
Water-cooling towers — Testing and rating of thermal performance

Tours de refroidissement de l'eau — Essais et détermination des caractéristiques de performance

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO 16345:2014](https://standards.iteh.ai/catalog/standards/sist/ec14dde3-4fc0-46c3-97bd-1c39bdb0de42/iso-16345-2014)

<https://standards.iteh.ai/catalog/standards/sist/ec14dde3-4fc0-46c3-97bd-1c39bdb0de42/iso-16345-2014>



iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO 16345:2014

<https://standards.iteh.ai/catalog/standards/sist/ec14dde3-4fc0-46c3-97bd-1c39bdb0de42/iso-16345-2014>



COPYRIGHT PROTECTED DOCUMENT

© ISO 2014

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

	Page
Foreword	v
1 Scope	1
2 Terms and definitions	1
3 Symbols and abbreviations	7
4 Performance tests — General	10
4.1 Application of standard.....	10
4.2 Test schedule.....	11
4.3 Pretest agreements.....	11
4.4 Flexibility.....	11
5 Objective of tests	12
5.1 General.....	12
5.2 Basis of guarantee.....	12
5.3 Form of the guarantee documents.....	12
6 Test preparation	17
6.1 Purpose.....	17
6.2 Test scheduling and site preparation.....	17
6.3 Tower physical condition.....	18
6.4 Provisions for instrumentation.....	19
6.5 Fan driver input power.....	22
6.6 Site conditions.....	23
6.7 Miscellaneous.....	23
7 Instrumentation and test setup	24
7.1 Calibration.....	24
7.2 Flow measurements.....	24
7.3 Temperature measurements.....	24
7.4 Pressure measurements.....	26
7.5 Fan/pump driver power.....	27
7.6 Wind velocity (speed and direction).....	27
7.7 Tower pump head.....	28
7.8 Water or process fluid analysis.....	28
8 Execution of test	28
8.1 Requirements for testing type.....	28
8.2 Basic tests.....	28
8.3 Extended tests.....	32
9 Evaluation of tests	34
9.1 General.....	34
9.2 Computation of test period values from test reading values.....	34
9.3 Basic thermal performance test evaluation (for all tower types).....	38
9.4 Extended thermal performance test evaluation (applicable to natural draft towers, only if required by contract).....	51
10 Reporting of results	55
10.1 General.....	55
10.2 Final report.....	55
10.3 Security.....	55
10.4 Limitations.....	56
11 Published ratings	56
Annex A (normative) Instruments and measurements	57
Annex B (normative) Wet-bulb determination	63
Annex C (normative) Inlet-air temperature measurement locations	68

Annex D (normative) Thermodynamic properties of moist air	71
Annex E (informative) Values of crossflow correction factor	84
Annex F (informative) Example evaluation of an open-circuit, mechanical draft cooling tower test using the performance curve method	86
Annex G (informative) Example evaluation of an open-circuit, mechanical draft cooling tower test using the characteristic curve method	95
Annex H (normative) Example evaluation of a natural draft cooling tower test using the performance curve method	102
Annex I (normative) Example evaluation of a natural draft cooling tower using the extended test method	119
Annex J (normative) Example evaluation of an open-circuit, wet/dry, mechanical draft cooling tower	125
Annex K (normative) Example evaluation of a closed-circuit cooling tower test using the performance curve method	138
Annex L (informative) Alternative measurements of test <i>L/G</i>	144
Annex M (informative) Precheck list	147
Bibliography	150

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO 16345:2014](https://standards.iteh.ai/catalog/standards/sist/ec14dde3-4fc0-46c3-97bd-1c39bdb0de42/iso-16345-2014)

<https://standards.iteh.ai/catalog/standards/sist/ec14dde3-4fc0-46c3-97bd-1c39bdb0de42/iso-16345-2014>

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 86, *Refrigeration and air-conditioning*, Subcommittee SC 6, *Testing and rating of air-conditioners and heat pumps*.

<https://standards.iteh.ai/catalog/standards/sist/ec14dde3-4fc0-46c3-97bd-1c39bdb0de42/iso-16345-2014>

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO 16345:2014

<https://standards.iteh.ai/catalog/standards/sist/ec14dde3-4fc0-46c3-97bd-1c39bdb0de42/iso-16345-2014>

Water-cooling towers — Testing and rating of thermal performance

1 Scope

This International Standard covers the measurement of the thermal performance and pumping head of open- and closed-circuit, mechanical draft, wet and wet/dry cooling towers and natural draft and fan-assisted natural draft, wet and wet/dry cooling towers. The standard rating boundaries for series mechanical draft, open- and closed-circuit cooling towers are specified.

This International Standard does not apply to the testing and rating of closed-circuit towers where the process fluid undergoes a change in phase as it passes through the heat exchanger or where the thermophysical properties of the process fluid are not available.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply. The symbols used to identify the terms contained in this International Standard are listed and defined in [Clause 3](#).

2.1

airflow rate

total amount of dry air and associated vapour water moving through the cooling tower

2.2

ambient air conditions

atmosphere adjacent to, but not affected by, the cooling tower

2.3

approach

difference between cold (re-cooled) water temperature and the inlet-air wet-bulb temperature

2.4

approach deviation

deviation between the guaranteed and adjusted test approach

2.5

atmospheric gradient (lapse rate)

average rate of change of dry-bulb temperature with change in altitude from cold water basin curb, or sill, level to around twice the height of the cooling tower

Note 1 to entry: The convention for use with this International Standard will be to use a negative value for decrease in temperature as height increases.

2.6

average wind direction

predominant direction of the wind over the duration of the test period

2.7

average wind speed

arithmetical average of wind speed measurements taken over the duration of the test period

2.8

barometric pressure

atmospheric pressure taken over the duration of each test period

2.9

basin

open structure located beneath the cooling tower for collecting the circulating water and directing it to the sump or suction line of the circulating pump

2.10

basin curb

top elevation of the tower basin

Note 1 to entry: Usually the datum from tower elevations is measured.

2.11

blowdown

water discharged from the system to control the concentration of salts or other impurities in the circulating water

2.12

capability

measured thermal capacity of a cooling tower, expressed as a percentage of the design water flow rate

2.13

cell

smallest subdivision of the tower, bounded by exterior walls and partition walls, which can function as an independent unit

Note 1 to entry: Each cell can have one or more fans or stacks and one or more distribution systems.

2.14

cell dimensions

dimensions that describe the size of a cooling tower cell

Note 1 to entry: The dimensions include

- a) dimension perpendicular to the tower longitudinal axis and usually at right angles to the air inlet faces,
- b) length: dimension parallel to the longitudinal axis and the plane where air inlets are usually located, and
- c) height: on induced draft towers, the distance from the basin curb to the top of the fan deck, but not including the fan stack.

Note 2 to entry: On forced and natural draft towers, the distance from the basin curb to the discharge plane of the tower.

2.15

closed-circuit cooling tower

cooling tower comprised of a water flow loop re-circulating over the outside of a closed-circuit heat exchanger containing the process fluid loop

Note 1 to entry: Air is drawn through the water passing over the outside of the closed-circuit heat exchanger, enabling cooling by evaporation. No direct contact occurs between the process fluid loop and the open evaporative cooling loop.

2.16

cold (re-cooled water temperature) water

in an open cooling tower, the average temperature of the water entering the tower basin

Note 1 to entry: The convention from here on will be to use the term "cold water" in ISO 16245.

Note 2 to entry: In the case where the measurement is downstream of the basin or the pump, corrections are needed for the effects of the pump and any other makeup water, blowdown, or heat sources entering the basin.

2.17**cooling range**

difference between the hot and cold water or process fluid temperatures

Note 1 to entry: The term 'range' is also applied to this definition, but is regarded as a non-preferred term.

2.18**cooling tower**

apparatus in which process fluid is cooled by evaporative heat exchange with ambient air

2.19**counter-flow**

situation in which air and water flow in opposite direction within the cooling tower

2.20**cross-flow**

situation in which air flows perpendicularly to the water flow within the cooling tower

2.21**discharge plume**

discharge air stream of the cooling tower when made visible (wholly or in part) by the condensation of water vapour as the moist air stream is cooled to ambient temperature

2.22**distribution system**

system for receiving the water entering the cooling tower and distributing it over the area where it contacts the atmospheric air

2.23**drift eliminator**

assemblies downstream of the heat transfer media which serve to reduce the drift loss

2.24**drift loss**

portion of the water flow rate lost from the tower in the form of fine droplets mechanically entrained in the discharge air stream, commonly expressed as mass per unit time or a percentage of the circulating water flow rate

Note 1 to entry: It is independent of water lost by evaporation.

2.25**dry-bulb temperature**

temperature of an air-vapour mixture indicated by a thermometer with a clean, dry sensing element that is shielded from radiation effects

Note 1 to entry: Dry-bulb temperature can be further categorised as either

- a) ambient dry-bulb temperature: the dry-bulb temperature of air measured windward of the tower and free from the influence of the tower or
- b) entering dry-bulb temperature: the dry-bulb temperature of the air entering the tower, including the effect of any re-circulation and/or interference.

2.26**entering air conditions**

average characteristics of the airflow entering the cooling tower

2.27**fan power**

power consumed by the fan driver, which might or might not include the efficiency of the driver, depending on the contract

2.28

fill (pack)

devices placed in the cooling tower within the heat exchange section for the purpose of enhancing the surface area and/or the rate of heat transfer from the water stream to the air stream

2.29

final test result

average of the results from the minimum number of valid test periods

2.30

flow rate

quantity of hot process fluid to be cooled by the tower

2.31

fluid type

type of process fluid to be cooled by the tower

2.32

fouling factors

expression of reduction of heat transfer capability caused by internal and/or external contamination of the heat exchanger

2.33

heat exchanger pressure drop

pressure drop of the process fluid across the contractual inlet and outlet locations of the heat exchanger(s) of a closed-circuit or wet/dry cooling tower, adjusted for elevation and velocity

2.34

heat load

rate of heat removal from the process fluid within the tower

2.35

hot process fluid temperature

average temperature of the process fluid entering the heat exchanger in a closed-circuit tower

2.36

hot water temperature

average temperature of the inlet water in an open-circuit cooling tower

2.37

interference

thermal contamination of air entering the cooling tower by a source extraneous to the tower, generally another cooling tower

2.38

L/G

ratio of total mass flow rates of liquid (water) over gas (dry air) in an open-circuit cooling tower

2.39

makeup

water added to the system to replace the water lost by evaporation, drift, blowdown, and leakage

2.40

mechanical draft cooling tower

cooling tower where the air circulation is produced by a fan

Note 1 to entry: Mechanical draft cooling towers can be further categorised as either

- a) forced draft: the fan is located in the entering air stream or
- b) induced draft: the fan is located in the discharge air stream.

2.41**natural draft cooling tower**

cooling tower wherein the air circulation is produced by a difference in density between the cooler air outside the cooling tower and the warmer, more humid air inside

Note 1 to entry: Natural draft towers can be fan assisted.

2.42**non-series type**

design, generally site constructed, for which the performance is project dependent

2.43**open-circuit (wet) cooling tower**

cooling tower wherein the process fluid is warm water which is cooled by the transfer of mass and heat through direct contact with atmospheric air

2.44**partition wall**

vertical interior wall, either transverse, longitudinal, or radial, that subdivides a cooling tower into cells

2.45**process fluid**

working fluid used to transport heat from heat source to the cooling tower

Note 1 to entry: It can be water or any chemical element, compound or mixture, liquid or gas, in single phase flow.

2.46**pump head**

in an open-circuit tower, the sum of static head and dynamic head from the contractual inlet interface to the discharge of the distribution system to atmosphere

2.47**re-circulation**

portion of the outlet air that re-enters the tower

2.48**relative humidity**

ratio of the mole fraction of water vapour in a given air sample to the mole fraction of water vapour in a sample of saturated air at the same temperature and pressure, usually expressed as a percentage

2.49**series type**

design which is fixed and described in the manufacturer's catalogue, generally factory assembled, and for which the performance data are pre-determined

2.50**spray water flow**

quantity of water flowing over the outside of the heat exchanger in a closed-circuit tower

2.51**test agent**

person or entity responsible for conducting the testing

2.52**test period**

time duration where readings or recordings of every measurement have to be averaged and test period results can be calculated

2.53**test readings**

individual sets of data recorded at regular intervals for each instrument or measurement point required

2.54

thermal lag

time interval before the temperature of the water leaving the influence of the cooling air is detected at the point of cold water temperature measurement

2.55

tolerance

numerical value defined in contract documents or by a certification program expressed in percentage points or degrees Celsius which can be applied to the test results when determining compliance with the pass/fail criteria

Note 1 to entry: Typically, a tolerance is agreed for taking test variability into account.

2.56

top of shell wind speed

for natural draft or fan-assisted natural draft towers, the wind speed at the elevation of the plane through the top of shell and within the defined distance from the tower

2.57

total dissolved solids

weight of inorganic and organic matter in true solution per unit volume of water

Note 1 to entry: Typically, over 90 % of all solids dissolved in water are present as six different ions. Calcium, magnesium, sodium, chlorides, sulphates, and carbonates are usually expressed as mg/l.

2.58

total suspended solids

weight of particulates, both organic and inorganic, suspended, but not dissolved, per unit of water

Note 1 to entry: Total suspended solids are usually expressed as mg/l.

2.59

uncertainty, random

estimate characterizing the range of values within which it is asserted with a given degree of confidence that the true value of the measure can be expected to lie

2.60

valid test period

test period where constancy and values of measured parameters are within the limits of this code

2.61

water flow rate

quantity of hot water flowing into an open cooling tower

2.62

water loading

water flow rate expressed as quantity per unit of fill plan area of the tower

2.63

wet-bulb temperature

temperature of air indicated by a thermometer, shielded from radiation, with the sensing element covered by a thoroughly wetted and adequately ventilated wick

Note 1 to entry: Properly measured, it closely approximates the temperature of an adiabatic saturation and can be further categorised as either

- a) ambient wet-bulb temperature: the wet-bulb temperature of air measured windward of the tower and free from the influence of the tower or
- b) entering wet-bulb temperature: the wet-bulb temperature of the air entering the tower, including the effect of any re-circulation and/or interference.

2.64**wet/dry cooling tower**

cooling tower incorporating two concurrent modes of heat transfer: wet or evaporative and dry or sensible

Note 1 to entry: Wet/dry towers can be of open or closed type and are most often used to control or limit the discharge plume, but can also be used to reduce water consumption.

2.65**design**

set of parameters defined by specification or contract as the basis against which the cooling tower performance is analyzed

3 Symbols and abbreviations

A_C	total internal area of hot water conduit at tower inlet, expressed in square metres, m^2
A_{FILL}	gross face area of fill, perpendicular to direction of airflow, expressed in square metres, m^2
a	area of transfer surface per unit of fill volume, expressed in square metres per cubic metres, m^2/m^3
C	heat transfer coefficient
C_{CAP}	tower capability, expressed as a percentage (%) of design flow
C_F	pressure loss coefficient, expressed as a dimensionless unit
c_p	specific heat of a fluid at constant pressure, expressed in $kJ/kg\ ^\circ C$
	NOTE Assumed to be $4,186\ kJ/kg\ ^\circ C$ for water.
D	diameter of pipe, expressed in metres, m
d	diameter of wet bulb and covering, expressed in millimetres, mm
ΔE	difference in elevation between the inlet and outlet nozzles of the heat exchanger of a closed-circuit tower, expressed in metres, m
G	mass flow rate of dry air through the cooling tower, expressed in kilograms of dry air per second, kg dry air/s
g_c	acceleration due to gravity, expressed in metres per square second, m/s^2
H	elevation difference between top of the shell of a natural draft tower and the midpoint of fill height, expressed in metres, m
H_P	tower pumping head of flowing fluid, expressed in metres, m
h	enthalpy, expressed in kilojoules per kilogram dry air, kJ/kg dry air
h	enthalpy difference, expressed in kilojoules per kilogram of dry air, kJ/kg dry air
h_A	enthalpy of air, expressed in kilojoules per kilogram dry air, kJ/kg dry air
h_{HA}	enthalpy of air-water vapour mixture at bulb air temperature, expressed in kilojoules per kilogram dry air, kJ/kg dry air
h_M	enthalpy of saturated air-water vapour mixture at bulb water temperature, expressed in kilojoules per kilogram of dry air, kJ/kg dry air
I_{CAP}	tolerance for instance for tests uncertainty on tower capability, expressed as a percentage, %

ISO 16345:2014(E)

I_{TEMP}	tolerance for instance for tests uncertainty on tower approach deviation, expressed in degrees Celsius, °C
K	overall heat and mass transfer coefficient, expressed in kilograms per second, $kg/s^{\circ}m^2$
KaV/L	tower characteristic, expressed in dimensionless units
kW_{FM}	input power to an electric fan motor, expressed in kilowatts, kW
kW_{PM}	input power to an electric pump motor, expressed in kilowatts, kW
$K_0;K_1:$	constants in formulae, derived by combining known values of K_2
L	mass flow rate of water entering the cooling tower, expressed in kilograms per second, kg/s
L/G	ratio of mass flow rate of water to that of air, expressed in dimensionless units
n	an integer number, typically the n^{th} term in a series
P_B	barometric pressure, expressed in pascals, Pa
P_{HE}	pressure loss across the heat exchanger of a closed-circuit or wet/dry cooling tower, expressed in kilopascals, kPa
P_I	static pressure of the process fluid at the inlet nozzle to the heat exchanger of a closed-circuit tower, expressed in pascals, Pa
P_O	static pressure of the process fluid at the outlet nozzle to the heat exchanger of a closed-circuit tower, expressed in pascals, Pa
P_T	total pressure referred to atmospheric, expressed in pascals, Pa
P_{ST}	static pressure at the centreline of the tower hot water inlet conduit, expressed in metres of flowing fluid, m
P_V	velocity pressure (computed from $v^2/2g_c$) at the centreline of tower hot water inlet conduit, expressed in metres of flowing fluid, m
P_1	static pressure of water or process fluid at suction of main circulating pump, expressed in kilopascals, kPa
P_2	static pressure of water or process fluid at discharge of main circulating pump, expressed in kilopascals, kPa
Q_A	volumetric flow rate of air, expressed in cubic metres per second, m^3/s
Q_{BD}	volumetric flow rate of blowdown water, expressed in mass flow rate of water per second, L/s
Q_{MU}	volumetric flow rate of makeup water, expressed in mass flow rate of water per second, L/s
Q_{PF}	volumetric flow rate of process fluid, expressed in mass flow rate of water per second, L/s
Q_{RW}	volumetric flow rate of water re-circulating over the external surface of the heat exchanger of a closed-circuit cooling tower, expressed in mass flow rate of water per second, L/s
Q_W	volumetric flow rate of circulating water in an open cooling tower, expressed in mass flow rate of water per second, L/s
q	heat transfer rate from water/process fluid to the ambient air, expressed in kilojoules per second, kJ/s
q_{DRY}	dry heat transfer rate for wet/dry cooling tower, expressed in kilojoules per second, kJ/s
q_{WET}	wet heat transfer rate for wet/dry cooling tower, expressed in kilojoules per second, kJ/s

q_{TOT}	total heat transfer rate for wet/dry cooling tower, expressed in kilojoules per second, kJ/s
R	cooling range, expressed in degrees Celsius, °C
RH	relative humidity, expressed as a percentage, %
S	thermal lag, expressed in seconds, s
T_{App}	approach deviation, expressed in degrees Celsius, °C
T_{BD}	temperature, blowdown water, expressed in degrees Celsius, °C
T_{CW}	temperature, cold water leaving the tower, expressed in degrees Celsius, °C
T_{CPF}	temperature, cold process fluid leaving the tower, expressed in degrees Celsius, °C
T_{DB}	temperature, air dry-bulb, expressed in degrees Celsius, °C
T_{HW}	temperature, hot water entering the cooling tower, expressed in degrees Celsius, °C
T_{HPF}	temperature, hot process fluid entering the tower, expressed in degrees Celsius, °C
T_{MU}	temperature, makeup water, expressed in degrees Celsius, °C
T_{RW}	temperature, re-circulating water of a closed-circuit cooling tower measured at the pump discharge, expressed in degrees Celsius, °C
T_{WB}	temperature, air wet-bulb, expressed in degrees Celsius, °C
T_{am}	ambient dry-bulb temperature, expressed in °C
T_{ent}	average entering dry-bulb temperature, expressed in °C
tex	linear mass density of fibres, expressed as mass in grams per 1 000 metres (1 tex = 10 ⁻⁶ kg/m)
V	effective cooling tower fill volume, expressed in cubic metres, m ³
V_A	velocity of air, expressed in metres per second, m/s
V_{avg}	average wind velocity
VFD	variable frequency drive
V_L	velocity of liquid, expressed in metres per second, m/s
V_W	velocity of wind, expressed in metres per second, m/s
v_A	specific volume of air, expressed in cubic metres of mixture per kilogram of dry air, m ³ mixture/kg dry air
W_{FM}	fan motor power output, expressed in kilowatts, kW
$X_{x, adj}$	designates the value has been adjusted, e.g. for fan power, makeup water temperature, etc.
$X_{x, amb}$	designates the value pertains to the ambient air surrounding the tower
$X_{x, 1}$	designates value pertains to air entering the tower inlet
$X_{x, 2}$	designates value pertains to air leaving the tower (discharge)
$X_{x, d}$	designates the value pertains to the design condition
$X_{x, dry}$	indicates the value pertains to the dry section of a wet/dry cooling tower