SLOVENSKI STANDARD
oSIST prEN ISO 12241:2021

01-maj-2021

Toplotna izolacija za opremo stavb in industrijske inštalacije - Pravila za računanje (ISO/DIS 12241:2021)

Thermal insulation for building equipment and industrial installations - Calculation rules (ISO/DIS 12241:2021)

Wärmedämmung an haus- und betriebstechnischen Anlagen - Berechnungsregeln (ISO/DIS 12241:2021)

Isolation thermique des équipements de bâtiments et des installations industrielles - Méthodes de calcul (ISO/DIS 12241:2021)

Ta slovenski standard je istoveten z: prEN ISO 12241

ICS:

91.120.10	Toplotna izolacija stavb	Thermal insulation of buildings
91.140.01	Napeljave v stavbah na splošno	Installations in buildings in general

oSIST prEN ISO 12241:2021 **en,fr,de**

DRAFT INTERNATIONAL STANDARD
ISO/DIS 12241

ISO/TC **163**/SC **2** Secretariat: **SN**

Voting begins on:
2021-02-23

Voting terminates on:
2021-05-18

Thermal insulation for building equipment and industrial installations — Calculation rules

Isolation thermique des équipements de bâtiments et des installations industrielles — Règles de calcul

ICS: 91.140.01; 91.120.10

This document is circulated as received from the committee secretariat.

ISO/CEN PARALLEL PROCESSING

Reference number
ISO/DIS 12241:2021(E)

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Published in Switzerland

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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 12241 was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*.

This second edition cancels and replaces the first edition (ISO 12241:1998), which has been technically revised, including methods to determine the correction terms for thermal transmittance and linear thermal transmittance for pipes that are added to the calculated thermal transmittance to obtain the total thermal transmittance to calculate the total heat losses for an industrial installation.

Introduction

Methods relating to conduction are direct mathematical derivations from Fourier's law of heat conduction, so no significant difference in the equations used in the member countries exists. For convection and radiation, however, there are no methods in practical use that are mathematically traceable to Newton's law of cooling or the Stefan-Boltzman law of thermal radiation, without some empirical element. For convection in particular, many different equations have been developed, based on laboratory data. Different equations have become popular in different countries, and no exact means are available to select between these equations.

Within the limitations given below, these methods can be applied to most types of industrial, thermal-insulation, heat-transfer problems.

1. These methods do not take into account the permeation of air and the transmittance of thermal radiation through transparent media.

2. The equations in these methods require for their solution that some system variables be known, given, assumed or measured. In all cases, the accuracy of the results depends on the accuracy of the input variables. This International Standard contains no guidelines for accurate measurement of any of the variables. However, it does contain guides that have proven satisfactory for estimating some of the variables for many industrial thermal systems.

3. When the steady-state calculations are used in a changing thermal environment (process equipment operating year-round, outdoors, for example), it is necessary to use local weather data based on yearly averages or yearly extremes of the weather variables (depending on the nature of the particular calculation) for the calculations in this International Standard.

4. In particular, the user should not infer from the methods of this International Standard that either insulation quality or avoidance of dew formation can be reliably assured based on minimal, simple measurements and application of the basic calculation methods given here. For most industrial heat flow surfaces, there is no isothermal state (no one, homogeneous temperature across the surface), but rather a varying temperature profile. Furthermore, the heat flow through a surface at any point is a function of several variables that are not directly related to insulation quality. Among others, these variables include ambient temperature, movement of the air, roughness and emissivity of the heat flow surface, and the radiation exchange with the surroundings (which often vary widely). For calculation of dew formation, variability of the local humidity is an important factor.

5. Except inside buildings, the average temperature of the radiant background seldom corresponds to the air temperature, and measurement of background temperatures, emissivities and exposure areas is beyond the scope of this International Standard. For these reasons, neither the surface temperature nor the temperature difference between the surface and the air can be used as a reliable indicator of insulation performance or avoidance of dew formation.

Clauses 4 and 5 of this International Standard give the methods used for industrial thermal insulation calculations not covered by more specific standards.

Clauses 6 and 7 of this International Standard are adaptations of the general equation for specific applications of calculating heat flow, temperature drop, and freezing times in pipes and other vessels. Thermal insulation to heating/cooling systems such as a boiler and refrigerator are not dealt with by this International Standard.

Annexes A and B of this International Standard are for information only.

Thermal insulation for building equipment and industrial installations — Calculation rules

1 Scope

This International Standard gives rules for the calculation of heat-transfer-related properties of building equipment and industrial installations, predominantly under steady-state conditions. This International Standard also gives a simplified approach for the treatment of thermal bridges.

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 7345, *Thermal performance of buildings and building components — Physical quantities and definitions*

ISO 9346, *Hygrothermal performance of buildings and building materials — Physical quantities for mass transfer — Vocabulary*

ISO 10211, *Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations*

ISO 13787, *Thermal insulation products for building equipment and industrial installations — Determination of declared thermal conductivity*

ISO 23993, *Thermal insulation products for building equipment and industrial installations — Determination of design thermal conductivity*

VDI 4610-2, *Energy efficiency of operational installations - Thermal bridges catalogue*

VDI 2055-1, *Thermal insulation of heated and refrigerated operational installation – Calculation rules*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345, ISO 9346, ISO 13787 and ISO 23993 apply.

3.2 Definition of symbols

Symbol	Definition	Unit
A	area	m^2
A_s	solar absorption coefficient	
a	length of a rectangle	m
a_r	temperature factor	K^3
b	width of a rectangle	m
C'	thickness parameter (see 4.2.2)	m
C_r	radiation coefficient	$W/(m^2 \cdot K^4)$
c_p	specific heat capacity at constant pressure	$J/(kg \cdot K)$

Symbol	Definition	Unit
D	diameter	m
d	thickness	m
F	overall conversion factor for thermal conductivity	
Gr	Grashof number	
H	height	m
h	surface coefficient of heat transfer	W/(m^2·K)
J_s	solar radiation	W/m^2
K	thermal bridge coefficient	W/K
L	length, pipe length	m
l	characteristic length	m
m	mass	kg
$\dot{m}$	mass flow rate	kg/s
Nu	Nusselt number	
P	perimeter	m
p	pressure	Pa
Pr	Prandtl number	
q	density of heat flow rate	W/m^2 or W/m
R	thermal resistance	m^2·K/W or m·K/W or K/W
Re	Reynolds number	
T	thermodynamic temperature	K
t	time	s
U	thermal transmittance	W/(m^2·K) or W/(m·K) or W/K
w	velocity of the air or other fluid	m/s
α	coefficient of longitudinal temperature drop	m^{-1}
α'	coefficient of cooling time	s^{-1}
Δh	specific enthalpy; latent heat	J/kg
ε	emissivity	
Φ	heat flow rate	W
λ	design thermal conductivity	W/(m·K)
λ_D	declared thermal conductivity	W/(m·K)
θ	Celsius temperature	°C
ρ	density	kg/m^3
φ	relative humidity	%
σ	Stefan-Boltzmann constant (see Reference[8])	W/(m^2·K^4)
ν	kinematic viscosity of air or other fluid	m^2/s
Δ	difference	
ΔA	equivalent area	m^2
Δl	equivalent length	m

3.3 Subscripts

A	valve	Ka	insulation box
a	ambient, anchore	l	linear
av	average	lab	laboratory
B	thermal bridge	MRT	mean radiant temperature

A	valve	Ka	insulation box
c	cooling	P	pump
cv	convection	p	pipe
cs	cross section	r	radiation
d	duct, dew point	ref	reference
E	soil	s	surface
e	exterior, external	se	exterior surface
ef	effective	si	interior surface
en	entrance	sph	spherical
ex	exit	sq	per square
f	fluid	T	total
fa	frontal of the fin	tw	start freezing
fi	final	V	vertical
fl	flange	v	vessel, cooling
fr	freezing	W	wall
H	horizontal	w	water
i	interior, internal	wp	start freezing
in	initial		

4 Calculation methods for heat transfer

4.1 Fundamental equations for heat transfer

4.1.1 General

The equations given in Clause 4 apply only to the case of heat transfer in steady state, i.e. to the case where temperatures remain constant in time at any point of the medium considered. The design thermal conductivity is temperature-dependent; see Figure 1, dashed line. However, in this International Standard, the design value for the mean temperature for each layer shall be used.

4.1.2 Thermal conduction

Thermal conduction normally describes molecular heat transfer in solids, liquids, and gases under the effect of a temperature gradient.

It is assumed in the calculation that a temperature gradient exists in one direction only and that the temperature is constant in planes perpendicular to it.

The density of heat flow rate, q, for a plane wall in the x-direction is given by Equation (1):

$$q = -\lambda \cdot \frac{d\theta}{dx} \tag{1}$$

For a single layer, Equations (2), (3) and (4) hold:

$$q = -\frac{\lambda}{d} \cdot (\theta_{si} - \theta_{se}) \tag{2}$$

or

$$q = \left(\frac{\theta_{si} - \theta_{se}}{R} \right) \tag{3}$$

Where

$$R = \frac{d}{\lambda} \tag{4}$$

where

λ is the design thermal conductivity of the insulation product or system, expressed in W/(m·K);

d is the thickness of the plane wall, expressed in m;

θ_{si} is the temperature of the internal surface;

θ_{se} is the temperature of the external surface;

R is the thermal resistance of the wall, expressed in m^2·K/W.

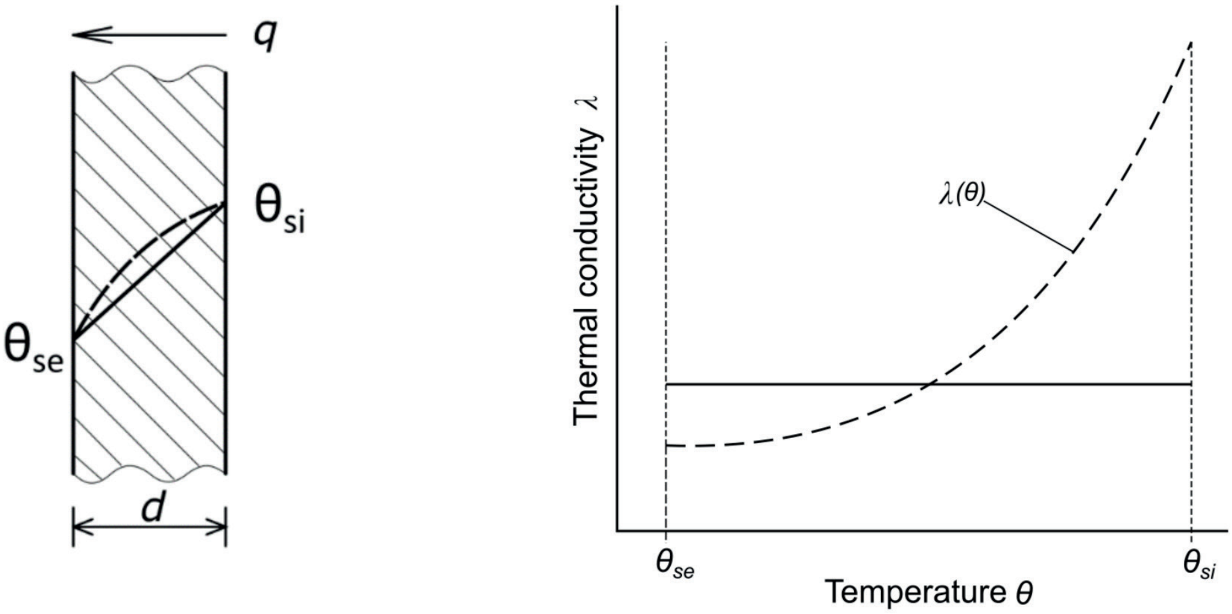

Figure 1 — Left: Temperature distribution in a single-layer wall. Right: Thermal conductivity as function of the temperature (dashed curve) and non-temperature-depending (solid line).

NOTE The dashed curve in Figure 1, left, represents the temperature variation in a wall, considering that the thermal conductivity depends on the temperature, this curve corresponds to the dashed curve on the right. In case that the thermal conductivity is considered as temperature-independent, the variation of the temperature inside a wall is represented by the solid line on the left; it corresponds to the solid line in the figure on the right, which shows no change in the thermal conductivity over the temperature.

For multi-layer wall (see Figure 2), q is calculated according to Equation (3), where R is the thermal resistance of the multi-layer wall, as given in Equation (5):

$$R=\sum_{j=1}^{n}\frac{d_j}{\lambda_j} \tag{5}$$

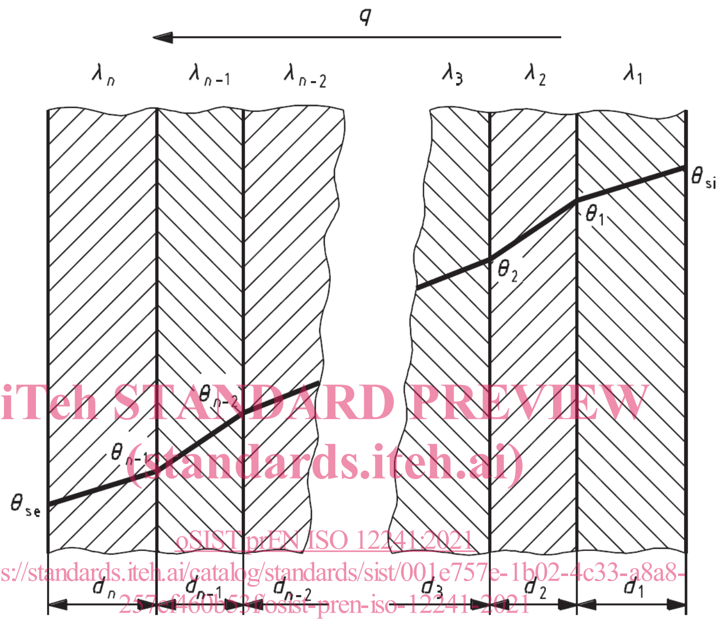

Figure 2 — Temperature distribution in a multi-layer wall

The linear density of heat flow rate, q_l, of a single-layer hollow cylinder (see Figure 3) is given in Equation (6):

$$q_l=\frac{\theta_{si}-\theta_{se}}{R_l} \tag{6}$$

where R_l is the linear thermal resistance of a single-layer hollow cylinder, as given in Equation (7):

$$R_l=\frac{\ln\frac{D_e}{D_i}}{2\cdot\pi\cdot\lambda} \tag{7}$$

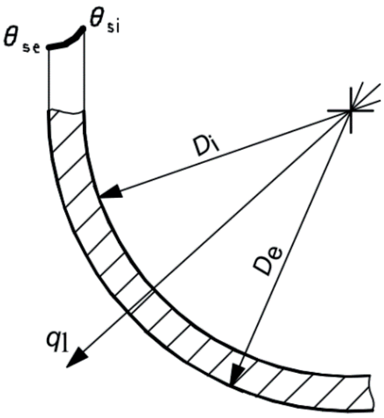

Figure 3 — Temperature distribution in a single-layer hollow cylinder

For multi-layer hollow cylinder (see Figure 4), the linear density of heat flow rate, q_l, is given in Equation (6), where R_l is given by Equation (8)

$$R_l = \frac{1}{2 \cdot \pi} \sum_{j=1}^{n} \left(\frac{1}{\lambda_j} \ln \frac{D_{e,j}}{D_{i,j}} \right) \tag{8}$$

where

$D_{i,1} = D_i$

$D_{e,n} = D_e$

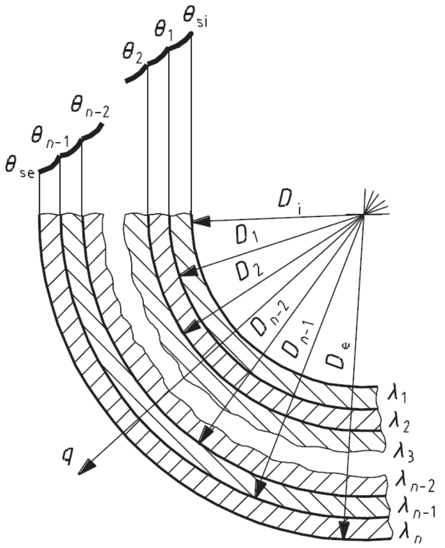

Figure 4 — Temperature distribution in a multi-layer hollow cylinder

NOTE For curved surfaces with a diameter larger than 1 200 mm, it is recommended to use formulas for wall surface.

The heat flow rate of a sphere, Φ_{sph}, of a single-layer hollow sphere (see Figure 5) is given by Equation (9):

$$\Phi_{sph} = \frac{\theta_{si} - \theta_{se}}{R_{sph}} \tag{9}$$

where R_{sph} is the thermal resistance of a single-layer hollow sphere, as given in Equation (10):

$$R_{sph} = \frac{1}{2 \cdot \pi \cdot \lambda} \left(\frac{1}{D_i} - \frac{1}{D_e} \right) \tag{10}$$

where

D_{e} is the outer diameter of the layer, expressed in m;

D_{i} is the inner diameter of the layer, expressed in m.

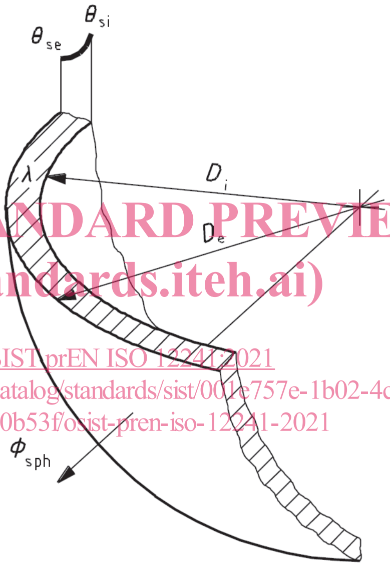

Figure 5 — Temperature distribution in a single-layer hollow sphere

For multi-layer hollow sphere (see Figure 6), the heat flow rate of a sphere, Φ_{sph}, is given in Equation (9), where R_{sph} is given by Equation (11)

$$R_{sph} = \frac{1}{2 \cdot \pi} \cdot \sum_{j=1}^{n} \frac{1}{\lambda_j} \cdot \left(\frac{1}{D_{j-1}} - \frac{1}{D_j} \right) \tag{11}$$

where:

$D_0 = D_i$

$D_n = D_e$