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Introduction

Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international and European standards, comments will be reviewed by the relevant UK national committee before submitting the consensus UK vote and comments. If the draft standard is approved, it is usual for the resulting published standard to be adopted as a British Standard.

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BS 5970:2026

Installation of thermal insulation systems on pipework, ductwork and associated equipment for all applications in the temperature range of $-40\text{ }^{\circ}\text{C}$ to $+700\text{ }^{\circ}\text{C}$ – Code of practice

DRAFT

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on **XX Month 202X**. It was prepared by Technical Committee B/546, *Flexible sheets for waterproofing*. A list of organizations represented on this committee can be obtained on request to the committee manager.

Supersession

This British Standard supersedes BS 5970:2012, which is withdrawn.

Information about this document

This is a full revision of the document, and introduces the following principal changes:

- realigned the Standard with the temperature ranges of BS 5422, including amending the title;
- Clause 8 updated for corrosion under insulation;
- updated competence requirements following the Building Safety Act 2022;
- updated figures for spacing of ducting, fixing distances of insulation to ducts;
- new Clause 34 on insulated pipe supports, with new figures;
- references made to fire protection as a related discipline;
- rationalization of the industrial figures and guidance; and
- further guidance regarding mechanical protection of internally located systems in plant rooms and busy areas.

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Presentational conventions

The provisions of this document are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

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

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. “organization” rather than “organisation”).

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In particular, attention is drawn to the following specific Acts and Regulations:

- Building Regulations 2010 [1], and the equivalent documents for use in Wales [2], Scotland [3] and Northern Ireland [4];
- Control of Substances Hazardous to Health (Amendment) Regulations 2004 [5];
- Chemicals (Hazard Information and Packaging for Supply) Regulations 2009 [6];
- Collection and Disposal of Waste Regulations 1988 [7];
- Petroleum Act 1998 [8];
- Control of Asbestos at Work Regulations 2012 [9];
- Dangerous Substances and Explosive Atmospheres Regulations 2002 [10];
- Building Safety Act 2022 [11];
- Control of Major Accident Hazards Regulations 2015 [12]; and
- Water Supply (Water Fittings) Regulations 1999 [13].

Section 1: General

1 Scope

This British Standard gives recommendations for the installation of thermal insulation systems on pipework, ductwork and associated equipment in the temperature range $-40\text{ }^{\circ}\text{C}$ to $+700\text{ }^{\circ}\text{C}$.

It is intended for use by designers/specifiers, contractors and manufacturers of thermal insulation.

The prime focus of each section within this British Standard is:

- design (Section 2), for manufacturers, contractors, and designers/specifiers;
- site considerations (Section 3), for all users;
- application (Section 4), for all contractors installing or interfacing with thermal insulation systems and including pre-insulated and off-site installations; and
- post-installation inspection (Section 5), for operators.

It does not cover, but might interface with, acoustic insulation, structural insulation of buildings and cold stores, fire protection of structures and services, refractory linings of plant, aircraft and all external buried/underground services.

NOTE Annex A provides further guidance on adhesives. Annex B provides guidance on water vapour pressure and the relation to water vapour barriers. Annex C provides guidance on the water vapour diffusion resistance ratio.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 1710, *Specification for identification of pipelines and services*

BS 3533, *Glossary of thermal insulation terms*

BS 3958-6, *Thermal insulating materials – Part 6: Finishing materials – Hard setting composition, self-setting cement and gypsum plaster*

BS 5241 (all parts), *Rigid polyurethane (PUR) and polyisocyanurate (PIR) foam when dispensed or sprayed on a construction site*

BS 5422¹⁾, *Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range $-40\text{ }^{\circ}\text{C}$ to $+700\text{ }^{\circ}\text{C}$*

BS 5908-1, *Code of practice for fire precautions in the chemical and allied industries*

BS 7021, *Code of practice for thermal insulation of roofs externally by means of sprayed rigid polyurethane (PUR) or polyisocyanurate (PIR) foam*

BS 9999, *Code of practice for fire safety in the design, management and use of buildings*

BS EN 12664, *Thermal performance of building materials and products – Determination of thermal resistance by means of guarded hot plate and heat flow meter methods – Dry and moist products of medium and low thermal resistance*

¹⁾ BS 5422:2009 is referenced informatively.

BS EN 12667, *Thermal performance of building materials and products – Determination of thermal resistance by means of guarded hot plate and heat flow meter methods – Products of high and medium thermal resistance*

BS EN 12939, *Thermal performance of building materials and products – Determination of thermal resistance by means of guarded hot plate and heat flow meter methods – Thick products of high and medium thermal resistance*

BS EN 13480 (all parts), *Metallic industrial piping*

BS EN 13941, *Design and installation of preinsulated bonded pipe systems for district heating*

BS EN 13599, *Copper and copper alloys – Copper plate, sheet and strip for electrical purposes*

BS EN 14015:2004, *Specification for the design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, steel tanks for the storage of liquids at ambient temperature and above*

BS EN 14303, *Thermal insulation products for building equipment and industrial installations – Factory made mineral wool (MW) products – Specification*

BS EN 14304, *Thermal insulation products for building equipment and industrial installations – Factory made flexible elastomeric foam (FEF) products – Specification*

BS EN 14305, *Thermal insulation products for building equipment and industrial installations – Factory made cellular glass (CG) products – Specification*

BS EN 14306, *Thermal insulation products for building equipment and industrial installations – Factory made calcium silicate (CS) products – Specification*

BS EN 14307, *Thermal insulation products for building equipment and industrial installations – Factory made extruded polystyrene foam (XPS) products – Specification*

BS EN 14308, *Thermal insulation products for building equipment and industrial installations – Factory made rigid polyurethane foam (PUR) and polyisocyanurate foam (PIR) products – Specification*

BS EN 14313, *Thermal insulation products for building equipment and industrial installations – Factory made polyethylene foam (PEF) products – Specification*

BS EN 14314, *Thermal insulation products for building equipment and industrial installations – Factory made phenolic foam (PF) products – Specification*

BS EN 62305 (all parts), *Protection against lightning*

BS EN ISO 7345, *Thermal insulation – Physical quantities and definitions*

BS EN ISO 8497, *Thermal insulation – Determination of steady-state thermal transmission properties of thermal insulation for circular pipes*

BS EN ISO 9229, *Thermal insulation – Vocabulary*

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

BS EN ISO 13732-1, *Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 1: Hot surfaces*

BS EN ISO 13732-3, *Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 3: Cold surfaces*

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

PD ISO/TS 13732-2, *Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 2: Human contact with surfaces at moderate temperature*

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS 3533, BS EN ISO 7345 and BS EN ISO 9229 and the following apply.

3.1 ambient temperature

temperature of the air surrounding the product to be insulated

NOTE This product might be a pipe, vessel, duct, etc.

3.2 coating

functional or decorative surface layer, usually applied by painting, brushing, spraying, pouring or trowelling

3.3 contractor

person or organization having responsibility for all or part of the process of installation

[SOURCE: BS 5839-1:2025, **3.33**, modified – term changed from ‘installer’ to ‘contractor’]

3.4 designer

person or organization taking responsibility for design

[SOURCE: BS 5839-1:2025, **3.16**]

3.5 finishing material

material used for covering thermal insulation, whether applied in a factory or on site

3.6 flexible elastomeric foam

pliable thermal insulation product made of natural or synthetic rubber, or a mixture of the two, and containing other polymers and other chemicals that may be modified by organic or inorganic additives

[SOURCE: BS EN ISO 9229:2020, **3.1.2.3**]

3.7 flexible insulation

flexible foamed or expanded plastics materials, many of which differ from true pre-formed materials only by the ease with which they can be bent or compressed to shape

NOTE This type is in addition to such fibrous products as felts, blankets, mats and mattresses.

3.8 foamed in situ insulation

material or mixture of materials sprayed, injected or otherwise applied at the site, which form a foam that subsequently cures to give a rigid insulation product

3.9 insulating brick

brick containing a high ratio by volume of air cells to solid matrix

3.10 insulating concrete

concrete containing a substantial percentage by volume of lightweight aggregate or that is made cellular by aeration or foaming

NOTE It can be cured by autoclaving.

3.11 insulated pipe support insert

load bearing insulation product used in conjunction with pipe bracket or pipe hanger to enable continuity of the vapour barrier and/or reduce thermal bridging

3.12 loosefill insulation

granules, nodules, beads, powder or similar forms of insulation material designed to be installed manually or with pneumatic equipment

3.13 microporous silica insulation

material in the form of compacted powder or fibres with an average interconnecting pore size comparable to or below the mean free path of air molecules at standard atmospheric pressure

NOTE 1 Microporous insulation might contain opacifiers to reduce the amount of radiant heat transmitted.

NOTE 2 This might also be referred to as aerogel.

3.14 paint

suitably filled dispersion of powders in an organic drying oil or similar vehicle that hardens to form a substantially continuous film on drying

3.15 polymeric plastics compound

compound formed by the reaction of simple organic molecules (monomers) having groups that react to form compounds of higher molecular weight

3.16 pre-formed insulation

insulation product fabricated so that at least one surface conforms to the shape of the surface to be insulated

NOTE For specialized types of application it can be advantageous to fabricate the insulation to predetermined shapes for ease of application and removal. Various types of insulating materials and claddings can be used for this purpose, e.g. moulded or prefabricated valve and flange covers, bends, flexible mattresses and dome ends.

3.17 purchaser

person or organization taking responsibility for acceptance of and payment for the installed system

NOTE The purchaser could be the client, the contractor or sub-contractor depending on the stage of the project and specific requirements of the project.

[SOURCE: BS 5839-1:2025, **3.53**, modified – Note added]

3.18 reflective thermal insulation

system with one or more surfaces of low emissivity that reduce thermal radiation transfer

NOTE Metals such as aluminium foil and thin polished stainless steel sheet are common examples, but reflective metal deposited on plastics film is also included. These materials are normally used in association with one or more air spaces, which can be closed or open.

3.19 sprayed insulation

insulation material applied to a surface by spraying that forms a firm surface

NOTE An adhesive can be included in the original mix or it can be applied through a separate nozzle during the application process.

3.20 sub-contractor

person or organization having responsibility for part of the process of installation i.e. thermal insulation contractor appointed by another contractor

3.21 supplier

organization or person that provides a construction product or service

NOTE Examples of a supplier might include producer/manufacturer, importer, distributor, or retailer of a product.

3.22 thermal insulation

material having air – or gas-filled pockets, void spaces, or heat-reflecting surfaces that, when properly applied, retard the transfer of heat

[SOURCE: BS EN 62395-1:2013, **3.39**]

3.23 thermal insulation system

assembly of two or more components at least one of which is an insulation material or product

NOTE The performance of the system is the performance of the total combined assembly

[SOURCE: BS EN ISO 9229:2020, **3.4.2**]

Section 2: Design and materials

4 Design

4.1 Reasons for insulation

The reason for insulating should be established by the purchaser and incorporated by the designer into the operating system.

NOTE Reasons for thermally insulating might include:

a) *energy conservation: thermal insulation is required to satisfy the Building Regulations [1, 2, 3, 4]/technical guidance documents so that reasonable provision is made for conservation of fuel and power in buildings. It is also required in pipework, ductwork and vessels to limit heat gains and losses as per the Approved Document L [14] and the equivalent documents for use in Wales [15], Scotland [16] and Northern Ireland [17]. Satisfactory solutions for heat gains and losses are as follows:*

- 1) determine appropriate thicknesses using the relevant tables and standardized assumptions in BS 5422; or*
- 2) calculate appropriate thicknesses in accordance with BS EN ISO 12241 using specific conditions based on compliance with maximum heat transfer requirements in BS 5422, where applicable.*

Additional requirements may also be specified, for example:

- i) insulate to the necessary thermal energy rating standards as per BS EN 17956; or*
 - ii) in certain situations (for example, heat network projects), CIBSE codes of practice may ask for something more exacting.*
- b) to minimize CO₂ emissions arising from energy consumption in operating systems;*
- c) to minimize capital, operational and whole life costs;*
- d) to maintain temperature or minimize temperature change within specific limits;*
- e) to confirm that a fluid in a pipe has specified physical properties at the point of delivery;*
- f) to avoid danger to personnel, e.g. from items of plant at high or low temperature;*
- g) reduction of moisture formation to avoid mould growth, water damage and slip hazards;*
- h) to delay the onset of freezing (see BS 5422:2023, Clause 11);*
- i) to stabilize items of plant with respect to thermal movement, particularly those exposed to high temperatures, and to prolong the life of equipment by reducing thermal expansion and contraction;*
- j) to limit the temperature of portions of hot plant to avoid damage by excessive temperature;*
- k) to minimize temperature gradients through the walls of pipe and equipment;*
- l) to prevent condensation on the internal/external surfaces of the insulation of cold plant including pipework, ductwork, associated equipment and other industrial installations, and to maintain the internal temperature of a system above a specified minimum to avoid corrosive attack;*
- m) to reduce excessive heat transfer to the surrounding environment to reduce the risk of overheating;*
- n) to minimize heating/cooling capacity for grant incentives and tax relief; and*
- o) to meet other government or global commitments.*

4.2 Design requirements

The specification for thermal insulation of plant and equipment should be given priority at the beginning of the design stage.

NOTE When designing the insulation system, technical suitability is of primary importance; and whilst the ultimate cost of the insulation system is also important, so too are other factors, such as availability and service.

Spatial allowances should be made by the designer for clearance around pipes, ducts, equipment and/or elements of construction and allowance should also be made for the additional weight of the finished insulation system.

Air spaces for thermal insulation purposes should not be provided, but air spaces should be incorporated between insulation and finish for economic or drainage requirements.

4.3 Multi-layered systems and ship-lapped systems

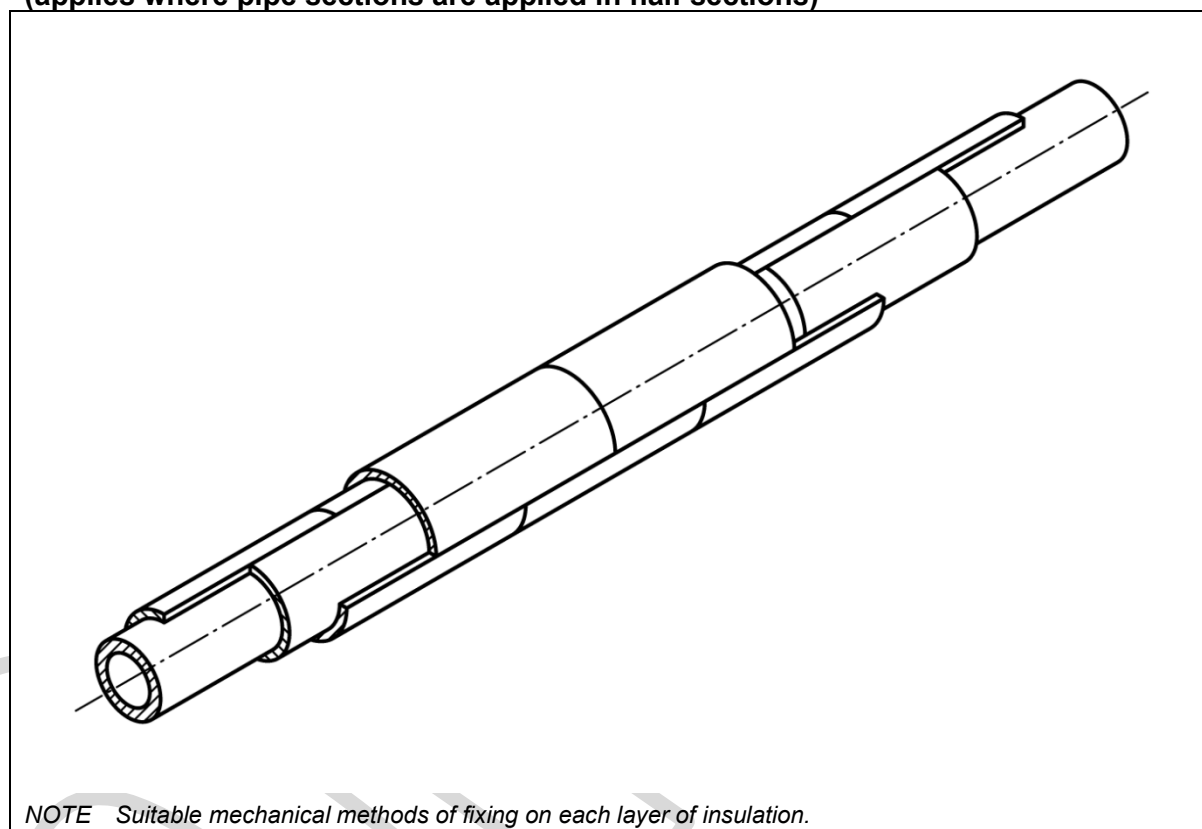
All insulation material used should be designed using mechanical fixings as appropriate for the temperature range e.g. adhesives, tapes banding or lacing wire.

Where multiple layers of insulation are required to achieve the thermal performance or for other reasons (e.g., water proofing or heat resistance), joints should be staggered.

Where the total thickness of insulation to be applied exceeds 50 mm for cold work and 100 mm for hot work, the insulation should normally be applied in multiple layers. Alternatively, where a single layer of material exceeding these thicknesses is proposed, reference should be made to manufacturer's instructions.

As some materials are suitable for applying in greater thicknesses, manufacturer's advice should be sought. All joints between adjacent layers of insulation should be staggered. Standard longitudinal joints in pipe sections should be staggered by at least 45°, preferably 90°. The circumferential joints in pipe sections and all joints in other forms of insulation (e.g. slabs and mattresses) should be staggered by half the associated dimension of the product or by at least 200 mm, whichever is the greater (see Figure 1).

Figure 1 – Typical method of staggering insulation sections on a straight pipe (applies where pipe sections are applied in half sections)

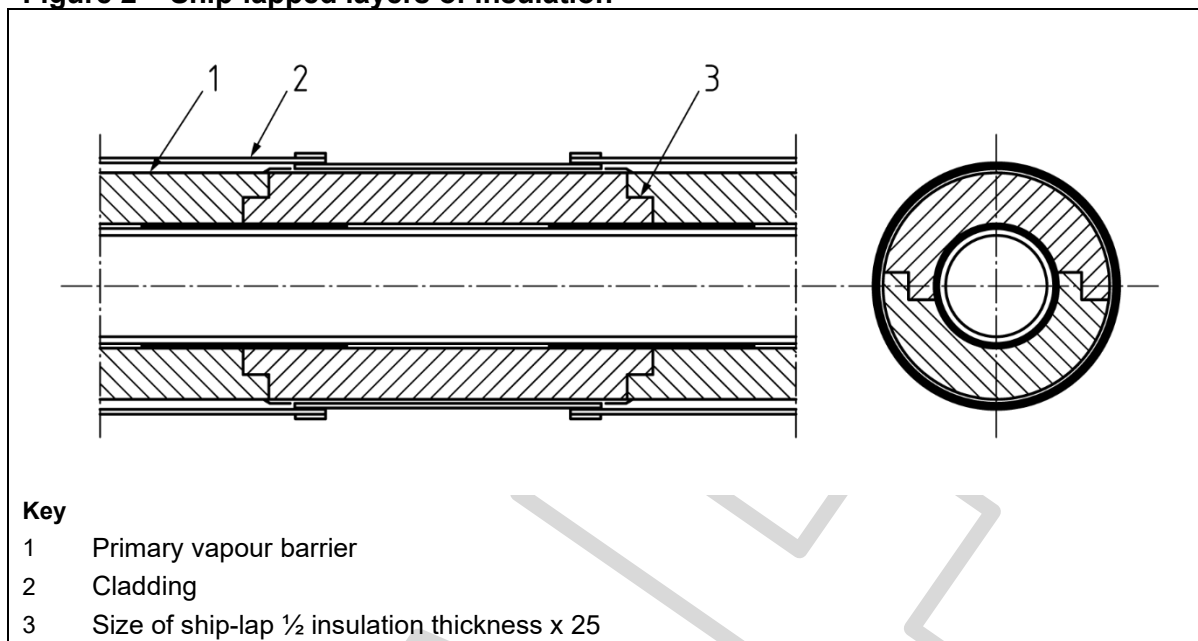


Where multiple insulation layers are required, load bearing insulated pipe support inserts should also be double layered with the inner pipe support layer being a minimum of 25 mm longer than the outer layer (see 34.3).

Where a ship-lapped solution is offered by the manufacturer as an alternative to a multi-layered system, the steps used for circumferential and longitudinal joints should be not less than 25 mm in length. Where a ship-lapped solution is specified, reference should be made to manufacturer's instructions.

NOTE A ship-lap is a pre-formed step joint engineered within the insulation material, by the manufacturer or by the contractor; see Figure 2.

Figure 2 – Ship-lapped layers of insulation



With a straight-through joint at extremes of temperature, multiple layers of insulation should be applied to prevent the increased risk of unacceptable heat loss/gain (see Clause 28 and Clause 29).

Insulation and cladding supports should be specified by the designer of the pipework, ductwork, associated equipment and industrial installations.

Where insulation is ship-lapped, load bearing insulated pipe support inserts should either be ship-lapped or double layered (see 34.3).

4.4 Determining insulation thickness

COMMENTARY ON 4.4

Underlying methodologies for determining insulation thickness, and the consequent CO₂ tonnage saving, are described in detail in BS 5422:2023, Annex A and Annex G, along with the calculation methodology.

Environmental insulation thicknesses are the current preferred methodology. The aim is to balance the cost of interest payments on the capital expenditure required to insulate against the cost of the energy saved as a result of insulating.

Economic insulation thicknesses were traditionally used to balance the actual cost of installing the insulation against the cost of running the system over a given time period. An increase in the amount of insulation applied raises the initial installed cost, but it reduces the rate of heat loss through the insulation, so reducing the total cost during the evaluation period.

The installation costs vary with the nature and type of the insulating material involved as well as with the conditions of application. In practice, certain factors such as the cost of scaffolding and the effect of site location are common to all thicknesses, but a change from single-layer to double-layer application results in an abrupt change in the cost/thickness ratio.

Although the costs for applying reinforcement and a simple finish are usually included in the cost for a specific insulation system, a change to a relatively expensive finish can disturb the balance of the ratio of costs. Also any factors that add to the initial cost, e.g. location remote from centres of population, difficulty of access, or abnormally high working level, can be weighting factors.

Additionally, calculations of economic thickness for general reference tables can be based on costs for insulating uniform types of surface, e.g. straight lengths of pipework, so that they might not take account of the costs for insulating valves, bends, elbows, etc. This is one reason for using calculations of economic thickness that select the greater thickness when the theoretical choice lies between two standard commercial thicknesses.

Determination of insulation thickness should be done in accordance with BS 5422 or BS EN ISO 12241.

4.5 Conditions at the point of delivery

4.5.1 When assessing the thicknesses and quality of insulating materials for conveyance systems that involve guaranteed conditions of a fluid at the point of delivery, there should be close co-operation between the designer of the system and the ultimate operator.

4.5.2 Where it is necessary for a fluid to emerge from a pipeline or duct system within a specific temperature range, the designer should confirm that the thickness of insulation applied is sufficient to achieve this point of delivery temperature.

NOTE The temperature change of moving fluids is heavily influenced by factors other than the performance of the insulation system, e.g. the physical properties of the fluid, flow rate of fluid, length of the pipe.

4.5.3 BS EN ISO 12241 contains equations for calculating the temperature change of fluids moving through insulated pipes and ducts, which should be used by the designer when evaluating whether the intended thickness of insulation achieves the design objectives.

4.5.4 Incidental heat losses not directly related to those through the insulating material should be taken into account.

NOTE Such incidental losses include losses by conduction through the suspension or supporting system and losses from uninsulated areas, e.g. valve or damper control spindles and operating gear. These losses can add approximately 20% to the theoretical heat loss from the insulated system. See BS EN ISO 12241 for more details.

4.5.5 Where the fluid is expected to experience a physical change of state between liquid and vapour during its passage through the pipeline or duct system, the designer should make two separate calculations for the temperature change of fluids. The first calculation should determine the distance before the change of state occurs. The second calculation should determine the temperature change of the fluid from the point at which the change of state occurs and the delivery outlet point.

NOTE Physical changes of state include liquids changing to gaseous or saturated vapour forms. A change of state typically affects the density and heat capacity of a material and the revised values need to be taken into account in the calculation.

4.5.6 To determine the mean temperature on which to base the calculations for heat loss, several calculations should be made in accordance with BS EN ISO 12241, on a trial-and-error basis because the temperature of the fluid, and therefore the temperature of the conveying system, changes appreciably between the inlet and the delivery ends of the system. Where the system comprises pipes or ducts of different sizes, e.g. multiple branches, the heat loss and resultant effect on the conveyed fluid should be calculated for each branch separately.

NOTE 1 Where the ambient temperature is lower than the freezing/solidifying point of the fluid in the system and the fluid is stationary for a period of time, it might be necessary to apply supplementary trace heating.

NOTE 2 For a liquid, or a dispersion that behaves as such, the internal pressure changes due to friction might not be important, so that the conditions at the point of delivery are controlled entirely by the external heat loss in relation to the rate of mass flow of the fluid through the system, together with the specific heat of the fluid itself.

NOTE 3 For further information on determining insulation thickness for the prevention of pipe freezing, see 4.7.

4.5.7 For systems incorporating supplementary heating, 4.5.3 to 4.5.6 should be disregarded and the designer should check and confirm that the heat loss through the insulated pipeline or duct system is less than the rating of the supplementary heating system.

4.5.8 Where the system has condensate from pressure and heat loss during transmission of the fluid through the system, it should be removed where necessary. Where reducing condensation to a minimum is preferable, the thickness of insulation should be increased accordingly and the rate of mass flow maintained as high as practicable.

NOTE Saturated vapour fluids are still saturated at the point of delivery, though under new conditions of temperature and pressure they are governed by internal fluid losses, external heat losses, specific heat, and rate of mass flow of the fluid.

4.5.9 The condition of dry gas or superheated vapour at the point of delivery essentially depends on the temperature and pressure loss during conveyance of the fluid through the system, as well as on the rate of mass flow; calculations should take all these factors into account. If the ambient temperature is below the temperature of liquefaction of the gas under the specific pressure conditions, the calculations for thickness of insulation and pressure drop in the system should take this into account.

NOTE For superheated vapour, excess heat loss with low pressure drop can result in loss of superheat with a reversion to saturated vapour conditions; alternatively, excessive pressure drop in the system can result in increased superheat if the external heat loss is reduced to a low value by the thickness of insulation.

4.6 Protection of personnel

4.6.1 Personnel should be prevented from touching hot or cold surfaces that could be harmful.

4.6.2 Where hot surfaces are not obvious, the following temperatures of bare surface or finished insulation should be regarded as threshold values of temperature above which people should be protected:

- a) non-metallic surfaces, within reach from a permanent working floor level without the use of portable access equipment, 59 °C maximum;
- b) metallic surfaces, within reach from a permanent working floor level without the use of portable access equipment, 55 °C maximum; and
- c) metallic and non-metallic surfaces at higher levels, within reach from ladders or any portable access equipment and where access is possible, 50 °C maximum.

4.6.3 A temperature limit of 43 °C should be used in calculations for short-term contact where services are accessed by high risk groups such as the children or the elderly. Where contact exceeds six hours, a lower temperature is required and should be determined by a risk assessment. Reference should be made to BS EN ISO 13732-1, PD ISO/TS 13732-2 and BS EN ISO 13732-3 for maximum and minimum safe surface temperatures.

4.6.4 Contact with very cold surfaces results in thermal shock or skin damage; protection should be provided for temperatures of approximately –10 °C or below, where necessary.

4.7 Insulation against freezing

COMMENTARY ON 4.7

Insulation retards the onset of freezing and if the intervals during which the liquid is static are short enough, freezing can be avoided. If more heat is supplied from the liquid passing through the system than is lost through the insulation together with the associated losses through supports and hangers, freezing can also be avoided.

There is no known insulation that prevents freezing of liquid in pipes and vessels under all conditions. If the outside temperature remains low enough for long enough and the movement of liquid through the pipe or vessel is slow, then no insulation, however thick, prevents internal freezing.

4.7.1 When fluids are static in pipes or vessels and the ambient temperature is below the freezing point of the contained fluid, heat should be applied to the system to prevent freezing, e.g. by means of tracer pipes or electric heating elements, which should be fitted before the particular item of plant is insulated (see **29.2.8**). The amount of heat supplied per unit period of time should be sufficient to replace that lost from the system during the same period.

NOTE Insulation against frost conditions also depends on climatic conditions and the duty cycle of the plant.

4.7.2 Pipes of small bore should have greater thicknesses of insulation for protection against frost conditions than pipes of large bore.

NOTE 1 The time taken for a liquid to reach freezing point under given conditions of temperature difference depends on the heat capacity of the liquid as well as that of the containing vessel and the insulation, so small pipes or vessels are more vulnerable than larger items of plant.

NOTE 2 The latent heat of the liquid has an influence on the rate of solidification once the freezing point has been reached, but danger normally exists, particularly at valves, as soon as the temperature of the system has fallen to the freezing point of the liquid.

4.7.3 Freezing should be analyzed in two stages:

- a) time required for the temperature of the system to fall from its initial temperature to that of the freezing point of the contained liquid; and
- b) time required for the liquid to freeze completely at this same temperature.

4.8 Protection against surface condensation

NOTE Condensation takes place on surfaces at temperatures below the dew-point of the ambient air.

4.8.1 A vapour barrier should be applied on the warm side of the insulation layer. Insulating material should not be applied to a cold surface in humid conditions without a vapour barrier unless the insulation system has sufficient vapour resistance, because this is a risk to the insulation becoming saturated, its heat-insulating properties impaired and mechanical strength reduced.

NOTE 1 Although the application of the insulation can prevent condensation at the insulation outer surface, it does not necessarily prevent the moisture being drawn through the insulation itself, and frequently the dew-point is reached at some distance inside the layer of insulation.

NOTE 2 If the cold surface is at a temperature lower than freezing point, the moisture freezes and can damage the insulation.

4.8.2 Certain cold-insulation materials have a high resistance to the passage of water vapour; even so, they should have a vapour seal and all joints should be adequately sealed (see also Clause 11).

4.8.3 For plant situated outdoors, water-tight coatings should not necessarily be considered vapour-tight.

NOTE For equations to determine the thickness of insulation, see BS EN ISO 12241.

4.9 Protection of insulation and outer protection from damage during construction and future maintenance operations

Insulation and cladding should be sequenced by the wider team on a project to protect it from damage. Operations such as commissioning and final plant installation should usually be practically complete.

Some insulation is installed to prevent heat transfer to the space, but the final insulation and checks of the vapour seal and cladding should be the last operation.

Areas that are potentially subject to damage from foot traffic (such as walkways or where pipes, ductwork etc are used to access equipment) should be provided with additional protection, such as gantries or high compressive strength insulation and cladding.

5 Exchange of design data

5.1 General

All aspects of **5.2**, **5.3** and **5.4** should be agreed between designer and manufacturer(s) or contractor before a contract is drawn.

5.2 Information to be supplied by the designer

5.2.1 General

The designer should state either:

- a) precise details of the insulation requirements; or
- b) the service conditions for which insulation materials are required, enabling the insulation contractor to make recommendations.

For **5.2.1b)**, where required by the contractor, the designer should submit the information recommended in **5.2.2**, **5.2.3**, **5.2.4**, **5.2.5** and **5.2.6**.

5.2.2 Details of plant to be insulated

In relation to the plant to be insulated, the following details should be supplied:

- a) whether the plant is located indoors, outdoors but protected, outdoors exposed to weather, or enclosed in ducts or trenches below ground level;
- b) any difficult or unusual site conditions that influences the selection and/or application of insulating materials, e.g. transport, scaffolding, weather-protection or excessive humidity;
- c) type of material to be insulated, with details of special or unusual materials;
- d) surface dimensions either adequately detailed on drawings, coloured to indicate areas to be insulated, or otherwise detailed, providing:
 - 1) surface dimensions of flat or large curved areas;
 - 2) external dimensions of pipework, ductwork and associated clearances;
 - 3) associated clearance distances between items to be insulated and any adjacent obstructions;
 - 4) lengths of each size of pipe/duct;
 - 5) type of pipe/duct fittings, e.g. flanged joints, valves, tees, bends with radius and angle; and
 - 6) surface orientation and height;
- e) details of any pipework/ductwork sections that are to be trace-heated, the trace-heating method and the arrangements of insulation required;
- f) details of any sections to be left temporarily or permanently uninsulated to facilitate testing, e.g. welded and flanged joints; and
- g) confirmation, with details, that heat is available in insulated pipework/ductwork where it is required for drying out materials or finishing compositions.

5.2.3 Operating conditions

The following design system operating conditions should be supplied where required:

- a) standard service temperature for each portion of the plant to be insulated;
- b) maximum or minimum temperature for each hot surface, if different from a);
- c) range of expected ambient air temperatures and air movement velocities; and
- d) maximum relative humidities possible at the highest ambient temperature anticipated to prevent surface condensation where insulating pipes or vessels that contain cold media are located.

NOTE As it is difficult to measure with accuracy and systems might not be fully operational at the stage of information provision, it is advisable to interpret site measurements of temperature, humidity, wind speed, etc. with reservation.

5.2.4 Preparation of surfaces

Special requirements should be clearly specified, e.g. for removing works-applied coatings or finishes, application at site of paint or other coatings to the surface to be insulated (see also Clause **26**).

5.2.5 Additional specification details

The following additional details should be specified:

- a) the types of fittings and supports, and which of these are to be provided by the contractor (see **10.4** and Clause **26**);
- b) the type of insulation material(s), including any specific physical properties required (see Clause **7**, Clause **8** and Clause **9**);
- c) the function and physical properties of the surface covering required (see Clause **11** and Clause **12**);
- d) the method and type of taping and/or sealing (see Clause **27**);
- e) the method and type of securement (see Clause **10**);
- f) any special service requirements, e.g. resistance to compression, resistance to fire, resistance to abnormal vibration (see Clause **7** to Clause **12**); and
- g) the proposed material and colour of the surface covering so its emissivity value can be determined.

Any special hazard from contact with chemicals or oils on the plant should be identified and the preferred method of protection provided.

5.2.6 Basis on which the thickness of insulation is to be determined

When insulating for more than one of the purposes listed in **4.1**, the most stringent design parameter(s) should apply.

NOTE Non-thermal requirements such as acoustic reduction and/or fire protection might also be deciding factors for the thickness of insulation. To achieve all purposes, a combination of insulation materials may be used.

5.3 Information to be supplied by the manufacturer or contractor

The following information should be supplied by the manufacturer or contractor:

- a) information on the relevant parts of **5.2**;
- b) manufacturer's declared value of thermal conductivity (λ) for the temperature used (the manufacturer's declared value should include any necessary commercial tolerances; when the thermal conductivity is liable to change on ageing, the aged value should be specified);
- c) manufacturer's declared water vapour properties of the vapour barrier or surface protection;
- d) manufacturer's declared emissivity of the facing of the final installation;
- e) manufacturer's declared reaction to fire as declared in BS EN 13501-1;
- f) any standardized/harmonized products should have a declaration of performance (DOP);
NOTE A means of presenting relevant data attributed to a product can be provided by a DOP and COSHH and MSDS (material safety data sheet).
- g) limitations of use, both physical and chemical;
- h) overall thickness, with details of the thickness and bulk density of the individual layers;
- i) information regarding the surface preparation; and
- j) the appropriate section of this British Standard (to be specified) with which the following are in accordance:
 - 1) insulating material;

- 2) reinforcement (if any); and
- 3) fixing devices and finishes.

5.4 Drawings and documentation

If requested, the insulation contractor should provide drawings and documentation showing the following details:

- a) type of insulation, and insulation supports and their spacing;
- b) type and spacing of cladding supports;
- c) method and type of securement;
- d) particular methods to be adopted when applying material;
- e) any special design; and
- f) shape and size of temporary buildings required by the contractor at site, together with particulars of required water, light and power supplies.

5.5 Competency

5.5.1 Introduction

In all instances, other than in the installation of flexible foams in dwellings (domestic heating and plumbing applications) and commercial refrigeration applications such as direct expansion and variable refrigerant flow applications, a specialist thermal insulation contracting organization should be appointed.

NOTE All other thermal insulation applications are likely to require a level of workmanship that will require evidence of a minimum level of competence.

5.5.2 Where a thermal insulation specialist is required

5.5.2.1 The competence and capability of the thermal insulation contracting organization should be assessed by the purchaser prior to award of contract.

5.5.2.2 Thermal insulation installations should only be carried out by individuals who have evidence of their competency as a skilled worker.

5.5.2.3 Individuals who undertake thermal insulation installations should hold a valid TICA Thermal Insulation CSCS Skilled Worker card or an equivalent qualification.

NOTE 1 BS 8670-1 defines competency as the skill, knowledge, experience and behaviours required at task level to achieve a defined outcome.

NOTE 2 Attention is drawn to the Building Safety Act (2022) [11] for information on industry competence.

6 Factors affecting planning and programming

6.1 General

Because the insulation contractors' operations on site are dependent upon the progress of other contractors, the insulation contractor should be provided with details of expected programmes that are used to control the work on site.

NOTE Examples of factors that can affect the insulation contractor's work are as follows:

- a) programme of commencement and completion dates;
- b) availability of materials and labour;
- c) responsibility for the supply and application of securing attachments;
- d) preparation of surfaces;
- e) areas to be left free from insulation on a temporary basis;
- f) precise information on extent of work covered by contract;

- g) *limitations of access to work;*
- h) *arrangements for dealing with repair and modification work;*
- i) *conditions of employment at site, including the working week, labour and supervision required;*
- j) *transport facilities;*
- k) *suitable storage for materials (dry);*
- l) *availability of water, power, heat and light;*
- m) *accommodation and canteen facilities (including lodgings);*
- n) *provision of access equipment;*
- o) *special safety and security regulations (including advice on health hazards);*
- p) *restriction on mixing compositions;*
- q) *protection of adjacent plant and machinery;*
- r) *clearing waste material from site; and*
- s) *provision of weather-protection during installation.*

6.2 Specialist insulation contractor engagement

A specialist insulation contractor should be engaged at the earliest opportunity in the pre-construction stage to advise on the following:

- a) the procurement of the insulated support inserts to correspond with the project thickness table;
- b) spacing of services to account for insulation thicknesses and associated components;
- c) coordination of all services to provide sufficient space for application of insulation; and
- d) accurate time to be scheduled for insulation works to be completed within the contract programme;

NOTE Benefits of this are a smoother project build and the coordination of all services.

6.3 Insulation quality management

The project quality management system should be in place to affect the planning of a project in the following ways:

- a) installation sign-off of pipework/ductwork (prior to handover to insulation contractor);
- b) leak and pressure testing of pipework/ductwork (prior to handover to insulation contractor);
- c) commissioning of pipework/ductwork (prior to handover to insulation contractor);
- d) the completion of the full thermal insulation system (including valves) prior to quality assurance sign-off, to enable void closures/other subsequent trades from proceeding.

The application of thermal insulation should be completed in one continuous operation and therefore all relevant testing of services should be completed prior to commencement of insulation.

The thermal insulation quality assurance procedure should be agreed to include:

- a) sign off of thermal insulation to pipework, valves and ductwork, including notes regarding the insulation type, cladding type, fixings, identification, vapour barrier;
- b) project overview sheet detailing individual areas, including a traffic light system of progress;
- c) any associated marked up drawings and/or completion photographs;
- d) details of material storage area; and

e) insulation thickness chart and data sheets.

7 Typical characteristics of insulating materials and insulation systems

7.1 Thermal conductivity

Design thickness should be determined in accordance with Clause 4. A material of low thermal conductivity should be selected to achieve a maximum resistance to heat transfer.

NOTE 1 For any given heat loss, a material of low thermal conductivity is thinner than an alternative material of higher conductivity. This is of particular advantage for pipes because thinner layers of insulation reduce the surface area that requires protection.

NOTE 2 The thermal conductivity of most insulating materials varies with temperature and bulk density. Manufacturers usually produce a range of products, each one designed for a different application and/or temperature range. An insulant's effectiveness depends essentially on a mass of material that contains a large number of minute air (or gas) cells. This structure restricts the transfer of heat by convection and radiation. The limitation in area of solid thermal bridges forms a barrier to the passage of conducted heat.

The thermal conductivity of certain inert gas-filled rigid plastics foams increases with age and should be specified in terms of initial value and aged value.

NOTE 3 Reference can be made to relevant British Standards for the determination of initial and aged values, e.g. BS EN 14308 for rigid polyurethane (PUR) and polyisocyanurate (PIR) foams, and BS EN 14314 for phenolic foam.

Where necessary, the manufacturer should be consulted for tables or graphs demonstrating how the thermal conductivity of each product varies with temperature.

NOTE 4 When determining the appropriate thermal conductivity, the mean temperature of the insulation, i.e. the arithmetic average of hot- and cold-face surface temperature, is normally used.

NOTE 5 An air space is much less effective for thermal insulation purposes than a space of similar dimensions filled with one of the conventional insulating materials. This is of particular significance at higher temperatures.

Thermal conductivities should be determined by the relevant thermal insulation manufacturer and verified in accordance with BS EN ISO 13787 and the relevant product standard as detailed in Table 1 and Table 2.

Test conditions should be in accordance with either BS EN 12664, BS EN 12667, BS EN 12939 (for flat products) or BS EN ISO 8497 (for cylindrical products); methods of calculating required thicknesses of insulation are specified in BS EN ISO 12241 and BS 5422.

NOTE 6 Some physical properties of thermal insulating materials, in particular thermal conductivity and strength, are dependent on the direction in which they are measured.

NOTE 7 BS EN 12664 may be used to measure samples whose thermal resistance is not less than 0.1 m² K/W; BS EN 12667 specifies simpler procedures for specimens whose thermal resistance is not less than 0.5 m² K/W.

7.2 Physical forms

Insulation should be supplied in the forms shown in Table 1 and Table 2.

NOTE Each of these forms are made up of granular, fibrous, cellular or reflective material (or a combination of these) depending on the purpose for which it was developed.

7.3 Bulk density

Where necessary for the purpose of design, the applied load due to the insulation should be determined and should be calculated either from the density and dimensions or from the weight of the particular products to be used.

NOTE The bulk density ranges for thermal insulating materials are included in Table 1 and Table 2.

7.4 Suitability for service temperature

Material should only be used within the temperature range for which it provides suitable service under conditions of normal usage (see Table 1 and Table 2 for a guide to approximate service temperatures).

WARNING. THIS IS A DRAFT AND MUST NOT BE REGARDED OR USED AS A BRITISH STANDARD. THIS DRAFT IS NOT CURRENT BEYOND **15 FEBRUARY 2026**.

For materials used at temperatures below ambient, the relevant limiting minimum and maximum temperatures, effects of possible excessive shrinkage, embrittlement and porosity, and resistance under conditions of occasional heating for cleaning and defrosting purposes should be identified and the material either accepted or rejected for use.

For materials used at elevated temperatures, factors that lead to deterioration under conditions of service, e.g. linear shrinkage under heat, loss of compressive strength during heating, effects of vibration and possible self-heating, should be identified and the material either accepted or rejected for use.

When establishing maximum service temperatures for pre-formed high-temperature insulation, particularly for pipe sections, insulation should be selected to withstand moderate loads and vibration whilst in service.

Compressive strength, both before and after heating, should be determined. Additionally, the effect of long-term heating should be identified.

Tests should be carried out by the manufacturer and the results used to compile a report on suitability for particular applications. Material should be selected for the specific conditions of use.

Table 1 – Typical insulating materials for use at temperatures higher than ambient with harmonized product standard, where available

Material	Relevant standards	Physical forms	Type	Approximate maximum service temperature ^{A)} °C	Material kg/m ³
Alumino silicate	No product standard at the time of publication	Loosefill ^{B)}	Fibrous	1 260	80 to 100
		Spray-applied	Fibrous	1 260	150 to 250
		Blanket felt	Fibrous	1 260	50 to 150
		Paper	Fibrous	1 260	200
		Ropes	Fibrous	1 260	100 to 150
Body soluble ceramic fibres	No product standard at the time of publication	Blanket felt and slab	Fibrous	1 300	48 to 384
Calcium silicate	BS EN 14306	Plastic composition	Granular	1 000	160 to 320
		Slabs/lags	Granular	1 010	160 to 320
		Pre-formed pipe sections	Granular	800	190 to 260
Cellular glass	BS EN 14305	Slabs and pipe sections	Cellular	480	120 to 160
Flexible elastomeric foam	BS EN 14304	Flexible			
Pre formed pipe sections, flexible slabs and rolls	Cellular	150	40 to 85		
Insulating compositions	No product standard at the time of publication	Plastic composition	Granular	1 000	250 to 1 100
Magnesia	No product standard at the time of publication	Plastic composition	Granular	310	180 to 220
		Pre-formed slabs	Granular	310	180 to 220
Mineral wool/cement/binder	No product standard at the time of publication	Sprayed	Fibrous	650	100 to 300
Mineral wool (glass)	BS EN 14303	Pre-formed pipe sections	Fibrous	250 to 450	40 to 100
		Flexible rolls	Fibrous	250 to 300	12 to 50
		Lamella mat	Fibrous	250 to 400	20 to 60
		Crimped rolls	Fibrous	250 to 400	20 to 60
		Wired mattresses	Fibrous	250 to 400	30 to 70

Table 1 – Typical insulating materials for use at temperatures higher than ambient with harmonized product standard, where available

Material	Relevant standards	Physical forms	Type	Approximate maximum service temperature ^{A)} °C	Material kg/m ³
Alumino silicate	No product standard at the time of publication	Loosefill ^{B)}	Fibrous	1 260	80 to 100
	No product standard at the time of publication	Slabs	Fibrous	250 to 400	15 to 100
		Pre-formed slabs and sections	Granular	650	190
Mineral wool (stone)	BS EN 14303	Loose wool ^{B)}	Fibrous	850	50 to 150
		Slabs	Fibrous	750	20 to 200
		Inorganically-bonded slabs/lags	Fibrous	1 100	80 to 150
		Pre-formed pipe sections	Fibrous	650	100 to 150
		Flexible rolls	Fibrous	400	30 to 48
		Wired mattresses	Fibrous	850	80 to 150
		Lamella mat	Fibrous	230	40 to 80
		Pipe section mat	Fibrous	650	100 to 150
Mineral wool (high temperature extruded processed mineral wool)	BS EN 14303	Loose wool ^{B)}	Fibrous	–200 to 700	15 to 130
		Slabs	Fibrous	700	80
		Pre-formed pipe sections	Fibrous	660	100
		Flexible rolls	Fibrous	400	36
		Wired mattresses	Fibrous	650	66
		Pipe section mat	Fibrous	400	80
Phenolic rigid foam	BS EN 14314	Pre-formed slabs and pipe sections	Cellular	110	28 to 200
Polyethylene	BS EN 14313	Pre-formed pipe sections	Cellular	100	30 to 40
Polyisocyanurate rigid foam	BS EN 14308	Pre-formed slabs and pipe sections	Cellular	200	30 to 320

Table 1 – Typical insulating materials for use at temperatures higher than ambient with harmonized product standard, where available

Material	Relevant standards	Physical forms	Type	Approximate maximum service temperature ^{A)} °C	Material kg/m ³
Alumino silicate	No product standard at the time of publication	Loosefill ^{B)}	Fibrous	1 260	80 to 100
Polyurethane and polyisocyanurate in situ	BS 5241	Liquid dispensed	Cellular	110	48 to 60
Polyurethane flexible foam	No product standard at the time of publication	Slab and pipe sections	Cellular	70	30 to 65
Polyurethane rigid foam	BS EN 14308	Pre-formed slabs and pipe sections, sprayed	Cellular	110	30 to 160
Silica, microporous	No product standard at the time of publication	Loosefill ^{B)}	Granular	Above ambient to 1 000	360 to 420
		Board	Granular	Above ambient to 1 000	180 to 250
		Block	Granular	Above ambient to 1 000	320 to 400
		Slotted blanket	Granular	Above ambient to 1 000	200 to 400
Silica aerogel	No product standard at the time of publication	Blanket	Fibrous	0 to 650	180
		Blanket	Fibrous	–200 to 90	130
Vermiculite	No product standard at the time of publication	Loosefill ^{B)}	Granular	1 100	50 to 150
		pre-formed slabs and sections			
Vermiculite/cement	No product standard at the time of publication	Sprayed	Granular	1 100	320
Vermiculite/sodium silicate	No product standard at the time of publication	Slabs	Granular	1 000	450

NOTE 1 For specific limiting temperature and minimum density requirements for the particular application, see manufacturer's instructions.

NOTE 2 Materials are without facings. It is possible to have facings on the cold side of the insulation which would have a melting point lower than the maximum surface temperature of the insulation.

^{A)} Temperatures shown are maximum temperatures depending on product type. Reference should always be made to manufacturer's literature before specifying. The limiting temperatures of any facing material should

Table 1 – Typical insulating materials for use at temperatures higher than ambient with harmonized product standard, where available

Material	Relevant standards	Physical forms	Type	Approximate maximum service temperature ^{A)} °C	Material kg/m ³
Alumino silicate	No product standard at the time of publication	Loosefill ^{B)}	Fibrous	1 260	80 to 100

also be checked. Not all materials of a particular product type are necessarily suitable for the full temperature range.

^{B)} Loosefill materials should be packed to densities to suit the application and thermal conductivity required; loose wool is outside CE marking, so not dependant on BS EN 14064 (all parts).

Table 2 – Typical insulating materials for use at temperatures below ambient with harmonized product standard, where available

Material	Relevant standards	Physical forms	Type	Typical service temperature range ^{A)} °C	Normal bulk density kg/m ³
Cellular glass	BS EN 14305	Rigid slabs, rigid pipe sections	Cellular	–268 to 480	120 to 160
Flexible elastomeric foam	BS EN 14304	Flexible slabs, flexible pipe sections	Cellular	–200 to 150	50 to 85
Mineral wool (glass)	BS EN 14303	Loose wool ^{B)} , slabs, pre formed pipe sections, flexible rolls, wired mattresses, lamella mat, pipe section mat, crimped rolls	Fibrous	–200 to 450	12 to 100
Mineral wool (stone)	BS EN 14303	Loose wool ^{B)} , slabs, pre formed pipe sections, flexible rolls, wired mattresses, lamella mat, pipe section mat, crimped rolls	Fibrous	–200 to 750	30 to 200
Mineral wool (high temperature extruded processed mineral wool)	BS EN 14303	Loose wool ^{B)} , slabs, pre formed pipe sections, flexible rolls, wired mattresses, lamella mat, pipe section mat, crimped rolls	Fibrous	–200 to 700	15 to 130
Perlite	No product standard at the time of publication	Loosefill ^{B)}	Granular	–250 to 1 000	40 to 150
Phenolic foam	BS EN 14314	Pre-formed slabs and pipe sections	Cellular	–50 to 120	28 to 200
Polyethylene	BS EN 14313	Pre-formed pipe sections	Cellular	–45 to 100	30 to 40
Polyisocyanurate rigid foam	BS EN 14308	Slabs, pipe sections, sprayed	Cellular	–180 to 200	30 to 60

Table 2 – Typical insulating materials for use at temperatures below ambient with harmonized product standard, where available

Material	Relevant standards	Physical forms	Type	Typical service temperature range ^{A)} °C	Normal bulk density kg/m ³
Cellular glass	BS EN 14305	Rigid slabs, rigid pipe sections	Cellular	–268 to 480	120 to 160
Polystyrene foam extruded	BS EN 14307	Pre-formed slabs, pre formed pipe sections	Cellular	–60 to 75	15 to 35
Polyurethane flexible foam	No product standard at the time of publication	Slabs, pipe sections	Cellular	–20 to 120	30 to 65
Polyurethane rigid foam	BS EN 14308	Slabs, pipe sections, sprayed	Cellular	–180 to 110	30 to 160
Silica aerogel	No product standard at the time of publication	Blanket	Fibrous	–200 to 250	180
Cellular glass	BS EN 14305	Rigid slabs, rigid pipe sections	Cellular	–268 to 480	120 to 160

NOTE 1 Care is necessary in interpreting the minimum continuous service temperatures in Table 2. These are based on manufacturer's claimed values and can require verification in practice.

NOTE 2 Materials are without facings.

NOTE 3 For additional protection using vapour barriers/joint sealing, see Clause 11.

^{A)} The upper/lower limiting temperature of insulating materials is dependent on several factors and the manufacturers should be consulted. Not all materials of a particular product type are necessarily suitable for the full temperature range.

^{B)} Loosefill materials should be packed to densities to suit the application and thermal conductivity required.

7.5 Thermal expansions

The risk of differential thermal movement between the insulated surface, insulation and outer finish should be assessed before selection of materials and metals.

NOTE When insulating plastics pipe, the thermal expansion coefficients of plastics are generally much higher than those of metals.

7.6 Resistance to compaction

Insulation materials should be selected in accordance with their resistance to compaction, particularly those with low compressive strengths such as loosefill materials and un-bonded mattresses under the influence of vibration and thermal cycling unless suitably supported.

7.7 Resistance to water vapour penetration and to water absorption

Where insulants are used outdoors, particular attention should be paid to the installation and maintenance of the weatherproof finish (see Clause 31).

Insulation applied to cold surfaces should be protected from water vapour penetration that gives increased conductivity and in extreme cases leads to freezing, the cells of the insulation rupturing, permanent damage and risk of corrosion accelerated.

The integrity of the vapour barrier should be maintained at all times (see 11.1).

7.8 Mechanical strength, resilience and durability

7.8.1 Mechanical and compressive strength and resilience

NOTE 1 Insulating materials can be mechanically weak and their strength normally decreases after heating. This is in comparison to solid materials. There are significant differences in the mechanical properties of insulation materials of different generic types and densities within a given type.

The finish applied frequently provides some protection against mechanical damage, but the insulation itself should be strong enough to withstand damage that could be caused during installation. Strength and abrasion resistance should be related to the work and material in question, and should be identified at the design stage.

When deciding which type of insulation to use, mechanical and compressive strength and resilience should be compared as well as other material properties, e.g. thermal efficiency. Insulation systems should also be chosen for their durability in withstanding damage.

NOTE 2 There are several significant differences between the mechanical properties of insulating materials of different generic types and diversity within a given type. In particular, some materials have a low compressive strength and might easily be damaged, e.g. by foot traffic.

7.8.2 Durability

Insulation systems should be designed to withstand the detrimental effects of vibration of equipment, service temperature cycling (particularly where above and below ambient), liquid spillage and chemical elements, where these effects have been identified in the process.

The selection of an outdoor insulation system should be made on the basis of its durability in withstanding the effects of ultraviolet (UV), heat, cold, wind, moisture, chemical and other environmental elements (for information on water vapour pressure and the relation to water vapour barriers, refer to Annex B).

7.8.3 Temperature limitations

NOTE 1 All insulation products can undergo physical changes within the operating temperature range, but this would normally have a negligible effect on thermal performance. as per the relevant harmonized standard, see Table 1.

NOTE 2 Equipment operating temperatures, even when within the limitations of an insulant, can still have an effect on the characteristics of the insulation material. This can include embrittlement, outgassing, loss of compressive strength, discolouration, volatilization, friability, shrinkage or expansion.

Relevant manufacturer information should be consulted to clarify any potential additional requirements of the insulation system to prevent any compromise to the thermal performance of the insulation system.

7.9 Fire and explosion hazards

7.9.1 Materials

Thermal insulation systems should be selected, with assessment of process conditions and plant arrangement, to prevent the proposed thermal insulating material contributing to the spread of fire, however initiated. All materials of the thermal insulation system should be selected or rejected accordingly.

The fire performance of the particular thermal insulant should be chosen based on the design requirements of the application for which it is intended. In the absence of special requirements, the characteristics of thermal insulation with respect to fire should be in accordance with BS 5422, BS 9991 for minimum criteria for reaction to fire and BS 9999 for ductwork.

NOTE 1 Attention is drawn to the applicable requirements of the Building Regulations [1], the Building (Scotland) Regulations [2] and the Building Regulations (Northern Ireland) [3].

NOTE 2 Not all thermal insulating materials are non-combustible. Many of them are of organic composition and can constitute a fire hazard, or can emit smoke and toxic fumes.

NOTE 3 The fire hazard associated with the use of a particular thermal insulant, e.g. combustibility, ignition susceptibility, surface spread of flame, emission of smoke, toxic gas or flaming droplets, can be influenced considerably by the presence of adhesives, vapour barriers and sealants, which complete the overall insulation system. Many insulating materials do not constitute a fire hazard, but can absorb quantities of oil or other flammable liquids that can ignite spontaneously (see 12.6).

In certain areas where there is a high risk of fire or explosion and strong oxidizing agents are being handled, the suitability of the insulation should be verified with the manufacturer.

NOTE 4 An anti-static finish may be used to eliminate the risk of sparks.

7.9.2 Finishes

Fire-retarding compounds and/or anti-oxidant materials should be applied to flammable finishes as some commonly used protective finishes are combustible and produce substantial quantities of smoke and flaming droplets on ignition, e.g. bituminous compounds, many plastics polymers, some impregnated cloth and tapes.

NOTE Fire protection afforded by these compounds is usually of short duration and temporary rather than permanent protection in a fire situation.

7.9.3 Aluminium cladding

Conditions where aluminium cladding constitutes a hazard in the event of fire in large process plant or the immediate vicinity should be identified and precautions taken to prevent aluminium melting and igniting adjacent materials.

NOTE In a major fire, molten incandescent aluminium can be scattered over a wide area.

7.9.4 Galvanized accessories

Precautions should be taken to prevent fire in the vicinity of the insulated plant causing molten zinc from galvanized accessories to drop onto and penetrate austenitic steel pipework or plant immediately below (see 8.5).

7.9.5 Electric earth bonding

In flammable atmospheres, particularly with long runs of insulated pipework, external metal cladding should be connected to earth to avoid possible build-up of static electricity (see 30.1).

7.9.6 Self-ignition

The potential for self-ignition in insulating materials that contain bonding agents, used within the service temperature specified for the material, should be identified. Precautions should be taken to prevent the fire risk through internal self-heating.

NOTE Evidence of self-heating can be a transient rise in temperature above the theoretical value for specific locations within the insulation system. This hazard can be accentuated if air can enter into material of low bulk density or by convection currents induced with insulated vertical pipework. Internal self-heating is associated with local concentration of organic bonding material, the thickness of insulation and the temperature of the insulated surface, together with its orientation. If excessive, this internal rise in temperature can constitute a fire hazard, particularly if the surrounding atmosphere is flammable or if there are flammable materials in the immediate vicinity (see BS 2972).

7.9.7 Hazards from contaminants

COMMENTARY ON 7.9.7

Three distinct situations have been observed following the spillage of contaminant or internal leakage from the plant onto heated thermal insulation:

- a) no reaction;
- b) a small rise of temperature within the body of the insulation material, followed by a slow decline of temperature; and
- c) a small rise of temperature, followed by a period of steady-temperature and then a relatively rapid rise to values associated with combustion. At this stage, fire can be initiated if flammable materials are present; in other circumstances, the thermal insulating material can smoulder or even glow with heat

and thereby constitute a source of ignition for other materials in the vicinity. This sequence of temperature rise can be initiated even though the insulated hot-face temperature is well below the flashpoint of the spillage material.

The factors influencing the initiation of a self-heating reaction can include:

- 1) *type and physical state of thermal insulating material and spillage material;*
- 2) *concentration and quantity of spillage material;*
- 3) *shape and dimension of the hot-face and of the thermal insulation;*
- 4) *temperature of the inner surface of the insulation material;*
- 5) *the ease with which the insulation system allows the spillage material to spread and to penetrate; when these factors approach a critical combination, a small change in one of them can initiate a transition from a small rise in temperature to a rapid rise, possibly leading to ignition; and*
- 6) *readily available source of air, i.e. either entrained or external when there is no surface seal.*

7.9.7.1 Precautions should be taken in accordance with **7.9.7.6** as the chemical and physical processes involved are complicated and conditions hazardous.

NOTE A number of dangerous fires have occurred in situations where non-combustible insulating materials have become accidentally contaminated by oil, chemical or other spillage.

7.9.7.2 The choice of an insulation system should be preceded by self-ignition experiments in a laboratory as the consequences of fire in an insulation system are most dangerous in locations where highly flammable and/or low-flashpoint materials are stored or processed, i.e. fire hazard areas.

7.9.7.3 In all circumstances, there should be a high standard of plant maintenance and vigilance to minimize the risk of accidental contamination by spillage or leaks.

7.9.7.4 Where an impervious finish is applied to provide protection against an otherwise dangerous combination of insulating material and spillage material, the potential for accidental and unobserved mechanical damage to the finish should be assessed and documented. The finish should be capable of withstanding mechanical damage to prevent it becoming ineffective.

7.9.7.5 The presence of flame-retardants and anti-oxidants in the body of the insulating material should not be regarded as fully protective because these compounds merely postpone, rather than preclude, the development of self-heating reactions once other critical conditions are established.

7.9.7.6 Precautions should be taken to prevent fire hazards in air-conditioning ductwork in accordance with BS 5422, BS 5908-1 and BS 9999. Thermal insulation applied to ductwork within a building should always be free from substances that, in the event of fire, generate appreciable quantities of smoke and noxious/toxic fumes. In all cases, before finally specifying insulating materials for use in an air-conditioning system, the local building and fire authorities should be consulted.

NOTE Attention is drawn to the Building Regulations [1, 2, 3].

7.9.8 Interface with fire-stopping materials and contractors

When services pass through fire-rated elements, such as walls, floors and ceilings, the penetration should be fire-stopped in accordance with the building and water regulations. Where possible, thermal insulation and vapour sealing on pipework should remain continuous through service penetrations to maintain the required performance of the wall, floor or ceiling, except where this is not permitted by tested fire-stopping systems from the fire protection manufacturer.

With reference to BS EN 1366-3, Table 1, the proprietary detail for thermal insulation on pipework should be continuous and sustained.

NOTE 1 This is achieved by the correct fire wall penetration detail, such as the incorporation of continuous fire resistance through the fire wall or through the use of passive fire protection.

The fire stopping detail should be supported by a suitable fire test and classified to BS EN 13501-2.

NOTE 2 Attention is drawn to the Energy Act [18], HNTAS, the Building Regulations Part L [14] and the equivalents for Wales [15], Scotland [16] and Northern Ireland [17], and the Water Supply (Water Fittings) Regulations 1999, Schedule 2 Section 4 Paragraph 9 [13] which provides explanation as to why insulation is continuous.

7.9.9 Fire resisting ductwork

Fire resisting ductwork should be provided either by specialist companies producing proprietary systems or by insulating satisfactorily constructed and supported steel ductwork. When selecting a fire resisting ductwork system, it should be confirmed that its ductwork fire performance meets with the requirements of the relevant application.

NOTE 1 Fire resisting ductwork is ductwork that has been successfully tested in accordance with BS EN 1366-1, BS EN 1366-8 or BS EN 1366-9 and classified in accordance with BS EN 13501-3 or BS EN 13501-4.

NOTE 2 Further guidance on fire resisting ductwork can be found in the ASFP Blue Book from the Association for Specialist Fire Protection (ASFP).

7.10 Resistance to vermin, fungus and moulds

Insulation, particularly in cold stores or food factories, should be resistant to vermin, insects and fungal growth. Insulation surfaces likely to become wet should not be finished with materials that can be attacked by these agents. Non-absorptive materials should be selected for finishes.

7.11 Health hazards

COMMENTARY ON 7.11

Attention is drawn to the current requirements of health and safety legislation, in particular to the Control of Substances Hazardous to Health (Amendment) Regulations 2004 [5], HSE codes of practice and guidance notes, and manufacturers' instructions.

7.11.1 Gloves should be worn when handling materials as some finishing cements are strongly alkaline when wet and can cause skin irritation.

WARNING. Chemical fumes arising from the in situ foaming or spraying of organic insulating materials, e.g. phenol-formaldehyde resins, isocyanates and polyurethanes, can be toxic or cause bronchial irritation, sometimes with persistent sensitization effects. When materials of these types are sprayed, new hazards can arise because non-volatile components are formed into respirable aerosols.

7.11.2 Respiratory protective equipment should be provided and, particularly in confined spaces, air-fed hoods or respirators should be used for many materials, especially epoxy-resin compounds and those materials containing isocyanates.

WARNING. With certain resinous coatings, adhesives and epoxy-resin components can cause dermatitis and other skin complaints, which can occur after brief contact. Long exposure can lead to allergy.

7.11.3 Goggles and gloves should be used where necessary to prevent associated solvents causing damage to the eyes and skin irritation.

7.11.4 Barrier cream and adequate washing facilities should be provided. Protection should also be provided against respiratory hazards when these materials are sprayed.

7.11.5 Precautions should be taken when using fibrous insulants that cause skin irritation.

NOTE For detailed advice on the subject, refer to the following publications from the Health and Safety Executive (HSE):

- EH44, *Dust in the workplace: General principles of protection* [19]; and
- OC 267/2, *Man-made mineral fibres* [20].

7.11.6 When insulating materials are handled, mixed or removed, precautions should be taken to minimize the risk of respirable dust particles entering the bronchial passages.

NOTE Reference should be made to HSE documents:

- EH40, *Workplace exposure limits* [21]; and
- EH44, *Dust in the workplace: General principles of protection* [19].

7.11.7 Before any stripping work is carried out, the type of insulating material used should be identified and relevant precautions taken to prevent insulants from deteriorating from vibration or heat soaking (see Clause **35**).

7.11.8 Guidance on hazard statements should be sought from manufacturers safety data sheets and a COSHH assessment should be carried out by the thermal insulation contractor prior to commencement of work.

7.12 Removal and replacement

When removal and replacement or abutment to insulation containing asbestos or refractory ceramic fibre is to be undertaken, precautions should be taken to safeguard against any health hazards associated with these activities (see also **34.3**).

NOTE Guidance notes issued by manufacturers together with legislation, codes of practice and guidance notes issued by the HSE provide recommendations for good practice in removal of some types of insulation.

7.13 Heat capacity

Where it is likely to have a significant impact, the heat capacity of the insulation material should be assessed when selecting a material to restrict temperature change of a flowing or stationary medium, or to retard pipe freezing.

NOTE 1 The heat capacity of insulating material is unlikely to have a significant impact unless the insulation thickness is great.

NOTE 2 An insulating material of low thermal capacity absorbs relatively small quantities of heat with an increase of temperature; under fluctuating temperature conditions, it is therefore associated with rapid heating and cooling. A material of high heat capacity tends to impart thermal stability to an insulation system.

As the heat capacity (thermal capacity) of an insulating material varies according to its bulk density, this thermal property should be expressed in terms of heat capacity per unit mass (specific heat capacity).

7.14 Freedom from objectionable odour

Insulating materials for use in food factories, canteens or buildings in which food is processed or served, should be free from objectionable odour (see also **7.10**) and should be resistant to shedding particles or fibres into the air either through their inherent properties or by enclosure within suitable covering.

7.15 Chemical resistance

The thermal insulation system as installed in process plant should not present a hazard if inadvertently contaminated with chemical spillages. The risk of contamination should be minimized by optimum choice and design of finishing insulation system.

7.16 Maintenance requirements

Maintenance costs should be minimized by the correct selection of materials and finishes and by attention to detail in the layout of the insulation system. The design of the insulation system should allow inspection and maintenance access to the insulated surface by removal and reinstatement with effective re-sealing of the insulation and surface finish.

NOTE It is advisable that the designer makes the purchaser aware that regular inspection and repair of damage will help minimize risk of large-scale deterioration of the insulation system and any subsequent corrosion of the plant. See **8.2.1.6**.

8 Corrosion

8.1 General

Insulation should be selected and installed so that the risk of corrosion is minimized. All forms of corrosion are possible and the procedures for protecting against them should be in accordance with this clause.

Subclauses **8.2**, **8.3**, **8.4** and **8.5** provide general guidance; where specific corrosion problems are possible due to the interaction of insulation and metal in a particular environment and for which specialist advice should be sought.

To prevent general corrosion issues, wet insulation should not be allowed to remain in contact with metal surfaces, particularly if acidic or alkaline products or other harmful contaminants are present in the water or if they are extracted from the insulating material itself. To minimize the risk of corrosive attack, metals that come into contact with wet insulating materials (e.g. those used as finishes) should be identified and materials accepted or rejected in accordance with their resistance to corrosion.

All installations should be evaluated both in terms of likelihood of corrosion under insulation, and the potential scale of the impact on the surrounding environment, should corrosion under insulation lead to failure. Where there is any doubt concerning any combination of materials and their suitability to the environment, further manufacturer guidance should be sought.

NOTE In some instances, corrosion under insulation could lead to catastrophic failure.

The designer should assess the compatibility of all components within the entire process and insulation system to minimize the risk of corrosion under insulation. The choice of insulation system should not be considered as the only means of preventing corrosion.

8.2 Corrosion under insulation

COMMENTARY ON 8.2

All forms of corrosion can occur on the surface of pipework under insulation. The application of insulation can also act to increase the concentration of moisture and chemicals present on the pipe surface, increasing the risk of all forms of corrosion. As insulation prevents a view of the pipework, a great deal of corrosion can occur before it is detected, increasing the scale of impact. Since all forms of corrosion occur more quickly in the presence of moisture and are accelerated by cyclic temperature, the general methods for preventing corrosion under insulation given in this sub-clause focus primarily on preventing the build-up of moisture on the pipe surface.

8.2.1 General

8.2.1.1 Before applying insulation, the surface to be insulated should be dry and free from scale and contamination.

8.2.1.2 Systems that normally operate at below ambient temperature should not be insulated whilst there is a risk of condensation forming on the surfaces to be insulated.

8.2.1.3 Only dry, undamaged insulation should be used.

NOTE This might require weatherproof storage.

8.2.1.4 Insulation should be as close fitting as possible to the equipment/pipe surface.

NOTE Drainage may be provided for voids on hot work.

8.2.1.5 Water ingress into the insulation system should be prevented. Where practicable, precautions should include:

- a) using an effective vapour barrier to minimize water vapour diffusivity through insulation on below ambient services;
- b) using an effective weather barrier on external services to minimize water ingress, so that cladding overlaps on all circumferential and longitudinal seams are sufficient;

- c) positioning longitudinal cladding seams away from the prevailing weather and more than 90° from the vertical position;
- d) installing valves with the spindles placed horizontal or below;
- e) using a sealing compound to seal all protrusions through insulation and cladding;
- f) installing horizontal flat cladding with a fall or slope to shed water and avoid pooling;
- g) providing temporary weather protection of incomplete insulation systems;
- h) installing drain holes into pipe cladding at all low points to allow for drainage (drain holes should always be drilled from the inside of the cladding to the outside);
- i) installing cladding so that the joints are weatherproofed/overlapped to shed water;
- j) protecting austenitic surfaces, especially if the plant is likely to be heated to a temperature above 50 °C at any time, e.g. for sterilizing or cleaning, see **8.4**;
- k) assessing thermal movement when selecting the appropriate materials, see **28.2**; and
- l) installing a load-bearing insulated pipe support insert, pre-clad with a material to match the cladding specification.

8.2.1.6 The line of insulation, vapour barrier and cladding should be continuous through all pipe supports.

8.2.1.7 Where removable inspection points are incorporated into the insulation system, they should be designed to minimize the risk of water ingress, see Clause **33**.

NOTE Leak detection systems may be incorporated into the insulation system.

8.2.1.8 The mechanical system should be designed so as to allow the full insulation thickness to be applied on all man ways, pipe stubs, walkway supports, thermocouples, name plates, ladder supports and all other protrusions. All protrusions and terminations should be fitted to shed water. For man ways and pipe stubs, extra distance should be allowed for bolt clearance.

8.2.1.9 The top plates of vertical manholes should always slope.

8.2.1.10 When insulating vessels, thicker insulation on the vessel top should be applied so that the lifting lugs are enclosed by the insulation so as to shed liquid.

8.2.2 Anti-corrosion barrier methods

Where appropriate, anti-corrosion barrier methods should be applied to all surfaces at risk from corrosion.

Where selecting anti-corrosion barrier methods, the following criteria should be assessed:

- a) the metal surface to which the anti-corrosion barrier method is to be applied;
- b) compatibility between barrier methods, adhesives and insulation materials; and
- c) operating temperature.

For piping, equipment and tanks that are cleaned by steam, “traced” or operated at various temperatures, the barrier method selected should be appropriate for the highest operating temperature possible.

All anti-corrosion barrier methods should be thoroughly dry before insulation is applied.

NOTE 1 Anti-corrosion barrier methods that might work well in the open air can fail when covered by insulation.

NOTE 2 Treatments can consist of coating with paints, bitumen or weatherproofing polymer solution, wrapping with self-adhesive PVC (polyvinyl chloride) pipe wrap tape, wax impregnated tape or factory applied plastic coating, VPCI's (Vapour Phase Corrosion Inhibitors) designed for use on the external facing of the metal substrate.

Treatments should be compatible with associated items to which they come into contact, e.g. gaskets and seals of pipework joints.

NOTE 3 Some treatments, e.g. plastic-coated pipework and tape wrapping of pipework components might increase the external dimensions of these items.

8.3 Oxidation, acidic, alkaline and galvanic corrosion

8.3.1 Oxidation

Where iron and carbon steel are exposed to air in the presence of moisture, only dry insulating material should be used to avoid corrosion. It should be kept dry until an effective vapour barrier, or weatherproof finish if above the dew-point, has been applied (see Clause 26, Clause 27 and 28.1).

NOTE 1 Oxidation can be particularly dangerous with insulated plant required to operate at temperatures below the dew-point of the surrounding air, or on insulating material that is allowed to remain wet over long periods.

Galvanized steel securement should not be used at temperatures above 350 °C (see 27.5.2).

NOTE 2 Attention is drawn to the possible effect of change of conditions in service as, e.g. at temperatures over about 60 °C, under conditions of high humidity, the zinc and iron of galvanized steel can undergo reversal of polarity so that the iron becomes sacrificial rather than the zinc surface film.

NOTE 3 Various methods are available for depositing protective films on the surface of iron and steel, e.g. galvanizing, aluminizing, and these can improve resistance to oxidation.

NOTE 4 Oxidation, with severe scaling and possible loss of mechanical strength, can occur when a metal is heated to relatively high temperatures in air, e.g. 460 °C and above for carbon steel, a condition that can occur due to the incorrect use of thermal insulating material on the external surface of refractory-lined equipment. This can raise the metal temperature to a dangerous level. If it is essential to have both internal and external insulation, high temperatures might reduce the strength of the metal.

NOTE 5 The formation of white deposits of oxide on the surface of zinc and certain types of aluminium sheet, particularly under moist conditions, can be unsightly rather than detrimental to the metal. These can be eliminated by cleaning, followed by painting where necessary. For aluminium, the formation of oxide deposits can be obviated by the use of an electrolytic oxidation pretreatment (see also 30.1 and 31.1).

8.3.2 Acidic corrosion

NOTE 1 Acidic corrosion is most prevalent with carbon steels, although many of the non-ferrous metals are also vulnerable. For example, the condensation of the acidic gases inside a metal flue when the temperature is allowed to fall below the dew-point of the contained gas, firing with heavy fuel oils or sulfite residues, can be particularly troublesome.

Vulnerable areas of thin metal, e.g. metal expansion bellows, should be identified. An adequate thickness of insulating material to prevent internal condensation should be used as an effective safety measure.

NOTE 2 As most insulating materials absorb water in the event of unsatisfactory or damaged weatherproofing, there is a serious risk of corrosion from wet insulation. The risk is increased in the presence of chlorides, nitrates, sulfates and other airborne contaminants that can be introduced with rain water or deluge water.

The risk of acidic corrosion attack, created when the products are heated in the presence of moisture, should be minimized by painting the base metal before the application of insulating material.

NOTE 3 Refrigeration plant might be heated on occasions, e.g. for defrosting, and consequent decomposition of halogenated compounds can occur.

NOTE 4 Acidic corrosion on the surface of carbon steel can result from the decomposition of halogenated compounds in certain types of organic plastics insulating materials.

NOTE 5 Acidic corrosion can also take place on copper pipes.

Underground pipework should be protected to prevent corrosion because failure is not easy to observe immediately.

NOTE 6 The leakage of acidic gases through areas of faulty welding or faulty joints can result in corrosive attack on insulated metal surfaces, and this is the more dangerous because it is hidden from view.

8.3.3 Alkaline corrosive attack

NOTE 1 Some non-ferrous metals, such as copper, brass, etc., can be attacked by alkalis extracted from certain types of insulating material under moist conditions, e.g. those that contain appreciable amounts of sodium silicate. Similar effects can occur with zinc coating on galvanized surfaces. Aluminium sheet used to protect calcium silicate is also vulnerable.

Designers should assess the need for protective measures such as preventing water egress from the insulation system, painting the metal surface or using a factory-applied or manually applied barrier.

NOTE 2 It is good practice to wrap brass fittings used in copper pipework with butyl self-amalgamated tape.

8.3.4 Electrolytic corrosion

COMMENTARY ON 8.3.4

The occurrence and extent of corrosion between metals mainly depends on three factors:

- a) the difference in electrode potential of the two metals;*
- b) the ratio of the anode to cathode surface areas; and*
- c) the presence of moisture.*

The degree of corrosion can be modified if either of the metals can form a protective film. Aluminium and stainless steel are both metals capable of forming protective oxide films that modify their electrode potentials. Under mildly corrosive conditions it is therefore possible to have electrolytic contact between the two metals without corrosion. If, however, the same two metals are exposed to severely corrosive environments such as a very badly polluted industrial atmosphere or continual immersion in sea water, the aluminium corrodes anodically. Corrosion of aluminium also occurs if the aluminium is coupled to a 13% chromium steel that does not form a passive film as easily as 18/8 chromium-nickel stainless steel does. Direct coupling of copper to aluminium or galvanized steel should be avoided; otherwise galvanic corrosion from the electrochemical potential difference is likely to cause pitting of the aluminium or zinc coating of the galvanized pipe.

Direct contact between many dissimilar metals in the presence of moisture, particularly in a marine environment or near the sea, can result in rapid corrosion of one of the metals, see PD 6484:1979, 2.1.

The compatibility of dissimilar metals for screws, rivets, welded attachments, and even bands, should be identified and selected or rejected for use.

Where potential for electrolytic corrosion is unavoidable, the metals should be isolated from each other, e.g. by plastics washers, insulation tape, bitumen mastic, or a paint of adequate film thickness.

NOTE Electrolytic corrosion is also known as bimetallic corrosion.

8.4 Stress-corrosion cracking

COMMENTARY ON 8.4

Most thermal insulating materials contain traces of water-soluble chlorides. Additionally, insulating materials might contain chlorinated organic compounds that can form soluble chlorides when heated in the presence of water. Both can give rise to stress-corrosion cracking in susceptible alloys, even if only trace quantities are present. It is not practicable to indicate a safe upper limit for chloride content as water can leach out soluble chlorides from substantial volumes of wet insulating material and cause them to be concentrated at the junction layer with the metal surface. Additionally, ingress of water from external sources, e.g. rain water, plant spillages and water used for hosing-down equipment, can contain sufficient chloride to be potentially dangerous.

Stress corrosion cracking (SCC) is the cracking induced from the combined influence of the following factors:

- a) tensile stress;*
- b) moisture;*
- c) agent (ammonia, chlorides, nitrates etc); or*
- d) alkaline (corrosive) environment.*

For SCC to occur, the alloy must be susceptible, and all above factors must be present.

Tensile stress may be in the form of directly applied stresses or in the form of residual stresses.

Forming, welding, heat treatment, physical damage, machining, operating pressures, and grinding can introduce residual stresses.

SCC is a particular problem in cold water systems where corrosive substances can be leached from certain types of insulation materials and where they interact with condensate which has formed on the outer surface of the pipework or fittings.

SCC is complex and classified as a catastrophic form of corrosion, as the detection of such fine cracks can be very difficult, and the damage not easily predicted.

8.4.1 Action of water-soluble chlorides and other halides on austenitic alloy-steels

COMMENTARY ON 8.4.1

Austenitic steels can be sensitive to corrosive attack by soluble inorganic halides in the presence of oxygen and moisture, especially when at the same time the alloy is stressed. This type of cracking has been defined as "degradation at a rate greater than that which would occur if either the stress or the corrosion were acting independently or successively" (see 8.1 concerning the possible liberation of water-soluble halides from certain organic foams).

The action is not likely to be significant at temperatures below 50 °C and is most severe in the temperature range from 50 °C to about 160 °C.

Stress-corrosion cracking requires the presence of moisture so precautions should include the provision and maintenance of an effective waterproof finish to the insulation system. Additionally, as far as is practicable, personnel should not touch austenitic steel surfaces with bare hands and the surfaces should not be scratched or indented, as local damaged areas form the starting point for the development of cracks in the metal (for further guidance on surface preparation, see Clause 26).

To provide protection, pure aluminium foil of grade EN-AW-1050A to BS EN 573-3 with a minimum aluminium content of 99.5% and thickness not less than 0.06 mm (60 micron) should be applied to the austenitic steel surface so that the insulation and support bracket and insulated support insert is applied over the foil. Aluminium foil should be applied directly to a pipework and fittings surface prior to installation of trace heating cables or any other pipework system components. Aluminium foil should be arranged to shed water wherever possible, and with an overlap of not less than 50 mm at the joints. Reinforced aluminium foil facing, including self-adhesive tapes, should not be used in direct contact with the austenitic steel surface.

NOTE 1 Reinforced aluminium foil facing may be used to secure the aluminium foil in place.

NOTE 2 For application of foil under load bearing pipe support inserts, refer to Figure 32.

The integrity of the 0.6 mm foil wrap when installing the trace heating should be maintained and if compromised or damaged, should be replaced.

NOTE 3 The aluminium foil acts in two ways, firstly as a physical barrier to moisture and secondly and, more importantly, in an electrochemical manner, such that the relatively anodic aluminium preferentially corrodes with respect to the more noble stainless steel, thereby providing protection (i.e. anodic protection). In order for the aluminium to work in this way it needs to be in direct electrical contact with the metal/alloy it needs to protect.

The melting point of aluminium is 660 °C, therefore, foil should not be used if the temperature of the alloy approaches this value under service conditions; a limit of 500 °C is recommended (see 34.2.3).

NOTE 4 At temperatures over 300 °C the risk of the ingress of water to the metal surfaces is not likely to be serious, except during plant shut-down and at start-up periods.

NOTE 5 As an alternative protective system, where the use of aluminium foil is impracticable, specially compounded paints for this type of resistance application may be used. Unlike aluminium foil these paints do not provide galvanic protection, but act solely as a physical barrier.

The manufacturer's instructions should be followed and the temperature limitation of the paint should not be exceeded. Paints containing metallic zinc should not be used (see **8.5** for the importance of keeping metallic zinc away from austenitic steel).

*NOTE 6 Factory applied VPCI's in the form of bore coatings, injectable gels or retro fit formulations are an alternative to traditional methods recommended within **8.4.1**.*

8.4.2 Stress-corrosion attack on other metals

NOTE 1 Many alloys, when subjected to the combined effects of stress and corrosion under conditions specific to the individual alloy, can develop cracking, although this is unlikely under normal operating conditions.

Where carbon steel (mild steel) is used, water should not be allowed to penetrate, and especially saturate, insulation systems as contaminants concentrate at the metal surface. The surface of the insulation system should be painted to mitigate against the risk of cracking caused by stress-corrosion, as the consequences of fracture of the metal are serious.

NOTE 2 Carbon steel (mild steel) can be attacked by soluble nitrates present as contamination in water from external sources under conditions of mild acidity and temperatures above about 80 °C. Commercial thermal insulating materials do not generally contain nitrates, but these can be present in the environment.

For copper tube, the surface should receive a compatible protective coating when installed in hostile environments (e.g. alkaline).

NOTE 3 In copper pipework systems, stress corrosion cracking (SCC) might affect brass fittings such unions, valves, and tees especially screwed type, due to over-tightening. Commercially pure copper and brass fittings are susceptible to SCC in the presence of ammonia.

NOTE 4 SCC does not usually affect the copper tube itself unless tube is installed in alkaline environment.

NOTE 5 Such protective coatings are effective only when the part is 100% covered.

To prevent moisture getting into threads/crimped junctions, brass or copper crimped fittings should be wrapped with butyl self-amalgamating or silicone tape if the system is exposed to wet environments or installed underground. Advice from the fittings manufacturers should be sought.

NOTE 6 Factory applied VPCI's in the form of bore coatings, injectable gels or retro fit formulations are an alternative to traditional methods of painting.

8.5 Attack by liquid metals

COMMENTARY ON 8.5

Although thermal insulating materials themselves do not contain zinc, this metal is associated with securing and reinforcing materials, usually as a protective coating, e.g. galvanized carbon steel.

The melting point of zinc is 419 °C and at temperatures above 450 °C molten zinc diffuses and penetrates stainless steel, although embrittlement is unlikely to occur until a temperature of about 750 °C is reached. The depth of penetration depends on the time and temperature of the exposure, and the structure and composition of the steel. It also depends on the degree of applied stress. In the absence of stress, very rapid embrittlement is unlikely.

Below 750 °C, the influence of stress upon the rate of diffusion and penetration is relatively small. However, at temperatures above 750 °C the tensile stress in the steel brings about rapid penetration, and cracking can occur in a matter of minutes or even seconds in the area of contamination. Zinc is volatile at such high temperatures and, whilst the major hazard arises from molten zinc, there is evidence that embrittlement can be caused from the gaseous phase.

It is thought that embrittlement arises from interaction between zinc and nickel in the steel, so it can be expected that the austenitic chromium-nickel family of stainless steels is particularly susceptible to zinc embrittlement.

Intergranular penetration can also result from contact with copper, lead and aluminium under certain conditions of temperature and stress.

Galvanized steel should not be welded. Contact between galvanized accessories, e.g. galvanized wire netting, and steels that are intended for use at service temperatures above 350 °C, should be rigorously avoided.

Paints containing metallic zinc should not be used as surface protection for insulated austenitic steel surfaces.

NOTE Embrittlement can also occur if molten zinc is allowed to drop on to heated alloy-steel surfaces, e.g. under conditions of external fire. This is of particular significance when the plant is under stressed conditions, particularly if the contents are flammable.

8.6 Attack on plastics pipes and equipment

The plastics manufacturer should be consulted as certain types of plastics pipework and equipment are susceptible to solvent stress cracking.

NOTE These solvents can be present in certain adhesives, welding agents, paints, sealants and coatings.

9 Selection of thermal insulating materials

9.1 General

Insulating material for a specific application should be selected dependent on the following factors.

a) For hot surfaces:

- 1) cold-face temperature (min. and max.);
- 2) hot-face temperature (max. and min.);
- 3) ambient temperature;
- 4) limiting heat loss;
- 5) thermal conductivity (aged);
- 6) differential thermal movement;
- 7) thickness of insulation required;
- 8) mechanical strength;
- 9) shape or configuration of insulated surface;
- 10) location of insulated surface;
- 11) health hazard (see **7.11**);
- 12) fire hazard;
- 13) environmental impact;
- 14) protection from water ingress;
- 15) protective covering and finish;
- 16) compatibility with atmosphere and possible spillages; and
- 17) design plant life.

b) For cold surfaces:

- 1) cold-face temperature (min. and max.);
- 2) warm-face temperature (max. and min.);
- 3) ambient temperature and humidity;
- 4) limiting heat gain;
- 5) thermal conductivity (aged);
- 6) differential thermal movement;
- 7) thickness of insulation required;

- 8) mechanical strength;
- 9) shape or configuration of insulated surface;
- 10) location of insulated surface;
- 11) health hazard (see **7.11**);
- 12) fire hazard;
- 13) environmental impact;
- 14) preventing condensation;
- 15) vapour sealing;
- 16) protective covering and finish;
- 17) compatibility with atmosphere and possible spillages; and
- 18) design plant life.

9.2 Applicability of thermal insulating materials

9.2.1 General

The suitability of any particular type of material and the expected performance data for the specified conditions should be obtained from the manufacturer.

The designer should distinguish between an insulation system that is applicable mainly for elevated temperatures (see Table 1) and one that is particularly for use at temperatures below ambient (see Table 2).

Water vapour should not be allowed to condense, or possibly freeze, inside internal or external insulation under cold conditions.

NOTE 1 The need to exclude water vapour from the insulation can be the dominant factor for applications at temperatures below the dew-point of the ambient air.

NOTE 2 Materials used above their recommended maximum service temperatures can degrade with possible detrimental effects.

Where insulation is located in areas liable to flooding, an insulation system capable of drying out should be applied in accordance with BS EN 13941. Buried pipes should also be insulated in accordance with BS EN 13941.

The manufacturer should be consulted about the specific properties of any material considered for use.

9.2.2 Refrigeration and general cold work between -40 °C and 0 °C

9.2.2.1 The thermal resistance of the insulating material should be compatible with design or process control and economic considerations. It should also be capable of remaining resistant under the expected conditions of service and plant life. For ease of application, either pre-formed material or foamed in situ products should be selected.

NOTE 1 An alternative is a sealed double-skin construction in which the annular space is filled with a loosefill material.

NOTE 2 If the double-skin enclosure can be evacuated so that the insulating material is maintained under relatively low pressure, the overall rate of heat transfer can be reduced appreciably, increasing the effectiveness of the insulation system. Microporous insulating materials are of value for small installations of this type.

9.2.2.2 Where the plant is to operate at temperatures below that of the ambient air, the insulating material should be protected by a vapour-sealing barrier. For full advantage, the insulating material should be resistant to the passage of water vapour to supplement the protective effect of the external vapour barrier.