BS EN 1048:2014

BSI Standards Publication

Heat exchangers — Air cooled liquid coolers ('dry coolers') — Test procedures for establishing the performance

National foreword

This British Standard is the UK implementation of EN 1048:2014. It supersedes BS EN 1048:1999 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RHE/30, Heat exchangers.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 80316 1

ICS 27.060.30; 27.200

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 August 2014.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1048

August 2014

ICS 27.060.30; 27.200

Supersedes EN 1048:1998

English Version

Heat exchangers - Air cooled liquid coolers ('dry coolers') - Test procedures for establishing the performance

Echangeurs thermiques - Refroidisseurs de liquide à convection forcée ('aéroréfrigérant sec') - Procédures d'essai pour la détermination de la performance

Wärmeübertrager - Luftgekühlte Flüssigkeitskühler ('Trockenkühltürme') - Prüfverfahren zur Leistungsfeststellung

This European Standard was approved by CEN on 22 May 2014.

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Foreword

This document (EN 1048:2014) has been prepared by Technical Committee CEN/TC 110 “Heat exchangers”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2015, and conflicting national standards shall be withdrawn at the latest by February 2015.

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This document supersedes EN 1048:1998.

The main changes with respect to the previous edition are listed below:

a) Clause 3 “Terms and definitions” is modified;

b) The revised standard takes into account the current state of the art.

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Introduction

This European Standard is one of a series of European Standards dedicated to heat exchangers.

1 Scope

This European Standard applies to remote forced convection air cooled liquid coolers, within which no change in the liquid phase occurs.

This European Standard does not apply to liquid coolers, designed primarily for installation within the machinery compartment of packaged products.

Its purpose is to establish uniform methods to test and ascertain the following:

— Product identification;

— Capacity;

— Air flow rate;

— Liquid side pressure drop;

— Energy requirements.

This European Standard does not cover technical safety aspects.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

3.1
forced convection air cooled liquid cooler: "dry cooler"
self contained system, that cools a single phase liquid by rejecting sensible heat via a heat exchanger to air that is mechanically circulated by integral fan(s)

Note 1 to entry: In the following, "forced convection air cooled liquid cooler" is referred to as "dry cooler".

3.2
liquid
working fluid circulated through the cooling system, which remains in liquid phase during the absorption and rejection of heat during the test

Note 1 to entry: The liquid can be any fluid which can be defined and that has known physical properties.

3.3
capacity
cooling effect on the liquid passing though the dry cooler

Note 1 to entry: It is defined as the product of the liquid mass flow rate and the difference between the enthalpies at the inlet and outlet connections of the dry cooler.

3.4
temperatures
Note 1 to entry: All temperatures are average values ascertained over the measuring period.

3.4.1
air inlet temperature
average dry bulb temperature of the air at the inlet of the dry cooler, taking into consideration the local air velocities

3.4.2
liquid inlet temperature
average temperature of the liquid at the inlet connection of the dry cooler, taking into consideration the local liquid velocities

3.4.3
liquid outlet temperature
average temperature of the liquid at the outlet connection of the dry cooler, taking into consideration the local liquid velocities

3.5
temperature differences
3.5.1
inlet temperature difference
difference between the liquid inlet temperature and air inlet temperature of the dry cooler

3.5.2
liquid temperature difference
difference between the liquid inlet and liquid outlet temperatures of the dry cooler

3.6
liquid pressure
3.6.1
liquid inlet pressure
static pressure of the liquid at the inlet connection of the dry cooler

3.6.2
liquid outlet pressure
average static pressure of the liquid at the outlet connection of the dry cooler

3.6.3
liquid pressure difference
difference between the liquid inlet pressure and the liquid outlet pressure

3.7
rotational speed of the fans
average rotational speed of all fans

3.8
heat transfer surface (air side)
whole external surface of the coil which is exposed to the air flow passing through the dry cooler

4 Symbols

For the purposes of this document the following apply:

4.1 Letters

Table 1 — Letters

cp_A	Specific heat capacity of the air	kJ/(kg K)
cp_L	Specific heat capacity of the liquid, at the mean temperature within the dry cooler	kJ/(kg K)
n_1	Rotational speed of the fans, measured during the capacity test	min^{-1}
n_2	Rotational speed of the fans, measured during the air volume flow test	min^{-1}
P	Capacity	kW
P_{fan}	Electrical power of the fan(s)	kW
p_{L1}	Liquid inlet pressure	bar
p_{L2}	Liquid outlet pressure	bar
p_{atm}	Atmospheric pressure	hPa
Δp_L	Liquid pressure difference	bar
q_{mL}	Mass flow rate of the liquid	kg/s
q_{vA}	Volumetric flow rate of the air	m^3/s
q_{vL}	Volumetric flow rate of the liquid	m^3/s
ρ_A	Density of the air	kg/m^3
ρ_L	Density of the liquid at temperature t_{L3}	kg/m^3
t_{A1}	Air inlet temperature	°C
t_{L1}	Liquid inlet temperature	°C
t_{L2}	Liquid outlet temperature	°C
t_{L3}	Liquid temperature at flow meter	°C
Δt_1	Inlet temperature difference	K
Δt_L	Liquid temperature difference	K
τ	Test duration	s

4.2 Superscripts

(a/b) refers to the test sequence, (a) above and (b) below the standard conditions.

(st) refers to standard conditions.

5 Standard capacity

5.1 Basis for standard capacity date

5.1.1 The capacity of the dry cooler is dependent on

a) Inlet and liquid temperature difference;

b) Mass flow of air and liquid;

c) Type of liquid and its temperature;

d) Mounting of unit.

The complex relationship that exists between these items and the capacity, means that it is not possible, with sufficient accuracy, to generalize this relationship over widely varying operating condition.

5.1.2 As dry coolers are usually designed to meet specific sets of operating conditions, this standard specifies

a) An acceptable test method which can be applied to any prescribed set of operating conditions;

b) A standard capacity operating condition, which can be used for comparison purposes.

5.2 Standard conditions for dry cooler capacity

Standard capacity shall be based on tests performed on a clean dry cooler under the following operating conditions:

Liquid type	Water
$t_{A1(st)}$	25 °C
$\Delta t_{1(st)}$	15 K
$\Delta t_{L(st)}$	5 K
$p_{atm(st)}$	1013,25 h Pa

The nominal electrical voltage, frequency and phase shall be as specified by the manufacturer.

5.3 Operating conditions for the nominal air flow

The nominal air volume air flow rate refers to an air temperature of + 20 °C and an ambient pressure of 1013,25 hPa.

NOTE The air volume flow is not influenced by the temperature or the atmospheric pressure if the fan speed is constant.

6 Manufacturer's data

To identify the dry cooler and allow its traceability, the manufacturer or supplier shall supply the test house with the following minimum information for every dry cooler:

a) manufacturer's identification;

b) model designation of unit;

c) model designation of fan;

d) rating of the fan motor(s) according to EN 60034-1;

e) standard capacity for the standard conditions in the range of application, stating the liquid used;

f) nominal air flow;

g) nominal fan power;

h) nominal voltage and frequency;

i) total heat transfer surface (air side);

j) fin pitch and thickness;

k) tube outside diameter and internal enhancement;

l) tube pattern;

m) circuiting arrangement;

n) internal volume including headers;

o) installation instructions;

p) maximum permissible operating pressure PS;

q) liquid pressure drop.

7 Measurements

7.1 Uncertainty of measurement

The permissible uncertainty for various parameters is given in Table 2.

Table 2 — Uncertainty of measurement

Measured quantity	Unit	Uncertainty of measurement
Temperatures — Air and liquid — Liquid temperature difference	 °C K	 ± 0,2 K ± 0,1 K
Pressures — Atmospheric — Liquid, differential pressure	kPa kPa	± 5 hPa ± 1 % of the reading or ± 0,02 bar, the higher value applies
Liquid flow rate	m^3/s	± 1 %
Electrical quantities (fans) — Electrical power input — Current — Voltage — Frequency	 W A V Hz	 ± 1 % or at least 1 W ± 0,5 % ± 0,5 % ± 0,5 %
Number of revolutions	min^{-1}	± 1 %

7.2 Measurement criteria

7.2.1 Temperature measuring pints, liquid side

a) Where the temperatures are measured by sensors immersed in the connecting pipes, it shall be ensured temperature stratification and flow patterns do not influence the accuracy of the measurements;

b) Where the temperatures are measured on the outside of the connecting pipes, they shall be measured at two opposite pints of the same cross section and, if the pipe is horizontal, there shall be one point above and one below.

The connecting pipes shall be insulated from the dry cooler for a distance of at least 10 times the outside diameter beyond the temperature measuring pints. Good thermal contact between the sensor and the pipe at the measuring pint shall be ensured. a) is the preferred method.

The liquid temperatures shall be measured as close as possible to the dry cooler connections and in any case within 15 times the outside diameter of the connecting pipe.

7.2.2 The measuring points, air side

The air temperature shall be measured in the centre of equal sections of the heat exchanger face area.

These sections shall be no larger than 0,2 m^2 and be square if possible. There shall be a minimum of four sections.

Additional sensors shall be placed along the edges of the inlet area.

Temperature sensing elements shall be shielded against thermal radiation.

The entering air shall not be subjected to significant temperature stratification. During the test, temperatures measured shall not vary by more than ± 0,5 K from the mean of all measurements.

7.2.3 Pressure measuring points, liquid side

The pressure measuring points shall be located in the middle of a straight part of the connecting pipe of constant diameter, (equal to the dry coolers connections) having a length of not less than 10 diameters ensuring that there is no restriction involved. They shall be placed between the temperature measuring points and the connections of the dry cooler.

7.2.4 Liquid flow rate

The liquid flow rate shall be measured using a measuring device, calibrated and installed in accordance with the instructions of the measuring device manufacturer.

8 Testing methods and equipment

8.1 General

The test method given in 8.2 has been judged the most applicable because the majority of dry coolers are in the capacity range above 100 kW.

8.2 Test principals

8.2.1 Test method for capacity

The principle of this method is to directly measure the liquid flow rate and determine the capacity by multiplying the mass flow rate by the difference between the enthalpies at the inlet and outlet connections of the dry cooler (see Annex A). The specific enthalpy difference is determined by the inlet and outlet temperatures of the liquid and its specific properties.

8.2.2 Test method for air volume flow

Dry coolers create a very turbulent air flow, therefore the measurements of air speeds at individual points cannot be used to determine air volume flow.

The testing method shall be capable of measuring the overall air volume flow in accordance with CEN standards. (If existing, otherwise national or international standards as agreed between manufacturer and test house).

8.3 Testing equipment

8.3.1 Air side

The test location shall be suitable for maintaining the prescribed inlet air temperatures within the allowable deviations. It shall designed in such a way that the dry cooler under test is not subject to any restriction, improvement or recirculation of the air flow.

For this reason the dry cooler shall be installed so that:

a) no obstacle is positioned within a distance of $1{,}5 \times (A \times B)^{0{,}5}$ away from the discharge of the dry cooler;

b) no obstacle is positioned within a distance of $0{,}75 \times (A \times B)^{0{,}5}$ parallel to the sides of the dry cooler;

c) all distances correspond to the minimum requirements of the installation instructions provided by the manufacturer.

A and B being the inlet dimensions of the dry cooler.

8.3.2 Liquid side

Adequate venting facilities shall be provided to ensure that the liquid is free from entrained air which could cause inaccurate measurements.

The heat capacity of the liquid contained in the system shall be sufficient to maintain good thermal stability.

9 Test procedure

9.1 Physical arrangement

— The dry cooler shall be installed in accordance with the manufacturer's specification;

— All components supplied by the manufacturer as part of the dry cooler shall be included in the test set-up and used in accordance with the manufacturer's instructions;

— The liquid shall be free from entrained air.

9.2 Capacity measurements

9.2.1 The measurement of the dry cooler capacity shall be carried out under steady-state conditions. Steady-state shall be reached a minimum of 30 min before testing commence

9.2.2 Steady-state conditions are assumed to exist when all changes and periodic fluctuations remain within the following

All temperatures and temperature differences	± 0,5 K;
Liquid flow rate	± 1 %;
Rotational speed of fans	± 0,5 %.

In order to ensure that steady-state conditions are maintained, the temperatures and flow rate shall be monitored at intervals small enough to identify all significant fluctuations.

9.2.3 Test duration

The test duration shall be chosen such that any deviation from steady-state conditions will not influence the uncertainty of the test result by more than 0,5 %.

The test duration shall be a minimum of 30 min.

During the test period at least five sets of measurements shall be taken at regular intervals.

9.2.4 Test conditions

To obtain sufficient accuracy when converting the measured capacity and pressure drop to the standard conditions, the mean test condition shall be within the following deviation from the standard condition:

Table 3 – Maximum allowable deviation of test conditions

Test	Unit	Deviation
All tests	t_{A1}	±0,2 K
	Supply voltage	±2,0 %
	Frequency	±1,0 %
Single test	Δt_1 and Δt_L	±0,2 K
Duplicate test	Δt_1	±2,0 K
	Δt_L	±1,0 K

Duplicate tests shall be conducted with $\Delta t_L^{(a,b)}$ / $\Delta t_1^{(a,b)}$ above and below $\Delta t_L^{(st)}$ / $\Delta t_1^{(st)}$

9.2.5 Data to be recorded

The following data shall be recorded during the test:

— p_{L1}, p_{L2}, (or Δp_L), p_{atm};

— $t_{Al}, t_{L1}, t_{L2}, t_{L3}$;

— q_{vL}, (or q_{mL}), $n_1, P_{fan}; \tau$

— Supply voltage, frequency.

9.3 Measurement of air flow rate and fan capacity

The dry cooler shall be tested without influencing the air resistance at air inlet and outlet.

The air temperature shall be +20°C ± 5 K.

The air flow rate and fan power shall be measured under steady-state conditions, which are assumed to exist when the fan speed does not change by more than 0,5 %.

The following data shall be recorded:

P_{fan}, n, t_{amb}, p_{atm}

For measuring the air flow rate, all data required by the test method shall be recorded.

10 Capacity calculations

The measured dry cooler capacity from each test shall be determined according to:

a) for liquid volume flow measurement

$$P^{(a,b)} = q_{vL}^{(a,b)} \times \rho_L^{(a,b)} \times c_{PL}^{(a,b)} \times \Delta t_L^{(a,b)}$$

b) for liquid mass flow measurement

$$P^{(a,b)} = q_{mL}^{(a,b)} \times c_{p_L}^{(a,b)} \times \Delta t_L^{(a,b)}$$

11 Conversion to standard conditions

11.1 Capacity

11.1.1 Correction for atmospheric pressure

For each test a correction factor for the deviation from standard atmospheric pressure (1013,25 hPa) shall be determined according to:

$$F^{(a,b)} = 1 + (1013{,}25 - p_{atm}{}^{(a,b)}) \times 6{,}5 \times 10^{-4}$$

11.1.2 Single test

Within the permissible deviations the following relationship shall apply:

$$P^{(st)} = P^{(a)} \times F^{(a)} \times \frac{\Delta t_1{}^{(st)}}{\Delta t_1{}^{(a)}}$$

11.1.3 Duplicate tests

Within the permissible deviations the following relationship shall apply:

a) Determine:

$$B^{(st)} = \frac{\Delta t_L{}^{(st)}}{\Delta t_1{}^{(st)}}$$

b) Determine for each test:

$$A^{(a,b)} = P^{(a,b)} \times \frac{F^{(a,b)}}{\Delta t_1{}^{(a,b)}}$$

$$B^{(a,b)} = \frac{\Delta t_L{}^{(a,b)}}{\Delta t_1{}^{(a,b)}}$$

c) Standard capacity is then determined according to:

$$P^{(st)} = \Delta t_1{}^{(st)} \times \left[A^{(b)} + \frac{(A^{(a)} - A^{(b)})}{(B^{(a)} - B^{(b)})} \times (B^{(st)} - B^{(b)}) \right]$$

11.2 Liquid side pressure drop

11.2.1 Single test

a) Determine:

$$\Delta p_L{}^{(a)} = p_{L1}{}^{(a)} - p_{L2}{}^{(a)}$$

$$q_{mL}{}^{(a)} = \frac{P^{(a)}}{cp_L \times \Delta t_L{}^{(a)}}$$

$$q_{mL}{}^{(st)} = \frac{P^{(st)}}{cp_L \times \Delta t_L{}^{(st)}}$$

b) Standard liquid side pressure drop is then determined according to:

$$\Delta p_L{}^{(st)} = \Delta p_L{}^{(a)} \times \left[\frac{q_{mL}{}^{(st)}}{q_{mL}{}^{(a)}} \right]^{1,8}$$

11.2.2 Duplicate tests

a) Determine:

$$q_{mL}{}^{(st)} = \frac{P^{(st)}}{cp_L \times \Delta t_L{}^{(st)}}$$

b) For each test determine:

$$\Delta p_L{}^{(a,b)} = p_{L1}{}^{(a,b)} - p_{L2}{}^{(a,b)}$$

$$q_{mL}{}^{(a,b)} = \frac{P^{(a,b)}}{cp_L \times \Delta t_L{}^{(a,b)}}$$

c) Standard liquid side pressure drop is then determined according to:

$$\log(\Delta_{P_L}{}^{(st)}) = \log(\Delta_{P_L}{}^{(b)}) + \frac{\log(\Delta_{P_L}{}^{(a)}) - \log(\Delta_{P_L}{}^{(b)})}{\log(q_{mL}{}^{(a)}) - \log(q_{mL}{}^{(b)})} \times (\log(q_{mL}{}^{(st)}) - \log(q_{mL}{}^{(b)}))$$

11.3 Nominal air flow

For the purposes of this standard the measured air flow rate shall be the nominal air flow rate. No correction to nominal conditions is necessary.

11.4 Nominal fan power consumption

For the purposes of this standard the fan power consumption, measured during the air flow test and corrected to the standard ambient pressure of 1013,25 hPa shall be the nominal fan power consumption. The following equation shall apply:

$$P_{fan}^{(st)} = P_{fan} \times \frac{1013,25}{p_{atm}}$$

Where

P_{fan} and p_{atm} are the values measured during the air flow rate test.

No correction to standard temperature conditions is required.

NOTE For the purposes of this standard a conversion of both the nominal air flow and standard fan power consumption to standard capacity measuring conditions is considered not to change the values significantly, as air side conditions do not differ significantly and will not cause a significant difference in fan speed. Moreover, this standard is intended to be used as basis for the certification of product ranges with numerous models, which not all can be capacity tested.

12 Test report

The test report shall be in accordance with EN ISO/IEC 17025. The test report shall at least contain:

a) date;

b) test institute;

c) test location;

d) test method;

e) test supervisor;

f) test object designation:

   1) type;

   2) serial number;

   3) name of the manufacturer;

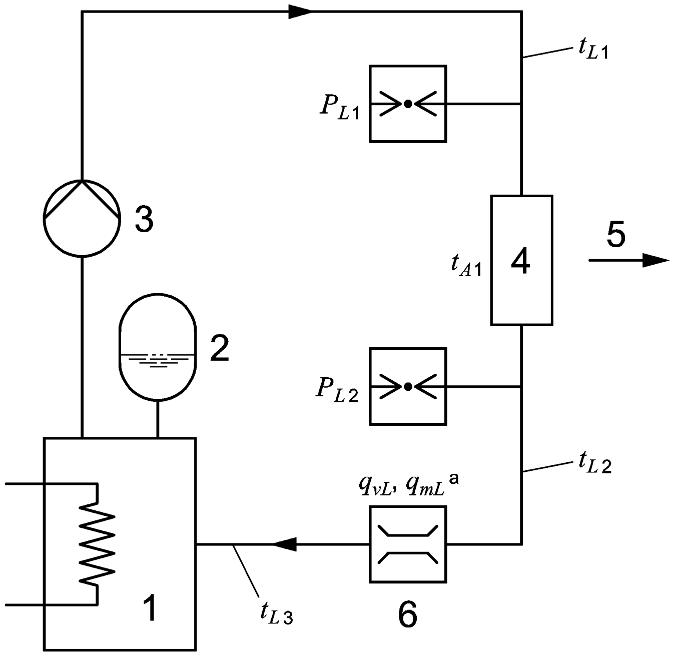
g) type of liquid and concentration;

h) the reference of the liquid properties including version number;

i) reference to this European Standard;

j) relevant measured values, see 9.2.5 and 9.3.

Annex A
(normative)
Flow meter method



Key

1	heat source
2	expansion vessel
3	pump
4	dry cooler
5	air flow
6	flow meter

Figure A.1 — Flow meter method

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[1] EN 247, *Heat exchangers - Terminology*

[2] EN 305, *Heat exchangers - Definitions of performance of heat exchangers and the general test procedure for establishing performance of all heat exchangers*

[3] EN 306, *Heat exchangers - Methods of measuring the parameters necessary for establishing the performance*

[4] EN 307, *Heat exchangers - Guidelines to prepare installation, operating and maintenance instructions required to maintain the performance of each type of heat exchangers*

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