

COOLING TECHNOLOGY INSTITUTE

CTI CODE TOWER Standard Specifications

Acceptance Test Code for Dry Fluid Coolers



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Dry Supplement to CTI Code ATC-105 (18)

This document was developed using the consensus procedure outlined in the CTI Operating Procedure 304 and has been approved for publication by the CTI Board of Directors

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This guideline document summarizes the best current state of knowledge regarding the specific subject. This document represents a consensus of those individual members who have reviewed this document, its scope and provisions. It is intended to aid all users or potential users of cooling towers.

Approved by the CTI Executive Board.



This document has been reviewed and approved as part of CTI's Five Year Review Cycle. This document is again subject to review in 2023.

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INTRODUCTION

Dry coolers, or air-cooled fluid coolers, consist of a closed fluid circuit, an air moving device, and a structure. In operation, heat flows from the hot Process Fluid in the closed circuit through the wall of the heat exchange surface to the cooling airstream that is circulated by the air moving device, or fan. The wall of the heat exchange surface may include internal and / or external fins to improve heat transfer rates. The entire external surface of the closed circuit is dry and as such the heat transfer process for dry coolers is strictly sensible cooling. Evaporative and adiabatic cooling are not covered by this Acceptance Test Code.

This document, ATC-105DS, is the Acceptance Test Code for Dry Coolers. Note that ATC-105 addresses open circuit cooling tower acceptance testing, ATC-105S addresses closed circuit cooling tower acceptance testing and ATC-106 addresses evaporative condenser acceptance testing, all of which rely on the evaporative cooling process.

1. SCOPE AND PURPOSE

1.1 Scope.

This dry supplement to ATC-105 covers the determination of the thermal capability of mechanical draft dry fluid coolers of both the forced and induced draft type. Its application is limited to the sensible cooling of water, aqueous glycol solutions, and other homogeneous, single phase Process Fluids for which mutually acceptable physical property data are available to the parties to the test, prior to the test. This standard does not apply to either two-phase flow, condensing, evaporative, or adiabatic applications.

1.2 Purpose.

The purpose of this supplement is to describe the instrumentation and procedures over and above or different than those set forth in ATC-105 as are necessary for the testing and evaluation of dry fluid coolers.

2. CONDITIONS OF TEST

2.1 Method of the Test.

The Method of the Test for mechanical draft, dry fluid coolers shall include the same definitions of terms and employ the same conditions, limitations, instrumentation, and methodology as set forth in Part 1 of CTI Code ATC-105, *ACCEPTANCE TEST CODE FOR WATER-COOLING TOWERS*, except as

hereinafter provided:

2.2 Process Fluid.

The Process Fluid flowing within the closed circuit can be any chemical element, compound, or mixture, liquid or gas, in single phase flow.

2.2.1 Properties of the Process Fluid.

The physical and thermodynamic properties of the Process Fluid or the reference source for these properties shall be specified in the contract documents and agreed upon by all parties to the test, **prior to the test.**

2.2.1.1 A sample of the Process Fluid shall be taken during the test. Should any questions arise concerning the composition of the Process Fluid, the sample shall be analyzed by a reputable testing laboratory acceptable to all parties to the test to confirm the composition of the Process Fluid at the time of test and, if necessary, the physical and thermodynamic properties.

2.2.1.2 Where the Process Fluid is a solution of ethylene or propylene glycol and water, the heat transfer and thermodynamic properties shall be based on the type of glycol and the concentration present in the sample taken during the test.

a) An illuminated or digital refractometer with automatic temperature compensation and an accuracy equivalent to ± 0.001 refractive units shall be used to determine the concentration of the water/glycol solution. This measurement, corrected for temperature, shall be converted to concentration of the glycol solution using standard conversion tables as in the *Handbook of Chemistry and Physics* ⁽¹³⁾ or available from the supplier of the fluid.

b) The properties of the glycol solution shall be interpolated from the data published in Section 31.4 of *2017 ASHRAE HANDBOOK, FUNDAMENTALS* ⁶, at the concentration corresponding to the measured refractive index and a temperature representative of the fluid at the point of interest. Alternatively, if acceptable to all parties to the test, properties data as supplied by the manufacturer of the glycol may be employed.

2.2.1.3 If, at the time of the test, the concentration of components comprising a mixed Process Fluid differ by more than 10 percentage points from the values specified (e.x. 20% glycol is specified, 10-30% is a valid test) in the contract documents, the test shall not be considered a valid Acceptance Test, unless all parties to the test so agree. However, for informational purposes the test may be evaluated by adjusting the physical and thermodynamic properties of the Process Fluid to correspond to the composition determined by analysis of the Process Fluid sample. The procedure for such adjustment of the test results is beyond the scope of this code.

2.2.2 Measurement of Process Fluid Flow Rate.

The measurement of the Process Fluid Flow Rate (Q_{Pft}) shall be made using any of the devices and procedures specified in Section 3.1 of ATC-105. Whatever device is employed, such adjustments and corrections as are necessary to account for the temperature and physical properties of the Process Fluid shall be made.

2.2.2.1 Care shall be taken in the selection of the flow measuring device and procedures employed to ensure they are suitable for the pressure and fluid that exists within the Process Fluid Circuit.

2.2.2.2 A Pitot tube is the preferred instrument for measuring water flow rates. When employed, it shall be used in accordance with CTI Bulletin STD-146 (95), "Standard for Water Flow Measurement"⁽¹²⁾.

2.2.2.3 When a device other than a Pitot tube is employed, it shall be used in accordance with CTI Bulletin STD-146 (95), "Standard for Water Flow Measurement"⁽¹²⁾, if applicable, or *ASME Fluid Meters: Their Theory and Application*⁽⁷⁾ and *ASME Power Test Code (PTC) 19.5 - 1972, Application, Part 11 of Fluid Meters: Interim Supplement on Instruments and Apparatus*⁽⁹⁾.

2.2.2.4 When the Process Fluid is other than water, the flow meter shall have been calibrated specifically for that fluid. Alternatively, where such calibration is impractical, and with the prior, mutual consent of the parties to the test, an instrument calibrated on another fluid may be used in accordance with the instrument manufacturer's directions for the fluid in question. See Section 2.2.2.6.

2.2.2.5 Flow measurement devices, whether temporarily or permanently installed, shall be inspected prior to the test for dimensional conformity and functionality.

2.2.2.6 Failure to comply with these calibration, in-

stallation, and/or usage requirements will significantly increase the uncertainty of the flow measurement. The flow measurement is directly related to the reported unit capability.

2.2.3 Measurement of Process Fluid Temperatures.

For Process Fluids other than water and/or when the static pressure within the Process Fluid circuit so dictates, thermo-wells shall be installed in the inlet and outlet lines to the heat exchanger to facilitate temperature measurement. When employed, these wells shall be filled with a thermal conducting liquid or paste to ensure the temperature sensing device is exposed to a representative temperature.

2.2.4 Measurement of Process Fluid Pressures.

Measurement of Process Fluid pressures shall be made in accordance with the provisions of *ASME Power Test Code (PTC) 19.2 -1987, Instruments and Apparatus, Part 2, Pressure Measurement*⁽⁸⁾.

2.2.4.1 Satisfactory instruments include pressure gages, manometers, pressure transducers, or other equivalent devices. The maximum allowable instrument accuracy of the devices shall be two percent (2%) of the absolute fluid pressure.

2.2.4.2 Stations for measuring the pressure drop of the Process Fluid across the heat exchanger shall be located as close as practicable to the inlet and outlet nozzles of the heat exchanger(s). Corrections shall be made for fitting losses, etc., that produce pressure differences between the measuring stations and the nozzles.

2.3 Air Temperature Measurements.

The measurement of the entering air dry-bulb temperature (Tdb) and entering air wet-bulb temperature (Twb) shall be made using any of the devices, procedures, and accuracies specified in Section 3.3 of ATC-105 except as noted below.

2.3.1 Inlet Air Temperatures.

The measurement of inlet air dry-bulb temperature (Tdb) is required for testing all types of dry coolers as described in this Code. For measurement of inlet air dry-bulb temperatures, the instruments shall be located within 1.5 m (5 ft) of the air intake(s). A sufficient number of measuring stations shall be designated to ensure that the test average is an accurate representation of the true average inlet dry-bulb temperature. Guidance on the minimum number and location of wet-bulb measuring stations is given in Appendix G of ATC-105 which, for this test code, should be utilized for inlet dry-bulb temperature measuring stations. The inlet air wet-bulb temperature (Twb) shall also be measured to allow calculation of inlet air psychrometric properties. For this test code, inlet wet-bulb temperature accuracy of 1°C

(2°F) is typically acceptable, which in most cases can be achieved by means of a single wet-bulb instrument.

For manually recorded data, the average of three successive readings taken at 10 second intervals at each station shall be considered the dry-bulb temperature at that time at that instrument station. The station averages shall be averaged to obtain the effective dry-bulb temperature for that run. Such runs shall be made every 5 minutes during the test period, and the arithmetic average of these runs shall be considered the inlet dry-bulb temperature and shall be used for evaluation of results. For computer data acquisition systems, the number of readings taken must be at least equal to that of the manually recorded system, a minimum of 36 readings per hour. The number recorded must also be at least equal to the manually recorded system, a minimum of 12 per hour. The procedure above also applies to the wet-bulb temperature station(s).

2.3.2 Exiting Air Temperatures.

Exiting air dry-bulb temperature (T_{db}) is required for the air density correction specified in Section 3.2, Equation 1. The measurement of the exiting air dry-bulb temperature shall be made using any of the devices specified in Section 3.3 of ATC-105. Due to the small impact of the density correction on the unit capacity calculation, a single exiting air dry-bulb measurement is usually adequate, depending on the size of the unit under test. The exiting air temperature measurements for induced draft units shall be located near the geometric center of the unit. The instrument should be located in the fan discharge airstream, within 0.3 meter (1') of the discharge plane at 1/3 the fan radius measured from the outside of the fan cylinder. Exiting air temperatures shall be recorded at the same intervals and averaged as the entering air temperatures as described in Section 2.3.1 above.

2.4 Wind Velocity (Speed and Direction).

Wind velocity and direction shall be measured as per Section 3.4 of ATC-105. For dry coolers with an overall height of 6 m (20 ft) or less, wind velocity shall be measured 1.5 m (5 ft) above curb elevation, at a point between 15 and 30 m (50 to 100 ft) of the dry cooler, if practical. For dry coolers where the distance between curb and discharge elevations exceeds 6 m (20 ft), the wind velocity shall be measured at an elevation above curb elevation that is approximately one-half the difference between the curb and discharge elevations and at a point at least 30 m (100 ft) from the dry cooler, if practical.

2.5 Fouling Factors.

Dry Fluid Coolers on occasion may be selected with "fouling factors" applied to the internal and/or external surfaces of the heat exchanger. While such fouling can have a significant, detrimental impact on the unit performance, the purpose of this standard is

not to determine the thermal performance of the tower with whatever "fouling" may actually be present at the time of the test. The determination of the extent or impact of such fouling as may be present is beyond the scope of this standard.

2.5.1 Condition of Equipment.

Testing should preferably be performed in the clean condition on both sides of heat exchanger tubes to minimize the effects of fouling.

2.5.1.1 External heat transfer surfaces shall be essentially free of scale, dirt, oil, and other foreign debris that would affect the heat transfer and obstruct the flow of air and/or water. If the need is established, these surfaces shall be cleaned by commercially acceptable methods.

2.5.1.2 Internal heat transfer surfaces and headers shall be essentially clean and free of scale, rust, dirt, and other foreign matter. If the need is established, these surfaces shall be cleaned by commercially acceptable methods.

2.5.2 Field Fouling Allowance.

If the performance guarantee includes a specified field fouling allowance, the parties to the test shall reach agreement, prior to the start of the test, upon the fouling factor(s) assumed to be present at the time of the test and the method for adjusting the test results to the field fouling allowance specified.

3. EVALUATION OF RESULTS

The performance of mechanical-draft, dry fluid coolers shall be evaluated from test data using the Performance Curve Method, as described in Part II Section 6 of CTI Code ATC-105, except as hereinafter noted:

3.1 Performance Curves.

The manufacturer of the Dry Fluid Cooler shall submit Performance Curves for the unit **prior to the test**, and preferably with the submittal documents.

3.1.1 Format of Performance Curves.

The performance curves, as a minimum, shall encompass three sets of curves, one set each for 90%, 100% and 110% of the design Flow Rate of the Process Fluid. Each set shall include a minimum of three curves, one each for 80%, 100%, and 120% of the design temperature Range for the Process Fluid. They shall be presented as a family of curves, plotted with Range as a parameter, the temperature of the leaving (cold) Process Fluid (T_{CPF}) as the ordinate and the dry-bulb temperature (T_{db}) as the abscissa.

3.1.2 Mixtures as Process Fluids.

Where the Process Fluid is a water/glycol solution or other mixture, the Performance Curves shall be expanded to encompass concentration as a parameter with curves for at least three (3) concentrations: design, 10 percentage points above design, and 10 percentage points below design (e.g. for a design concentration of 25%, performance curves shall be submitted for 15%, 25%, and 35% concentrations). These curves shall be interpolated to the measured concentration at the time of test.

3.1.3 Additional Data.

In all cases, the Performance Curve submittal shall include the following data:

- The composition of the Process Fluid on which the Performance Curves are based.
- The density of the air entering the fan(s) at the design operating point (ρ_d).
- The Exponent (EXP) to be used in the Fan Driver Power Correction procedure (Section 3.2 of this supplement). Alternatively, the manufacturer may, at his discretion, submit a unit performance curve showing % Capability versus % Design Fan Driver Power encompassing, as a minimum, the range of 90% to 110% of the Design Fan Driver Power.

3.2 Fan Driver Power Correction.

If the measured output of the fan driver(s) ($\dot{W}_t$) is other than design and provided that:

$$(0.90) \dot{W}_d \leq \dot{W}_t \leq (1.10) \dot{W}_d$$

the Measured Flow Rate of the Process Fluid shall be adjusted as follows to account for the variation:

$$Q_{PFT\ adj2} = (Q_{PFT\ adj1}) \left(\frac{\dot{W}_d}{\dot{W}_t} \right)^{EXP} \left(\frac{\rho_d}{\rho_t} \right)^{EXP} \quad (Eq. 1)$$

where:

$Q_{PFT\ adj2}$ = Flow Rate of Process Fluid, Measured and Adjusted for Fan Driver Output Power (L/s) [gpm].

$\dot{W}_d$ = Fan Driver Output Power, Design (kW) [bhp]. Note, for electrically commutated (EC) style motors, fan driver input power shall be substituted unless a motor efficiency value is available.

$\dot{W}_t$ = Fan Driver Output Power, Test (kW) [bhp]. Note, for electrically commutated (EC) style motors, fan driver input power shall be substituted unless a motor efficiency

value is available.

ρ_d = Density of air at the Dry Fluid Cooler Fan(s) when operating at Design Conditions (supplied by the manufacturer) (kg/m³) [lb/ft³].

ρ_t = Density of air at the Dry Fluid Cooler Fan(s) when operating at Test Conditions (kg/m³) [lb/ft³].

EXP = An exponent to be supplied by the dry fluid cooler manufacturer prior to the test which shall be limited in magnitude such that:

$$0.15 \leq EXP \leq 0.33$$

The density of the air at the fans shall be estimated as follows:

Forced Draft Units: The actual density (ρ_t) of the air at the fan(s) of a forced draft unit shall be determined from Psychrometric data using the measured test values of Entering Air Dry Bulb and Entering Air Wet Bulb, adjusted for the elevation at the site.

Induced Draft Units: The actual density (ρ_t) of the air at the fan(s) of an induced draft unit shall be determined from Psychrometric data using the measured test values of Entering Air Dry-Bulb, Exiting Air Dry-Bulb and Entering Air Wet Bulb, adjusted for the elevation at the site.

3.3 Performance Capabilities.

The method for determining the Performance Capability (C) of the Dry Fluid Cooler (expressed as a percentage of design) shall be to compare the Adjusted Measured Flow Rate of the Process Fluid to the Predicted Flow Rate of Process Fluid, as determined from the Performance Curves for the measured test conditions,

$$C = \left(\frac{Q_{PFT\ adj2}}{Q_{Pred}} \right) (100) \quad (Eq. 2)$$

Where: Q_{Pred} = Flow Rate of Process Fluid predicted from the Performance Curves for the measured test conditions (L/s) [gpm].

3.4 Heat Exchanger Pressure Drop.

It is best practice to use differential pressure transmitters, unless absolutely necessary, to minimize measurement uncertainty of a critical measurement.

3.4.1 Pressure Differential Instruments.

If a process fluid pressure differential instrument is used to measure the pressure difference between the Heat Exchanger Inlet Nozzle and Outlet Nozzle, this measurement, corrected for any losses that occur between the measurement

points and the Nozzles, is the Pressure Drop across the Heat Exchanger.

3.4.2 Individual Pressure Measurements.

If the fluid pressures at the Inlet and Outlet Nozzles of the Heat Exchanger are measured separately, an adjustment must be made when determining the Pressure Drop across the Heat Exchanger to correct for any difference in elevation of the pressure transmitter manifold.

3.4.2.1 With the Inlet Nozzle situated above the Outlet Nozzle, the pressure drop across the Heat Exchanger (ΔP_{HE}) is determined as:

$$\Delta P_{HE} = P_l - P_0 + \Delta E \quad (\text{Eq. 3})$$

3.4.2.2 With the Inlet Nozzle situated below the Outlet Nozzle, the pressure drop across the Heat Exchanger (ΔP_{HE}) is determined as:

$$\Delta P_{HE} = P_l - P_0 - \Delta E \quad (\text{Eq. 4})$$

Where:

ΔP_{HE} = The pressure drop across the Heat Exchanger(s), (kPa) [psi].

P_l = The pressure at the inlet nozzle of the Heat Exchanger(s).

P_0 = The pressure at the outlet nozzle of the Heat Exchanger(s).

ΔE = The difference in elevation between the pressure transmitter manifold on the inlet and outlet nozzles on the Heat Exchanger(s) expressed in units consistent with the Pressure measurements, P_l , P_0 , or ΔP_{HE}

4. FORMULAS, CALCULATIONS and CONVERSIONS

4.1 The velocity of a fluid flowing within a conduit may be determined as:

$$V_f = (K_1)(K_{fm})\sqrt{H_{avg}} \quad (\text{Eq. 5})$$

Or

$$V_f = (K_2)(K_{fm})\sqrt{\Delta P_{Vavg}/\rho_f} \quad (\text{Eq. 6})$$

Where:

K_{fm} = Coefficient of the flow measuring device

K_1 = Constant equal to 0.07721 for SI and 2.3156 for IP

K_2 = Constant equal to 44.732 for SI and 96.258 for IP

V_f = Velocity of fluid (m/s) [ft/s]

H_{avg} = Average Velocity Head (mm) [inches]

ΔP_{Vavg} = Average Velocity Pressure (kPa) [psi]

ρ_f = Density of fluid (kg/m³) [lb/ft³]

4.2 The mass flow rate of the fluid may be determined as:

$$\dot{m} = (V_f)(\rho_f)(A_c) \quad (\text{Eq. 7})$$

Where:

A_c = Internal Area of Conduit (m²)[ft²].

$\dot{m}$ = Mass flow rate (kg/s) [lb/s].

4.3 The volumetric flow rate may be determined as:

$$Q_f = (K_3)(V_f)(A_c) \quad (\text{Eq. 8})$$

Where:

Q_f = Volumetric flow rate (L/s) [gpm]

K_3 = Constant equal to 1000 for SI or 448.833 for I-P.

4.4 Frequently pressures measured with liquid manometers must be converted into other units of measure. In many such cases, it may be sufficient to use a factor based upon some average temperature for the manometer fluid and to take no further account of the effects of temperature. Assuming a manometer temperature of 20 °C (68 °F), such factors are:

(mm Hg) (0.13284) = kPa

(In Hg) (0.4893) = LB_f/in^2

(mm Hg under water) (0.1231) = kPa

(In Hg under water) (0.4532) = LB_f/in^2

(mm H_2O) (9.7969) = Pa

(In. H_2O) (0.0361) = lb_f/in^2

5. REFERENCES

Listed here are standards, handbooks, and other publications which may provide useful information and background to the implementation of this standard. Publications 6,7,8,9, and 12 are essential to the implementation of this standard and considered a part of this standard.

1. *ANSI/ASHRAE 41.1 -1986 (RA 91), Standard Method for Temperature Measurement*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.1991.
2. *ANSI/ASHRAE 41.3 -1989, Standard Method for Pressure Measurement*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA. 1989.
3. *ANSI/ASHRAE 41.8 -1989, Standard Methods for Measurement of Flow of Fluids — Liquids*,