INTERNATIONAL STANDARD

ISO 12241

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Thermal insulation for building equipment and industrial installations — Calculation rules

Isolation thermique des équipements du bâtiment et des installations industrielles — Méthodes de calcul

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Contents

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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.

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.

International Standard ISO 12241 was prepared by Technical Committee ISO/TC 163, *Thermal insulation*, Subcommittee SC 2, *Calculation methods*.

Annexes A to C of this International Standard are for information only.

Introduction

Methods relating to conduction are direct mathematical derivations from Fourier´s Law of Heat Conduction, so international consensus is purely a matter of mathematical verification. No significant difference in the equations used in the member countries exists. For convection and radiation, however, there are no methods in practical use which 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, these methods can be applied to most types of industrial thermal insulation heat transfer problems.

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

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 will depend 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 which have proven satisfactory for estimating some of the variables for many industrial thermal systems.

It should be noted that the steady-state calculations are dependent on boundary conditions. Often a solution at one set of boundary conditions is not sufficient to characterize a thermal system which will operate in a changing thermal environment (process equipment operating year-round, outdoors, for example). In such cases local weather data based on yearly averages or yearly extremes of the weather variables (depending on the nature of the particular calculation) should be used for the calculations in this International Standard.

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. This condition suggests the need for numerous calculations to properly model thermal characteristics of any one surface. Furthermore, the heat flow through a surface at any point is a function of several variables which 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 (often including a great variety of interest). For calculation of dew formation, variability of the local humidity is an important factor.

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. In applications where precise values of heat energy conservation or (insulated) surface temperature need not be assured, or where critical temperatures for dew formation are either not approached or not a factor, these methods can be used to calculate heat flow rates.

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 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, assuming one-dimensional heat flow only.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standards are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7345:1987, *Thermal insulation — Physical quantities and definitions*

ISO 9346:1987, *Thermal insulation — Mass transfer — Physical quantities and definitions*

NOTE — For further publications, see annex C.

3 Definitions, symbols and abbreviations

For the purposes of this International Standard, the definitions given in ISO 7345 and ISO 9346 apply.

3.1 Physical quantities, symbols and units

Physical quantities	Symbol	Unit
heat flow rate	Φ	W
density of heat flow rate	q	W/m^2
linear density of heat flow rate	q	W/m
thermodynamic temperature	T	K
Celsius temperature	θ	°C
temperature difference	$\Delta\theta$	K
thermal conductivity	λ	W/(m·K)
design thermal conductivity	λ_d	W/(m·K)
surface coefficient of heat transfer	h	$W/(m^2 \cdot K)$
thermal resistance	R	$m^2 \cdot K/W$
linear thermal resistance	R_l	m·K/W
linear thermal surface resistance	R_{le}	m·K/W
surface resistance of heat transfer	R_s	$m^2 \cdot K/W$
thermal resistance for hollow sphere	R_{sph}	K/W
thermal transmittance for hollow sphere	U_{sph}	W/K
thermal transmittance	U	$W/(m^2 \cdot K)$
linear thermal transmittance	U_l	W/(m·K)
specific heat capacity at constant pressure	c_p	kJ/(kg·K)
thickness	d	m
diameter	D	m
temperature factor	a_r	K^3
radiation coefficient	C_r	$W/(m^2 \cdot K^4)$
emissivity	ε	-
Stefan Boltzmann constant (see reference [9])	σ	$W/(m^2 \cdot K^4)$
height	H	m
length	l	m
thickness parameter (see 4.2)	C'	m
perimeter	P	m
area	A	m^2
volume	V	m^3
velocity	v	m/s
time	t	s
mass	m	kg
mass flow rate	$\dot{m}$	kg/h
density	ρ	kg/m^3
specific enthalpy; latent heat of freezing	h_{fr}	kJ/kg
relative humidity	ϕ	%

3.2 Subscripts

ambient	a
average	av
cooling	c
convection	cv
design, duct, dewpoint	d
exterior,external	e
effective	ef
final medium	fm
freezing	fr
interior, internal	i
initial medium	im
laboratory	lab
linear	l
pipe	p
radiation	r
reference	ref
surface	s
exterior surface	se
interior surface	si
spherical	sph
soil	E
total	T
vessel	v
water	w
wall	W

4 Calculation methods for heat transfer

4.1 Fundamental equations for heat transfer

The formulae given in this clause apply only to the case of heat transfer in the steady-state, i.e. to the case where temperatures remain constant in time at any point of the medium considered.
Generally the thermal conductivity design value is temperature dependent (see figure 1, dashed line).
For further purposes of this International Standard, the design value for the mean temperature for each layer shall be used.

NOTE —This may imply iterative calculation.

4.1.1 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:

$$q = -\lambda \cdot \frac{d\theta}{dx} \quad \mathrm{W/m^2} \qquad (1)$$

For a single layer

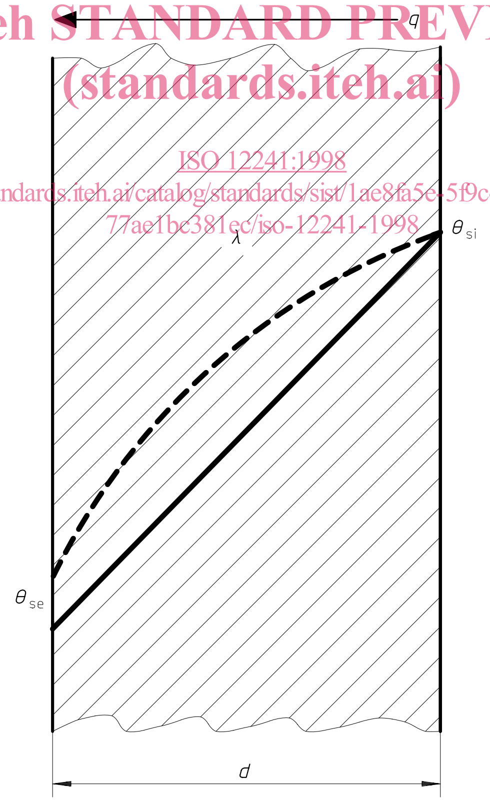
$$q = \frac{\lambda}{d} \cdot \left(\theta_{\mathrm{si}} - \theta_{\mathrm{se}}\right) \quad \mathrm{W/m^2} \tag{2}$$

or

$$q = \frac{\theta_{\mathrm{si}} - \theta_{\mathrm{se}}}{R} \quad \mathrm{W/m^2} \tag{2a}$$

where

λ is the thermal conductivity of the material, in W/(m·K);
d is the thickness of the plane wall, in m;
θ_{si} is the temperature of the internal surface, in °C;
θ_{se} is the temperature of the external surface, in °C;
R is the thermal resistance of the wall in (m²·K)/W.



λ.

Figure 1: Temperature distribution in a single layer wall

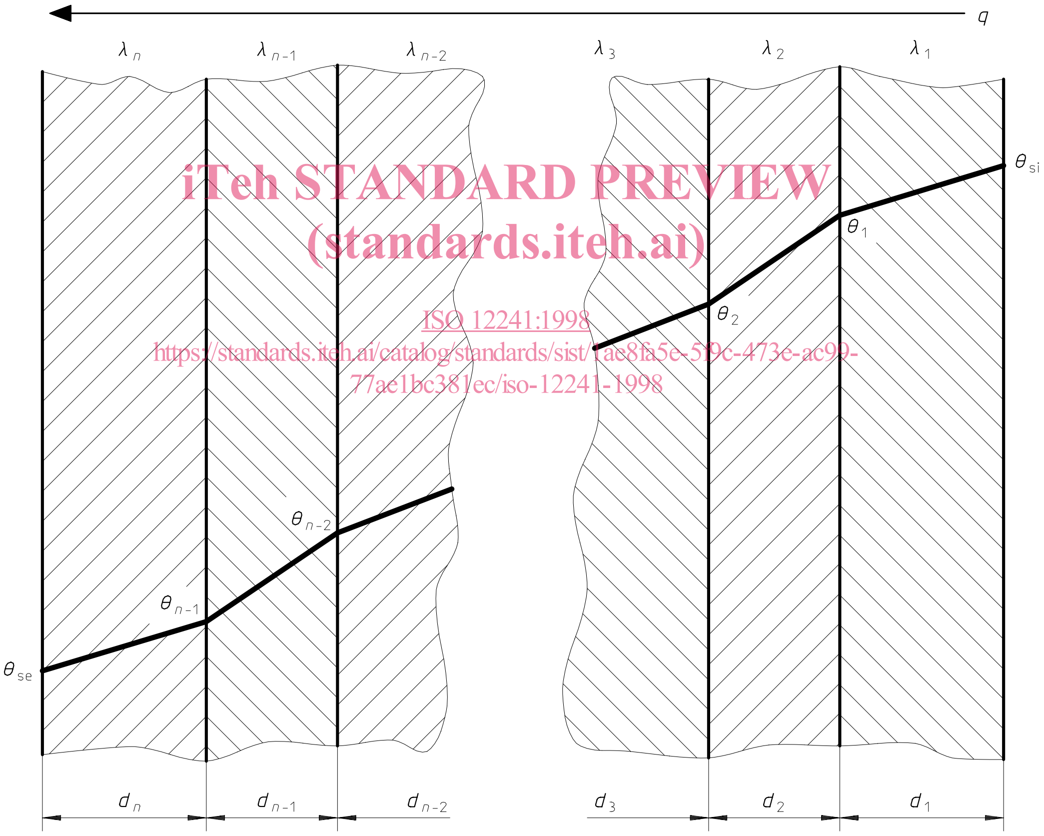
For multi-layer insulation

$$q = \frac{\theta_{\mathrm{si}} - \theta_{\mathrm{se}}}{R'} \quad \mathrm{W/m^2} \tag{3}$$

where R' is the thermal resistance of the multi-layer wall

$$R' = \sum_{j=1}^{n} \frac{d_j}{\lambda_j} \quad \mathrm{m^2 \cdot K/W} \tag{4}$$

NOTE — The prime denotes a multi-layer quantity.



The linear density of heat flow rate q_l of a single layer hollow cylinder:

$$q_l = \frac{\theta_{si} - \theta_{se}}{R_l} \quad \text{W/m} \qquad (5)$$

where R_l is the linear thermal resistance of a single layer hollow cylinder:

$$R_l = \frac{\ln \frac{D_e}{D_i}}{2 \cdot \pi \cdot \lambda} \quad \text{m} \cdot \text{K/W} \qquad (6)$$

D_e is the exterior diameter of the layer, in m;
D_i is the interior diameter of the layer, in m.

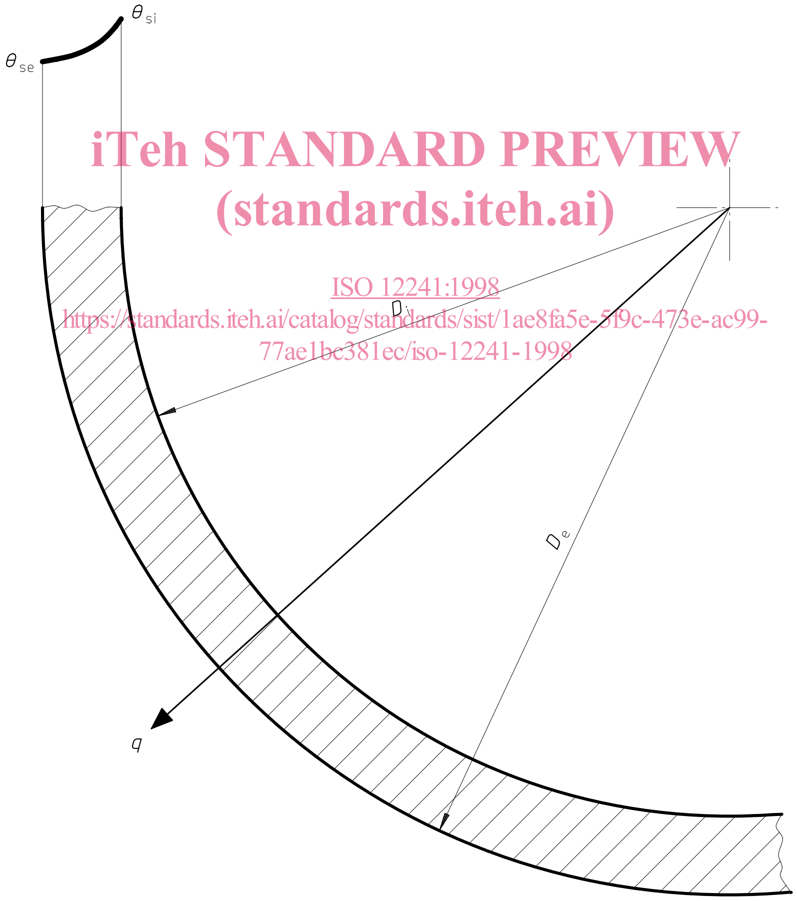


Figure 3: **Temperature distribution in a single layer hollow cylinder**

For multi-layer hollow cylinder:

$$q_l = \frac{\theta_{si} - \theta_{se}}{R_l'} \qquad \mathrm{W/m} \qquad (7)$$

where

$$R_l{}' = \frac{1}{2\cdot\pi}\sum_{j=1}^{n}\left(\frac{1}{\lambda_j}\cdot\ln\frac{D_{ej}}{D_{ij}}\right) \qquad \mathrm{m\cdot K/W} \qquad (8)$$

with $D_0 \equiv D_i$ and $D_n \equiv D_e$

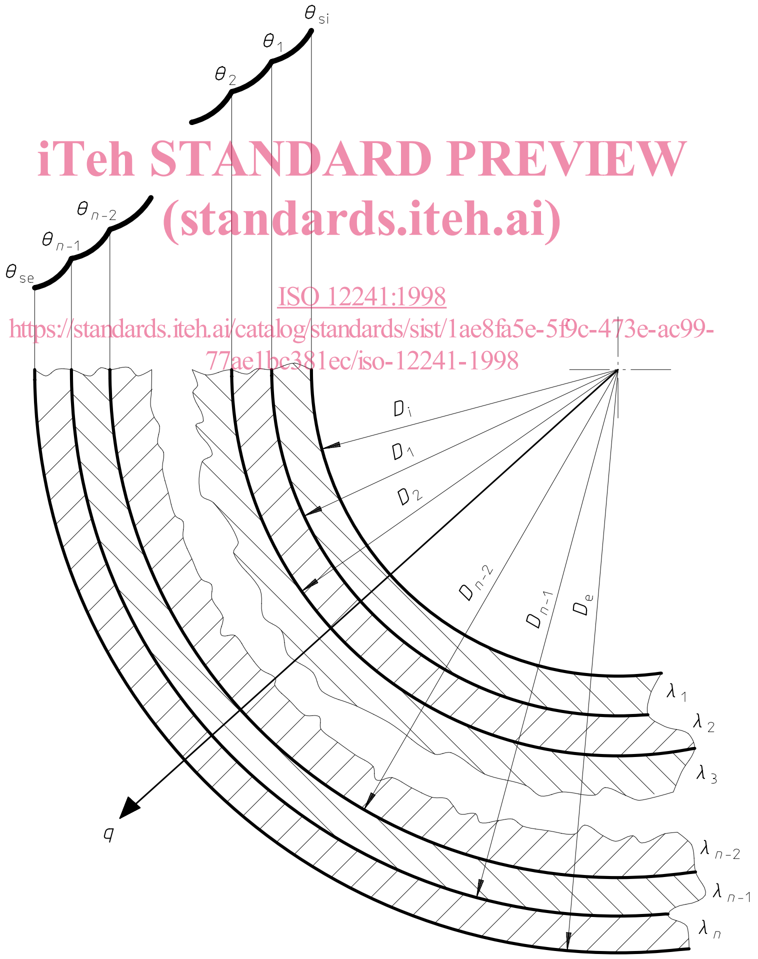


Figure 4: **Temperature distribution in a multi-layer hollow cylinder**