listed here are standards, handbooks and other publications which may provide useful information and background but are not considered essential. References in this appendix are not considered part of the standard.

None.

APPENDIX C. ROUNDING REQUIREMENTS – NORMATIVE

Calculations shall use measurement values and prior calculation values without rounding as defined below. Recorded values shall round values of measurements and calculated results as defined below to a number of *significant figures* per Section 6.

C.1. Rounding Requirements

Numerical data can be obtained, and calculations can be made with more digits than are justified by their accuracy or precision. For accuracy, such data shall be rounded to the number of figures consistent with the confidence that can be determined when recorded. At least two more *significant figures* shall be retained at intermediate stages of calculation than the final recorded value to prevent compounding of rounding errors.

C.2. Identifying Significant Figures

The rules for identifying *significant figures* when writing or interpreting numbers are as follows:

1) All non-zero digits are *significant figures*. For example, 91 has two *significant figures* (9 and 1), while 123.45 has five *significant figures* (1, 2, 3, 4 and 5).
2) Zeroes appearing anywhere between two non-zero digits are *significant figures*. Example: 101.1203 has seven *significant figures*: 1, 0, 1, 1, 2, 0 and 3.
3) Leading zeroes are not *significant figures*. For example, 0.00052 has two *significant figures*: 5 and 2.
4) Trailing zeroes in a number containing a decimal point are *significant figures*. For example:
    a) The number 12.2300 has six *significant figures*: 1, 2, 2, 3, 0 and 0.
    b) The number 0.000122300 has six *significant figures* because the zeros before the 1 are not *significant figures*.
    c) The number 120.00 has five *significant figures* because there are 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 misinterpreted that two decimal places of precision are indicated. Stating the result as 12.2300 makes clear that it is precise to four decimal places, or six *significant figures*.

C.3. Trailing Zeroes

The significance of trailing zeroes in a number not containing a decimal point can be ambiguous. For example, it is not clear if a number such as 1300 is precise to the nearest unit (and is an exact multiple of one hundred) or if it is shown to the nearest hundred due to rounding or uncertainty. Five conventions exist to address this issue:

1) A bar can be placed over the last *significant figure* and any trailing zeros following this are not *significant figures*. For example, $13\bar{0}0$ has three *significant figures*, indicating that the number is precise to the nearest ten.
2) The last *significant figure* of a number can be underlined. For example, "$2\underline{0}00$" has two *significant figures*.
3) A decimal point can be placed after the number. For example, "100." indicates three *significant figures*.
4) In the combination of a number and a unit of measurement, the ambiguity can be prevented by choosing a unit magnitude prefix. For example, the number of *significant figures* in a power measurement written as 1300 W is ambiguous, while a power of 1.30 kW is unambiguous.
5) Scientific notation or exponential notation can be used; for example, 1.30×10^3 W.

C.4. Significant Figures in Calculations

In multiplication and division, the operand with the least number of *significant figures* determines the number of *significant figures* to be recorded in the result. For example, the product 1256 x 12.2 = 15,323.2 is recorded as 15,$\bar{3}$00.

In addition and subtraction, the operand with the least number of *significant figures* to either the right or the left of the decimal point determines the number of *significant figures* to be recorded. For example, the sum of 120.05 + 10.1 + 56.323 = 156.473 is recorded as 156.5 because 10.1 defines the reporting level.

In calculations involving multiple operations, order of operations is followed, and the result is rounded according to the least number of *significant figures* involved. For example, (1256 x 12.2) + 125 = 15,323.2 + 125 =15,$\bar{4}$00.

C.5. Rounding Values

The following rules shall be used in rounding values:

1) When the digit next beyond the one to be retained is less than five, the retained digit is kept unchanged. For example, 2.541 becomes 2.5 to two *significant figures*.
2) When the digit next beyond the one to be retained is greater than or equal to five, the retained digit is increased by one. For example, 2.453 becomes 2.5 to two *significant figures*.
3) Two or more digits to the right of the last digit to be retained are a group in rounding decisions. For example, in 2.4(501), the group (501) is >5 while for 2.5(499), (499) is <5.