BS 5422:2009

Incorporating Corrigendum No. 1

BSI Standards Publication

Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range –40 °C to +700 °C

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Publishing and copyright information

ISBN 978 0 580 69184 3

ICS 23.020.01, 27.220, 91.100.60

The following BSI references relate to the work on this standard:
Committee reference B/540/7
Draft for comment 08/30147222 DC

Publication history

First published July 1977
Second edition, July 1990
Third edition, December 2001
Fourth (present) edition, December 2008

Amendments issued since publication

Amd. No.	Date	Text affected
C1	November 2009	Tables 4, 5, 7, 9, 14, 15, 16, 20, 21, 27, 30, 31, A.1, C.1, D.1 8.3.3, 10.3.1 F.3 Note 4 See foreword

Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 74, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 1 January 2009. It was prepared by Technical Committee B/540/7, *Thermal insulation for equipment and industrial applications*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 5422:2001, which is withdrawn.

Relationship with other publications

The methods used in this standard to calculate heat transfer are in accordance with BS EN ISO 12241:1998.

Information about this document

The start and finish of text introduced or altered by Corrigendum No. 1 is indicated in the text by tags [C1] [C1].

The Non-domestic Technical Handbook [1] and the Domestic Technical Handbook [2] cite BS 5422:2001 as a means of demonstrating compliance with certain requirements of the Building (Scotland) Regulations 2004 [3]; this British Standard does not replace the 2001 edition for this purpose.

All tables of insulation thicknesses have been reviewed in the light of current working practices. The assumptions on which the tables are based are given in each case.

The "environmental insulation thickness" tables have been revised to take account of the increased awareness of the importance of limiting carbon dioxide (CO_2) emissions, whilst taking account of practical factors, current materials and energy costs. Annex A shows the way in which the environmental thickness was derived.

Specific guidance is included in Annex H for plastic pipes, in recognition of the increase in their use. Guidance for non-standard pipe sizes is also included in Annex H.

The standard is not prescriptive, and recognizes that there are many reasons why the insulation of pipes, tanks, vessels, ductwork and equipment may be required. It is therefore important that a specifier states the criteria, specific Clause or reference in this standard in any specification.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Introduction

In any single application for pipework and equipment, thermal insulation material can perform a variety of functions simultaneously, including:

a) conserve energy for both cooled and heated systems;

b) retard freezing of contents;

c) control condensation on refrigerated, chilled or cold surfaces;

d) protect personnel from exposure to extremes of surface temperature;

e) control process or service temperatures;

f) limit effects of system on indoor building temperature.

Even within the range listed, consideration should be given to sub-sectors of these functions.

For example, energy conservation can be driven by two distinct considerations. The first, and more traditional, reason for seeking energy saving is to save cost. The second, and more recent, reason for seeking energy saving is to minimize carbon dioxide emissions from the associated power source. Although any insulation measure has desired effects in both of these areas simultaneously, the extent of insulation that can be justified varies with the comparative costs of energy on the one hand, and alternative costs of carbon dioxide emission abatement on the other. Since thermal insulation of pipework and equipment represents one of the most cost-effective ways available of limiting carbon dioxide emissions, this standard highlights a series of thicknesses within its core tables, which have been calculated in accordance with environmental principles as outlined in Annex A.

Although the tables provided in this standard offer a simple method of determining the minimum thickness levels, their use will require the basic information outlined in Clause **4** and, in some cases, additional information may be required. This specific information is outlined in the clauses pertaining to specific applications.

Where information such as the thermal conductivity of the chosen insulation material or the pipe diameter do not conform to the categories highlighted in the relevant tables, it is possible to interpolate between either columns or rows where the margin of error is not likely to be critical. For greater accuracy, and where the application parameters differ from those covered within the scope of a Table (e.g. different ambient air temperature), the specifier should calculate from first principles by using methods set out in BS EN ISO 12241:1998 and the Annexes to this standard.

The default values for use in relation to this standard are given in Annex B, the criteria used to establish the tables are summarized in Annex C, and the standard diameters of pipes considered are given in Annex D.

1 Scope

This British Standard describes a method for specifying requirements for thermal insulating materials on pipes, tanks, vessels, ductwork and equipment for certain defined applications and conditions within the temperature range –40 °C to +700 °C. It also specifies some physical requirements for the insulating materials. It is intended for use by designers, specifiers, contractors and manufacturers of thermal insulation.

This British Standard does not apply to pipelines that are embedded underground, nor does it refer to the insulation of building construction.

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.

BS 476-4, *Fire tests on building materials and structures – Part 4: Non-combustibility test for materials*

BS 476-6, *Fire tests on building materials and structures – Part 6: Method of test for fire propagation for products*

BS 476-7:1997, *Fire tests on building materials and structures – Part 7: Method of test to determine the classification of the surface spread of flame of products*

BS 476-11, *Fire tests on building materials and structures – Part 11: Method for assessing the heat emission from building materials*

BS 3177, *Method for determining the permeability to water vapour of flexible sheet materials used for packaging*

BS 4370-2:1993+A2:2001, *Methods of test for rigid cellular materials – Part 2: Methods 7 to 9*

BS EN ISO 12241:1998, *Thermal insulation for building equipment and industrial installations – Calculation Rules*

3 Terms and definitions

For the purposes of this British Standard, the following definitions apply.

3.1 chilled water
water that has been processed through cooling plant (typically 0 °C to +10 °C)

3.2 cold water
water delivered from the mains or natural supply

3.3 economic thickness
thickness of insulation that minimizes the total cost (investment and running costs) over a chosen evaluation period

3.4 environmental thickness
thickness of insulation that balances the cost of the interest payments incurred to insulate the system against the cost of the energy saved as a consequence (see Annex A)

3.5 evaluation period
time over which the heat transfer through insulated surfaces is to be calculated, e.g. to carry out frost protection or economic thickness calculations

3.6 finishing materials
materials used to cover the insulation, whether pre-applied or applied on site

3.7 insulation thickness
thickness of insulating material, excluding any finish or covering

3.8 maximum service temperature
highest temperature to which a thermal insulation or other material may be exposed and at which it will continue to function within the specified limits of its performance

3.9 minimum service temperature
lowest temperature to which a thermal insulation or other material may be exposed and at which it will continue to function within the specified limits of its performance

3.10 pre-applied
applied to the insulation prior to delivery to the point of use

3.11 termination point
point at which the thermal insulation applied to a pipe, duct or vessel is terminated, e.g. at a valve or flange, or where traversing a wall or ceiling

3.12 water vapour barrier
layer intended to control water vapour diffusion

NOTE In practice it is impossible to achieve a total vapour barrier with a single layer.

3.13 water vapour permeance
density of water vapour flow rate divided by the water vapour pressure difference between the two surfaces of the specimen during the test

3.14 water vapour resistance
reciprocal of water vapour permeance

3.15 water vapour retarder
material which reduces water vapour diffusion

4 Application of this standard

A specification produced in accordance with this British Standard shall specify only those elements of the standard to which conformity is required for a specific application. A specification shall be deemed to conform to this British Standard if it makes reference to the clauses and tables within this standard that pertain to the application being specified. The selection of materials and the insulation thickness to be specified shall be determined according to the intended function of the insulation.

The specification shall state the prime purpose of the insulation and shall specify the performance requirements for the selected insulation system. The specification shall identify the minimum performance requirements for each application or parameter. The application or parameter that requires the greatest thickness of insulation shall take precedence.

The performance requirements shall be specified in accordance with the appropriate clauses and tables of this standard, which shall be determined from the following factors:

a) system operating temperature;

b) design ambient air temperature;

c) relative humidity of the ambient air;

d) air velocity;

e) location of the plant (indoors or outdoors);

f) pipe diameter (or flat surface dimensions);

g) orientation of pipes (horizontal or vertical);

h) vertical dimensions of flat surfaces;

i) emissivity of outer surface.

For refrigerated, chilled and other cold applications, where applicable, water vapour permeance or resistance of the complete insulation system (including water vapour barrier where applied) shall also be specified in accordance with the appropriate clauses and tables of this standard.

5 General requirements

5.1 Physical characteristics

The specifier shall specify the required performance and physical characteristics of the materials, including finishing materials, whether pre-applied or applied on site, in accordance with the appropriate British Standard.

The manufacturer or supplier shall declare the performance and physical characteristics of the materials in accordance with the appropriate British Standard.

To help ensure that the insulation material specified is suitable for the intended application, consideration shall be given as to whether:

a) the material contains substances that will support pests or encourage the growth of fungi;

b) the material gives off an objectionable odour at the temperatures at which it is to be used;

   NOTE 1 Transient effects during the initial period of use may generally be ignored.

c) the material suffers permanent structural or physical deterioration as a result of contact with moisture;

d) the material suffers structural or physical deterioration as a result of use at specified operating temperatures;

e) the material is suitable for specified conditions of use without the physical properties falling outside the tolerances allowed in the appropriate British Standard for the material;

f) materials in contact are compatible and do not cause corrosion or degradation under normal site conditions;

g) the material and its method of application constitutes a known risk to health during application or use.

   NOTE 2 Reference should be made to BS 5970 for health hazards when selecting, storing or removing insulation. Attention is also drawn to the latest edition of COSHH Regulations [4].

5.2 Installation requirements

NOTE Guidance on the correct application of insulation and associated attachments is given in BS 5970.

5.3 Thermal conductivity

5.3.1 General

Manufacturers or suppliers of insulating materials shall supply declared thermal conductivity values based on results of tests carried out in accordance with the appropriate British or European Standards. Thermal conductivity shall be expressed in Watts per square metre for 1 m thickness and a temperature difference of 1 K.

NOTE 1 The values quoted for thermal conductivity relate to the appropriate insulation mean temperature, which is defined as the mean of the operating temperature of the system added to the temperature of the outer surface of the insulation system.

NOTE 2 In terms of unit symbols thermal conductivity should be expressed as W/(m · K).

The contractor shall state the manufacturer’s declared values of thermal conductivity for each material proposed. These declared values shall be appropriate to the mean temperature of the applied insulation.

5.3.2 Composite insulation

When two or more layers of dissimilar insulating material are to be used, the contractor shall provide the declared value of thermal conductivity for each layer under the appropriate temperature conditions. The thickness of each layer shall also be stated.

5.3.3 Design value of thermal conductivity and thermal bridges

Additional allowances shall be made to ensure that the specified performance is achieved where system inefficiencies are created through the ageing of the product, or by the presence of valves or other in-line or ancillary fittings.

NOTE 1 Guidance is given in BS EN ISO 12241:1998.

NOTE 2 To limit heat transfer through supports, load-bearing insulating material should be used on the pipe or vessel between the support and the surface to be insulated. If a water vapour barrier is required, the sealing of the load-bearing material should conform to the same requirements as the basic insulation and be fitted so that the integrity of the vapour barrier of the system is maintained. Where the heat transfer through the supports does not need to be limited but a water vapour barrier is required, the edges of the insulation, where interrupted at the support, should be sealed to maintain the effectiveness of the vapour barrier.

Other structural elements, such as stiffening rings, should be insulated externally to reduce thermal bridging.

5.4 Temperature limitations

The manufacturer or supplier shall state the maximum or minimum service temperatures of the products specified, as appropriate.

If the temperature of the surface to be insulated is above the limiting temperature of the preferred main insulating material, composite or alternative insulation shall be specified. Where composite insulation is specified, the thickness of each layer shall be calculated to ensure that the interface temperature between the two materials does not exceed the limiting temperature for the material of the outer layer.

5.5 Thickness

If thicknesses are required other than those given in the tables in the appropriate section, or bases needed other than those from which they were derived, the specification shall state the thickness required or the bases to be used in the calculation.

If the thicknesses derived using this standard do not correspond with commercially available thicknesses, the nearest higher available thickness shall be used.

In multilayer applications, where material thicknesses are rounded up to suit available thicknesses, a further calculation in accordance with BS EN ISO 12241:1998 shall be made to ensure that each interface temperature is below the maximum service temperature of the materials involved.

NOTE 1 Additional allowances should be made for heat transfer through joints, valves and other fittings when determining insulation thickness in accordance with BS EN ISO 12241:1998.

NOTE 2 Thicknesses given in the tables within this standard are specifically calculated against the criteria noted in each Table. Adopting these thicknesses may not necessarily satisfy other design requirements.

5.6 Vapour barrier – Permeance requirements

NOTE 1 Condensation of water vapour will occur on a surface that is at a temperature below the atmospheric dew point temperature. Moisture can be deposited within the insulating material and on the insulated metal surface. Where the insulated surface is likely to be at or below the dew point temperature during any part of its operating cycle, an effective vapour barrier should be applied on the warmer face of the insulation to avoid deposition of moisture within the insulating system. The presence of water within an insulation system can reduce thermal effectiveness and lead to corrosion of metal components.

For the purpose of this standard an effective vapour barrier shall be deemed to be one that meets the water vapour permeance requirements given in this subclause.

Different levels of water vapour permeance shall be specified according to the type of application. Where the insulating material itself does not conform to the water vapour permeance requirement, a "vapour barrier" on the outside (warm side) of the insulation shall be used.

The vapour barrier shall take the form of a coating or sheet material. Any joints in the coating or sheet material or in the insulating material itself, where it is providing the water vapour permeance requirement, shall be fully sealed.

NOTE 2 This is to ensure that the vapour permeance performance is maintained continuously in the system as installed.

Particular care shall be taken at termination points. The external vapour barrier, where required, shall be pre-applied or applied before the fluid in the pipe, duct, or vessel is cooled.

When a vapour barrier is used, the system as installed, shall have a fire performance at least equal to that specified in **6.2.2**, **7.2.2**, **8.2.2**, **9.2.2** and **10.2.2** as appropriate to the type of application.

The water vapour permeance of flexible sheets used as external vapour barriers shall be assessed in accordance with the method given in BS 3177. The test conditions, e.g. temperate or tropical, and the thickness of the test specimen shall be stated. Where the apparatus for the method in BS 3177 is unsuitable because of the thickness of the test specimen, BS 4370-2:1993+A2, method 8 shall be used. The water vapour permeance of the insulated system shall be selected according to the relationship between the cold surface temperature of the plant and the temperature difference, in degrees centigrade (°C), between the plant temperature and ambient temperature as indicated in Table 1.

NOTE 3 The permeance values given in Table 1 are applicable at an ambient temperature of 20 °C and a relative humidity of 70%, and other environmental conditions resulting in an equal or lesser partial vapour pressure difference. In order to calculate the partial vapour pressure difference, the internal temperature should be assumed to be equal to the plant temperature and the internal relative humidity to be 100%. In situations where the environmental conditions are normally 25 °C and a relative humidity of 80% the vapour barrier permeance is selected from Table 1 by subtracting 10 °C from the plant operating temperature.

NOTE 4 Additional guidance may be found in BS EN 14114, which sets out a methodology for the calculation of water vapour transmission through a water vapour barrier.

Table 1 **Maximum permitted water vapour permeance in relation to plant temperature at an ambient temperature of +20 °C (dry bulb)**

Temperature of plant (cold surface) °C	**Water vapour permeance of barrier** g/(s · MN)
10	0.050
5	0.015
0	0.010
–5	0.004
–10	0.002
–15	0.0015
–20 to –40	0.0010

Where it is necessary to add additional claddings to an external vapour barrier, e.g. to provide weather or mechanical protection, the specifier shall state the type of finish to be applied. The installer shall ensure that the application of any additional coverings does not damage the vapour barrier during installation and that it is unlikely to cause damage to, or degrade the performance of, the vapour barrier in service.

NOTE 5 For further details see BS 5970.

5.7 Tests on physical properties

Where particular physical properties are required the specifier shall nominate the appropriate British Standard test methods. Only where no suitable British Standard test methods exist shall the specifier authorize the use of an alternative test method to determine whether the required level of performance is met.

6 Refrigeration applications

6.1 Information to be supplied by the specifier

The specifier shall supply details of the intended function and performance requirements of the application, and the materials to be used, in accordance with Clause **4**.

NOTE In addition to the parameters outlined in Clause ***4****, items such as specific heat capacity and mass flow rates of fluids may also be required under certain circumstances, particularly where calculating from first principles using BS EN ISO 12241:1998. However, these additional parameters are not required for the use of the tables contained in this standard.*

6.2 Physical characteristics

6.2.1 General

The physical characteristics of the insulating material including finishing materials and vapour barriers, whether applied during manufacture or on site, shall conform to **5.1**, **6.2.2** and **6.2.3**.

6.2.2 Fire performance

Insulation materials and systems used for refrigeration shall conform to the following requirements.

NOTE 1 Attention is drawn to the applicable requirements of the Building Regulations [5], the Building (Scotland) Regulations [3] and the Building Regulations (Northern Ireland) [6].

Insulation systems on pipework or ductwork traversing a fire-resisting division shall maintain the level of fire resistance of the wall, floor or cavity barrier through which they pass.

NOTE 2 In the event of a fire some insulation systems can generate appreciable quantities of smoke and toxic fumes. Consideration should be given to the choice of materials bearing in mind their location, e.g. enclosed areas or adjacent to air ducts through which the smoke or fumes may spread.

In buildings other than dwellings, the complete assembly of installed insulation materials (whether faced or unfaced) shall be Class O (national class) or better.

In dwellings, the complete assembly of installed insulation materials (whether faced or unfaced) shall be Class 1 (national class) or better.

For faced or over-clad materials, which are not Class 1 (national class) or better when tested without the facing, particular care shall be taken with the facing to ensure that all joints and seams, etc., are fitted correctly, so that the underlying insulation is not left exposed to a potential ignition source. Where the complete assembly is liable to mechanical damage in use, the final finish shall be sufficiently strong to ensure that the insulation does not become exposed.

If there is a potential hazard from contamination by oil or other flammable chemicals, a suitably resistant finish, e.g. a metal sheet or appropriate non-absorbent coating, shall be applied over the vulnerable areas. The lapped joints of sheet finishes shall be arranged to shed contaminating fluids away from the insulating material.

In underground or windowless buildings, the underlying thermal insulation material used for external insulation of ventilation ductwork or pipes greater than 100 mm nominal bore shall itself be of "limited combustibility" or be "non-combustible". In addition, the complete assembly of installed insulation materials (whether faced or unfaced) shall be Class O (national class) or better.

NOTE 3 See Annex E for an explanation of "limited combustibility", "non-combustible", Class O and Class 1 (national classes) and Classes A1, A2, B, C, D, E or F (European classes).

6.2.3 Water vapour barrier – Permeance requirements

Insulation materials and systems used for refrigeration shall be installed in accordance with and shall conform to the permeance requirements specified in **5.6**.

When tested in accordance with BS 3177 or BS 4370-2, as appropriate, the permeance of the material used as a vapour barrier shall not exceed the values given in Table 1 for the appropriate temperature of the plant.

6.3 Insulation thickness – Protection against condensation and control of heat gain

6.3.1 In the absence of specific instructions from the specifier, the insulation thickness shall be not less than that given in Table 2 to Table 5, as appropriate.

6.3.2 Where the contribution of the heat gain of the distribution pipe work does not exceed 5% of the total heat load, the thicknesses given in Table 2 to Table 5 to control condensation shall also be used to limit heat transfer. Where the contribution of the heat gain of the distribution pipe work does exceed 5%, the thickness of insulation shall be increased such that the heat gain of the distribution pipe is reduced to less than 5%. Calculating distribution pipe-work heat gains shall be carried out in accordance with Annex F.

6.3.3 Thicknesses of insulation for pipe diameters not shown in Table 2 to Table 5, and for all plastic pipes, shall be determined in accordance with Annex H.

Table 2 **Minimum insulation thickness for refrigeration applications to control condensation and control heat gain on a high emissivity outer surface (0.90) with an ambient temperature of +20 °C and a relative humidity of 70%**

Outside diameter of steel pipe on which insulation thickness has been based	**Insulation thickness** (mm)																			
	t = 0				*t* = –10				*t* = –20				*t* = –30				*t* = –40			
(mm)	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**
21.3	5	7	9	11	8	11	14	16	10	14	18	22	13	18	22	27	15	21	26	31
33.7	5	8	10	12	8	12	15	18	11	16	20	24	14	20	25	30	17	23	29	35
60.3	6	8	11	13	9	13	17	21	13	18	23	28	16	22	29	34	19	27	34	41
114.3	6	9	12	15	10	15	19	24	14	20	26	32	18	25	33	40	21	30	39	47
168.3	7	10	13	16	11	16	21	25	15	22	28	34	19	27	35	43	23	33	42	51
273.0	7	10	13	17	12	17	22	27	16	23	30	37	20	29	38	47	24	35	46	56
508.0	7	11	14	18	12	18	24	29	17	25	33	40	22	32	41	51	26	38	50	62
610.0	8	11	15	18	12	18	24	30	17	25	33	41	22	32	42	52	27	39	51	63
Flat surfaces	8	11	15	18	12	18	24	30	17	26	34	43	22	33	44	55	27	40	54	67

Key

t = temperature of contents (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements. In situations where the ambient air temperature is greater than 20 °C and/or the relative humidity exceeds 70%, these thicknesses will not be sufficient to control condensation.

Table 3 **Minimum insulation thickness for refrigeration applications to control condensation and control heat gain on a low emissivity outer surface (0.05) with an ambient temperature of +20 °C and a relative humidity of 70%**

Outside diameter of steel pipe on which insulation thickness has been based	**Insulation thickness** (mm)																			
	***t* = 0**				***t* = –10**				***t* = –20**				***t* = –30**				***t* = –40**			
(mm)	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**
21.3	9	13	16	20	14	20	26	31	19	27	35	42	24	34	44	53	28	41	52	64
33.7	10	14	19	23	16	23	30	36	22	31	40	49	27	39	50	61	33	47	60	73
60.3	12	17	22	27	19	27	35	43	26	37	48	59	33	47	60	73	39	56	72	88
114.3	14	20	27	33	23	33	43	52	31	45	58	71	39	57	73	89	47	68	88	107
168.3	16	23	30	36	25	37	48	59	35	50	65	80	44	64	82	101	53	76	99	121
273.0	17	26	34	41	29	42	55	67	40	58	75	92	50	73	95	116	61	88	114	140
508.0	20	30	39	49	33	49	65	80	46	68	89	110	59	87	113	139	72	105	137	167
610.0	21	31	41	51	35	52	68	84	49	71	94	115	62	91	119	146	75	110	144	176
Flat surfaces	20	30	40	50	34	51	68	85	48	72	96	119	62	93	123	154	76	113	151	188

Key

t = temperature of contents (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE Thickness given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements. In situations where the ambient air temperature is greater than 20 °C and/or the relative humidity exceeds 70%, these thicknesses will not be sufficient to control condensation.

Table 4 **Minimum insulation thickness for refrigeration applications to control condensation and control heat gain on a high emissivity outer surface (0.90) with an ambient temperature of +25 °C and a relative humidity of 80%**

Outside diameter of steel pipe on which insulation thickness has been based	**Insulation thickness** (mm)																			
	***t* = 0**				***t* = –10**				***t* = –20**				***t* = –30**				***t* = –40**			
(mm)	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**
21.3	10	14	17	21	13	19	24	28	17	23	29	35	20	28	35	42	23	32	41	49
33.7	11	15	19	23	15	21	26	32	19	26	33	40	22	31	39	47	26	36	46	55
60.3	12	17	22	26	17	24	30	36	21	30	38	46	26	36	45	55	30	42	53	63
114.3	13	19	25	30	19	27	34	42	24	34	44	53	29	41	53	63	34	48	61	74
168.3	14	20	26	32	20	29	37	45	26	37	47	57	31	44	57	69	36	52	66	80
273.0	15	22	28	35	21	31	40	49	27	40	51	63	33	48	62	76	39	57	73	88
508.0	16	23	30	37	23	33	44	54	29	43	56	69	36	53	69	84	43	62	81	99
610.0	16	24	31	38	23	34	44	55	30	44	58	71	37	54	70	86	44	64	83	102
Flat surfaces	16	24	32	39	23	35	46	58	31	46	61	76	38	57	76	94	45	68	90	113

Key

t = temperature of contents (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements. In situations where the ambient air temperature is greater than [C1⟩ 25 °C ⟨C1] and/or the relative humidity exceeds [C1⟩ 80% ⟨C1], these thicknesses will not be sufficient to control condensation.

Table 5 **Minimum insulation thickness for refrigeration applications to control condensation and control heat gain on a low emissivity outer surface (0.05) with an ambient temperature of +25 °C and a relative humidity of 80%**

Outside diameter of steel pipe on which insulation thickness has been based	**Insulation thickness** (mm)																			
	t = 0				*t* = –10				*t* = –20				*t* = –30				*t* = –40			
(mm)	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**
21.3	19	28	36	43	27	39	50	61	35	50	64	79	42	60	78	96	49	71	92	113
33.7	22	32	41	50	31	45	58	70	40	57	74	90	48	69	90	109	57	81	105	129
60.3	27	38	49	60	37	53	69	84	48	68	88	107	58	83	107	130	68	97	125	153
114.3	32	46	60	73	45	65	84	102	58	83	107	131	70	101	130	158	82	118	152	185
168.3	36	51	67	82	51	73	94	115	65	93	121	147	79	113	146	178	93	133	171	209
273.0	40	59	77	94	58	84	109	133	75	108	140	170	91	131	169	206	107	154	198	242
508.0	47	69	91	112	68	99	130	159	88	128	167	205	108	157	203	249	127	184	239	291
610.0	49	73	95	117	71	104	136	167	93	135	176	216	113	165	214	262	134	194	252	308
Flat surfaces	49	73	97	122	72	107	143	179	95	142	189	236	117	176	234	292	140	210	280	349

Key

t = temperature of contents (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE Thickness given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements. In situations where the ambient air temperature is greater than [C1⟩ *25 °C* ⟨C1] *and/or the relative humidity exceeds* [C1⟩ *80%* ⟨C1]*, these thicknesses will not be sufficient to control condensation.*

7 Chilled and cold water applications

7.1 Information to be supplied by the specifier

The specifier shall supply details of the intended function and performance requirements of the application, and the materials to be used, in accordance with Clause **4**.

*NOTE In addition to the parameters outlined in Clause **4**, items such as specific heat capacity and mass flow rates of fluids may also be required under certain circumstances, particularly where calculating from first principles using BS EN ISO 12241:1998. However, these additional parameters are not required for the use of the tables contained in this standard.*

7.2 Physical characteristics

7.2.1 General

The physical characteristics of the insulating material, including fixing and finishing materials whether pre-applied or applied on site, shall conform to **5.1**, **7.2.2** and **7.2.3**.

7.2.2 Fire performance

Insulation materials and systems used for chilled and cold water applications shall conform to the following requirements.

NOTE 1 Attention is drawn to the applicable requirements of the Building Regulations [5], the Building (Scotland) Regulations [3] and the Building Regulations (Northern Ireland) [6].

Insulation systems on pipework or ductwork traversing a fire-resisting division shall maintain the level of fire resistance of the wall, floor or cavity barrier through which they pass.

NOTE 2 In the event of a fire some insulation systems can generate appreciable quantities of smoke and toxic fumes. Consideration should be given to the choice of materials bearing in mind their location, e.g. enclosed areas or adjacent to air ducts through which the smoke or fumes may spread.

The complete assembly of installed insulation materials (whether faced or unfaced) shall be Class O (national class) or better.

The insulation material itself (i.e. tested without any facing) shall be Class 1 (national class) or better.

If there is a potential hazard from contamination by oil or other flammable chemicals, a suitably resistant finish, e.g. a metal sheet or appropriate non-absorbent coating, shall be applied over the vulnerable areas. The lapped joints of sheet finishes shall be arranged to shed contaminating fluids away from the insulating material.

In underground or windowless buildings, the underlying thermal insulation material used for external insulation of ventilation ductwork or pipes greater than 100 mm nominal bore shall itself be of "limited combustibility" or be "non-combustible". In addition, the complete assembly of installed insulation materials (whether faced or unfaced) shall be Class O (national class) or better.

NOTE 3 See Annex E for an explanation of "limited combustibility", "non-combustible", Class O and Class 1 (national classes) and Classes A1, A2, B, C, D, E or F (European classes).

7.2.3 Water vapour barrier – Permeance requirements

Insulation materials and systems used for chilled and cold water applications shall be installed in accordance with and shall conform to the permeance requirements specified in **5.6**.

When tested in accordance with BS 3177 or BS 4370-2, as appropriate, the permeance of the material used as a vapour barrier shall not exceed the values given in Table 1 for the relevant temperature of the plant.

7.3 Insulation thickness

7.3.1 Protection against condensation

In the absence of specific instructions from the specifier, the insulation thickness shall be not less than that given in Table 6 to Table 9 as appropriate.

Thicknesses of insulation for pipe diameters not shown in Table 6 to Table 9, and for all plastic pipes, shall be determined in accordance with Annex H.

7.3.2 Control of heat gain to cooled and chilled water pipes

In the absence of specific instructions from the specifier, and where the cooling load is not proven to be less than 5%, the insulation thickness shall be not less than that given in Table 10 or Table 11, as appropriate.

The cooling load shall be calculated in accordance with Annex F.

Thicknesses of insulation for pipe diameters not shown in Table 10 and Table 11, and for all plastic pipes, shall be determined in accordance with Annex H.

For an intermediate pipe diameter not listed in Table 10 and Table 11, compliance calculations shall use the nearest larger diameter listed.

For pipes or vessels of diameter greater than 273 mm, the items in Table 10 and Table 11 shall be assumed to be 273 mm for calculation purposes.

To show compliance with the requirements of Table 10 and Table 11, insulation thicknesses shall be calculated using standardized assumptions: horizontal pipe at *t* °C in still air at 25 °C, emissivity of outer surface of insulated system as specified.

NOTE 1 Guidance on cooled ducts is given in Table 12 and Table 14.

NOTE 2 Attention is drawn to the energy performance requirements of Approved Document L2B [7], Technical Booklet F2 [8] and Non-domestic Technical Handbook [1], Section 6.

The thicknesses of insulation specified in Table 10 and Table 11 to limit heat transfer meet or improve upon the minimum requirements of Approved Documents L2B [7] and Technical Booklet F2 [8]. However, these thicknesses of insulation might not comply with future revisions of the Building Regulations [5] and the Building Regulations (Northern Ireland) [6], and the current versions of these documents should be consulted to ensure compliance.

Section 6 of the Non-domestic Technical Handbook [1] retains references to guidance given in BS 5422:2001 as a means of showing compliance.

NOTE 3 It should be noted that Building Regulations [3], [5], [6] provide minimum requirements for heat transfer to reduce energy use. The use of greater thicknesses of insulation can provide substantial financial and environmental benefits. Additional considerations might include acoustic performance, aesthetic qualities, fire properties, durability and thermal performance for reasons other than energy reduction; such as process control, control of condensation, internal building environment, surface temperature and freezing. This standard provides guidance on fire properties and thermal performance only.

Table 6 **Minimum insulation thickness for chilled and cold water steel pipes to control condensation on a high emissivity outer surface (0.9) with an ambient temperature of +25 °C and a relative humidity of 80%**

	ε = 0.9																				
Outside diameter of steel pipe on which insulation thickness has been based (mm)	***t* = 10**							***t* = 5**							***t* = 0**						
	Insulation thickness (mm)							**Insulation thickness** (mm)							**Insulation thickness** (mm)						
	λ = 0.02	**λ = 0.025**	**λ = 0.03**	**λ = 0.035**	**λ = 0.04**	**λ = 0.045**	**λ = 0.05**	**λ = 0.02**	**λ = 0.025**	**λ = 0.03**	**λ = 0.035**	**λ = 0.04**	**λ = 0.045**	**λ = 0.05**	**λ = 0.02**	**λ = 0.025**	**λ = 0.03**	**λ = 0.035**	**λ = 0.04**	**λ = 0.045**	**λ = 0.05**
17.2	6	7	8	9	10	11	12	8	9	10	12	13	15	16	9	11	13	15	16	18	20
21.3	6	7	8	9	10	11	12	8	9	11	12	14	15	17	10	12	14	15	17	19	21
26.9	6	7	9	10	11	12	13	8	10	12	13	15	16	18	10	12	14	16	18	20	22
33.7	6	8	9	10	11	13	14	9	10	12	14	15	17	19	11	13	15	17	19	21	23
42.4	7	8	9	11	12	13	14	9	11	13	14	16	18	19	11	14	16	18	20	22	24
48.3	7	8	9	11	12	13	15	9	11	13	15	17	18	20	12	14	16	19	21	23	25
60.3	7	8	10	11	13	14	15	10	12	14	15	17	19	21	12	15	17	19	22	24	26
76.1	7	9	10	12	13	15	16	10	12	14	16	18	20	22	12	15	18	20	23	25	28
88.9	7	9	10	12	13	15	16	10	12	14	17	19	21	23	13	16	18	21	24	26	29
114.3	8	9	11	12	14	16	17	10	13	15	17	19	22	24	13	16	19	22	25	27	30
139.7	8	9	11	13	14	16	18	11	13	15	18	20	22	25	14	17	20	23	25	28	31
168.3	8	10	11	13	15	16	18	11	13	16	18	21	23	25	14	17	20	23	26	29	32
219.1	8	10	12	14	15	17	19	11	14	16	19	21	24	26	14	18	21	24	27	30	33
273	8	10	12	14	16	17	19	12	14	17	19	22	25	27	15	18	22	25	28	31	35
323.9	8	10	12	14	16	18	20	12	14	17	20	22	25	28	15	19	22	25	29	32	35
355.6	8	10	12	14	16	18	20	12	15	17	20	23	25	28	15	19	22	26	29	32	36
406.4	9	10	12	14	16	18	20	12	15	18	20	23	26	28	15	19	23	26	30	33	36
457	9	11	13	15	16	18	20	12	15	18	21	23	26	29	16	19	23	26	30	33	37
508	9	11	13	15	17	19	21	12	15	18	21	24	26	29	16	19	23	27	30	34	37
610	9	11	13	15	17	19	21	12	15	18	21	24	27	30	16	20	24	27	31	35	38

Key

t = temperature of contents (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements. In situations where the ambient air temperature is greater than 25 °C and/or the relative humidity exceeds 80%, these thicknesses will not be sufficient to control condensation.

Table 7 **Minimum insulation thickness for chilled and cold water copper pipes to control condensation on a high emissivity outer surface (0.9) with an ambient temperature of +25 °C and a relative humidity of 80%**

	$\varepsilon = 0.9$																				
Outside diameter of [C1] copper [C1] pipe on which insulation thickness has been based (mm)	$t = 10$							$t = 5$							$t = 0$						
	Insulation thickness (mm)							**Insulation thickness** (mm)							**Insulation thickness** (mm)						
	$\lambda = 0.02$	$\lambda = 0.025$	$\lambda = 0.03$	$\lambda = 0.035$	$\lambda = 0.04$	$\lambda = 0.045$	$\lambda = 0.05$	$\lambda = 0.02$	$\lambda = 0.025$	$\lambda = 0.03$	$\lambda = 0.035$	$\lambda = 0.04$	$\lambda = 0.045$	$\lambda = 0.05$	$\lambda = 0.02$	$\lambda = 0.025$	$\lambda = 0.03$	$\lambda = 0.035$	$\lambda = 0.04$	$\lambda = 0.045$	$\lambda = 0.05$
10	5	6	7	8	9	9	10	7	8	9	10	12	13	14	8	10	11	13	14	16	17
12	5	6	7	8	9	10	11	7	8	10	11	12	13	14	9	10	12	13	15	16	18
15	5	7	8	9	10	10	11	7	9	10	11	13	14	15	9	11	13	14	16	17	19
22	6	7	8	9	10	11	12	8	10	11	13	14	15	17	10	12	14	16	17	19	21
28	6	7	9	10	11	12	13	8	10	12	13	15	16	18	10	12	15	16	18	20	22
35	6	8	9	10	11	13	14	9	10	12	14	16	17	19	11	13	15	17	19	21	23
42	7	8	9	11	12	13	14	9	11	13	14	16	18	19	11	14	16	18	20	22	24
54	7	8	10	11	12	14	15	9	11	13	15	17	19	21	12	14	17	19	21	24	26
76.1	7	9	10	12	13	15	16	10	12	14	16	18	20	22	12	15	18	20	23	25	28
108	7	9	11	12	14	15	17	10	13	15	17	19	21	23	13	16	19	22	24	27	30

Key

t = temperature of contents (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements. In situations where the ambient air temperature is greater than 25 °C and/or the relative humidity exceeds 80%, these thicknesses will not be sufficient to control condensation.

Table 8 **Minimum insulation thickness for chilled and cold water steel pipes to control condensation on a low emissivity outer surface (0.05) with an ambient temperature of +25 °C and a relative humidity of 80%**

	ε = 0.05																				
Outside diameter of steel pipe on which insulation thickness has been based (mm)	t = 10							t = 5							t = 0						
	Insulation thickness (mm)							**Insulation thickness** (mm)							**Insulation thickness** (mm)						
	λ = 0.02	λ = 0.025	λ = 0.03	λ = 0.035	λ = 0.04	λ = 0.045	λ = 0.05	λ = 0.02	λ = 0.025	λ = 0.03	λ = 0.035	λ = 0.04	λ = 0.045	λ = 0.05	λ = 0.02	λ = 0.025	λ = 0.03	λ = 0.035	λ = 0.04	λ = 0.045	λ = 0.05
17.2	11	13	15	17	19	21	23	14	18	21	23	26	29	32	18	22	26	30	33	37	41
21.3	11	14	16	18	20	23	25	15	19	22	25	28	31	34	19	24	28	32	36	40	43
26.9	12	15	17	20	22	24	27	17	20	24	27	30	34	37	21	25	30	34	38	42	47
33.7	13	16	18	21	24	26	29	18	21	25	29	32	36	39	22	27	32	36	41	46	50
42.4	14	17	20	22	25	28	31	19	23	27	31	35	39	42	24	29	34	39	44	49	54
48.3	14	17	20	23	26	29	32	20	24	28	32	36	40	44	25	30	36	41	46	51	56
60.3	15	18	22	25	28	31	34	21	26	30	34	39	43	47	27	32	38	44	49	54	60
76.1	16	20	23	27	30	33	37	22	27	32	37	42	46	51	28	35	41	47	53	58	64
88.9	17	20	24	28	31	35	38	23	29	34	39	44	48	53	30	36	43	49	55	61	67
114.3	18	22	26	30	34	37	41	25	31	36	42	47	52	57	32	39	46	53	60	66	73
139.7	19	23	27	32	36	40	44	26	32	38	44	50	55	61	34	41	49	56	63	70	77
168.3	20	24	29	33	38	42	46	28	34	40	46	52	58	64	36	44	51	59	67	74	82
219.1	21	26	31	36	40	45	49	30	37	43	50	56	63	69	38	47	55	64	72	80	88
273	22	27	33	38	43	48	53	31	39	46	53	60	67	74	40	50	59	68	77	85	94
323.9	23	29	34	39	45	50	55	33	41	48	55	63	70	77	42	52	62	71	80	90	99
355.6	24	29	35	40	46	51	56	34	41	49	57	64	72	79	43	53	63	73	82	92	101
406.4	25	30	36	42	47	53	58	35	43	51	59	67	74	82	45	55	65	76	86	95	105
457	25	31	37	43	49	54	60	36	44	52	61	69	77	85	46	57	68	78	88	98	109
508	26	32	38	44	50	56	62	37	45	54	62	71	79	87	47	58	69	80	91	101	112
610	27	33	40	46	52	59	65	38	47	56	65	74	83	91	49	61	73	84	95	106	117

Key

t = temperature of contents (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements. In situations where the ambient air temperature is greater than 25 °C and/or the relative humidity exceeds 80%, these thicknesses will not be sufficient to control condensation.

Table 9 **Minimum insulation thickness for chilled and cold water copper pipes to control condensation on a low emissivity outer surface (0.05) with an ambient temperature of +25 °C and a relative humidity of 80%**

Outside diameter of [C1⟩ copper ⟨C1] pipe on which insulation thickness has been based (mm)	**ε = 0.05**																				
	***t* = 10**							***t* = 5**							***t* = 0**						
	Insulation thickness (mm)							**Insulation thickness** (mm)							**Insulation thickness** (mm)						
	λ = 0.02	**λ = 0.025**	**λ = 0.03**	**λ = 0.035**	**λ = 0.04**	**λ = 0.045**	**λ = 0.05**	**λ = 0.02**	**λ = 0.025**	**λ = 0.03**	**λ = 0.035**	**λ = 0.04**	**λ = 0.045**	**λ = 0.05**	**λ = 0.02**	**λ = 0.025**	**λ = 0.03**	**λ = 0.035**	**λ = 0.04**	**λ = 0.045**	**λ = 0.05**
10	9	11	13	15	16	18	20	12	15	17	20	22	25	27	15	19	22	25	28	32	35
12	9	11	13	15	17	19	21	13	16	18	21	24	26	29	16	20	23	27	30	33	37
15	10	12	14	16	18	20	22	14	17	20	23	25	28	31	17	21	25	28	32	36	39
22	11	14	16	18	21	23	25	16	19	22	25	28	32	35	20	24	28	32	36	40	44
28	12	15	17	20	22	25	27	17	20	24	27	31	34	37	21	26	30	34	39	43	47
35	13	16	18	21	24	26	29	18	22	25	29	33	36	40	23	27	32	37	42	46	51
42	14	17	19	22	25	28	31	19	23	27	31	35	38	42	24	29	34	39	44	49	53
54	15	18	21	24	27	30	33	20	25	29	33	37	42	46	26	31	37	42	47	53	58
76.1	16	20	23	27	30	33	37	22	27	32	37	42	46	51	28	35	41	47	53	58	64
108	18	22	26	29	33	37	41	25	30	36	41	46	51	56	31	38	45	52	59	65	71

Key

t = temperature of contents (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements. In situations where the ambient air temperature is greater than 25 °C and/or the relative humidity exceeds 80%, these thicknesses will not be sufficient to control condensation.

Table 10 **Indicative thickness of insulation for cooled and chilled water systems to control heat gain – Low emissivity outer surfaces**

Outside diameter of steel pipe on which insulation thickness has been based	Low emissivity surface finish (ε = 0.05)																	
	Cooled water temperatures >10 °C						Chilled water temperatures >4.9 °C to <10 °C						Chilled water temperatures of 0 °C to <4.9 °C					
	t = 10						t = 5						t = 0					
	λ = 0.02	λ = 0.025	λ = 0.030	λ = 0.035	λ = 0.040	Maximum permissible heat gain	λ = 0.02	λ = 0.025	λ = 0.030	λ = 0.035	λ = 0.040	Maximum permissible heat gain	λ = 0.02	λ = 0.025	λ = 0.030	λ = 0.035	λ = 0.040	Maximum permissible heat gain
(mm)	Thickness of insulation (mm)					(W/m)	Thickness of insulation (mm)					(W/m)	Thickness of insulation (mm)					(W/m)
17.2	6	8	11	15	20	2.48	7	11	15	20	28	2.97	9	13	18	24	33	3.47
21.3	7	9	12	16	21	2.72	8	12	16	21	28	3.27	9	14	19	25	34	3.81
26.9	7	10	13	17	22	3.05	9	13	18	23	30	3.58	11	15	21	27	36	4.18
33.7	8	11	14	18	23	3.41	10	14	19	24	31	4.01	12	17	22	29	38	4.6
42.4	9	12	15	19	24	3.86	11	15	20	25	32	4.53	13	18	24	31	40	5.11
48.3	9	13	16	20	25	4.11	12	16	21	26	33	4.82	14	19	25	32	41	5.45
60.3	10	13	16	20	25	4.78	13	17	22	27	34	5.48	15	20	26	33	42	6.17
76.1	11	14	17	21	26	5.51	14	18	23	28	35	6.3	16	22	28	35	44	6.7
88.9	11	14	18	21	26	6.17	14	19	24	29	36	6.9	17	22	29	35	43	7.77
114.3	12	15	19	22	27	7.28	15	19	24	29	35	8.31	18	24	30	36	44	9.15
139.7	12	15	19	22	27	8.52	16	20	25	30	36	9.49	19	25	31	37	45	10.45
168.3	12	15	19	22	26	9.89	16	20	25	30	36	10.97	20	25	32	38	46	11.86
219.1	12	15	19	22	26	12.27	16	21	25	30	36	13.57	20	26	32	38	45	14.61
273	12	16	19	22	26	14.74	16	21	26	30	36	16.28	21	26	32	38	45	17.48

Key

t = water temperature; standardised assumption for calculation purposes (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

ε = emissivity of outer surface of insulated system

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe at t °C in still air at 25 °C, emissivity of outer surface of insulated system as specified.

NOTE 2 Thicknesses derived solely against the criteria noted in this table may not necessarily satisfy other design requirements such as control of condensation.

NOTE 3 Heat gain relates to the specified thickness and temperature.

Table 11 **Indicative thickness of insulation for cooled and chilled water systems to control heat gain – High emissivity outer surfaces**

Outside diameter of steel pipe on which insulation thickness has been based	High emissivity surface finish (ε = 0.9)																	
	Cooled water temperatures >10 °C						Chilled water temperatures >4.9 °C to <10 °C						Chilled water temperatures of 0 °C to <4.9 °C					
	t = 10						t = 5						t = 0					
	λ = 0.02	λ = 0.025	λ = 0.030	λ = 0.035	λ = 0.040	Maximum permissible heat gain	λ = 0.02	λ = 0.025	λ = 0.030	λ = 0.035	λ = 0.040	Maximum permissible heat gain	λ = 0.02	λ = 0.025	λ = 0.030	λ = 0.035	λ = 0.040	Maximum permissible heat gain
(mm)	**Thickness of insulation** (mm)					(W/m)	**Thickness of insulation** (mm)					(W/m)	**Thickness of insulation** (mm)					(W/m)
17.2	8	11	15	20	26	2.48	10	14	19	25	33	2.97	11	16	22	29	39	3.47
21.3	9	12	16	21	27	2.72	10	15	20	26	34	3.27	12	17	23	30	40	3.81
26.9	10	13	17	22	28	3.05	12	16	22	28	36	3.58	13	18	25	33	42	4.18
33.7	10	14	18	23	29	3.41	13	17	23	30	37	4.01	15	20	27	35	44	4.6
42.4	11	15	20	25	30	3.86	14	19	24	31	38	4.53	16	22	29	37	46	5.11
48.3	12	16	21	26	31	4.11	15	20	25	32	39	4.82	17	23	30	38	47	5.45
60.3	13	17	21	26	31	4.78	16	21	26	33	40	5.48	18	24	31	39	48	6.17
76.1	13	18	22	27	32	5.51	17	22	28	34	42	6.3	21	28	35	44	54	6.7
88.9	14	18	22	27	33	6.17	17	23	29	35	43	6.9	20	26	34	42	50	7.77
114.3	15	19	24	29	34	7.28	18	23	29	36	43	8.31	21	28	35	43	51	9.15
139.7	15	19	24	29	34	8.52	19	25	31	37	44	9.49	22	29	36	44	53	10.45
168.3	16	20	24	29	34	9.89	20	25	31	37	44	10.97	23	30	37	45	54	11.86
219.1	16	20	25	29	34	12.27	20	26	31	38	44	13.57	24	31	38	46	54	14.61
273	16	21	25	30	35	14.74	21	26	32	38	44	16.28	25	31	39	46	54	17.48

Key

t = water temperature; standardised assumption for calculation purposes (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

ε = emissivity of outer surface of insulated system

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe at t °C in still air at 25 °C, emissivity of outer surface of insulated system as specified.

NOTE 2 Thicknesses derived solely against the criteria noted in this table may not necessarily satisfy other design requirements such as control of condensation.

NOTE 3 Heat gain relates to the specified thickness and temperature.

8 Central heating, air conditioning and direct hot water supply installations in non-domestic applications

NOTE 1 Attention is drawn to the energy performance requirements of Approved Documents L2A [9] and L2B [7], Technical Booklet F2 [8] and Non-domestic Technical Handbook [1], Section 6.

The thicknesses of insulation specified in Table 13 to Table 18 to limit heat transfer meet or improve upon the minimum requirements of Approved Documents L2A [9] and L2B [7] and Technical Booklet F2 [8]. However, these thicknesses of insulation might not comply with future revisions of the Building Regulations [5] and the Building Regulations (Northern Ireland) [6], and the current versions of these documents should be consulted to ensure compliance.

Section 6 of the Non-domestic Technical Handbook [1] retains references to guidance given in BS 5422:2001 as a means of showing compliance.

NOTE 2 It should be noted that Building Regulations [3], [5], [6] provide minimum requirements for heat transfer to reduce energy use. The use of greater thicknesses of insulation can provide substantial financial and environmental benefits. Additional considerations might include acoustic performance, aesthetic qualities, fire properties, durability and thermal performance for reasons other than energy reduction; such as process control, control of condensation, internal building environment, surface temperature and freezing. This standard provides guidance on fire properties and thermal performance only.

8.1 Information to be supplied by the specifier

The specifier shall supply details of the intended function and performance requirements of the application, and the materials to be used, in accordance with Clause **4**.

NOTE In addition to the parameters outlined in Clause ***4****, items such as specific heat capacity and mass flow rates of fluids may also be required under certain circumstances, particularly where calculating from first principles using BS EN ISO 12241:1998. However, these additional parameters are not required for the use of the tables contained in this standard.*

8.2 Physical characteristics

8.2.1 General

The physical characteristics of the insulating material, together with adhesive, fixing, vapour barrier and finishing material, whether pre-applied or applied on site, shall conform to **5.1**, **8.2.2** and **8.2.3**.

8.2.2 Fire performance

Insulation materials and systems used for central heating, air conditioning and direct hot water supply installations in non-domestic applications shall conform to the following requirements.

NOTE 1 Attention is drawn to the applicable requirements of the Building Regulations [5], the Building (Scotland) Regulations [3] and the Building Regulations (Northern Ireland) [6].

Insulation systems on pipework or ductwork traversing a fire-resisting division shall maintain the level of fire resistance of the wall, floor or cavity barrier through which they pass.

NOTE 2 In the event of a fire some insulation systems can generate appreciable quantities of smoke and toxic fumes. Consideration should be given to the choice of materials bearing in mind their location, e.g. enclosed areas or adjacent to air ducts through which the smoke or fumes may spread.

The complete assembly of installed insulation materials (whether faced or unfaced) shall be Class O (national class) or better.

The insulation material itself (i.e. tested without any facing) shall be Class 1 (national class) or better.

For faced or over-clad materials, which are not Class 1 (national class) or better when tested without the facing, particular care shall be taken with the facing to ensure that all joints and seams, etc. are fitted correctly, so that the underlying insulation is not left exposed to a potential ignition source. Where the complete assembly is liable to mechanical damage in use, the final finish shall be sufficiently strong to ensure that the insulation does not become exposed.

If there is a potential hazard from contamination by oil or other flammable chemicals, a suitably resistant finish, e.g. a metal sheet or appropriate non-absorbent coating, shall be applied over the vulnerable areas. The lapped joints of sheet finishes shall be arranged to shed contaminating fluids away from the insulating material.

In underground or windowless buildings, the underlying thermal insulation material used for external insulation of ventilation ductwork or pipes greater than 100 mm nominal bore shall itself be of "limited combustibility" or be "non-combustible". In addition, the complete assembly of installed insulation materials (whether faced or unfaced) shall be Class O (national class) or better.

NOTE 3 See Annex E for an explanation of "limited combustibility", "non-combustible", Class O and Class 1 (national classes) and Classes A1, A2, B, C, D, E or F (European classes).

8.2.3 Water vapour barrier – Permeance requirements

If pipework or ductwork for central heating, air conditioning or direct hot water supply systems is likely to have a surface temperature below the dew point temperature, the insulation materials and system shall conform to the permeance requirements and installation methods for water vapour barriers detailed in **5.6**.

Insulation materials and systems used for chilled air ductwork shall be installed in accordance with and shall conform to the permeance requirements specified in **5.6**.

When tested in accordance with BS 3177 or BS 4370-2, as appropriate, the permeance of the material used as a vapour barrier shall not exceed the values given in Table 1 for the appropriate temperature of the plant.

8.2.4 Maximum and minimum service temperature

The insulation selected shall be suitable for use at the maximum and minimum temperatures of the intended application.

NOTE For example, pipes serving solar heated hot water systems may be subject to peak temperatures of greater than 150 °C.

8.3 Insulation thickness

8.3.1 Minimum thickness of insulation to control condensation on ductwork carrying chilled air

In the absence of specific instructions from the specifier, the insulation thickness shall be not less than that given in Table 12.

Thicknesses of insulation for pipe diameters not shown in Table12, and for all plastic pipes, shall be determined in accordance with Annex H.

8.3.2 Minimum thickness of insulation to control heat transfer through ducts

In the absence of specific instructions from the specifier, the thickness applied shall be not less than that given in Table 13 and Table 14.

For Table 13, insulation thicknesses shall be calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal duct at 35 °C, with 600 mm vertical sidewall in still air at 15 °C, emissivity of outer surface of insulated system as specified.

For Table 14, insulation thicknesses shall be calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal duct at 13 °C, with 600 mm vertical sidewall in still air at 25 °C, emissivity of outer surface of insulated system as specified.

8.3.3 Minimum thickness of insulation to control heat loss from pipes

NOTE The relevant thicknesses defined in Table 15, Table 16, Table 17 and Table 18 have been derived using the methodology set out in Annex A.

In the absence of specific instructions from the specifier, the insulation thickness shall be as given in Table 15 to Table 18.

For an intermediate pipe diameter not listed in Table 15 and Table 16, compliance calculations shall use the nearest larger diameter listed.

Thicknesses of insulation for pipe diameters not shown in Table 15 to Table 18, and for all plastic pipes, shall be determined in accordance with Annex H.

For pipes or vessels of diameter greater than 273 mm, the items in Table 15 to Table 18 shall be assumed to be 273 mm for calculation purposes.

For Table 15 and Table 16, insulation thicknesses shall be calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe [C1⟩ at *t* °C in still air at 15 °C ⟨C1], emissivity of outer surface of insulated system as specified.

For Table 17 and Table 18, insulation thicknesses shall be calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe at 60 °C in still air at 15 °C, emissivity of outer surface of insulated system as specified.

Table 12 **Minimum insulation thickness for condensation control on ductwork carrying chilled air in ambient conditions: indoor still air temperature +25 °C, relative humidity 80%, dewpoint temperature 21.3 °C**

Minimum air temperature inside duct (°C)	**Minimum thickness of insulating material** (mm)																				
	λ = 0.020			**λ = 0.025**			**λ = 0.030**			**λ = 0.035**			**λ = 0.040**			**λ = 0.045**			**λ = 0. 050**		
	ε = 0.05	**ε = 0.44**	**ε = 0.90**	**ε = 0.05**	**ε = 0.44**	**ε = 0.90**	**ε = 0.05**	**ε = 0.44**	**ε = 0.90**	**ε = 0.05**	**ε = 0.44**	**ε = 0.90**	**ε = 0.05**	**ε = 0.44**	**ε = 0.90**	**ε = 0.05**	**ε = 0.44**	**ε = 0.90**	**ε = 0.05**	**ε = 0.44**	**ε = 0.90**
15	15	8	5	18	9	6	22	11	7	25	13	8	29	15	10	32	17	11	36	18	12
10	26	10	9	32	17	11	39	20	13	45	23	15	52	26	17	58	29	19	64	33	21
5	37	19	12	47	24	15	56	28	18	64	33	21	75	38	24	83	42	27	92	47	30
0	48	25	16	60	31	20	72	37	24	84	43	27	96	49	31	108	56	35	120	61	39

Key

λ = thermal conductivity of insulating material at a mean temperature of 10 °C [W/(m · K)]

ε = external surface emissivity

NOTE 1 Thicknesses given are calculated in accordance with BS EN ISO 12241:1998 based on 0.6 m vertical flat surface of rectangular duct but are also adequate for horizontal surfaces.

NOTE 2 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

NOTE 3 Refer to Annex B, Table B.1 for surface emissivities of common finishing materials. In situations where the ambient air temperature is greater than 25 °C and/or the relative humidity exceeds 80%, these thicknesses will not be sufficient to control condensation.

Table 13 **Indicative thickness of insulation for ductwork carrying warm air to control heat loss**

Thermal conductivity at insulation mean temperature [W/(m · K)]							Maximum Permissible Heat loss (W/m²)
0.020	0.025	0.030	0.035	0.040	0.045	0.050	
Thickness of insulation (mm) with low emissivity facing: 0.05							
17	21	25	29	33	38	42	16.34
Thickness of insulation (mm) with medium emissivity facing: 0.44							
21	26	31	36	41	46	51	16.34
Thickness of insulation (mm) with high emissivity facing: 0.90							
22	27	33	38	44	49	54	16.34

NOTE 1 Heat loss relates to the specified thickness and temperature.

NOTE 2 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal duct at 35 °C, with 600 mm vertical sidewall in still air at 15 °C, emissivity of outer surface of insulated system as specified.

Table 14 **Indicative thickness of insulation for chilled and dual-purpose ducting to control heat transfer**

Thermal conductivity at insulation mean temperature [W/(m · K)]							Maximum Permissible Heat gain (W/m²)
0.020	0.025	0.030	0.035	0.040	0.045	0.050	
Thickness of insulation (mm) with low emissivity facing: 0.05							
29	36	43	50	57	64	71	6.45
Thickness of insulation (mm) with medium emissivity facing: 0.44							
33	41	49	58	66	74	82	6.45
Thickness of insulation (mm) with high emissivity facing: 0.90							
35	43	52	61	69	78	86	6.45

NOTE 1 Heat [C1⟩ gain ⟨C1] relates to the specified thickness and temperature.

NOTE 2 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal duct at 13 °C, with 600 mm vertical sidewall in still air at 25 °C, emissivity of outer surface of insulated system as specified.

NOTE 3 Thicknesses derived solely against the criteria noted in this table may not necessarily satisfy other design requirements such as control of condensation.

Table 15 **Indicative thickness of insulation for non-domestic heating services to control heat loss – Low emissivity outer surfaces**

Outside diameter of steel pipe on which insulation thickness has been based	Low emissivity surface finish (ε = 0.05)																							
	Low temperature heating services (≤ 95 °C)								Medium temperature heating services (96 °C – 120 °C)								High temperature heating services (121 °C – 150 °C)							
	t = 75								t = 100								t = 125							
	λ = 0.025	λ = 0.03	λ = 0.035	λ = 0.04	λ = 0.045	λ = 0.05	λ = 0.055	Max heat loss	λ = 0.025	λ = 0.03	λ = 0.035	λ = 0.04	λ = 0.045	λ = 0.05	λ = 0.055	Max heat loss	λ = 0.025	λ = 0.03	λ = 0.035	λ = 0.04	λ = 0.045	λ = 0.05	λ = 0.055	Max heat loss
(mm)	Thickness of insulation (mm)							(W/m)	Thickness of insulation (mm)							(W/m)	Thickness of insulation (mm)							(W/m)
17.2	12	17	22	30	39	51	66	8.9	11	15	20	26	34	44	56	13.34	10	13	18	24	31	39	50	17.92
21.3	14	20	26	35	46	59	75	9.28	14	18	25	32	42	54	69	13.56	12	17	22	29	38	48	61	18.32
26.9	16	22	29	38	49	62	78	10.06	17	24	31	41	53	67	85	13.83	16	22	28	37	47	60	76	18.7
33.7	18	24	31	40	51	64	79	11.07	21	28	37	48	62	78	98	14.39	20	27	36	46	59	74	93	19.02
42.4	20	26	33	42	52	65	79	12.3	24	32	41	52	66	83	103	15.66	26	35	45	59	74	93	117	19.25
48.3	21	27	35	44	55	67	82	12.94	25	33	42	53	67	83	102	16.67	28	37	48	61	77	97	120	20.17
60.3	23	29	37	46	56	68	82	14.45	27	36	46	57	71	87	106	18.25	31	41	52	66	83	102	125	21.96
76.1	24	31	39	48	58	70	83	16.35	30	39	49	60	74	89	107	20.42	34	45	57	71	88	107	129	24.21
88.9	25	32	40	49	59	70	82	17.91	31	40	51	62	76	91	108	22.09	36	47	60	74	91	110	132	25.99
114.3	27	34	42	51	61	71	83	20.77	34	43	54	65	79	93	110	25.31	40	51	64	79	96	115	136	29.32
139.7	28	35	43	52	61	71	82	23.71	36	46	57	68	82	96	112	28.23	43	55	68	83	100	118	139	32.47
168.3	29	37	44	53	62	72	82	26.89	38	48	59	70	83	98	113	31.61	46	58	71	86	103	121	141	36.04
219.1	30	38	45	54	62	72	82	32.54	40	50	61	72	85	98	113	37.66	49	62	75	90	106	124	144	42.16
273	31	38	46	54	62	71	80	38.83	42	52	63	74	87	100	114	43.72	52	64	78	93	109	127	145	48.48

Key

t = water temperature; standardized assumption for calculation purposes (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

ε = emissivity of outer surface of insulated system

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe [C1〉 at t °C in still air at 15 °C, 〈C1] emissivity of outer surface of insulated system as specified.

NOTE 2 Heat loss relates to the specified thickness and temperature.

NOTE 3 The thicknesses in this table are applicable to pipes serving commercial solar hot water panels.

Table 16 Indicative thickness of insulation for non-domestic heating services to control heat loss – High emissivity outer surfaces

Outside diameter of steel pipe on which insulation thickness has been based	High emissivity surface finish (ε = 0.9)																							
	Low temperature heating services (≤ 95 °C)								Medium temperature heating services (96 °C – 120 °C)								High temperature heating services (121 °C – 150 °C)							
	t = 75								t = 100								t = 125							
	λ = 0.025	λ = 0.03	λ = 0.035	λ = 0.04	λ = 0.045	λ = 0.05	λ = 0.055	Max heat loss	λ = 0.025	λ = 0.03	λ = 0.035	λ = 0.04	λ = 0.045	λ = 0.05	λ = 0.055	Max heat loss	λ = 0.025	λ = 0.03	λ = 0.035	λ = 0.04	λ = 0.045	λ = 0.05	λ = 0.055	Max heat loss
(mm)	Thickness of insulation (mm)							(W/m)	Thickness of insulation (mm)							(W/m)	Thickness of insulation (mm)							(W/m)
17.2	14	19	25	34	44	57	72	8.9	13	17	23	30	38	49	62	13.34	12	16	21	28	35	45	57	17.92
21.3	16	22	30	39	50	64	81	9.28	16	21	28	36	47	60	75	13.56	15	20	26	33	42	54	67	18.32
26.9	18	25	33	42	54	68	85	10.06	20	26	35	45	58	73	92	13.83	18	24	32	41	52	66	82	18.7
33.7	20	27	35	44	56	69	85	11.07	23	31	41	53	67	84	106	14.39	23	30	39	51	64	81	100	19.02
42.4	22	29	37	46	57	70	86	12.3	26	35	45	57	72	89	110	15.66	28	38	49	63	80	100	124	19.25
48.3	23	30	39	48	60	73	88	12.94	27	36	46	58	72	89	109	16.67	30	40	52	66	83	103	127	20.17
60.3	25	32	41	51	62	74	89	14.45	30	39	50	62	77	94	113	18.25	34	44	57	71	88	109	133	21.96
76.1	27	35	43	53	64	76	90	16.35	32	42	53	65	80	96	115	20.42	37	48	61	76	94	114	137	24.21
88.9	28	36	44	54	64	76	90	17.91	34	44	55	68	82	98	116	22.09	39	51	64	79	97	117	140	25.99
114.3	30	38	47	56	66	78	91	20.77	37	47	58	71	85	100	118	25.31	43	55	69	85	102	122	144	29.32
139.7	31	39	48	57	67	78	90	23.71	39	50	61	74	88	103	120	28.23	46	59	73	89	106	126	148	32.47
168.3	33	40	49	58	68	79	90	26.89	41	52	64	76	90	105	122	31.61	49	62	76	92	109	129	150	36.04
219.1	34	42	50	60	69	79	90	32.54	44	55	66	79	92	106	122	37.66	53	66	81	96	114	132	153	42.16
273	35	43	51	60	69	79	89	38.83	46	57	68	81	94	108	123	43.72	56	69	84	100	117	135	155	48.48

Key

t = water temperature; standardized assumption for calculation purposes (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

ε = emissivity of outer surface of insulated system

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe [C1⟩ at t °C in still air at 15 °C, ⟨C1] emissivity of outer surface of insulated system as specified.

NOTE 2 Heat loss relates to the specified thickness and temperature.

NOTE 3 The thicknesses in this table are applicable to pipes serving commercial solar hot water panels.

Table 17 **Indicative thickness of insulation for non-domestic hot water service areas to control heat loss – Low emissivity outer surfaces**

Outside diameter of pipe on which insulation thickness has been based (mm)	**Thermal conductivity at insulation mean temperature** [W/(m · K)] **(low emissivity outer surface: ε = 0.05)**							**Maximum Permissible Heat loss**
	0.025	**0.030**	**0.035**	**0.040**	**0.045**	**0.050**	**0.055**	
	Thickness of insulation (mm)							(W/m)
17.2	12	17	23	31	41	53	69	6.60
21.3	14	19	25	33	43	55	70	7.13
26.9	15	21	27	35	45	57	71	7.83
33.7	17	22	29	37	47	58	72	8.62
42.4	18	23	30	38	47	57	70	9.72
48.3	19	25	32	40	49	60	73	10.21
60.3	20	26	33	41	50	60	71	11.57
76.1	22	28	35	43	52	61	72	13.09
88.9	22	28	35	43	51	60	70	14.58
114.3	23	29	36	43	51	60	69	17.20
139.7	24	31	37	44	52	60	69	19.65
168.3	25	32	38	45	53	61	70	22.31
219.1	26	32	38	45	52	60	68	27.52
273.0 and above	27	33	39	46	53	60	68	32.40

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe at 60 °C in still air at 15 °C, emissivity of outer surface of insulated system as specified.

NOTE 2 Heat loss relates to the specified thickness and temperature.

Table 18 **Indicative thickness of insulation for non-domestic hot water service areas to control heat loss – High emissivity outer surfaces**

Outside diameter of pipe on which insulation thickness has been based (mm)	Thermal conductivity at insulation mean temperature [W/(m · K)] (high emissivity outer surface: ε = 0.90)							Maximum Permissible Heat loss
	0.025	**0.030**	**0.035**	**0.040**	**0.045**	**0.050**	**0.055**	
	Thickness of insulation (mm)							(W/m)
17.2	14	19	26	34	45	58	75	6.60
21.3	16	21	28	37	47	60	76	7.13
26.9	17	23	30	39	49	62	77	7.83
33.7	19	25	32	41	51	63	78	8.62
42.4	20	26	33	42	52	63	76	9.72
48.3	21	28	35	44	54	66	79	10.21
60.3	23	29	37	45	55	66	78	11.57
76.1	25	31	39	47	57	67	79	13.09
88.9	25	32	39	47	56	66	77	14.58
114.3	26	33	40	48	57	66	77	17.20
139.7	27	34	41	49	58	67	77	19.65
168.3	29	35	43	51	59	68	77	22.31
219.1	29	36	43	51	59	67	76	27.52
273.0 and above	30	37	44	52	60	68	77	32.40

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe at 60 °C in still air at 15 °C, emissivity of outer surface of insulated system as specified.

NOTE 2 Heat loss relates to the specified thickness and temperature.

9 Central heating and hot water services for domestic applications

NOTE 1 Attention is drawn to the energy performance requirements of Approved Documents L1A [10] and L1B [11], Technical Booklet F1 [12] and Domestic Technical Handbook [2], Section 6.

The thicknesses of insulation specified in Table 19 and Table 20 to limit heat transfer meet or improve upon the minimum requirements of Approved Documents L1A [10] and L1B [11] and Technical Booklet F1 [12]. However, these thicknesses of insulation might not comply with future revisions of the Building Regulations [5] and the Building Regulations (Northern Ireland) [6], and the current versions of these documents should be consulted to ensure compliance.

Section 6 of the Domestic Technical Handbook [2] retains references to guidance given in BS 5422:2001 as a means of showing compliance.

NOTE 2 For replacement systems, whenever a boiler or hot water storage vessel is replaced in an existing system, any pipes that are exposed as part of the work or are otherwise accessible should be insulated with insulation labelled as complying with the Domestic Heating Compliance Guide [13] or to some lesser standard where practical constraints dictate.

NOTE 3 It should be noted that Building Regulations [5], [3], [6] provide minimum requirements for heat transfer to reduce energy use. The use *of greater thicknesses of insulation can provide substantial financial and environmental benefits. Additional considerations might include acoustic performance, aesthetic qualities, fire properties, durability and thermal performance for reasons other than energy reduction; such as process control, control of internal building environment, surface temperature and freezing. This standard provides guidance on fire properties and thermal performance only.*

9.1 Information to be supplied by the specifier

The specifier shall supply details of the intended function and performance requirements of the application, and the materials to be used, in accordance with Clause **4**.

9.2 Physical characteristics

9.2.1 General

The physical characteristics of the insulating material, together with adhesive, fixing, vapour barrier and finishing materials, shall conform to **5.1**, **9.2.2** and **9.2.3**.

9.2.2 Fire performance

Insulation materials and systems used for central heating and hot and cold water supply installations for domestic applications shall conform to the following requirements.

NOTE 1 Attention is drawn to the applicable requirements of the Building Regulations [5], the Building (Scotland) Regulations [3] and the Building Regulations (Northern Ireland) [6].

Insulation systems on pipework or ductwork traversing a fire-resisting division shall maintain the level of fire resistance of the wall, floor or cavity barrier through which they pass.

NOTE 2 In the event of a fire some insulation systems can generate appreciable quantities of smoke and toxic fumes. Consideration should be given to the choice of materials bearing in mind their location, e.g. enclosed areas or adjacent to air ducts through which the smoke or fumes may spread.

The complete assembly of installed insulation materials (whether faced or unfaced) shall be Class 1 (national class) or better.

For faced or over-clad materials, which are not Class 1 (national class) or better when tested without the facing, particular care shall be taken with the facing to ensure that all joints and seams, etc. are fitted correctly, so that the underlying insulation is not left exposed to a potential ignition source. Where the complete assembly is liable to mechanical damage in use, the final finish shall be sufficiently strong to ensure that the insulation does not become exposed.

If there is a potential hazard from contamination by oil or other flammable chemicals, a suitably resistant finish, e.g. a metal sheet or appropriate non-absorbent coating, shall be applied over the vulnerable areas. The lapped joints of sheet finishes shall be arranged to shed contaminating fluids away from the insulating material.

In underground or windowless buildings, the underlying thermal insulation material used for external insulation of ventilation ductwork or pipes greater than 100 mm nominal bore shall itself be of "limited combustibility" or be "non-combustible". In addition, the complete assembly of installed insulation materials (whether faced or unfaced) shall be Class O (national class) or better.

NOTE See Annex E for an explanation of "limited combustibility", "non-combustible", Class O and Class 1 (national classes) and Classes A1, A2, B, C, D, E or F (European classes).

Where insulation is used on the exterior of pipework that is exposed within the building, the complete assembly of materials as installed shall have a rating for the surface spread of flame of not less than that for the wall or ceiling it traverses.

9.2.3 Vapour barriers – Permeance requirements

Insulation materials and systems used for cold water services shall be installed in accordance with and shall conform to the permeance requirements specified in **5.6**.

When tested in accordance with BS 3177 or BS 4370-2, as appropriate, the permeance of the material used for the vapour barrier shall not exceed the values given in Table 1 depending on the temperature of the plant.

9.2.4 Maximum and minimum service temperature

The insulation selected shall be suitable for use at the maximum and minimum temperatures of the intended application.

NOTE For example, pipes serving solar heated hot water systems may be subject to peak temperatures of greater than 150 °C.

9.3 Thickness for central heating and hot water pipes to limit heat losses

NOTE 1 Attention is drawn to the thicknesses of insulation for hot water pipes referred to by the Domestic Heating Compliance Guide [13] in order to restrict uncontrolled heat losses.

NOTE 2 Particular attention should be paid to situations where cold water pipes run adjacent to heating or hot water pipes in order to prevent uncontrolled pipe warming.

NOTE 3 Where pipes are in unheated areas or pass outside the envelope of the building, attention is drawn to the need to protect pipes against freezing.

Thicknesses of insulation to limit heat losses shall be not less than those specified in Table 19 and Table 20.

Thicknesses of insulation for pipe diameters not shown in Table 19 and Table 20, and for all plastic pipes, shall be determined in accordance with Annex H.

For pipes of diameter greater than 54 mm, the pipes in Table 19 and Table 20 shall be assumed to be 54 mm for calculation purposes.

For Table 19 and Table 20, insulation thicknesses shall be calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe at 60 °C in still air at 15 °C, emissivity of outer surface of insulated system as specified.

Table 19 **Indicative thickness of insulation for domestic heating and hot water systems having low emissivity outer surfaces**

Outside diameter of pipe on which insulation thickness has been based (mm)	**Thermal conductivity at 40 °C** [W/(m · K)] **(low emissivity facing: 0.05)**					**Maximum Permissible Heat loss**
	0.025	**0.030**	**0.035**	**0.040**	**0.045**	
	Thickness of insulation (mm)					(W/m)
8.0	3	5	6	8	11	7.06
10.0	5	6	8	11	14	7.23
12.0	6	8	10	14	18	7.35
15.0	7	9	12	15	20	7.89
22.0	8	11	14	18	23	9.12
28.0	10	12	16	20	24	10.07
35.0	11	14	17	22	26	11.08
42.0	12	15	18	23	27	12.19
54.0	12	16	19	23	28	14.12

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe at 60 °C in still air at 15 °C, emissivity of outer surface of insulated system as specified.

NOTE 2 Heat loss relates to the specified thickness and temperature.

NOTE 3 This table is applicable to pipes serving solar hot water panels.

Table 20 **Indicative thickness of insulation for domestic heating and hot water systems having high emissivity outer surfaces**

Outside diameter of pipe on which insulation thickness has been based (mm)	**Thermal conductivity at 40 °C** [W/(m · K)] **(high emissivity facing: [C1⟩ 0.95 ⟨C1])**					**Maximum Permissible Heat loss**
	0.025	**0.030**	**0.035**	**0.040**	**0.045**	
	Thickness of insulation (mm)					(W/m)
8.0	5	7	9	12	16	7.06
10.0	6	8	11	15	20	7.23
12.0	7	10	14	18	23	7.35
15.0	9	12	15	20	26	7.89
22.0	11	14	18	23	29	9.12
28.0	12	16	20	25	31	10.07
35.0	13	17	22	27	33	11.08
42.0	14	18	23	28	34	12.19
54.0	15	19	24	29	35	14.12

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe at 60 °C in still air at 15 °C, emissivity of outer surface of insulated system as specified.

NOTE 2 Heat loss relates to the specified thickness and temperature.

NOTE 3 This table is applicable to pipes serving solar hot water panels.

10 Process pipework and equipment applications

10.1 Information to be supplied by the specifier

10.1.1 General

The specifier shall supply details of the intended function and performance requirements of the application, and the materials to be used, in accordance with Clause **4**, as well as the requirements specified in **10.1.2** and **10.1.3**.

NOTE For the applications appropriate to this Clause, the specifier typically indicates the precise performance requirements of the insulation system.

10.1.2 Special service requirements

Reference shall be included in the specification to any difficult or unusual site conditions that influence the selection and/or application of insulating materials, e.g. relevant to transport, access, storage, scaffolding and weather protection.

10.1.3 Basis on which thickness is to be determined

The specifier shall state the basis for selection to be used and provide the relevant information giving due consideration to safety and environmental requirements.

*NOTE See **10.3**.*

10.2 Physical characteristics

10.2.1 General

The physical characteristics of the insulating material, fixing and finishing materials, whether applied during manufacture or on site, shall conform to **5.1**, **10.2.2** and **10.2.3**.

10.2.2 Fire performance

Insulation materials and systems used for process applications shall conform to the following requirements.

NOTE 1 Attention is drawn to the applicable requirements of the Building Regulations [5], the Building (Scotland) Regulations [3] and the Building Regulations (Northern Ireland) [6].

Insulation systems on pipework or ductwork traversing a fire-resisting division shall maintain the level of fire resistance of the wall, floor or cavity barrier through which they pass.

NOTE 2 In the event of a fire some insulation systems can generate appreciable quantities of smoke and toxic fumes. Consideration should be given to the choice of materials bearing in mind their location, e.g. enclosed areas or adjacent to air ducts through which the smoke or fumes may spread.

Insulation materials for use at temperatures above 230 °C (excluding finishing materials) shall be of "limited combustibility" or "non-combustible".

The complete assembly of installed insulation materials (whether faced or unfaced) shall be Class O (national class) or better.

The insulation material itself (i.e. tested without any facing) shall be Class 1 (national class) or better.

For faced or over-clad materials, which are not Class 1 (national class) or better when tested without the facing, particular care shall be taken with the facing to ensure that all joints and seams, etc. are fitted correctly, so that the underlying insulation is not left exposed to a potential ignition source. Where the complete assembly is liable to mechanical damage in use, the final finish shall be sufficiently strong to ensure that the insulation does not become exposed.

If there is a potential hazard from contamination by oil or other flammable chemicals, a suitably resistant finish, e.g. a metal sheet or appropriate non-absorbent coating, shall be applied over the vulnerable areas. The lapped joints of sheet finishes shall be arranged to shed contaminating fluids away from the insulating material.

In underground or windowless buildings, the underlying thermal insulation material used for external insulation of ventilation ductwork or pipes greater than 100 mm nominal bore shall itself be of "limited combustibility" or "non-combustible". In addition, the complete assembly of installed insulation materials (whether faced or unfaced) shall be Class O (national class) or better.

NOTE See Annex E for an explanation of "limited combustibility", "non-combustible", Class O and Class 1 (national classes) and Classes A1, A2, B, C, D, E or F (European classes).

10.2.3 Water vapour barrier – Permeance requirements

NOTE 1 Process applications can encompass systems running at temperatures throughout the full range of this standard, –40 °C to +700 °C, and beyond.

Where a process application has a normal operating temperature below ambient temperature, the insulation material and systems used for such an application shall be installed in accordance with and shall conform to the permeance requirements for water vapour barriers specified in **5.6**.

Where a process application has a normal operating temperature above ambient temperature, and a water vapour barrier is installed, the system shall be installed in accordance with and shall conform to the permeance requirements specified in **5.6**.

NOTE 2 The need to apply a vapour barrier is dependant upon whether such a system can on occasion have a surface temperature below the dew point temperature.

10.3 Insulation thickness

10.3.1 Control of heat loss

NOTE The thicknesses of insulation to control heat loss under process conditions have been derived according to the methodology given in Annex A. Recognizing the need to reduce carbon dioxide emissions, particularly in the process sector, the thicknesses given in Table 21 are intended to support this objective.

In the absence of specific instructions from the specifier, the insulation thickness shall be as given in Table 21.

For Table 21, insulation thicknesses shall be calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe in still air at [C1) 20 °C (C1]. Surface emissivity corresponding to outer surface specified.

Thicknesses of insulation for pipe diameters not shown in Table 21, and for all plastic pipes, shall be determined in accordance with Annex H.

The heat losses applicable for pipes of diameter greater than 273 mm and flat surfaces shall be calculated as if the pipe or plant was a 273 mm diameter surface as shown in Table 21.

10.3.2 Economic parameters

NOTE 1 Guidance for the determination of insulation thickness in accordance with economic parameters other than those used to calculate the control of heat loss in Table 21 is given in Annex G.

*NOTE 2 Control of heat loss thicknesses (**10.3.1**) are preferred where practicable because of their potentially greater contribution to environmental objectives in this sensitive sector.*

10.3.3 Other design criteria

Where there is a requirement to control surface temperature to the extent described in Table 22, Table 23 and Table 24, the insulation thicknesses given in these tables shall be used, as appropriate.

NOTE These tables provide information, which may be relevant to a risk assessment undertaken in relation to the protection of personnel from contact injury or to process performance requirements. BS EN ISO 13732-1, ISO/TS 13732-2 and BS EN ISO 13732-3 give guidance on surface temperatures for protection of personnel from contact injury.

Thicknesses of insulation for pipe diameters not shown in Table 22, Table 23 and Table 24, and for all plastic pipes, shall be determined in accordance with Annex H.

Where other design criteria are identified, e.g. a specified heat loss (see Table 25, Table 26 and Table 27), a specified temperature on the outer surface, or a special condition at the point of delivery, the calculation shall be in accordance with BS EN ISO 12241:1998 (see also BS 5970).

Table 21 **Minimum insulation thickness for process pipework and equipment to control heat loss**

Outside diameter of steel pipe on which insulation thickness has been based (mm)	*t* = 100								*t* = 200								*t* = 300							
	Insulation thickness (mm)							Max. heat loss (W/m)	Insulation thickness (mm)							Max. heat loss (W/m)	Insulation thickness (mm)							Max. heat loss (W/m)
	λ = 0.025	λ = 0.030	λ = 0.035	λ = 0.040	λ = 0.045	λ = 0.050	λ = 0.055		λ = 0.035	λ = 0.040	λ = 0.045	λ = 0.050	λ = 0.055	λ = 0.060	λ = 0.065		λ = 0.045	λ = 0.050	λ = 0.055	λ = 0.060	λ = 0.065	λ = 0.070	λ = 0.075	
17.2	10	14	19	24	31	40	51	12.79	20	26	33	42	54	68	85	28.67	30	38	47	59	73	91	112	47.12
21.3	11	15	20	25	32	40	51	14.04	22	28	36	46	57	71	88	30.72	32	41	50	62	76	93	114	50.54
26.9	13	17	21	27	34	42	52	15.42	24	30	38	47	59	72	88	33.73	35	43	53	65	79	95	115	54.97
33.7	14	18	23	28	35	43	52	17.25	26	32	40	49	60	73	88	37.11	38	46	56	68	81	97	116	59.90
42.4	15	19	24	30	37	45	54	19.15	28	35	43	52	63	76	90	40.76	41	49	59	71	84	99	116	65.79
48.3	16	20	25	31	38	46	54	20.42	29	36	44	53	64	76	90	43.42	43	51	61	73	86	101	118	69.42
60.3	17	21	26	32	39	46	54	23.17	31	38	46	55	65	77	90	48.44	46	54	64	76	88	102	119	76.66
76.1	18	23	28	34	41	48	56	26.21	34	41	49	58	68	80	92	54.20	49	58	68	80	92	106	122	85.08
88.9	19	24	29	35	42	49	57	28.73	36	43	51	60	70	81	94	58.66	51	60	70	81	94	107	122	92.02
114.3	20	25	30	36	43	49	57	33.89	38	46	54	63	73	84	96	67.25	55	64	74	85	97	110	125	104.55
139.7	21	26	31	37	44	50	57	38.74	40	48	56	65	75	85	97	75.74	58	67	77	88	100	113	127	116.62
168.3	22	27	33	38	44	51	58	43.99	42	50	58	67	77	87	98	84.85	61	70	80	91	103	115	129	129.46
219.1	23	28	34	39	45	52	58	53.38	44	52	60	69	78	88	99	101.24	64	73	83	94	105	117	130	152.70
273	24	29	35	40	46	53	59	62.87	46	54	62	71	80	90	100	117.64	67	76	86	97	108	120	132	175.73

Key

t = hot face temperature (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe in still air at [C1⟩ 20 °C ⟨C1]. Surface emissivity corresponding to outer surface specified.

NOTE 2 Maximum heat loss values for intermediate operating temperatures may be deduced by interpolation.

NOTE 3 Heat loss measured in Watts per metre (W/m) relates to the specified thickness and temperature.

NOTE 4 The thermal conductivity of insulation materials increases with mean temperature and for any given material. The use of a different thermal conductivity can be required for each operating temperature.

NOTE 5 These thicknesses may not satisfy other design requirements, in particular those for control of surface temperature (see Table 22, Table 23 and Table 24).

Table 21 **Minimum insulation thickness for process pipework and equipment to control heat loss** *(continued)*

Outside diameter of steel pipe on which insulation thickness has been based (mm)	*t* = 400								*t* = 500								*t* = 600							
	Insulation thickness (mm)							Max. heat loss (W/m)	Insulation thickness (mm)							Max. heat loss (W/m)	Insulation thickness (mm)							Max. heat loss (W/m)
	λ = 0.055	λ = 0.060	λ = 0.065	λ = 0.070	λ = 0.075	λ = 0.080	λ = 0.085		λ = 0.065	λ = 0.070	λ = 0.075	λ = 0.080	λ = 0.085	λ = 0.090	λ = 0.095		λ = 0.075	λ = 0.080	λ = 0.085	λ = 0.090	λ = 0.095	λ = 0.100	λ = 0.105	
17.2	39	48	59	73	89	108	131	69.08	46	56	67	80	96	115	137	96.08	52	62	73	87	102	120	141	126.93
21.3	42	51	62	76	91	110	132	74.10	49	59	70	83	98	116	137	103.00	56	66	77	91	106	123	143	135.40
26.9	46	55	66	80	95	113	134	80.06	54	64	75	88	103	121	141	110.72	61	71	82	96	111	128	147	145.58
33.7	49	58	69	82	97	114	134	87.16	58	68	79	92	107	124	143	119.80	66	76	87	101	115	132	151	156.77
42.4	53	62	73	86	101	117	136	95.05	62	72	83	96	110	127	145	130.57	71	81	92	105	120	136	155	170.00
48.3	55	65	76	89	104	120	139	99.66	64	75	86	99	113	129	148	136.95	73	84	95	108	123	139	157	178.30
60.3	59	68	79	92	106	121	139	109.91	69	80	91	104	118	134	151	149.28	78	89	101	113	127	143	160	194.30
76.1	63	73	84	97	111	126	143	121.21	74	85	96	109	123	138	155	164.62	84	95	107	119	133	149	165	213.22
88.9	66	76	87	100	113	128	145	130.15	77	88	99	112	125	140	157	176.67	88	99	111	123	137	152	168	227.69
114.3	71	81	92	105	118	133	148	146.83	83	94	105	118	131	146	161	198.17	95	106	118	130	144	159	174	254.18
139.7	74	84	95	107	120	134	149	163.60	88	99	110	123	136	150	166	218.23	100	111	123	135	149	163	178	279.81
168.3	78	88	99	111	124	138	153	180.38	92	103	114	126	140	154	169	240.54	106	117	129	141	155	169	184	305.53
219.1	83	93	104	116	129	142	156	209.59	98	109	120	132	145	159	173	277.77	113	124	136	148	161	175	189	350.96
273	87	97	108	120	133	146	159	239.40	103	114	125	137	150	163	176	315.35	123	135	147	159	173	191	191	386.92

Key

t = hot face temperature (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe in still air at [C1) 20 °C (C1]. Surface emissivity corresponding to outer surface specified.

NOTE 2 Maximum heat loss values for intermediate operating temperatures may be deduced by interpolation.

NOTE 3 Heat loss measured in Watts per metre (W/m) relates to the specified thickness and temperature.

NOTE 4 The thermal conductivity of insulation materials increases with mean temperature and for any given material. The use of a different thermal conductivity can be required for each operating temperature.

NOTE 5 These thicknesses may not satisfy other design requirements, in particular those for control of surface temperature (see Table 22, Table 23 and Table 24).

Table 21 **Minimum insulation thickness for process pipework and equipment to control heat loss** *(continued)*

Outside diameter of steel pipe on which insulation thickness has been based (mm)	t = 700							
	Insulation thickness (mm)							Max. heat loss (W/m)
	C1 λ = 0.085 C1	C1 λ = 0.090 C1	C1 λ = 0.095 C1	C1 λ = 0.100 C1	C1 λ = 0.105 C1	C1 λ = 0.110 C1	C1 λ = 0.115 C1	
17.2	56	65	76	88	103	119	138	163.63
21.3	60	69	80	92	106	122	141	174.49
26.9	65	75	86	98	113	128	146	186.89
33.7	70	80	91	103	117	133	150	201.20
42.4	76	86	97	109	123	138	155	217.29
48.3	79	89	100	112	126	141	158	227.84
60.3	85	95	106	118	132	147	163	247.23
76.1	91	102	113	125	139	153	169	270.20
88.9	95	106	117	129	143	157	173	288.43
114.3	103	114	125	137	151	165	180	320.67
139.7	109	120	131	143	157	170	185	351.43
168.3	115	126	137	149	162	176	191	383.75
219.1	123	135	146	158	170	184	192	437.18
273	128	139	154	166	179	193	193	495.09

Key

t = hot face temperature (°C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE 1 Insulation thicknesses in this table have been calculated according to BS EN ISO 12241:1998 using standardized assumptions: horizontal pipe in still air at C1 20 °C C1. Surface emissivity corresponding to outer surface specified.

NOTE 2 Maximum heat loss values for intermediate operating temperatures may be deduced by interpolation.

NOTE 3 Heat loss measured in Watts per metre (W/m) relates to the specified thickness and temperature.

NOTE 4 The thermal conductivity of insulation materials increases with mean temperature and for any given material. The use of a different thermal conductivity can be required for each operating temperature.

NOTE 5 These thicknesses may not satisfy other design requirements, in particular those for control of surface temperature (see Table 22, Table 23 and Table 24).

Table 22 **Minimum insulation thickness to control the surface temperature of a non-metallic surface with a surface emissivity of 0.90 and design cold face temperature of 59 °C**

Outside diameter of steel pipe (mm)	***t* = 100**				***t* = 200**				***t* = 300**			
	Insulation thickness (mm)				**Insulation thickness** (mm)				**Insulation thickness** (mm)			
	λ = 0.025	**λ = 0.035**	**λ = 0.045**	**λ = 0.055**	**λ = 0.035**	**λ = 0.045**	**λ = 0.055**	**λ = 0.065**	**λ = 0.035**	**λ = 0.045**	**λ = 0.055**	**λ = 0.065**
17.2	2	3	3	4	7	9	11	12	12	14	17	19
21.3	2	3	4	4	8	10	11	13	12	15	18	20
26.9	2	3	4	4	8	10	12	14	13	16	19	22
33.7	2	3	4	4	9	11	13	15	14	17	20	23
42.4	2	3	4	5	9	11	13	15	14	18	21	24
48.3	2	3	4	5	9	12	14	16	15	18	22	25
60.3	3	3	4	5	10	12	14	17	15	19	23	26
76.1	3	3	4	5	10	13	15	17	16	20	24	28
88.9	3	3	4	5	10	13	15	18	17	21	25	29
101.6	3	4	4	5	11	13	16	18	17	21	25	29
114.3	3	4	4	5	11	13	16	19	17	22	26	30
139.7	3	4	5	5	11	14	17	19	18	23	27	31
168.3	3	4	5	6	11	14	17	20	19	23	28	32
219.1	3	4	5	6	12	15	18	21	19	24	29	34
244.5	3	4	5	6	12	15	18	21	20	25	30	35
273.0	3	4	5	6	12	15	18	21	20	25	30	35
323.9	3	4	5	6	12	16	19	22	20	26	31	36
355.6	3	4	5	6	12	16	19	22	21	26	31	37
406.4	3	4	5	6	13	16	19	23	21	27	32	37
457.0	3	4	5	6	13	16	20	23	21	27	33	38
508.0	3	4	5	6	13	16	20	23	22	27	33	39
610.0	3	4	5	6	13	16	20	23	22	27	33	39
Flat surfaces	3	4	5	6	13	17	20	24	22	28	34	41

Key

t = hot face temperature at mean temperature (°C) (with ambient still air at 20 °C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE 1 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

NOTE 2 To simplify the use of this table, the values shaded have been adjusted to avoid the specification of apparently anomalous results given by the calculation method in BS EN ISO 12241:1998, due to the transition from turbulent to laminar flow.

Table 22 **Minimum insulation thickness to control the surface temperature of a non-metallic surface with a surface emissivity of 0.90 and design cold face temperature of 59 °C** *(continued)*

Outside diameter of steel pipe (mm)	*t* = 400					*t* = 500					*t* = 600					*t* = 700				
	Insulation thickness (mm)					Insulation thickness (mm)					Insulation thickness (mm)					Insulation thickness (mm)				
	λ = 0.045	λ = 0.055	λ = 0.065	λ = 0.075	λ = 0.085	λ = 0.055	λ = 0.065	λ = 0.075	λ = 0.085	λ = 0.095	λ = 0.065	λ = 0.075	λ = 0.085	λ = 0.095	λ = 0.105	λ = 0.065	λ = 0.075	λ = 0.085	λ = 0.095	λ = 0.105
17.2	19	22	26	29	32	27	32	35	39	43	37	42	46	51	55	43	48	53	59	64
21.3	20	24	27	30	34	29	33	37	42	46	39	44	49	54	58	45	51	56	62	67
26.9	21	25	29	32	36	31	35	40	44	48	42	47	52	57	62	48	54	60	66	71
33.7	22	26	30	34	38	33	38	42	47	51	44	50	55	61	66	51	57	64	70	76
42.4	24	28	32	36	40	35	40	45	50	55	47	53	59	64	70	54	61	68	74	80
48.3	24	29	33	37	42	36	41	46	51	56	49	55	61	67	72	56	63	70	77	83
60.3	26	31	35	40	44	38	44	49	54	60	52	58	64	71	77	59	67	74	81	88
76.1	27	32	37	42	47	40	46	52	58	63	55	62	68	75	81	63	71	79	86	94
88.9	28	33	38	43	48	42	48	54	60	66	57	64	71	78	85	66	74	82	90	97
101.6	29	34	40	45	50	43	49	56	62	68	59	66	74	81	88	68	76	85	93	101
114.3	30	35	41	46	51	44	51	57	64	70	60	68	76	83	90	70	79	87	96	104
139.7	31	37	42	48	54	46	53	60	67	73	63	71	79	87	95	73	82	92	100	109
168.3	32	38	44	50	56	48	55	63	70	77	66	74	83	91	99	76	86	96	105	114
219.1	33	40	46	53	59	50	58	66	74	81	70	79	88	97	105	81	91	102	112	122
244.5	34	41	47	54	60	51	60	68	75	83	71	81	90	99	108	83	94	104	115	125
273.0	35	42	48	55	61	52	61	69	77	85	73	83	92	101	111	85	96	107	117	128
323.9	36	43	50	57	63	54	63	71	80	88	75	85	95	105	115	87	99	111	122	133
355.6	36	43	51	58	64	55	64	73	81	90	77	87	97	107	117	89	101	113	124	135
406.4	37	44	52	59	66	56	65	74	83	92	79	89	100	110	117	91	104	113	124	135
457.0	37	45	53	60	67	57	67	76	85	92	80	89	100	110	117	91	104	113	124	135
508.0	38	46	53	61	67	58	67	76	85	92	80	89	100	110	117	91	104	113	125	136
610.0	38	46	53	61	67	58	67	76	85	92	80	89	100	110	120	91	104	116	128	139
Flat surfaces	40	49	57	66	75	63	74	85	97	108	91	104	118	132	146	107	124	140	156	173

Key

t = hot face temperature at mean temperature (°C) (with ambient still air at 20 °C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE 1 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

NOTE 2 To simplify the use of this table, the values shaded have been adjusted to avoid the specification of apparently anomalous results given by the calculation method in BS EN ISO 12241:1998, due to the transition from turbulent to laminar flow.

Table 23 **Minimum insulation thickness to control the surface temperature of a metallic surface with a surface emissivity of 0.05 and design cold face temperature of 50 °C**

Outside diameter of steel pipe (mm)	*t* = 100				*t* = 200				*t* = 300			
	Insulation thickness (mm)				**Insulation thickness** (mm)				**Insulation thickness** (mm)			
	$\lambda = 0.025$	$\lambda = 0.035$	$\lambda = 0.045$	$\lambda = 0.055$	$\lambda = 0.035$	$\lambda = 0.045$	$\lambda = 0.055$	$\lambda = 0.065$	$\lambda = 0.035$	$\lambda = 0.045$	$\lambda = 0.055$	$\lambda = 0.065$
17.2	5	7	8	10	17	21	25	29	27	33	40	46
21.3	5	7	9	10	18	23	27	31	28	35	42	49
26.9	6	7	9	11	19	24	29	34	31	38	46	53
33.7	6	8	10	12	21	26	31	36	33	41	49	57
42.4	6	8	11	13	22	28	33	39	35	44	52	61
48.3	6	9	11	13	23	29	35	40	37	46	55	63
60.3	7	9	12	14	25	31	37	43	39	49	58	68
76.1	7	10	12	15	27	33	40	46	42	53	63	73
88.9	8	10	13	15	28	35	42	49	44	55	66	77
101.6	8	11	13	16	29	36	44	51	46	57	69	80
114.3	8	11	14	17	30	38	45	52	48	60	71	83
139.7	8	11	14	17	32	40	48	56	50	63	76	88
168.3	9	12	15	18	33	42	50	59	53	67	80	93
219.1	9	13	16	20	36	45	54	63	57	72	87	101
244.5	10	13	17	20	37	47	56	65	59	75	90	104
273.0	10	14	17	21	38	48	58	68	61	77	93	108
323.9	10	14	18	22	40	50	61	71	64	81	97	113
355.6	10	14	18	22	41	52	62	73	66	83	100	116
406.4	11	15	19	23	42	53	65	75	68	86	104	121
457.0	11	15	19	23	43	55	67	78	70	89	107	121
508.0	11	16	20	24	45	57	69	80	72	92	107	121
610.0	12	16	21	25	45	57	69	80	72	92	107	121
Flat surfaces	12	16	21	25	46	59	72	85	76	98	120	141

Key

t = hot face temperature at mean temperature (°C) (with ambient still air at 20 °C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE 1 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

NOTE 2 To simplify the use of this table, the values shaded have been adjusted to avoid the specification of apparently anomalous results given by the calculation method in BS EN ISO 12241:1998, due to the transition from turbulent to laminar flow.

Table 23 **Minimum insulation thickness to control the surface temperature of a metallic surface with a surface emissivity of 0.05 and design cold face temperature of 50 °C** *(continued)*

Outside diameter of steel pipe (mm)	*t* = 400					*t* = 500					*t* = 600					*t* = 700				
	Insulation thickness (mm)					Insulation thickness (mm)					Insulation thickness (mm)					Insulation thickness (mm)				
	λ = 0.045	λ = 0.055	λ = 0.065	λ = 0.075	λ = 0.085	λ = 0.055	λ = 0.065	λ = 0.075	λ = 0.085	λ = 0.095	λ = 0.065	λ = 0.075	λ = 0.085	λ = 0.095	λ = 0.105	λ = 0.065	λ = 0.075	λ = 0.085	λ = 0.095	λ = 0.105
17.2	45	54	62	71	80	67	79	90	101	112	95	108	122	135	148	111	126	142	158	174
21.3	48	57	67	76	85	72	84	95	107	119	101	115	129	143	157	117	134	151	167	184
26.9	51	61	71	81	91	77	90	102	114	127	108	123	138	153	168	125	143	161	178	196
33.7	55	66	76	87	97	82	96	109	122	135	115	131	147	163	179	134	153	171	190	209
42.4	59	71	82	93	104	88	103	117	131	145	123	140	157	174	191	143	163	183	203	222
48.3	62	74	85	97	109	92	107	122	136	151	128	146	163	181	198	149	170	190	211	231
60.3	66	79	91	104	116	99	114	130	146	161	137	156	174	193	211	159	181	203	225	246
76.1	71	85	98	112	125	106	123	140	156	173	147	167	187	207	226	171	194	218	241	264
88.9	74	89	103	117	131	111	129	147	164	181	154	175	196	217	237	179	204	228	252	276
101.6	78	93	108	122	137	116	135	153	171	189	161	183	204	226	247	187	212	237	262	287
114.3	80	96	112	127	142	120	140	158	177	196	167	190	212	234	256	194	220	246	272	287
139.7	86	102	119	135	151	128	149	169	189	208	178	202	225	249	272	206	234	262	272	287
168.3	91	108	126	143	160	136	157	179	200	221	188	214	239	249	272	218	248	262	272	290
219.1	98	118	136	155	173	147	171	194	217	221	204	232	239	250	272	237	248	262	284	307
244.5	101	121	141	160	179	152	177	201	224	221	211	232	239	256	277	237	248	267	291	315
273.0	105	126	146	166	186	157	183	208	224	224	211	232	240	262	283	237	248	274	298	323
323.9	110	132	154	175	186	166	183	208	224	231	211	232	249	271	294	237	257	284	310	335
355.6	113	136	158	175	186	166	183	208	224	236	211	232	253	277	300	237	262	289	316	342
406.4	118	141	158	175	186	166	183	208	224	242	211	235	260	284	308	240	269	297	325	351
457.0	118	141	158	175	186	166	183	208	226	247	214	240	266	291	315	245	275	304	333	360
508.0	118	141	158	175	187	166	184	208	230	252	218	245	271	297	322	250	281	311	340	368
610.0	118	141	158	175	192	166	190	214	237	260	224	253	280	307	333	258	290	321	352	381
Flat surfaces	137	167	198	228	259	215	254	293	332	371	311	358	406	454	501	367	423	480	536	593

Key

t = hot face temperature at mean temperature (°C) (with ambient still air at 20 °C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE 1 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

NOTE 2 To simplify the use of this table, the values shaded have been adjusted to avoid the specification of apparently anomalous results given by the calculation method in BS EN ISO 12241:1998, due to the transition from turbulent to laminar flow.

Table 24 **Minimum insulation thickness to control the surface temperature of a non-metallic surface with a surface emissivity of 0.90 and design cold face temperature of 50 °C**

Outside diameter of steel pipe (mm)	***t* = 100**				***t* = 200**				***t* = 300**			
	Insulation thickness (mm)				**Insulation thickness** (mm)				**Insulation thickness** (mm)			
	λ = 0.025	**λ = 0.035**	**λ = 0.045**	**λ = 0.055**	**λ = 0.035**	**λ = 0.045**	**λ = 0.055**	**λ = 0.065**	**λ = 0.035**	**λ = 0.045**	**λ = 0.055**	**λ = 0.065**
17.2	3	4	5	6	10	13	15	17	15	19	22	26
21.3	3	4	5	6	11	13	16	18	16	20	24	27
26.9	3	5	6	7	11	14	16	19	17	21	25	29
33.7	4	5	6	7	12	15	17	20	18	23	27	31
42.4	4	5	6	7	13	15	18	21	19	24	28	32
48.3	4	5	6	7	13	16	19	22	20	25	29	33
60.3	4	5	6	8	13	17	20	23	21	26	31	35
76.1	4	5	7	8	14	18	21	24	22	27	32	37
88.9	4	5	7	8	14	18	22	25	23	28	34	39
101.6	4	6	7	8	15	18	22	26	23	29	35	40
114.3	4	6	7	8	15	19	23	26	24	30	35	41
139.7	4	6	7	9	16	20	23	27	25	31	37	43
168.3	4	6	7	9	16	20	24	28	26	32	38	44
219.1	5	6	8	9	17	21	25	29	27	34	40	47
244.5	5	6	8	9	17	21	26	30	27	34	41	48
273.0	5	6	8	9	17	22	26	30	28	35	42	49
323.9	5	6	8	10	18	22	27	31	28	36	43	50
355.6	5	6	8	10	18	22	27	32	29	36	44	51
406.4	5	6	8	10	18	23	28	32	29	37	44	52
457.0	5	7	8	10	18	23	28	33	30	37	45	53
508.0	5	7	8	10	19	23	28	33	30	38	46	54
610.0	5	7	8	10	19	24	29	34	31	39	46	54
Flat surfaces	5	7	8	10	19	24	29	35	31	40	49	58

Key

t = hot face temperature at mean temperature (°C) (with ambient still air at 20 °C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE 1 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

NOTE 2 To simplify the use of this table, the values shaded have been adjusted to avoid the specification of apparently anomalous results given by the calculation method in BS EN ISO 12241:1998, due to the transition from turbulent to laminar flow.

Table 24 **Minimum insulation thickness to control the surface temperature of a non-metallic surface with a surface emissivity of 0.90 and design cold face temperature of 50 °C** *(continued)*

Outside diameter of steel pipe (mm)	*t* = 400					*t* = 500					*t* = 600					*t* = 700				
	Insulation thickness (mm)					**Insulation thickness** (mm)					**Insulation thickness** (mm)					**Insulation thickness** (mm)				
	λ = 0.045	**λ = 0.055**	**λ = 0.065**	**λ = 0.075**	**λ = 0.085**	**λ = 0.055**	**λ = 0.065**	**λ = 0.075**	**λ = 0.085**	**λ = 0.095**	**λ = 0.065**	**λ = 0.075**	**λ = 0.085**	**λ = 0.095**	**λ = 0.105**	**λ = 0.065**	**λ = 0.075**	**λ = 0.085**	**λ = 0.095**	**λ = 0.105**
17.2	25	29	34	38	42	36	42	47	52	57	49	55	61	67	73	56	63	70	77	84
21.3	26	31	36	40	45	38	44	49	55	60	52	58	65	71	77	59	67	74	81	88
26.9	28	33	38	43	47	41	47	53	58	64	55	62	69	75	82	63	71	79	86	94
33.7	30	35	40	45	50	43	50	56	62	68	58	66	73	80	87	67	75	84	92	99
42.4	32	37	43	48	53	46	53	59	66	72	62	70	77	85	92	71	80	89	97	105
48.3	33	39	44	50	55	47	54	61	68	74	64	72	80	88	95	74	83	92	100	109
60.3	34	41	47	53	58	50	58	65	72	79	68	76	85	93	101	78	88	97	106	116
76.1	36	43	50	56	62	53	61	69	76	84	72	81	90	99	107	83	93	103	113	123
88.9	38	45	51	58	64	55	63	72	79	87	75	84	94	103	111	86	97	107	118	128
101.6	39	46	53	60	67	57	66	74	82	90	78	87	97	106	115	89	100	111	122	132
114.3	40	47	55	62	68	59	67	76	84	93	80	90	100	109	119	92	103	114	125	136
139.7	42	49	57	64	72	61	71	80	89	97	84	94	105	115	125	96	109	120	132	143
168.3	43	51	59	67	75	64	74	83	93	102	87	99	110	120	131	101	114	126	138	150
219.1	45	54	63	71	79	68	78	88	98	108	93	105	117	128	139	107	121	134	147	160
244.5	46	55	64	73	81	69	80	90	101	111	95	107	120	131	143	110	124	138	151	164
273.0	47	56	66	74	83	71	82	93	103	114	97	110	123	135	147	112	127	141	155	169
323.9	49	58	68	77	86	73	85	96	107	118	101	114	127	140	152	117	132	147	161	176
355.6	49	59	69	78	87	74	86	98	109	120	103	116	130	143	156	119	134	150	165	176
406.4	50	61	70	80	90	76	88	100	112	123	105	120	133	143	156	122	138	150	165	176
457.0	51	62	72	82	92	78	90	102	114	123	108	120	133	143	156	122	138	150	165	178
508.0	52	63	73	83	89	79	92	102	114	123	108	120	133	144	157	122	138	152	166	181
610.0	52	63	73	83	90	79	92	102	114	124	108	121	135	148	161	123	140	155	171	186
Flat surfaces	56	68	80	93	105	87	103	119	135	151	126	145	165	184	203	149	172	194	217	240

Key

t = hot face temperature at mean temperature (°C) (with ambient still air at 20 °C)

λ = thermal conductivity at mean temperature of insulation [W/(m · K)]

NOTE 1 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

NOTE 2 To simplify the use of this table, the values shaded have been adjusted to avoid the specification of apparently anomalous results given by the calculation method in BS EN ISO 12241:1998, due to the transition from turbulent to laminar flow.

Table 25 **Heat loss from bare surfaces calculated in accordance with BS EN ISO 12241:1998 (black steel pipes)**

Outside diameter of pipe (mm)	**Heat loss** (W/m for pipes and W/m² for flat surfaces)													
	***t* = 50**	***t* = 100**	***t* = 150**	***t* = 200**	***t* = 250**	***t* = 300**	***t* = 350**	***t* = 400**	***t* = 450**	***t* = 500**	***t* = 550**	***t* = 600**	***t* = 650**	***t* = 700**
12.0	17	57	110	176	257	356	476	620	791	993	1 231	1 509	1 832	2 206
15.0	20	69	133	214	313	435	582	758	969	1 220	1 514	1 859	2 260	2 723
17.2	23	78	150	241	353	491	658	859	1 099	1 384	1 720	2 113	2 571	3 100
21.3	27	93	180	290	427	594	798	1 043	1 337	1 687	2 099	2 583	3 146	3 798
22.0	28	96	186	299	439	611	821	1 074	1 378	1 738	2 164	2 662	3 243	3 916
26.9	33	114	221	356	525	732	985	1 291	1 658	2 095	2 611	3 217	3 923	4 742
28.0	35	118	229	369	544	759	1 022	1 340	1 721	2 175	2 711	3 341	4 075	4 926
33.7	41	139	269	435	641	897	1 209	1 588	2 042	2 585	3 226	3 979	4 859	5 878
42.0	49	168	326	528	781	1 094	1 478	1 944	2 505	3 175	3 968	4 901	5 990	7 254
42.4	50	169	329	532	788	1 104	1 491	1 961	2 527	3 203	4 004	4 945	6 045	7 320
48.3	56	190	369	598	885	1 242	1 679	2 212	2 853	3 619	4 527	5 595	6 843	8 292
54.0	61	209	407	660	979	1 374	1 860	2 452	3 165	4 018	5 029	6 220	7 612	9 228
60.3	68	230	448	728	1 081	1 519	2 058	2 715	3 508	4 456	5 582	6 908	8 458	10 258
67.0	74	253	492	800	1 188	1 672	2 268	2 994	3 871	4 921	6 167	7 636	9 354	11 350
76.1	83	283	551	896	1 333	1 878	2 550	3 370	4 360	5 548	6 958	8 621	10 566	12 827
80.0	87	295	576	938	1 395	1 966	2 670	3 530	4 569	5 815	7 296	9 041	11 084	13 459
88.9	95	324	632	1 031	1 535	2 165	2 943	3 894	5 044	6 424	8 064	9 998	12 263	14 897
101.6	107	365	712	1 162	1 733	2 447	3 330	4 410	5 718	7 287	9 155	11 358	13 940	16 942
108.0	113	385	752	1 228	1 832	2 588	3 523	4 668	6 056	7 721	9 703	12 042	14 782	17 969
114.3	119	405	791	1 292	1 929	2 726	3 714	4 922	6 387	8 147	10 241	12 713	15 609	18 979
139.7	142	484	947	1 549	2 316	3 279	4 474	5 939	7 716	9 853	12 399	15 406	18 932	23 036
168.3	167	571	1 119	1 833	2 746	3 894	5 321	7 072	9 200	11 760	14 812	18 420	22 653	27 582
219.1	212	722	1 419	2 330	3 498	4 971	6 806	9 063	11 809	15 117	19 065	23 736	29 220	35 609
273.0	258	880	1 731	2 848	4 283	6 098	8 362	11 152	14 550	18 647	24 221	30 135	37 067	45 134
323.9	301	1 027	2 021	3 331	5 016	7 151	10 254	13 667	17 813	22 798	28 737	35 754	43 978	53 549
Flat surfaces	285	1 212	2 405	3 949	5 897	8 317	11 286	14 890	19 226	24 396	30 515	37 700	46 081	55 794

Key

t = operating temperature (°C)

Operating conditions: ambient still air temperature 20 °C; surface emissivity 0.9; height of flat surface 0.6 m; surface orientation horizontal.

Table 26 **Heat loss from bare surfaces calculated in accordance with BS EN ISO 12241:1998 (copper pipes – commercial grade, scoured to a shine)**

Outside diameter of pipe (mm)	**Heat loss** (W/m for pipes and W/m^2 for flat surfaces)			
	***t* = 50**	***t* = 100**	***t* = 150**	***t* = 200**
12.0	11	36	66	100
15.0	12	43	79	119
17.2	14	47	87	132
21.3	16	56	103	156
22.0	17	57	105	160
26.9	19	66	123	186
28.0	20	69	127	192
33.7	23	79	146	222
42.0	27	93	173	263
42.4	28	94	174	265
48.3	31	104	192	292
54.0	33	113	210	319
60.3	36	123	228	347
67.0	39	134	248	377
76.1	43	148	273	416
80.0	45	153	284	432
88.9	49	166	308	469
101.6	54	184	341	520
108.0	57	193	358	545
114.3	59	202	374	570
139.7	69	236	437	666
168.3	80	272	505	770
219.1	98	334	619	946
273.0	116	396	735	1 123
323.9	133	452	840	1 284
Flat surfaces	119	647	1 244	1 938

Key

t = operating temperature (°C)

Operating conditions: ambient still air temperature 20 °C; surface emissivity 0.07; height of flat surface 0.6 m; surface orientation horizontal

Table 27 **Heat loss from bare surfaces calculated in accordance with BS EN ISO 12241:1998 (copper pipes – oxidized)**

Outside diameter of pipe (mm)	**Heat loss** (W/m for pipes and W/m^2 for flat surfaces)			
	***t* = 50**	***t* = 100**	***t* = 150**	***t* = 200**
12.0	15	52	99	158
15.0	18	63	120	191
17.2	21	70	135	215
21.3	25	84	162	258
22.0	25	87	166	265
26.9	30	103	197	315
28.0	31	106	204	326
33.7	36	124	239	383
42.0	44	150	289	464
42.4	44	151	292	468
48.3	50	169	326	524
54.0	55	186	359	578
60.3	60	205	395	636
67.0	66	224	433	698
76.1	73	250	484	781
80.0	77	261	505	816
88.9	84	286	554	895
101.6	94	321	623	1 007
108.0	99	339	657	1 063
114.3	104	356	691	1 118
139.7	124	424	824	1 336
168.3	146	499	971	1 577
219.1	184	629	1 226	1 997
273.0	224	763	1 491	2 432
323.9	261	888	1 737	2 837
Flat surfaces	245	1 076	2 125	3 464

Key

t = operating temperature (°C)

Operating conditions: ambient still air temperature 20 °C; surface emissivity [C1⟩ 0.70 ⟨C1]; height of flat surface 0.6 m; surface orientation horizontal

11 Protection against freezing

11.1 Information to be supplied by the specifier

The specifier shall supply details of the intended function and performance requirements of the application, and the materials to be used, in accordance with Clause **4**.

NOTE In addition to the parameters outlined in Clause **4***, items such as specific heat capacity and mass flow rates of fluids may also be required* *under certain circumstances, particularly where calculating from first principles using BS EN ISO 12241:1998. However, these additional parameters are not required for the use of the tables contained in this standard.*

11.2 Insulation thickness

NOTE 1 The use of insulation alone does not afford complete protection against the freezing of water in pipes and vessels under all atmospheric conditions. If the ambient temperature remains low enough for a sufficiently long period and the movement of water through the pipe or vessel is very slow or if the water is static, no insulation, however thick, will prevent internal freezing.

Nonetheless, insulation does reduce the rate of cooling and delays the onset of freezing, such that the formation of ice may be avoided if the time intervals during which the water is static are short enough, or if more heat is supplied from the water passing through the system than is lost from the surface of the insulation together with the associated losses through the metal supports and hangers, or if supplementary heating is used, even if only in local areas.

Where an insulation material is used with a heat trace, the heat loss shall be calculated according to the known worst case design condition and the insulation thickness shall be such that it limits the heat loss to 10% less than the maximum heat output of the heat trace.

NOTE 2 The time taken for water to reach its freezing point under given initial conditions and ambient temperatures is a function of the ratio between the heat capacity of the system (including that of the containing vessel and of the insulation) and the rate of heat loss from it. Consequently pipes of small bore are more vulnerable than those of larger bore and therefore the smaller pipes require relatively greater thicknesses of insulation for the same degree of protection against freezing.

NOTE 3 Calculations of the insulation thickness given in this standard have been made ignoring the heat capacity of the insulation and the surface resistance of the outer finish in order to give a worst case condition which allows for the common situation where the temperature of the insulation is lower than the initial temperature of the water.

A separate calculation is required if the conditions indicated in Table 28 to Table 31 do not apply.

Where protection against freezing is required, the insulation thickness shall, wherever possible (see Note 3 and Note 4), be in accordance with the values given in Table 28 to Table 31, as appropriate.

Thicknesses of insulation for pipe diameters not shown in Table 28 to Table 31, and for all plastic pipes, shall be determined in accordance with Annex H.

NOTE 4 Some of the theoretical thicknesses in the tables are impractical to accommodate, and in such cases other means of protection, e.g. trace-heating, drain-down, frost-stats or water-flow, should be adopted to supplement the protection that is afforded by any reduced thickness of insulating material.

Where insulating materials of alternative thermal conductivity are proposed, calculation methods in accordance with BS EN ISO 12241:1998 can be used to ensure that the thickness selected affords at least the equivalent degree of frost protection.

For smaller pipes it may not be practical to install thermal insulation of sufficient thickness to avoid entirely the possibility of ice formation overnight in sub-zero temperatures.

Table 28 **Minimum insulation thickness to protect steel pipes against freezing – Selected industrial process conditions**

Outside diameter of pipe (mm)	**Inside diameter (bore)** (mm)	**Insulation thickness** (mm)							
		Specified conditions 1				**Specified conditions 2**			
		λ = 0.020	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**	**λ = 0.020**	**λ = 0.030**	**λ = 0.040**	**λ = 0.050**
21.3	16.0	—	—	—	—	1 034	10 350	—	—
26.9	21.6	5 028	—	—	—	179	715	2 740	—
33.7	27.2	716	4 812	—	—	74	194	472	1 119
42.4	35.9	203	708	2 349	—	37	75	137	240
48.3	41.8	124	340	875	2 195	28	51	85	135
60.3	53.0	66	141	275	513	19	32	48	69
76.1	68.8	41	75	123	193	13	21	30	40
88.9	80.8	31	54	84	122	11	17	23	31
114.3	105.3	22	35	51	70	8	12	17	21
168.3	158.6	14	21	29	37	5	8	10	13
219.1	207.9	10	16	21	27	4	6	8	10

Key

Specified conditions 1: water temperature +5 °C; ambient temperature –10 °C; evaluation period 12 h; permitted ice formation nil

Specified conditions 2: water temperature +5 °C; ambient temperature –10 °C; evaluation period 12 h; permitted ice formation 10 %

λ = thermal conductivity [W/(m · K)]

NOTE 1 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

NOTE 2 Some of the insulation thicknesses given are too large to be applied in practice but a selection is included to highlight the difficulty in protecting small diameter pipes against freezing. To provide the appropriate degree of frost protection to certain sizes of pipes, it may be necessary to provide additional heat to the system, for example by circulating the water or heat tracing.

NOTE 3 Assumed densities (ρ) and heat capacities (CP) are as follows:

— *ρ water = 1 000 kg/m^3, CP water = 4 200 J/kg · K;*

— *ρ steel = 7 840 kg/m^3, CP steel = 455 J/kg · K.*

Table 29 **Minimum insulation thickness required to give protection against freezing – Selected commercial and institutional conditions**

Outside diameter (mm)	**Inside diameter (bore)** (mm)	**Insulation thickness** (mm)									
		Specified conditions 1					**Specified conditions 2**				
		λ = 0.020	**λ = 0.025**	**λ = 0.030**	**λ = 0.035**	**λ = 0.040**	**λ = 0.020**	**λ = 0.025**	**λ = 0.030**	**λ = 0.035**	**λ = 0.040**
Copper pipes A)											
15.0	13.6	23	35	53	78	113	68	126	229	413	740
22.0	20.2	10	14	18	23	28	21	30	42	58	78
28.0	26.2	7	9	11	13	16	13	17	22	28	35
35.0	32.6	5	7	8	10	11	9	12	15	18	22
42.0	39.6	4	5	6	7	9	7	9	11	13	16
54.0	51.6	3	4	5	5	6	5	7	8	9	11
76.1	73.1	2	3	3	4	4	4	5	5	6	7
108.0	105.0	2	2	2	3	3	3	3	4	4	5
Steel pipes B)											
21.3	16.0	18	26	35	48	64	44	71	112	173	265
26.9	21.6	10	13	17	21	26	20	28	39	52	68
33.7	27.2	7	9	12	14	17	13	18	23	29	36
42.4	35.9	5	6	8	9	11	9	11	14	17	20
48.3	41.8	4	5	6	7	9	7	9	11	13	16
60.3	53.0	3	4	5	6	7	5	7	8	10	11
76.1	68.8	3	3	4	4	5	4	5	6	7	8
88.9	80.8	2	3	3	4	4	3	4	5	6	7

Key

Specified conditions 1: water temperature 2 °C; ambient temperature –6 °C; evaluation period 12 h; permitted ice formation 50%; indoor

Specified conditions 2: water temperature 2 °C; ambient temperature –10 °C; evaluation period 12 h; permitted ice formation 50%; outdoor

λ = thermal conductivity [W/(m · K)]

A) Dimensions in accordance with BS EN 1057.

B) Dimensions in accordance with BS EN 10255.

NOTE 1 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

NOTE 2 Some of the insulation thicknesses given are too large to be applied in practice but are included to highlight the difficulty in protecting small diameter pipes against freezing. To provide the appropriate degree of frost protection to certain sizes of pipes, it may be necessary to provide additional heat to the system, for example by circulating the water or heat tracing.

NOTE 3 Assumed densities (ρ) and heat capacities (CP) are as follows:

— *ρ water = 1 000 kg/m^3, CP water = 4 200 J/kg · K;*

— *ρ steel = 7 840 kg/m^3, CP steel = 455 J/kg · K;*

— *ρ copper = 8 900 kg/m^3, CP copper = 390 J/kg · K.*

Table 30 **Minimum insulation thickness to protect against freezing – Selected domestic cold water systems (12 hour period)**

Outside diameter (mm)	**Inside diameter (bore)** (mm)	**Insulation thickness** (mm)									
		Specified conditions 1					**Specified conditions 2**				
		λ = 0.020	**λ = 0.025**	**λ = 0.030**	**λ = 0.035**	**λ = 0.040**	**λ = 0.020**	**λ = 0.025**	**λ = 0.030**	**λ = 0.035**	**λ = 0.040**
Copper pipes [A]											
15.0	13.6	20	30	43	62	88	23	35	53	78	113
22.0	20.2	9	12	16	20	24	10	14	18	23	28
28.0	26.2	6	8	10	12	14	7	9	11	13	16
35.0	32.6	5	6	7	9	10	5	7	8	10	11
42.0	39.6	4	5	6	7	8	4	5	6	7	9
54.0	51.6	3	4	4	5	6	3	4	5	5	6
76.1	73.1	2	3	3	4	4	2	3	3	4	4
Steel pipes [B]											
21.3	16.1	15	21	29	38	50	18	26	35	48	64
26.9	21.7	9	12	15	18	22	10	13	17	21	26
33.7	27.3	7	8	10	12	15	7	9	12	14	17
42.4	36.0	5	6	7	8	10	5	6	8	9	11
48.3	41.9	4	5	6	7	8	4	5	6	7	9
60.3	53.0	3	4	5	5	6	3	4	5	6	7
76.1	68.8	2	3	3	4	4	3	3	4	4	5

Key

Specified conditions 1: water temperature [C1⟩ 7 °C ⟨C1]; ambient temperature –6 °C; evaluation period 12 h; permitted ice formation 50%; [C1⟩ normal installation, i.e. inside the building and inside the envelope of the structural insulation ⟨C1]

Specified conditions 2: water temperature 2 °C; ambient temperature [C1⟩ –6 °C ⟨C1]; evaluation period 12 h; permitted ice formation 50%; [C1⟩ extreme installation, i.e. inside the building but outside the envelope of the structural insulation ⟨C1]

λ = thermal conductivity [W/(m · K)]

[A] Dimensions in accordance with BS EN 1057.

[B] Dimensions in accordance with BS EN 10255.

NOTE 1 Some of the insulation thicknesses given are too large to be applied in practice. The purpose of including very high thicknesses is to demonstrate that the application of a material of the given thermal conductivity is not able to provide the degree of frost protection on the pipe size indicated under the design conditions. Therefore in order to increase the degree of frost protection it is necessary to increase the pipe size, select an insulation with a lower thermal conductivity or use some means of putting heat back into the system.

NOTE 2 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

Table 31 **Minimum insulation thickness to protect against freezing – Selected domestic cold water systems (8 hour period)**

Outside diameter (mm)	**Inside diameter (bore)** (mm)	**Insulation thickness** (mm)									
		Specified conditions 1					**Specified conditions 2**				
		λ = 0.020	**λ = 0.025**	**λ = 0.030**	**λ = 0.035**	**λ = 0.040**	**λ = 0.020**	**λ = 0.025**	**λ = 0.030**	**λ = 0.035**	**λ = 0.040**
Copper pipes [A]											
15.0	13.6	11	15	20	26	34	12	17	23	31	41
22.0	20.2	6	7	9	11	13	6	8	10	12	15
28.0	26.2	4	5	6	7	9	4	6	7	8	10
35.0	32.6	3	4	5	6	7	4	4	5	6	7
42.0	39.6	3	3	4	5	5	3	4	4	5	6
54.0	51.6	2	3	3	3	4	2	3	3	4	4
76.1	73.1	2	2	2	3	3	2	2	2	3	3
Steel pipes [B]											
21.3	16.1	9	12	15	19	24	10	14	18	23	29
26.9	21.7	6	7	9	11	13	6	8	10	12	15
33.7	27.3	4	5	7	8	9	5	6	7	9	10
42.4	36.0	3	4	5	5	6	3	4	5	6	7
48.3	41.9	3	3	4	5	5	3	4	4	5	6
60.3	53.0	2	3	3	4	4	2	3	3	4	4
76.1	68.8	2	2	2	3	3	2	2	3	3	3

Key

Specified conditions 1: water temperature [C1⟩ 7 °C ⟨C1]; ambient temperature –6 °C; evaluation period [C1⟩ 8 h ⟨C1]; permitted ice formation 50%; [C1⟩ normal installation, i.e. inside the building and inside the envelope of the structural insulation ⟨C1]

Specified conditions 2: water temperature 2 °C; ambient temperature [C1⟩ –6 °C ⟨C1]; evaluation period [C1⟩ 8 h ⟨C1]; permitted ice formation 50%; [C1⟩ extreme installation, i.e. inside the building but outside the envelope of the structural insulation ⟨C1]

λ = thermal conductivity [W/(m · K)]

[A] Dimensions in accordance with BS EN 1057.

[B] Dimensions in accordance with BS EN 10255.

NOTE 1 Some of the insulation thicknesses given are too large to be applied in practice. The purpose of including very high thicknesses is to demonstrate that the application of a material of the given thermal conductivity is not able to provide the degree of frost protection on the pipe size indicated under the design conditions. Therefore in order to increase the degree of frost protection it is necessary to increase the pipe size, select an insulation with a lower thermal conductivity or use some means of putting heat back into the system.

NOTE 2 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.

Annex A (informative) Underlying methodology

A.1 Determination of thicknesses for environmental insulation thickness for process pipework and equipment to control heat loss

Table 21 provides thicknesses of insulation satisfying the maximum permissible heat losses for process pipework and equipment.

Larger pipes invariably experience greater heat losses and as such, in common with BS 5422:2001 and BS 5422:1990, it was recognized that it is not practical for the heat loss per metre of pipe to be constant for pipes of differing diameters and operating temperatures.

In line with other industries it was decided to pursue a change in net income methodology as a means to determine the most environmentally appropriate insulation thickness. A change in net income methodology concentrates on minimizing annual outgoings. Only interest on the capital is considered, not the capital itself.

The objective of this methodology is to select a thickness of insulation which minimizes the total annual cost as follows:

$$C_T = P_D C_I + C_C$$

where

C_T is the total cost per year;

C_I is the cost of the installation;

C_C is the total cost of carbon used;

P_D is the percentage discount rate;

and

$$C_I = \left(1 + P_G\right)\left(\frac{C_L}{P_I}\right)$$

where

C_L is the cost of the insulation;

P_I is the percentage material cost of a project;

P_G is the percentage gross margin.

Any thickness of insulation specified should match the same maximum permissible heat loss as this calculated thickness of insulation.

A.2 Social cost of carbon

All energy used is assumed to have not only a direct financial cost but also an indirect cost which reflects costs arising from the social implications of carbon emissions. This indirect social cost of carbon is calculated based on a standard government guideline. The value assumed is laid out in Table A.1.

The energy use of a system (E_I) was defined as follows:

$$E_I = q_I h$$

where

q_I is the heat loss in kW/m;

h is the number of hours.

Each fuel has a particular carbon loading, which reflects the quantity of carbon released as the fuel is expended. Using this value the carbon use of a system (C_C) was derived using the following equation:

$$C_C = E_I\left(C_E + L_C C_{SCC}\right)$$

where

E_I is the annual energy not saved in kWh/m;

C_E is the price of energy per kWh;

L_C is the carbon loading of the fuel per kWh;

C_{SCC} is the additional social cost attributed to carbon.

NOTE A conversion factor may be required to adjust for the social cost of carbon dioxide versus the social cost of carbon.

A.3 Calculation of heat loss

Heat losses were calculated in accordance with the methodology laid out in BS EN ISO 12241:1998. All variables required by BS EN ISO 12241:1998 which have been assumed in the creation of the thickness tables contained within this standard are detailed in Table C.1.

All heat losses have been calculated to one thousandth of a W/m or W/m^2, as applicable.

A.4 Implementation of methodology

For the creation of the tables stated in this standard a spreadsheet was used and the minimum total cost was derived empirically. The heat loss from the next largest whole millimetre of insulation to the minimum was selected and used as the maximum permissible heat loss.

Table A.1 **Variables assumed in development of methodology for process pipework tables**

	Units	**Value**
Fuel type	—	Gas
Fuel price	£/kWh	0.01
Carbon loading	kg/kWh	0.1944
Utilization rate	h/yr	8400
Insulation cost proportion	%	14
Social cost of carbon	[C1⟩ £/tonne ⟨C1]	82.5
Discount rate	%/yr	0.035
Volumetric insulation cost	£/m^3	404
Emissivity of outer surface of insulated system	—	0.05

Table A.2 **Reference thermal conductivities of insulation**

Operating temperature of insulated system (°C)	Thermal conductivity [W/(m · K)]
100	0.041
200	0.048
300	0.056
400	0.065
500	0.076
600	0.087
700	0.100

Annex B (informative) Default values for use in BS EN ISO 12241:1998 heat transfer calculations

B.1 General

Complete information is not always available at the preliminary design stages. Additionally, the effect that small changes in some design parameters can have may not be immediately apparent. To provide common guidance on the selection of physical data, values of surface emissivity are given in Table B.1 for various common surfaces, together with typical default information for other physical properties.

B.2 Default data

The information given in Table B.2 is intended to provide assistance to the user on the following basis. Conditions shown in *italics* are the "most onerous". These conditions will require the largest insulation thickness for a given application. The values shown in parentheses ( ) are "typical" default values.

The information should be used only as general guidance in the absence of specific site data. It is extremely important to note that physical variations that result in a change from laminar to turbulent airflow over the insulated surface may affect the validity of this guidance. In particular, use of those default conditions annotated in the Table should be treated with caution for the following applications:

- hot pipes located in still air and *typically* larger than 300 mm OD;
- hot flat surfaces located indoors *typically* having a height greater than 700 mm;
- cold flat surfaces located indoors *typically* having a height greater than 1 500 mm.

Table B.1 **Surface emissivity (ε)**

Material	ε
Aluminium, bright	0.05
Aluminium, oxidized	0.13
Aluminium foil, bright reinforced	0.05
Aluminium foil, polyester faced reinforced	0.40
Alu-zinc	0.18
Austenitic steel	0.15
Brass, dull tarnished	0.61
Brass, unoxidized	0.035
Cast iron (and iron)	0.35
Cast iron, rusted or oxidized	0.65
Chrome, polished	0.10
Cloth	0.90
Copper, commercial scoured to a shine	0.07
Copper, oxidized	0.70
Copper, polished	0.02
Fire brick	0.75
Galvanized steel, blank	0.26
Galvanized steel, dusty	0.44
Paint, black	0.95
Paint, other colours	0.90
Paint, white	0.85
Paint, aluminium weathered	0.55
Paint, aluminium new	0.30
Roofing felt	0.94
Rubber, black	0.95
Rubber, grey	0.85
Steel	0.35
Steel, black painted	0.90
Steel, oxidized	0.80
White lacquer	0.95

NOTE The above values provide a useful guide to surface emissivity. However, it should be noted that the emissivity of a material varies with temperature and surface finish. Therefore, the precise material emissivity should be ascertained where a high degree of accuracy is required.

Table B.2 **Default data for use in BS EN ISO 12241:1998 calculations**

Variable	Flat or cylindrical	Condition			
		P_1	P_2	P_3	P_4
Diameter	Flat	N/A	N/A	N/A	N/A
	Cylindrical	*Largest* [a)]	*Largest* [a)]	*Largest*	*Smallest*
Orientation	Flat	N/A	N/A	N/A	N/A
	Cylindrical	*Vertical*	*Horizontal*	*Horizontal*	N/A
Height	Flat	*Smallest* [b)] (600 mm for horizontal ducts, 3 000 mm for vertical ducts and for vessels)	*Greatest* [b)] (600 mm for horizontal ducts, 3 000 mm for vertical ducts and for vessels)	*Greatest* [c)] (600 mm for horizontal ducts, 3 000 mm for vertical ducts and for vessels)	N/A
	Cylindrical	N/A	N/A	N/A	N/A
Surface emissivity	Flat	*Highest*	*Lowest*	*Lowest*	N/A
	Cylindrical	*Highest*	*Lowest*	*Lowest*	N/A
Air velocity	Flat	*Highest* (still air)	*Lowest* (still air)	*Lowest* (still air)	N/A
	Cylindrical	*Highest* (still air)	*Lowest* (still air)	*Lowest* (still air)	N/A
Ambient air temperature	Flat	*Lowest for hot surfaces, highest for cold* (20 °C)	*Highest* (20 °C)	*Highest* (25 °C)	*Lowest*
	Cylindrical	*Lowest for hot surfaces, highest for cold* (20 °C)	*Highest* (20 °C)	*Highest* (25 °C)	*Lowest*

Key

P = Purpose of insulation:

P_1 = Reduce total heat loss/gain;

P_2 = Minimize temperature on hot surfaces;

P_3 = Control condensation on cold surface;

P_4 = Retard freezing.

NOTE 1 The use of annotated default conditions should be treated with caution for the following applications.

a) Hot pipes located in still air and typically larger than 300 mm OD.

b) Hot flat surfaces located indoors typically having a height greater than 700 mm.

c) Cold flat surfaces located indoors typically having a height greater than 1 500 mm.

Annex C (informative) Summary of criteria used to establish the tables

The criteria used to establish the tables are summarized in Table C.1.

Table C.1 **Summary of criteria used to establish the tables**

Table	Description	Horizontal or vertical (pipes only)	Height (flat surfaces only) m	Outer surface emissivity	Ambient air velocity m/s	Ambient air temp. °C	Relative humidity (r.h.) and dewpoint temp.	Evaluation time and ice formation	Contents temp. °C	Max outer surface temp. °C
1	Vapour barrier permeances	—	—	—	—	—	—	—	–40 to +10	—
2	Refrigeration condensation	Horizontal	0.6	0.90	0	20	70% 14.4 °C	—	–40 to 0	—
3	Refrigeration condensation	Horizontal	0.6	0.05	0	20	70% 14.4 °C	—	–40 to 0	—
4	Refrigeration condensation	Horizontal	0.6	0.90	0	25	80% 21.3 °C	—	–40 to 0	—
5	Refrigeration condensation	Horizontal	0.6	0.05	0	25	80 % 21.3 °C	—	–40 to 0	—
6	Chilled and cold condensation	Horizontal	0.6	0.90	0	25	80% 21.3 °C	—	0, 5, 10	—
7	Chilled and cold condensation	Horizontal	0.6	0.90	0	25	80% 21.3 °C	—	0, 5, 10	—
8	Chilled and cold condensation	Horizontal	0.6	0.05	0	25	80% 21.3 °C	—	0, 5, 10	—
9	Chilled and cold condensation	Horizontal	0.6	0.05	0	25	80% 21.3 °C	—	0, 5, 10	—
10	Chilled and cold indicative	Horizontal	0.6	0.05	0	25	—	—	0, 5, 10	—
11	Chilled and cold indicative	Horizontal	0.6	0.90	0	25	—	—	0, 5, 10	—
12	Ductwork condensation	Horizontal	0.6	0.05, 0.44, 0.90	0	25	80% 21.3 °C	—	0, 5, 10, 15	—
13	Ductwork indicative	Horizontal	0.6	0.05, 0.44, 0.90	0	15	—	—	35	—
14	Ductwork indicative	Horizontal	0.6	0.05, 0.44, 0.90	0	25	—	—	13	—
15	Non-domestic heating	Horizontal	0.6	0.05	0	15	—	—	75, 100, 125	—
16	Non-domestic heating	Horizontal	0.6	0.90	0	15	—	—	75, 100, 125	—
17	Non-domestic hot water	Horizontal	0.6	0.05	0	15	—	—	60	—
18	Non-domestic hot water	Horizontal	0.6	0.90	0	15	—	—	60	—

Table C.1 **Summary of criteria used to establish the tables** *(continued)*

Table	Description	Horizontal or vertical (pipes only)	Height (flat surfaces only) m	Outer surface emissivity	Ambient air velocity m/s	Ambient air temp. °C	Relative humidity (r.h.) and dewpoint temp.	Evaluation time and ice formation	Contents temp. °C	Max outer surface temp. °C
19	Domestic heating and hot water	Horizontal	0.6	0.05	0	15	—	—	60	—
20	Domestic heating and hot water	Horizontal	0.6	0.95	0	15	—	—	60	—
21	Process heat loss	Horizontal	0.6	0.05	0	20	—	—	100 to 700	—
22	[C1⟩ Control of surface temperature ⟨C1]	Horizontal	0.6	0.90	0	20	—	—	100 to 700	59
23	[C1⟩ Control of surface temperature ⟨C1]	Horizontal	0.6	0.05	0	20	—	—	100 to 700	50
24	[C1⟩ Control of surface temperature ⟨C1]	Horizontal	0.6	0.90	0	20	—	—	100 to 700	50
25	Heat loss from bare steel pipes	Horizontal	0.6	0.90	0	20	—	—	50 to 700	—
26	Heat loss from bare bright copper pipes	Horizontal	0.6	0.07	0	20	—	—	50 to 200	—
27	Heat loss from bare oxidized copper pipes	Horizontal	0.6	0.70	0	20	—	—	50 to 200	—
28	Industrial process freezing	—	—	—	0	–10	—	12 h nil and 10%	5	—
29	Commercial and [C1⟩ institutional ⟨C1] freezing	—	—	—	0	–6, –10	—	12 h 50%	2	—
30	Domestic freezing	—	—	—	0	–6	—	12 h 50%	2, 7	—
31	Domestic freezing	—	—	—	0	–6	—	8 h 50%	2, 7	—

Annex D (informative) Dimensions of steel, copper and plastic pipes

Table D.1 and Table D.2 give the outside diameters of steel and copper pipes and are taken from BS EN 10220 and BS EN 1057.

Further information on the relative thermal performance of steel, copper and plastic pipes with respect to diameter is given in Annex H.

Table D.1 **Outside diameter of steel pipe (from BS EN 10220)**

Nominal size		Outside diameter	
mm	in	mm	in
10	[C1⟩ ⅜ ⟨C1]	17.2	0.677
20	¾	26.9	1.059
25	1	33.7	1.327
32	1¼	42.4	1.669
40	1½	48.3	1.900
50	2	60.3	2.375
65	2½	76.1	3.000
80	3	88.9	3.500
90	3½	101.6	4.000
100	4	114.3	4.500
125	5	139.7	5.500
150	6	168.3	6.625
200	8	219.1	8.625
250	10	273.0	10.750
300	12	323.9	12.750
350	14	355.6	14.000
400	16	406.4	16.000
450	18	457.0	18.000
500	20	508.0	20.000
600	24	610.0	24.000

NOTE 1 This table gives sizes of pipe commonly used in the engineering and process industries.

NOTE 2 Although the pipework may be ordered and referred to generally by quoting nominal (metric) sizes and thickness, for insulating materials, the listed outside diameters should be quoted for pipe conforming to specific British Standards.

Table D.2 **Outside diameter of copper pipe (from BS EN 1057)**

Outside diameter mm	**Internal diameter (bore)** mm
10	8.8
12	10.8
15	13.6
22	20.2
28	26.2
35	32.6
42	39.6
54	51.6
76.1	73.1
108	105.0

NOTE 1 This table gives sizes of pipe commonly used in the engineering and process industries.

NOTE 2 Although the pipework may be ordered and referred to generally by quoting nominal (metric) sizes and thickness, for insulating materials, the listed outside diameters should be quoted for pipe conforming to specific British Standards.

Annex E (informative) Definition of "non-combustible", "limited combustibility", Class O (national class), Class 1 (national class), Class A (European class) and Class B (European Class).

E.1 Non-combustible materials

A non-combustible material is one which:

- is classified non-combustible in accordance with BS 476-4; or
- does not flame and does not cause any rise in temperature on either the centre (specimen) or furnace thermocouples when tested to BS 476-11; or
- is classified A1 in accordance with BS EN 13501-1.

E.2 Materials of limited combustibility

A material of limited combustibility is one which:

- is non-combustible in accordance with **E.1**; or
- has a density of at least 300 kg/m^3 which, when tested to BS 476-11, does not flame for more than 10 seconds and does not cause a rise in temperature on the centre (specimen) thermocouple exceeding 35 °C and a rise exceeding 20 °C on the furnace thermocouple; or
- is classified A2 in accordance with BS EN 13501-1.

E.3 Class 1 (national class) materials

A Class 1 (national class) material is one which:

- has a Class 1 surface spread of flame rating in accordance with BS 476-7; or
- is of limited combustibility in accordance with **E.2**; or
- is non-combustible in accordance with **E.1**.

Class 1 is the highest rating of the four classes defined in BS 476-7 (Classes 1, 2, 3 and 4).

E.4 Class O (national class) materials

A Class O (national class) material is one which:

- has a Class 1 surface spread of flame rating in accordance with BS 476-7 and has a fire propagation index of (I) of not more than 12.0 and a sub-index (i_1) of not more than 6.0 in accordance with BS 476-6; or
- is of limited combustibility in accordance with **E.2**; or
- is non-combustible in accordance with **E.1**.

Class O is a term defined in Approved Document B of Building Regulations and is not a classification identified in any British Standard test.

E.5 Classes A1, A2, B, C, D, E and F (European class) materials

Materials are classified A1, A2, B, C, D, E or F in accordance with BS EN 13501-1.

Euro-class A1 is the safest fire classification, and Euro-class E is the most fire hazardous. Products with Euro-classes A1, A2 and B do not flash over, whereas those with Euro-classes C, D and E do. Euro-class F denotes products, which have not been tested or do not meet the requirements of classes A1 to E.

British Standard classifications do not necessarily correspond to European (EN) classifications and a product cannot be assumed to meet any class unless tested in accordance with the relevant standard.

Annex F (normative) Method for assessing the system load for refrigeration pipe-work

F.1 Determination of total system heat gain

The total system heat gain (x) shall be calculated from the sum of the heat gains of the various components of the system, in both air conditioning and refrigeration applications. This calculation shall adopt standard methodologies for which both ASHRAE and CIBSE provide appropriate guidance (these normally exclude pipe-work).

NOTE 1 In most cases the total system heat gain will have been calculated according to the CIBSE methodology by the relevant building service engineer with the compressors correctly dimensioned to meet this demand.

NOTE 2 Further information can be obtained from the CIBSE Guides, particularly Volume A [14], and the ASHRAE Handbooks, in particular that covering Systems and Equipment [15].

F.2 Determining the Coefficient of Performance (CoP) for the system

NOTE The CoP of a refrigeration system describes the additional efficiency improvement arising from the direct expansion of the refrigerant, and the value for the CoP is therefore defined for each refrigerant type and is determined by reference to the appropriate Mollier diagram.

In order to establish the real impact of the total system heat gain (x) on the energy demand of the system, the value shall be adjusted using the CoP as follows:

$$\frac{x}{\text{CoP}} = y_1$$

where

x is the total system heat gain;

y_1 is the energy demand.

F.3 Assessing the distribution pipe-work load

NOTE 1 The contribution of distribution pipe-work to the total system heat gain might be relatively small. However, there are circumstances where the contribution from distribution pipe-work is significant (defined as greater than 5%) and, under these circumstances, reference should be made to the thicknesses specified in Table 10 and Table 11 (chilled and cold water, indicative).

In order to determine whether the contribution from distribution pipe-work is greater than 5%, heat gains shall be calculated according to BS EN ISO 12241:1998 on the assumption that the pipe-work is already insulated to control condensation assuming the use of a high emissivity surface (emissivity = 0.90). The resulting pipe-work heat gain (z) shall then be used to determine the energy demand (y_2) arising from the distribution pipe-work as follows:

$$\frac{z}{\text{CoP}} = y_2$$

where

z is the total pipework heat gain

y_2 is the energy demand.

The percentage of the overall system load [I] represented by the pipework shall then be given by:

$$I = \left[\frac{y_2}{(y_1 + y_2)}\right] \times 100\%$$

NOTE 2 This assumes that y_1 has been calculated without any consideration of distribution heat gains.

*NOTE 3 As can be seen from **F.2** and **F.3**, the same CoP is common to both calculations and can be cancelled out in the final determination of the percentage impact. Accordingly, there is normally no need to consider the impact of CoP for calculation purposes.*

NOTE 4 The following is an example calculation of distribution pipe-work load as a percentage of total heat load.

A small supermarket has employed a chiller rated at 2 000 W to run the refrigeration units in its store. The lines are 22 mm copper pipes running at –10 °C in an ambient temperature of 25 °C and have been insulated using 19 mm of high emissivity closed cell insulation to prevent condensation.

The heat gain to this insulated pipework is 6.71 W/m.

Since the chiller is rated at 2 000 W it is reasonable to assume that this is the maximum heat load of the system (the maximum load may in fact be much lower). 5% of this load would therefore be 100 W.

<5% of total system load

The chiller plant has been positioned such that 10 m of distribution pipework is required. Therefore in order to achieve the target of reducing heat gains to the distribution pipework to less than 5% of the total system load the maximum permissible heat gain will be:

$$q_{max} = \frac{100}{10} = 10 \text{ W/m}$$

Since the heat gain to the distribution pipework when insulated to prevent condensation formation already limits the linear heat gain to less than this (6.71 W/m), no further insulation thickness is required.

>5% of total system load

The chiller plant has been positioned such that 20 m of distribution pipework is required. Therefore in order to achieve the target of reducing heat gains to the distribution pipework to less than 5% of the total system load the maximum permissible heat gain will be:

$$q_{max} = \frac{100}{20} = 5 \text{ W/m}$$

As the heat gain of the distribution pipework does not limit the distribution pipework to less than this it will be necessary in this case to select a greater thickness of insulation.

This thickness should be calculated using 5 W/m as the maximum permissible heat [C1⟩ gain ⟨C1].

Annex G (informative) Calculation of economic insulation thickness

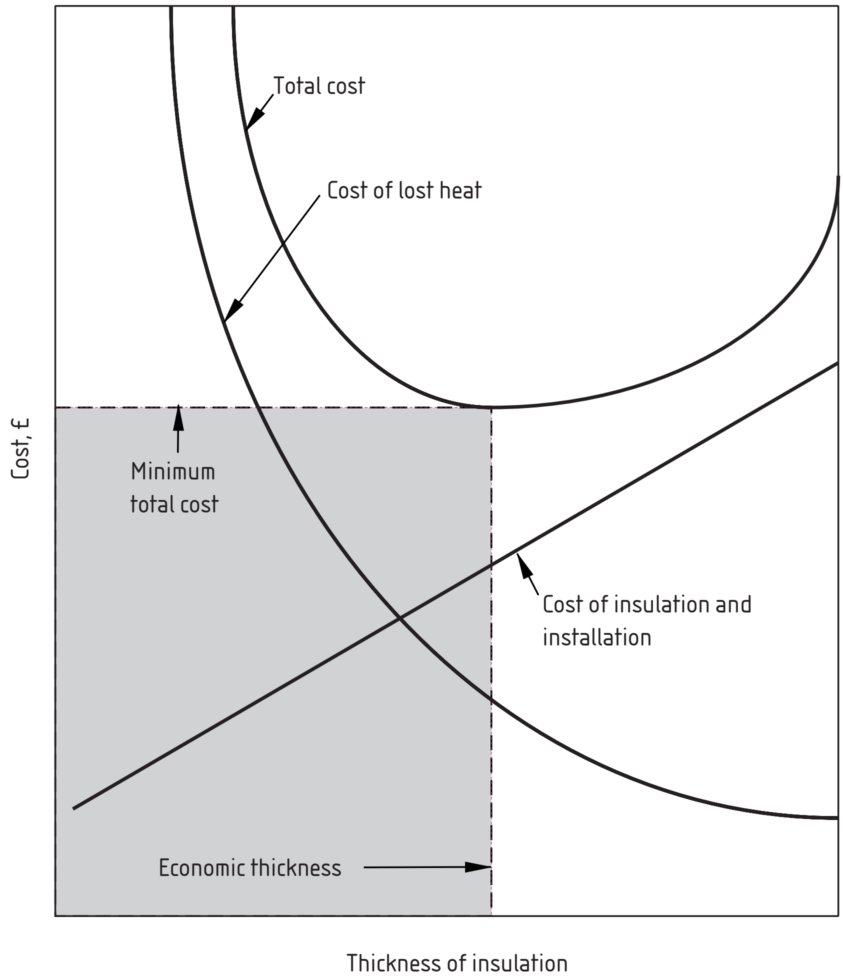
G.1 Principle

The cost of the energy consumed by a process and the cost of providing insulation to reduce this consumption is different for every project.

The installation of the economic thickness of insulation results in the lowest combined cost of insulation plus energy consumption over a given period of time (evaluation period).

NOTE Figure G.1 illustrates this principle.

Figure G.1 **Economic thickness**



G.2 Method of calculating economic thickness

The following information is typical of that needed to calculate the economic insulation thickness:

a) cost of fuel;

b) process efficiency (e.g. boiler efficiency);

c) total hours of operation per year;

d) number of years over which the investment in insulation is to be evaluated;

e) installed cost of the proposed insulation in various thicknesses;

NOTE 1 Total installed cost encompasses insulation material, fixings, cladding, labour and all ancillaries.

f) heat transfer, both insulated and uninsulated.

NOTE 2 Heat transfer (usually stated in W/m for pipes and W/m² for flat surfaces) depends on type of insulation, insulation thickness, pipe diameter, pipe orientation, height of flat surfaces, operating temperature, surface emissivity of outer face, air velocity and ambient air temperature.

The economic insulation thickness should be calculated either by tabulation, as follows, or by another method that can be demonstrated to give the same result.

1) Starting with the uninsulated condition, tabulate the cost of installing successive, commercially available thicknesses of a particular insulation material (including labour and ancillaries).

NOTE 3 Inclusion of the uninsulated condition provides a comparison of potential savings. The additional costs associated with the installation of multiple layers of insulation should be considered.

2) Tabulate the cost of the energy consumption for each of the insulation thicknesses considered over the evaluation period.

3) Add the costs to identify the minimum total and the associated economic insulation thickness.

Annex H (normative) Non-standard pipe diameters and plastic pipes

H.1 General

The thicknesses of insulation provided by the tables in this standard have been calculated for standard diameter copper or steel pipes.

H.2 Non-standard steel and copper pipe diameters

For steel or copper pipes with diameters not shown in the relevant table, determination of the appropriate thickness of insulation shall be as follows.

a) **Thicknesses of insulation to control condensation.** For an intermediate pipe diameter not listed in the tables providing guidance on the control of condensation (Table 2 to Table 9), the thickness of insulation shown for the nearest larger diameter listed shall be used unless the thickness of insulation is calculated from first principles in accordance with BS EN ISO 12241:1998, using the calculation process specified in Annex I.

NOTE 1 A summary of criteria is given in Annex C.

b) **Thicknesses of insulation to control surface temperature.** For an intermediate pipe diameter not listed in the tables providing guidance on the control of surface temperature (Table 22, Table 23 and Table 24), the thickness of insulation shown for the nearest larger diameter listed shall be used unless the thickness of insulation is calculated from first principles in accordance with BS EN ISO 12241:1998, using the calculation process specified in Annex I.

NOTE 2 A summary of criteria is given in Annex C.

c) **Thicknesses of insulation to protect against freezing.** For an intermediate pipe diameter not listed in the tables providing guidance to retard freezing (Table 28 to Table 31), the thickness of insulation shown for the nearest smaller diameter listed shall be used unless the thickness of insulation is calculated from first principles in accordance with BS EN ISO 12241:1998, using the calculation process specified in Annex I.

NOTE 3 A summary of criteria is given in Annex C.

d) **Thicknesses of insulation to control heat transfer.** The methodology set out in this standard to control heat transfer ensures that there is a unique maximum permissible heat transfer for each pipe, which forms the benchmark performance for compliance with this standard.

The maximum permissible heat transfer applicable to a steel or copper pipe with a diameter not shown in Table 10, Table 11 or Table 13 to Table 21 shall be calculated from first principles in accordance with Annex A (for Table 21 only) and Annex I. For an intermediate pipe diameter not listed in these tables, it will in most cases be sufficient to undertake calculations using the maximum permissible heat gain shown for the nearest larger diameter listed.

NOTE 4 A summary of criteria is given in Annex C.

H.3 Plastic pipes

The tables of insulation thicknesses in this standard apply to metal pipes. Where plastic pipes are used, determination of the appropriate thickness of insulation shall be as follows.

a) **Thicknesses of insulation to control condensation.** For an intermediate plastic pipe diameter not listed in the tables providing guidance on the control of condensation (Table 2 to Table 9), the thickness of insulation shown for the nearest larger diameter listed shall be used unless the thickness of insulation is calculated from first principles in accordance with BS EN ISO 12241:1998, using the calculation process specified in Annex I. The performance of the system is then undertaken considering the plastic pipe wall to be an additional layer of insulation (i.e. a "double-layer" calculation).

NOTE 1 A summary of criteria is given in Annex C.

b) **Thicknesses of insulation to control surface temperature.** For an intermediate plastic pipe diameter not listed in the tables providing guidance on the control of surface temperature (Table 22, Table 23 and Table 24), the thickness of insulation shown for the nearest larger diameter listed shall be used unless the thickness of insulation is calculated from first principles in accordance with BS EN ISO 12241:1998, using the calculation process specified in Annex I. The performance of the system is then undertaken considering the plastic pipe wall to be an additional layer of insulation (i.e. a "double-layer" calculation).

NOTE 2 A summary of criteria is given in Annex C.

c) **Thicknesses of insulation to protect against freezing.** The tables in this standard providing guidance on protection against freezing relate to the specific steel and copper pipes shown. For plastic pipes, it is recommended that calculations are undertaken from first principles in accordance with BS EN ISO 12241:1998, using the calculation process specified in Annex I. Further guidance may be required from the pipe manufacturer regarding the performance of specific plastic pipes at sub-zero temperatures.

NOTE 3 A summary of criteria is given in Annex C.

d) **Thicknesses of insulation to control heat transfer.** The methodology set out in this standard to control heat transfer ensures that there is a unique maximum permissible heat transfer for each pipe, which forms the benchmark performance for compliance with this standard. When considering the comparative heat losses of pipes made from materials with high thermal conductivities, the wall thickness of each pipe does not have a significant thermal resistance. As a result, it is reasonable to conclude that the use of copper and steel pipes of identical outer diameter will, in practice, result in comparable heat transfer regardless of the pipe wall thickness.

It is however recognized that, when working with plastic pipes with lower thermal conductivity values and larger wall thicknesses, this may not always be a reasonable conclusion. Thus, in cases where it is intended to take the insulating properties of the pipe wall into consideration, the maximum permissible heat loss shall be chosen as follows:

- identify bore of chosen (plastic) pipe;
- identify outside diameter of copper pipe having identical bore;
- select maximum permissible heat transfer based on outer diameter of copper pipe (interpolation between sizes may be required).

It is also acceptable to select the maximum permissible heat transfer from the tables as if the inner bore of the plastic pipe was the outside diameter given in Table 2 to Table 9, although adopting this procedure may result in a requirement for greater insulation thicknesses. The performance of the system shall then be undertaken considering the plastic pipe wall to be an additional layer of insulation (i.e. a "double-layer" calculation).

Alternatively, the required thickness of insulation for a plastic pipe shall be calculated using the maximum permissible heat transfer that corresponds to the pipe's outer diameter only if the insulating properties of the pipe wall are disregarded.

Annex I (normative) Calculations undertaken to show compliance with this standard

For the purposes of showing compliance with this standard:

- heat transfer shall be calculated in accordance with BS EN ISO 12241:1998;

  NOTE 1 It is to be expected that a computer program will normally be used to undertake such calculations.

- the values used or occurring within computer calculations shall not be manually truncated or approximated;
- where iterative calculation methods are employed, the process shall be continued until the difference between successive values of calculated heat flux in W/m or W/m^2, or outer surface temperature in °C, is less than 0.001;
- where declared as a whole number, the thickness of insulation resulting from calculation shall be rounded to the next higher whole mm; one decimal place shall be considered when rounding.

  NOTE 2 For example, a calculated insulation thickness of 37.107 mm becomes 38 mm whereas 37.090 mm becomes 37 mm.

NOTE 3 Insulation thicknesses are given for a range of thermal conductivities appropriate to the usual materials used for the application; thicknesses for intermediate thermal conductivities and pipe sizes can be deduced by calculation or interpolation. For assistance in selecting an appropriate type of insulation and suitable methods of application, reference should be made to BS 5970.

NOTE 4 Unless otherwise stated, the temperature of the surface to be insulated is taken to be the temperature of the fluid inside the pipe, tank, duct, vessel or other piece of equipment.

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