SLOVENSKI STANDARD

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

Wärmeaustauscher - Prüfverfahren zur Bestimmung der Leistungskriterien von Ventilatorluftkühlern

Echangeurs thermiques - Procédures d'essai pour la détermination de la performance des aérofrigoriferes a convection forcée

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

Echangeurs thermiques - Procédures d'essai pour la détermination de la performance des aérofrigorifères à convection forcée

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This European Standard was approved by CEN on 10 March 1999.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

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Contents

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of an identical text or by endorsement, at the latest by October 1999, and conflicting national standards shall be withdrawn at the latest by October 1999.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.

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 1013 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 1013 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 *dew point temperature:* 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)

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 **operation with refrigerants**

3.8.1 ***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).

3.8.2 ***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).

3.9 refrigerant enthalpies

3.9.1 ***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 intlet enthalpy cannot be defined by temperature and pressure measurement at the unit cooler's connections (see annex E).

3.9.2 ***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).

3.9.3 ***specific vaporization enthalpy:*** Enthalpy at the evaporating pressure without regard to the pressure drop across the unit cooler (see annex E).

3.10 **nominal air flow:** Air volume flow rate flowing through the unit cooler, when its air side is dry and clean.

3.11 **oil content:** Proportion of oil by mass in the refrigerant related to the pure refrigerant.

3.12 **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_1	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:

a) the inlet temperature and the humidity content of the entering air;
b) the mass flows of air, refrigerant or liquid;
c) the evaporating temperature or the inlet temperature of the liquid;
d) the state of superheating;
e) further conditions e.g. state of subcooled refrigerant, oil content;
f) the state of frosting.

Because of the related dependence of the overall coefficient of heat transfer on both the mass flow and the temperature difference, it is not permissible to specify cooling capacities per unit of temperature difference, as the coefficient of heat transfer can only be taken as a constant value in a very limited range of operating conditions.

Therefore cooling capacities are given for specific operating conditions.
The influence of frosting on the unit cooler surfaces (latent cooling capacity) can only be measured with great difficulty because of the changing processes. Therefore this standard only considers cooling capacities under non frosting conditions, as these can be measured and tested under steady state conditions.

5.2 Standard conditions for the cooling capacity

5.2.1 *General*

The standard capacity shall be based on tests performed on a clean unit cooler at nominal voltage and frequency under one or more of the conditions specified in 5.2.2 and 5.2.3.

5.2.2 *Refrigerants*

The standard conditions for refrigerants are given in table 1.

Table 1: Standard conditions for refrigerants

Standard condition	t_{A1} °C	t_{dP} °C	t_e °C	Δt_{sup} / Dt_1 --	t_{R1} °C
SC 1	+10	< -2	0	0,65	30
SC 2	0	< -10	- 8	0,65	30
SC 3	- 18	<- 27	- 25	0,65	20
SC 4	- 25	<- 33	- 31	0,65	20
SC 5	- 34	< - 42	- 40	0,65	20
NOTE: The oil content shall be below 1% of mass.					

For standard conditions for operation with liquid overfeed by pump circulation see annex E.

5.2.3 *Liquids*

The standard conditions for liquids are given in table 2.

Table 2: Standard conditions for liquids

Standard condition	t_{A1} °C	t_{dP} °C	t_{L1} °C	t_{L2} °C	Intended for	Comments
SC 10	+ 16	< +2	+ 4	+ 8	Water	The flow direction shall be given
SC 11	0	< -12	-10	-7	liquid specified by manufacturer	
NOTE: The quality of the liquid shall be such that it does not cause measurable fouling during the entire operation for establishing the test.						

5.3 Conditions for the nominal air flow rate

The nominal air volume flow rate shall be referred to an air temperature of + 20°C.

NOTE: The air volume flow rate is not influenced by atmospheric pressure and air temperature when the fan speed is constant.

5.4 Conditions for nominal fan power

The nominal fan power shall be referred to an air temperature of + 20°C and to an atmospheric pressure of 1013 hPa.

6 Manufacturer's data

To identify the unit cooler and allow traceability, the manufacturer or supplier shall supply the test house with the following minimum information for each unit cooler to be tested:

a) type;
b) rating of the fan motor(s) according to IEC 60034-1.
c) standard capacity for the standard conditions in the range of application, stating the refrigerants used;
d) nominal air flow;
e) nominal fan power
f) nominal voltage and frequency
g) total heat transfer surface (air side),
h) fin spacing and thickness
i) tube nominal bore
j) tube geometry
k) circuiting arrangement
l) internal volume including distributors and headers
m) installation instructions

7 Measurements

7.1 Uncertainty of measurements

The permissible uncertainty of significant measurements is given in table 3.

Table 3: Uncertainty of measurements

Measurements	Uncertainty of measurements
Air inlet temperature	± 0,2 K
Dew point temperature of the air	± 2 K
All other air temperatures	± 0,5 K
Refrigerant temperature	± 0,2 K
Refrigerant pressure	Shall be small enough for the measurement of the evaporating temperature to be obtained within ± 0,2 K
At the unit cooler Liquid temperature and temperature difference. liquid pressure drop refrigerant and liquid flow rate	 ± 0,2 K ± 5% of the measured value or 1 kPa (larger value applies) ± 2 % of the measured value
For the balancing air heater when supplied by water water temperature difference water flow rate	 ± 0,5 % of the measured value ± 2 % of the measured value
Electrical energy	± 1 % of the measured value
Current, voltage, cycles	± 0,5 % of the measured value
Time interval	± 0,1 % of the measured value or ± 2 s (smaller value applies)
Oil content in the refrigerant	± 20 % of the measured value
Mass	± 0,5 % of the measured value
Atmospheric pressure	± 5 hPa
Fan speed	± 1 % of the measured value

7.2 Measurement criteria

7.2.1 *Pipe side temperature measurement*

7.2.1.1 *Methods of measurement*

One of two methods of measurement shall be used as follows:

a) Method A
When the temperature is measured on the outside of the connecting pipe it shall be measured at two opposite points of the same cross-section and, if the pipe is horizontal, there shall be one point above and one below.
The pipe shall be insulated on each side of the temperature measuring point for a length of at least ten times of its outside diameter. It shall be ensured, that good thermal contact exists between the sensor and the pipe at the measuring point.
This method is only applicable if the active temperature difference is small and the internal heat transfer is much higher than the external one.
The measured value is the arithmetic mean of both individual values.
b) Method B
When the temperature is measured by a sensor immersed in the pipe, care shall be taken that temperature stratifications and flow patterns do not influence the accuracy of the measurements.