# Thermal performance acceptance testing of mechanical draught series wet cooling towers

The European Standard EN 13741:2003 has the status of a British Standard

ICS 91.060.50



British Standards

# National foreword

This British Standard is the official English language version of EN 13741:2003.

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 international/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, was published under the authority of the Standards Policy and Strategy Committee on 22 December 2003

**Summary of pages**

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 33 and a back cover.

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**Amendments issued since publication**

| Amd. No. | Date | Comments |
|---|---|---|
| | | |
| | | |
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| | | |



ISBN 0 580 43139 8

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

# EN 13741

December 2003

ICS 91.060.50

English version

# Thermal performance acceptance testing of mechanical draught series wet cooling towers

Essais de réception des performances thermiques des aéroréfrigérants humides à tirage mécanique et fabriqués en série

Wärmetechnische Abnahmeprüfung an zwangsbelüfteten standardisierten Nasskühltürmen

This European Standard was approved by CEN on 1 October 2003.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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

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Ref. No. EN 13741:2003 E

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# Foreword

This document (EN 13741:2003) 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 June 2004, and conflicting national standards shall be withdrawn at the latest by June 2004.

Annexes A, B and C are informative.

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, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

## 1 Scope

This European Standard specifies requirements, test method and acceptance tests for thermal performance of mechanical draught series cooling towers.

This European Standard is applicable to series type wet cooling towers as defined in 3.1.

The acceptance testing covers the verification of the thermal and hydraulic performance data of the cooling tower selected from the product line (see 3.1) and 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.

A methodology to calculate the test tolerance is included in this standard. The contract should specify whether this methodology shall be used for the assessment of the test results or not.

Legal and commercial consequences that might result from achieving or not achieving the contractually agreed performance are not part of this European Standard.

## 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 (including amendments).

Not applicable.

## 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**
**air flow rate**
total amount of dry air and associated water vapour moving through the cooling tower

**3.1.2**
**approach**
difference between cold water temperature and the inlet wet bulb temperature

**3.1.3**
**approach deviation**
deviation between the design approach and the measured (adjusted) approach

**3.1.4**
**barometric pressure**
atmospheric pressure at the test site

**3.1.5**
**basin**
open structure located beneath the cooling tower for collecting the circulating water and directing it to the sump or suction line of the circulating pump

**3.1.6**
**basin curb**
top elevation of the tower basin

usually the datum from which the tower elevations are measured.

**3.1.7**
**blow-down**
water discharged from the system to control the concentration of salts or other impurities in the circulating water

**3.1.8**
**cell**
smallest subdivision of the tower, bounded by exterior walls and partition walls , which can function as an independent unit Each cell may have one or more fans or stacks and one or more distribution systems

**3.1.9**
**cold water temperature**
average temperature of the water entering or leaving the tower basin In the case where the measurement is downstream of the basin or the pump, corrections are needed for the effects of the pump, and any other make up water blow down or heat sources entering the basin

**3.1.10**
**cooling range**
difference between the temperature of the water entering the distribution system and the cold water temperature

**3.1.11**
**cooling tower**
apparatus in which water is cooled down by heat exchange with ambient air

**3.1.12**
**drift eliminator**
the assemblies downstream of the heat transfer media, which serve to reduce the drift loss

**3.1.13**
**drift loss**
portion of the water flow rate lost from the tower in form of fine droplets mechanically entrained in the discharge air stream, commonly expressed as mass per unit time or a percentage of the circulating water flow rate. It is independent by water lost from evaporation

**3.1.14**
**dry bulb temperature**
temperature of an air-vapour mixture indicated by a thermometer with a clean, dry sensing element that is shielded from radiation effects. May be further categorised as either:

a) ambient dry bulb temperature: the dry bulb temperature of air measured windward of the tower and free from influence of the tower

b) entering dry bulb temperature: the dry bulb temperature of the air entering the tower, including the effect of any recirculation and/ or interference

**3.1.15**
**fan power**
power consumed by the fan driver, including the indication whether the efficiency of the driver is included or not

**3.1.16**
**make up**
water added to the system to replace the water lost by evaporation, drift blowdown and leakage

**3.1.17**
**mechanical draught cooling tower**
cooling tower where the air circulation is produced by a fan. May further be categorized as either:

forced draught: the fan is located in the entering air stream

induced draught: the fan is located in the discharge air stream

**3.1.18**
**non series type wet cooling tower**
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

**3.1.19**
**open circuit (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

**3.1.20**
**pump head**
sum of static head and dynamic head from the contractual interface to the discharge of the distribution system to the atmosphere

**3.1.21**
**relative humidity**
ratio of the mole fraction of water vapour in a given air sample to the mole fraction of water vapour in a sample of saturated air at the same temperature and pressure, usually expressed as percentage

**3.1.22**
**series type wet cooling tower**
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 test evaluation over a defined range of operating conditions

**3.1.23**
**test period**
time duration where readings or recordings of every measurement have to be averaged, and test period results may be calculated

**3.1.24**
**test readings**
individual sets of data recorded at regular intervals for each instrument or measurement point required

**3.1.25**
**thermal lag**
time interval before the temperature of the water leaving the influence of the cooling air is detected at the point of cold water temperature measurement

**3.1.26**
**water flow rate**
quantity of warm water flowing into the open cooling tower

**3.1.27**
**water loading**
water quantity expressed as quantity per unit of fill plan area of the tower

**3.1.28**
**wet bulb temperature**
temperature of air, which when properly measured approximates the temperature of adiabatic saturation. May further be categorised as either:

ambient wet bulb temperature: the wet bulb temperature of air measured windward of the tower and free from influence of the tower

entering wet bulb temperature: the wet bulb temperature of the air entering the tower, including the effect of any recirculation and/or interference

NOTE Terms like « guarantee » « values » and « acceptance » used in this standard are understood in a technical but not in a legal or commercial sense.

## 3.2 Symbols

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

**Table 1 — Symbols**

| Symbols | Designated parameters | Units |
|---|---|---|
| $t_w$ | Wet bulb temperature | °C |
| $t_{wG}$ | Guaranteed wet bulb temperature | °C |
| $t_{wk}$ | Wet bulb temperature measured at reading k | °C |
| $t_h$ | Hot water temperature | °C |
| $t_{hk}$ | Hot water temperature measured at reading k | °C |
| $t_c$ | Cold water temperature | °C |
| $t_{cg}$ | Guaranteed cold water temperature | °C |
| $t_{ck}$ | Cold water temperature at reading k | °C |
| $t_{cfk}$ | Face value of cold water temperature at conditions found at reading k from performance curves | °C |
| $t_m$ | Temperature of the make up water | °C |
| $z$ | Range ($t_h - t_c$) | K |
| $z_G$ | Guaranteed range | K |
| $z_k$ | Range calculated for reading k ($t_{hK} - t_{ck}$) | K |
| $t_P$ | Temperature increase due to pump energy | K |
| $t_k$ | Difference between measured cold water temperature ($t_{ck}$) and face value ($t_{cfk}$) for reading k | K |
| $t_a$ | Arithmetic average of all $t_k$ | K |
| $k$ | Reading indication | |
| $m$ | Hot water flow | l/s |
| $m_G$ | Guaranteed hot water flow | l/s |
| $m_k$ | Hot water flow measured at reading *k* | l/s |
| $m_m$ | Make up water flow | l/s |
| $m_b$ | Blow down water flow | l/s |
| $F_P$ | Fan motor power | kW |
| $F_{PG}$ | Guaranteed fan motor power | KW |
| $p_h$ | Pump discharge pressure | kPa |
| $p_c$ | Pump suction pressure | kPa |
| $p_{si}$ | Static pressure at contractual tower inlet | kPa |
| $p_{di}$ | Dynamic pressure at contractual tower inlet | kPa |
| $gh_j$ | Gravity pressure contractual inlet | KPa |
| $p_{SO}$ | Static pressure at contractual outlet | kPa |
| $p_{do}$ | Dynamic pressure at contractual outlet | kPa |
| $gh_o$ | Gravity pressure at contractual outlet | kPa |
| $H$ | Difference between contractual inlet and outlet gravity terms | kPa |
| $p_{io}$ | Total pressure difference between contractual tower inlet and outlet | kPa |

(to be continued)

**Table 1** (end)

| Symbols | Designated parameters | Units |
|---|---|---|
| $_{p}$ | Pump efficiency | |
| $S_l$ | Thermal lag | min |
| $Q_b$ | Average volume of water basin | l |
| $v_w$ | Wind velocity | m/s |
| $t_t$ | Test tolerance including systematic and random deviations and base tolerance | K |
| $t_m$ | Measurement result error | K |
| $t_b$ | Base tolerance | K |
| $t_s$ | Error due to systematic non-measurable influences | K |
| $t_r$ | Error caused by random deviations | K |
| $_{w}$ | Wet bulb influence factor | K/°C |
| $_{z}$ | Range influence factor | K/°C |
| $_{F}$ | Fan power influence factor | K/% |
| $_{m}$ | Water flow influence factor | K/ % |
| $_{x}$ | Measuring tolerance for measuring equipment x | |
| $s_t$ | Student number | |

# 4 Performance tests — General

## 4.1 Subject of the thermal performance acceptance

The guaranteed cooling tower outlet water temperature at the condition ($t_{wG}$, $z_G$, $m_G$, $F_{PG}$, $p_{io}$*) shall be lower or equal to a specific value. Prior to a thermal performance acceptance test additional performance data (performance curves) shall be provided by the cooling tower supplier. These additional data shall define the area around the guaranteed point and show the area in which acceptance testing is permitted (see 6.3.3).

* $p_{io}$ will only be evaluated if specifically required by the contract.

## 4.2 Performance curves

### 4.2.1 Performance curves format

Performance curves shall be submitted in a way that they describe the relation between the cold water temperature ($t_c$) and wet bulb temperature ($t_w$) for a variation of flow ($m$) range ($z$) and fan power ($F_P$).

Performance curves or appropriate formulas should be presented in the format shown in annex A , however other formats are acceptable providing they give the same information.

Curves shall allow readings to be made to a precision of 0,1 K. The area in which acceptance tests are permitted shall be indicated in accordance with 6.3.3.

### 4.2.2 Performance curve parameters

The face value of the cold water temperature ($t_{cf}$) shall be shown as a function of following parameters:

¾ wet bulb temperature,

¾ hot water flow rate,

¾ hot water temperature or cooling range,

¾ fan power.

# 5 Measuring procedures and instrumentation

## 5.1 General

**5.1.1** The following quantities shall be measured in acceptance tests:

hot water flow rate ($m$),

hot water temperature ($t_h$),

cold water temperature ($t_c$),

entering wet bulb temperature ($t_w$),

fan power ($F_P$),

wind velocity ($v_w$).

And if required:

pumping head ( $p_{io}$),

temperature ($t_m$) and flow ($m_m$) of the make up and blow down water.

The measuring procedures described here shall comply with accepted standards.

**5.1.2** A summary of the instrumentation needed is given in annex B.

All measuring equipment shall have been calibrated. Instruments shall be checked prior to test. The deviations found shall be considered in the assessment of the results.

The measuring range of the instruments shall be selected so that minimal measuring errors occur. Acceptable tolerances are specified in Table 7. Counting water flow measuring instruments are acceptable, upon condition that they are backed up by additional instantaneous measurements to verify that water flow fluctuations remain within the permitted limits stated in 6.3.4.

Measuring equipment, its calibration and location shall be in accordance with accepted standards.

## 5.2 Measurements

### 5.2.1 Temperatures

#### 5.2.1.1 General

The temperatures to be measured are the hot water temperature $t_h$, the cold water temperature $t_c$, the entering wet bulb temperature $t_w$, and if applicable also the temperature of the make-up water $t_m$ and blow down.

Calibrated measuring instruments shall be used, such as:

¾ liquid thermometers,

¾ platinum resistance thermometers,

¾ thermocouples,

¾ thermistors,

¾ quartz thermometers.

The indicator or recorder of the thermometer shall have a graduation of not more than 0,1 K readable to 0,05 K and shall have been calibrated. The temperature sensors shall be checked prior to test by submerging in liquid at constant temperature together with a calibrated thermometer. Every sensor having a deviation larger than 0,1 K shall be replaced.

#### 5.2.1.2 Water temperatures

##### 5.2.1.2.1 General

The measuring instruments shall be as specified in 5.2.1.1.

The locations of the temperature measurement stations shall be such that true averages are determined.

##### 5.2.1.2.2 Hot water temperature

A suitable location for the measuring equipment for the hot water temperature is the common supply conduit to the tower or its water distribution system.

##### 5.2.1.2.3 Cold water temperature

The cold water temperature shall reflect the true average temperature of the water leaving the cooling tower and care shall be taken to eliminate all possibility of temperature stratification at the point of measurement. If the cold water temperature is measured at the pump discharge in a well in the pump discharge piping, the measured temperature shall be corrected for the effects of pressure and throttling as follows :

$$t_p = 0{,}00239\ (p_h \quad p_c)\ (1 \quad {}_p)\ / \quad {}_p$$

NOTE Unless the static head between the water level in the tower basin and the centerline of the pump suction is significant or the pipe run is quite long, $p_c$ can be assumed to be 0 kPa without any significant loss of accuracy.

If the test is run with make-up water introduced to the system upstream of the cold water measurement station, e.g. in the tower basin, the measured water temperature shall be corrected for the effect of the make-up and blow down using a heat balance calculation taking into account the temperature and flow rate of the make-up.

#### 5.2.1.3 Wet bulb temperature

The entering wet bulb temperature can be measured using mechanically aspirated instruments of sufficient number and location to ensure measured temperatures accurately reflect the true wet bulb temperature entering the cooling tower. The instruments shall meet the following requirements:

a) The indicator or recorder shall be graduated in increments of not more than 0,1 K.

b) The temperature-sensitive element shall be accurate to +/- 0,05 K.

c) The temperature-sensitive element shall be shielded from direct sunlight or from other significant sources of radiant heat. The temperature of the shielding device shall be close to the ambient dry bulb temperature.

d) The temperature-sensitive element shall be covered with a wick that is continuously fed from a reservoir of distilled water.

e) The temperature of the distilled water used to wet the wick shall be at approximately the wet bulb temperature being measured. This may be obtained in practice by allowing adequate ventilated wick between the water supply and the temperature-sensitive element.

f) The wick shall fit snugly over the temperature-sensitive element and extend at least two centimetres past the element over the stem. It shall be kept clean while in use.

g) The air velocity over the temperature-sensitive element shall be maintained between 3 m/s and 6 m/s.

Measurement of the dry bulb and the relative humidity of the entering air may be used as an alternative to wet bulb temperature measurements. In such case the entering dry bulb temperature shall be measured using temperature sensors of sufficient number and location to ensure the measured temperatures reflect the true dry bulb temperature entering the tower. The indicator or recorder shall be graduated in increments of not more than 0.1 K and the temperature sensitive element shall have an accuracy of +/- 0.05 K. The temperature sensitive elements shall be shielded from direct sunlight or from other significant sources of radiant heat. The shielding device enables air circulation resulting from the draught around the probe.

The relative humidity of the entering air shall be measured by using hygrometers (for example capacive hygrometers) with an accuracy of +/- 3 % with the same shielding requirements as for the dry bulb measurements.

Other wet bulb assessment methods, such as dewpoint measurement, are permitted, upon conditon that they meet the requirements specified under subsections a), b) and c) above.

### 5.2.2 Water flow

The flow rate of the hot water supply shall be measured. It is only admissible to carry out a flowrate measurement in the cold water pipe if local conditions do not allow a measurement in the hot water pipe. In this case a mass balance calculation should be made to correct the measured cold water flow for any change of specific volume/gravity at the measured temperatures. The location of the flow measurement station should be such that no water is added or removed between the measurement station and the cooling tower inlet.

Flowmeters shall be installed according to accepted standards. Acceptable flow measuring devices with their typical linearity are listed in Table 2.

**Table 2 — Typical linearity for different flow measurements**

| Flow measurement method | Typical linerarity as % of flow |
|---|---|
| Throttling measurement devices | depending on differential pressure measurement |
| Pitot or Prandtl tubes | ± 1,0 to ± 3,0 |
| Turbine meters | ± 0,5 to ± 1,0 |
| Electro-magnetic measuring equipment | ± 0,5 to ± 4,0 |
| Ultrasonic measuring equipment | ± 0,1 to ± 1,0 |
| Counters (only if flow is constant) | Depends on type of counter |

For the acceptance tests, all these devices shall have a basic accuracy of ± 1,5 % guaranteed by the works and certified by an independent inspection agency.

If the measurement is carried out using permanently installed service measuring equipment then the parties involved shall mutually agree to a measuring tolerance for the water flow measurement prior to the test being performed. This measuring tolerance may not, however, exceed 3 %.

### 5.2.3 Fan power

Only the electrical power used by the fan motors shall be measured.

Power input shall be determined by measurement of the voltage, current, and power factor or by direct measurement of the power input. When it is necessary to measure fan motor power input at some point distant from the motor, provision shall be made to account for line losses between the point of measurement and the motor.

If the performance guarantee is based on driver output, efficiencies stated by the manufacturer of the driver may be used.

The power measuring instrument shall be calibrated by a recognised, independent laboratory to an accuracy of at least ± 1,5 % prior to test.

**Table 3 — Typical tolerances for different power measurements**

| Fan power measurement | Typical tolerance range as % of fan power |
|---|---|
| Watt meter | 1 % to 5 % |
| Volt / Amp. meter | 3 % to 8 % |

### 5.2.4 Cooling tower pumping head

Tower pumping head ( $p_{io}$) is the total pressure difference between the contractual tower inlet and outlet.

$$p_{io} = (p_{si} + p_{di} + \quad gh_i) - (p_{so} + p_{do} + \quad gh_o)$$

with *gh* the gravity pressure term or

$$p_{io} = (p_{si} + p_{di}) \quad (p_{so} + p_{do}) + H$$

where :

$H$ = the geometrical height difference in terms of pressure.

In most cases, inlet and outlet cross sections are the same, therefore in these cases the simplified equation:

$$p_{io} = (p_{si} \quad p_{so}) + H$$

can be used.

#### 5.2.5 Temperature and flow of make up and blow down

For these measurements the procedure described for measuring the water temperatures and the circulating water flow can be used.

## 6 Acceptance tests

### 6.1 General

#### 6.1.1 Introduction

The purchaser and supplier shall agree on acceptance testing.

A list of measuring parameters and points is given in annex B.

Should it not be possible to install the measuring points according to the rules, the contractual partners shall reach a mutual agreement.

#### 6.1.2 Time of the acceptance test

Acceptance tests should be conducted after a period of operation under heat load (preferably not less than 400 h or six weeks) and not later than 12 months after start-up, at climate conditions, range and water flow, which are close to the guaranteed conditions. (See 6.3.3, Table 5).

#### 6.1.3 Management of the acceptance tests

Management of the acceptance test procedure and program, for example reference testing of selected cells in a multi-cell installation, shall be agreed between purchaser and supplier. Each of the contractual parties have the right to witness/participate in the test.

### 6.2 Preparation of acceptance tests

#### 6.2.1 General

To measure the most important parameters, it is recommended to install special fittings and/or immersion shells, so that the acceptance test can be carried out without interference of the operational measuring devices.

### 6.2.2 Number and arrangement of the measuring points

The number and arrangement of the measuring points shall be according to Table 4 and the schematic in annex B, taking into account local restrictions. The arrangement of measuring points needs to be executed according to relevant recognised standards.

**Table 4 — Recommended number and arrangement of measuring points**

| No. | Quantity | Minimum number M | Arrangement |
|---|---|---|---|
| 1 | Water flow *m* | $M = 1$ for each feed pipe | as per accepted standard |
| 2 | Hot water temp. $t_h$ | $M = 1$ for each feed pipe | in the main flow through the feed pipes |
| 3 | Cold water temp. $t_c$ | $M$ 2 for each outlet | at basin outlet or pump discharge see 5.2.1.2.3 |
| 4 | Wet bulb temp. $t_w$ | $M \quad \mathbf{0.5} \left(\frac{A}{m^2}\right)^{0.4}$ <br> but not less than one station per air inlet face <br> ***A = air intake surface*** <br> $M$ 2 | Maximum distance from cooling tower air inlet 2 m, evenly distributed to ensure test average is an accurate representation of the true average entering wet bulb temperature |
| 5 | Fan power $F_P$ | $M = 1$ | direct on the motor or in the control room |
| 6 | Pump head $p_{io}$ | $M = 1$ | see 5.2.4. |

### 6.2.3 Condition of the plant

Before execution of the acceptance test the cooling tower shall be inspected to ensure it operates properly. In particular it shall be ensured that:

- all functional components are undamaged and operational,
- fill pack and eliminators are free of debris, settlements and biological growth,
- the water distribution is clean and not clogged,
- cooling water and air supply do not have any leaks,
- the intake and discharge air flows are unimpeded.

It shall be assured that the quality and composition of the cooling water is as specified in the order and that particularly the water is free of oil and grease.

In the case of multi-cell cooling towers, water flow rates to individual cells shall be balanced properly. Proper balancing can be assessed by adjusting flows such that spray pressures (pressure at cooling tower inlets) or water levels in the hot water distribution basins are equal.

Prior to testing it shall be reported to the persons assigned to run the test and the manufacturer that the cooling tower is ready for acceptance testing.

## 6.3 Execution of acceptance tests

### 6.3.1 Pre conditions

Prior to acceptance testing following conditions shall be fulfilled:

¾ the plant shall be in acceptable condition,

¾ all necessary acceptance documents shall be available,

¾ all relevant measuring instruments in the cooling loop shall be accessible,

¾ exterior influences such as influence of sun radiation on thermometers shall be eliminated, for example by sun shields.

### 6.3.2 Trial measurements

Opportunity to run a trial test shall be given to the persons assigned to run the acceptance test prior to the acceptance test itself. This is to allow a check of the instruments as well as training of people taking the readings.

A trial test could be accepted as acceptance test provided all conditions of this standard were fulfilled.

### 6.3.3 Acceptable deviations of operating conditions

If the conditions of the guaranteed point ($t_{wG}$, $z_G$, $m_G$, $F_{PG}$) cannot be achieved during the acceptance test, deviations should not exceed the values indicated in Table 5. Tests should be arranged so that valid readings can be taken consecutively.

**Table 5 — Maximum deviations from guaranteed values admitted during the acceptance tests**

| Quantity | Deviation from guaranteed conditions |
|---|---|
| Entering wet bulb temperature $t_w$ | ±10 K but $t_w$ + 4 °C |
| Range $z$ | ± 20 % |
| Water flow $m$ | ± 10 % |
| Heat load | ± 20 % |
| Fan power $F_P$ | |
| — with speed control or adjustable blades | ± 5 % |
| — fans with no controls | ± 20 % |

Mean wind velocity shall not exceed 3,5 m/s during the measuring period.

If wind velocity is close to this value, it can be decided to measure it continuously; in that case, gusts of more than 7 m/s shall not occur more than 10 times within an hour or for more than one minute (cumulative value).

Wind velocity shall be measured at a height of 1,0 m to 1,5 m above the basin curb elevation, and where possible in an open and unobstructed location to the windward of the equipment at a horizontal distance sufficient to eliminate the influence of the upstream effects of the equipment.

Wind measurements are typically done with a rotating cup or rotating vane anemometer; general direction of wind may be determined by using a vane-type device.

If in exceptional cases the validity limits cannot be maintained, the acceptance test results shall only be considered to be valid, if the contractual partners can make an agreement on the calculated influence of the deviating operating and climate conditions.

### 6.3.4 Operating conditions during the test

The test must be run in absence of rain or fog. The operating conditions should be constant during the test period. The entering wet bulb temperature may fluctuate but may not change by more than 1 K per hour.

During the measurement period it shall be ensured that the test conditions do not vary by more than:

¾ ± 5 % for the thermal load,

¾ ± 5 % for the water flow,

¾ ± 5 % for the cooling tower range.

NOTE The conditions are dependent upon each other but individually should not exceed these limits.

### 6.3.5 Frequency of readings

The measurements shall be taken at regular intervals and all readings shall be recorded. The choice of time intervals generally relates to the constancy of the test conditions in as much that for more constant conditions longer time intervals may be chosen. The recommended frequency of readings per measurement station are listed in Table 6.

**Table 6 — Recommended frequency of reading**

| Measurement station | Recommended frequency each hour per station | Unit | Record to the nearest |
|---|---|---|---|
| Wet bulb temperature | 12 | °C | 0,05 |
| Cold water temperature | 12 | °C | 0,05 |
| Hot water temperature | 12 | °C | 0,05 |
| Water flow (see a)) | 3 (see a)) | See b) | |
| Pumping head * | 1 | kPa | 2 |
| Fan power | 1 | See b) | |
| Wind velocity | 6 | M/s | 1 |
| Make up temperature * | 2 | °C | 0,05 |
| Make up flow * | 2 (see a)) | See b) | |
| Blow down temperature * | 2 | °C | 0,05 |
| Blow down flow * | 2 (see a)) | See b) | |
| NOTE (* if applicable) | | | |

a) When water flow measurement time is excessive, such as when Pitot or Prandtl tubes are used, it may not be possible to achieve the recommended frequency specified in the table. In such case one flow measurement is acceptable, providing repetitive measurements at a sample point (for example at the centre of the water pipe) are taken to ensure water flow variations which may occur during the test are recorded and do not exceed the allowable limits of 6.3.4.

b) Type of units to be recorded depend on measurement methods actually used. Recording shall be in line with the precision of the instruments.

#### 6.3.6 Test duration

The test duration shall be chosen so that, taking into account the fluctuation of air temperatures and the scatters of operating parameters, a sufficient number (min. 10) of valid readings can be obtained.

The time period shall be 1 h minimum but not more than 8 h.

For mechanical draught, standardised cooling towers the thermal lag time is rather small (e.g. 2 minutes) and in general need not be considered. But if this time interval determined by the following equation is greater than two minutes, the test time period shall be lengthened by a like amount, and the test averages shall be based on compensating time spans, so that the readings chosen will represent true tower performance.

$$S_1 = \frac{Q_B}{60(m + m_b)}$$

Where as $S_1$ = thermal lag time (minutes)

$Q_B$ = average water volume in cold water basin during the test (l)

$m$ = hot water flow (l/s)

$m_b$ = blow down flow (l/s)

Where the thermal lag exceeds 5 minutes, it is assumed that the period of the cold water temperature readings lays an equivalent time behind the period of the other readings.

#### 6.3.7 Validity of test results

Fluctuations of load, temporary periods of bad weather, failure of instrumentation, or other incidents may require elimination of certain readings from the test data. If readings occur that are outside the limits of 6.3.3 or 6.3.4, the test should be continued until a minimum of one hour of uninterrupted data can be taken, all falling within the limits of 6.3.3 and 6.3.4.

## 7 Assessment of test results in view of guaranteed performance data

### 7.1 Assessment of test results

After completion of the measurements, the people assigned to do the test, the cooling tower owner or his representative, together with the cooling tower supplier, decide which span of readings shall be used in the final assessment, based on the requirements of 6.3. All readings shall be used though isolated anomalous readings resulting from faulty instrumentation or other similar causes may be eliminated from the assessment, providing all other data indicate that the test is valid per 6.3.3 and 6.3.4, and a minimum of ten valid readings remains for the assessment.

### 7.2 Finding of face values from performance data

Cold water face values are the water outlet temperatures derived from the performance curves for the tested model at the measured water flow, range, entering wet bulb temperature and absorbed fan power. The method of determining face values for the measured conditions will depend on the way the performance curves are presented. The method of how the predicted water outlet temperatures were found from the performance curves shall however be indicated in the test report.

## 7.3 Comparison with the guaranteed performance data

Using the measured values the face value of the cold water $t_{cfk}$ is found from the performance curves for each reading and the difference between the measured cold water temperature $t_{ck}$ and the face value $t_{cfk}$ as given by

$$t_k = t_{ck} \quad t_{cfk}$$

and the arithmetic average of all $t_K$ for all measuring periods is calculated from

$$t_a = \frac{1}{n} \sum_{k=1}^{n} t_k$$

The guaranteed condition has been achieved, if $t_a < 0$. Taking into account measurement errors the guaranteed condition is achieved, if

$$0 < \quad t_a \qquad t_t = \quad t_m + \quad t_b$$

The deviation $t_t$ is the sum of the error of the results of $t_m$ (calculated according to paragraph 8.6) and the base tolerance $t_b$. The base tolerance takes into account manufacturing tolerances of series cooling towers, which occur during the production of the equipment and cannot be quantified. Since manufacturing tolerances typically have a higher impact on smaller approaches (difficult thermal duties), they are defined as a base tolerance, which is set at $t_b = 0.2$ K.

# 8 Test tolerance

## 8.1 General

To compare the guaranteed cold water temperature with the measured cold water temperature, the tolerances of the temperature measurement shall be taken into account. In addition, deviations forthcoming from the measuring tolerances of wet bulb temperature, range, water flow rate and fan power shall be considered, since the cold water temperature depends on these quantities. The relationship of these quantities to the cold water temperature can generally be found in the performance curves.

Errors can occur through systematic non-measurable deviations during the test and through temporary fluctuations of the quantity to be measured.

## 8.2 Error created by measuring tolerances

### 8.2.1 General

The measurement errors of the individual parameters have influence on the determination of the cold water temperature. An example of performance curves which demonstrate how these influences can be determined is shown in annex A.

### 8.2.2 Influence of wet bulb measurement uncertainties $_w$

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

The variation of $t_w$ shall be selected so, that a relation between $t_w$ and $t_c$ is close to linear. (see annex A for example).

### 8.2.3 Influence of cooling range measurement uncertainties $_z$

The influence factor $_z$ indicates the change of cold water temperature $t_c$ 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 variation of $z$ shall be ± 1 K.

(see annex A for example)

### 8.2.4 Influence of fan power measurement uncertainties $_F$

The influence factor $_F$ indicates the change of cold water temperature $t_c$ 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. 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.

(see annex A for example)

### 8.2.5 Influence of water flow rate measurement uncertainties $_m$

The influence factor $_m$ indicates the change of cold water temperature $t_c$ 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. Variations of $m$ shall be ± 10 %.

(see annex A for example)

## 8.3 Determination of measuring equipment tolerances

The measuring tolerances for different instruments are indicated in clause 5. The values actually to be used shall be defined by the contractual parties prior to the measurement and should not exceed the values shown in Table 7.

**Table 7 — Measuring equipment tolerances acceptable for the test**

| Quantity | Acceptable tolerance of instrumentation |
|---|---|
| Wet bulb temperature, $t_w$ | 0,1 K |
| Water temperature, $t_c$ | 0,1 K |
| Water flow rate, $m$ | 3 % |
| Fan power, $F_P$ | 3 % |

For the individual instruments the systematic deviations $_{x}$ shall be determined from the operation guidelines for the instruments used or can be taken from Table 7.

The applicable tolerances ( $_{x}$) are combined with the influence factors $_{x}$ found in 8.2 and allow the calculation of the error caused by non-measurable systematic deviations of the operating parameters.

## 8.4 Determination of measuring tolerances

The error $t_s$ due to systematic non-measurable influences shall be calculated as follows :

$$t_s = \sqrt{( \;_{w} \;\; _{t_w})^2 + ( \;_{z} \; 2 \; _{t_c})^2 + ( \;_{m} \;\; _{m})^2 + ( \;_{F} \;\; _{F_P})^2 + ( \; _{t_c})^2}$$

The tolerance of the measurement of the cold water temperature $_{t_c}$ naturally is applied directly in the result.

## 8.5 Determination of random errors

Random events cause the differences $t_k$ between measured and guaranteed cold water temperature, calculated according to 7.2, to fluctuate around the average $t$ calculated from all measuring periods.

A measure for this fluctuation is the empirial standard deviation

$$S_{t_k} = \sqrt{\frac{1}{k \;\; 1} \sum_{k=1}^{k} ( \; t_a \;\;\; t_k)^2}$$

The measuring tolerance $t_r$ 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 Table 8.

$$t_r = \frac{S_t(k)}{\sqrt{k}} S_{t_k}$$

**Table 8 — Distribution according to Student for a level of confidence of 95 %**

| ***k*** | ***S*t (*k*)** | ***k*** | ***S*t (*k*)** |
|---|---|---|---|
| 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 |

### 8.6 Determination of the test tolerance

The test tolerance $t_m$ is the result of the tolerances caused by systematic $t_s$ and random $t_r$ deviations and can be calculated as follows :

$$t_m = \sqrt{t_3^2 + t_r^2}$$

The test tolerance $t_t$ is found by adding the base tolerance $t_b$.

$$t_t = t_m + t_b$$

## 9 Test report

The test report should include the following information:

a) place, date,

b) manufacturer of the cooling tower;

c) main dimensions (drawing, sketch or photograph);

d) guarantee clauses with documents;

e) statement that the test was conducted according to EN 13741;

f) report on how the measurements were made;

g) results of the measurement (in the form of Tables, reports and graphs) and the test analysis;

h) declaration on whether the guarantee was fulfilled.

# Annex A
(informative)

# Example

Cooling tower type : xyz

Number of cells : 2

Hot water entries : 1 per cell

Cold water outlets : 1 for two cells

**Design data:**

¾ water flow $m$ = 2 34,7 l/s

¾ hot water temp. $t_h$ = 30 °C

¾ cold water temp. $t_c$ = 24 °C

¾ wet bulb temp. $t_w$ = 19 °C

¾ fan power $F_P$ = 2 10 kW

NOTE In this example evaluation of pumping head is not included.

**Used instrumentation:**

¾ Temperatures

¾ water mercury thermometers with 0,1 K gradation

¾ wet bulb temp. aspiration psychrometer with 0,1 K gradation

¾ Water flow Pitot tube ( = 2 %)

¾ Fan power, motor amps Watt meter at switch board.

**Measuring locations:**

¾ water flow 1 measuring point in each feeder pipe

¾ hot water temperature 1 measuring point in each feeder pipe

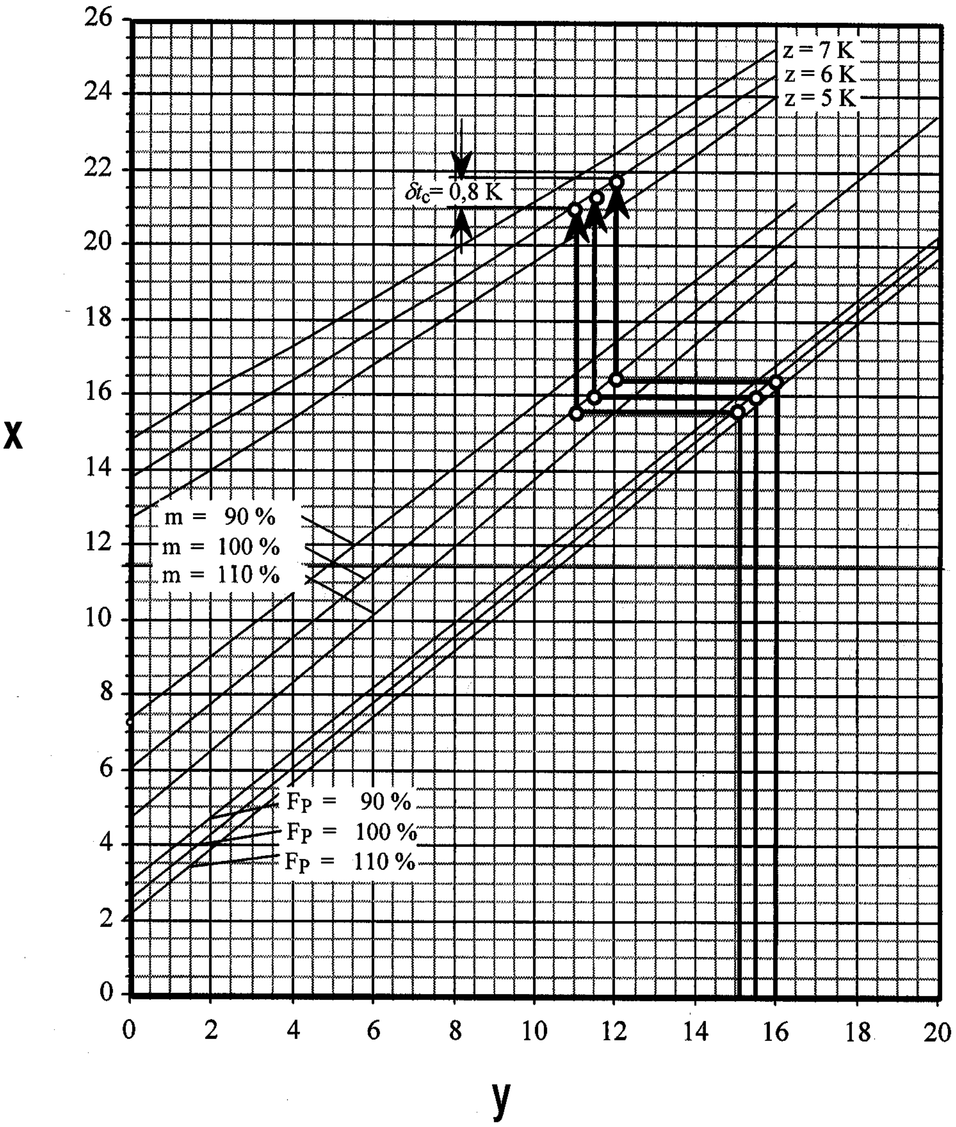
¾ cold water temperature 2 measuring points in common suction line

¾ wet bulb temperature 1 m in front of air entry, 4 measuring points at each air entry side

Test protocol in annex C and result analysis in annex D.

# Annex B
(informative)

## Performance curves




**Key**

x cold water temperature $t_c$

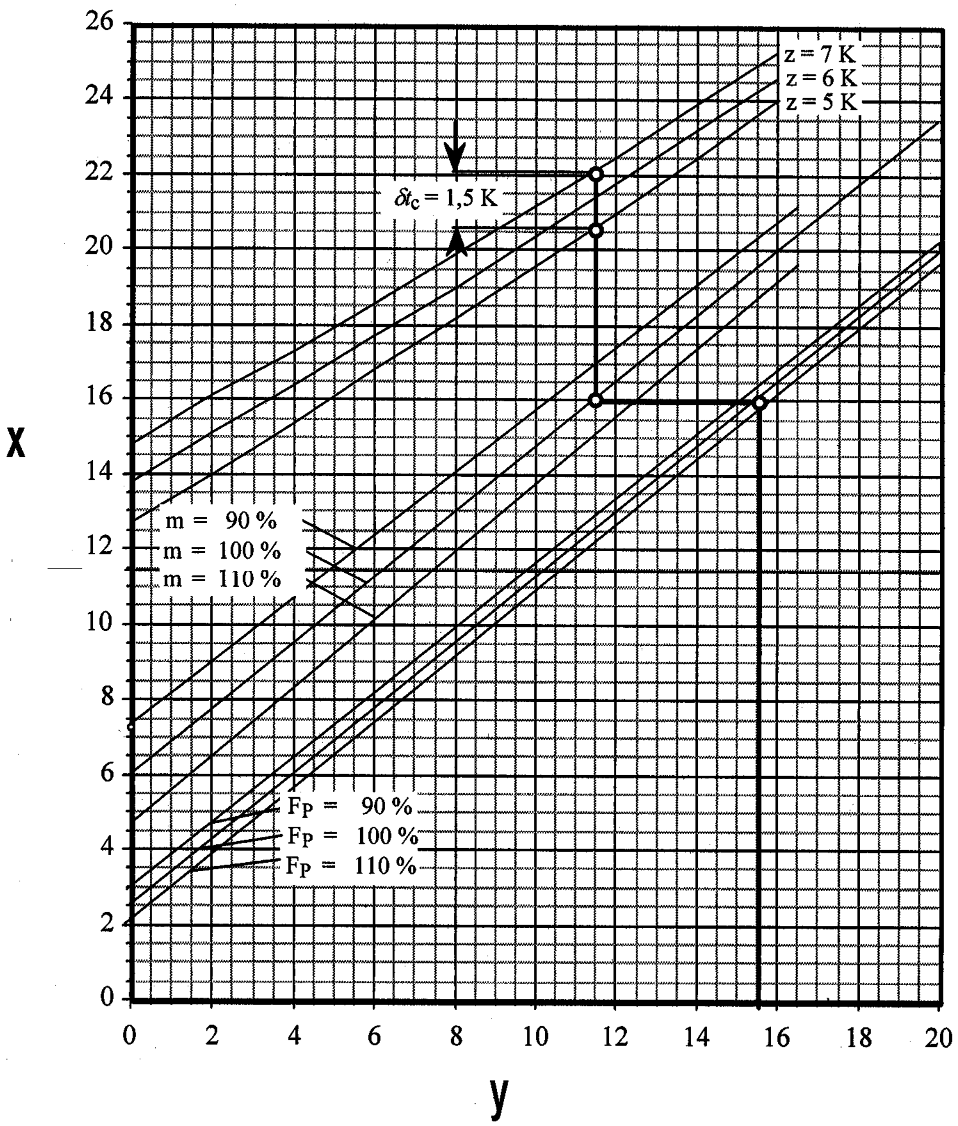
y wet bulb temperature $t_w$ (° C)

**Figure B.1**

Performance curve with example to find the change of the cold water temperature $t_c$ due to changes of the influencing factor "wet bulb temperature" $t_w$.

With : $t_w$ = 15,5 ± 0,5 °C→ $t_w$ = 1 °C; and $z$ = 6 K ; $F_P$ = 100 % ; $m$ = 100 % constant, the result is:

$$w = \frac{t_c}{t_w} = \frac{0{,}8K}{1°C} \qquad w = 0{,}8\frac{K}{°C}$$




**Key**

x cold water temperature $t_c$

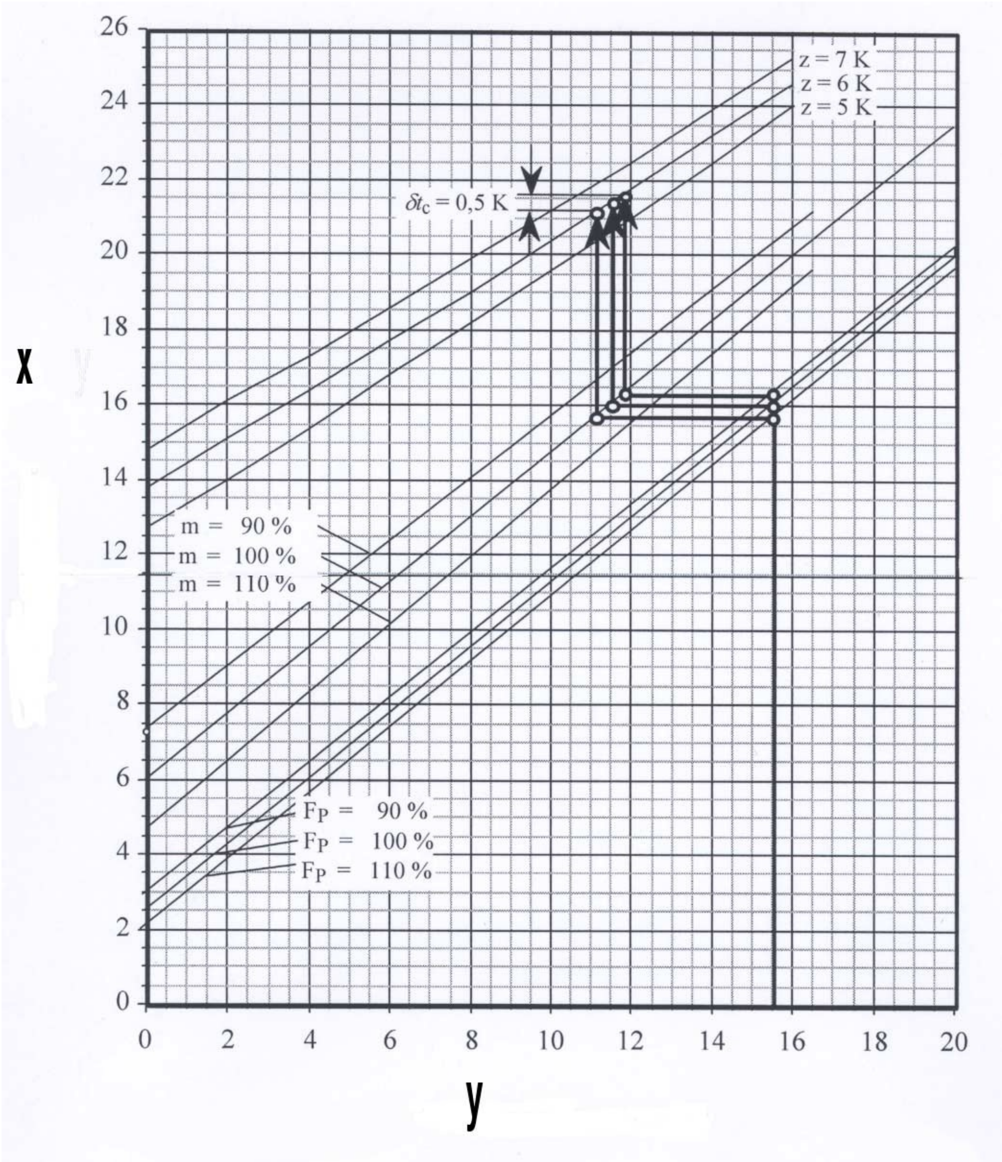
y wet bulb temperature $t_w$ (°C)

**Figure B.2**

Performance curve with example to find the change of the cold water temperature $t_c$ due to changes of the influencing factor "range *z*".

With : $z = 6 \pm 1$ K → $z = 2$ K ; and $t_w = 15{,}5$ °C ; $F_P = 100$ %, $m = 100$ % constant, the result is:

$$z = \frac{t_c}{z} = \frac{1{,}5K}{2K} \qquad z = 0{,}75\frac{K}{K}$$




**Key**

x cold water temperature $t_c$

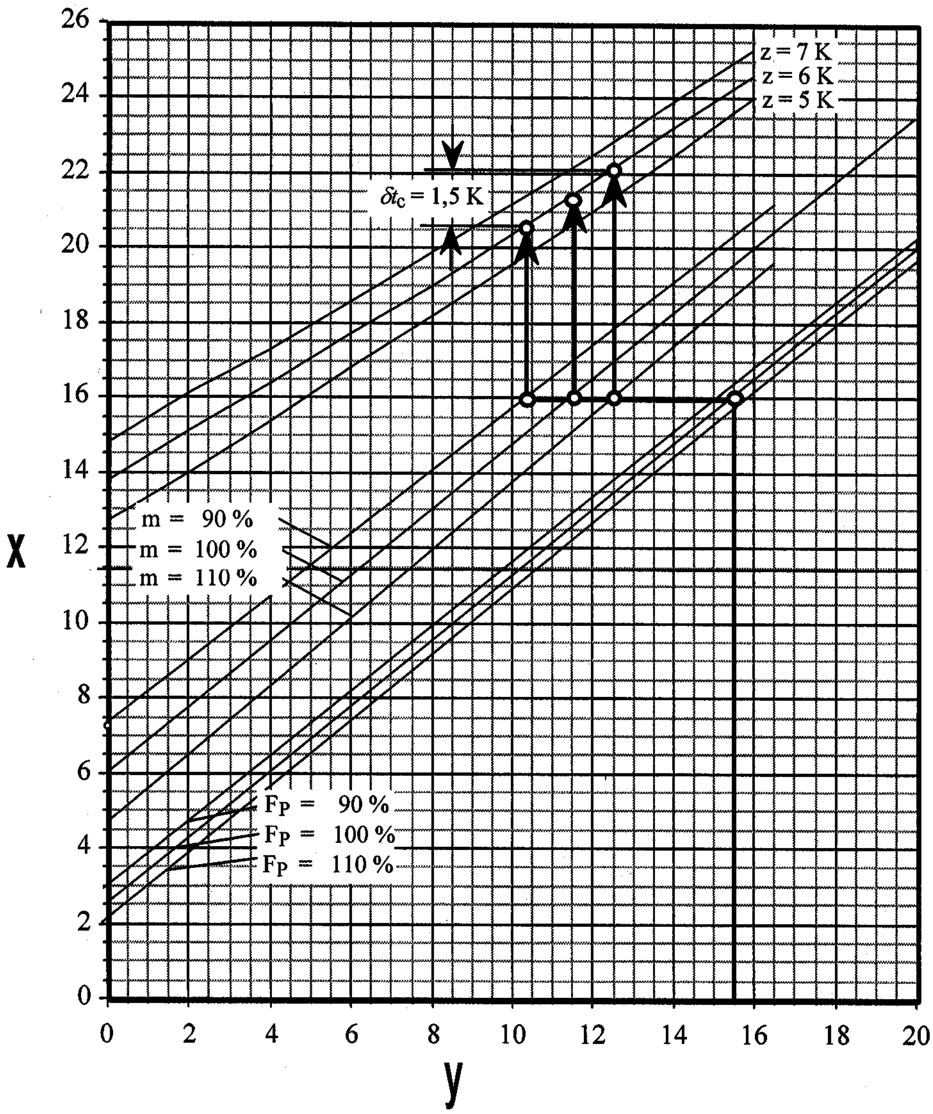
y wet bulb temperature $t_w$ (°C)

**Figure B.3**

Performance curve with example to find the change of the cold water temperature $t_c$ due to changes of the influencing factor "fan power $F_P$".

With : $F_P$ = 100 ± 10 % → $F_P$ = 20 %; and $t_w$ = 15,5 °C ; $z$ = 6 K, $m$ = 100 %, the result is :

$$_F = \frac{t_c}{F_P} = \frac{0{,}5K}{20\%} \qquad _F = 0{,}025\frac{K}{\%}$$




**Key**

x cold water temperature $t_c$

y wet bulb temperature $t_w$ (° C)

**Figure B.4**

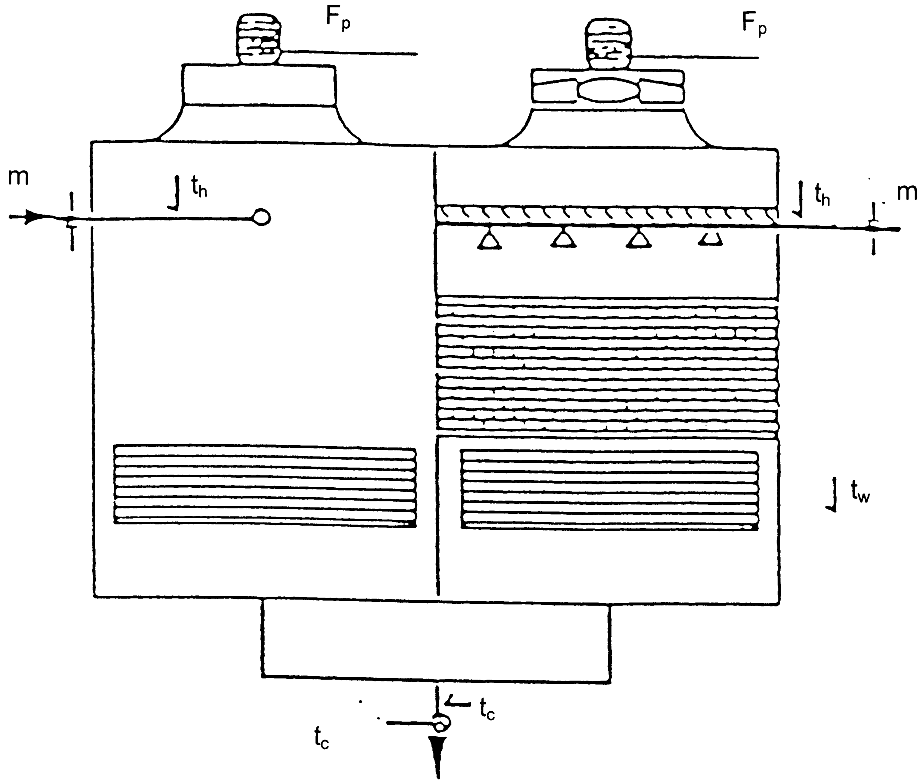
Performance curve with example to find the change of the cold water temperature $t_c$ due to changes of the influencing factor "water flow *m*".

With : $m = 100 \pm 10$ % → $m = 20$ %; and $t_w = 15{,}5$ °C ; $z = 6$ K, $F_P = 100$ % constant, the result is:

$$_{m} = \frac{t_c}{m} = \frac{1{,}5K}{20\%} \qquad _{m} = 0{,}075\frac{K}{\%}$$

# Annex C
(informative)

## Position of measuring points for cooling towers




**Key**

| | |
|---|---|
| $t_w$ | wet bulb temperature |
| $m$ | hot water flow |
| $t_h$ | hot water temperature |
| $t_c$ | cold water temperature |
| $F_P$ | fan power |

**Figure C.1 — Position of measuring points for a mechanical draught water cooling tower with two cells**

Acceptance Test of Standardized Mechanical Draught Cooling Towers

Model:.........................................

Location:.........................................

Supplier :.........................................

Date :.........................................

Tested by:.........................................

**Remarks:** Measured mean wind velocity during test c = 2.2 m/s

| Designation | Symbol | Unit | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reading | K | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Time | | | 12:00 | 12:05 | 12:10 | 12:15 | 12:20 | 12:25 | 12:30 | 12:35 | 12:40 | 12:45 | 12:50 | 12:55 | 13:00 |
| Entering wet bulb temperature 1 | tw 1 | °C | 15,2 | 15,2 | 15,4 | 15,6 | 15,5 | 15,5 | 15,4 | 15,5 | 15,6 | 15,6 | 15,7 | 15,6 | 15.5 |
| Entering wet bulb temperature 2 | tw 2 | °C | 15,0 | 15,1 | 15,3 | 15,3 | 15,4 | 15,5 | 15,5 | 15,3 | 15,4 | 15,4 | 15,5 | 15,4 | 15.3 |
| Entering wet bulb temperature 3 | tw 3 | °C | 15,2 | 15,1 | 15,2 | 15,3 | 15,4 | 15,4 | 15,4 | 15,4 | 15,3 | 15,3 | 15,2 | 15,2 | 15.3 |
| Entering wet bulb temperature 4 | tw 4 | °C | 15,2 | 15,3 | 15,3 | 15,4 | 15,4 | 15,5 | 15,4 | 15,5 | 15,5 | 15,5 | 15,5 | 15,5 | 15.5 |
| Average entering wet bulb temp. | twk | °C | 15,15 | 15,18 | 15,30 | 15,40 | 15,43 | 15,48 | 15,43 | 15,43 | 15,45 | 15,45 | 15,48 | 15,43 | 15,40 |
| Hot water temperature 1 | t h1 | °C | 26,7 | 26,8 | 27,3 | 27,4 | 27,5 | 27,9 | 27,8 | 27,8 | 27,9 | 28,1 | 28,2 | 28,2 | 28.1 |
| Hot water temperature 2 | t h2 | °C | 26,7 | 26,8 | 27,3 | 27,3 | 27,4 | 27,8 | 27,8 | 27,8 | 28,0 | 28,2 | 28,2 | 28,3 | 28.1 |
| Average hot water temperature | thk | °C | 26,70 | 26,80 | 27,30 | 27,35 | 27,45 | 27,85 | 27,80 | 27,80 | 27,95 | 28,15 | 28,20 | 28,25 | 28,10 |
| Cold water temperature 1 | tc1 | °C | 21,1 | 21,2 | 21,5 | 21,6 | 21,7 | 22,0 | 22,0 | 22,0 | 22,0 | 22,1 | 22,2 | 22,1 | 22.1 |
| Cold water temperature 2 | tc2 | °C | 21,2 | 21,2 | 21,6 | 21,7 | 21,8 | 22,1 | 22,0 | 22,0 | 22,1 | 22,2 | 22,2 | 22,2 | 22.1 |
| Average cold water temperature | tck | °C | 21,15 | 21,20 | 21,55 | 21,65 | 21,75 | 22,05 | 22,00 | 22,00 | 22,05 | 22,15 | 22,20 | 22.15 | 22.10 |
| Average range | zk | K | 5,55 | 5,60 | 5,75 | 5,70 | 5,70 | 5,80 | 5,80 | 5,80 | 5,90 | 6,00 | 6.00 | 6.10 | 6.00 |
| Water flow 1/ nominal value | m1 | % | 101 | | | | 103 | | | | | 104 | | | |
| Water flow 2/ nominal value | m2 | % | 101 | | | | 103 | | | | | 104 | | | |
| Average water flow / nominal value | mk | % | 101 | | | | 103 | | | | | 104 | | | |
| Fan motor power 1 | FP 1 | kW | 9,5 | | | | | | | | | | | | 9.5 |
| Fan motor power 2 | FP 2 | kW | 9,4 | | | | | | | | | | | | 9.4 |
| Average fan motor power/ nominal value | FP | % | 95 | | | | | | | | | | | | 95 |
| | | | | | | | | from performance curve | | | | | | | |
| Face value of cold water temp. | tcfk | °C | 21,0 | 21,1 | 21,3 | 21,4 | 21,5 | 21,7 | 21,6 | 21,6 | 21,8 | 21.9 | 21.9 | 21.9 | 21.8 |
| Diff.nom.value to measured value | Δ tk | °C | 0,15 | 0,10 | 0,25 | 0,25 | 0,25 | 0,35 | 0,40 | 0,40 | 0,25 | 0.25 | 0.30 | 0.25 | 0.30 |
| Av. difference for all readings | Δ ta | °C | 0,27 | | | | | | | | | | | | |

**Figure C.2 Example of a test report**

# Annex D
(informative)

## Test Result analysis

Acceptance Test of Standardized Mechanical Draught Cooling Towers

Model:……………………………………

Location:…………………………………

Supplier :…………………………………

Date :……………………………………

Tested by:…………………………………

**Remarks:** Measured mean wind velocity during test c = 2.2 m/s

## Test Tolerance

***Error created by non-measurable systematic deviations of operating parameters***

**Instrumentation tolerances**

| | | | | | Influence of measurement uncertainties ( derived from performance curve) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Wet bulb temperature | εtw | K | 0,1 | * | φw | 0,8 K/°C | = | φw*εtw | 0,08 | K |
| Water temperature | εt | K | 0,1 | * | φz | 0,75 K/°C | = | φz*2*εt | 0,15 | K |
| Water flow | εm | % | 2 | * | φm | 0,075 K/1% | = | φm*εm | 0,15 | K |
| Fan power | εf | % | 3 | * | φF | 0,025 K/1% | = | φf*εf | 0,075 | K |

| | | | |
|---|---|---|---|
| **Error propagation** | δ t s | K | **0,259** |

***Error caused by random deviation of measurement results***

| | | | |
|---|---|---|---|
| Standard deviation | s Δ tk | K | 0,085 |
| Student number for 95 % | St | | 2,179 |
| Tolerance caused by random deviations | δ tr | K | **0,052** |

***Determination of the test tolerance***

| | | | |
|---|---|---|---|
| Tolerance caused by deviations | δ tm | K | 0,264 |
| Test tolerance | δ tT | K | **0,464** |

| 0,2 K | base tolerance δ tb |
|---|---|

**Test result** Δta < δ tT **Cooling tower performs as predicted**

**Figure D.1 Example of test result analysis and calculation of test tolerance.**

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