

Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range $-40\text{ }^{\circ}\text{C}$ to $+700\text{ }^{\circ}\text{C}$

ICS 23.040.01; 27.220

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee RHE/9, Thermal insulating materials, upon which the following bodies were represented:

- Association of Building Component Manufacturers
- Autoclaved Aerated Concrete Products
- BEAMA Ltd. Power Generation Contractors' Association
- Chartered Institution of Building Services
- Concrete Block Association
- Cork Industry Federation
- Cranfield University
- Department of the Environment, Transport and the Regions (represented by the Building Research Establishment)
- Electricity Association
- Energy Industries Council
- EURISOL — UK Mineral Wool Association
- European Phenolic Foam Association
- Gypsum Products Development Association
- National Physical Laboratory
- Thermal Insulation Contractors' Association
- Thermal Insulation Manufacturers' and Suppliers' Association
- Co-opted members

The following bodies were also represented in the drafting of the standard, through subcommittees:

- British Refrigeration Association
- British Rigid Urethane Foam Manufacturers' Association
- HEVAC Association
- Insulation Jacket Manufacturers' Federation
- Polyethelene Foam Insulation Association

This British Standard, having been prepared under the direction of the Engineering Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 05 December 2001

© BSI 13 November 2002

First published July 1977
Second edition July 1990
Third edition December 2001

The following BSI references relate to the work on this British Standard:
Committee reference RHE/9
Draft for comment 01/706326 DC

ISBN 0 580 38645 7

Amendments issued since publication

Amd. No.	Date	Comments
13982 Corrigendum No. 1	13 November 2002	Changes to Table 19, Table 20, Table 21, Table A.1 and Table C.1

Contents

	Page
Committees responsible	Inside front cover
Foreword	iii
Introduction	1
1 Scope	1
2 Normative references	1
3 Definitions	2
4 Application of this standard	3
5 General requirements	5
6 Refrigeration applications	8
7 Chilled and cold water applications	16
8 Central heating, air conditioning and direct hot water supply installations in non-domestic applications	18
9 Central heating and hot and cold water services for domestic applications	23
10 Process pipework and equipment applications	24
11 Protection against freezing	36
Annex A (informative) Determination of environmental thickness	41
Annex B (informative) Default values for use in BS EN ISO 12241 heat transfer calculations	43
Annex C (informative) Summary of criteria used to establish the tables	45
Annex D (informative) Outside diameters of steel and copper pipes	46
Annex E (informative) Explanation of “Class 0” rating and “limited combustibility”	47
Annex F (normative) Method for assessing the system load for refrigeration pipe-work	48
Annex G (normative) Calculation of economic insulation thickness	50
Bibliography	52
Figure 1 — Flow chart indicating application of the standard	4
Figure 2 — Graph to determine environmental heat gain for intermediate temperatures	21
Figure A.1 — Heat loss related to pipe diameter for non-domestic heating pipe at 75 °C insulated in accordance with Table 12	41
Figure F.1 — Example of Mollier diagram for R-22	49
Figure G.1 — Economic thickness	50
Table 1 — Maximum permitted water vapour permeance in relation to plant temperature at an ambient temperature of +20 °C (dry bulb)	8
Table 2 — Minimum insulation thickness for refrigeration applications to prevent condensation on a high emissivity outer surface (0.90) with an ambient temperature of +20 °C and a relative humidity of 70 %	10
Table 3 — Minimum insulation thickness for refrigeration applications to prevent condensation on a low emissivity outer surface (0.05) with an ambient temperature of +20 °C and a relative humidity of 70 %	11
Table 4 — Minimum insulation thickness for refrigeration applications to prevent condensation on a high emissivity outer surface (0.90) with an ambient temperature of +25 °C and a relative humidity of 80 %	12
Table 5 — Minimum insulation thickness for refrigeration applications to prevent condensation on a low emissivity outer surface (0.05) with an ambient temperature of +25 °C and a relative humidity of 80 %	13
Table 6 — Environmental insulation thickness for refrigeration applications to control heat gain	14
Table 7 — Minimum insulation thickness for chilled and cold water supplies to prevent condensation on a high emissivity outer surface (0.90) with an ambient temperature of +25 °C and a relative humidity of 80 %	17

	Page
Table 8 — Minimum insulation thickness for chilled and cold water supplies to prevent condensation on a low emissivity outer surface (0.05) with an ambient temperature of +25 °C and a relative humidity of 80 %	17
Table 9 — Environmental insulation thickness for chilled water supplies to control heat gain	18
Table 10 — 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	20
Table 11 — Environmental insulation thickness on ductwork carrying warm air	21
Table 12 — Environmental insulation thickness for non-domestic heating installations to control heat loss	22
Table 13 — Environmental insulation thickness for non-domestic hot water service areas to control heat loss	23
Table 14 — Environmental insulation thickness for domestic central heating installations and hot water systems in potentially unheated areas to control heat loss	24
Table 15 — Environmental insulation thickness for process pipework and equipment to control heat loss	26
Table 16 — Insulation thickness for personnel protection from a non-metallic surface with a surface emissivity of 0.90 and design cold face temperature of 59 °C	28
Table 17 — Insulation thickness for personnel protection from a metallic surface with a surface emissivity of 0.05 and design cold face temperature of 50 °C	30
Table 18 — Insulation thickness for personnel protection from a non-metallic surface with a surface emissivity of 0.90 and design cold face temperature of 50 °C	32
Table 19 — Heat loss from bare surfaces calculated in accordance with BS EN ISO 12241 (black steel pipes)	34
Table 20 — Heat loss from bare surfaces calculated in accordance with BS EN ISO 12241 (copper pipes — commercial grade, scoured to a shine)	35
Table 21 — Heat loss from bare surfaces calculated in accordance with BS EN ISO 12241 (copper pipes — oxidized)	36
Table 22 — Minimum insulation thickness to protect steel pipes against freezing under selected industrial process conditions	37
Table 23 — Minimum insulation thickness required to give protection against freezing under specified commercial and institutional conditions	38
Table 24 — Minimum insulation thickness to protect against freezing for domestic cold water systems (12 h)	39
Table 25 — Minimum insulation thickness to protect against freezing for domestic cold water systems (8 h)	40
Table A.1 — Environmental thickness methodologies	42
Table B.1 — Surface emissivity (ϵ)	43
Table B.2 — Default data for use in BS EN ISO 12241 calculations	44
Table C.1 — Summary of criteria used to establish the tables	45
Table D.1 — Outside diameter of steel pipe (from BS 3600)	46
Table D.2 — Outside diameter of copper pipe (from BS EN 1057)	46

Foreword

This British Standard has been prepared by Technical Committee RHE/9, Thermal insulating materials. It supersedes BS 5422:1990, which is withdrawn. The methods of calculation used in this standard have been revised to harmonize with the methods in BS EN ISO 12241, which were developed to give uniform international methods of calculation, and differ slightly from those given in the previous edition of BS 5422.

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

The previous “economic insulation thicknesses” have been revised in the context of their potential to limit carbon dioxide (CO₂) emissions, whilst maintaining due consideration of both economic and practical factors. This new approach is referred to as the “environmental thickness” calculation. Annex A shows the way in which the environmental thickness was derived from the economic thickness.

The frost protection tables have been revised to reflect more accurately UK design and operating conditions.

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 specifiers state the criteria or specific clause or reference in this standard in any specification.

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 may 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.

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.

NOTE Requirements in this standard are expressed in accordance with BS 0-3:1997, 10.1.3.1.1, which states, “Requirements shall be expressed using wording such as: ‘When tested as described in annex A, the product shall ...’”. This means that only those products that are capable of passing the specified test will be deemed to conform to this standard.

Annex F and Annex G are normative. Annex A, Annex B, Annex C, Annex D and Annex E are informative.

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 does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 53 and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

Introduction

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

- a) inhibit freezing in an unheated pipe;
- b) prevent condensation on a chilled or cold pipe;
- c) protect personnel from exposure to extremes of temperature;
- d) conserve energy for both cooled and heated systems;
- e) control process temperatures.

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 environmental thicknesses within its core tables. (The derivation of these thicknesses from the previous edition of BS 5422 is explained in Annex A.) Nonetheless, it is still possible, and fully justified, to choose an economic insulation thickness where carbon dioxide emissions are of lower importance (e.g. with low carbon fuels) and cost minimization is the priority.

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.

It is also common that 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. Under these circumstances, it is possible to interpolate between either columns or rows where the margin of error is not likely to be critical. For situations where the application parameters differ from those covered within the scope of a table (e.g. different ambient air temperature), the specifier will need to revert to first principles by using methods set out in BS EN ISO 12241.

The default values for use in BS EN ISO 12241 heat transfer calculations are given in Annex B, the criteria used to establish the tables are summarized in Annex C, and the 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 $+700^{\circ}\text{C}$. It also specifies physical requirements for the insulating materials. It is intended for use by 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 normative documents contain provisions which, through reference in this text, constitute provisions of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 476-6:1989, *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 476-12:1991, *Fire tests on building materials and structures — Part 12: Method of test for ignitability of products by direct flame impingement*.

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

BS 4370-2:1993, *Methods of test for rigid cellular materials — Part 2: Methods 6 to 10*.

BS 5970: 2001, *Code of practice for thermal insulation of pipework and equipment (in the temperature range $-100\text{ }^{\circ}\text{C}$ to $+870\text{ }^{\circ}\text{C}$)*.

BS EN ISO 12241:1998, *Thermal insulation for building equipment and industrial installations — Calculation rules*.

ISO 1182, *Fire tests — Building materials — Non-combustibility tests*.

3 Definitions

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

3.1

assumed lifetime

lifetime assumed for insulation installed in a defined application

NOTE This is used to provide an assessment of the amount of energy (and hence carbon dioxide) saved by the use of the insulation.

3.2

chilled water

water that has been processed through cooling plant (typically $0\text{ }^{\circ}\text{C}$ to $+10\text{ }^{\circ}\text{C}$)

3.3

cold water

water delivered from the mains or natural supply

3.4

economic thickness

thickness of insulation that minimizes the total cost (investment and running costs) over a chosen evaluation period (usually significantly less than the assumed lifetime)

3.5

environmental thickness

thickness of insulation that delivers energy saving at an investment level commensurate with other measures to save carbon dioxide (CO_2) and offers parallel performance to other insulation materials selected to the same criteria

3.6

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

3.7

finishing materials

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

3.8

insulation thickness

thickness of insulating material, excluding any finish or covering

3.9

pre-applied

applied to the insulation prior to delivery to the point of use

3.10

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

3.11

vapour barrier

water-vapour-retarding layer

NOTE Permeance values for vapour barriers are given in Table 1.

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 (see Figure 1).

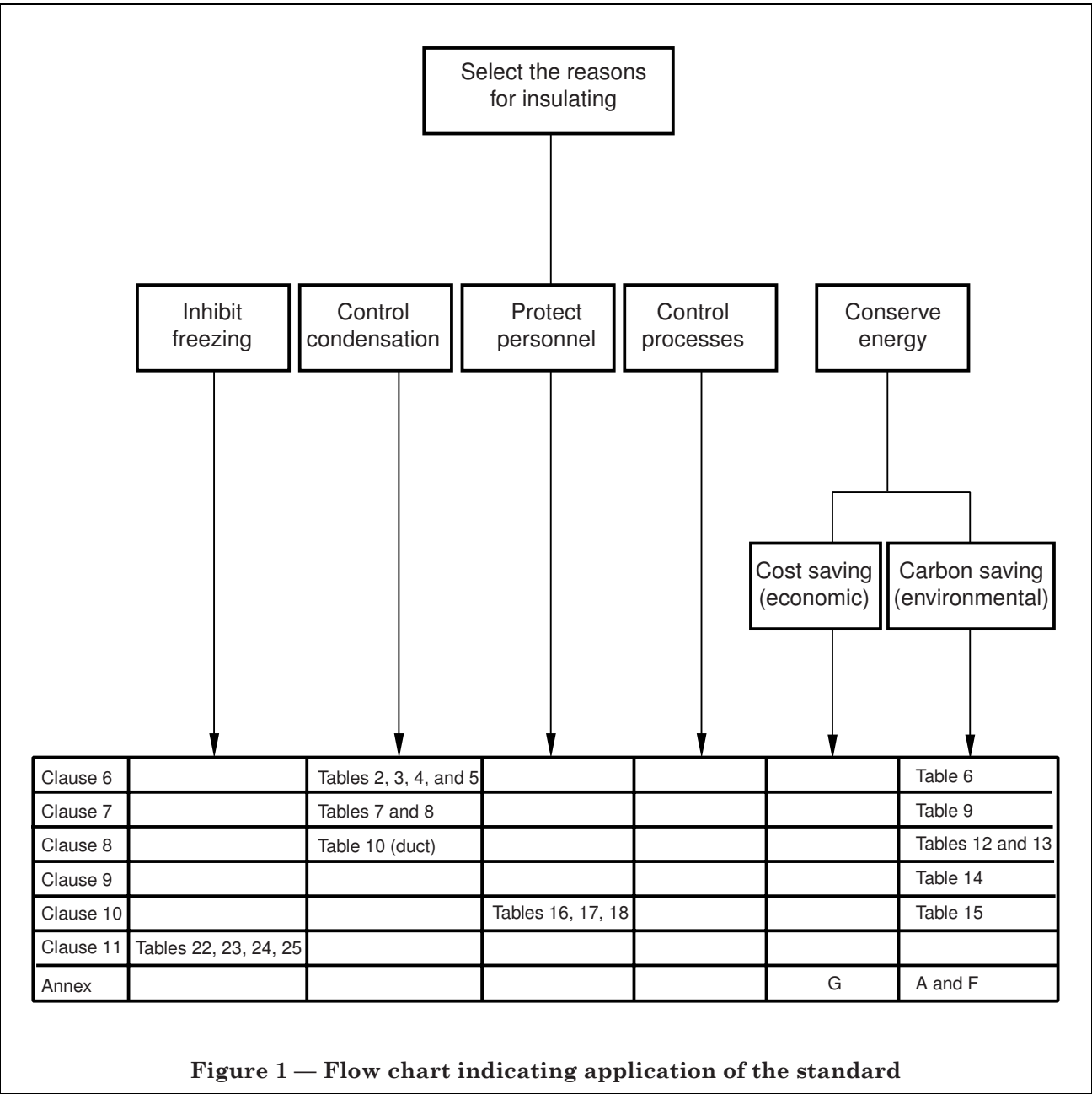
The specification shall state the prime purpose of the insulation and shall specify the performance requirements for the selected insulation system. The specification shall identify the minimum thickness requirements for each parameter of performance and shall identify the parameter that requires the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

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 the following performance requirements, if applicable, shall also be specified in accordance with the appropriate clauses and tables of this standard:

- j) resistance of the insulation material to the passage of water;
- k) permeance of any vapour barriers used.



5 General requirements

5.1 Physical characteristics

The manufacturer or specifier shall specify requirements for the physical characteristics of the insulating material, including finishing materials whether pre-applied or applied on site, to conform to the appropriate British Standard.

Where combustible insulating materials are used, the fire performance shall conform to **6.2.2**, **7.2.2**, **8.2.2**, **9.2.2**, or **10.2.2**, as appropriate.

The manufacturer or supplier shall specify requirements, together with appropriate methods for verification, for the insulating material to conform to whichever of the following conditions are deemed to be appropriate.

- a) The materials do not contain substances that will support pests or encourage the growth of fungi.
- b) The materials are free from objectionable odour at the temperatures at which they are to be used.

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

- c) The materials do not suffer permanent structural or physical deterioration as a result of contact with moisture.
- d) The insulation is suitable for specified conditions of use without the physical properties falling outside the tolerances allowed in the appropriate British Standard for the material.
- e) The materials in contact are compatible and do not cause corrosion or degradation under normal site conditions.
- f) The materials and their method of application do not constitute 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 HSE Guidance Note EH 40 [1].

5.2 Installation requirements

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

If different forms of insulation are likely to be used for specific areas of the installation, the specifier shall indicate whether or not such areas are to be treated identically or differently.

The specifier shall state the type of finish to be applied if additional protection is required.

5.3 Thermal conductivity

5.3.1 General

Manufacturers of insulating materials shall supply a table of declared thermal conductivity values based on results of tests carried out in accordance with the appropriate British Standards. The information shall include the corresponding cold face temperatures and the product identification. 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 for thermal conductivity quoted in the tables 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 $W \cdot m / (m^2 \cdot K)$ but in normal practice it is simplified to $W / (m \cdot K)$.

5.3.2 Single-layer insulation (or multilayer insulation where the layers are of the same composition)

In all cases 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.

5.3.3 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.

5.3.4 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 use of uninsulated valves or other ancillary fittings.

NOTE 1 An appropriate methodology for ensuring compliance is given in BS EN ISO 12241:1998, Annex A.

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 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.

NOTE 3 Although it is possible to compensate for uninsulated valves by increasing insulation levels elsewhere, it can prove more cost-effective to insulate the valves themselves using appropriate fittings which should be selected on the basis of ease of access where necessary.

5.4 Temperature limitations

The manufacturer shall state the maximum and minimum continuous operating temperatures of the products specified, and any other temperature limitation appropriate to the anticipated service conditions.

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 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 given in, or interpolated from, the tables do not correspond with 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 shall be made to ensure that each interface temperature is below the maximum continuous operating 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.

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 Fire performance

5.6.1 Different levels of fire performance, the requirements for which are given in **5.6.2**, **5.6.3**, **5.6.4**, **5.6.5**, **5.6.6**, **5.6.7**, **5.6.8**, **5.6.9**, **5.6.10** and **5.6.11**, shall be specified according to the type of application.

The particular requirements to be specified for each type of application shall be selected in accordance with **6.2.2**, **7.2.2**, **8.2.2**, **9.2.2** or **10.2.2**.

NOTE 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.

5.6.2 When tested in accordance with BS 476-12:1991, insulation materials shall be resistant to ignition sources types A and B.

5.6.3 When tested in accordance with BS 476-7:1997, the complete assembly of insulation materials, as installed, shall conform to the class 1 “spread of flame” requirements.

5.6.4 Where the insulating material itself (i.e. without any facing) is not rated class 1 when tested in accordance with BS 476-7:1997, particular care shall be taken with the added facing material to ensure that all joints and seams, etc. are fitted correctly, so that the underlying insulation is not left exposed and does not therefore provide a potential ignition source.

NOTE Where the complete assembly is liable to mechanical damage in use, the final finish should be sufficiently strong to ensure that the insulation does not become exposed.

5.6.5 Fire certification for faced materials shall state the nature of the facing material, the type and weight of any reinforcement, the type and weight of adhesive, the type and manufacturer of the substrate and any other factors pertinent to the fire performance of the system.

5.6.6 When tested in accordance with BS 476-7:1997, the insulation material itself (i.e. without any facing) shall conform to the class 1 “spread of flame” requirements.

5.6.7 When tested in accordance with BS 476-6:1989, the complete insulation assembly as installed, and the insulation material itself where it is used unfaced, shall achieve a fire propagation index (I) not exceeding 12.0, of which the initial subindex of performance (i_1) shall be not more than 6.0.

5.6.8 When tested in accordance with ISO 1182, insulation systems on pipework or ductwork traversing a fire-resisting division shall be shown by independent data to maintain the level of fire resistance of the wall, floor or cavity barrier through which they pass.

5.6.9 In underground or windowless buildings, the thermal insulation material used for external insulation of ventilation ductwork or pipes greater than 100 mm nominal bore size, when tested in accordance with ISO 1182, shall itself be of “limited combustibility” or “non-combustible”, with a weight loss during the test of not more than 50 %. In addition, the complete insulation assembly as installed shall conform to the class 1 “spread of flame” requirements when tested in accordance with BS 476-7:1997, and the fire propagation requirements when tested in accordance with BS 476-6:1989 (see **5.6.7**).

NOTE See Annex E for an explanation of “limited combustibility”.

5.6.10 When tested in accordance with ISO 1182, insulation materials for use at temperatures above 230 °C (excluding finishing materials) shall be of “limited combustibility” or “non-combustible”, with a weight loss during the test of not more than 50 %.

NOTE See Annex E for an explanation of “limited combustibility”.

5.6.11 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.

5.7 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 immediately after fitting the insulating material and before the fluid in the pipe, duct, or vessel is cooled.

When a vapour barrier is used, the system as installed, when tested in accordance with the various methods specified in **5.6**, shall have a fire performance at least equal to that specified in **5.6** as appropriate to the type of application.

The water vapour permeance of a flexible sheet material used as the vapour barrier 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, method 8 shall be used. The permeance of the vapour barrier shall be selected according to its relationship to the cold surface temperature of the plant and to the temperature difference, in degrees centigrade (°C), between the plant temperature and ambient temperature as indicated in Table 1.

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

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 the table by subtracting 10 °C from the plant operating temperature.

Where an external vapour barrier is used in service, separate layers in the form of coatings or sheet material shall be used for the individual purposes. The specifier shall state the type of finish to be applied where additional protection is required. Where such additional protection is specified, the installer shall ensure that its application does not cause any damage to the vapour barrier during its installation and is unlikely to cause damage in service. (For further details see BS 5970:2001.)

NOTE 4 The use of an external vapour barrier where specified is an essential requirement for the proper functioning of the insulation system. It is essential that its use for this purpose is not compromised by its additional use for other purposes e.g. as a form of weather protection or as mechanical protection for the thermal insulation.

5.8 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. 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 **5.6.2**, **5.6.3**, **5.6.5**, **5.6.8** and **5.6.9**. Insulation materials and systems used for refrigeration shall also conform to **5.6.4** except where the installed insulation assembly is unfaced, when **5.6.6** shall apply.

Where the equipment and pipework is located in non-domestic buildings, but excluding process applications, the insulation system shall conform to **5.6.7**.

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 **5.7**.

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

6.3.1 Protection against condensation

In the absence of specific instructions from the specifier, the insulation thickness shall be not less than that given in Table 2, Table 3, Table 4 and Table 5, as appropriate.

6.3.2 Insulating to minimize heat gain

NOTE Under certain circumstances, typically where heat gain from distribution pipes represents greater than 5 % of the total system refrigeration load, it may be appropriate to consider insulating to minimize heat gain. This can require greater thicknesses than those required for condensation control.

If insulation is used to minimize heat gain, the insulation thickness shall be not less than that given in Table 6 for the temperature range 0 °C to –40 °C.

Table 2 — Minimum insulation thickness for refrigeration applications to prevent condensation 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 (mm)	Insulation thickness (mm)																			
	<i>t</i> = 0				<i>t</i> = −10				<i>t</i> = −20				<i>t</i> = −30				<i>t</i> = −40			
	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																				
<i>t</i> = 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.																				

Table 3 — Minimum insulation thickness for refrigeration applications to prevent condensation 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 (mm)	Insulation thickness (mm)																			
	$t = 0$				$t = -10$				$t = -20$				$t = -30$				$t = -40$			
	$\lambda = 0.020$	$\lambda = 0.030$	$\lambda = 0.040$	$\lambda = 0.050$	$\lambda = 0.020$	$\lambda = 0.030$	$\lambda = 0.040$	$\lambda = 0.050$	$\lambda = 0.020$	$\lambda = 0.030$	$\lambda = 0.040$	$\lambda = 0.050$	$\lambda = 0.020$	$\lambda = 0.030$	$\lambda = 0.040$	$\lambda = 0.050$	$\lambda = 0.020$	$\lambda = 0.030$	$\lambda = 0.040$	$\lambda = 0.050$
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 Thicknesses given are calculated specifically against the criteria noted in the table. These thicknesses may not satisfy other design requirements.																				

Table 4 — Minimum insulation thickness for refrigeration applications to prevent condensation 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 (mm)	Insulation thickness (mm)																			
	<i>t</i> = 0				<i>t</i> = −10				<i>t</i> = −20				<i>t</i> = −30				<i>t</i> = −40			
	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																				
<i>t</i> = 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.																				