SLOVENSKI STANDARD
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Prenosniki toplote – Merilna metoda in ocenjevanje toplotnih lastnosti mokrih hladilnih stolpov

Heat exchangers - Method of measurement and evaluation of thermal performances of wet cooling towers

Wärmeaustauscher - Verfahren zur Messung und Bewertung der wärmetechnischen Leistungskenndaten von Nasskühltürmen

Echangeurs de chaleur - Méthode de mesure et évaluation des performances thermiques des aéroréfrigérants humides

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Foreword

This European Standard (EN 14705:2005) 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of an identical text or by endorsement, at the latest by December 2005, and conflicting national standards shall be withdrawn at the latest by December 2005.

This document includes a Bibliography.

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

1 Scope

This European Standard specifies requirements, test methods and acceptance tests for thermal performances pumping head verification of wet cooling towers and plume abatement for wet/dry cooling towers.

This European Standard is applicable to natural draught wet cooling towers (see in 3.1.2.2) fan assisted natural draught cooling tower (see 3.1.2.3), wet/dry cooling towers (see 3.1.2.4) and "Mechanical draught cooling towers", except series ones.

It specifies the test methods, the apparatus required, the limitation of errors and the method for results examination.

The acceptance testing covers the verification of the thermal performance data and pumping head of the cooling tower as specified in the contract between the supplier and the purchaser. If these tests are required then this should be recognized at the time of the contract, as additional fittings, and preparations for the test may be required.

Deviations from the rules laid down below as well as additions need special agreement between purchaser and supplier and should be documented.

This standard does not apply to mechanical draught series wet cooling towers which are dealt with in EN 13741.

NOTE Terms like "design", "values", "guarantee" and "acceptance" used in this standard should be understood in a technical but not in a legal or commercial sense.

2 Normative references

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

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

EN 872, *Water quality - Determination of suspended solids - Method by filtration through glass fibre filters*

EN 60751, *Industrial platinum resistance thermometer sensors (IEC 60751:1983 + A1:1986)*

EN ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 1: General principles and requirements (ISO 5167-1:2003)*

ISO 1438-1, *Water flow measurement in open channels using weirs and Venturi flumes - Part 1: Thin-plate weirs*

ISO 2975-3, *Measurement of water flow in closed conduits - Tracer methods - Part 3: Constant rate injection method using radioactive tracers*

ISO/TR 3313, *Measurement of fluid flow in closed conduits - Guidelines on the effects of flow pulsations on flow-measurement instruments*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply.

3.1.1
cooling tower
apparatus in which water is cooled down by heat exchange with ambient air

3.1.2
wet cooling tower
cooling tower in which the heat exchange between the water and the air is achieved by a direct contact

3.1.2.1
mechanical draught wet cooling tower
wet cooling tower where the air circulation is produced by a fan

3.1.2.1.1
series type mechanical draught wet cooling tower
mechanical draught wet cooling tower, the design of which is fixed and described in the manufacturer's catalogue and for which the performance data are available, which allows tests evaluation over the defined range of operating conditions

3.1.2.1.2
non series type mechanical draught wet cooling tower
mechanical draught wet cooling tower, the design of which is project dependent and for which the performance data and test evaluation at specific operating conditions may be subject to agreement

3.1.2.2
natural draught cooling tower
wet cooling tower where the air circulation is produced only by a density difference between the cold air outside the cooling tower and the hot air inside

3.1.2.3
fan assisted natural draught cooling tower
natural draught cooling tower with the addition of fan to boost the draught

3.1.2.4
wet/dry cooling tower (reduced plume cooling tower)
cooling tower comprising two parts. In the first part, the heat exchange between the water and the air is achieved by direct contact and through a tight wall in the second part

3.1.2.4.1
reduced plume wet/dry cooling tower
wet/dry cooling tower designed for plume abatement

3.1.2.4.2
water conservation wet/dry cooling tower
wet/dry cooling tower designed for water conservation

3.1.3
air flow
total quantity of air, including associated water vapour flowing through the tower

3.1.3.1
counterflow
where air and water flows are in opposite direction in the filling

3.1.3.2
cross flow
where air flows perpendicular to the water in the filling

3.1.4
ambient wet (dry) bulb temperature
wet (dry) bulb temperature of air measured windward of the tower and free from the influence of the tower

3.1.5
approach
difference between recooled water temperature and inlet air wet bulb temperature

3.1.6
inlet water flow
quantity of hot water flowing into the tower

3.1.7
cold water basin
device underlying the tower to receive the recooled water from the tower and direct its flow to the suction line or sump

3.1.8
cooling range
difference between the hot water temperature and the recooled water temperature

NOTE The term "range" is also applied to this definition, but is regarded as a non-preferred term.

3.1.9
drift loss
water lost from the tower as liquid droplets with the same chemical characteristics as the circulating water, entrained in the outlet air

3.1.10
heat load
rate of heat to be removed from the water within the tower

3.1.11
hot water temperature
temperature of inlet water

3.1.12
inlet air wet (dry) bulb temperatures
average wet (dry) bulb temperatures of the inlet air; including any recirculation effect

3.1.13
make-up
water added to the circulating water system to compensate for water loss from the system by evaporation, drift, purge and leakage

3.1.14
purge (blow down)
water discharged from the system to control concentration of salts or other impurities in the circulating water

3.1.15
recooled water temperature
average temperature of the water at the cold water basin discharge excluding the effect of any make-up entering the basin or at the exhaust of the exchanger for wet/dry cooling tower

3.1.16
recirculation
portion of the outlet air that re-enters the tower

3.1.17
interference
intake of outlet air of adjacent cooling towers

3.1.18
tower pumping head
total head of water required at the inlet to the tower, to deliver the inlet water through the distribution system

3.1.19
surfacic flow
inlet water flow expressed in quantity per unit of plan packing area of the tower

3.1.20
wet (dry) bulb temperature
the temperature indicated by an adequately ventilated and wetted (non-wetted) thermometer in the shade and (where applicable) protected from any radiation effect

3.1.21
atmospheric gradient
air dry bulb temperature variation with altitude expressed in degree Celsius per 100 m

3.2 Symbols

For the purposes of this European Standard, the symbols of Table 1 shall apply.

Table 1

Symbols	Designated parameters	Units
A	Transfer surface per unit of volume	m^{-1}
a	Angle of an elbow	degree
ap	Approach (t_C - t_W)	K
C	Heat coefficient	-
CEV	Evaporation coefficient related to the difference in water content	$kg \cdot m^{-2} \cdot s^{-1}$
C_F	Load loss coefficient	-
CFV	Evaporation coefficient related to the difference in water content	$kg \cdot m^{-2} \cdot s^{-1}$
C_S	Specific water consumption	$kg \cdot J^{-1}$
c_{pa}	Mass heat capacity of the air at constant pressure	$J \cdot kg^{-1} \cdot K^{-1}$
c_{pe}	Mass heat capacity of the water	$J \cdot kg^{-1} \cdot K^{-1}$
c_{pv}	Mass heat capacity of the vapour at constant pressure	$J \cdot kg^{-1} \cdot K^{-1}$
D_{10}	Direction of the reference wind in relation to the north	degree
d	Hydraulic diameter	m
F_p	Fan motor power	kW
F_{pG}	Guaranteed fan motor power	kW
g	Gravity acceleration	$m \cdot s^{-2}$
H	Draught height	m
h	Mass enthalpy of the air	$J \cdot kg^{-1}$
h_1	Mass enthalpy of the air at the air inlet calculated from p_a, t_s and φ	$J \cdot kg^{-1}$
h_2	Mass enthalpy of the saturated hot air at the air outlet downstream from the drift eliminators	$J \cdot kg^{-1}$
h_s	Mass enthalpy of the saturated moist air at the water temperature	$J \cdot kg^{-1}$
h_{s1}, h_{s2}	Mass enthalpy of the saturated moist air at the water temperature with 1 = inlet, 2 = outlet	$J \cdot kg^{-1}$
k	Number of tests	
$\frac{KAV}{q_{me}}$	Merkel number	-
L_{vt}	Water vaporization latent heat at temperature t	$J \cdot kg^{-1}$
m	Circulating water volume flow rate at the cooling tower inlet	$m^3 \cdot s^{-1}$
m_b	Calculated blow-down water volume flow rate	$m^3 \cdot s^{-1}$
m_{bm}	Measured blow-down water volume flow rate	$m^3 \cdot s^{-1}$

(to be continued)

Table 1 *(continued)*

Symbols	Designated parameters	Units
m_E	Evaporated water volume flow rate	$m^3 \cdot s^{-1}$
m_m	Make-up water volume flow rate	$m^3 \cdot s^{-1}$
m^0	Number of a wind velocity class	
m_p	Volume flow rate of water entrained by drift losses	$m^3 \cdot s^{-1}$
N	Characteristic index of nominal pattern	
n	Constant exponent of the exchange law	
n^b	Number of tests per m^0 class	
n^bm	Number of recorded values for each test	
P	Thermal load	kW
p_a	Atmospheric pressure	Pa
p_{vs}	Saturating vapour pressure	Pa
p_s	Static pressure	Pa
p_v	Partial pressure of vapour in the air	Pa
q_{mas}	Dry air mass flow rate	$kg \cdot s^{-1}$
q_{me}	Circulating water mass flow rate at cooling tower inlet	$kg \cdot s^{-1}$
q_{VF}	Recooled water recuperation system leaking water volume flow rate	$m^3 \cdot s^{-1}$
q_{Vi}	Local volume flow rate	$m^3 \cdot s^{-1}$
q_{VPC}	Volume flow rate of circulating pumps	$m^3 \cdot s^{-1}$
S_i	Flow section corresponding to the measurement point i	m^2
S_1, S_2	Cross sections perpendicular to the pressure taps on the water circuit	m^2
S_F	Exchange body front surface	m^2
T	Test starting time	h, min
t	Temperature	°C
t_a	Dry temperature of the ambient air	°C
t_b	Blow-down water temperature	°C
t_c	Mean temperature of the recooled water immediately above the plane of the cold water basin (rain water cooling tower) or immediately above the plane of the water in the troughs (water recuperator cooling tower)	°C
$t_{c,i}$	Mean temperature of the recooled water for the test i	°C

(to be continued)

Table 1 *(continued)*

Symbols	Designated parameters	Units
$T_{cG,i}$	Guaranteed mean temperature of the recooled water for the test i	°C
t_e	Mean temperature of the cold water at the cooling tower outlet (mixture of cooled water and make-up water)	°C
t_h	Mean temperature of the hot water in the cooling tower inlet	°C
t'_h, t''_h	Mean temperatures of the hot water in the inflows	°C
t_k	Local temperature	°C
t_m	Make-up water temperature	°C
t_w	Wet bulb temperature at the air inlet	°C
t_{wa}	Wet bulb temperature of ambient air	°C
t_s	Dry bulb mean temperature at the air inlet	°C
T_V	Basin cold water renewal time	min
V	Total volume of the exchange body	m^3
v_D	Mean frontal velocity of the air at the exchange body inlet	$m \cdot s^{-1}$
v_i	Local flow velocity	$m \cdot s^{-1}$
v_1, v_2	Water velocities perpendicular to the measurement sections	$m \cdot s^{-1}$
v_{W10}	Reference wind velocity 10 m above ground level	$m \cdot s^{-1}$
x	Difference in level between the spray hole nozzle outlet and the water plane of the cold water basin	m
γ	Coefficient of correction in the Merkel integral	-
τ	Student coefficient	-
$x\varphi$	Absolute humidity of the ambient air	$\frac{\text{kg water}}{\text{kg dryair}}$
$x\varphi_1$	Absolute humidity of the air at air inlet	$\frac{\text{kg water}}{\text{kg dryair}}$
$x\varphi_2$	Absolute humidity of the air at cooling tower outlet	$\frac{\text{kg water}}{\text{kg dryair}}$
φ	Relative humidity of the ambient air	%
φ_1	Relative humidity of the ambient air at air inlet	%
φ_2	Relative humidity of the ambient air at cooling tower outlet	%
Φ	Fan power influence factor	K/%
ρ	Density of the air	$kg \cdot m^{-3}$

(to be continued)

Table 1 *(concluded)*

Symbols	Designated parameters	Units
ρ_e (t)	Density of the water of the circulating water circuit at temperature t	$kg{\cdot}m^{-3}$
ρ_1	Density of the air entering the cooling tower	$kg{\cdot}m^{-3}$
ρ_2	Density of the hot air at the outlet, downstream from the drift eliminators	$kg{\cdot}m^{-3}$
σ	Standard deviation of the wind velocity at 10 m (V_{w10}) during the test	$m{\cdot}s^{-1}$
α_r	Weighting coefficient of the class r reference wind velocity	
Δp	Circulating water pressure loss	Pa
Δp_s	Differential static pressure measured on the water circuit between sections s_1 and s_2	Pa
Δt	Weighted difference on the recooled water temperature	K
z	Difference in temperature on the water between the cooling tower inlet and outlet (Cooling range)	K
t_{cK} - t_{cG}	Difference to the guarantee on the recooled water temperature for a test	K
Δt_r	Recooled water temperature difference for the class r reference wind velocity	K
θ	Instantaneous temperature of the recooled water	°C
λ	Universal load loss coefficient for water conduits	
μ	Coefficient $\mu = \dfrac{h_2 - h_1}{h_{s1} - h_1}$	
ν	Coefficient $\nu = \dfrac{h_{s1} - h_{s2}}{h_2 - h_1}$	

4 Performance tests – General

The performance tests forming the subject of this standard shall be carried out, unless otherwise specified, in the contract at least after three months of continuous operation and definitely after commissioning. It concerns the following performances:

— pumping head - flow rates and pressure loss (see 6.4.5);

— thermal performances - determination of the recooled water temperature at measured conditions (see 6.4.4.4);

— emission performances (drift losses);

— plume characteristics at the outlet (only for wet/dry cooling towers).

The method described in this standard for the verification of thermal performances apply to all cooling towers defined in the scope.

5 Guarantee

5.1 General

Prior to the contract the supplier shall have submitted performance documents available setting out the guaranteed properties as a function of the admissible influence parameters in order to document the guaranteed properties of the cooling tower supplied.

5.2 Guarantee documents

The supplier of a cooling tower shall guarantee:

a) the cooling tower pumping head;

b) the mean recooled water temperature (t_c) as a function of;

. dry bulb temperature, t_s

. relative humidity, φ or wet bulb temperature t_w

. cooling range (*z*), or hot water temperature t_h

. water flow rate (m or q_{me})

and where applicable as a function of other parameters such as

. fan power consumption, F_p

. interference factor

. recirculation factor

. ambient (atmospheric) pressure, P_a

. atmospheric (vertical) temperature gradient, G

However for natural draft cooling towers extended tests checking wind effect at site on tower performance may be performed subject to the contract. If so, the supplier shall guarantee the average temperature of the recooled water t_c as function of

. wind velocity, V_{10}

. wind direction, D_{10}

The guarantee documents can be in the form of spread sheets, curves, analytical expressions, computer program etc.

Performance curves should be presented in the format shown in Annex A, however other formats or appropriate formulas as acceptable provided they give the same information.

Curves shall have reading accuracy of 0,1 K. The area in which acceptance tests are permitted shall be indicated as per 5.3.2.

If correction curves are provided for the effect of other parameters (e.g. wind speed, atmospheric gradient, plume abatement, atmospheric pressure, interference factor, recirculation factor), they shall be used subject to contract.

c) For hybrid cooling towers the outlet air status has to be predicted for all specified boundary conditions:

. dry bulb temperature, t_s

. relative humidity, φ or wet bulb temperature t_w

Other parameters may be guaranteed subject to the contract.

5.3 Validity conditions for measurements

5.3.1 General

The measurement results obtained during the course of the tests shall only be taken into account if the requirements mentioned below are met.

5.3.2 Acceptable operating conditions

a) During the tests:

The values of the following quantities may differ from the design values of the percentages shown below:

— circulating water volume flow rate m: ± 10 % of the design volume flow rate m_N,

— cooling range t_h - t_c: ± 20 % of the design temperature rise t_h - t_{cN},

— thermal load P: ± 20 % of the design thermal load P_N,

b) During the hour finishing at the end of the measuring period, the following gradient conditions shall be fulfilled:

— water flow rate ≤ ± 2 % per hour;

— heat load ≤ ± 5 % per hour;

— ambient wet bulb temperature ≤ 1 K/hour.

5.3.3 Water conditions

The quality of the circulating water flow as well as that of the make-up water shall be within the range of the specification defined in the contract.

In particular dissolved and suspended solids, oil and organic components concentration shall be checked.

The total dissolved solid shall not exceed the greater of the following:

a) 5000 ppm;

b) 1,1 time the design concentration.

The circulating water shall contain not more than 10 ppm of oil, tar or fatty substances.