



Eurovent 9/12 - 2016

Performance Efficiency Standard for Evaporative Cooling Equipment

First Edition

Published on 11 October 2016 by
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Document history

This Eurovent Industry Recommendation / Code of Good Practice supersedes, if applicable, all of its previous editions, which automatically become obsolete with the publication of this document.

Modifications

This Eurovent publication was modified as against previous editions in the following manner:

Modifications as against	Key changes
1 st edition	Present document

Preface

In a nutshell

The purpose of this standard is to:

- Define energy efficiency for mechanical draught evaporative cooling products.
- Determine target levels with the aim to improve the energy efficiency of the population of mechanical draught evaporative cooling products within Europe and the Middle East over a period of time.
- Define the methods to be applied by suppliers to verify that the defined efficiency targets are actually met.

Authors

This document was published by the EUROVENT association and was prepared in a joint effort by participants of a dedicated project within the Eurovent Product Group 'Evaporative Cooling Equipment' (PG-CT), which represents a vast majority of all manufacturers of these products active on the EMEA market. For a detailed composition list, please contact the Eurovent Secretariat.

Adoption

It has been approved and adopted through a formal voting procedure by EUROVENT's national member associations from 20+ European countries, which ensures a wide-ranging representativeness based on democratic decision-making procedures. More information on these members can be found on www.eurovent.eu.

The EUROVENT Association does not grant any certification based on this document. All certification-related issues are managed by the association's independent subunit EUROVENT CERTITA CERTIFICATION in Paris.

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1. Background

Evaporative cooling products are used to remove waste heat from processes and reject it to the atmosphere. Unlike with other heat rejection equipment, the thermal performance of evaporative cooling products largely depends on the evaporation of water caused by effective mixing of water and air. The latent heat transfer, caused by evaporation, is not governed by aerodynamic principles only. In fact, aerodynamic efficiency plays only a minor role in the total heat transfer. It is for that reason that aerodynamic efficiency, for which fan efficiency is a good indicator, cannot be used to judge the thermal performance efficiency of evaporative cooling products. Instead, efficiency targets need to be defined, which take into account the specific nature of evaporative heat transfer and provide goals to improve the thermal energy efficiency of the evaporative cooling industry in Europe and the Middle East. Regulation are encouraged to refer to this energy efficiency target standard for evaporative cooling equipment within legislation (e.g. within the 'EU Fan Regulation').

2. Normative references

- [1] EN 13741:2003 – Thermal performance acceptance testing of mechanical draught series wet cooling towers
- [2] EN 14705:2005 - Heat exchangers. Method of measurement and evaluation of thermal performances of wet cooling towers
- [3] ISO 16345:2015 – Water-cooling towers — Testing and rating of thermal performance
- [4] ISO/IEC 17025:2005 – General requirements for the competence of testing and calibration laboratories
- [5] ANSI/ASHRAE/IES 90.1-2013 – Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)
- [6] CTI ATC-106 - Acceptance Test Code for Mechanical Draft Evaporative Vapor Condensers

3. Definitions

Acceptance test

A test according to the provisions of Chapter 8 during which the actual performance of a cooling tower or evaporative condenser (base model or not) is determined.

Axial fan

A mechanical device that moves air by increasing the speed of the air stream with a rotating propeller. The propeller is composed of a number of blades mounted around a hub. While the assembly turns on a driveshaft it forces air to move axial/parallel to the shaft. The design of the propeller determines the pressure difference and hence the suction force that retains the flow across the fan.

Base model

Cooling tower or evaporative condenser, which must have a thermal energy efficiency equal or better than the minimum values specified in this standard. A base model is without accessories, which create resistance to air flow – such as sound attenuation, plume abatement devices, or any other accessories creating static pressure drop. Thermal energy efficiency of base models is based on unimpeded intake

and discharge air flow. Included in the base model design are drift eliminators and air intake louvers, as these items should be part of every standard offering.

Centrifugal fan

A mechanical device, which moves air by increasing the speed of the air stream with a rotating impeller. The impeller or fan wheel is composed of a number of fan blades, or ribs, mounted around a hub. The assembly turns on a driveshaft that passes through the fan housing in which the air enters from the side, turns 90 degrees and accelerates due to centrifugal force as it flows over the fan blades and exits the fan housing.

Closed-circuit cooling tower

Equipment in which the process fluid circulates inside a heat exchanger which is cooled by water circulating in direct contact with air. The heat exchanger may be inside or close-coupled outside the cooling tower.

Condensing temperature

Temperature at which compressed gas changes from gas to a liquid in a condenser.

Cooling tower

Apparatus in which process fluid is predominantly cooled or refrigerant condensed by evaporative heat exchange with ambient air.

Entering wet bulb temperature

The entering wet bulb temperature is the wet bulb temperature of the air entering the cooling tower or evaporative condenser, including the effect of any recirculation and/or interference.

Evaporative condensers

Cooling tower wherein refrigerant is condensed by the transfer of mass and heat composed of a water flow loop re-circulating over the outside of a closed-circuit heat exchanger containing the refrigerant.

Fan power

The fan power or motor power is defined as the absorbed shaft power at design condition. The absorbed power should not be confused with the installed power which might include safety factors. The motor shaft power includes the efficiency loss of any gear reduction or belt and shall not be confused with the motor electrical power.

Fluid type

Type of process fluid to be cooled such as, for instance, pure water, salty water, or glycol.

Inlet temperature

Temperature of the fluid entering the cooling tower or evaporative condenser.

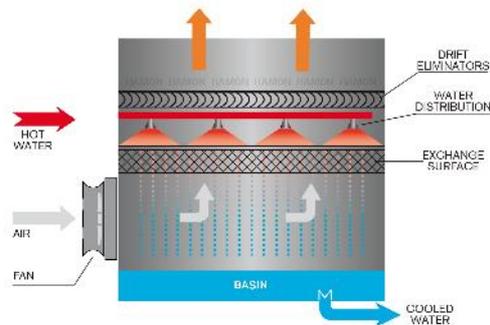
Mechanical draft cooling tower

Cooling tower where the air circulation is produced by a fan.

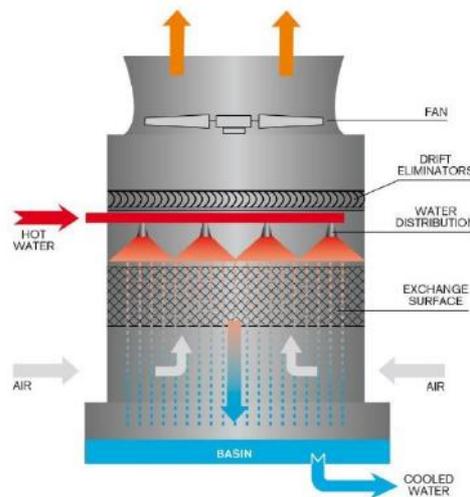
Note 1 to entry: Mechanical draft cooling towers can be further categorised as either

- a) Forced draft: the fan is located in the entering air stream.

Forced Draft



b) induced draft: the fan is located in the discharge air stream.



Open 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.

Outlet temperature

Temperature of the fluid leaving the cooling tower.

Pump power

The pump power is defined as the absorbed shaft power of the spray water pump. The absorbed power should not be confused with the installed power which might include safety factors.

Series cooling tower

Series Cooling Tower is a cooling tower or evaporative condenser for which technical and performance data can be published at the time the product is brought to the market. Series cooling towers are grouped in product lines consisting of models that are functionally related to one another by a

common design and material construction, but varying in size and cooling capacities. The models are of consistent type and design in that they employ the same design configuration and the same fan type plus any other design or application consideration as the manufacturer may employ. Series cooling towers are usually factory produced, however on special instances they can be shipped as a flat package and assembled on site using technically trained personnel. In general, series cooling towers can be easily certifiable throughout the world by known accredited certification companies.

Wet/dry closed-circuit heat exchanger

Heat exchanger incorporating two modes of heat transfer. Wet or evaporative and dry or sensible whereas the performance during the operating period is driven by sensible heat transfer, i.e. the majority of the operating hours are in the dry mode.

4. Scope

This standard applies to mechanical draught evaporative cooling products, which transfer heat of the atmosphere primarily by the evaporation of water (latent heat transfer). Mechanical draught evaporative products include open wet cooling towers as well as closed-circuit cooling towers and evaporative condensers in the forced and the induced draught configuration using either axial or centrifugal fans.

Excluded from this standard are products of which the thermal performance is predominantly driven by sensible heat transfer and where the evaporation of water is only occasionally used for adiabatic pre-cooling of the air. Also excluded are products using latent heat transfer equipped with accessories, which create resistance to the air flow and hence reduce the thermal efficiency of the product. Due to the great variety of such accessories, it is not possible to establish minimum efficiency targets for all of these options.

In summary, the exclusions are as follows:

- Air-cooled heat exchangers with adiabatic pre-cooling of the air.
- Wet/dry closed-circuit heat exchangers incorporating two modes of heat transfer, evaporative (latent) and dry (sensible), whereas the performance during the operating period is predominantly driven by sensible heat transfer (i.e. the majority of the operating hours are in the dry mode).
- Products equipped with plume abatement devices.
- Products equipped with sound attenuation, either on the air intake or discharge or both.
- Products with ductwork on the air intake or discharge or both.

However, for excluded accessories and options, manufacturers can still decide to meet the energy efficiency requirements specified within this standard, providing that there is evidence as outlined in Chapter 8.

6. Thermal energy efficiency definitions and targets

The thermal energy efficiency for mechanical draught open wet and closed-circuit cooling towers is defined as the amount of heat rejection at specified inlet and outlet and entering wet bulb temperatures, expressed in kW per kW power consumed by the fan driver using water as the fluid type.

For evaporative condensers, the thermal efficiency is defined as the amount of heat rejection at specified condensing and entering wet bulb temperatures for R717 (NH₃) refrigerant.

Example energy efficiency calculation

The thermal energy efficiency for mechanical draught open wet cooling towers is defined as the amount of heat rejection at specified inlet and outlet and entering wet bulb temperatures, expressed in kW heat rejection per kW absorbed shaft power at the fan drive system using water as the fluid type.

The thermal energy efficiency for mechanical draught wet closed circuit cooling towers is defined as the amount of heat rejection at specified inlet and outlet and entering wet bulb temperatures, expressed in kW heat rejection per kW absorbed shaft power at the fan and spray pump drive system using water as the fluid type.

$$\text{Thermal capacity (kW}_{\text{th}}) = \text{water flow (kg/s)} * (T_{\text{IN}}^{\circ\text{C}} - T_{\text{OUT}}^{\circ\text{C}}) * c_p \text{ (kJ/kgK)}$$

Remark: $c_p = 4,182$ which equals the specific heat kJ/kgK at 20°C. For simplicity reasons, this value shall be used regardless of the actual water temperature.

The thermal energy efficiency for mechanical draught evaporative condensers is defined as the amount of heat rejection at specified condensing and entering wet bulb temperatures, expressed in kW heat rejection per kW absorbed shaft power at the fan and spray pump drive system using R717 (NH₃) as the refrigerant.

A mechanical draught open wet cooling tower with an absorbed fan shaft power of 42,3 kW, that can cool 4627 kW of water down from 35,0°C to 29,4°C with an ambient wet bulb temperature of 23,9°C, has a thermal energy efficiency of 109,4 at these reference conditions:

$$\text{Thermal energy efficiency} = \frac{4627 \text{ kWth}}{42,3 \text{ kW}} = 109,4 \text{ kWth/kW}$$

Thermal energy efficiency targets are defined for the following product categories:

- Open wet cooling towers with centrifugal fans,
- Open wet cooling towers with axial fans,
- Closed-circuit cooling towers with centrifugal fans,
- Closed-circuit cooling towers with axial fans,
- Evaporative condensers with centrifugal fans,
- Evaporative condensers with axial fans.

Minimum thermal energy efficiency targets for open wet cooling towers are defined for the temperatures in Table 1 below.

Temperatures (°C), inlet, outlet, wet bulb	kWth/kW centrifugal fans	kWth/kW axial fans
35/29,44/23,89 (ASHRAE)	40	80
35/25/20	42	84
32/27/21	36	72

Table 1: Minimum thermal energy efficiency targets for open wet cooling towers

Table 2 specifies the minimum thermal energy efficiency targets for closed-circuit cooling towers to be met for the different temperature conditions.

Temperatures (°C), inlet, outlet, wet bulb	kWth/kW centrifugal fans	kWth/kW axial fans
38,89/32,22/23,89 (ASHRAE)	16	33
38/28/20	15	30
35/30/21	15	32

Table 2: Minimum thermal energy efficiency targets for closed-circuit cooling towers

For evaporative condensers, the efficiency is defined as the amount of kW heat rejection for the condensing and entering wet bulb temperatures for an R717 (NH₃) system shown in Table 3 below.

Temperatures (°C), condensing, wet bulb	kWth/kW centrifugal fans	kWth/kW axial fans
35,72/23,89 (ASHRAE)	30	45
32/20	25	40

Table 3: Minimum thermal energy efficiency targets for evaporative condensers

Note: The thermal energy efficiency targets for the different temperature conditions represent the same level of efficiency. In other words, if a product meets the efficiency level at one temperature condition, it will also meet the efficiency levels at the other specified temperature conditions. Reason for defining different temperature conditions is to facilitate verification by test under field conditions.

7. Thermal testing and uncertainty

7.1 Thermal testing

Thermal energy efficiency shall be based on thermal tests of the various products. Tests shall be carried out in accordance to ISO 16345:2015 for open wet and closed-circuit cooling towers.

For evaporative condensers, tests shall be carried out in accordance with CTI ATC-106, as no comparable EN or ISO standard is available.

See Appendix C for uncertainty calculations.

7.2 Tolerance and uncertainty

The uncertainty percentage is defined as the predicted capacity (with measured conditions adjusted for uncertainty) over the predicted capacity at measured conditions multiplied by 100. The tolerance percentage is equal to the uncertainty, but shall not be more than 7 %, and 5 % for series cooling towers. Uncertainty for open wet and closed-circuit cooling towers shall be carried out as shown in Annex C.

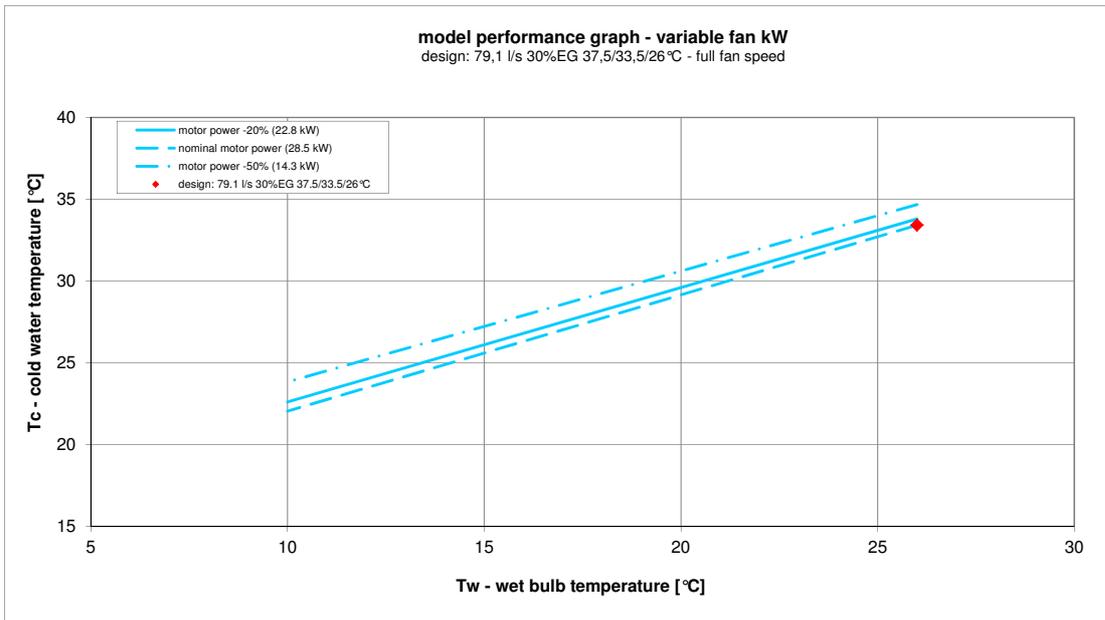
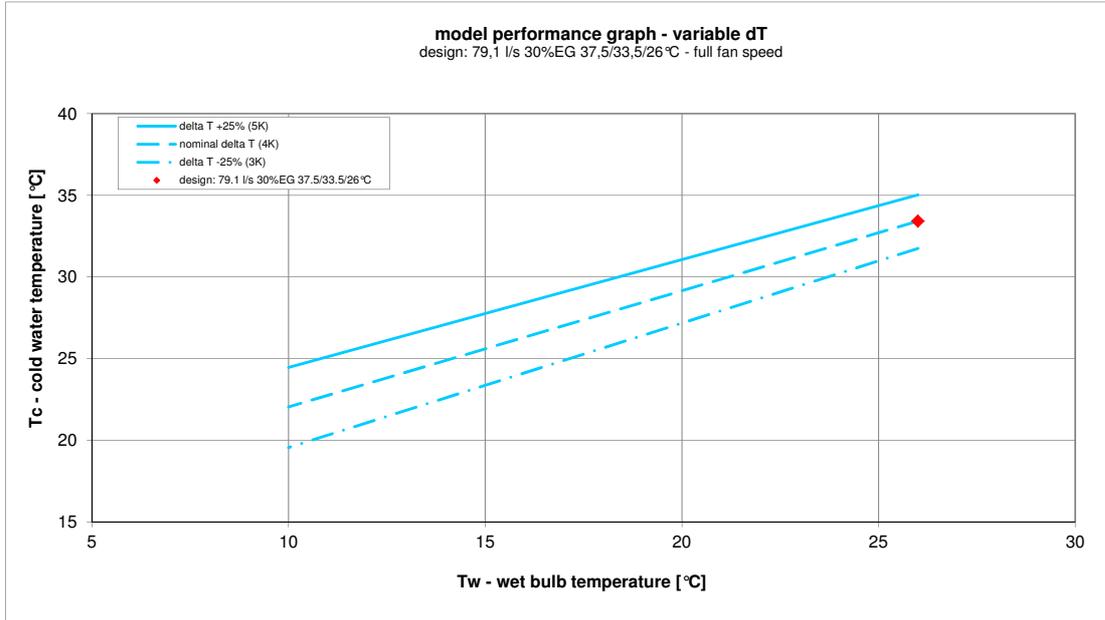
8. Efficiency target verification

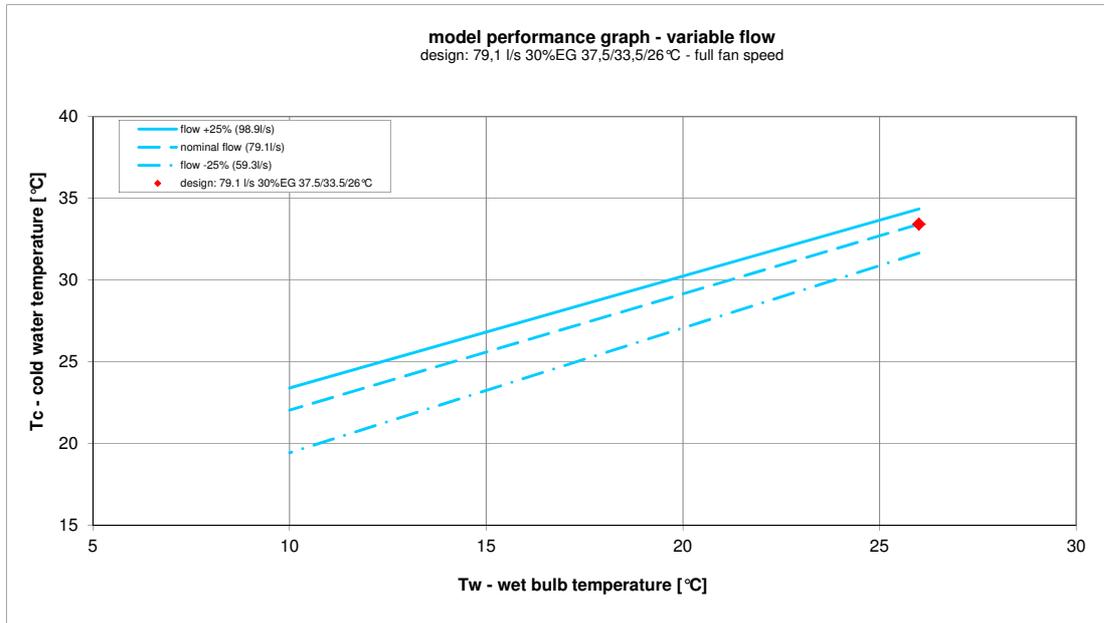
The thermal energy efficiency of each model must be determined by a thermal test following the outlines of chapter 6 (acceptance test). The test must either be conducted prior to bringing the model on the market or after the model is installed. Upon request of the buyer, the supplier shall supply for

the relevant model performance curves (see Annex B). Technical data (see Annex A) for all series models must be published.

It is also possible for the supplier to register in a thermal performance certification programme. Evidence of certified performance provided by an accredited, third-party European certification agency for a series of base models will eradicate the supplier from the need of testing each model prior to order or after installation.

Annex B: Sample performance curves





Annex C: Uncertainty calculation and example

General

For the calculation of the thermal efficiency as a result of a thermal test, the test uncertainty must be established. In order to establish the uncertainty level, the accuracy of the fluid temperature measurement shall be taken into account. In addition, deviations forthcoming from the measuring accuracy of wet bulb temperature, range, water flow rate and fan power shall be considered, since the outlet temperature depends on these quantities. The relationship between the outlet temperature and the parameters above is found in performance curves submitted for the product tested (instrumentation error).

Uncertainty also occurs through systematic non-measurable deviations during the test and through temporary fluctuations of the quantity to be measured (scatter error).

Instrumentation error

Influence of wet bulb measurement uncertainties

The influence factor Φ_w indicates the change in outlet temperature delta t_c for a given variation of the wet bulb temperature delta t_w , providing all other influencing parameters, water flow rate, fan power and range are according to guaranteed conditions.

The variation of delta t_w shall be selected in such a manner that a relation between t_w and t_c is close to 1°C.

Influence of cooling range measurement uncertainties

The influence factor Φ_z indicates the change of outlet temperature delta t_c for a given variation of the range z , providing the water flow rate and fan power are at guaranteed conditions and the wet bulb temperature is the average measured value. The maximum variation of z shall be $\pm 1K$.

Influence of fan power measurement uncertainties

The influence factor Φ_F indicates the change of the outlet temperature delta t_c for a given variation of the fan power F_P (in %), providing the water flow rate and range are at guaranteed conditions and the wet bulb temperature is the average measured value. Maximum variations of F_P shall be ± 10 %.

If the curves do not give the influence of fan power, the influence on the water outlet temperature shall be calculated using a corrected flow.

$$\text{Adjusted flow} = \text{measured flow} \times (\text{design fan power} / \text{measured fan power})^3.$$

Influence of water flow rate measurement uncertainties

The influence factor Φ_m indicates the change of the outlet temperature delta t_c for a given variation of the water flow rate m (in %), providing fan power and range are at guaranteed conditions and the wet bulb temperature is at the average measured value. Maximum variations of m shall be ± 10 %.

Recommended measuring equipment accuracy

Quantity	Acceptable accuracy of instrumentation
Wet bulb temperature, ϵ_{tw}	0,1K
Water temperature, ϵ_{tc}	0,1K
Water flow rate, ϵ_m	3 % or calculated according to installation condition
Fan power, ϵ_{FP}	3 %

Table 4: Measuring equipment accuracy must be verified prior to a test. The values provided here are for guidance.

The precision of the measuring devices and hence the applicable uncertainty ϵ_x shall be determined from the operation guidelines for the instruments used and or from calibration certificates.

The applicable accuracies (ϵ_x) are combined with the influence factors Φ_x and allow the calculation of the instrumentation error.

Determination of the instrumentation error

The instrumentation error δt_s due to systematic non-measurable influences shall be calculated as follows:

$$\delta t_s = \sqrt{(\Phi_W \cdot \epsilon_{tw})^2 + (\Phi_Z \cdot 2\epsilon_{tc})^2 + (\Phi_m \cdot \epsilon_m)^2 + (\Phi_F \cdot \epsilon_{FP})^2 + (\epsilon_{tc})^2}$$

Determination of the scatter error

Random events cause the different t_k between measured and guaranteed outlet temperature, fluctuating around the average t calculated from all measuring periods.

A measure for this fluctuation is the empirical standard deviation:

$$s_{t_k} = \frac{1}{k-1} \sum_{k=1}^k (t_a - t_k)^2$$

The uncertainty δt_r caused by random deviation of measuring results and temporary oscillations of the measured quantities with the level of confidence for a probability of 95 % shall be found using the equation below. Values of the S_t distribution according to Student can be found in the table below.

$$\delta t_r = \frac{St(k) S}{t_k \cdot k}$$

<i>k</i>	<i>S_t (k)</i>	<i>k</i>	<i>S_t (k)</i>
2	12,710	16	2,131
3	4,303	17	2,120
4	3,182	18	2,110
5	2,776	19	2,101
6	2,571	20	2,093
7	2,447	21	2,086
8	2,365	22	2,080
9	2,306	23	2,074
10	2,262	24	2,069
11	2,228	25	2,064
12	2,201	26	2,060
13	2,179	27	2,056
14	2,160	28	2,052
15	2,145	29	2,048

Table 5: Distribution according to Student for a level of confidence of 95 %

Determination of the test uncertainty

The total uncertainty δt_m is the result of the uncertainties caused by instrumentation δt_s and scatter δt_r errors and can be calculated as follows:

$$\delta t_m = \pm \sqrt{\delta t_s^2 + \delta t_r^2}$$

Uncertainty calculations for evaporative condenser tests shall be executed according to CTI ATC-106.

Uncertainty is the positive and negative deviation added together (positive and negative deviations have the same absolute value).

The measured outlet temperature is corrected with the deviation as shown in the example uncertainty calculation below.

Example of calculation for a mechanical induced draft (axial fan) open wet cooling tower

The cooling tower has been designed for the following conditions:

- Number of cells: 4
- Water flow: 7350 m³/h
- Hot water: 40°C
- Cold water: 30°C
- Wet bulb: 25°C
- Installed motor power: 200 kW
- Guaranteed motor power at shaft: 169.6 kW

The heat rejected is computed as $7350/3.6 * (40-30) * 4.182 = 85361$ kWth

The total power is computed as $4 * 169.6 = 678$ kW

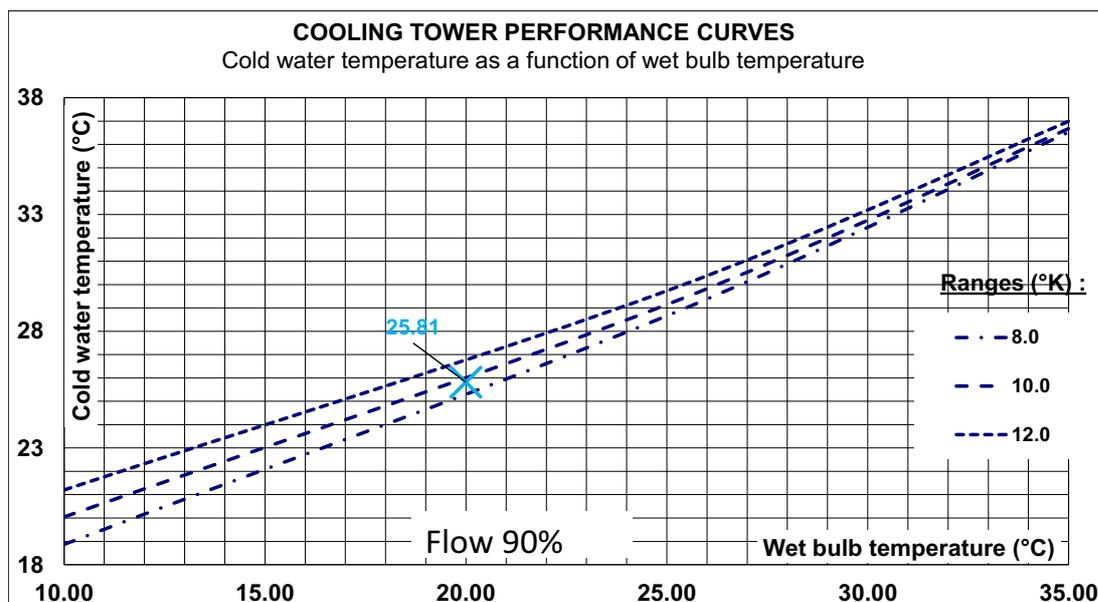
The design energy ratio is thus $85361/678 = 126$ kWth/kW.

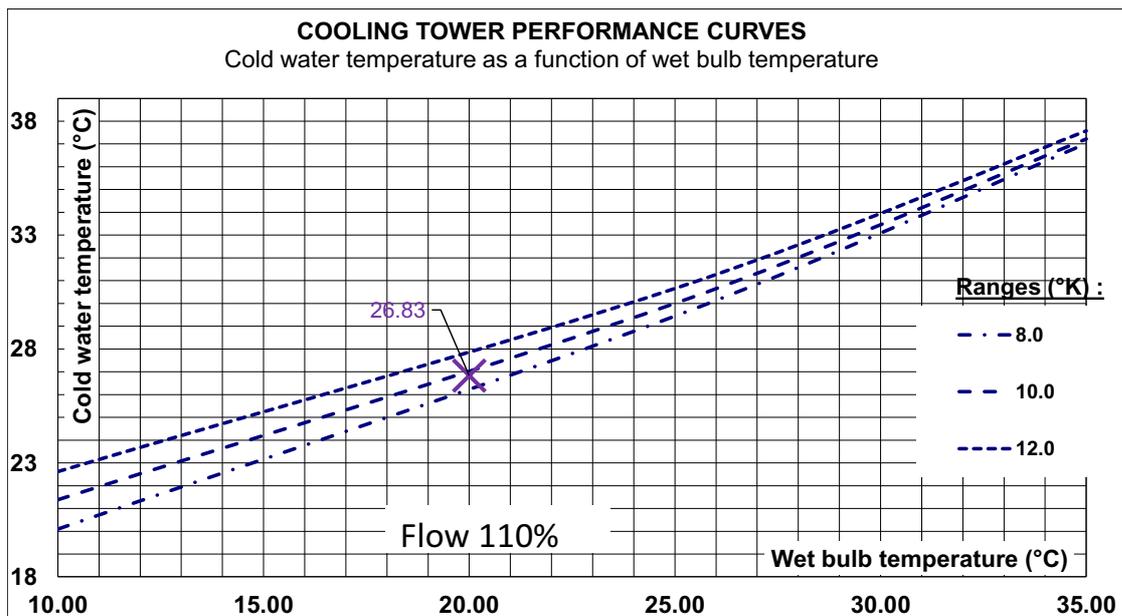
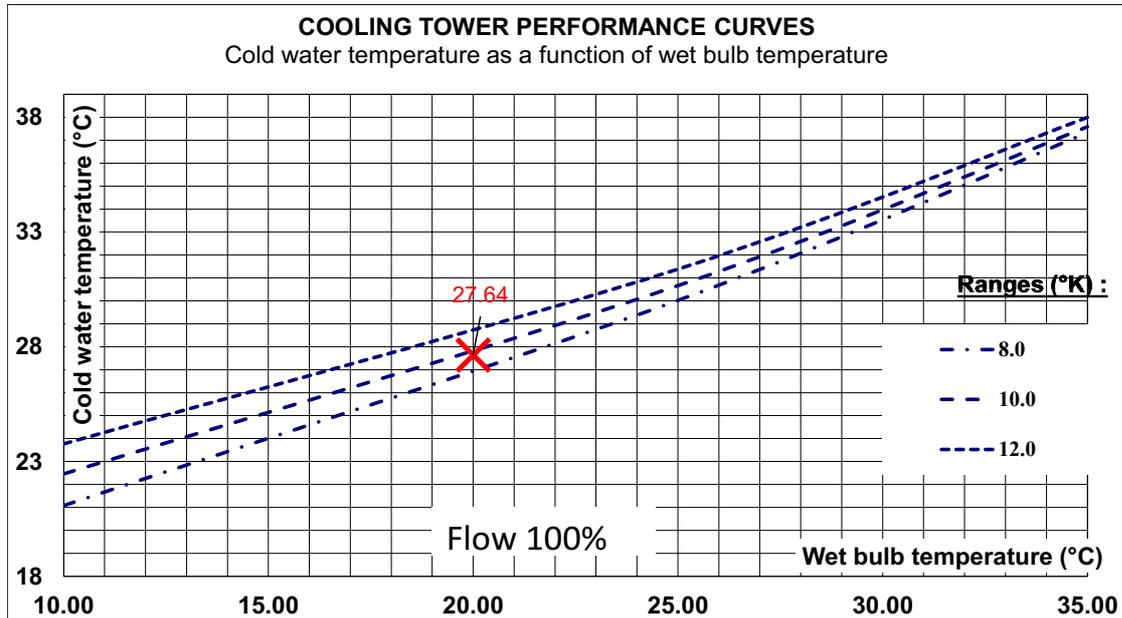
However, this ratio is the ratio at design conditions. The present standard intends to allow for comparison between different operating conditions. Therefore, the energy consumption shall be computed at the standardised operating point (shown in Table 1) and not at design conditions.

The conditions closest to the design condition will be selected. In this case, it is: 35/25/20.

In order to demonstrate that the cooling tower complies with this standard, the manufacturer must provide performance curves at constant motor power. These curves will be used to determine which flow can be cooled at 35/25/20. Interpolation or extrapolation might be needed. An example is provided here after.

From each performance curve, cold water is read at wet bulb 20°C and range 10°K (35°-25°).

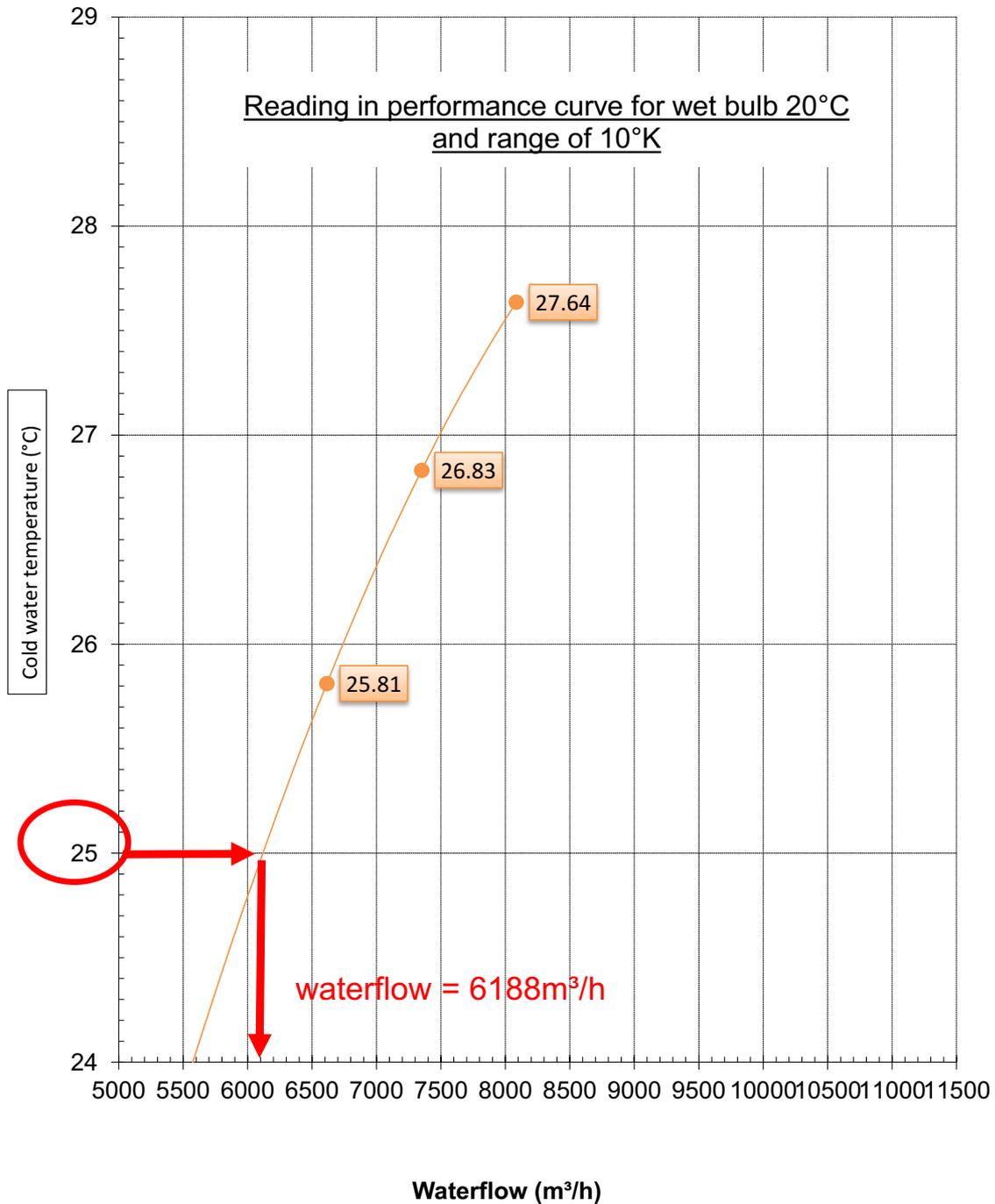




Values read in the curves are the following:

Cold Water (°C)	WaterFlow			%
	90%	100%	110%	
	6615	7350	8085	m3/h
Range= 10 °C	25.81	26.83	27.64	°C

From these values, extrapolation will be used to find which flow can cool water at 25°C.



From the curve, it is possible to predict that a cold water of 25°C can be reached at a range of 10°K and a wet bulb of 20°C with a flow of 6188 m³/h.

This flow will be used to compute the energy efficiency as per this standard.

The results as follows:

- The heat rejected is computed as $6188/3.6 * (40 - 30) * 4.186 = 71\,935$ kWth
- The total power is computed as $4 * 169.6 = 678$ kW
- The ratio is thus $71\,935 / 678 = 106$ kWth/kW
- To be compared with the limit of 84 kWth/kW given in Table 1.
- The ratio is higher. Consequently, the cooling towers comply with this standard.

Verification by thermal test

It is possible to verify compliance with the standard by performing a thermal test according to the ISO standard specified within this document.

The performance is then based on the average test conditions. Using the performance curves (see example above), compliance with the standard is verified.

If, as in the example above, the minimum thermal energy efficiency target is met or exceeded, there is no need for an uncertainty calculation.

If the specified minimum thermal energy efficiency target is not met, an uncertainty analysis can be done and the tested thermal performance can be adjusted for uncertainty following the procedure below:

1. Establish average test values for inlet, outlet and wet bulb temperatures, flow and fan power.
2. Find the instrumentation and scatter error and calculate the total test uncertainty (Annex C)
3. Add the 'total test uncertainty' to the average in and outlet temperatures of the test and find adjusted flow (and capacity) from performance curves.
4. Use the 'adjusted conditions' for conversion to standard conditions (see above)
5. If the thermal energy efficiency target is met with the performance based on 'adjusted conditions', the compliance to the standard is achieved.

About Eurovent

We are Europe's Industry Association for Indoor Climate, Process Cooling, and Food Cold Chain Technologies – thinking beyond 'HVAC&R'

Eurovent is Europe's Industry Association for Indoor Climate, Process Cooling, and Food Cold Chain Technologies. Its members from throughout Europe, the Middle East and Africa represent more than 1.000 companies, the majority small and medium-sized manufacturers. Based on objective and verifiable data, these account for a combined annual turnover of more than 30bn Euros, employing around 150.000 people within the association's geographic area. This makes Eurovent one of the largest cross-regional industry committees of its kind. The organisation's activities are based on highly valued democratic decision-making principles, ensuring a level-playing field for the entire industry independent from organisation sizes or membership fees.

Eurovent's roots date back to 1958. Over the years, the Brussels-based organisation has become a well-respected and known stakeholder that builds bridges between manufacturers it represents, associations, legislators and standardisation bodies on a national, regional and international level. While Eurovent strongly supports energy-efficient and sustainable technologies, it advocates a holistic approach that also integrates health, life and work quality as well as safety aspects. Eurovent holds in-depth relations with partner associations around the globe. It is a founding member of the ICARHMA network, supporter of REHVA, and contributor to various EU and UN initiatives.

Our Members and 'Affiliated Manufacturers'



Our Members are national associations from Europe, the Middle East and Africa that are representing manufacturers in the area of Indoor Climate, Process Cooling, and Food Cold Chain technologies.



The more than 1000 companies within their networks (Eurovent 'Affiliated Manufacturers') can directly participate in Eurovent activities in a democratic and transparent manner.

