BS 4485 : Part 3 : 1988

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British Standard

Water cooling towers

Part 3. Code of practice for thermal and functional design

Tours de refroidissement par l'eau
Partie 3. Conception thermique et fonctionnelle — Code de bonne pratique

Wasserkühltürme
Teil 3. Leitfaden für die Bemessung unter thermischen und funktionalen Gesichtspunkten

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Foreword

This Part of BS 4485, which has been prepared under the direction of the Civil Engineering and Building Standards Committee, deals with the thermal and functional design of natural draught, mechanical draught and factory prefabricated cooling towers. This Part of BS 4485 is a revision of BS 4485 : Part 3 : 1977, together with its Addendum No. 1 (1978) both of which are withdrawn.

In this revision the following principal changes have been made.

(a) The guidelines on water treatment have been expanded as these were not considered sufficient for good operating practice.

(b) Reference has been made to the potential health hazard arising from the bacterial population of cooling towers, as it relates to the design of the towers. However, operational techniques for control in this area are outside the scope of this Part of BS 4485.

(c) Factory prefabricated cooling towers previously dealt with in Addendum No. 1 to BS 4485 : Part 3 : 1977 have been covered by suitable modification of the main text of this Part of BS 4485.

(d) Information to be supplied by the purchaser and the manufacturer, which was included in Addendum No. 1 to BS 4485 : Part 3 : 1977, now appears as appendix A in this Part of BS 4485 as it is considered relevant to all types of cooling towers.

(e) Materials of construction have been omitted as these are dealt with in BS 4485 : Part 4*.

(f) A new clause on maintenance has been added which was in Addendum No. 1 to BS 4485 : Part 3 : 1977.

This Part of BS 4485 provides information on design principles, siting and spacing. Guidance is given on specific thermal and hydraulic requirements, on mechanical equipment and on environmental aspects such as discharge into rivers and cooling tower noise.

The other Parts of BS 4485 are as follows.

Part 1 Glossary of terms

Part 2 Methods for performance testing

Part 4 Structural design of cooling towers

Where necessary, definitions have been included in the revisions of BS 4485 : Parts 2, 3 and 4 so that when they have all been published BS 4485 : Part 1 can be withdrawn.

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Contents

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Code of practice

1 Scope

This Part of BS 4485 gives recommendations for the thermal and functional design of industrial and natural draught water cooling towers and factory prefabricated cooling towers.

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Symbols and units

For the purposes of this Part of BS 4485, the symbols and units given in table 1 apply.

Table 1. Symbols and units

Symbol	Quantity	Unit
a	Area of effective transfer surface per unit of tower packing volume	m^2/m^3
A_s	Area of sound propagation	m^2
A_p	Total packing area normal to air flow	m^2
B	Width or length dimensions perpendicular to tower axis	m
c	Specific heat capacity of water	kJ/(kg·K)
C	Concentration factor at equilibrium	
C_T	Concentration factor at time T	
C_1	Original make-up concentration of impurities	%
C_2	Stable state concentration of impurities in circulating system under continuous purge	%
D	Diameter	m
g	Acceleration due to gravity	
G	Mass flow of dry air per unit plan area of packing	$kg/(m^2 \cdot s)$
h	Enthalpy* of air-water vapour mixture	kJ/kg
h_m	Mean driving force	kJ/kg
h_G	Enthalpy* of air-water vapour mixture passing through the packing	kJ/kg
h_L	Enthalpy* of saturated air film in contact with and at the temperature of the water passing through the packing	kJ/kg
H	Height (vertical distance above or below basin kerb level)	m
H_e	Effective height of shell, normally taken as height from middle of packing to top of shell	m
K	Coefficient of mass transfer defined in terms of difference in absolute humidity	$kg/[m^2 \cdot s \cdot (kg/kg)]$
L	Mass water flow per unit plan area of packing	$kg/(m^2 \cdot s)$
m_1	Mass of solute	kg
m_2	Mass of solvent	kg
M_1	Relative molecular mass of solute	
M_2	Relative molecular mass of solvent	
n	Mole fraction of solvent	
N	Number of velocity heads representing the system resistance	
p	Total pressure	Pa
p_2	Vapour pressure of pure solvent	Pa
p_3	Vapour pressure of solution	Pa
P_s	Sound pressure	N/m^2
P_0	Sound pressure reference datum	N/m^2
Q_l	Circulating water flow	m^3/s
R	Surface radius from sound source	m

* All enthalpies relate to 1 kg dry air and associated water vapour.

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Table 1 *(concluded)*

Symbol	Quantity	Unit
S_w	Sound power level reading at a point source	dB
S_p	Sound pressure level reading some specified distance away from the source	dB
T	Time	h
t_b	Temperature of water with which boundary vapour is associated	°C
t_m	Mean water temperature	°C
t_{DB}	Dry bulb temperature	°C
t_E	Temperature of mixture of recooled water and make-up leaving cold water basin	°C
t_{WB}	Wet bulb temperature	°C
t_1	Hot water temperature at inlet	°C
t_2	Recooled water temperature	°C
V	Effective packing volume per unit area of packing	m^3/m^2
V_b	Volume in cold water basin	m^3
v_e	Evaporation rate	m^3/h
v_p	Purge rate	m^3/h
V_s	Volume in system excluding pond	m^3
w_1	Atmospheric moisture content of ambient air condition	kg/kg
w_2	Atmospheric moisture content at mean water temperature saturated conditions	kg/kg
W_d	Fan driver power	kW
W_o	Sound power threshold	W
W_s	Sound power	W
x	Pond surface area	m^2
X	Spacing	m
ρ	Density of air	kg/m^3
Δh	Change in air enthalpy	kJ/kg
Δt	Cooling range	K
$\Delta \rho$	Change in air density	kg/m^3
	Approach	K
	Power	W
KaV/L	Tower characteristic	
L/G	Water/air ratio	

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3 Thermal design principles

3.1 Cooling process

A water cooling tower is a heat exchanger in which warm water falls gravitationally through a cooler current of air. Heat is transferred from the water to the air in two ways:

(a) by evaporation as latent heat of water vapour;

(b) by sensible heat in warming the air current in its passage through the tower.

As a general measure, about 80 % of the cooling occurs by evaporation and about 20 % by sensible heat transfer.

The transfer of heat is effected from the water through the boundary film of saturated air in contact with the water surface. This air is saturated at the water temperature. From this saturated air film, heat transfer occurs to the general mass of air flowing through the tower.

In the interests of efficiency, it is essential that both the area of water surface in contact with the air and the time of contact be as great as possible. This may be achieved either by forming a large number of water droplets as repetitive splash effects in one basic kind of tower packing, or by leading the water in a thin film over lengthy surfaces.

Air flow is achieved either by reliance on wind effects, by thermal draught or by mechanical means. The direction of air travel may be opposed to the direction of water flow giving counterflow conditions, or may be at right angles to the flow of water giving crossflow conditions. Although the methods of analysis may be different for counterflow and crossflow conditions, the fundamental heat transfer process is the same in both cases. In some designs mixed flow conditions exist. These patterns of flow are illustrated in figure 1.

Present cooling tower technology relies on the fact that, with acceptable error, the effects of evaporative and sensible heat transfer can be combined into one dependent on enthalpy difference. The difference concerned is that between the enthalpy of the film of air surrounding the water surface (taken to be at water temperature) and the enthalpy of the general mass of air flowing through the tower. This enthalpy difference varies according to the point of measurement in the tower, but at all points it provides the enthalpy potential or driving force for the heat transfer.

The so-called combined transfer theory depends upon certain approximations, which are reasonable at normal cooling water temperatures and particularly when the characteristics of the packing have been determined in accordance with the theory. However, the approximations become progressively less valid with increasing water temperature and a more exact analysis should be adopted in applications where the mean water temperature exceeds 35 °C.

The air and air-water film conditions, in passage through the tower, may be illustrated on a psychrometric chart as shown in figure 2. The cooling range of the tower corresponds to the difference in temperature of the air-water film between entry to and exit from the tower.

Air enters the tower having wet and dry bulb characteristics dependent on the ambient conditions. It is generally in an unsaturated state and achieves near-saturation in passing through the tower. It may be considered saturated at exit in all but very dry climates.

The enthalpy of the entering air is considered, with acceptable error, to be equivalent to the enthalpy of air saturated at the wet bulb temperature. For the purposes of enthalpy differences in heat transfer, only the wet bulb temperature of the ambient air is therefore of significance.

The dry bulb temperature has, however, to be considered for draught assessment purposes in those towers whose air flow relies on thermally created draught. The thermal draught is defined by the change of density of the air between entry to and exit from the cooling tower multiplied by the effective shell height, and the dry bulb temperature as well as the wet bulb temperature is of significance in determining the density of ambient air.

The theoretical limit to which the water may be cooled is that of the ambient wet bulb temperature. This could only be achieved with an infinitely large tower and, in practice, the terminal or recooled water temperature has some approach to the wet bulb temperature. This approach may vary from about 3 K in rigorous chemical plant cooling to 10 K or above in easier conditions. The approach is fixed only at design air conditions and increases or decreases as ambient conditions vary from cold to warm, respectively, about the design point.

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