ADDENDA

ANSI/ASHRAE Addendum c to ANSI/ASHRAE Standard 30-2019

Method of Testing Liquid Chillers

Approved by ASHRAE and the American National Standards Institute on December 31, 2024.

This addendum was approved by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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FOREWORD

ASHRAE Standard 30 prescribes methods for obtaining performance data relating to liquid-chilling or liquid-heating equipment using any type of compressor. The intent of this standard is to provide uniform test methods to measure the performance of this equipment by addressing the test and instrumentation requirements, test procedures, data to be recorded, and calculations to generate and confirm valid test results.

Addendum c includes the following major revisions:

- *Added a definition for heat exchanger allowing reference to capacity measurement in cooling or heating.*
- *Redefined heat reclaim and combined heating and cooling metrics to allow capacity and total efficiency calculation including all heat exchangers* **.**
- *Added definitions for various operating modes such as any hybrid mode that makes use of simultaneous cooling and heating, and any hybrid mode that makes use of passive operation, provided that all system components are included as part of the liquid-chilling system to be tested. Such components may include air-to-liquid, refrigerant-to-liquid, refrigerant-to-air, or liquid-to-liquid heat exchangers.*

Informative Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum c to Standard 30-2019

Modify Section 3 as shown. The remainder of Section 3 is unchanged. Note: The text below reflects changes made my previously approved addenda. See www.ashrae.org/addenda for a complete list.

3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

[. . .]

capacity: a measurable physical quantity, the rate that heat (energy) is added to or removed from the liquid side of a refrigerating system. Capacity is defined as the mass flow rate of the liquid multiplied by the difference in enthalpy of liquid entering and leaving the heat exchanger~~. For the purposes of 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 liquid-side pressure losses.~~ (***Informative Note:*** When the impact of test result uncertainty is acceptable to the test plan requirements, 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 liquid-side pressure losses.)

gross heating capacity: the capacity of the liquid-cooled condenser as measured by the total heat transferred from the refrigerant to the liquid in the condenser. This value includes both the sensible heat transfer and the friction heat losses from pressure drop effects of the liquid flow through the condenser. This value is used to calculate the energy balance of a test.

gross refrigerating capacity: the capacity of the evaporator as measured by the total heat transferred from the liquid to the refrigerant in the evaporator. This value includes both the sensible heat transfer and the friction heat losses from pressure drop effects of the liquid flow through the evaporator. This value is used to calculate the energy balance of a test.

net heating capacity: the capacity of the condenser available for useful heating of the thermal load, external to the liquid-chilling system, calculated using only the sensible heat transfer.

net refrigerating capacity: the capacity of the evaporator available for useful cooling of the thermal load, external to the liquid-chilling system, calculated using only the sensible heat transfer.

[. . .]

condenser: a refrigerating system component which condenses refrigerant from vapor state to liquid state by the removal of heat. ~~Desuperheating and subcooling of the refrigerant may occur as well.~~ (***Informative Note:*** Desuperheating and subcooling of the refrigerant may occur as well. A condenser may include one or more refrigerant circuits.)

~~***air-cooled condenser:*** a condenser, including condenser fans, that condenses refrigerant vapor by rejecting heat to air mechanically circulated over a dry heat transfer surface, causing a temperature an enthalpy rise in the air.~~

~~***evaporatively-cooled condenser:*** a condenser which condenses refrigerant vapor by rejecting heat to a water and air mixture mechanically circulated over a wetted heat transfer surface, causing evaporation of the water and an increase in the enthalpy of the air.~~

~~***liquid-cooled condenser:*** a condenser that condenses refrigerant vapor by rejecting heat to liquid mechanically circulated over its heat transfer surface, causing a temperature and enthalpy rise in the liquid.~~

~~***liquid-cooled heat reclaim condenser:*** a liquid-cooled condenser, that may be either a separate parallel condenser in a refrigerating system using two or more condensers, or a portion of a liquid-cooled condenser with two or more liquid circuits, with the purpose of heat recovery.~~

[. . .]

efficiency: ~~performance at specified operating conditions, expressed as the ratio of the capacity output and the total input power of a process or a machine. Depending on the specific efficiency metric, the numerator and denominator may be switched, and the units of measure may be dimensionless or not. All efficiency metrics shall be stated in conjunction with a complete set of operating conditions.~~ a ratio of two quantities at specified operating conditions for a given operating mode, the thermal energy movement expressed as a rate (thermal output power) and the required energy input rate (input power) to move that thermal energy. The thermal output power is the sum of all useful capacity of the process or machine to satisfy a thermal load external to the liquid-chilling system, and input power is the total input power.

cooling efficiency: efficiency expressed as a ratio of net refrigerating capacity and the total input power when operating in cooling mode. The ratio may be inverted depending on the selected units of measure.

COP_R: coefficient of performance; the cooling efficiency expressed as a dimensionless ratio of net refrigerating capacity divided by the total input power.

EER: energy efficiency ratio; the cooling efficiency expressed as a ratio of net refrigerating capacity divided by the total input power. EER shall use the following units of measure: Btu/h for net refrigerating capacity and W for total input power.

kW/ton_R: power input per unit capacity; the cooling efficiency expressed as a ratio of the total input power divided by the net refrigerating capacity. kW/ton_R shall use the following units of measure: kW for total input power and ton_R for net refrigerating capacity.

~~***energy efficiency:*** any one of several metrics calculated as a ratio of two quantities: (a) thermal energy movement expressed as a rate and (b) required energy input to move that thermal energy. The numerator and denominator may be switched depending on the specific metric, and the units of measure may be dimensionless or not.~~

heating efficiency: efficiency expressed as a ratio of net heating capacity and the total input power when operating in heating mode.

COP_H: coefficient of performance; the heating efficiency expressed as a dimensionless ratio of net heating capacity divided by the total input power.

~~***COP_{HR}:*** coefficient of performance; the heating efficiency expressed as a dimensionless ratio of the sum of net heating capacity of a water-cooled heat reclaim condenser plus the net refrigerating capacity of an evaporator divided by the total input power.~~

total efficiency: efficiency expressed as a ratio of the total useful thermal capacity and the total input power when operating in a hybrid mode. The total useful thermal capacity is the sum of all net refrigerating capacities and net heating capacities.

COP_{total}: coefficient of performance, the total efficiency expressed as a dimensionless ratio of the sum of net refrigerating capacity and net heating capacity divided by the total input power.

energy balance: a dimensionless ratio metric used to check for gross errors in measurement instrumentation and test results for units with a ~~water~~ liquid-cooled condenser ~~(with or without water-cooled heat reclaim condenser)~~ and defined as the difference between energy inputs and energy outputs to the liquid-chilling system ~~package~~, normalized to a percentage by dividing by the mean of the total input energy and the total output energy. For this standard, the energy inputs are generally limited to the gross refrigerating capacity and the input power, although other auxiliary power inputs are included when analysis demonstrates significance to the energy balance.

[. . .]

heat exchanger: a refrigerating system component used to transfer heat. Each heat exchanger may include multiple refrigerant circuits and sub heat exchangers which can be differentiated by the test plan.

air ↔ refrigerant heat exchanger: a heat exchanger, including condenser fans, that rejects heat to or accepts heat from air. Air is mechanically circulated over a dry heat transfer surface, causing an enthalpy rise in the air when heat is rejected and an enthalpy decrease when heat is accepted.

adiabatically cooled heat exchanger: an air ↔ refrigerant heat exchanger which precools air by mechanical circulation and evaporation of water before that air reaches the dry heat transfer surface. This heat exchanger only operates in cooling mode.

evaporatively cooled heat exchanger: a heat exchanger which rejects heat to a water and air mixture mechanically circulated over a wetted heat transfer surface, causing evaporation of the water and an increase in the enthalpy of the air. This heat exchanger only operates in cooling mode.

liquid ↔ refrigerant heat exchanger: a heat exchanger that rejects heat to or accepts heat from liquid. Liquid is mechanically circulated over a heat transfer surface, causing an enthalpy rise in the liquid when heat is rejected and an enthalpy decrease when heat is accepted. (***Informative Note:*** Useful heat transfer occurs when heat is added or removed from the intended thermal load.)

Informative Note: "↔" means "to or from."

[. . .]

liquid-chilling system: a machine specifically designed to make use of a refrigeration cycle to remove heat from a liquid and reject the heat to a cooling medium, ~~usually~~ such as air or water or a mixture of both. For the purposes of this standard, the system may be packaged (factory-made and prefabricated assembly) or field-erected. The refrigerant condenser may or may not be an integral part of a packaged liquid-chilling system.

cooling mode: an operating mode of the equipment or liquid ↔ refrigerant heat exchanger that controls the heat exchanger liquid leaving temperature to a target set point, providing a net refrigerating capacity.

heating mode: an operating mode of the equipment or liquid ↔ refrigerant heat exchanger that controls the heat exchanger liquid leaving temperature to a target set point, providing a net heating capacity.

active mode: an operating mode of the equipment that operates one or more compressors within any individual refrigerant circuit.

passive mode: an operating mode of the equipment that does not operate a compressor in any refrigerant circuit, other auxiliary devices may or may not be operating.

hybrid mode: any combination of equipment operating mode types, either cooling mode or heating mode or both simultaneously, either active or passive, and either full or partial capacity. (***Informative Note:*** Heat reclaim (or heat recovery) is a form of heating mode to make use of heat that would otherwise be wasted from a system or process, in some cases as a hybrid operating mode (e.g., cooling mode operation with heat reclaim or heat recovery of a portion of the rejected heat).

Replace all of Section 4 as shown.

4. EQUIPMENT TYPES

~~**4.1** This standard covers the following equipment types.~~

4.1 This standard includes methods of test for the equipment types described in Section 2 using the vapor compression cycle with the following limitations.

~~**4.1.1 Vapor Compression Cycle**~~

4.1.1.1 ~~Driver types: electric motor, steam turbine, combustion engine.~~

	~~Heat Rejection~~		
~~Operating Mode~~	~~Liquid Cooled~~	~~Evaporatively Cooled~~	~~Air Cooled~~
~~Cooling~~	~~✓~~	~~✓~~	~~✓~~
~~Heating~~	~~✓~~	~~N/A~~	~~✓~~
~~Heat Reclaim~~	~~✓~~	~~N/A~~	~~N/A~~
~~Cooling and heating~~	~~✓~~	~~N/A~~	~~N/A~~

4.1.1 Driver Types. Each compressor shall be driven by either an electric motor, a steam turbine, or a combustion engine.

4.1.2 Heat Exchangers and Operating Modes. Liquid-chilling systems with various combinations of heat exchangers and operating modes are included. However, only liquid-cooled heat exchangers are included within capacity calculations.

Modify Section 5 as shown. The remainder of Section 5 is unchanged.

5. CALCULATIONS AND CONVERSIONS

[. . .]

5.4 Performance. Refer to Normative Appendix B for schematics of each system type and the physical location of measurement instruments.

5.4.1 Capacity. Depending on the available measurements, and with consideration of the acceptable test uncertainty required by the test plan, one ~~One~~ of the following three methods shall be used ~~depending on the available measurements and with consideration of the acceptable test uncertainty required by the test plan.~~ to calculate the capacity of each liquid ↔ refrigerant heat exchanger that is operating to provide useful heat transfer. Enthalpy capacity method shall be used for setups with significant distance and pressure drop between the temperature and pressure measurements on the inlet and/or outlet external piping. The additional temperature increase due to frictional pressure losses shall be determined by measuring pressure at a location within ±2 pipe diameters of each temperature measurement point in the external piping. The pressure measurements adjacent to the temperature measurements of the flowing liquid shall be used when determining the physical properties of enthalpy.

The sign convention, positive or negative, is to show all capacity values as positive whether energy is input into the chiller system or energy is removed from the chiller system. Per Section 5.4.1.4, adjust the sign for temperature difference or enthalpy difference accordingly by subtracting the lesser of inlet and outlet from the greater value, however, the sign is significant with respect to the direction of energy flow.

Determine the total thermal capacity of all liquid ↔ refrigerant heat exchangers operating to provide useful heat transfer. Nonuseful heat rejected to a heat sink shall be excluded.

Operating Mode	Capacity	Summation
Cooling mode	Net refrigerating capacity	$Q_{ev} = \sum_j Q_j$
Heating mode	Net heating capacity	$Q_{cd} = \sum_j Q_j$
Hybrid mode	Net refrigerating capacity and net heating capacity	$Q_{total} = \sum_j Q_j$

[. . .]

5.4.3 Energy Efficiency. ~~The coefficient of performance (COP) is defined in the following sections.~~ Calculations for efficiency during various operating modes are defined in the following sections. Other efficiency metrics are derived as variations on the ratio of capacity and input work, or its inverse, and may be used according to the definitions in Section 3.

For use in efficiency calculations, determine the total thermal capacity by summation of the net capacity values for the relevant liquid heat exchangers. Nonuseful heat rejected to a heat sink shall be excluded.

Operating Mode	Capacity	Summation
Cooling mode	Net refrigerating capacity	$Q_{ev} = \sum_j Q_j$
Heating mode	Net heating capacity	$Q_{cd} = \sum_j Q_j$
Hybrid mode	Net refrigerating capacity and net heating capacity	$Q_{total} = \sum_j Q_j$

5.4.3.1 Cooling Energy Efficiency. The cooling efficiency η_R shall be calculated using the following:

$$\eta_R = \frac{Q_{ev}}{W_{input}}$$

$$U_{\eta_R} = \sqrt{(\theta_{Q_{ev}} U_{Q_{ev}})^2 + (\theta_{W_{input}} U_{W_{input}})^2}$$

$$\theta_{Q_{ev}} = \frac{1}{W_{input}}$$

$$\theta_{W_{input}} = -\frac{Q_{ev}}{W_{input}{}^2}$$

Informative Note: If the cooling efficiency ratio is inverted, then the sensitivity coefficients need to be revised accordingly.

5.4.3.2 Heating Energy Efficiency

5.4.3.2.1 The ~~heating coefficient of performance~~ heating efficiency η_H shall be calculated using the following:

$$\eta_H = \frac{Q_{cd}}{W_{input}}$$

$$U_{\eta_H} = \sqrt{(\theta_{Q_{cd}} U_{Q_{cd}})^2 + (\theta_{W_{input}} U_{W_{input}})^2}$$

$$\theta_{Q_{cd}} = \frac{1}{W_{input}}$$

$$\theta_{W_{input}} = -\frac{Q_{cd}}{W_{input}{}^2}$$

Informative Note: If the heating efficiency ratio is inverted, then the sensitivity coefficients need to be revised accordingly.

5.4.3.2.2 The average heating efficiency $\eta_{H,avg}$ for the "T" test method of (Section 8.5.3) shall be calculated using the following:

$$\eta_{H,\,avg} = \frac{(Q_{cd})_{avg}}{(W_{input})_{avg}}$$

where

$$(Q_{cd})_{avg} = \frac{1}{\tau_2 - \tau_1}\int_{\tau_1}^{\tau_2} Q_{cd} \times \delta_\tau = \frac{1}{\tau_2 - \tau_1}\sum_{i=1}^{n} (Q_{cd})_i \times \Delta\tau_i$$

$$(W_{input})_{avg} = \frac{1}{\tau_2 - \tau_1}\int_{\tau_1}^{\tau_2} W_{input} \times \delta_\tau = \frac{1}{\tau_2 - \tau_1}\sum_{i=1}^{n} (W_{input})_i \times \Delta\tau_i$$

5.4.3.3 Total Energy Efficiency. The total efficiency η_{total} shall be calculated using the following:

$$\eta_{total} = \frac{Q_{ev} + Q_{cd}}{W_{input}}$$

$$U_{\eta_{total}} = \sqrt{(\theta_{ev} U_{Q_{ev}})^2 + (\theta_{Q_{cd}} U_{Q_{cd}})^2 + (\theta_{W_{input}} U_{W_{input}})^2}$$

$$\theta_{Q_{ev}} = \frac{1}{W_{input}}$$

$$\theta_{Q_{cd}} = \frac{1}{W_{input}}$$

[. . .]

5.5 Validation [. . .]

5.5.1 Energy Balance [. . .]

5.5.1.1 Concurrent Redundant Verification Method for ~~Air-Cooled or Evaporatively Cooled Condensers or Air-Source Evaporators for Heating Mode~~ Equipment Operating with Air-Cooled, Adiabatically Cooled, or Evaporatively Cooled Heat Exchangers

[. . .]

5.5.2 Condensation Verification. Per requirements of Section 6.4, condensation should not occur on the air side prior to entering any air ↔ refrigerant heat exchanger. In the event condensation does occur, or relative humidity reaches 100% in the entering air during a test point, the test point shall be rerun at conditions that do not reach 100% relative humidity.

Modify Section 6 as shown.

6. TEST REQUIREMENTS

[…]

6.3.1.4.2.1 Air-Sampling-Tree Requirements. The air sampling tree is intended to draw a uniform sample of the airflow entering the ~~air-cooled condenser~~ air ↔ refrigerant heat exchanger section. A typical configuration for the sampling tree is shown in Figure 6-3 for a tree with overall dimensions of 1.2 × 1.2 m (4 × 4 ft) sample. Other sizes and rectangular shapes can be used and should be scaled accordingly as long as the aspect ratio (width to height) of no greater than 2:1 is maintained. It shall be constructed of stainless steel, plastic, or other suitable durable materials. It shall have a main flow trunk tube with a series of branch tubes connected to the trunk tube. It must have from 10 to 20 branch tubes. The branch tubes shall have appropriately spaced holes sized to provide equal airflow by increasing hole size further from the trunk tube to account for the static pressure regain effect in the branch and trunk tubes. The number of sampling holes shall be greater than 50. The average minimum velocity through the sampling tree holes shall be 0.75 m/s (2.5 ft/s) as determined by evaluating the sum of the open area of the holes as compared to the flow area in the aspirating psychrometer. The assembly shall have a tubular connection to allow a flexible tube to be connected to the sampling tree and to the aspirating psychrometer.

[. . .]

6.3.1.7.1 For air-cooled or evaporatively cooled ~~condensers~~ heat exchangers, the test shall include the condenser fan power and condenser spray pump power in the measurements of total input power.

[. . .]

6.4 Plan. A test plan shall document all requirements for conducting the test. This includes a list of the required full-load and part-load test points and associated operating conditions, including adjusted liquid temperature targets based on the rated fouling factor allowance. In addition to the requirements specifically listed in this standard, the test plan shall include intended heat exchanger operation (useful or not) and all other input signals or controls positions necessary to place the chiller in the operating mode for each test to be performed.

The results of the test shall not exceed 100% relative humidity when considering operating condition, tolerances, and measurement uncertainty. This test plan criterion is intended to avoid difficulties maintaining stability of the required moisture content during testing. Condensation or frosting due to cold surface temperatures of an air ↔ refrigerant heat exchanger may occur and is expected under certain operating conditions.

[. . .]

6.7.1 Energy Balance. ~~For the case of liquid-cooled condensers,~~ For equipment operating with only liquid ↔ refrigerant heat exchangers, measurement data shall be collected to calculate an energy balance (per Section 5.5.1) to substantiate the validity of each test point. Test validity tolerance for energy balance is found in Table 6-7. The energy balance (%) shall be within the allowable tolerance calculated per Section 5.6 for the applicable conditions.

For ~~air-cooled and evaporatively cooled condensers~~ equipment operating with an air ↔ refrigerant heat exchanger, adiabatically cooled heat exchanger, or evaporatively cooled heat exchanger, it is impractical to measure heat rejection in a test, and an energy balance cannot be readily calculated. To validate test accuracy, a concurrent redundant instrumentation method (Section 6.7.4) shall be used to measure liquid temperatures, flow rates, and power inputs.

~~For heat reclaim units with air-cooled condensers or liquid-cooled condensers, where the capacity is not sufficient to fully condense the refrigerant, the concurrent redundant instrumentation methods in Section 6.7.4 shall be used.~~

~~For heat reclaim units with liquid-cooled condensers that fully condense the refrigerant, the energy balance method shall be used.~~

If evaporator liquid is used to remove heat from any other sources within the package, the temperature, pressure drop, and flow measurements of chilled liquid shall be made at points so that the measurements reflect the gross refrigerating capacity.

If condenser liquid is used to cool the compressor motor or for some other incidental function within the package, the temperature, pressure drop, and flow measurements of condenser liquid must be made at points such that the measurements reflect the gross heating capacity.

[. . .]

6.7.4 Concurrent Redundant Instrumentation. For ~~the case of air-cooled or evaporatively cooled condensers, or air source evaporators for heating mode,~~ <u>equipment operating with an air ↔ refrigerant heat exchanger, adiabatically cooled heat exchanger, or evaporatively cooled heat exchanger</u> redundant measurement data shall be collected to substantiate the validity of each test point.

[. . .]

Replace Table 6-6 with the following table. (Note: Underline is omitted to make the table easier to read.)

Table 6-6 Definition of Operating Condition Tolerances and Stability Criteria

Heat Exchanger Type	Measurement or Calculation Result		Values Calculated from Data Samples: Mean	Values Calculated from Data Samples: Std. Dev.	Operating Condition Tolerance Limits	Stability Criteria
Liquid ↔ refrigerant providing useful heat	Net *capacity* (cooling or heating)		$\bar{Q}$	s_Q	Unit with continuous unloading: Part-load test *capacity* shall be within 2% of the target part-load *capacity*[a] $\frac{\lvert\bar{Q}-Q_{target}\rvert}{Q_{100\%}} \le 2.000\%$	No requirement
					Units with discrete *capacity* steps: Part-load test points shall be taken as close as practical to the specified part-load rating points as stated in the test plan.	
	Liquid temperature	Entering	$\bar{T}$	s_T	No requirement	No requirement
		Leaving			$\lvert\bar{T}-T_{target}\rvert \le 0.28$ Δ°C [0.50 Δ°F]	$s_T \le 0.10$ Δ°C [0.18 Δ°F]
		Difference	$\overline{\Delta T}$	$s_{\Delta T}$	No requirement	$\frac{s_{\Delta T}}{\Delta T} \le 1.500\%\left(\frac{Q_{100\%}}{Q_{target}}\right)$
Liquid ↔ refrigerant Not as useful capacity	*Liquid temperature*	Entering[b]	$\bar{T}$	s_T	During cooling, heating, or *hybrid mode*: $\lvert\bar{T}-T_{target}\rvert \le 0.28$ Δ°C [0.50 Δ°F] During defrost cycle: $\lvert\bar{T}-T_{target}\rvert \le 1.11$ Δ°C [2.00 Δ°F]	During cooling, heating, or *hybrid mode*: $s_T \le 0.10$ Δ°C [0.18 Δ°F] During defrost cycle: $s_T \le 0.28$ Δ°C [0.50 Δ°F]
		Leaving			No requirement	No requirement
		Difference	$\overline{\Delta T}$	$s_{\Delta T}$	No requirement	No requirement

Notes:

a. The ±2.0% tolerance shall be calculated as 2.0% of the full-load rated capacity ~~(kW)~~. 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.

b. 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.

c. When computing average air temperatures for heating-mode tests, omit data samples collected during the defrost portion of the cycle.

d. 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 in Section 6.3.1.7. For dual nameplate voltage ratings, tests shall be performed at the lower of the two voltages.

e. For steam-turbine and gas-turbine drive machines, the pressure shall be maintained at the nameplate rating values within the tolerance limits.

f. For speed-controlled compressors, the speed shall be maintained at the nameplate rating value within the tolerance limits.

g. Refer to Table 10-1 for definition of the unit symbols Δ°C and Δ°F. Refer to Section 5.2 for the definition of "mean" (denoted by the overline) and sample standard deviation (denoted by *s*).

h. The $\overline{\Delta T}$ represents the average of the liquid temperature difference of each data sample. The $s_{\Delta T}$ represents the sample standard deviation of the liquid temperature difference of each data sample.

Table 6-6 Definition of Operating Condition Tolerances and Stability Criteria

Heat Exchanger Type	Measurement or Calculation Result			Values Calculated from Data Samples: Mean	Values Calculated from Data Samples: Std. Dev.	Operating Condition Tolerance Limits	Stability Criteria
Air ↔ refrigerant Not as useful capacity	Air *temperature*[c]	Entering	Dry-bulb	$\bar{T}$	s_T	When nonfrosting: $\lvert\bar{T} - T_{target}\rvert \le 0.56\ \Delta°C\ [1.00\ \Delta°F]$	When nonfrosting: $S_T \le 0.42\Delta°C\ [0.75\Delta°F]$
						When frosting: $\bar{T} - T_{target}\rvert \le 1.11\ \Delta°C\ [2.00\ \Delta°F]$	When frosting: $S_T \le 0.56\Delta°C\ [1.00\Delta°F]$
						During defrost cycle: No requirement	During defrost cycle: $S_T \le 1.39\Delta°C\ [2.50\Delta°F]$
			Wet-bulb			When nonfrosting: $\lvert\bar{T} - T_{target}\rvert \le 0.56\ \Delta°C\ [1.00\ \Delta°F]$	$S_T \le 0.28\Delta°C\ [0.50\Delta°F]$
						When frosting: $\lvert\bar{T} - T_{target}\rvert \le 0.83\ \Delta°C\ [1.50\ \Delta°F]$	When frosting: $S_T \le 0.42\Delta°C\ [0.75\Delta°F]$
						During defrost cycle: No requirement	During defrost cycle: No requirement
Adiabatically cooled, evaporatively cooled	Make-up water *temperature*			$\bar{T}$	s_T	$\lvert\bar{T} - T_{target}\rvert \le 0.56\ \Delta°C\ [1.00\ \Delta°F]$	No requirement
Liquid ↔ refrigerant	*Liquid* flow (volumetric, entering)			$\bar{V}_{liq}$	$s_{V_{liq}}$	$\frac{\lvert\bar{V}_{liq} - V_{liq,\,target}\rvert}{V_{liq,\,target}} \le 5.000\%$	$\frac{s_{V_{liq}}}{\bar{V}_{liq}} \le 0.750\%$
Condenserless	Refrigerant saturated discharge *temperature*			$\bar{T}$	s_T	$\lvert\bar{T} - T_{target}\rvert \le 0.28\ \Delta°C\ [0.50\ \Delta°F]$	$s_T \le 0.14\ \Delta°C\ [0.25\ \Delta°F]$
	Liquid temperature			$\bar{T}$	s_T	$\lvert\bar{T} - T_{target}\rvert \le 0.56\ \Delta°C\ [1.00\ \Delta°F]$	$s_T \le 0.28\ \Delta°C\ [0.50\ \Delta°F]$

Notes:

a. The ±2.0% tolerance shall be calculated as 2.0% of the full-load rated capacity ~~(kW)~~. 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.

b. 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.

c. When computing average air temperatures for heating-mode tests, omit data samples collected during the defrost portion of the cycle.

d. 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 in Section 6.3.1.7. For dual nameplate voltage ratings, tests shall be performed at the lower of the two voltages.

e. For steam-turbine and gas-turbine drive machines, the pressure shall be maintained at the nameplate rating values within the tolerance limits.

f. For speed-controlled compressors, the speed shall be maintained at the nameplate rating value within the tolerance limits.

g. Refer to Table 10-1 for definition of the unit symbols Δ°C and Δ°F. Refer to Section 5.2 for the definition of "mean" (denoted by the overline) and sample standard deviation (denoted by *s*).

h. The $\overline{\Delta T}$ represents the average of the liquid temperature difference of each data sample. The $s_{\Delta T}$ represents the sample standard deviation of the liquid temperature difference of each data sample.

Table 6-6 Definition of Operating Condition Tolerances and Stability Criteria

Heat Exchanger Type	Measurement or Calculation Result	Values Calculated from Data Samples		Operating Condition Tolerance Limits	Stability Criteria
		Mean	Std. Dev.		
All types	Voltage[d] (if multiphase, this is the average of all phases)	$\overline{V}$	s_V	$\frac{\lvert\overline{V} - V_{target}\rvert}{V_{target}} \le 10.00\%$	$\frac{s_V}{\overline{V}} \le 0.500\%$
	Frequency[d]	$\overline{\omega}$	s_ω	$\frac{\lvert\overline{\omega} - \omega_{target}\rvert}{\omega_{target}} \le 1.000\%$	$\frac{s_\omega}{\overline{\omega}} \le 0.500\%$
	Test rooms air mean dry-bulb *temperature* [f]	$\overline{T}$	s_T	$\lvert\overline{T} - T_{target}\rvert \le 2.78\Delta°C\ [5.00\Delta°F]$	No requirement
Heat exchanger type	Steam turbine pressure/vacuum[e]	$\overline{p}$	s_p	$\lvert\overline{p} - p_{rating}\rvert \le 3.45$ kPa [0.500 psid]	$s_p \le 1.72$ kPa [0.250 psid]
	Gas turbine inlet gas pressure[e]				
	Governor control compressor speed[g]	$\overline{n}$	s_n	$\frac{\lvert\overline{n} - n_{target}\rvert}{n_{target}} \le 0.500\%$	$\frac{s_n}{\overline{n}} \le 0.250\%$

Notes:

a. The ±2.0% tolerance shall be calculated as 2.0% of the full-load rated capacity ~~(kW)~~. 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.

b. 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.

c. When computing average air temperatures for heating-mode tests, omit data samples collected during the defrost portion of the cycle.

d. 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 in Section 6.3.1.7. For dual nameplate voltage ratings, tests shall be performed at the lower of the two voltages.

e. For steam-turbine and gas-turbine drive machines, the pressure shall be maintained at the nameplate rating values within the tolerance limits.

f. For speed-controlled compressors, the speed shall be maintained at the nameplate rating value within the tolerance limits.

g. Refer to Table 10-1 for definition of the unit symbols Δ°C and Δ°F. Refer to Section 5.2 for the definition of "mean" (denoted by the overline) and sample standard deviation (denoted by *s*).

h. The $\overline{\Delta T}$ represents the average of the liquid temperature difference of each data sample. The $s_{\Delta T}$ represents the sample standard deviation of the liquid temperature difference of each data sample.

Replace Table 7-1 with the version shown and modify Table 7-2 as shown.

Table 7-1 Data to be Recorded During the Test

All types	General	Date and time for each data point sample
		Atmospheric pressure
		Liquid-chilling system operating mode (cooling, heating, active, passive, hybrid)
	Liquid ↔ refrigerant *heat exchangers* (one data set for each)	Providing useful heat transfer (or not)
		T_{in} (record P_{in} at the same location if using the enthalpy *capacity* calculation method)
		T_{out} (record P_{out} at the same location if using the enthalpy *capacity* calculation method)
		m_w or V_w
		ΔP_{test}
Air ↔ refrigerant heat exchanger		Spatial average dry-bulb *temperature* of entering air
Evaporatively cooled *heat exchanger* or Adiabatically cooled *heat exchanger*		Spatial average dry-bulb *temperature* of entering air
		Spatial average wet-bulb *temperature* of entering air
		Net make-up water flow rate
		Make-up water *temperature*
Equipment without heat rejection	Compressor	Discharge *temperature*
		Discharge pressure
	Liquid line	*Liquid* refrigerant *temperature* entering the expansion device
		Liquid pressure entering the expansion device
Electric drive	Chiller	W_{input} (and W_{refrig} if needed)
		Voltage for each phase
		If three-phase: average voltage
		Frequency for one phase
Nonelectric drive	Chiller	If steam turbine: • Steam consumption • Steam supply pressure • Steam supply *temperature* • Steam exhaust pressure
		If gas turbine or gas engine: Fuel consumption (natural gas or propane) calorific value
		If internal combustion engine: *Liquid* fuel consumption (diesel or gasoline) calorific value
Remote *heat exchanger*	Refrigerant tubing	Equivalent length of each line; if more than one test room, record the proportion in each location.
		If more than one test room, record the *temperature* in each room.
		Size of each line
		Insulation details (location, thickness, type, etc.)

Table 7-2 Auxiliary Data to be Recorded

Type	Data Item
All	Date, place, and time of test
	Names of test supervisor and witnessing personnel
	Ambient temperature at test site
	Nameplate data, including make, model, size, serial number, voltage, frequency, and refrigerant designation number (in accordance with ASHRAE Standard 34) ~~Unit voltage and frequency shall be recorded.~~
	Prime mover nameplate data (motor, engine, or turbine)
Nonelectric drive	Fuel specification (if applicable) and calorific value

Modify Section 8 as shown. The remainder of Section 9 is unchanged.

8. TEST PROCEDURES

[. . .]

8.2 Test Procedures. For each test point at a specific load and set of operating conditions, the test will measure capacity, input power, and liquid-side pressure drop. Capacity, a measurement of the heat added to or removed from the liquid as it passes through the heat exchanger, ~~may be cooling, heating, heat recovery, and/or heat reclaim~~ may be cooling or heating according to the test plan. Net capacity is always required, and gross capacity is required when an energy balance requirement applies. Each test point will collect multiple data points versus time. The test shall use instrumentation meeting the requirements in Section 6 and calculations in Section 5.

[. . .]

Modify Section 9, replacing Table 9-1 as shown. The remainder of Section 9 is unchanged.

9. REPORTING OF RESULTS

9.1 General. Table 9-1 summarizes the results to be reported for each test type.

Table 9-1 Data to be Reported[a]

Type	Report Item
General	Name and address of the chiller test facility
	Report identification number
Chiller configuration	A description or schematic of all connections (fluid and electrical) to the unit under test for each operating mode.
Operating mode	All inputs necessary to ensure that the equipment under test runs in the operating mode tested[b]
Capacity	Net capacity for each tested liquid ↔ refrigerant heat exchanger
	Gross capacity values as used for energy balance
Input power	Total input power
	List of components that utilize auxiliary power
Energy efficiency[c]	One or more of the energy efficiency metrics per Section 5.4.3
Liquid pressure drop[d]	Liquid corrected pressure drop $\Delta P_{corrected}$ at operating conditions per the test plan, measured per Section 8.4 and corrected per Section 5.4.4
	If ΔP_{adj} > 10% of ΔP_{test} then report the value of ΔP_{adj} and include the statement "ΔP_{adj} exceeded 10% of ΔP_{test}."
Test validation	Energy balance when required per Sections 5.5.1 and 5.5.1.4
	Voltage balance per Section 5.5.2
	Concurrent redundant instrumentation confirmation of compliance for each value when required per Sections 6.7.4.1 to 6.7.4.5.
Correction values	ΔP_{adj} per Section 5.4.4 (even if exceeding 10% of ΔP_{test})
	Any other correction values required by the test plan
Test plan	Attach a copy of the test plan in accordance with Section 6.4.
Test data	All data recorded in accordance with Section 7.
Uncertainty analysis	Results of the uncertainty analysis in accordance with Section 6.7.3.

a. Test Results shall be rounded to the number of significant figures identified in section 5.7, using the definitions in Section 3, and rounding rules and formats in Section 5.7.
b. Example: In the case that a unit operates in heating mode only when the ambient temperature is below 12.8°C (55.0°F) the report shall state the temperature and how the ambient temperature signal is provided to the equipment under test.
c. Pump energy associated with pressure drop through the chiller heat exchangers is not included in the total input power. This is done because any adjustment to the chiller performance would confuse the overall system analysis for capacity and efficiency. It is therefore important for any system analysis to account for the cooling loads associated with the system pump energy and to include the pump power into the overall equations for system efficiency.
d. Liquid pressure drop shall be reported in units of pressure differential, not in head or liquid column height.

Modify Table 10-2 as shown. The remainder of Section 10 is unchanged.

Table 10-2 Subscripts

Subscripts	**Description**
[. . .]	[. . .]
make-up	replacement water
total	total summation, referring to one or more *capacity* values, or to one or more *input power* values
[. . .]	[. . .]

Modify Section 11 as shown. The remainder of Section 11 is unchanged.

11. NORMATIVE REFERENCES

[. . .]

2. ASHRAE. ~~1999~~2001. *Develop Design Data on Pressure Loss of Large Pipe Fittings*. Final Report RP-1034. Atlanta: ASHRAE

[. . .]

4. ASHRAE. ~~2013~~2020. ANSI/ASHRAE Standard 41.1, Standard Methods for Temperature Measurement. Atlanta: ASHRAE

[. . .]

13. ASHRAE. ~~2014~~2020. ANSI/ASHRAE Standard 41.11, Standard Methods for Power Measurement. Atlanta: ASHRAE.

[. . .]

15. ASME. ~~2013~~2018. Standard PTC 19.1, Test Uncertainty. New York: American Society of Mechanical Engineers.
16. ASHRAE. ~~2014~~2022. ANSI/ASHRAE Standard 41.3, Standard Methods for Pressure Measurement. Atlanta: ASHRAE.

Replace Normative Appendix B Figures B-1 through B-4 and keys as shown. (Original figures and keys are omitted for brevity. Add new Figure B-5 and key as shown.) See following pages.

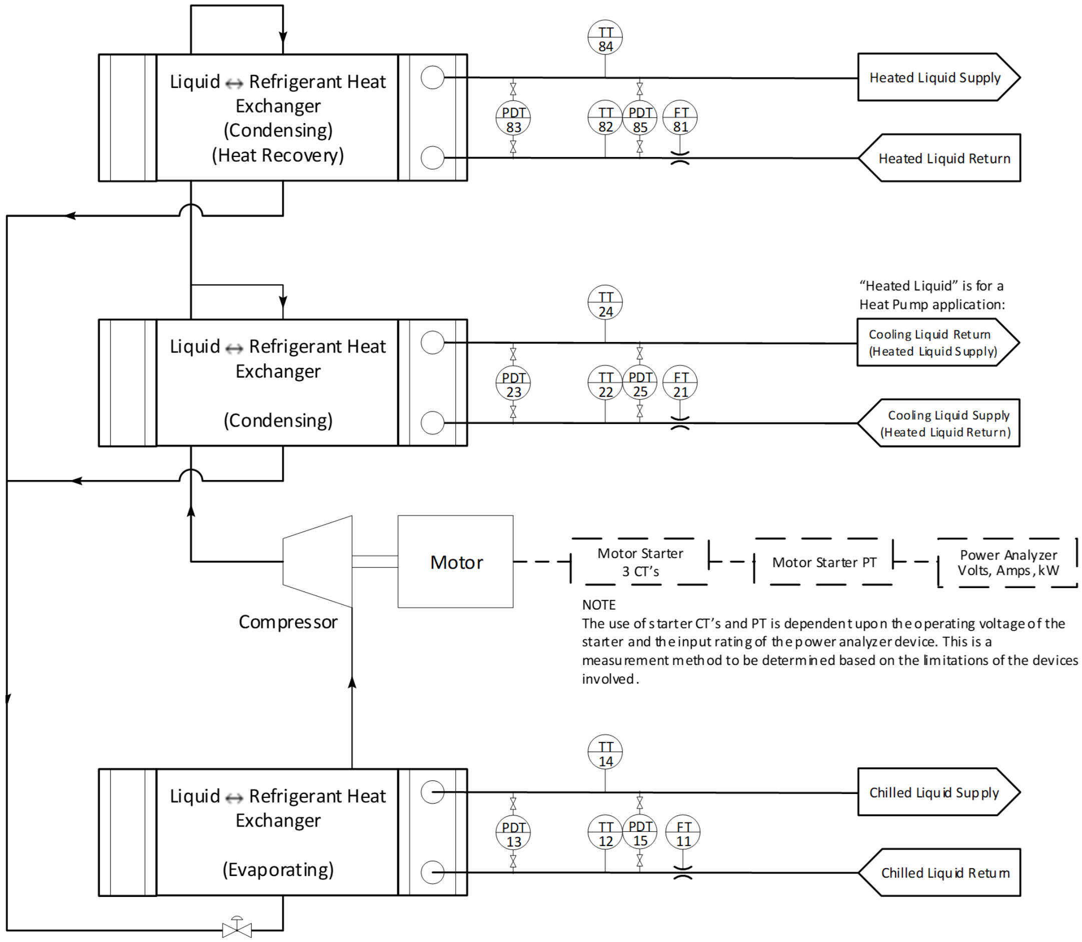

Figure B-1 Electrically driven liquid-cooled chiller (with or without heat recovery) or heat pump.[a]

ID	Description of Measurement
FT-11[b]	Chilled liquid flow; used to calculate refrigerating capacities
TT-12	Chilled liquid inlet temperature; used to calculate net refrigerating capacities
PDT-13	Chilled liquid pressure difference; used to calculate net refrigerating capacity
TT-14	Chilled liquid outlet temperature; used to calculate refrigerating capacities
PDT-15[c]	Chilled liquid pressure difference at temperature measurement location
FT-21[b]	Liquid flow; used to calculate heating capacity (for heat-pump applications) and heat rejection for energy balance
TT-22	Heated liquid inlet temperature; used to calculate heating capacity (for heat-pump applications) and heat rejection for energy balance
PDT-23	Heated liquid to refrigerant heat exchanger pressure difference
TT-24	Heated liquid outlet temperature; used to calculate heating capacity (for heat-pump applications) and heat rejection for energy balance
PDT-25[c]	Heated liquid pressure difference at temperature measurement location
FT-81[b]	Heat recovery liquid-to-refrigerant heat exchanger (when included) liquid flow; used to calculate heating capacity (for heat-pump applications) and heat rejection for energy balance
TT-82	Heat recovery liquid-to-refrigerant heat exchanger (when included) liquid (when included) inlet temperature; used to calculate heating capacity (for heat-pump applications) and heat rejection for energy balance
PDT-83	Heat recovery liquid-to-refrigerant heat exchanger pressure difference (when included) pressure difference
TT-84	Heat recovery liquid-to-refrigerant heat exchanger (when included) liquid (when included) outlet temperature; used to calculate heating capacity (for heat-pump applications) and heat rejection for energy balance
PDT-85[c]	Heat recovery liquid-to-refrigerant heat exchanger pressure difference (when included) pressure difference at temperature measurement location
CT31, CT32, CT33	Current transformers for measuring current for three-phase motor used in calculating power consumption (will be different for other motor types)
PT41, PT42, PT43	Potential transformers for measuring voltage for three-phase motor used in calculating power consumption (will be different for other motor types)
Not identified	Power consumption for the chiller, including any auxiliary systems contained in the test boundary; includes voltage balance measurement

Notes:
a. Reference Section 6.3 for instrumentation location requirements.
b. Flowmeter location shown is one of the options identified in Section 6.3.1.5.
c. Optional pressure measurement used for enthalpy capacity calculation method

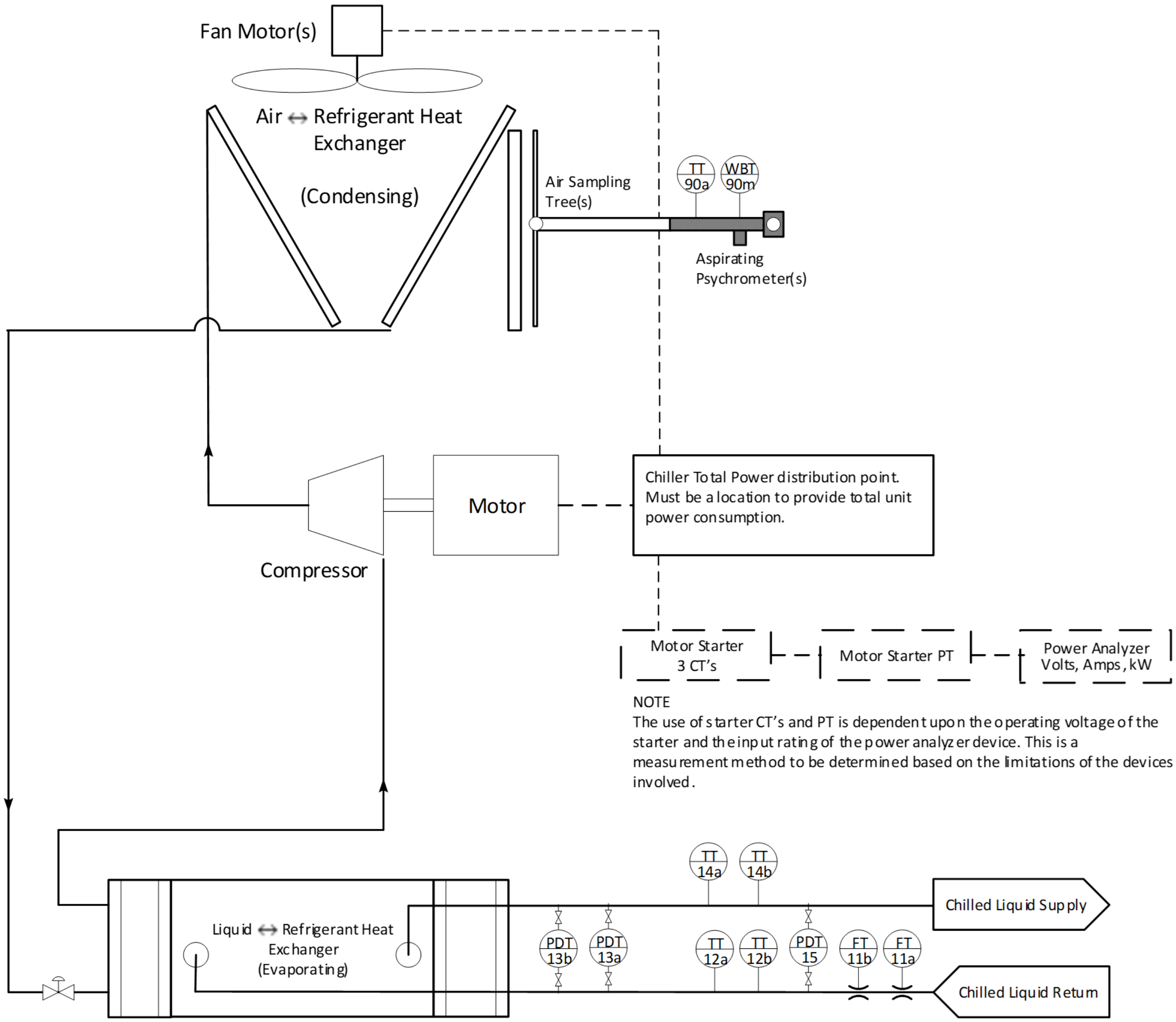

Figure B-2 Electrically driven air-cooled chiller.[a]

ID	Description of Measurement
FT-11a, b[b]	Chilled liquid flow; used to calculate refrigerating capacities (redundant measurements)
TT-12a, b	Chilled liquid inlet temperature; used to calculate net refrigerating capacities (redundant measurements)
PDT-13a, b	Chilled liquid pressure difference; used to calculate net refrigerating capacity (redundant measurements)
TT-14a, b	Chilled liquid outlet temperature; used to calculate refrigerating capacities (redundant measurements)
PDT-15[c]	Chilled liquid pressure difference at temperature measurement location
TT-90a to n	Ambient air temperature (one or more aspirating psychrometers)
WBT-90m	Entering wet-bulb temperature for evaporatively cooled or air-cooled in heating mode
CT31, CT32, CT33	Current transformers for measuring current for three-phase motor used in calculating power consumption (will be different for other motor types)
PT41, PT42, PT43	Potential transformers for measuring voltage for three-phase motor used in calculating power consumption (will be different for other motor types)
Not identified	Power consumption for the chiller, including any auxiliary systems contained in the test boundary; includes voltage balance measurement.

Notes:
a. Reference Section 6.3 for instrumentation location requirements.
b. Flowmeter location shown is one of the options identified in Section 6.3.1.5.
c. Optional pressure measurement used for enthalpy capacity calculation method.

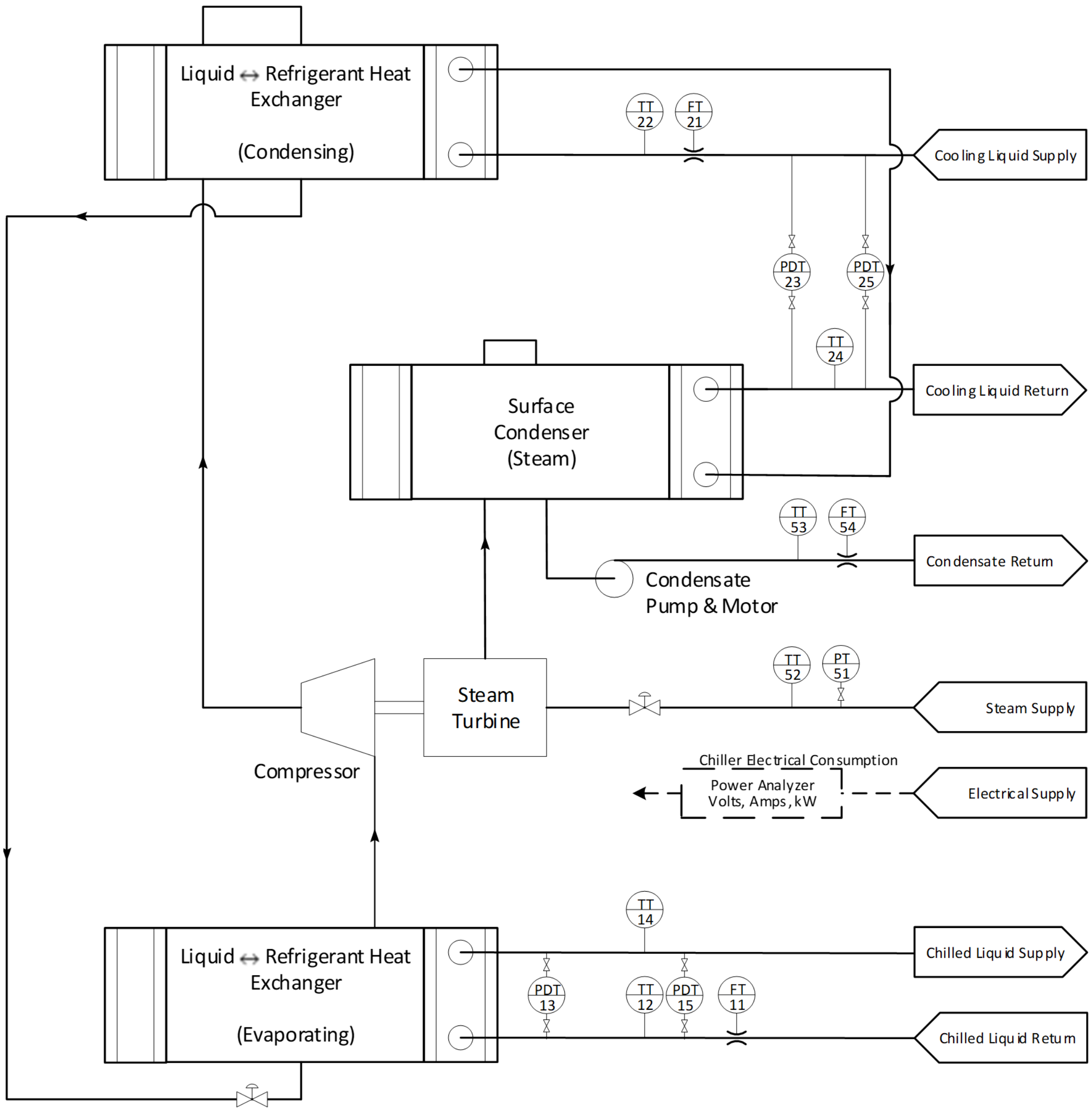

Figure B-3 Steam-turbine-driven liquid-cooled chiller.[a]

ID	Description of Measurement
FT-11	Chilled liquid flow; used to calculate refrigerating capacities
TT-12	Chilled liquid inlet temperature; used to calculate net refrigerating capacities
PDT-13	Chilled liquid pressure difference; used to calculate net refrigerating capacity
TT-14	Chilled liquid outlet temperature; used to calculate refrigerating capacities
PDT-15[b]	Chilled liquid pressure difference at temperature measurement location
FT-21[c]	Heated liquid flow, used to calculate heating capacity (for heat pump applications) and heat rejection for energy balance
TT-22	Heated liquid inlet temperature, used to calculate heating capacity (for heat pump applications) and heat rejection for energy balance
PDT-23	Heated liquid to refrigerant heat exchanger pressure difference
TT-24	Heated liquid outlet temperature, used to calculate heating capacity (for heat pump applications) and heat rejection for energy balance
PDT-25[b]	Heated liquid pressure difference at temperature measurement location
PT-51	Steam supply pressure
TT-52	Steam supply inlet temperature
TT-53	Steam condensate temperature
FT-54	Steam condensate flow
Not identified	Power consumption for the chiller, including any auxiliary systems contained in the test boundary; includes voltage balance measurement

Notes:
a. Reference Section 6.3 for instrumentation location requirements.
b. Optional pressure measurement for enthalpy capacity calculation method.
c. Flowmeter location shown is one of the options identified in Section 6.3.1.5.

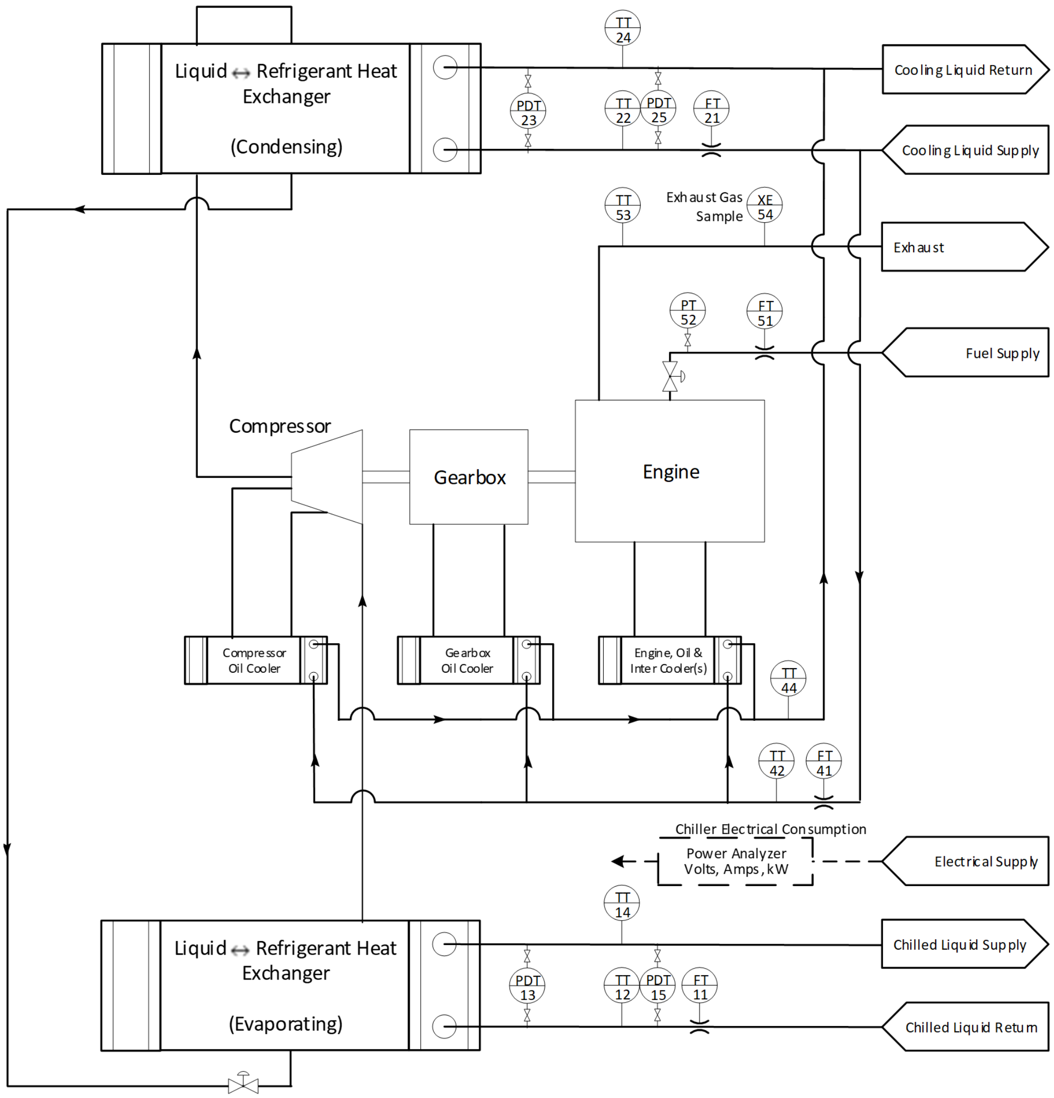

Figure B-4 Engine-driven liquid-cooled chiller.[a]

ID	Description of Measurement
FT-11	Chilled liquid flow; used to calculate refrigerating capacities
TT-12	Chilled liquid inlet temperature; used to calculate net refrigerating capacities
PDT-13	Chilled liquid pressure difference; used to calculate net refrigerating capacity
TT-14	Chilled liquid outlet temperature; used to calculate refrigerating capacities
PDT-15[b]	Chilled liquid pressure difference at temperature measurement location
FT-21[c]	Heated liquid flow; used to calculate heating capacity (for heat-pump applications) and heat rejection for energy balance
TT-22	Heated liquid inlet temperature; used to calculate heating capacity (for heat-pump applications) and heat rejection for energy balance
PDT-23	Heated liquid to refrigerant heat exchanger pressure difference
TT-24	Heated liquid outlet temperature; used to calculate heating capacity (for heat-pump applications) and heat rejection for energy balance
PDT-25[a]	Heated liquid pressure difference at temperature measurement location
FT-41	Compressor and drive system cooling system liquid flow
TT-42	Compressor and drive system cooling system liquid outlet temperature
PT-51	Fuel supply flow
TT-52	Fuel supply inlet pressure
TT-53	Exhaust temperature
Not identified	Power consumption for the chiller, including any auxiliary systems contained in the test boundary; includes voltage balance measurement

Notes:
a. Reference Section 6.3 for instrumentation location requirements.
b. Optional pressure measurement used for enthalpy capacity calculation method.
c. Flowmeter location shown is one of the options identified in Section 6.3.1.5.

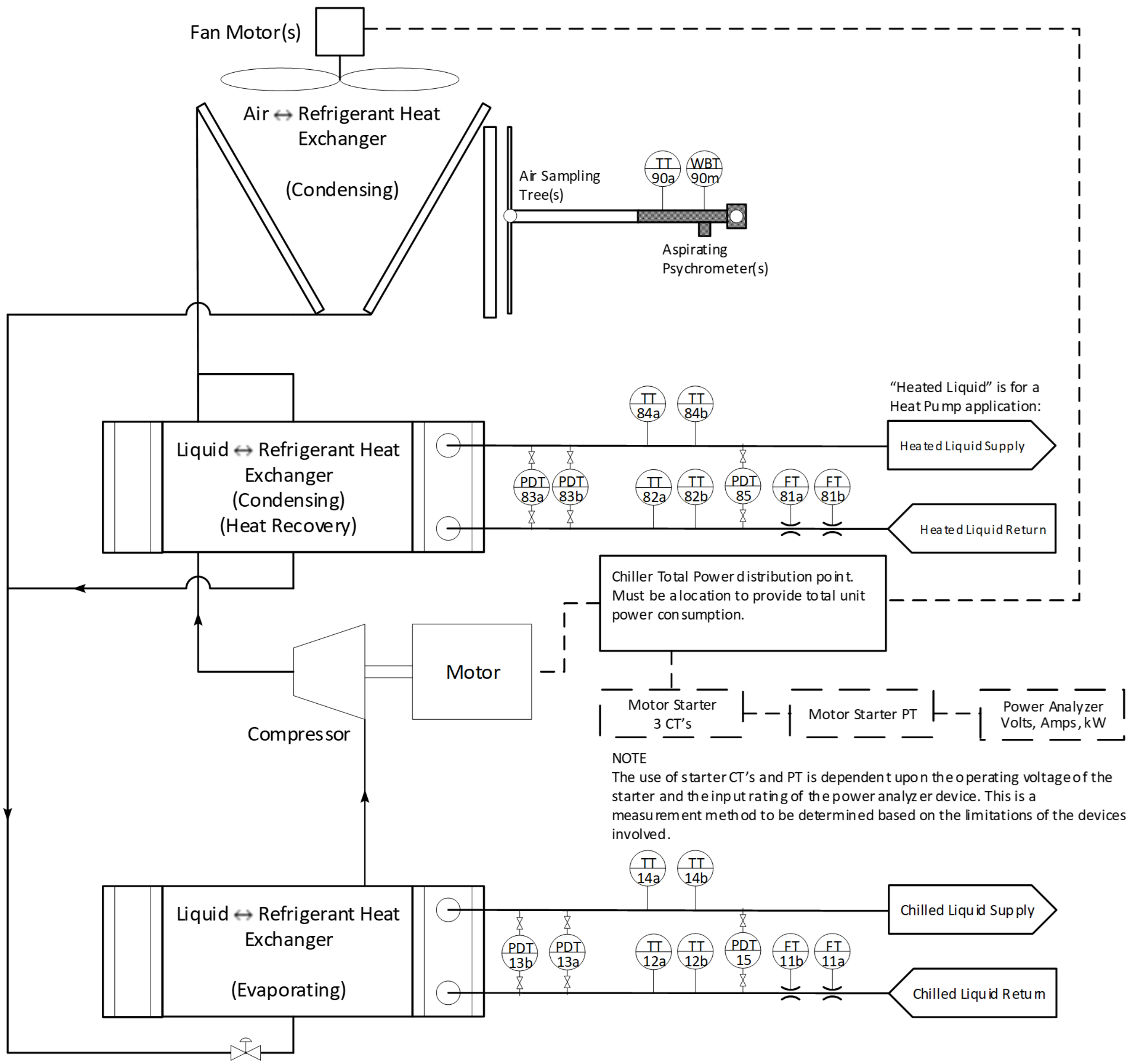

Figure B-5 Electrically driven air-cooled chiller with heat recovery.[a]

ID	Description of Measurement
FT-11a, b	Chilled liquid flow; used to calculate refrigerating capacities (redundant measurements)
TT-12a, b	Chilled liquid inlet temperature; used to calculate net refrigerating capacities (redundant measurements)
PDT-13a, b	Chilled liquid pressure difference; used to calculate net refrigerating capacity (redundant measurements)
TT-14a, b	Chilled liquid outlet temperature; used to calculate refrigerating capacities (redundant measurements)
PDT-15[a]	Chilled liquid pressure difference at temperature measurement location
TT-90a to n	Ambient air temperature (one or more aspirating psychrometers)
WBT-90m	Entering wet-bulb temperature for evaporatively cooled or air-cooled in heating mode (one or more)
FT-81a, b	Liquid flow; used to calculate heating capacity
TT-82a, b	Heated liquid inlet temperature; used to calculate heating capacity and heat rejection for energy balance
PDT-83a, b	Heated liquid-to-refrigerant heat exchanger pressure difference
TT-84a, b	Heated liquid outlet temperature; used to calculate heating capacity and heat rejection for energy balance
PDT-85[a]	Heated liquid pressure difference at temperature measurement location
Not identified	Power consumption for the chiller, including any auxiliary systems contained in the test boundary; includes voltage balance measurement

Notes:
a. Optional pressure measurement used for enthalpy capacity calculation method

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ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

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