

Heat exchangers — Test procedures for establishing the performance of forced convection unit air coolers for refrigeration

The European Standard EN 328:1999, with the incorporation of amendment A1:2002, has the status of a British Standard

ICS 23.120; 27.060.30

National foreword

This British Standard is the English language version of EN 328:1999, including amendment A1:2002. It supersedes DD ENV 328:1993 which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **A1** **A1**.

The UK participation in its preparation was entrusted to Technical Committee RHE/30, Heat exchangers, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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This British Standard, having been prepared under the direction of the Engineering Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 October 1999

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 37 and a back cover.

The BSI copyright date displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments
14285	13 February 2003	See national foreword

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ISBN 0 580 32410 9

EUROPEAN STANDARD

EN 328

NORME EUROPÉENNE

April 1999

EUROPÄISCHE NORM

+ A1

October 2002

ICS 23.120.00; 27.060.30

Supersedes ENV 328:1992

English version

Heat exchangers — Test procedures for establishing the performance of forced convection unit air coolers for refrigeration
(includes amendment A1:2002)

Echangeurs thermiques — Procédures d'essai pour la détermination de la performance des aérofrigorifères à convection forcée
(inclut l'amendement A1:2002)

Wärmeaustauscher — Prüfverfahren zur Bestimmung der Leistungskriterien von Ventilatorluftkühlern
(enthält Änderung A1:2002)

This European Standard was approved by CEN on 10 March 1999 and amendment A1 was approved by CEN on 14 September 2002.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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Ref. No. EN 328:1999 + A1:2002 E

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 110, Heat exchangers, the Secretariat of which is held by BSI.

This European Standard replaces ENV 328:1992.

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 October 1999, and conflicting national standards shall be withdrawn at the latest by October 1999.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Foreword to amendment A1

This document EN 328:1999/A1:2002 has been prepared by Technical Committee CEN/TC 110, Heat exchangers, the Secretariat of which is held by BSI.

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 April 2003, and conflicting national standards shall be withdrawn at the latest by April 2003.

This amendment is introduced to accommodate newly available refrigerants such as R404A, R407C and R410A.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

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

1 Scope

This European Standard is applicable to non-ducted unit air coolers for refrigeration operating:

- a) with direct dry expansion of a refrigerant;
- b) with liquid overfeed by pump circulation of a refrigerant;
- c) with a liquid.

This standard specifies uniform methods of performance assessment to test and ascertain the following:

- product identification;
- standard capacity;
- standard liquid pressure drop;
- standard refrigerant pressure drop (for operation with liquid overfeed by pump circulation only);
- nominal air flow rate;
- nominal fan power.

It does not cover evaluation of conformity.

It is not applicable to air coolers for duct mounting or with natural air convection.

This standard does not cover technical safety aspects.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

ISO 5801, *Industrial fans — Performance testing using standardized airways*.

EN 45001, *General criteria for the operation of testing laboratories*.

IEC 60034-1, *Rotating electrical machines — Part 1: Rating and performance*.

3 Definitions

For the purposes of this standard, the following definitions apply.

3.1 physical definitions

3.1.1

forced convection unit air cooler

refrigeration system component transferring heat from air to a refrigerant or liquid. The air is mechanically circulated over the heat transfer surface by integral fan(s) and fan drive(s). The heat transfer coil includes refrigerant distributing and collecting headers

In the following, “forced convection unit air cooler” is referred to as “unit cooler”.

3.1.2

heat transfer surface (air side)

total external surface of the cooling coil which is in contact with the air flow passing the cooling coil

3.1.3

internal volume

volume of the refrigerant containing parts of the unit cooler between its two connections

3.1.4

fouling resistance

thermal resistance of a layer of unwanted deposit on the heat exchanger surface reducing its heat transfer performance

NOTE The fouling resistance for a clean surface is zero. Clean, in this context, means that all production residues have been removed from the heat transfer surface and the fan(s) by the factory's cleaning process.

3.2

refrigerant

working fluid in a refrigerating system absorbing heat at low pressure/temperature by evaporation and rejecting it at a higher pressure/temperature by condensation

3.3

liquid

working fluid remaining liquid during the absorption of heat

3.4 capacities

3.4.1

sensible (dry) air cooling capacity

heat flow rejected by the air resulting from a dry bulb temperature drop

3.4.2

latent cooling capacity

heat flow rejected by the air resulting from condensation of water vapour or frost formation including subcooling on the unit cooler surface

3.4.3

total cooling capacity

sum of the sensible and the latent capacities measured at the same time

3.4.4

gross cooling capacity

total heat flow absorbed by the refrigerant or liquid

3.4.5

net cooling capacity

cooling capacity available for cooling the air, equal to the gross cooling capacity minus the fan power

3.4.6

standard capacity

gross cooling capacity, at standard conditions and normal atmospheric pressure of 1 013 hPa, of a unit cooler with clean internal and external surfaces

3.4.7

fan power

electric power absorbed by the fan motors at the electrical terminals of the motor(s)

3.4.8

nominal fan power

fan power measured during the air flow test and corrected to the normal atmospheric pressure of 1 013 hPa

NOTE The fan power will also differ with the temperature at which the fan runs. As the fan power is only a small proportion of the total cooling load, the deviations are considered to be negligible.

3.5 pressures and pressure differences

for the purposes of this standard, all pressures are average values ascertained over the test duration

3.5.1

evaporating pressure

absolute pressure of the refrigerant at the outlet connection of the unit cooler

3.5.2

liquid inlet pressure

static pressure of the liquid at the inlet connection of the unit cooler

3.5.3

liquid outlet pressure

static pressure of the liquid at the outlet connection of the unit cooler

3.5.4

liquid pressure difference

difference between the liquid inlet pressure and the liquid outlet pressure

3.5.5

refrigerant inlet pressure

absolute pressure of the refrigerant at the inlet connection of the unit cooler (see annex E)

3.6 temperatures

for the purposes of this standard, all temperatures are average values ascertained over the test duration

3.6.1 air temperatures

3.6.1.1

air inlet temperature

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

3.6.1.2

A_1 air dew point temperature A_1

dew point temperature of the air within the calorimeter room

3.6.1.3

inside temperature

air temperature inside the calorimeter room responsible for the heat exchange with the ambient

3.6.1.4

ambient temperature

temperature around the calorimeter room responsible for the heat exchange with the inside

3.6.2 refrigerant temperatures

3.6.2.1

evaporating temperature

dew point temperature of the refrigerant, corresponding to the evaporating pressure

3.6.2.2

superheating temperature

temperature of the refrigerant vapour at the outlet connection of the unit cooler, measured on the wall of the tube at the location recommended by the manufacturer for fixing the expansion valve sensing element or downstream of the liquid-suction heat exchanger where this is an integral part of the unit cooler

3.6.2.3

subcooled refrigerant temperature:

temperature of the liquid refrigerant at the inlet connection to the expansion device (not necessarily part of the unit cooler)

[A₁]

3.6.2.4

bubble point temperature

temperature corresponding to the absolute pressure of the refrigerant at the outlet connection of the unit cooler **[A₁]**

3.6.3 liquid temperatures

3.6.3.1

liquid inlet temperature

average temperature of the liquid at the inlet connection of the unit cooler taking into consideration the local liquid velocities

3.6.3.2

liquid outlet temperature

average temperature of the liquid at the outlet connection of the unit cooler taking into consideration the local liquid velocities

3.6.4 water temperatures

(applicable only where the balancing heat is supplied by water)

3.6.4.1

water inlet temperature

temperature of the water as it enters the calorimeter

3.6.4.2

water outlet temperature

temperature of the water as it leaves the calorimeter

3.6.5

vapour outlet temperature

temperature of the refrigerant vapour at the vapour outlet connection of the separator

3.7 temperature differences

3.7.1 temperature differences for refrigerants

3.7.1.1

inlet temperature difference

difference between the air inlet temperature and the evaporating temperature

3.7.1.2

superheating

difference between the superheating temperature and the evaporating temperature

3.7.1.3

degree of superheating

ratio of the superheating to the inlet temperature difference

3.7.1.4

subcooling

difference between the bubble point temperature corresponding to the absolute pressure of the refrigerant at the inlet connection to the expansion device and the subcooled refrigerant temperature

3.7.2 temperature differences for liquids

3.7.2.1

inlet temperature difference

difference between the air inlet temperature and the liquid inlet temperature

3.7.2.2

liquid temperature difference

difference between the liquid inlet and outlet temperatures

ⓘ

3.8

high glide

refrigerant where the difference between the condensing and bubble point temperatures at a condensing temperature of 40 °C is greater than 3K ⓘ

ⓘ

3.9 ⓘ operation with refrigerants

ⓘ

3.9.1 ⓘ

direct expansion operation

evaporation process in which the refrigerant enters the unit cooler via a direct expansion device as a liquid-vapour mixture and leaves it in superheated state (see system boundaries in annex A)

ⓘ

3.9.2 ⓘ

operation with liquid overfeed by pump circulation

evaporation process in which the refrigerant leaves the unit cooler in partially evaporated state, the process being operated by a mechanical liquid pump and a separator being parts of a refrigerating machine. The refrigerant is transported from the separator to the unit cooler by the mechanical pump (see annex E)

ⓘ

3.10 ⓘ refrigerant enthalpies

ⓘ

3.10.1 ⓘ

refrigerant inlet specific enthalpy

specific enthalpy of the refrigerant at the inlet connection of the unit cooler system. For capacity calculation it is defined as the specific enthalpy of the saturated liquid refrigerant at the inlet to the expansion device corresponding to the subcooled refrigerant temperature

NOTE For liquid overfeed by pump circulation, the refrigerant inlet enthalpy cannot be defined by temperature and pressure measurement at the unit cooler's connections (see annex E).

ⓘ

3.10.2 ⓘ

refrigerant outlet specific enthalpy

specific enthalpy of the refrigerant at the outlet connection of the unit cooler system. For capacity calculation it is defined as the specific enthalpy of the refrigerant corresponding to the evaporating pressure and the superheating temperature

NOTE For liquid overfeed by pump circulation, the refrigerant outlet enthalpy cannot be defined by temperature and pressure measurement at the unit cooler's connections (see annex E).

A1

3.10.3 **A1**

specific vaporization enthalpy

enthalpy at the evaporating pressure without regard to the pressure drop across the unit cooler (see annex E)

A1

3.11 **A1**

nominal air flow

air volume flow rate flowing through the unit cooler when its air side is dry and clean

A1

3.12 **A1**

oil content

proportion of oil by mass in the refrigerant related to the pure refrigerant

A1

3.13 **A1**

refrigerant recirculation rate

ratio between the actual mass flow rate through the unit cooler and the mass flow rate necessary for the total evaporation of the refrigerant (see annex E)

4 Symbols

For the purposes of this standard the following apply.

E_{el}	Electrical energy input into the calorimeter	kJ
F	Correction factor for the deviation from standard atmospheric pressure	Pa
h_{L1}	Liquid inlet specific enthalpy	kJ/kg
h_{L2}	Liquid outlet specific enthalpy	kJ/kg
h_{R1}	Refrigerant inlet specific enthalpy	kJ/kg
h_{R2}	Refrigerant outlet specific enthalpy	kJ/kg
h_{R3}	Refrigerant specific enthalpy at the outlet connection of the unit cooler (see annex E)	kJ/kg
h_{W1}	Water inlet specific enthalpy (balancing air heater)	kJ/kg
h_{W2}	Water outlet specific enthalpy (balancing air heater)	kJ/kg
HL	Heat flow from the calorimeter inside to its ambient	kW
n	Rotational speed of fans	1/min
p_{atm}	Atmospheric pressure	Pa
p_e	Evaporating pressure	bar
p_{e1}	Refrigerant pressure at the inlet connection of the unit cooler (see annex E)	bar
p_{e2}	Refrigerant pressure at the vapour outlet connection of the separator (see annex E)	bar
p_{L1}	Liquid pressure at unit cooler inlet	bar
p_{L2}	Liquid pressure at unit cooler outlet	bar
p_{R1}	Refrigerant pressure at expansion device inlet	bar
P_1	Capacity (primary method)	kW
P_2	Capacity (confirming method)	kW
P_M	Measured capacity	kW
q_m	Mass flow rate	kg/s
q_{mRPu}	Refrigerant mass flow rate on the low pressure side through the pump	kg/s
q_V	Volume flow rate	m ³ /s
rd	Relative deviation	—
ρ	Density	kg/m ³
rr	Recirculation rate	—
t_{amb}	Ambient air temperature	°C
t_{LM}	Temperature of liquid at the flow measuring point	°C

t_{RM}	Temperature of refrigerant at the flow measuring point (liquid line)	°C
t_{WM}	Temperature of water at the flow measuring point (balancing air heater)	°C
t_{A1}	Air inlet temperature (dry bulb)	°C
t_{dp}	Air dew point temperature within the calorimeter room	°C
t_e	Evaporating temperature	°C
t_i	Individual air temperature inside the calorimeter	°C
$t_{(pR1)}$	Saturation temperature corresponding to p_{R1}	°C
t_{L1}	Liquid inlet temperature	°C
t_{L2}	Liquid outlet temperature	°C
t_{R1}	Subcooled refrigerant temperature	°C
t_{R2}	Vapour outlet temperature at the vapour outlet connection of the separator (see annex E)	°C
t_{R3}	Actual temperature at unit cooler outlet connection (see annex E)	°C
t_{W1}	Water inlet temperature	°C
t_{W2}	Water outlet temperature	°C
t_{sup}	Superheating temperature	°C
Dp	Pressure drop	bar
Dt_i	Inlet temperature difference	K
Δh_e	Refrigerant specific enthalpy change in the unit cooler at p_e (see annex E)	kJ/kg
Δh_O	Specific vaporization enthalpy at p_e (see annex E)	kJ/kg
Δh_R	Difference between refrigerant outlet and inlet specific enthalpies	kJ/kg
Δt_{sub}	Subcooling = $t_{(pR1)} - t_{R1}$	K
Δt_{sup}	Superheating	K
Δt_L	Temperature difference between liquid inlet and outlet	K
τ	Test duration	s

Subscripts

m	Mass
v	Volume
L	Liquid
M	Flow meter
R	Refrigerant
W	Water

Numbers indicate positions defined on the circuit diagrams.

Superscripts

(st)	Standard
(a,b)	Identifies a set of tests

5 Standard capacity

5.1 Basis of standard-capacity data

The cooling capacity of a given unit cooler, or its overall coefficient of heat transfer, depends on the following:

- the inlet temperature and the humidity content of the entering air;
- the mass flows of air, refrigerant or liquid;
- the evaporating temperature or the inlet temperature of the liquid;
- the state of superheating;
- further conditions e.g. state of subcooled refrigerant, oil content;
- the state of frosting.