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

## Public Review Draft

# Proposed Addendum *c* to Standard 30-2019, Method of Testing Liquid Chillers

**First Public Review (May 2024)**
**(Draft shows Proposed Changes to Current Standard)**

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).



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**(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)**

## 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:

1. Adds a definition for heat exchanger allowing reference to capacity measurement in cooling or heating.
2. Redefines heat reclaim and combined heating and cooling metrics to allow capacity and total efficiency calculation including all heat exchangers.
3. Adds 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.

# Addendum c to ANSI/ASHRAE Standard 30-2019

***Previously approved Sections 1 and 2 are shown below for information purposes only.***

## 1. PURPOSE

**1.1** The purpose of this standard is to prescribe methods of testing to measure the thermal capacity, energy efficiency, and liquid pressure drop of packaged liquid chiller equipment using a refrigerant vapor compression cycle.
**1.2** This standard does not specify methods of establishing published ratings or performance tolerances.

## 2. SCOPE

**2.1** This standard applies to the following packaged equipment using any type of compressor:
a. liquid chilling
b. liquid heating
c. simultaneous liquid chilling and liquid heating

**2.1.1** Using the following methods of heat rejection during the cooling cycle or heat absorption during the heating cycle:
a. air cooled
b. adiabatically cooled
c. evaporatively cooled
d. liquid cooled

**2.2** This standard includes packaged equipment provided in more than one assembly if the separated or remote assemblies are designed to be used together and are connected together during the test.

**2.3** This standard does not include the following types of equipment:
a. self-contained, mechanically refrigerated drinking-water coolers within the scope of ASHRAE Standard 18
b. unitary water-to-air heat-pump equipment within the scope of ASHRAE Standard 37
c. absorption water-chilling packages within the scope of ASHRAE Standard 182

**2.4** This standard does not include testing of chillers in field installations.

**2.5** This standard does not specify the test operating conditions.

**2.6** This standard does not specify methods of performance ratings certification.

***Modify Section 3 as shown below. The remainder of Section 3 is unchanged.***

## 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~~n~~ 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 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.
>
> ***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.
>
> ***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.
>
> ***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.

***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:*** De-superheating and sub-cooling 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 its 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 an 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.
>
> ***Informative Note***: "↔" means "to or from"
>
> ***adiabatically cooled heat exchanger***: an air ↔ refrigerant heat exchanger which pre-cools 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.

***liquid-chilling system:*** a machine specifically designed to make use of a refrigeration cycle to transfer heat to or from one or more liquids. The machine is either packaged (factory-made and prefabricated assembly) or field-erected. Refrigerant *heat exchangers* within the machine are either an integral part of an assembly or remotely located.

> ***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.

***useful heat***: net transfer of heat added or removed from the intended thermal load as defined in the test plan.

***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).

***refrigerating system:***

a. a combination of interconnected parts forming a closed circuit in which refrigerant is circulated for the purpose of extracting then rejecting heat.
b. a system that, in operation between a heat source (evaporator) and a heat sink (condenser) at two different temperatures, absorbs heat from the heat source at the lower temperature and rejects heat to the heat sink at the higher temperature.

***Replace all of Section 4 as shown below.***

## 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.

~~4.1.1.1 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 below. 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 of the following three methods shall be used ~~depending on the available measurements and with consideration of the acceptable test uncertainty required by the parties 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 ~~point~~ temperature ~~of flowing liquid~~ 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. Non-useful 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 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. Non-useful 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* $\eta_R$ shall be calculated using the following:

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

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

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

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

***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 efficiency* $\eta_H$ shall be calculated using the following:

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

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

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

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

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

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

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

where:

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

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

**5.4.3.3 Total Energy Efficiency.** The *total efficiency* $\eta_{total}$ shall be calculated using the following:

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

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

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

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

$$\theta_{W_{input}} = -\frac{Q_{ev} + Q_{cd}}{\left(W_{input}\right)^2}$$

[…]

**5.5 Validation** […]

**5.5.1 Energy Balance** […]

**5.5.1.4 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**

**[…]**

**5.5.3 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 re-run at conditions that do not reach 100% relative humidity.

***Modify Section 6 as shown below.***

## 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.

***Replace Table 6-6 with Table below.***

**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] $\frac{\lvert \bar{Q} - Q_{target} \rvert}{Q_{100\%}} \leq 2.000\%$ | 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 | | | $\lvert \bar{T} - T_{target} \rvert \leq 0.28\ \Delta°C\ [0.50\ \Delta°F]$ | $s_T \leq 0.10\ \Delta°C\ [0.18\ \Delta°F]$ |
| | | Difference | $\overline{\Delta T}$ | $s_{\Delta T}$ | No requirement | $\frac{s_{\Delta T}}{\overline{\Delta T}} \leq 1.500\% \left(\frac{Q_{100\%}}{Q_{target}}\right)$ |
| Liquid ↔ Refrigerant Not providing useful heat | Liquid Temperature | Entering [b] | $\bar{T}$ | $s_T$ | During Cooling, Heating, or Hybrid mode: $\lvert \bar{T} - T_{target} \rvert \leq 0.28\ \Delta°C\ [0.50\ \Delta°F]$ During defrost cycle: $\lvert \bar{T} - T_{target} \rvert \leq 1.11\ \Delta°C\ [2.00\ \Delta°F]$ | During Cooling, Heating, or Hybrid mode: $s_T \leq 0.10\ \Delta°C\ [0.18\ \Delta°F]$ During defrost cycle: $s_T \leq 0.28\ \Delta°C\ [0.50\ \Delta°F]$ |
| | | Leaving | | | No requirement | No requirement |
| | | Difference | $\overline{\Delta T}$ | $s_{\Delta T}$ | No requirement | No requirement |

**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 providing useful heat | Air Temperature [c] | Entering | Dry Bulb | $\overline{T}$ | $s_T$ | When non-frosting: $\lvert \overline{T} - T_{target} \rvert \leq 0.56\ \Delta°C\ [1.00\ \Delta°F]$ | When non-frosting: $s_T \leq 0.42\ \Delta°C\ [0.75\ \Delta°F]$ |
| | | | | | | When frosting: $\lvert \overline{T} - T_{target} \rvert \leq 1.11\ \Delta°C\ [2.00\ \Delta°F]$ | When frosting: $s_T \leq 0.56\ \Delta°C\ [1.00\ \Delta°F]$ |
| | | | | | | During defrost cycle: No requirement | During defrost cycle: $s_T \leq 1.39\ \Delta°C\ [2.50\ \Delta°F]$ |
| | | | Wet Bulb | | | When non-frosting: $\lvert \overline{T} - T_{target} \rvert \leq 0.56\ \Delta°C\ [1.00\ \Delta°F]$ | $s_T \leq 0.28\ \Delta°C\ [0.50\ \Delta°F]$ |
| | | | | | | When frosting: $\lvert \overline{T} - T_{target} \rvert \leq 0.83\ \Delta°C\ [1.50\ \Delta°F]$ | When frosting: $s_T \leq 0.42\ \Delta°C\ [0.75\ \Delta°F]$ |
| | | | | | | During defrost cycle: No requirement | During defrost cycle: No requirement |
| Adiabatically-cooled, Evaporatively-cooled | Make-up water temperature | | | $\overline{T}$ | $s_T$ | $\lvert \overline{T} - T_{target} \rvert \leq 0.56\ \Delta°C\ [1.00\ \Delta°F]$ | No requirement |
| Liquid ↔ Refrigerant | Liquid flow (volumetric, entering) | | | $\overline{V}_{liq}$ | $s_{V_{liq}}$ | $\frac{\lvert \overline{V}_{liq} - V_{liq,target} \rvert}{V_{liq,target}} \leq 5.000\%$ | $\frac{s_{V_{liq}}}{\overline{V}_{liq}} \leq 0.750\%$ |
| Condenser-less | Refrigerant Saturated Discharge Temperature | | | $\overline{T}$ | $s_T$ | $\lvert \overline{T} - T_{target} \rvert \leq 0.28\ \Delta°C\ [0.50\ \Delta°F]$ | $s_T \leq 0.14\ °C\ [0.25\ °F]$ |
| | Liquid Temperature | | | $\overline{T}$ | $s_T$ | $\lvert \overline{T} - T_{target} \rvert \leq 0.56\ \Delta°C\ [1.00\ \Delta°F]$ | $s_T \leq 0.28\ °C\ [0.50\ °F]$ |
| All types | Voltage [d] (if multiphase, this is the average of all phases) | | | $\overline{V}$ | $s_V$ | $\frac{\lvert \overline{V} - V_{target} \rvert}{V_{target}} \leq 10.00\%$ | $\frac{s_V}{\overline{V}} \leq 0.500\%$ |

**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. | | |
| | Frequency [d] | $\bar{\omega}$ | $s_{\omega}$ | $\frac{\lvert\bar{\omega} - \omega_{target}\rvert}{\omega_{target}} \leq 1.000\%$ | $\frac{s_{\omega}}{\bar{\omega}} \leq 0.500\%$ |
| | Test rooms<br>Air Mean Dry Bulb Temperature [f] | $\bar{T}$ | $s_T$ | $\lvert\bar{T} - T_{target}\rvert \leq 2.78\ \Delta°C\ [5.00\ \Delta°F]$ | No requirement |
| | Steam Turbine Pressure/Vacuum [e]<br>Gas Turbine Inlet Gas Pressure [e] | $\bar{p}$ | $s_p$ | $\lvert\bar{p} - p_{rating}\rvert \leq 3.45$ kPa [0.500 psid] | $s_p \leq 1.72$ kPa [0.250 psid] |
| | Governor Control Compressor Speed [g] | $\bar{n}$ | $s_n$ | $\frac{\lvert\bar{n} - n_{target}\rvert}{n_{target}} \leq 0.500\%$ | $\frac{s_n}{\bar{n}} \leq 0.250\%$ |

Notes:

a. The ±2.0% tolerance shall be calculated as 2.0% of the full load rated capacity. For example, a nominal 50.0% part-load point shall be tested between 48.0% and 52.0% of the full-load capacity. 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 over bar) 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.

**6.7.1 Energy Balance.** ~~For the case of liquid-cooled condensers, measurement~~ 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,~~ equipment operating with an air ↔ refrigerant heat exchanger, adiabatically cooled heat exchanger, or evaporatively cooled heat exchanger redundant measurement data shall be collected to substantiate the validity of each test point.

[…]

***Modify Section 7 as shown below. The remainder of Section 7 is unchanged.***

## 7. DATA TO BE RECORDED

**7.1 General.** For each test point, at a specific load and set of operating conditions report the test time period and number of data point measurements. Include the sample mean and sample standard deviation for each measurement value (temperature, flow, pressure drop, power, etc.) as calculated per Section 5.2.

**7.2 Primary Data.** Table 7-1 summarizes the data to be recorded during the test for each of the data point samples.

**Table 7-1 Data to be Recorded During the Test**

| ~~Type~~ | | ~~Data Item~~ |
|---|---|---|
| ~~All types~~ | ~~General~~ | ~~Time of day for each data point sample~~ |
| | | ~~Atmospheric pressure~~ |
| | ~~Evaporator~~ | ~~$T_{in}$~~ |
| | | ~~$T_{out}$~~ |
| | | ~~$m_w$ or $V_w$~~ |
| | | ~~$\Delta p_{test}$~~ |
| ~~Liquid-cooled condenser~~ | ~~Condenser~~ | ~~$T_{in}$~~ |
| ~~Liquid-cooled heat reclaim condenser~~ | | ~~$T_{out}$~~ |
| | | ~~$m_w$ or $V_w$~~ |
| | | ~~$\Delta p_{test}$~~ |
| ~~Air-cooled condenser~~ | ~~Condenser~~ | ~~Spatial average dry-bulb temperature of entering air~~ |
| ~~Evaporatively cooled condenser~~ | ~~Condenser~~ | ~~Spatial average dry-bulb temperature of entering air~~ |
| | | ~~Spatial average wet-bulb temperature of entering air~~ |
| ~~Without condenser~~ | ~~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~~ | ~~$W_{input}$ (and $W_{refrig}$ if needed)~~ |
| | | ~~If steam turbine:~~<br>~~Steam consumption~~<br>~~Steam supply pressure~~<br>~~Steam supply temperature~~<br>~~Steam exhaust pressure~~ |
| | | ~~If gas turbine or gas engine:~~<br>~~Fuel consumption (natural gas or propane)~~<br>~~Calorific value~~ |
| | | ~~If internal combustion engine:~~<br>~~Liquid fuel consumption (diesel or gasoline)~~<br>~~Calorific value~~ |

**Table 7-1 Data to be Recorded During the Test**

| | | |
|---|---|---|
| All Types | General | Date & 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 $V_w$ |
| | | $\Delta P_{test}$ |
| air ↔ refrigerant heat exchanger | | Spatial average dry-bulb temperature of entering air. |
| evaporatively-cooled heat exchanger Or adiabatic 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 3-phase: average voltage |
| | | Frequency for one phase |
| Non-Electric Drive | Chiller | If Steam Turbine:<br>Steam consumption<br>Steam supply pressure<br>Steam supply temperature<br>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, and refrigerant designation number, sufficient to completely identify the liquid chiller. Unit voltage and frequency shall be recorded.~~ |
| | ~~Prime mover nameplate data (motor, engine, or turbine).~~ |
| ~~Nonelectric Drive~~ | ~~Fuel specification (if applicable) and calorific value.~~ |

**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, serial number, voltage, frequency and refrigerant designation number (in accordance with ASHRAE Standard 34). |
| | Prime mover nameplate data (motor, engine, or turbine). |
| Non-electric Drive | Fuel specification (if applicable) and calorific value. |
| | |

***Modify Section 8 as shown below. The remainder of Section 8 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 as shown below. 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 Operation | Operating mode (cooling, heating, simultaneous heating and cooling, or heat recovery) |
| | All inputs necessary to ensure that the equipment under test runs in the operating mode tested [b] |
| Capacity | Net capacity |
| | Gross capacity values as used for energy balance |
| | Heat reclaim capacity [c] |
| Input power | Total input power |
| | List of components that utilize auxiliary power |
| Energy efficiency[d] | One or more of the *energy efficiency* metrics per Section 5.4.3 |
| Liquid pressure drop[e] | Liquid corrected pressure drop $\Delta p_{corrected}$ at water temperaturesoperating conditions per the test plan, measured per Section 8.4 and corrected per Section 5.4.4 |
| | If $\Delta p_{adj}$ > 10%$\Delta p_{test}$, then report the value of $\Delta p_{adj}$ and include the statement "$\Delta p_{adj}$ exceeded 10% of $\Delta p_{test}$" |
| Test validation | Energy Balance when required per Sections 5.5.1 and 5.5.1.4 |
| | Voltage Balance per Section 5.5.2 |
| Correction values | $\Delta p_{adj}$ per Section 5.4.4 (even if exceeding 10% of $\Delta p_{test}$) |
| | Any other correction values required by the test plan |
| Test plan | Attach a copy of the test plan in accordance with Section 6.4 or provide target operating condition values such as capacity, temperature, and flow. |
| 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. Required for liquid-cooled heat reclaim condenser only.
d. 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.
e. Liquid pressure drop shall be reported in units of pressure differential, not in head or liquid column height. **Note:** Due to industry typical practice, Liquid Pressure Drop is often reported in head (ft H2O) and corrected to a reference temperature (e.g. 60 °F); however, test data is acquired in pressure, psid, for use in calculations and test result reporting.

**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 $\Delta P_{adj}$>10%$\Delta P_{test}$ then report the value of $\Delta P_{adj}$ and include the statement "$\Delta P_{adj}$ exceeded 10% of $\Delta P_{test}$" |
| 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 | $\Delta P_{adj}$ per Section 5.4.4 (even if exceeding 10% of $\Delta P_{test}$) |
| | 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 10-1 by changing the definitions shown below. The remainder of Table 10-1 is unchanged.***

**Table 10-1 Nomenclature**

| Group | Symbol | Description | SI Unit Name | Unit Symbol | IP Unit Name | Unit Symbol |
|---|---|---|---|---|---|---|
| […] | […] | | | | | |
| General | U | uncertainty of a variable [a] | | | | |
| | […] | | | | | |
| | θ | sensitivity coefficient for uncertainty [b] | | | | |
| […] | […] | | | | | |

[a] The symbol U will have a subscript that is the symbol for another variable; the other variable is either a measurement or a result. This subscript defines the variable to which the uncertainty applies. For example, the symbol $U_{\eta_H}$ refers to the uncertainty of the heating energy efficiency result $\eta_H$.

[b] The symbol θ will have a subscript that is the symbol for another variable; the other variable is either a measurement or another intermediate result. This subscript defines the variable to which the sensitivity coefficient applies, where the sensitivity coefficient for a particular result is the partial derivative with respect to this other variable denoted in the subscript. For example, the symbol $\theta_{Q_{cd}}$ refers to the sensitivity coefficient with respect to the variable $Q_{cd}$. The symbols for sensitivity coefficients will repeat between calculations of uncertainties for different results that may use the same input variable. However, each sensitivity coefficient is only applicable to the uncertainty equation for which it was derived.

***Modify Table 10-2 by adding subscript definitions as shown below. The remainder of Section 10 is unchanged.***

**Table 10-2 Subscripts**

| Subscripts | Description |
|---|---|
| […] | […] |
| *make-up* | replacement water |
| *reservoir* | water reservoir or similar means to contain water |
| *total* | total summation, referring to one or more *capacity* values, or to one or more *input power* values |
| […] | […] |

***Modify references 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
6. ASHRAE. ~~2014~~ 2020. ANSI/ASHRAE Standard 41.11, Standard Methods for Power Measurement. Atlanta: ASHRAE.
8. ASME. ~~2013~~ 2018. Standard PTC 19.1, Test Uncertainty. New York: American Society of Mechanical Engineers.
9. ASHRAE. ~~2014~~ 2022. ANSI/ASHRAE Standard 41.3, Standard Methods for Pressure Measurement. Atlanta: ASHRAE.

***Modify Appendix B as shown. All figures in Appendix B have been updated. Original figures are not shown***

## NORMATIVE APPENDIX B MEASUREMENT POINTS

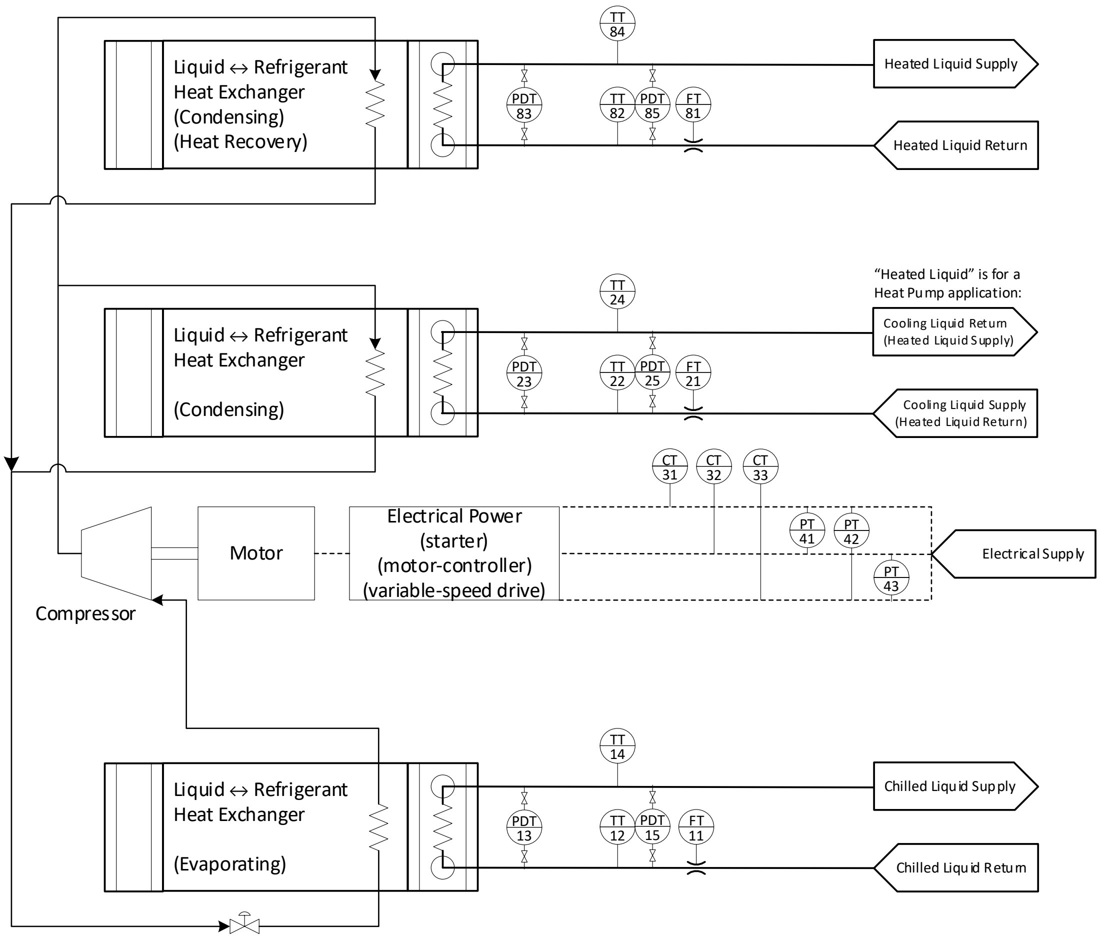


**Figure B-1 Electrically driven liquid-cooled chiller (with or without heat recovery) or heat pump.**

| ID | Description of Measurement [c] |
|---|---|
| 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 capacities |
| TT-14 | Chilled liquid outlet temperature, used to calculate refrigerating capacities |
| <u>PDT-15[a]</u> | <u>Chilled liquid pressure difference at temperature measurement location</u> |
| FT-21[b] | Liquid flow, used to calculate heating capacities (for heat pump applications) and heat rejection for energy balance |
| TT-22 | Heated liquid inlet temperature, used to calculate heating capacities (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 capacities (for heat pump applications) and heat rejection for energy balance |
| <u>PDT-25[a]</u> | <u>Heated liquid pressure difference at temperature measurement location</u> |
| FT-81[b] | Heat recovery liquid to refrigerant heat exchanger (when included) liquid flow, used to calculate heating capacities (for heat pump applications) and heat rejection for energy balance |
| TT-82 | Heat recovery liquid to refrigerant heat exchanger (when included) liquid inlet temperature, used to calculate heating capacities (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 | Heta recovery liquid to refrigerant heat exchanger (when included) liquid outlet temperature, used to calculate heating capacities (for heat pump applications) and heat rejection for energy balance |
| <u>PDT-85[a]</u> | <u>Heat recovery liquid to refrigerant heat exchanger pressure difference (when included) pressure difference at temperature measurement location</u> |

| | |
|---|---|
| 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, other than the compressor motor. ~~including any a~~ Auxiliary systems contained in the test boundary, ~~includes~~ including voltage balance measurement. |

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

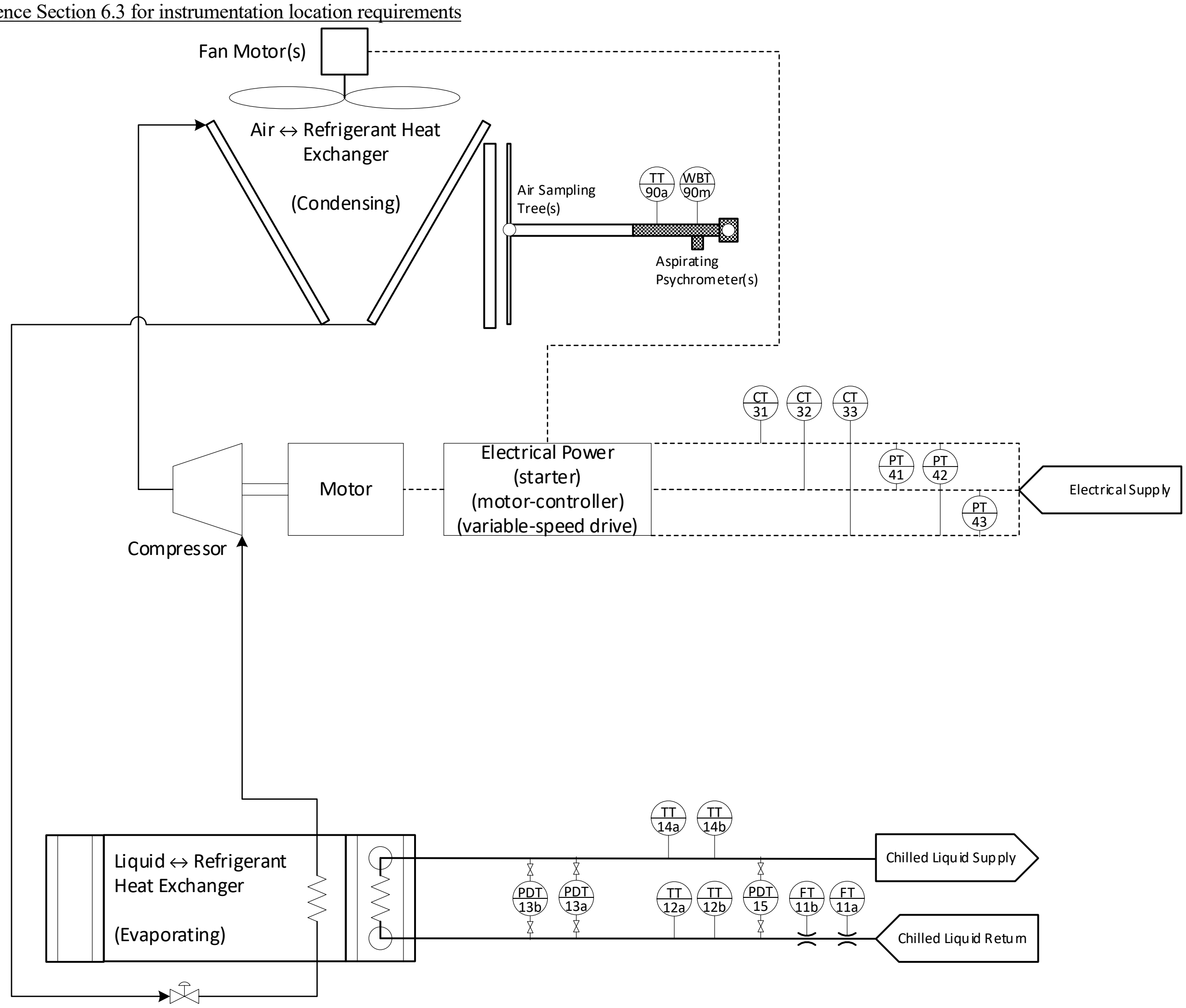


**Figure B-2 Electrically driven air-cooled chiller.**

| 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 capacities (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 |
| 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, other than the compressor and fan motors. ~~including any a~~ Auxiliary systems contained in the test boundary, ~~includes~~ including voltage balance measurement. |

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

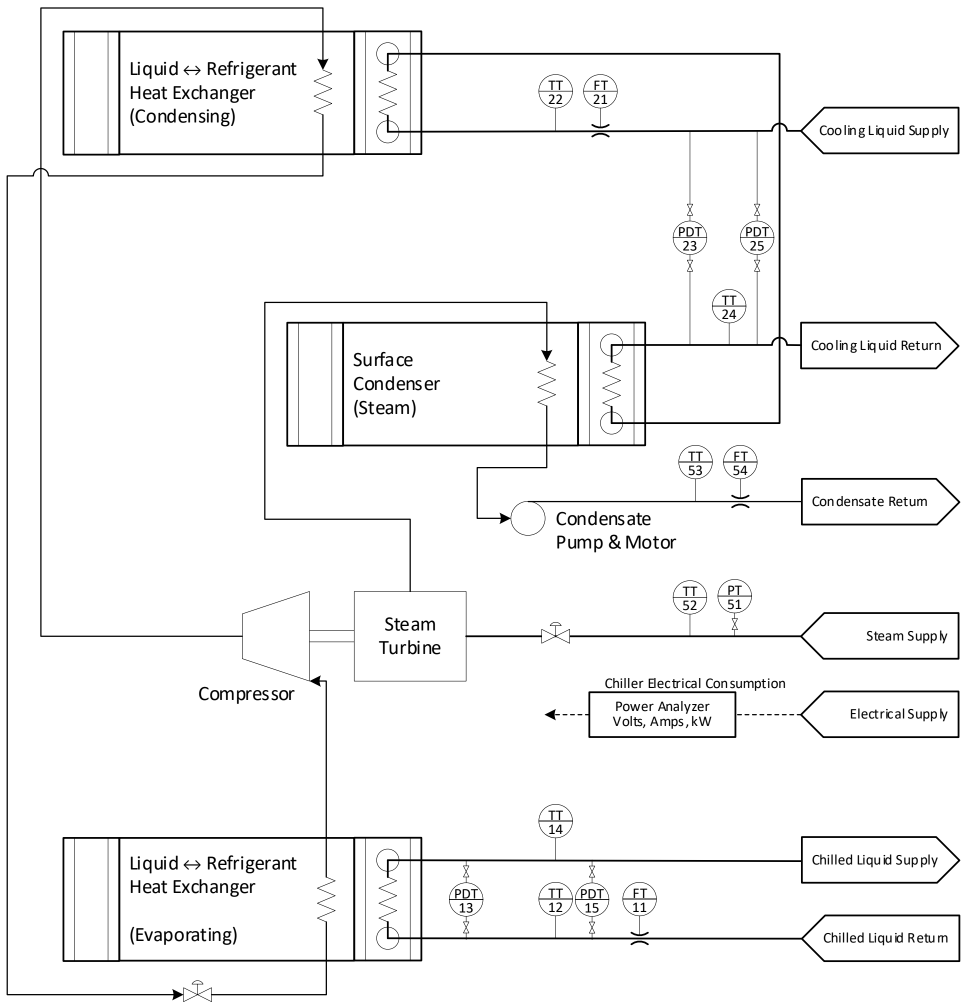


**Figure B-3 Steam-turbine-driven liquid-cooled chiller.**

| **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 capacities |
| TT-14 | Chilled liquid outlet temperature, used to calculate refrigerating capacities |
| PDT-15 [a] | Chilled liquid pressure difference at temperature measurement location |
| FT-21 | Heated liquid flow, used to calculate heating capacities (for heat pump applications) and heat rejection for energy balance |
| TT-22 | Heated liquid inlet temperature, used to calculate heating capacities (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 capacities (for heat pump applications) and heat rejection for energy balance |
| PDT-25 [a] | 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, ~~includes~~ including any auxiliary systems contained in the test boundary; includes voltage balance measurement |

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

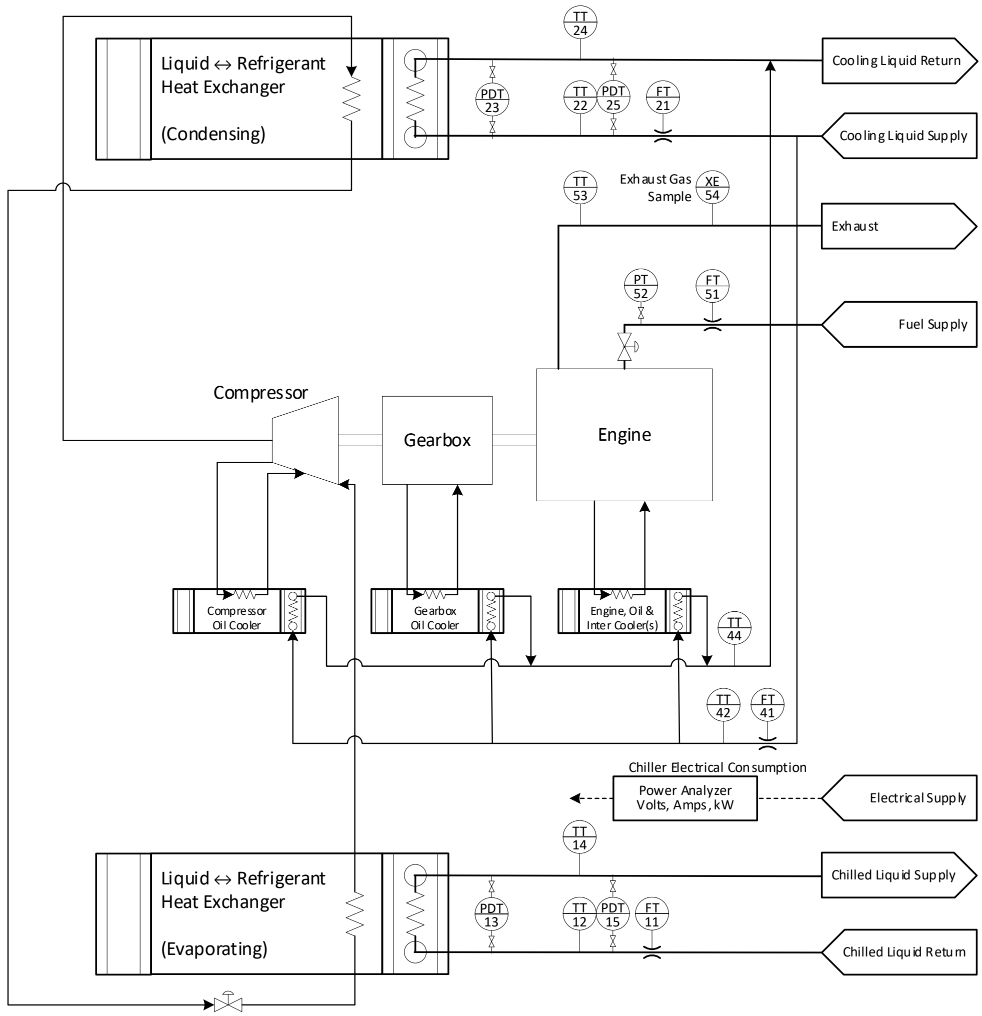


**Figure B-4 Engine-driven liquid-cooled chiller.**

| 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 capacities |
| TT-14 | Chilled liquid outlet temperature, used to calculate refrigerating capacities |
| PDT-15 [a] | Chilled liquid pressure difference at temperature measurement location |
| FT-21 | Heated liquid flow, used to calculate heating capacities (for heat pump applications) and heat rejection for energy balance |
| TT-22 | Heated liquid inlet temperature, used to calculate heating capacities (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 capacities (for heat pump applications) and heat rejection for energy balance |
| PDT-25 [a] | Heated liquid pressure difference at temperature measurement location |
| FT-41 | Compressor & drive system cooling system liquid flow |
| TT-42 | Compressor & 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] Optional pressure measurement used for enthalpy capacity calculation method.
[b] Flow meter location shown is one of options identified in Section 6.3.1.5.
[c] Reference Section 6.3 for instrumentation location requirements.

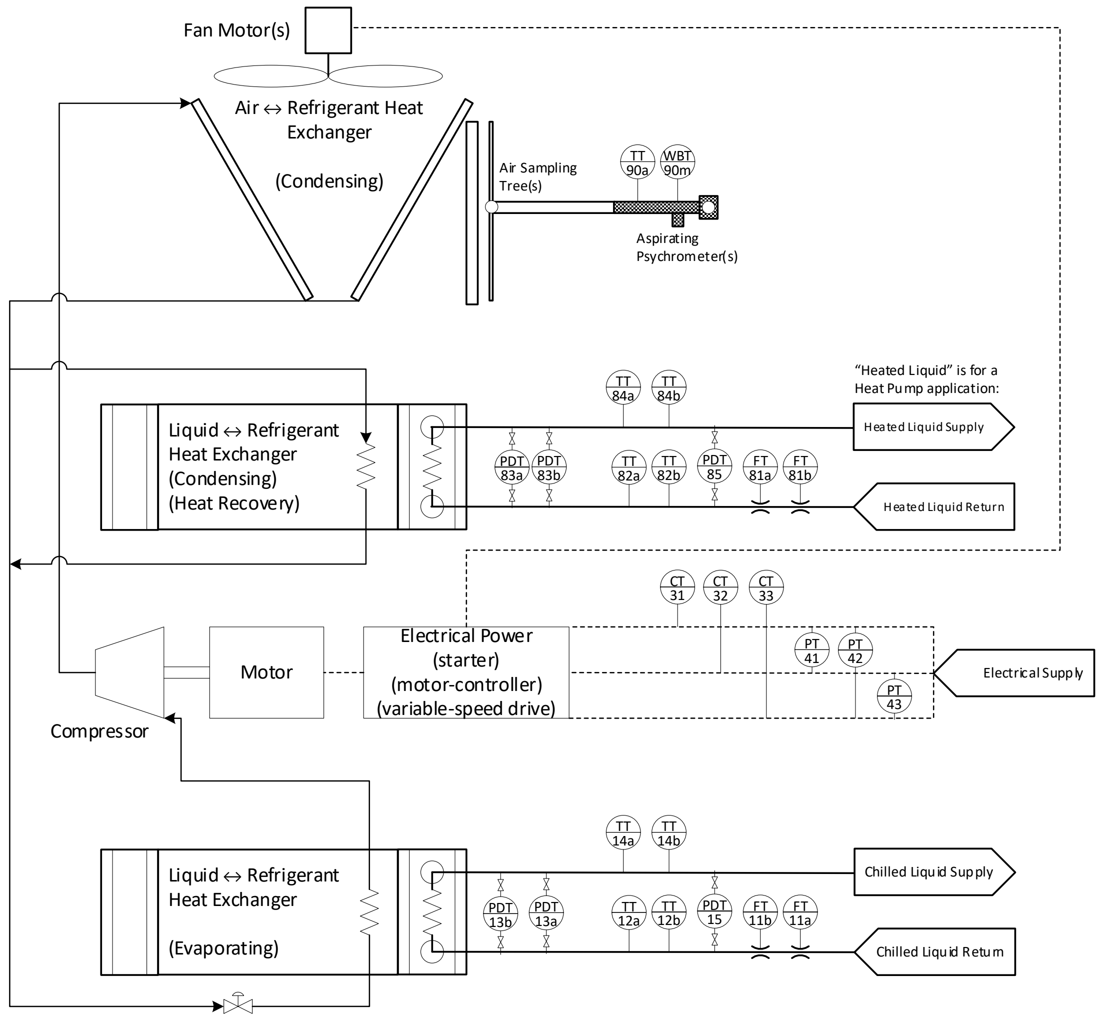


**Figure B-5 Electrically driven air-cooled chiller with heat recovery.**

| 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 capacities (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 capacities |
| TT-82a, b | Heated liquid inlet temperature, used to calculate heating capacities 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 capacities and heat rejection for energy balance |
| PDT-85 [a] | Heated liquid 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, other than the compressor and fan motors. ~~including any a~~ Auxiliary systems contained in the test boundary, ~~incudes~~ including voltage balance measurement. |

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

[b] Flow meter location shown is one of options identified in Section 6.3.1.5.
[c] Reference Section 6.3 for instrumentation location requirements.