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Hygrothermal performance of building equipment and industrial installations — Calculation of water vapour diffusion — Cold pipe insulation systems

Performance hygrothermique des équipements de bâtiments et installations industrielles — Calcul de la diffusion de vapeur d'eau — Systèmes d'isolation de tuyauteries froides

[Revision of first edition (ISO 15758:2004)]

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ISO/CEN PARALLEL PROCESSING

This draft has been developed within the International Organization for Standardization (ISO), and processed under the **ISO-lead** mode of collaboration as defined in the Vienna Agreement.

This draft is hereby submitted to the ISO member bodies and to the CEN member bodies for a parallel five-month enquiry.

Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month approval vote in ISO and formal vote in CEN.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

Pour accélérer la distribution, le présent document est distribué tel qu'il est parvenu du secrétariat du comité. Le travail de rédaction et de composition de texte sera effectué au Secrétariat central de l'ISO au stade de publication.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15758 was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*, in cooperation with CEN/TC 89, *Thermal performance of buildings and building components*.

This second edition cancels and replaces the first edition (ISO 15758:2004) which has been technically revised. The main changes compared to the previous edition are given in the following table:

Clause	Changes
5 b) Boundary conditions	The alternative to use the annual mean temperature and vapour pressure is removed. Only the monthly mean temperature and vapour pressure of the warmest month shall be used.
6.3 Calculation of the rate of condensation in a multi-layer insulation system f)	The method of calculation is changed. The total amount of the condensation water in the whole pipe system is calculated based only on the outermost tangent to the saturation pressure, p_{sat}.
6.3 Figure 1	Figure 1 is changed.
Annex A.3	Changed.
Annex B Experimental determination of the evaporation rate from the surface of a wet wick fabric	The explanation of the system with capacity for drying is added.
Bibliography	References [10] to [15] are added.

Introduction

If the thermal insulation of a cold pipe system is not completely water vapour tight, there will be a flow of water vapour from the warm environment to the surface of the pipe, whenever the temperature of the surface of the cold pipe is below the dew point of the ambient air. This flow of water vapour leads to an interstitial condensation in the insulation layer and/or dew formation on the surface of the pipe itself. Interstitial condensation may cause the insulation material to deteriorate and dew formation on the surface of a metal pipe may cause corrosion over time. If the temperature is below 0 °C ice will be formed and the methods of this standard will not apply.

In period , when the dew point of the ambient air is higher than the temperature of the outer surface of the insulation, surface condensation will occur. This is dealt with in ISO 12241.

Different measures are available to control water vapour transfer and reduce the amount of condensation. The following are normally applied:

a) Installation of a vapour retarder;

b) Use of insulation materials with a high water vapour resistance factor (low permeability);

c) Use of a vapour retarder and a capillary active fabric to continuously remove condensed water from the pipe surface to the environment, see Annex B for an example.

Which protection measure is chosen depends on the ambient climate, the temperature of the medium in the pipe and the water vapour diffusion resistance of the insulation layer. The success of any system is strongly dependent on workmanship and maintenance. In any case anti-corrosion measures should be applied to a metal pipe in severe conditions.

The expected economic lifetime of an insulation system, assuming a maximum acceptable accumulated moisture content, can be calculated using the methods in this standard.

Hygrothermal performance of building equipment and industrial installations — Calculation of water vapour diffusion — Cold pipe insulation systems

1 Scope

This standard specifies a method to calculate the density of water vapour flow rate in cold pipe insulation systems, and the total amount of water diffused into the insulation over time. This calculation method presupposes that water vapour can only migrate into the insulation system by diffusion, with no contribution from airflow. It also assumes the use of homogeneous, isotropic insulation materials so that the water vapour partial pressure is constant at all points equidistant from the axis of the pipe.

The standard is applicable when the temperature of the medium in the pipe is above 0 °C. It applies to pipes inside buildings as well as in the open air.

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.

ISO 9346, *Thermal insulation – Mass transfer – Physical quantities and definitions*

ISO 12241, *Thermal insulation for building equipment and industrial installations – Calculation rules*

ISO 12572, *Hygrothermal performance of building materials and products – Determination of water vapour transmission properties*

ISO 13788, *Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods*

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9346, ISO 12572, ISO 13788 and the following apply.

3.1.1
exposed moist area
surface area of a capillary active fabric that is exposed to the ambient atmosphere

3.1.2
vapour retarder
material with high resistance to the flow of water vapour

3.1.3
corrected water vapour diffusion equivalent air layer thickness
thickness of an imaginary plane layer with μ =1, and an area of πD_j which has the same diffusion resistance as the layer j with $\mu = \mu_j$

NOTE See Formula (14 should be 18?).

3.2 Symbols and units

Table 1 — Symbols and units

Symbol	Quantity	Unit
A'_e	surface area from which evaporation takes place per linear metre of the pipe	m^2/m
D_0	outside diameter of cold pipe	m
D_j	outside diameter of j-th layer of an insulation system	m
G	total moisture uptake over a period per linear metre of pipe (refer to formula (2))	kg/m
G'	total moisture uptake over a period per linear metre of pipe	kg/m
P	actual atmospheric pressure	Pa
P_0	standard atmospheric pressure = 101 325	Pa
R_v	gas constant for water vapour = 461,5	J/(kg·K)
T	thermodynamic temperature	K
Z'_{fl}	water vapour resistance of one thin foil, cladding or skin per linear metre of pipe	m·s·Pa/kg
Z'_j	water vapour resistance of j-th layer of an insulation system per linear metre of pipe	m·s·Pa/kg
Z'_P	water vapour resistance of insulation system per linear metre of pipe	m·s·Pa/kg
d	thickness of an insulation layer	m
f_e	evaporation factor	$kg/(m^2·s·Pa)$
g'	water vapour flow rate within the insulation per linear metre of pipe	kg/(m·s)
g'_c	rate of condensation per linear metre of pipe	kg/(m·s)
g'_e	evaporation rate per linear metre of pipe	kg/(m·s)
h_c	convection heat transfer coefficient	$W/(m^2·K)$
p	partial water vapour pressure	Pa
p_a	partial water vapour pressure of air	Pa

Symbol	Quantity	Unit
p_{sat}	saturated water vapour pressure	Pa
s_d	water vapour diffusion equivalent air layer thickness	m
s_{df}	water vapour diffusion equivalent air layer thickness of foils	m
t	period of calculation (month or year)	month, year
x	distance	m
δ	water vapour permeability	kg/(m·s·Pa)
δ_0	water vapour permeability of air	kg/(m·s·Pa)
$\sigma_{d,j}$	corrected water vapour diffusion equivalent air layer thickness of layer j	M
$\tilde{\sigma}_{d,j}$	total corrected water vapour diffusion equivalent air layer thickness from surface of cold pipe to the outside of layer j	M
μ	water vapour resistance factor	–
θ_0	temperature of the medium in the pipe	°C
NOTE For practical reasons, hours or days are often used instead of seconds as time units.		

4 Calculation formulae

4.1 General

The density of water vapour flow rate, g, through a material is calculated by the following formula:

$$g = -\delta \frac{dp}{dx} \tag{1}$$

where

δ is the water vapour permeability of the material.

The total moisture uptake during a period, G, is given by:

$$G = \int_0^t g \, dt \tag{2}$$

In calculations the diffusion resistance factor, μ, is commonly used instead of the permeability

$$\mu = \frac{\delta_0}{\delta} \tag{3}$$

where δ_0 is the water vapour permeability of still air, which can be calculated from:

$$\delta_0 = \frac{0{,}083 \times P_0}{R_v\ T\ P}\left(\frac{T}{273}\right)^{1{,}81} \tag{4}$$

For approximate calculations, δ_0 can be assumed to be constant in the temperature range under consideration; the following value can therefore be used:

$$\delta_0 = 2{,}0 \times 10^{-10} \tag{5}$$

4.2 Homogeneous insulation

In the case of a cold pipe with a single homogeneous layer of insulation, the density of water vapour flow per metre of an insulated cold pipe is given by replacing the differential expression by the vapour pressure difference in Formula (1):

$$g' = \frac{p_a - p_{sat}(\theta_0)}{Z'_P} \tag{6}$$

where

p_a is the vapour pressure of the ambient air, in Pa;

$p_{sat}(\theta_0)$ is the saturation vapour pressure at the outside surface of the pipe, in Pa;

Z'_P is the water vapour resistance per linear metre of the pipe insulation, in m·s·Pa/kg, defined by Formula (7):

$$Z'_P = \frac{\ln\left(\frac{D_1}{D_0}\right)}{2\,\pi\,\delta} \tag{7}$$

If the actual vapour pressure p does not cross the saturation pressure p_{sat}, condensation occurs only at the surface of the cold pipe when the actual vapour pressure does not cross the saturation vapour pressure.

The total water uptake over a period t is then given by:

$$G' = \int_0^t \frac{p_a(t) - p_{sat}(\theta_0(t))}{Z'_P}\,dt \tag{8}$$

