

AHRI Standard 480-2007
(formerly ARI Standard 480-2007)

**2007 Standard for
Performance Rating of
Remote Type Refrigerant-
Cooled Liquid Coolers**



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IMPORTANT

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Note:

This standard supersedes ARI Standard 480-2001.

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PERFORMANCE RATING OF REMOTE TYPE REFRIGERANT-COOLED LIQUID COOLERS

Section 1. Purpose

1.1 Purpose. The purpose of this standard is to establish for Remote Type Refrigerant-Cooled Liquid Coolers: definitions; test requirements; rating requirements; minimum data requirements for Published Ratings; marking and nameplate data; and conformance conditions.

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

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

Section 2. Scope

2.1 Scope. This standard applies to Remote Type Refrigerant-Cooled Liquid Coolers of the Shell-and-Tube, Shell-and-U-Tube, Shell-and-Coil, and Tube-in-Tube types using single component and azeotropic refrigerants only.

2.2 Exclusions.

2.2.1 This standard does not apply to liquid coolers supplied as part of factory-assembled liquid-chilling packages.

2.2.2 This standard does not apply to liquid coolers of the following types:

- a. Baudelot-type coolers
- b. Open-tank and coil coolers
- c. Open shell-and-tube coolers

2.2.3 This standard does not include sanitary provisions necessary for the handling of potable Liquids.

2.2.4 This standard does not apply to liquid coolers using zeotropic refrigerants.

Section 3. Definitions

All terms in this document follow the standard industry definitions in the current edition of *ASHRAE Terminology of Heating, Ventilation, Air Conditioning and Refrigeration*, unless otherwise defined in this section.

3.1 Evaporating Temperature. The saturation temperature corresponding to the refrigerant pressure at the liquid cooler refrigerant outlet.

3.2 Field Fouling Allowance. Provision for the anticipated Fouling Factor during use.

3.2.1 Fouling Factor. The thermal resistance due to fouling accumulated on the heat transfer surface.

3.3 Liquid. Where used in this standard, the term Liquid by itself shall denote the fluid being cooled.

3.4 Mechanically-Cleanable Liquid Cooler. A liquid cooler in which Liquid flows through tubes which are accessible from both ends for cleaning by mechanical means, or accessible from one end when U-tubes are used.

3.5 *Net Refrigerating Capacity.* The useful heat exchange between the refrigerant and the Liquid being cooled. This value is the product of the liquid mass flow rate and the difference in enthalpy between the Liquid entering and the Liquid leaving the cooler.

3.5.1 *Clean Tube Capacity.* The Net Refrigerating Capacity of the liquid cooler with clean tubes at Standard Rating Conditions expressed in Btu/h [W].

3.6 *Published Rating.* A statement of assigned values of those performance characteristics, under stated Rating Conditions, by which a unit may be chosen to fit its application. These values apply to all Remote Type Refrigerant-Cooled Liquid Coolers of like nominal size and type produced by the same manufacturer. As used herein, the term Published Rating includes all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated Rating Conditions.

3.6.1 *Application Rating.* A rating based on tests performed at application Rating Conditions.

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

3.7 *Rating Conditions.* Any set of operating conditions under which a single level of performance results and which causes only that level of performance to occur.

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

3.8 *Remote Type Refrigerant-Cooled Liquid Cooler.* A factory-made assembly in which heat is transferred from the Liquid to the refrigerant causing the refrigerant to evaporate and the Liquid to be cooled. The liquid cooler is furnished separately for field installation in a refrigeration system, rather than for inclusion in a factory-assembled liquid-chilling package.

3.8.1 *Direct-Expansion.* A liquid cooler in which the refrigerant is normally fed into the tubes or coil by a flow-control device responsive to temperature or pressure, or both, at some point in or near the cooler.

3.8.2 *Flooded.* A liquid cooler in which refrigerant level is maintained within the evaporating chamber and the Liquid being cooled is circulated through the tubes.

3.8.3 *Shell-and-Coil.* A liquid cooler in which heat is transferred through one or more coils contained within a closed shell.

3.8.4 *Shell-and-Tube.* A liquid cooler in which heat is transferred through a group of straight parallel tubes within a closed shell with the tubes terminating at both ends of the cooler.

3.8.5 *Shell-and-U-Tube.* A liquid cooler in which heat is transferred through a U-tube bundle in a closed shell with the U-tubes terminating at one end of the cooler.

3.8.6 *Spray-Type.* A liquid cooler which is provided with a refrigerant distributor above a bundle of tubes not normally submerged in liquid refrigerant. The refrigerant which is not evaporated in its passage over the tubes is recirculated through the distributor. The liquid being cooled is circulated in the tubes.

3.8.7 *Tube-in-Tube.* A liquid cooler which consists of one or more assemblies of two tubes, one within the other, in which heat is transferred between the fluid in the inner tube or tubes and the fluid flowing between the inner and outer tubes.

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

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

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

3.10 Superheat. The amount of temperature increase of the refrigerant above its saturation temperature at the exit of the liquid cooler.

Section 4. Test Requirements

4.1 Test Requirements. All Standard Ratings shall be verified by tests conducted in accordance with ASHRAE Standard 24.

Section 5. Rating Requirements

5.1 Standard Ratings. Published Ratings shall include the Standard Rating, as specified, for at least one of the Standard Rating Conditions shown in Table 1 and properly identified as the Standard Rating. Standard Ratings shall be based on tests with initially clean tubes. The liquid-side and refrigerant-side Fouling Factors shall be assumed to be zero.

Table 1. Standard Rating Conditions									
Rating Condition	Liquid Being Cooled	Entering Liquid Temperature		Leaving Liquid Temperature		Saturated Refrigerant Temperature Leaving the Evaporator		Liquid Refrigerant Entering Expansion Device	
		°F	°C	°F	°C	°F	°C	°F	°C
1	Water	54	12	44	6.7	35	1.7	100	37.8
2	30% Ethylene Glycol	20	-6.7	15	-9.4	5.0	-15	100	37.8
3†	Water	68	20	60	16	43	6.1	110	43.3

Note: Ratings are for single component and azeotropic refrigerants only. Zeotropic refrigerants are excluded. The minimum Superheat of the leaving refrigerant shall be specified by the manufacturer.

† For water-source heat pump application only.

5.2 Application Ratings. Application Ratings provide performance data at operating conditions other than those shown in Table 1. Whenever Application Ratings are published or printed, they shall include, or be accompanied by, the Standard Rating, clearly designated as such, including a statement of the conditions at which the ratings apply. Application Ratings shall contain all information shown in 6.2. When Application Ratings include a water-side Field Fouling Allowance they shall be calculated by the method specified in 5.3. Published Ratings shall be subject to the tolerances of this standard.

5.2.1 Either Application Ratings or a method of adjusting the clean tube ratings may be presented to show the effect of various liquid-side Field Fouling Allowances. These calculation methods or method of adjusting these ratings shall be calculated in accordance with 5.3.

5.2.2 The manufacturer shall publish the maximum and minimum recommended liquid flow rates.

5.3 Determination of Ratings. Ratings shall be determined in accordance with the following:

5.3.1 Clean Tube Ratings. Clean tube ratings shall be based on tests with initially clean tubes conducted in accordance with 4.1. The results of these tests shall be accepted as reflecting a Fouling Factor of zero.

5.3.2 Fouled Tube Ratings. From the results of the clean tube tests, calculate the clean tube overall heat transfer coefficient, U_c . Then, mathematically add the specified Fouling Factor to the reciprocal of U_c and calculate the fouled tube ratings for publication using the following method (refer to ARI Guideline E for discussion of Fouling Factors).

$$U_c = \frac{q}{A \cdot (LMTD)_c} \tag{1}$$

where:

$$\begin{aligned}
 \text{LMTD} &= \frac{(t_{we} - t_s) - (t_{wl} - t_s)}{\ln \left[\frac{(t_{we} - t_s)}{t_{wl} - t_s} \right]} \\
 &= \frac{(t_{we} - t_{wl})}{\ln \left[\frac{(t_{wl} - t_s) + (t_{we} - t_{wl})}{t_{wl} - t_s} \right]} \\
 \text{LMTD} &= \frac{R}{\ln (1 + R/S)} \tag{2}
 \end{aligned}$$

The following equations shall be used to calculate the fouled tube ratings:

5.3.2.1 For fouling inside tubes (evaporating outside):

- a. Based on outside surface:

$$U_{fo} = \frac{1}{\frac{1}{U_{co}} + \left(\frac{A_o}{A_i} \right) r_{fi}} \tag{3a}$$

- b. Based on inside surface:

$$U_{fi} = \frac{1}{\frac{1}{U_{ci}} + r_{fi}} \tag{3b}$$

5.3.2.2 For fouling outside tubes (evaporating inside):

- a. Based on outside surface:

$$U_{fo} = \frac{1}{\frac{1}{U_{co}} + r_{fo}} \tag{3c}$$

- b. Based on inside surface:

$$U_{fi} = \frac{1}{\frac{1}{U_{ci}} + \left(\frac{A_i}{A_o} \right) r_{fo}} \tag{3d}$$

5.3.2.3 The following equations shall be used for all configurations to obtain the small temperature difference, S_f , at the fouled condition:

- a. Based on outside surface:

$$S_f = \frac{R}{e^x - 1} \tag{4a}$$

where:

$$x = \frac{R \cdot U_{fo} \cdot A_o}{q}$$

b. Based on inside surface:

$$S_f = \frac{R}{e^y - 1} \tag{4b}$$

where:

$$y = \frac{R \times U_{fi} \times A_i}{q}$$

5.3.2.4 The new evaporating temperature with fouled tubes, t_{sf} , can then be found using the small difference, S_f :

$$t_{sf} = t_{w1} - S_f \tag{5}$$

5.4 Symbols and Subscripts. The symbols and subscripts used in Equations 1 through 5 are as follows:

Symbols:

- A = Total heat transfer surface area, ft² [m²]
- A_i/A_o = Ratio of inside to outside surface area
- A_o/A_i = Ratio of outside to inside surface area
- e = Base of natural logarithm
- $LMTD$ = Logarithmic mean temperature difference, °F [°C]
- q = Net Refrigerating Capacity, Btu/h [W]
- r = Heat transfer resistance, h · ft² · °F/Btu [m² · °C/W]
- R = Liquid temperature range = $t_{we} - t_{wl}$, °F [°C]
- S = Small temperature difference = $t_{wl} - t_s$, °F [°C]
- t = Temperature, °F [°C]
- U = Overall heat transfer coefficient, Btu/h · ft² · °F [W/m² · °C]

Subscripts:

- c = Clean
- e = Entering
- f = Fouled or fouling
- i = Inside
- l = Leaving
- o = Outside
- s = Saturated vapor leaving the evaporator
- w = Liquid

5.5 Tolerance. To comply with this standard, measured test results shall not be less than 95% of the Published Rating for Net Refrigerating Capacity and shall not exceed 110% of the Published Ratings for pressure drop.

Section 6. Minimum Data Requirements for Published Ratings

6.1 *Minimum Data Requirements for Published Ratings.* As a minimum, Published Ratings shall include all Standard Ratings. All claims to ratings within the scope of this standard shall be accompanied by the statement “Rated in accordance with AHRI Standard 480.” All claims to ratings outside the scope of this standard shall be accompanied by the statement “Outside the scope of AHRI Standard 480.” Wherever Application Ratings are published or printed, they shall include a statement of the conditions at which the ratings apply.

Application Ratings shall contain all information shown in 6.2. When Application Ratings include a liquid-side Fouling Factor, they shall be calculated by the method specified in 5.3.

6.2 Published Ratings

6.2.1 Published Ratings shall include the following:

- a. Refrigerant designation(s) in accordance with ANSI/ASHRAE Standard 34 with Addenda
- b. Saturated refrigerant temperature leaving the evaporator, °F [°C]
- c. Net Refrigerating Capacity, Btu/h or tons [W]
- d. Liquid flow rate, gpm [L/s]
- e. Liquid pressure drop, psi [kPa]
- f. Leaving liquid temperature, °F [°C]
- g. Superheat, °F [°C] (direct-expansion)
- h. Fouling Factor (liquid-side), $\text{ft}^2 \cdot \text{h} \cdot ^\circ\text{F}/\text{Btu}$ [$\text{m}^2 \cdot ^\circ\text{C}/\text{W}$]
- i. Type of Liquid being cooled

6.2.2 Published Ratings shall be accompanied by the following information:

- a. Design pressures for liquid-side and refrigerant-side, psig [kPa gage]
- b. Overall dimensions
- c. All connection sizes and types
- d. Shipping weight, lb [kg]
- e. Operating weight (including refrigerant and water), lb [kg]
- f. If only clean tube ratings are published, a statement shall be included to contact the manufacturer if fouled tube ratings are required

Section 7. Marking and Nameplate Data

7.1 *Marking and Nameplate Data.* As a minimum, each liquid cooler shall have the following information shown in a conspicuous place:

- a. Name of manufacturer
- b. Manufacturer's model or serial number
- c. Design pressure for the liquid-side, psig [kPa]
- d. Design pressure for the refrigerant-side, psig [kPa]
- e. Refrigerant designation in accordance with ANSI/ASHRAE 34 with Addenda

Section 8. Conformance Conditions

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

APPENDIX A. REFERENCES – NORMATIVE

A1 Listed here are all standards, handbooks and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of the standard.

A1.1 ANSI/ASHRAE Standard 24-2000, (RA 2005) *Methods of Testing for Rating Liquid Coolers*, 2005, American National Standards Institute, 11 West 42nd Street, New York, NY 10036, U.S.A./American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.2 ANSI/ASHRAE Standard 34-2004 with Addenda, *Designation and Safety Classification of Refrigerants*, 2004, American National Standards Institute, 11 West 42nd Street, New York, NY 10036, U.S.A./American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.3 *ASHRAE Terminology of Heating, Ventilation, Air-Conditioning and Refrigeration*, Second Edition, 1991, American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc., Second Edition, 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

APPENDIX B. REFERENCES – INFORMATIVE

B1 Listed here are standards, handbooks and other publications which may provide useful information and background but are not considered essential. References in this appendix are not considered part of the standard.

B1.1 AHRI Guideline E-1997 (formerly ARI Guideline E-1997), *Fouling Factors: A Survey of Their Application in Today's Air-Conditioning and Refrigeration Industry*, 1997, Air-Conditioning Heating and Refrigeration Institute, 2111 Wilson Blvd., Suite 500, Arlington, VA 22201, U.S.A.