



Specification for
The use of thermal insulating materials

Spécification pour l'utilisation des matériaux d'isolation thermique

Spezifikation für den Gebrauch von wärmedämmenden Stoffen

Contents

	Page		Page
Foreword	1	J. Outside diameters of steel tube and copper tube	30
Cooperating organizations	Back cover	K. Fuel cost comparisons: cost of heat related to fuel price	31
Specification		Tables	
Section one. General		1. Required water vapour permeance in relation to plant temperature	5
1. Scope	2	2. Minimum thickness (mm) of insulation for refrigeration applications to prevent condensation	6
2. References	2	3. Calculated minimum thickness (mm) of insulation for chilled and cold water industrial supplies to prevent condensation	8
3. Definitions	2	4. Calculated minimum thickness (mm) of insulation required to give protection against freezing under industrial conditions assumed in 19.2.1	9
4. Information required	3	5. Times to the onset of freezing for some conditions of ambient air temperature and initial water temperature (other than those in 19.2.1)	9
Section two. General use of thermal insulating materials		6. Recommended thickness of insulation for central heating installations served by solid fuel-fired boiler plant	10
5. Physical characteristics	4	7. Recommended thickness of insulation for central heating installations served by oil-fired or gas-fired boiler plant	10
6. Thermal conductivity (manufacturer's declared value)	4	8. Recommended thickness of insulation for domestic hot water service installations served by solid fuel-fired boiler plant	11
7. Thickness	4	9. Recommended thickness of insulation for domestic hot water service installations served by oil-fired or gas-fired boiler plant	11
8. Tests	4	10. Recommended thickness of insulation on ductwork carrying warmed or chilled air	11
Section three. Refrigeration applications		11. Recommended thickness of insulation to protect against freezing: cold water services	12
9. Definitions	5	12. Recommended thickness of insulation (mm) for process pipework and equipment	15
10. Information required	5	13. Heat loss from hot surfaces for thicknesses given in table 12 expressed in W/m for pipes and W/m ² for flat surfaces	16
11. Physical characteristics	5	14. Heat loss from bare hot surfaces	21
12. Thermal conductivity	6	15. Economic thickness; typical method by tabulation	23
13. Thickness	6	16. Variation of dew point with relative humidity for ambient still air temperatures of 15 °C to 30 °C and with standard barometric pressure	27
14. Tests	6	17. Variation of outer surface coefficient (f) with temperature difference between surface and air for various outer diameters of insulation	27
Section four. Chilled and cold water supplies; Industrial applications		18. Steel tube outside diameters	30
15. Definitions	6	19. Copper tube outside diameters	30
16. Information required	6	20. Fuel cost comparisons: cost of heat related to fuel price	31
17. Physical characteristics	7	Figures	
18. Thermal conductivity (manufacturer's declared value)	7	1. Example of thermal conductivity determination	20
19. Thickness	7	2. Chart for economic thickness of thermal insulating material	24
Section five. Central heating, air conditioning and domestic hot and cold water supply installations		3. Chart solution for the expression	25
20. Definitions	9	$\chi = 0.5(d_o + 2L) \ln \left(1 + \frac{2L}{d_o} \right)$	25
21. Information required	9	4. Time to reach freezing point from 10 °C (static water in a pipe), air at -10 °C, thermal conductivity of insulation 0.04 W/(m K)	29
22. Physical characteristics	9	5. Additional time for complete ice formation (static water at 0 °C in a pipe), air at -10 °C, thermal conductivity of insulation 0.04 W/(m K)	29
23. Thermal conductivity (manufacturer's declared value)	11		
24. Thickness	12		
Section six. Process pipework and equipment applications			
25. Definitions	12		
26. Information required	13		
27. Physical characteristics	13		
28. Thermal conductivity (manufacturer's declared value)	14		
29. Thickness	14		
Appendices			
A. Symbols and conversion factors	18		
B. Calculation of heat losses	19		
C. Assessment of thermal conductivity values	19		
D. Heat losses and surface temperature	20		
E. Calculation of economic thickness	21		
F. Formulae for determining temperature at the point of delivery	26		
G. Calculation of thickness of insulating material required to prevent condensation	27		
H. Calculation of the thickness of insulating material required to prevent freezing of water in a pipe	28		

Foreword

This revision of the three standards, BS 1334, BS 1588 and BS 3708 was prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Committee, with the recommendation that an endeavour should be made to rationalize the method of presentation, and that the scope should be extended to include the temperature range appropriate to refrigeration plant. At the same time, the drafting committee has been aware of the national requirement to conserve all resources of energy and of the valuable contribution to this objective that can result from the efficient use of thermal insulating materials.

In the earlier standards, the emphasis was directed to specific temperature ranges for application, i.e. up to 95 °C, 95 °C to 230 °C, and 230 °C to 650 °C, with only the first range, i.e. up to 95 °C, referring to a definite type of use. This standard is intended to be comprehensive for all temperatures from -40 °C to +650 °C. It contains six sections. Section one and section two are of general application and they include requirements that are common to the remaining sections, which relate to installations for refrigeration, for chilled and cold water supplies, central heating, air conditioning, and domestic hot and cold water supplies, and for process pipework and associated equipment respectively. It does not deal with pipes which are embedded underground or in unventilated ducts, nor does it refer to the insulation of building structures. All the nomenclature is based on the use of SI units except appendix K, which gives certain units in imperial terms to follow current industrial practice.

For refrigeration and chilled or cold water systems, tables are provided to show the minimum thicknesses that are necessary to avoid condensation of atmospheric moisture on the vapour barrier, or on the external surface of the insulation under specific conditions. Methods of calculation are provided for conditions other than these. Reference is made to cold water systems both in section four and section five and the tables relating to these sections show minimum thicknesses of differing magnitude for protection against freezing. This is because section four covers industrial applications where the conditions of exposure are likely to be severe and the consequences of ice formation within the system relatively serious, whereas section five relates to domestic installations where the water normally is static for shorter periods. Methods of calculation for conditions other than those appropriate to the tables are given in the appendices.

For central heating installations it is preferred that economic thickness shall be applied, however, if it is not convenient to do this then reference should be made to the tables in section five which are based on calculations for intermittent working, i.e. for an evaluation period of 20 000 working hours (5 years at 4000 hours per year). They do not represent uniform heat losses. The thicknesses for domestic hot water services and air conditioning ducts are based on an evaluation period of 40 000 working hours (5 years at 8000 hours per year) and again, they do not represent uniform heat losses.

Many users of thermal insulation for process pipework and equipment will wish to calculate thicknesses which are appropriate for their specific requirements, and methods for doing this are given in the appendices. If the purchaser does not wish to indicate any special thickness details, then table 12 in section six should be used. However, as the thicknesses in this table do not correspond to uniform heat losses, table 13 shows the magnitude of the heat loss which will result from the application of the indicated thickness, for the size of pipe, the temperature of use, and the thermal conductivity shown.

In using tables 12 and 13 the thermal conductivity taken should be that for the arithmetic mean temperature of the hot surface and the outer surface of the insulation. However, in many cases it is sufficiently accurate to base the temperature of the hot surface and ambient air of these two on the average. Other methods of calculation are provided in the appendices so that the correct thicknesses can be ascertained for special requirements, e.g. for a specified temperature at the point of delivery, etc.

It will be noted that the recommended thicknesses shown in the tables for the conservation of heat are appreciably greater than those which appeared in the earlier standards. This is because of the urgent need to conserve energy supplies but, if the recommended thicknesses are to be adequately effective, the user should ensure that there is sufficient clearance in the various parts of his installation to permit the full use of these increased thicknesses.

Provision has been made for further revision of the tables of recommended thicknesses, in respect of the conservation of heat, should circumstances render this necessary.

British Standard Specification for

The use of thermal insulating materials

Section one. General

1. Scope

This British Standard relates to the use of thermal insulating materials within the temperature range -40°C to $+650^{\circ}\text{C}$. It is restricted to surfaces that do not exhibit appreciable change in temperature as a result of the application of such materials; thus it refers particularly to insulation for process plant, tanks, ducts and pipelines, as well as to the metallic surfaces of boilers and ancillary plant as used for heating fluids or for steam-raising. It does not refer to pipelines which are embedded underground or in unventilated ducts, nor does it refer to the insulation of building structures.

Guidance is given for the selection of correct thicknesses and for making the relevant calculations but, for the choice of any particular type of insulating material or for suitable methods of application, reference should be made to CP 3005.

Throughout this standard, unless otherwise stated, reference to the temperature of the surface to be insulated shall be understood to mean the temperature of the fluid inside the pipe, duct or vessel.

The standard has six sections:

Section one. General. This contains information which is of general application for the complete standard, i.e. scope, definitions, and details which are required to permit correct assessment of the work.

Section two. General use of thermal insulating materials.

This includes reference to physical characteristics of general import, thermal conductivity, and to tests for thermal conductivity, thickness, uniformity, and for bulk density.

Section three. Refrigeration applications. This relates to thermal insulation for pipes, ducts, tanks and vessels containing fluid which is maintained at temperatures between 0°C and -40°C . Reference to vapour barriers is also included. It does not relate to particular requirements for refrigeration plant, for insulated compartments, or for non-metallic containment structures.

Section four. Chilled and cold water supplies: industrial applications. This refers essentially to insulation for industrial service, with special application to pipes, tanks and vessels which are used for the conveyance or containment of chilled water (0°C to 5°C) or cold water (normally about 10°C). Reference to vapour barriers is included. In particular it deals with the use of insulation to prevent freezing of water in pipes, tanks and fittings, and to prevent the condensation of atmospheric moisture on their surfaces.

Section five. Central heating, air conditioning and domestic hot and cold water supply installations. This section relates to thermal insulation applications for central heating, air conditioning, mechanical ventilation, and hot and cold water supply installations, mainly within buildings, but it can be used for such associated ducts and piping as may be located outside the buildings in the open air. It does not refer to transmission lines which are buried directly in the ground or in unventilated ducts.

Reference is made to materials for application to:

- (a) direct fired boilers, calorifiers, hot water cylinders, storage tanks, ducts, pipes and fittings for working temperatures up to but not exceeding 200°C .
- (b) storage vessels, pipes and fittings for cold water supply installations, (but excluding application for refrigeration work) and for the purpose of protection against condensation and freezing (see CP 99 and CP 3005).

Section six. Process pipework and equipment applications.

This section relates to the use of thermal insulating materials on process pipework and equipment for service temperatures between ambient and 650°C , but it does not apply to vessels and conveyance systems which are lined internally with protective refractory or insulating material, and it does not refer to pipes which are buried directly in the ground or are contained in unventilated ducts. Tables of recommended thicknesses are given, together with the corresponding heat losses and methods for calculation of thicknesses in special cases are provided.

2. References

The titles of the standards publications referred to in this standard are listed on the inside back cover.

3. Definitions

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

3.1 preformed insulating material. Thermal insulating material that is fabricated in such a manner that at least one surface conforms to the shape of the surface to be covered and which, when handled, will maintain its shape without cracking, breaking, crumbling or permanent deformation.

3.2 plastic composition insulating material. Thermal insulating material in loose dry form, that is prepared for application as a paste or dough by mixing with water, usually on site. The normal variety sets under the influence of heat applied to the internal surface.

3.3 flexible insulating material. Thermal insulating material that, lacking rigidity, tends to drape or to conform to the shape of the surface against which it is laid.

3.4 loose fill insulating material. Thermal insulating material in the form of powder, granules or loose or pelleted fibres, that is used in the dry state as a filling for cavities, casings or jackets.

3.5 multilayer insulation. Thermal insulating comprising two or more contiguous layers of insulating material.

3.6 composite insulation. Multilayer insulation in which layers have different characteristics. (The most usual type of composite insulation is one in which a layer of a relatively high temperature resisting material is interposed between the hot face and the main insulating material and serves to protect the latter from excessive temperature.)

3.7 bulk density. The mass per unit volume of dry insulating material, kg/m^3 .

3.8 thermal conductivity (k). The quantity of heat which passes in unit time through unit area of a homogeneous flat slab of infinite extent and of unit thickness, when unit difference of temperature is established between its faces, W/(m K) .

3.9 equivalent thermal conductivity. The effective thermal conductivity of a composite or non-uniform insulation assembly (see appendix C).

3.10 evaluation period. The time (working hours) over which the cost of heat lost from the insulated surfaces is to be calculated.

3.11 thickness of insulation. The thickness of insulating material only, excluding any protective finish or covering composition.

3.12 economic thickness. The thickness of insulation which gives a minimum total cost over a chosen evaluation period.

3.13 incremental cost. The cost per unit volume of an increment of insulation (see E.3.1).

3.14 cold water. The water delivered from the mains or natural supply.

3.15 chilled water. Water after processing through a cooling plant.

3.16 water vapour permeance. The rate of passage of water vapour through unit area of a specimen, at unit difference of water vapour pressure between the surfaces.

3.17 vapour barrier. Material used to restrict the transmission of vapour (usually water vapour). See BS 2972 : 1975, clause 48 (for conversion factors see A.2 of this standard).

3.18 finishing materials. All materials used to cover the insulation whether applied in a factory or on site.

3.19 factory applied covering. The surfacing material applied by the insulation manufacturer.

4. Information required

To permit the insulation requirements to be assessed by the insulation contractor, the following information will be required from the purchaser.

4.1 Type of insulating material required. This shall also include the form in which the material is to be provided, e.g. pre-formed, flexible, etc., and whether any portions are to be fabricated specially for ease of removal.

4.2 Type of finish. Preference should be indicated between a dry finish, e.g. sheet metal, and a wet finish, e.g. composition or a cement mixture.

4.3 Dimensions of items to be insulated. Unless these are adequately detailed in drawings, information will be required relative to surface dimensions of flat or large curved areas, external diameters of pipes, lengths of each size of pipe, numbers and shapes of bends, numbers and types of fittings (valves, flanges, tees, etc.) and space available for insulation especially at flanges and valves.

4.4 Nature of surfaces which are to be insulated. Indication should be given concerning special alloys for which care should be exercised and the purchaser must notify the contractor of any specific chemical requirement for insulation and finish.

4.5 Location of plant. The information should indicate if the plant to be insulated is:

- (a) indoors;
- (b) outdoors but protected from the weather;
- (c) outdoors exposed to the weather;
- (d) carried in ventilated ducts or open trenches.

4.6 Temperature conditions. The information should include:

- (a) the normal operating temperature;
- (b) the extreme temperature if other than (a) above;
- (c) any fluctuating temperatures, and duration of extreme or fluctuating temperatures.

4.7 Surrounding atmospheric conditions. Special note should be made of abnormally high or low temperatures, high humidity, flammable conditions, potentially corrosive atmosphere, etc.

4.8 Special conditions or service requirements. This should include:

- (a) requirements for resistance to compression;
- (b) resistance to fire;
- (c) abnormal vibration;
- (d) exposure to mechanical damage;
- (e) the presence of corrosive fluid;
- (f) anticipated wide fluctuations of temperature;
- (g) resistance of surface to ingress of oils and flammable liquids.

4.9 Basis on which thickness is to be determined. Some alternatives would be:

- (a) economic thickness;
- (b) selection as appropriate from a numbered table in this standard;
- (c) specified heat gain or loss per unit dimension, or relative to the complete system;
- (d) specified temperature on the outer surface of the insulation, e.g. for the protection of personnel (see CP 3006);
- (e) specified conditions of fluid at the point of delivery;
- (f) special thickness requirements.

See also the relevant clauses in each section of this standard.

Section two. General use of thermal insulating materials

5. Physical characteristics

The physical characteristics of the insulating material, including finishing materials whether applied during manufacture or on site, shall comply with the relevant British Standards where they exist, e.g. BS 3958 : Parts 1 to 5, and additionally with 5.1 to 5.7 (see CP 3005 : 1969 sections two and five for fuller details).

5.1 Certain insulating materials are combustible and reference shall be made to the fire hazard as given in each section of this standard depending on the application.

5.2 The materials shall not contain substances which will support pests or encourage the growth of fungi.

5.3 The materials shall be free from objectionable odour at the temperature at which they are to be used subject to prior agreement with the user. Transient effects during the initial period of use generally may be ignored.

5.4 The materials shall not suffer permanent structural deterioration as a result of inadvertent contact with moisture. If subsequent drying is practicable, the material after drying shall substantially recover its physical form and thermal properties.

5.5 The insulation shall be suitable for the specified conditions of use without the physical properties falling outside the tolerances allowed in the relevant material (see clause 5 above).

5.6 Any materials liable to be in contact with the surfaces concerned shall not cause corrosion under normal site conditions.

5.7 The materials shall not cause a known hazard to health during application, while in use, or on removal, either from particulate matter or from toxic fumes.

6. Thermal conductivity (manufacturer's declared value)

6.1 General. The manufacturer shall have tests for thermal conductivity carried out by the appropriate method described in BS 874, in a laboratory competent to undertake the tests. The test report shall include the bulk density of the samples tested and the hot and cold temperatures used for each determination.

Thermal conductivity shall be expressed in terms of watts (joules per second) per square metre for one metre thickness and a temperature difference of one kelvin. In symbols this should be written $k = W \text{ m}/(\text{m}^2 \text{ K})$ but in normal practice it is simplified to $k = W/(\text{m K})$.

The manufacturers shall provide a table of declared thermal conductivity values based on these test results and covering a suitable range of hot face temperatures. The corresponding cold face temperatures and the relevant bulk densities shall be stated. The figures given in the table shall contain any tolerances deemed to be appropriate by the manufacturer.

6.2 Single layer insulation (or multi-layer insulation where the layers are of the same composition). In all cases the contractor shall state the manufacturers' declared values of thermal conductivity for each material he is proposing to supply. These declared values shall contain the appropriate tolerances and they shall also be appropriate to the hot and cold face temperatures of use.

6.3 Composite insulation. When two or more layers of dissimilar insulating material are to be used, the supplier shall either quote the equivalent thermal conductivity based

on his declared values or provide a declared value of thermal conductivity for each layer under the appropriate temperature conditions. The thickness of each layer shall also be stated (see appendices B and C).

It will not normally be necessary for the user to indicate the thicknesses of each layer when composite insulation is to be used, as these will depend on the appropriate limiting interface temperature; the supplier can be expected to provide the requisite information.

6.4 Assessment of thermal conductivity. Thermal conductivity values corresponding to the working conditions of the plant concerned shall be calculated by the appropriate method in appendix C.

In using the tables in this standard it will be sufficiently accurate to use the thermal conductivity appropriate to the arithmetic mean of the hot face and the ambient air temperature. If greater accuracy is required, the surface temperature must be calculated and the thermal conductivity at the mean of the hot face temperature and the insulation surface temperature used (see appendix D).

7. Thickness

Requirements for thickness are given in each section of this standard. Where these do not correspond with available commercial thicknesses, the nearest higher commercial thickness should be applied, subject to agreement between the purchaser and the contractor.

Tables 2, 3, 4, 12 and 13 are based on datum figures for thermal conductivity and thickness so that the appropriate thicknesses for intermediate thermal conductivities can be deduced by interpolation.

Tables 6, 7, 8, 9, 10 and 11 give commercial thicknesses appropriate to specific thermal conductivity figures so that, correctly, the next greater thickness should be selected from the table for intermediate thermal conductivities. However, subject to prior agreement between the purchaser and the supplier, it may be possible to determine the thickness by reference to the column headed by the thermal conductivity figure nearest to that of the preferred insulating material for the specified temperature of use.

If the temperature of the surface to be insulated is above the limiting temperature for the preferred main insulating material, it is necessary to use an inner protective layer of an insulating material of greater temperature resistance. In this case the total thickness applied shall be appropriate to the equivalent thermal conductivity. The thickness of each layer shall be computed to ensure that the interface temperature between the two materials does not exceed the limiting temperature for the material of the outer layer. See also appendix B.

8. Tests

8.1 General. The purchaser may call for:

- (a) tests to ensure compliance with the provisions of clause 5;
- (b) thermal conductivity tests on representative samples of the insulating material;
- (c) site tests to be made in respect of thickness and bulk density.

All tests shall be in accordance with the requirements of the appropriate British Standards, e.g. BS 874, BS 2972, etc.

In the absence of a relevant British Standard test method, the purchaser and the supplier shall agree on the use of a suitable test method, except in the case of a test for thermal conductivity.





NOTE. There is no suitable test method for the accurate determination of thermal conductivity of insulation material in the form of pipe sections. Flat slabs of the same material, bulk density and structure are used in the hot-plate test method of BS 874.

8.2 Tests for thermal conductivity. The thermal conductivity of the samples tested shall not be greater than the manufacturer's declared value.

8.3 Tests for thickness. Tests for thickness shall be carried out after application. Local irregularities (e.g. bolt heads) on the surface to be insulated shall be ignored.

If the tests for thickness carried out as above show that any part of the insulating material has not been applied at the agreed thickness (subject to tolerances previously agreed between the purchaser and the contractor), then the insulation shall be deemed not to comply with the requirements of this standard.

8.4 Uniformity of thickness. Uniformity of thickness shall be assessed in the same manner as in 8.3. If any one measurement varies by more than $\pm 10\%$ subject to a minimum of 3 mm and a maximum of 10 mm, whichever is less, from the arithmetic mean of all the readings, the purchaser may call for the portion of the materials represented by such measurements to be replaced.

8.5 Tests for bulk density. Tests for bulk density shall be carried out after application, except in the case of pre-formed material, and measurements of thickness and area shall be taken on the insulating material before cutting and/or removal. If the tests show that the insulating material has been applied at a bulk density within $\pm 15\%$ of that quoted as the basis of the thermal conductivity declaration, the portion of the material represented by the tests shall be deemed to comply, in respect of bulk density, with the requirements of this standard.

Section three. Refrigeration applications

9. Definitions

See clause 3.

10. Information required

To permit the insulation requirements to be assessed by the insulation contractor, information shall be provided by the purchaser generally in accordance with clause 4, as modified by 10.1 to 10.9, and with table 2 of this standard. (See CP 3005.)

10.1 Type of insulating material. It is important that the form of the material shall be such that an adequately effective vapour barrier can be applied outside the zone of potential condensation (see 11.2). Preferably the material should be of a type that will be resistant to the passage of water.

10.2 Type of finish. The finish selected shall be a vapour barrier or shall be suitable for use in association with a vapour barrier and it should not contain water unless there is adequate provision for drying out before the temperature of the contained fluid is reduced to below the dew point.

10.3 Dimensions of items to be insulated. See 4.3.

10.4 Nature of surfaces which are to be insulated. See 4.4.

10.5 Location of plant. See 4.5.

10.6 Temperature conditions. The information shall include the normal working temperature of the fluid in

the pipe or vessel and the duration, and extent of any significant variations from this temperature, e.g. elevated temperatures for 'steaming-out', even though these may apply only at rare intervals.

10.7 Surrounding atmospheric conditions. The thicknesses in table 2 have been calculated for still air conditions of 25°C and 90 % relative humidity. If the actual conditions are likely to be significantly different from these figures then the true figures shall be stated.

10.8 Special conditions or service requirements. See 4.8.

10.9 Basis on which thickness is to be determined. The thicknesses specified in table 2 ensure that atmospheric moisture does not condense on the external surface of the insulation under the conditions noted. If other requirements are to be considered, e.g. energy conservation, a stated temperature at the point of delivery or maintenance of the temperature for a bulk of static fluid over a specific period of time, then it is essential that these requirements shall be stated. If the fluid is not static, information on the rate of flow will be required.

11. Physical characteristics

The physical characteristics of the insulating material, including finishing materials and vapour barriers whether applied during manufacture or on site, shall comply with clause 5 and also with 11.1 and 11.2.

11.1 Fire hazard. No recommendation in respect of fire hazard is made in this section. It is the responsibility of the purchaser and the supplier to agree on the specific properties needed for the materials used on any particular contract, since some materials commonly used are susceptible to burning.

11.2 Vapour barrier. A vapour barrier on the outside (warm side) of the insulation is essential. It shall take the form of a coating or sheet material, adequately sealed, which is resistant to the passage of water vapour. Care should be taken to ensure that the vapour barrier layer does not seriously increase the fire hazard of the insulation system.

The permeance of the vapour barrier shall be related to the cold surface temperature of the plant in accordance with table 1 and in no case shall it exceed 0.01 g/(s MN) for refrigeration work.

The appropriate permeance values for intermediate temperatures may be deduced from this table.

The vapour barrier is a technical requirement and it is not to be used as the surface finish if it is likely to be easily damaged. It shall be applied immediately after fitting the insulation and before the fluid in the pipe or vessel is cooled.

Table 1. Required water vapour permeance in relation to plant temperature

Temperature of plant (cold surface) $^{\circ}\text{C}$	Water vapour permeance of barrier g/(s MN)
0	0.010
— 5	0.004
— 10	0.002
— 15	0.0015
— 20 to — 40	0.001



Documents

Document Sharing Hub

Table 2. Minimum thickness (mm) of insulation for refrigeration applications to prevent condensation

Pipe outside diameter on which insulation thicknesses have been based*	Temperature of contents											
	0 °C				−10 °C				−20 °C			
	Thermal conductivity, W/(m K)											
	0.02	0.03	0.04	0.05	0.02	0.03	0.04	0.05	0.02	0.03	0.04	0.05
	Thickness of insulation, mm											
mm												
21.3	20	28	36	43	27	38	48	57	34	47	58	70
33.7	23	32	40	48	30	42	53	64	38	52	65	79
60.3	26	36	46	55	34	48	61	73	43	60	75	90
114.3	29	41	53	64	40	56	71	85	50	69	88	106
168.3	31	44	57	69	42	60	77	92	53	75	95	114
273	33	47	61	75	45	65	84	101	58	82	104	126
508	35	51	66	81	48	70	91	111	62	89	115	141
Above 508 and including flat surfaces	38	56	75	94	54	81	107	134	70	105	139	174

Pipe outside diameter on which insulation thicknesses have been based*	Temperature of contents							
	−30 °C				−40 °C			
	Thermal conductivity, W/(m K)							
	0.02	0.03	0.04	0.05	0.02	0.03	0.04	0.05
	Thickness of insulation, mm							
mm								
21.3	40	55	69	83	46	63	79	95
33.7	45	62	78	93	51	71	89	106
60.3	51	71	89	106	59	81	102	121
114.3	59	82	104	124	68	95	119	142
168.3	64	89	112	134	74	103	129	155
273	69	98	125	150	80	113	144	172
508	75	106	138	166	87	125	160	194
Above 508 and including flat surfaces	86	129	172	215	102	153	204	255

*Outside diameters shown are to the requirements of BS 3600 (see also appendix J). Thicknesses of insulation for other pipe outside diameters can be obtained by interpolation or extrapolation.

12. Thermal conductivity

See clause 6.

13. Thickness

13.1 Protection against condensation

13.1.1 Minimum thickness. In the absence of specific instructions from the purchaser, the thickness applied shall be in accordance with table 2. This table gives the minimum thicknesses needed to avoid condensation on the outer surface of the insulating material when the ambient temperature and the relative humidity are 25 °C and 90 % respectively and the emissivity of the external surface is 0.9. See also clause 7.

13.1.2 Other conditions. If thicknesses are to be calculated for specific conditions other than those relevant to table 2, e.g. for other temperatures and humidities, for a specified condition at the point of delivery, etc., see appendices F and G.

14. Tests

See clause 8.

For tests for permeance, see BS 2972 : 1975, section twelve and BS 3177.

Section four. Chilled and cold water supplies: industrial applications

15. Definitions

See clause 3.

16. Information required

To permit the requirements to be assessed by the insulation contractor, information shall be provided by the purchaser and shall generally be in accordance with clause 4 as modified by the following:

16.1 Type of insulating material. As there is a possibility that moisture can be deposited within the insulating material as a result of the condensation of water vapour under service conditions, the material itself should be resistant to the passage of water.

16.2 Type of finish. If the insulated surface is likely to be at or below the dew point temperature for prolonged periods, it is preferable that an effective vapour barrier shall be applied over the outer (warm) surface of the insulation.

16.3 Dimensions of items to be insulated. See 4.3.

16.4 Nature of surfaces which are to be insulated. See 4.4.

16.5 Location of plant. See 4.5.

16.6 Temperature conditions. As 'chilled' water services (approximate temperature range 0 °C to 5 °C) may require consideration which is different from that for 'cold' water (temperature about 10 °C), the information for the two types of service should be kept separate.

16.7 Surrounding atmospheric conditions. Indication should be given relative to conditions of high atmospheric humidity and to possible exposure to temperatures which are below the freezing point of water.

16.8 Special conditions or service requirements. If the water in the pipe or vessel is likely to remain static for long periods when the ambient temperature is below freezing point, it is important that this shall be stated. Also, as water in small diameter pipes may be specially susceptible to freezing, particularly if the rate of flow is intermittent or slow, it may be necessary to consider the use of supplementary means of heating, possibly even in local areas only.

16.9 Basis on which thickness is to be determined. The following requirements shall receive consideration:

- (a) prevention of surface condensation (see 19.1);
- (b) prevention of freezing of the fluid in the containment system (see 19.2);
- (c) specified conditions of the fluid at the point of delivery; in this case it is essential that the rate of flow shall be indicated, with emphasis on the minimum rate (see appendix F);
- (d) control of heat-gain to chilled water systems (see 19.4).

17. Physical characteristics

The physical characteristics of the insulation material, including fixing and finishing materials whether applied during manufacture or on site, shall comply with clause 5 and with 17.1 and 17.2:

17.1 Fire hazard. The following are minimum requirements. Where there are more stringent requirements the standards of fire protection shall be agreed between the purchaser and the supplier.

- (a) All the materials shall be graded 'P' in the ignitability test as given in BS 476 : Part 5.
- (b) Certain insulation systems in a fire may generate appreciable quantities of smoke and noxious and toxic fumes. At present there is no standard test available for the assessment of this hazard so that it is not possible to offer mandatory requirements. However, consideration shall be given to the choice of materials, bearing in mind their location, e.g. in enclosed areas or adjacent to air ducts through which smoke or fumes may spread.

If there is a potential hazard from contamination by oil or other flammable chemical, a suitably resistant finish, e.g. 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.

17.2 Vapour barrier. Condensation of water vapour will occur on a surface which is at a temperature below the atmospheric dew point. Where these conditions are transient or periodic, there may not be a need to make provision for such condensation since the condensate will re-evaporate later. If the conditions are not transient, a vapour barrier shall be applied on the warmer face of the insulation to avoid deposition of moisture within the insulating material so preserving its thermal characteristics and preventing possible corrosion of the insulated cold metal surface.

Care should be taken to ensure that the choice of vapour barrier does not affect the fire performance of the whole assembly of insulating and finishing materials (see 17.1).

When a vapour barrier is required it shall take the form of a coating or sheet material, adequately sealed, which is resistant to the passage of water vapour. The permeance of the vapour barrier shall not exceed the appropriate values as follows:

- (a) for chilled water supplies (temperature 0 °C to 5 °C); 0.015 g/(s MN)
- (b) for cold water supplies (temperature about 10 °C); 0.05 g/(s MN)

(See CP 3005 : 1969 table 7 for a typical values of water vapour permeance.)

The vapour barrier is a technical requirement and it is not to be used as the surface finish if it is likely to be easily damaged.

18. Thermal conductivity (manufacturer's declared value)

See clause 6.

19. Thickness

19.1 Protection against condensation

19.1.1 Minimum thickness. In the absence of specific instructions from the purchaser, the thickness applied shall be in accordance with table 3. This table gives the minimum thicknesses needed to avoid condensation on the outer surface of the insulating material when the ambient temperature and the relative humidity are 25 °C and 90 % respectively and the emissivity of the external surface is 0.9. See also clause 7.

19.1.2 Other conditions. If thicknesses are to be calculated for specific conditions other than those relevant to table 3, e.g. for other temperatures and humidities or for surface finishes with different emissivities see appendix G.

19.2 Protection against freezing. The use of insulation alone will 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 of time, and the movement of the water through the pipe or vessel is very slow or if the water is static, then no insulation however thick, will prevent internal freezing.

Table 3. Calculated minimum thickness (mm) of insulation for chilled and cold water industrial supplies to prevent condensation

Pipe outside diameter on which insulation thicknesses have been based*	Temperature of contents							
	10 °C				0 °C			
	Thermal conductivity, W/(m K)							
	0.02	0.03	0.04	0.05	0.02	0.03	0.04	0.05
mm	Thickness of insulation, mm							
21.3	13	18	23	27	20	28	36	43
33.7	14	20	25	30	23	32	40	48
60.3	16	23	29	35	26	36	46	55
114.3	18	25	33	40	29	41	53	64
168.3	19	27	35	42	31	44	57	69
273	20	29	37	45	33	47	61	75
508	21	30	39	48	35	51	66	81
Above 508 and including flat surfaces	22	32	43	53	38	56	75	94

*Outside diameters shown comply with the requirements of BS 3600 (see also appendix J). Thicknesses of insulation for other pipe outside diameters can be obtained by interpolation or extrapolation. (See 19.4 for reference to heat-gain.)

Insulation will reduce the rate of cooling and will delay the onset of freezing, but the formation of ice may be avoided entirely 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. It should be noted that valves are particularly vulnerable.

19.2.1 Minimum thickness. 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 are those of larger bore so that the smaller pipes will require relatively greater thicknesses of insulation for the same degree of protection against freezing. Thicknesses of insulation for reasonable protection against freezing are given in table 4 (see also clause 7). Table 4 has been compiled for the following assumed conditions.

- Outdoor service (infinite coefficient for the rate of transmission of heat from the external surface; i.e. this allows for air movement over the exposed surface).
- Static water in the pipe, initially at a temperature of 10 °C.
- Ambient air temperature of -10 °C.
- Mild steel pipe.
- Thermal conductivities of insulation as shown in the table. These relate to a hot face temperature of 5 °C (mean of initial and final water temperatures, if ice is to form) and a cold face temperature of -10 °C (ambient air temperature).
- Insulation of bulk density 30 kg/m³ and of heat capacity 1000 J/(kg K).
- An elapsed time to 'no ice' or to '10 % ice' (by volume) respectively of 12 h.

A separate calculation is required if any of these conditions do not apply.

Obviously, some of the theoretical thicknesses in table 4 are impracticable, especially those above the values printed in bold type. In such cases, other means of protection, e.g. trace-heating or water-flow, should be adopted to supplement the protection that is afforded by the reduced thickness of insulating material.

19.2.2 Other conditions. Although the thicknesses shown in table 4 are those derived by calculation for a specific temperature/time combination, the same thicknesses could be appropriate for other temperature/time conditions, as is indicated in table 5.

Further data on times for the water to reach freezing point under other conditions are given in appendix H.

Thicknesses applied in accordance with table 4 can provide periods of protection longer than 12 h when the average ambient air temperature is higher than -10 °C and/or the initial water temperature is higher than +10 °C (see table 5). Conversely there would be a reduction in the period for temperatures lower than -10 °C for air and +10 °C for water.

If 10 % ice formation by volume is acceptable then the times shown in table 5 may be increased, the increment being dependent mainly on the size of pipe.

19.3 Special conditions at the point of delivery. See appendix F.

19.4 Heat-gain to chilled water lines. Normally it will be advisable to control the rate at which heat is gained by a chilled water system, in order to conserve the energy input for cooling purposes. The minimum thicknesses quoted in table 3 correspond to heat-gain at the rate of approximately 12 to 14 W/m² of external surface over the insulation, and these should be found to be suitable for most applications. If separate calculations are required for any particular installation, they shall be in accordance with appendix B.

Table 4. Calculated minimum thickness (mm) of insulation required to give protection against freezing under industrial conditions assumed in 19.2.1

Pipe outside diameter on which insulation thicknesses have been based *	No ice formed in 12 h			10 % ice formed in 12 h		
	Thermal conductivity, W/(m K)					
	0.02	0.03	0.04	0.02	0.03	0.04
	Thickness of insulation, mm					
mm						
21.3	259			178		
26.9	186	304		87	185	
33.7	112	218	318	47	99	173
42.4	61	125	207	26	49	81
48.3	45	88	148	20	36	56
60.3	30	53	84	14	24	35
88.9	17	27	38	8	13	18
114.3	12	19	26	6	10	13
168.3	8	12	16	4	6	8
219.1	6	9	12			

*Outside diameters shown comply with the requirements of BS 3600. (See also appendix J.) Thicknesses of insulation for pipe outside diameters can be obtained by interpolation or extrapolation.

All methods employed to deduce a thickness of insulation to meet a specified heat-gain include an element of iteration within the calculation, even when a constant value for thermal conductivity is assumed. Of these, perhaps the most elementary routine is to select a thickness and then calculate the corresponding heat-gain, using equations of the type shown in appendix B. The procedure is repeated, with an appropriate choice of further thicknesses, until the specified gain, or the one next lower in value, is observed. It should be noted that the symbol q in appendix B relates to the heat transmission per unit area of pipe surface, so that to relate this figure to the external surface over the insulation it will be necessary to multiply by a factor which is obtained from the ratio:

$$\text{factor} = \frac{\text{outer diameter of pipe}}{\text{diameter over external surface of insulation.}}$$

Section five. Central heating, air conditioning and domestic hot and cold water supply installations

20. Definitions

See clause 3.

21. Information required

To permit the requirements to be assessed by the insulation contractor, information shall be provided by the purchaser generally in accordance with clause 4 as modified by 21.1 to 21.9 below.

21.1 Type of insulating material. In the types of application relative to this section is is not unusual for several different forms of insulating material to be employed. Indication shall be given on whether specific areas of the installation are to be treated identically or differently.

Table 5. Times to the onset of freezing for some conditions of ambient air temperature and initial water temperature (other than those in 19.2.1)

Ice formation	Initial water temperature °C	Ambient air temperature, °C		
		-5	-2	-1
		Time, hours		
Nil	+10	19	31	41
	+ 5	12	21	31

21.2 Type of finish. Frequently the insulating material for pipes relative to this section may have a factory-applied covering in the form of a flexible sheet material. Where the insulation is concealed from sight and not exposed to mechanical damage it may be convenient to omit a finishing layer entirely, provided that an unacceptable fire hazard is not created.

21.3 Dimensions of items to be insulated. See 4.3.

21.4 Nature of surfaces which are to be insulated. See 4.4.

21.5 Location of plant. See 4.5.

21.6 Temperature conditions. See 4.6.

21.7 Surrounding atmospheric conditions. See 4.7.

21.8 Special conditions or service requirements. See 4.8.

21.9 Basis on which thickness is to be determined. Tables 6 to 9 give recommended thicknesses for the conditions stated in 24.3 and 24.3.2. Table 11 gives recommended thicknesses for reasonable protection against freezing. The purchaser should indicate if these tables are to be used, or if other determinants are to be considered.

22. Physical characteristics

The physical characteristics of the insulating material, together with adhesive, fixing, vapour barrier and finishing material, whether applied during manufacture or on site, shall comply with clause 5 of this standard and with 22.1 and 22.2.

22.1 Fire hazard. The following are minimum requirements. Where there are more stringent requirements the standards of fire protection shall be agreed between the purchaser and the supplier.

(a) Except where otherwise stated all materials used shall be graded 'P' in the ignitability test as given in BS 476 : Part 5.

(b) Where used for internal linings of ventilation ductwork, the thermal insulating material itself shall be non-combustible, as defined in BS 476 : Part 4, and the complete assembly of materials shall:

(1) when tested in accordance with BS 476 : Part 6, have an index of performance not exceeding 12, of which not more than 6 should derive from the initial period of the test, and

(2) not be installed within 1 m of a fire damper.

NOTE. By prior agreement between the purchaser and the supplier, the internal lining may be acceptable provided that the insulation material itself is non-combustible and that the complete assembly of materials, when tested in accordance with BS 476 : Part 7, shall be graded as class 1.

Table 6. Recommended thickness of insulation for central heating installations served by solid fuel-fired boiler plant

Outside diameter of pipe on which insulation thicknesses have been based*	Hot face temperature, °C (with ambient still air at 20 °C)								
	75			100			150		
	Thermal conductivity, W/(m K)								
	0.04	0.055	0.07	0.04	0.055	0.07	0.04	0.055	0.07
mm	Thickness of insulation, mm								
17.2	19	25	25	25	25	25	25	32	32
21.3	19	25	25	25	25	25	25	32	32
26.9	25	25	25	25	25	25	25	32	32
33.7	25	25	25	25	25	25	32	32	32
42.4	25	25	25	25	25	25	32	32	38
48.3	25	25	25	25	32	32	32	32	38
60.3	25	25	25	25	32	32	32	38	38
76.1	25	25	32	32	32	32	32	38	44
88.9	25	25	32	32	32	32	38	44	44
114.3	25	32	32	32	32	38	44	44	44
139.7	25	32	32	32	38	44	44	44	50
168.3	25	32	38	38	44	44	44	50	50
219.1	32	32	44	44	44	44	44	50	50
273.0	32	44	44	44	44	44	44	50	50
Above 323.9 and including flat surfaces	32	44	44	44	44	44	50	50	50

NOTE. The same thickness of insulation would be used for copper pipework of approximately similar outside diameters.

Table 7. Recommended thickness of insulation for central heating installations served by oil-fired or gas-fired boiler plant

Outside diameter of pipe on which insulation thicknesses have been based*	Hot face temperature, °C (with ambient still air at 20 °C)								
	75			100			150		
	Thermal conductivity, W/(m K)								
	0.04	0.055	0.07	0.04	0.055	0.07	0.04	0.055	0.07
mm	Thickness of insulation, mm								
17.2	19	25	25	25	32	32	32	32	32
21.3	19	25	25	25	32	32	32	32	32
26.9	25	25	25	25	32	32	32	32	32
33.7	25	32	32	32	32	32	32	32	32
42.4	25	32	32	32	32	32	32	38	44
48.3	32	32	32	32	32	32	32	38	44
60.3	32	32	32	32	32	38	38	44	50
76.1	32	32	32	32	32	38	38	50	63
88.9	32	32	32	32	44	44	44	63	63
114.3	32	32	38	38	44	44	63	63	63
139.7	32	38	44	44	44	63	63	63	75
168.3	32	44	44	44	63	63	63	63	88
219.1	44	44	44	44	63	75	75	88	88
273.0	44	44	63	63	63	75	75	88	88
Above 323.9 and including flat surfaces	44	44	63	63	63	75	75	88	88

NOTE. The same thickness of insulation would be used for copper pipework of approximately similar outside diameters.

*Outside diameters shown are to the requirements of BS 3600 (see also appendix J).