STANDARD

ASHRAE

ANSI/ASHRAE Standard 30-2017
(Supersedes ASHRAE Standard 30-1995)

Method of Testing Liquid Chillers

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ANSI/ASHRAE Standard 30-2017, Method of Testing Liquid Chillers

NOTE

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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 in order to generate and confirm valid test results.

The 2017 revision realigns ASHRAE Standard 30 with the latest testing methods developed by AHRI Standard 550/590 committee members.The content for the method of test is now consolidated in this standard and will be removed from AHRI Standards 550/590 and 551/591.

1. PURPOSE

1.1 The purpose of this standard is to prescribe methods of testing to measure the thermal capacity, energy efficiency, and water 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 liquid-chilling or liquid-heating packaged equipment using any type of compressor and using the following methods of heat rejection during the cooling cycle:

a. Air cooled
b. Evaporatively cooled
c. Water 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.

3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

air-sampling tree: an air-sampling tube assembly that draws air through sampling tubes in a manner to provide a uniform sampling of air entering the air-cooled condenser coil. See Section 6.3.1.4.2.1 for design details.

aspirating psychrometer: a piece of equipment with a monitored airflow section that draws a uniform airflow velocity through the measurement section and has probes for measurement of air temperature and humidity. See Section 6.3.1.4.2.2 for design details.

auxiliary power: see *power.*

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 also, in some calculations, the energy associated with liquid-side pressure losses.

gross cooling 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 water-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 cooling 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.

compressor saturated discharge temperature: for single-component and azeotrope refrigerants, it is the saturated temperature corresponding to the refrigerant pressure at the compressor discharge. For zeotropic refrigerants, it is the arithmetic average of the dew-point and bubble-point temperatures corresponding to refrigerant pressure at the compressor discharge. It is usually taken at or immediately downstream of the compressor discharge service valve (in either case on the downstream side of the valve seat), where discharge valves are used.

condenser: a refrigerating system component that condenses refrigerant from vapor state to liquid state by the removal of heat. Desuperheating and subcooling of the refrigerant may occur as well.

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

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

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

liquid-cooled heat reclaim condenser: a liquid-cooled condenser, with the purpose of heat recovery, 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.

design conditions: any set of operating conditions under which a single level of performance results and that causes only that level of performance to occur.

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.

cooling efficiency: a ratio of net refrigerating capacity and the total input power. 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: a ratio of net heating capacity and the total input power.

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.

energy balance: a dimensionless ratio metric used to check for gross errors in measurement instrumentation and test results for units with a water-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 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.

evaporator: a refrigerating system component that boils refrigerant from liquid state to vapor state by the addition of heat. Superheating of the refrigerant may occur as well. For the purposes of this standard, the heat is exchanged from a liquid as opposed to air; in this context, an evaporator may also be called a "cooler."

fouling factor: thermal resistance due to fouling accumulated on the liquid-side or air-side heat transfer surface.

heat reclaim (or heat recovery): use of heat that would otherwise be wasted from a system or process.

liquid: the fluid being cooled in the evaporator (cooler) or heated in the condenser, as distinguished from refrigerant in the liquid state. Examples of liquids include water, glycol mixture, or other heat transfer fluid.

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 air or water. 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.

liquid pressure drop: a measured value of the reduction in liquid pressure associated with the flow through a liquid-type heat exchanger.

operating conditions: a unique set of system parameters resulting in a single level of performance.

operating condition tolerance: the maximum permissible variation between the time-averaged measurement data observations and the specified (target) operating conditions as established in the test plan.

percent load (%load): the part-load net capacity divided by the full-load net capacity at the full-load rating conditions, stated in decimal format. (e.g., 100% = 1.0).

power: the rate at which energy is transferred, used, or transformed.

auxiliary power: power input to devices that are not integral to the operation of the vapor compression cycle, excluding power input to integrated pumps (if present) used for liquid in either the evaporator or the condenser. Auxiliary power includes devices such as, but not limited to, oil pumps, refrigerant pumps, control power, fans, and heaters.

input power: a term used to refer to the power input to any of the following:

a. mechanical power input to the shaft of open compressors
b. electrical power input at the motor terminals for hermetic compressors, semihermetic compressors, or motor-compressors
c. electrical power at the input terminals for starter, motor-controller, or variable-speed drives
d. thermal energy or chemical energy input per unit of time for steam turbine, gas turbine, or combustion-engine-driven compressor.

total input power: the sum of input power and auxiliary power to all components of a liquid-chilling system.

published ratings: a statement of the assigned values of those performance characteristics, under stated design conditions, by which a unit may be chosen to fit its application. These values apply to all units of like nominal size and type (identification) produced by the same manufacturer. The term "published rating" includes the rating of all performance characteristics, at stated rating conditions, shown on the unit or published in specifications, advertising, or other literature controlled by the manufacturer.

application rating: a rating based on tests performed at application rating conditions other than standard design conditions.

standard rating: a rating based on tests performed at standard design conditions.

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.

standard design conditions: rating conditions used as the basis of comparison for performance characteristics.

steady state: a state or condition of a system or process that does not change in time, or a condition that changes only negligibly over a specified time interval.

temperature: measurement of warmth or coldness with respect to an arbitrary zero or to the absolute zero. Temperatures are indicated on defined scales, such as Kelvin and Rankine for absolute temperatures and Celsius and Fahrenheit for ordinary temperatures.

bubble-point temperature: a liquid-vapor equilibrium point for a volatile pure liquid or for a multicomponent mixture of miscible, volatile pure component liquids in the absence of noncondensables, where the temperature of the mixture at a defined pressure is the minimum temperature required for a vapor bubble to form in the liquid.

dew-point temperature: a liquid-vapor equilibrium point for a volatile pure liquid or for a multicomponent mixture of miscible, volatile pure component liquids, in the absence of noncondensables, where the temperature of the mixture at a defined pressure is the maximum temperature required for a liquid drop to form in the vapor.

saturation temperature:

a. temperature where a substance changes between its liquid and its vapor phases. If the pressure in a system remains constant, a vapor at saturation temperature will begin to condense into its liquid phase as thermal energy is removed; conversely, a liquid at saturation temperature will begin to evaporate as thermal energy is applied.
b. equilibrium temperature of a pure refrigerant or an azeotropic refrigerant in a two-phase mixture of a vapor and liquid at a given absolute pressure.

temperature of flowing liquid: the mixed mean stream temperature at a station perpendicular to the liquid flow direction.

total heat rejection: heat rejected through the condenser, including heat used for heat recovery.

4. EQUIPMENT TYPES

4.1 This standard covers the following equipment types.

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

N/A = Not applicable (excluded from the scope of the standard)

5. CALCULATIONS AND CONVERSIONS

5.1 Fluid Properties

5.1.1 Water. One of the following two methods shall be used.

5.1.1.1 Method 1. Use NIST REFPROP to calculate physical properties such as density, specific heat, or enthalpy as a function of both pressure and temperature.

5.1.1.2 Method 2. Use the following polynomial equations to calculate density and specific heat of water as a function of temperature only.

$$\rho = (\rho_4 \times T^4) + (\rho_3 \times T^3) + (\rho_2 \times T^2) + (\rho_1 \times T^1) + \rho_0$$

$$c_p = (c_{p5} \times T^5) + (c_{p4} \times T^4) + (c_{p3} \times T^3) + (c_{p2} \times T^2) + (c_{p1} \times T^1) + c_{p0}$$

	I-P, °F	SI, °C
T	32~212	0~100

	I-P, lbm/ft³	SI, kg/m³
ρ_4	-7.4704×10^{-10}	-1.2556×10^{-7}
ρ_3	5.2643×10^{-7}	4.0229×10^{-5}
ρ_2	-1.8846×10^{-4}	-7.3948×10^{-3}
ρ_1	1.2164×10^{-2}	4.6734×10^{-2}
ρ_0	62.227	1000.2
	I-P, Btu/lbm·°F	**SI, kJ/kg·K**
c_{p5}	-4.0739×10^{-13}	-3.2220×10^{-11}
c_{p4}	3.1031×10^{-10}	1.0770×10^{-8}
c_{p3}	-9.2501×10^{-8}	-1.3901×10^{-6}
c_{p2}	1.4071×10^{-5}	9.4433 × 10[illegible]
c_{p1}	-1.0677×10^{-3}	–3.11[illegible] × 10[illegible]
c_{p0}	1.0295	4[illegible]160

Note: Density and specific-heat polynomial equations are curve fit from data generated by NIST REFPROP v9.1 (see Informative Appendix A) at 100 psia (689.5 kPa) and using a temperature range of 32°F to 212°F (0°C to 100°C). The 100 psia value used for the water property curve fits was established as a representative value to allow for the calculation of water-side properties as a function of temperature only.

5.1.2 Other Liquids. Physical properties of the liquid versus temperature, and also by concentration for solutions or mixtures, shall be determined from published data sources such as manufacturer data sheets. Systems using aqueous solutions or mixtures shall be tested to measure or determine the concentration by mass of the liquid. Concentration tests shall be performed within two (2) weeks or less prior to the date of the chiller tests, or within two (2) days after the tests.

5.2 Data Processing. Data-point measurements collected during the duration of the testing period shall be processed to calculate sample mean and sample standard deviation per the following equations. Calculate final performance metrics (capacity, efficiency, liquid pressure drop) and other test results (energy balance, voltage balance, average values from redundant sensors) from the mean values of measurement data. (This method of test is not intended for transient testing).

Sample mean:

$$\bar{x} = \frac{1}{n}\sum_{j=1}^{n}(x_j)$$

Sample standard deviation:

$$s = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(x_j - \bar{x})^2}$$

5.3 Redundant Measurements. When redundant sensors are used to measure the same property, the average of the sample means shall be used with associated uncertainty when calculating results.

$$\bar{y} = \frac{\bar{x}_1 + \bar{x}_2 + \ldots + \bar{x}_3}{}$$

$$U_{\bar{y}} = \sqrt{(\theta_{\bar{x}_1}U_{\bar{x}_1})^2 + (\theta_{\bar{x}_2}U_{\bar{x}_2})^2 + \ldots + (\theta_{\bar{x}_n}U_{\bar{x}_n})^2}$$

$$\theta_{\bar{x}_i} = \frac{1}{n}$$

5.4 Performance

5.4.1 Capacity. 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. 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. Adjust the sign for temperature difference or enthalpy difference accordingly by subtracting the lesser of inlet and outlet from the greater value. For pressure difference, however, the sign is significant with respect to the direction of energy flow.

5.4.1.1 Gross Capacity and Net Capacity Given Liquid Volume Flow Rate, Inlet and Outlet Temperatures, Pressure Loss, Density, and Specific Heat. The density shall be calculated at the temperature and pressure coincident with the volume flow rate measurement. The specific heat shall be calculated at the mean of the entering and leaving temperatures and pressures.

5.4.1.1.1 Gross Capacity

$$Q' = V\rho c_p \Delta T + V\Delta p$$

$$U_{Q'} = \sqrt{(\theta_V U_V)^2 + (\theta_\rho U_\rho)^2 + (\theta_{c_p} U_{c_p})^2 + (\theta_{\Delta p} U_{\Delta p})^2}$$

$$\theta_V = \rho c_p \Delta T + \Delta p$$

$$\theta_\rho = V c_p \Delta T$$

$$\theta_{c_p} = V\rho\Delta T$$

$$\theta_{\Delta T} = V\rho c_p$$

$$\theta_{\Delta p} = V$$

5.4.1.1.2 Net Capacity

$$Q = V\rho c_p \Delta T$$

$$U_Q = \sqrt{(\theta_V U_V)^2 + (\theta_\rho U_\rho)^2 + (\theta_{c_p} U_{c_p})^2 + (\theta_{\Delta T} U_{\Delta T})^2}$$

$$\theta_V = \rho c_p \Delta T$$

$$\theta_\rho = V c_p \Delta T$$

$$\theta_{c_p} = V\rho \Delta T$$

$$\theta_{\Delta T} = V\rho c_p$$

5.4.1.2 Gross Capacity and Net Capacity Given Liquid Mass Flow Rate, Inlet and Outlet Temperatures, Pressure Loss, Density, and Specific Heat. The specific heat and density shall be calculated at the mean of the entering and leaving temperatures and pressures.

5.4.1.2.1 Gross Capacity

$$Q' = mc_p \Delta T + m\frac{\Delta p}{\rho}$$

$$U_{Q'} = \sqrt{(\theta_m U_m)^2 + (\theta_{c_p} U_{c_p})^2 + (\theta_{\Delta T} U_{\Delta T})^2 + (\theta_{\Delta p} U_{\Delta p})^2 + (\theta_\rho U_\rho)^2}$$

$$\theta_m = c_p \Delta T + \frac{\Delta p}{p}$$

$$\theta_{c_p} = m\Delta T$$

$$\theta_{\Delta T} = mc_p$$

$$\theta_{\Delta p} = \frac{m}{\rho}$$

$$\theta_\rho = \frac{m\Delta p}{\rho^2}$$

5.4.1.2.2 Net Capacity

$$Q = mc_p \Delta T$$

$$U_Q = \sqrt{(\theta_m U_m)^2 + (\theta_{c_p} U_{c_p})^2 + (\theta_{\Delta T} U_{\Delta T})^2}$$

$$\theta_m = c_p \Delta T$$

$$\theta_{c_p} = m\Delta T$$

$$\theta_{\Delta T} = mc_p$$

5.4.1.3 Gross Capacity and Net Capacity from Liquid Mass Flow Rate, Liquid Enthalpy Change between Inlet and Outlet, Pressure Loss, and Density. The density shall be calculated at the mean of the entering and leaving temperatures and pressures.

5.4.1.3.1 Gross Capacity

$$Q' = m\Delta h$$

$$U_{Q'} = \sqrt{(\theta_m U_m)^2 + (\theta_{\Delta h} U_{\Delta h})^2}$$

$$\theta_m = \Delta h$$

$$\theta_{\Delta h} = m$$

5.4.1.3.2 Net Capacity

$$Q = m\Delta h - m\frac{\Delta p}{\rho}$$

$$U_Q = \sqrt{(\theta_m U_m)^2 + (\theta_{\Delta h} U_{\Delta h})^2 + (\theta_{\Delta p} U_{\Delta p})^2 + (\theta_\rho U_\rho)^2}$$

$$\theta_m = \Delta h - \frac{\Delta p}{\rho}$$

$$\theta_{\Delta h} = m$$

$$\theta_{\Delta p} = -\frac{m}{\rho}$$

$$\theta_\rho = \frac{m\Delta p}{\rho^2}$$

5.4.1.4 Temperature Difference, Enthalpy Difference, and Pressure Difference

5.4.1.4.1 Temperature Difference

$$\Delta T = \max(T_{in}, T_{out}) - \min(T_{in}, T_{out}) = |T_{in} - T_{out}|$$

$$U_{\Delta T} = \sqrt{(\theta_{T_{in}} U_{T_{in}})^2 + (\theta_{T_{out}} U_{T_{out}})^2}$$

$$\theta_{T_{in}} = \mathrm{sign}(T_{in} - T_{out})$$

$$\theta_{T_{out}} = \mathrm{sign}(T_{out} - T_{in})$$

where $\mathrm{sign}(x) = 1$ if $x > 0$, $\mathrm{sign}(x) = -1$ if $x < 0$, and $\mathrm{sign}(x) = 0$ otherwise.

5.4.1.4.2 Enthalpy Difference

$$\Delta h = \max(h_{in}, h_{out}) - \min(h_{in}, h_{out}) = |h_{in} - h_{out}|$$

$$U_{\Delta h} = \sqrt{(\theta_{h_{in}} U_{h_{in}})^2 + (\theta_{h_{out}} U_{h_{out}})^2}$$

$$\theta_{h_{in}} = \mathrm{sign}(h_{in} - h_{out})$$

$$\theta_{h_{out}} = \mathrm{sign}(h_{out} - h_{in})$$

5.4.1.4.3 Pressure Difference. For the case when energy is input into the system (i.e., heat into evaporator):

$$\Delta p = p_{in} - p_{out} - \Delta p_{adj}$$

$$U_{\Delta p} = \sqrt{(\theta_{p_{in}} U_{p_{in}})^2 + (\theta_{p_{out}} U_{p_{out}})^2 + (\theta_{\Delta p_{adj}} U_{\Delta p_{adj}})^2}$$

$$\theta_{p_{in}} = 1$$

$$\theta_{p_{out}} = -1$$

$$\theta_{\Delta p_{adj}} = -1$$