BS 5970:2012

BSI Standards Publication

Thermal insulation of pipework, ductwork, associated equipment and other industrial installations in the temperature range of –100 °C to +870 °C – Code of practice

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This document comprises a front cover, an inside front cover, pages i to vi, pages 1 to 150, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 September 2012. It was prepared by Subcommittee B/540/7, *Thermal insulation for equipment and industrial applications*, under the authority of Technical Committee B/540, *Energy performance of materials, components and buildings*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 5970:2001, which is withdrawn.

Information about this document

Combustion of fossil fuel is a major cause of the "greenhouse effect", the term given to global warming caused by the build-up of greenhouse gases in the atmosphere, principally carbon dioxide, which inhibits the re-radiation of heat from the Earth. This British Standard acknowledges that the application of thermal insulation leads to a reduction in these greenhouse gases.

This British Standard explains the basic principles for selecting insulation systems for specific requirements. It is not practical to deal with every possible combination of insulating material and finish, so only general principles are indicated.

Hazard warnings

WARNING. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relation to health and safety at any stage.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that compliance with its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

This British Standard contains many references to the literature and advice provided by the source of the materials to be used. Traditionally, this was the manufacturer and ultimately still is. However, there has been a rise in the use of suppliers or distributors offering a whole range of insulation and ancillary products, made by others, who are "middlemen" between the manufacturer and the user. In this instance, the contractor has the commercial/contractual relationship with the supplier who obtains the material literature or advice from the manufacturer.

Presentational conventions

The provisions in this standard 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.

The word "should" is used to express recommendations of this standard. The word "may" is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the Clause. The word "can" is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Contractual and legal considerations

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

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

Particular attention is drawn to the following specific regulations:

- The Building Regulations 2010 [1, 2, 3];
- The Control of Substances Hazardous to Health (Amendment) Regulations 2004 [4];
- The Chemicals (Hazard Information and Packaging for Supply) Regulations 2009 [5];
- The Collection and Disposal of Waste Regulations 1988 [6];
- The Petroleum Act 1998 [7]; and
- The Control of Asbestos at Work Regulations 2006 [8].

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Section 1: General

1 Scope

This British Standard gives recommendations for thermal insulation of pipework, ductwork, associated equipment and other industrial installations in the temperature range −100 °C to +870 °C.

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

- design (Section 2), for design consultants and specifiers;
- site considerations (Section 3), for all users;
- application (Section 4), for mechanical contractors and thermal insulation contractors;
- post-installation inspection (Section 5), for operators.

It does not cover structural insulation of buildings and cold stores, fire protection of structures, refractory linings of plant, aircraft and all external underground mains.

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. Annex D gives illustrative examples of termination methods for hot and cold pipework.

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 3958-3, *Thermal insulating materials – Part 3: Metal mesh faced man-made mineral fibre mattresses*

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 5422 [1)], *Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range −40 °C to +700 °C*

BS 5908, *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*

1) BS 5422:2009 is referenced informatively.

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*

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 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 rule*s

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*

ISO 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 cellular concrete
concrete containing a substantial number of small air cells

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

3.5 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.

3.6 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

3.7 foamed slag concrete
insulating concrete with foamed slag as aggregate

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

3.9 insulating castable refractory
insulating concrete containing a suitably graded, insulating refractory aggregate

3.10 insulating concrete lightweight 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 insulating (plastic) composition
mixture of dry-fibrous and/or powdery materials that, when mixed with water, develop a plastic consistency and dry in place

NOTE Normally the wet materials require the use of heat for drying out after application, but some products harden by hydraulic setting. Plastic compositions and organic plastics materials are distinguishable by the latter being spelt with a letter "s" at the end of the word plastics.

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 insulation silica aerogel

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

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 reflective 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.

3.18 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.

Section 2: Design and materials

4 Design considerations

4.1 Reasons for insulation

The specification for thermal insulation of plant and equipment should be prepared at the beginning of the design stage. The reason for insulating should be identified to enable the insulation contractor to submit a system which can be incorporated by the plant designer.

At the design stage, allowance should be made for sufficient clearance around pipes, 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 can be incorporated between insulation and finish for economic or drainage requirements.

When designing the insulation system, technical suitability is of primary importance; and whilst the ultimate cost of the insulation system is also important, other factors, such as availability and service, should be taken into account.

NOTE Reasons for thermally insulating might include:

a) *energy conservation: thermal insulation is required to satisfy the Building Regulations [1, 2, 3]/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 RIBA "Non-Domestic Building Services Compliance Guide" [9]. Satisfactory solutions for heat gains and losses are as follows:*

   1) *calculate appropriate thicknesses using the relevant tables in BS 5422 and the "TIMSA – HVAC Compliance Guide" [10] using standardized assumptions detailed within the tables in accordance with BS EN ISO 12241;*

   2) *calculate appropriate thicknesses in accordance with BS EN ISO 12241 using specific conditions where applicable;*

b) *enhanced CO_2 emission reductions;*

c) *to minimize capital, operational and whole life costs;*

d) *to maintain temperature or temperature change within specific limits;*

e) *to ensure 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) *prevention of slip hazards from moisture formation;*

h) *to delay the onset of freezing (see BS 5422:2009, 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 improve ambient conditions;

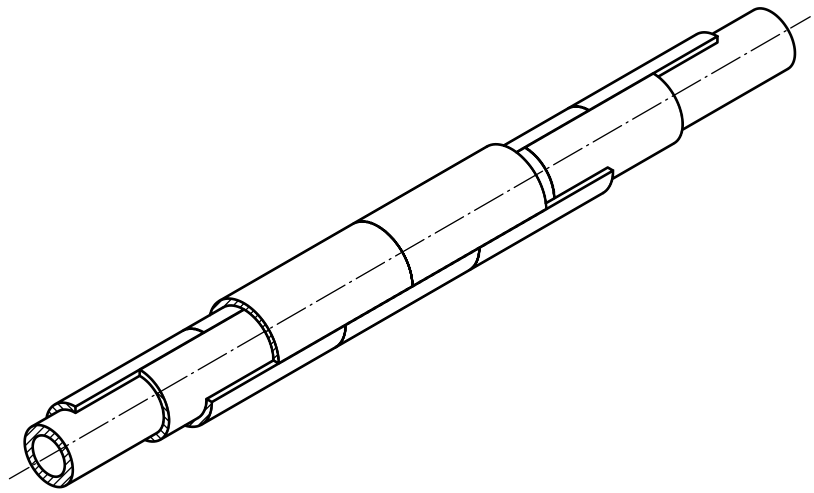
n) to minimize heating/cooling capacity for grant incentives and tax relief;

o) other government or global commitments.

4.2 Application

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; reference should be made to manufacturer's/applicator'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, by at least 200 mm (see Figure 1).

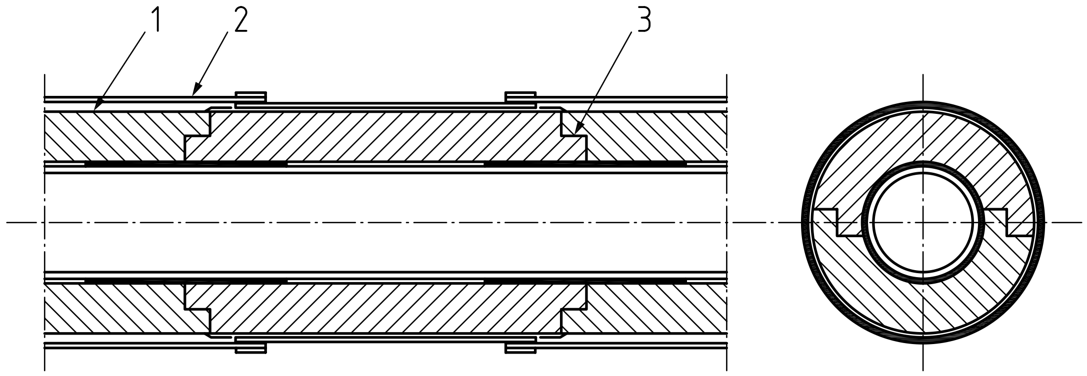
Figure 1 **Typical method of staggering insulation sections on a straight pipe (applies where pipe sections are applied in half sections)**



NOTE Lacing wire or circumferential bands on each layer of insulation.

Alternatively, adjacent layers of insulation can be ship-lapped (a pre-formed step joint engineered within the insulation material, by the manufacturer or by the contractor; see Figure 2). The step should be not less than 25 mm in length. This should be used for circumferential and longitudinal joints.

Figure 2 **Ship-lapped layers of insulation**



Key

1 Primary vapour barrier

2 Cladding

3 Size of ship-lap: ½ insulation thickness × 25 mm

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 other industrial installations.

4.3 Determining insulation thickness

*COMMENTARY ON **4.3***

Underlying methodologies for determining insulation thickness, and the consequent CO_2 tonnage saving, are described in detail in BS 5422:2009, 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.

4.4 Conditions at the point of delivery

4.4.1 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.

4.4.2 Where it is necessary for a fluid to emerge from a pipeline or duct system within a specific temperature range, the designer should ensure 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.

4.4.3 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.

4.4.4 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.

4.4.5 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.

4.4.6 The temperature of the fluid, and therefore the temperature of the conveying system, can change appreciably between the inlet and the delivery ends of the system; several calculations should be made in accordance with BS EN ISO 12241, on a trial-and-error basis, to determine the mean temperature on which to base the calculations for heat loss. 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 **4.6**.*

4.4.7 For systems incorporating supplementary heating, **4.4.3** to **4.4.6** should be disregarded and the designer should ensure the heat loss through the insulated pipeline or duct system is less than the rating of the supplementary heating system.

4.4.8 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.

4.4.9 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.

4.5 Protection of personnel

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

4.5.2 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;

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.

4.5.3 A temperature limit of 43 °C should be used in calculations for short-term contact where services can be accessed by high risk groups such as the children or the elderly. Where contact can exceed 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, ISO 13732-2 and BS EN ISO 13732-3 for maximum and minimum safe surface temperatures.

4.5.4 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.

4.6 Insulation against freezing

*COMMENTARY ON **4.6***

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.

4.6.1 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.

4.6.2 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.

4.6.3 Freezing should be analysed 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.

4.7 Protection against surface condensation

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

4.7.1 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 as the insulation can become saturated, its heat-insulating properties impaired and its 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.

4.7.2 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**).

4.7.3 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.

5 Exchange of design data

5.1 General

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

5.2 Information to be supplied by the specifier

5.2.1 General

The specifier should state either:

a) precise details of the insulation requirements; or

b) the service conditions for which insulation materials are required so that the insulation contractor can make recommendations.

For **5.2.1**b), where required by the contractor, the specifier 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 can influence 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:

- surface dimensions of flat or large curved areas;
- external diameters of pipework, ductwork and associated clearances;
- lengths of each size of pipe/duct;
- number and type of pipe/duct fittings, e.g. flanged joints, valves, tees, bends with radius and angle; and
- 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.

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 **10.3** 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**); and

f) any special service requirements, e.g. resistance to compression, resistance to fire, resistance to abnormal vibration (see Clause **7** to Clause **12**).

Any special hazard from contact with chemicals or oils on the plant should be identified and protection should be 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) limitations of use, both physical and chemical;

d) overall thickness, with details of the thickness and bulk density of the individual layers;

e) information regarding the surface preparation; and

f) 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.

6 Factors affecting planning and programming

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) storage for materials;

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;

s) provision of weather-protection during installation.

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 to Table 4.

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.

BS EN 12664 may be used to measure samples whose thermal resistance is not less than 0.1 m^2 K/W; BS EN 12667 specifies simpler procedures for specimens whose thermal resistance is not less than 0.5 m^2 K/W.

7.2 Physical forms

Insulation should be supplied in one of the following forms:

- pre-formed (slabs or sections);
- rigid;
- flexible;

- plastic composition;
- sprayed and blown;
- loosefill; or
- metallic, e.g. dimpled foil.

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. For lists of typical materials, see Table 1 to Table 4.

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 to Table 4.

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 to Table 4 for a guide to approximate service temperatures).

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 can result in 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** *(1 of 2)*

Material	Relevant standards	Physical forms	Type	Approximate maximum service temperature A) °C	Normal bulk density kg/m³
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	50 to 65
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
		Loose wool	Fibrous/ granular	450	N/A
		Wired mattresses	Fibrous	250 to 400	30 to 70
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	120	28 to 200
Polyethylene	BS EN 14313	Pre-formed pipe sections	Cellular	100	30 to 40

Table 1 **Typical insulating materials for use at temperatures higher than ambient** *(2 of 2)*

Material	Relevant standards	Physical forms	Type	Approximate maximum service temperature A) °C	Normal bulk density kg/m^3
Polyisocyanu-rate rigid foam	BS EN 14308	Pre-formed slabs and pipe sections	Cellular	200	30 to 320
Polyurethane rigid foam	BS EN 14308	Pre-formed slabs and pipe sections, sprayed	Cellular	110	30 to 160

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

NOTE 2 Materials are without facings.

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 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 that 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 higher than ambient with no product standard** *(1 of 2)*

Material	Relevant standards	Physical forms	Type	Approximate maximum service temperature A) °C	Normal bulk density kg/m³
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
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
		Pre-formed pipe sections	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)	No product standard at the time of publication	Slabs	Fibrous	250 to 400	15 to 100
Perlite	No product standard at the time of publication	Loosefill B)	Granular	870	40 to 150
		Pre-formed slabs and sections	Granular	650	190
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

Table 2 **Typical insulating materials for use at temperatures higher than ambient with no product standard** *(2 of 2)*

Material	Relevant standards	Physical forms	Type	Approximate maximum service temperature A) °C	Normal bulk density kg/m³
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
Stainless steel	No product standard at the time of publication	Plain and dimpled foil	Reflective	760	NA
Vermiculite	No product standard at the time of publication	Loosefill B) pre-formed slabs and sections	Granular	1 100	50 to 150
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.

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 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 3 **Typical insulating materials for use at temperatures below ambient**

Material	Relevant standards	Physical forms	Type	Temperature range A) °C	Normal bulk density kg/m³
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	60 to 100
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
Phenolic foam	BS EN 14314	Pre-formed slabs and pipe sections	Cellular	–180 to 120	28 to 200
Polyethylene	BS EN 14313	Pre-formed pipe sections	Cellular	–45 to 105	30 to 40
Polyisocyanurate rigid foam	BS EN 14308	Slabs, pipe sections, sprayed	Cellular	–200 to 200	30 to 60
Polystyrene foam extruded	BS EN 14307	Pre-formed slabs, pre-formed pipe sections	Cellular	–60 to 75	15 to 35
Polyurethane rigid foam	BS EN 14308	Slabs, pipe sections, sprayed	Cellular	–180 to 110	30 to 160

NOTE 1 Care is necessary in interpreting the minimum continuous service temperatures in Table 3. 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.

Table 4 **Typical insulating materials for use at temperatures below ambient with no product standard**

Material	**Relevant standards**	**Physical forms**	**Type**	**Temperature range** A) °C	**Normal bulk density** kg/m³
Perlite	No product standard at the time of publication	Loosefill B)	Granular	–250 to 1 000	40 to 150
Polyurethane flexible foam	No product standard at the time of publication	Slabs, pipe sections	Cellular	–20 to 120	30 to 65
PVC expanded	No product standard at the time of publication	Pre-formed slabs	Cellular	–100 to 95	40 to 300

NOTE 1 Care is necessary in interpreting the minimum continuous service temperatures in Table 4. 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

As differential thermal movement between the insulated surface, insulation and outer finish can occur, it should be determined 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 maintainance 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 can cause freezing, resulting in rupturing the cells of the insulation causing permanent damage and accelerating the corrosion risk.

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 by installers during application. 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.

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 BS EN 14706 and Table 3 (relevant standards).

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, discoloration, volatization, friability, shrinkage or expansion.

Relevant manufacturer information should be consulted to clarify any potential additional requirements of the insulation system to ensure the thermal performance of the insulation system is not compromised.

7.9 Fire and explosion hazards

7.9.1 General

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

The fire performance of the particular insulant should be chosen based on the design requirements of the application for which it is intended. For further guidance, reference should be made to BS 5422, the Building Regulations [1, 2, 3] and the fire prevention authorities.

NOTE 1 The fire hazard associated with the use of a particular thermal insulant, e.g. combustibility, ignition susceptibility, surface spread of flame, emission of smoke or toxic gas, 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 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 An anti-static finish may be used to eliminate the risk of sparks.

7.9.2 Materials

In the absence of special requirements, the characteristics of thermal insulation systems with respect to fire should be in accordance with BS 5422.

7.9.3 Finishes

Fire-retarding compounds and/or anti-oxidant materials should be applied to flammable finishes as some commonly used protective finishes are combustible and can produce substantial quantities of smoke 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.

7.9.4 Aluminium cladding

Conditions where aluminium cladding can constitute 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.

7.9.5 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**).

7.9.6 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**).

7.9.7 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).

7.9.8 Hazards from contaminants

*COMMENTARY ON **7.9.8***

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.

7.9.8.1 Precautions should be taken in accordance with **7.9.8.6** as the chemical and physical processes involved are complicated and conditions can be 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.

7.9.8.2 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.

7.9.8.3 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.

7.9.8.4 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 ensure it is not rendered ineffective.

7.9.8.5 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.

7.9.8.6 Precautions should be taken to prevent fire hazards in air-conditioning ductwork in accordance with BS 5422, BS 5908 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].

7.10 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 (COSHH) Regulations [4], HSE codes of practice and guidance notes, and manufacturers' instructions.

7.11.1 As certain finishing cements are strongly alkaline when wet and can cause skin irritation, gloves should be worn when handling these materials.

> **WARNING**. Chemical fumes arising from the in situ foaming or spraying of organic insulating materials, e.g. phenol-formaldehyde resins, isocyanurates 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 As associated solvents can cause damage to the eyes and skin irritation, goggles and gloves should be used where necessary.

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):

- *EH 44, Dust: General principles of protection [11]; and*
- *EH 46, Man-made mineral fibres [12].*

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:

- *EH 40, Workplace exposure limits [13]; and*
- *EH 44, Dust: General principles of protection [11].*

7.11.7 As insulants can deteriorate from vibration or heat soaking, before any stripping work is carried out, the type of insulating material used should be identified and relevant precautions taken (see Clause **34**).

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 considered 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**).

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 can be significant in the total cost of an insulation system and should be minimized by 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 carefully selected and installed so that the risk of corrosion is minimized. All forms of corrosion should be considered and the procedures should be in accordance with this clause.

Subclauses **8.2**, **8.3**, **8.4** and **8.5** provide only general guidance; where specific corrosion problems are possible due to the interaction of insulation and metal in a particular environment, 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 can be extracted from the insulating material itself. The possibility of corrosive attack on a variety of metals that might be in 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.

The designer/specifier should consider the compatibility of the 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 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 Only dry, undamaged insulation should be used.

NOTE This might require weatherproof storage.

8.2.1.3 Insulation should be as close fitting as possible to the equipment/pipe surface; drainage may be provided for voids on hot work.

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

a) using an effective vapour/weather barrier;

b) ensuring 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 cladding overlaps to shed water (weatherwise – roof tile method);

g) installing horizontal flat cladding with a fall or slope to shed water and avoid pooling;

h) providing temporary weather protection of incomplete insulation systems;

i) 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);

j) installing cladding so as to ensure the joints are weatherwise and shed water; and

k) 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**.

8.2.1.5 The line of insulation and cladding should be continuous through all pipe supports.

8.2.1.6 Removable inspection points may be incorporated into the insulation system, but should be designed to minimize the risk of water ingress, see Clause **33**.

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

8.2.1.7 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.

8.2.1.8 It should be ensured that the top plates of vertical manholes always slope.

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

8.2.2 Anti-corrosion coating systems

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

Where selecting anti-corrosion coating systems, the following criteria should be taken into account:

a) the metal surface to which the anti-corrosion coating is to be applied;

b) compatibility between coatings, 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 coating system selected should be appropriate for the highest operating temperature possible.

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

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

NOTE 2 Treatments can consist of coating with paint, bitumen or weatherproof polymer solution, wrapping with self-adhesive PVC, polypropylene pipe-wrap tape or wax-impregnated tape.

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 65 °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.

Acidic corrosion can occur when the products are heated in the presence of moisture; this attack should be minimized by suitably 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 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 and specifiers should consider protective measures such as preventing water egress from the insulation system, painting the metal surface or using a factory-applied barrier.

8.3.4 Bimetallic (galvanic) corrosion

*COMMENTARY ON **8.3.4***

The occurrence and extent of bimetallic corrosion between any two 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 bimetallic 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 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. PD 6484:1979, ***2.1*** *states: "When two different metals are in electrical contact and are also bridged by water containing an electrolyte (e.g. water containing salt, acid, combustion product), current flows through the solution from the anodic or baser metal to the cathodic or nobler metal. As a result, the nobler metal tends to be protected, but the baser metal can suffer greater corrosion. In the past, schedules of electrode potentials have been published which have been of value in drawing the attention of designers to the dangers of bimetallic corrosion. Such schedules can, however, be misleading, since the potential difference between metals, although it is the prime driving force of the corrosion current, is not a reliable guide to the rate and form of corrosion suffered at any particular contact. In particular, statements claiming that specific differences of potential are safe or unsafe, are unreliable."*

It is important that 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 bimetallic 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.

8.4 Stress-corrosion cracking

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

COMMENTARY ON ***8.4.1***

Most thermal insulating materials contain traces of water-soluble chlorides. Additionally, some organic-foam insulating materials 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.

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 possible, personnel should avoid touching austenitic steel surfaces with bare hands and the surfaces should not be scratched or indented in any way as local damaged areas can form a starting point for the development of cracks in the metal.

To provide protection, aluminium foil of not less than 0.06 mm thickness should be applied to the austenitic steel surface so that the insulation can be applied over the foil, which should be arranged to shed water with an overlap of not less than 50 mm at the joints. The melting point of aluminium is 660 °C so foil should not be used if the temperature of the alloy can approach this value under service conditions; a limit of 500 °C is recommended.

NOTE 1 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 2 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 closely 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).

Certain insulation materials contain additives that are used to inhibit stress-corrosion cracking; if selected they should be used with the recommendations in **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 can concentrate at the metal surface. The danger of cracking from this type of attack is remote, but painting of the surface should be adopted as a precaution where the consequences of fracture of the metal could be 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 non-ferrous metals, precautions should be taken to exclude moisture from the insulation system and, if necessary, the surface of the metal should receive a protective coating.

NOTE 3 Non-ferrous metals, notably the aluminium-zinc, aluminium-zinc-magnesium alloys, and various copper-zinc (brass) alloys can be sensitive to stress-corrosion attack, e.g. when brass compression fittings are over-tightened in the presence of moisture and alkalis.

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 absences 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 can be 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

To ensure the suitability of any particular type of material, the expected performance data for the specified conditions should always be obtained from the manufacturer.

The designer/specifier should distinguish between an insulation system that is applicable mainly for elevated temperatures (see Table 1 and Table 2) and one that is particularly for use at temperatures below ambient (see Table 3 and Table 4).

It should be ensured that water vapour does not condense, and 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

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, it is essential that the insulating material is 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.

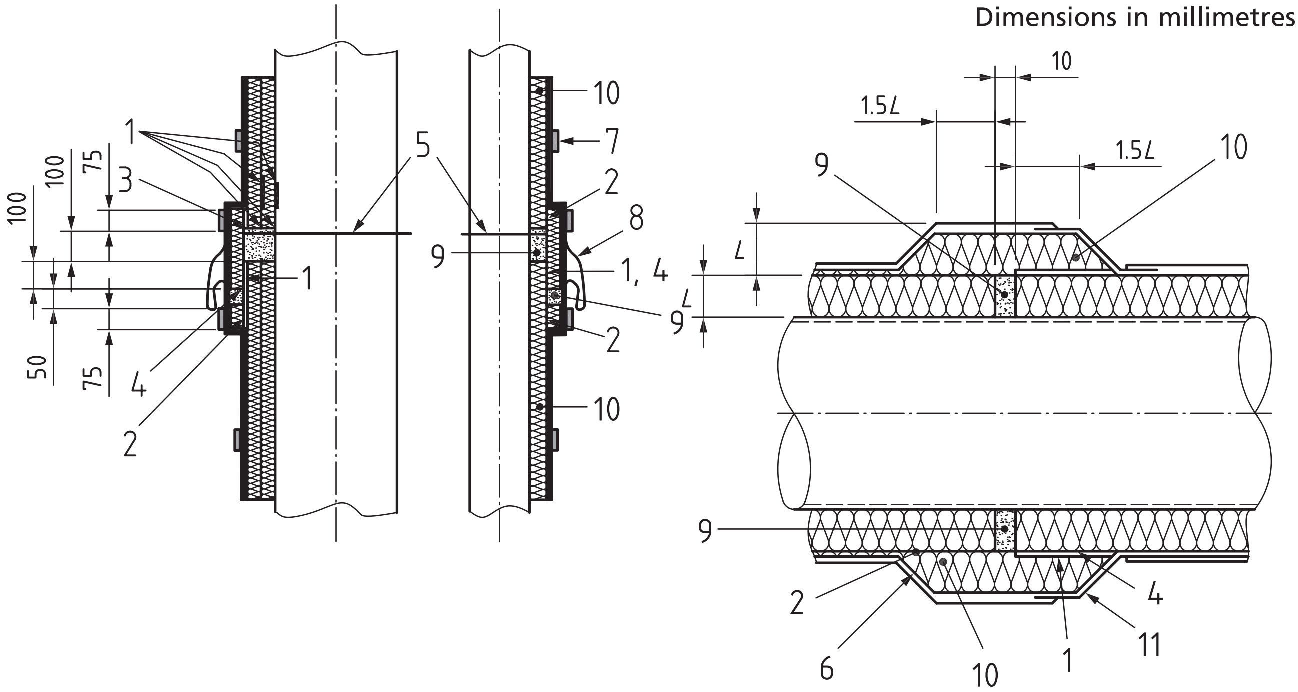
9.2.2.3 Only dry insulating material should be used, which should be kept dry until after the vapour barrier has been applied and completed. The insulating material chosen should be one that can be secured in close contact with the insulated surface by an adhesive, tape or bands (see Clause **27**). Additionally, all cavities should be filled with vapour barrier/joint sealant. For example, thermal bridges at through-metal supports should be avoided wherever possible.

NOTE Unsealed joints between sections and at branch connections, or badly fitting insulation, can provide easy passage for water vapour.

9.2.2.4 Where necessary, the insulating material should be resistant to occasional defrosting of the plant, particularly if this is to be done by steam-purging that can raise the temperature of the plant locally to a level above the softening point of the insulation. Allowance should be made for expansion/contraction of plant under hot/cold cycles and the insulation system, i.e. insulation and vapour barrier, should be designed to accommodate thermal movement of plant (see **28.2** and Figure 3 for contraction joints).

Figure 3 **Typical contraction/expansion joints for insulated pipework (for use at 5 °C or colder)**

Dimensions in millimetres



a) Vertical double-layer and single-layer insulation

b) Single-layer insulation

Key

1	Butyl mastic
2	Adhesive
3	Create vapour stop in this area
4	Sliding surface
5	Pipe support
6	Vapour barrier and weather finish
7	Stainless steel bands
8	Adhered butyl rubber with expansion overlap
9	Compressed fibreglass blanket
10	Rigid insulation
11	Slip joint
L	Insulation thickness

9.2.2.5 Where compression-resisting insulation is required, e.g. at pipe supports, sling points, or support areas for the inner container in double-skin construction, a compression-resistant load-bearing thermal insulation, e.g. cellular glass, expanded plastics, should be used. If an absorbent material is used, it should be kept dry during service. Pipe supports should be of the same thickness as the insulation to enable the vapour barrier to be easily continued and maintained.

9.2.2.6 Many insulating and ancillary materials used for the insulation of low temperature plant are classified as combustible and therefore are potential fire hazards, which should be identified and materials accepted or rejected in accordance with their resistance to fire (see **4.3**, **7.9** and **12.6**).

9.2.2.7 Insulating materials, joints sealers and vapour barriers that can be exposed to liquid oxygen, e.g. by direct spillage, leakage, or by the partial condensation of air, should be of inorganic composition and should be free from oil or other organic contaminants.

9.2.2.8 The material of the vapour barrier should be selected to be resistant to other reactive oxidizing chemicals. It should be protected by an outer metallic cover adequately sealed (see also **7.9**). When fixing the outer metallic cover, the vapour barrier should not be penetrated.

9.2.2.9 When selecting insulating material for the protection of pipes of small diameter against frost conditions, heat tracing should be used where the thickness of insulation is impracticable (see BS 5422).

*NOTE A high thermal capacity improves the thermal stability of the insulation system and therefore increases the level of protection against transient frost conditions. The effect of the thermal capacity of the insulating material decreases with increase in pipe diameter (see also **4.6.2**).*

9.2.2.10 To perform at the lower temperature and when using different types of insulating material for a portion of the plant, the inner layer should be used in sufficient thickness to maintain the temperature at the interface with the main insulant at an acceptable level.

NOTE Different types of insulating material can be convenient to use if the service temperature is below the limiting-temperature for the preferred insulating material.

9.2.3 For normal ambient and elevated temperatures

9.2.3.1 Flexible materials may be used for plant of both regular and irregular shape, but they are relatively easily deformed by superimposed loads, e.g. by the weight of finishing material. To ensure reliable thermal efficiency in service, if necessary, additional support should be provided from the plant surface for any substantial protective layer, independently of the insulating material itself. However, a flexible fabric-covered mattress may be used for locations where frequent removal of the insulation is required, e.g. for valves or access manhole covers.

9.2.3.2 Certain types of plant with double-skin construction, e.g. reaction or storage vessels, can require the annular space to be packed with a loosefill insulating material, which might be in the form of a loose mass of fibre or a porous granular aggregate; in such cases, reasonably uniform packing at an optimum bulk density should be achieved, e.g. by the provision of internal spacer supports to prevent settlement under service conditions.

9.2.3.3 For irregular shapes of plant, plastic composition insulating materials may be used, but, in these cases, the plant should be preheated and the heat maintained until all the insulation is dry.

9.2.3.4 If used for repairs, wet plastic composition should be applied in successive layers, allowing each one to dry before the next is applied.

NOTE The costs for labour and for the provision of heat for drying out can be substantial.

9.2.3.5 Because plastic composition mixes are likely to contain soluble chloride salts, either as normal impurities or in the water used for forming the paste, they should not be used for direct application to austenitic steel surfaces due to the potential danger from stress-corrosion attack. Additionally, only potable water should be used for mixing plastic composition to minimize the risk of corrosion from soluble salts in contaminated water (see **8.4.2**).

9.2.3.6 The foamed material should only be used within the correct temperature range and should not add to the fire hazard in the insulated plant.

NOTE Low thermal conductivity values, together with light weight, are characteristic of many types of foamed in situ insulating materials, which normally involve the mixing of reactive chemicals, e.g. production of polyurethane, isocyanurate and phenolic foam. Such materials are of particular value for filling the annular spaces between the containment surfaces of a lightweight structure as, in many cases, they can increase the mechanical stability of the structure. A similar process can be used to produce pre-formed insulating shapes.

9.2.3.7 Microporous silica insulation should not become wet as this can result in an irreversible breakdown of the microporous structure and loss of insulating properties.

NOTE The advantage of microporous insulation relates to its low thermal conductivity, which persists to high temperatures; this characteristic permits the use of lesser thicknesses than for conventional materials.

9.2.3.8 Metallic surfaces are more effective than non-metallic surfaces in reducing absorption or emission of radiant heat, but allowance should be made for heat loss due to edge effects.

NOTE Reflective metal foils may be used together with granular, cellular, fibrous or powder-type insulating materials and, where required, as an intermediate layer in air cavities for thermal insulating purposes. Multilayer all-metallic reflective thermal insulation is particularly useful for certain applications in the nuclear industry.

9.2.3.9 Fire hazard, moisture absorption, upper limiting-temperature and the thermal conductivity under the required conditions of use should be assessed and documented to determine the type of insulating board for a specific application.

NOTE Insulating boards can be substantially of organic composition, e.g. made from plastics foam, or wholly inorganic, e.g. cellular glass or mineral fibres bonded with a cement-type product. Included in this range are gypsum plasterboard and sheet products made from rigid organic polymer foam, both of which can have one or both surfaces covered with aluminium foil to reduce thermal transmission.

9.2.3.10 Insulating fire brick and related pre-fired or formed rigid shapes should be used where the insulation has to be self-supporting or partially load-bearing or where it is to be exposed directly to hot gaseous products, e.g. for lining flues that contain hot low-abrasion gas.

NOTE It is useful to distinguish between hot-face insulating bricks and those used only for "backing" insulation, i.e. behind a protective surface, due to their sensitivity to abrasive attack or because of limited resistance to the expected temperature conditions.

9.2.3.11 The high crushing strength of calcium silicate blocks or cellular glass blocks combined with a low thermal conductivity makes them useful in partially load-bearing applications, and they should be used as a back-up to fire bricks where they have to resist crushing movement due to expansion at high temperature (see **9.2.3.14**).

NOTE Significant advantages over insulating fire brick can be gained in lesser thicknesses and/or lower heat losses by the use of calcium silicate insulating blocks or slabs.

9.2.3.12 High temperature resistant fibre should be used in applications where low thermal mass and high resistance to thermal shock are important, such as in annealing furnaces or those used intermittently. Greater resistance to abrasion and mechanical damage should, where required, be obtained by the use of board or inorganically-bonded wet felt as a lining or by the use of a rigidizer directly on to the surface of the ceramic blanket.

9.2.3.13 Insulating concretes should be mixed with water immediately before application; they should be poured, spray-applied, or placed in position manually. Alternatively, the wet mass should be foamed or aerated so that large numbers of air-cells are contained in the final dry product to give material lower bulk density and improved insulating properties.

NOTE 1 Insulating concretes are normally based on a mixture of Portland cement or aluminous cement with a lightweight aggregate.

NOTE 2 Many lightweight insulating concretes can undergo appreciable changes in volume with variations of moisture content and their mechanical strength can be reduced on heating.

9.2.3.14 When using two different types of insulating material for a portion of plant, the inner layer, for resistance to the higher temperature, should be used in sufficient thickness to reduce the temperature at the interface with the main insulating material to an acceptable level (see also **7.4**).

NOTE Two different types of insulating material may be used if the service temperature is above the limiting-temperature for the preferred main insulating material.

10 Selection of securing materials

*COMMENTARY ON CLAUSE **10***

*Insulation systems may be permanently secured directly to the plant by means of adhesives, by mechanical means, or by a combination of both. Alternatively the insulation may be installed as a removable module (see also Clause **25** and Clause **26**).*

If the insulation is not installed properly using the correct securements, the insulation product can sag or become detached from the underlying surface, and can suffer from the effects of vibration.

*Additionally, this can result in stresses placed on any aluminium foil tape being used. This can lead to mechanical failure between the tape and the foil covered surface of the insulation, damaging the integrity of the vapour barrier and the thermal efficiency of the insulation system. See **27.3**.*

10.1 Adhesives

10.1.1 General

Adhesive users and specifiers should consult all available safety information before individual products are used. Container labels, technical data series and manufacturers' health and safety data sheets give valuable information and should be obtained for study.

NOTE 1 Attention is drawn to the BASA guide, "Safe Handling of Adhesives" [14] and to HSE Guidance Note "EH 40, Workplace exposure limits" [13].

The adhesives should be compatible with the surfaces involved; particular insulating materials might require specific adhesives. Where necessary, primers should be used to assist penetration and wetting, particularly for bonding or consolidating friable surfaces.

NOTE 2 Adhesives of nominally similar type can differ in their resistance to water, in their behaviour under conditions of fire, and in their resistance to temperature variation.

If the surfaces in thermal insulation systems are rough or irregular, adhesives used for these systems should have special gap-filling properties.

*NOTE 3 See **A.3** for adhesive types and typical properties.*

10.1.2 Classification according to use

Adhesives for insulation should be classified as follows.

- Insulation bonding adhesives (see Table 5): used for securing pre-formed slabs and sections, or flexible insulating materials to themselves and to structures such as equipment and ducts. Generally, the substances in this group are of relatively heavy consistency and have good gap-filling and tack characteristics.

- Facing and film-attachment adhesives: used for attaching flexible laminates, foils and plastics films to thermal insulation, and for bonding and overlaps of these materials. This group includes a wide range of products, generally of consistency for brush or spray application. They are chosen for economy and for ease of application. For plastics films in particular, the long-term compatibility with the chosen adhesive should be established at the design stage.
- Other insulation adhesives: used for bonding, sizing and coating surface-finishing fabrics over insulated pipework and equipment. Usually these are waterborne compounded products based on single or combination polymers using ethylene, vinyl acetate, vinyl chloride or acrylic monomers.

NOTE Some overlapping occurs in the above groups, which are intended to illustrate the primary function of an adhesive. Good design practice frequently permits economical brush or spray-type adhesives to be used for attachment of insulating materials where existing features of the design might be employed to provide back-up mechanical support, e.g. metal banding or a strong fabric-reinforced mastic finish.

Final selection should be made only after full consideration of all the factors in **10.1.2** together with any special chemical resistance or other requirements.

Table 5 **Insulation bonding adhesives for pre-formed sections and slabs**

Insulant	**Adhesive system**
Mineral fibre (glass, stone)	Styrene-butadiene rubber (SBR), neoprene, natural rubber (NR) solutions, bitumen/rubber emulsion and solutions, latex hydraulic cements, alkyd resin compositions, copolymer emulsions
Polystyrene foam	SBR, neoprene, NR solutions, bitumen/rubber emulsions, moisture curing polyurethane, latex hydraulic cements
Polyurethane Polyisocyanurate Phenolic foams	SBR, neoprene, NR solutions, bitumen/rubber emulsions and solutions, latex hydraulic cement, alkyd resin compositions, polyurethane, epoxides, hot-melt bitumens
Baked cork	SBR, neoprene, NR solutions, copolymer emulsions, hot-melt bitumens
Expanded plastics and rubbers	SBR, nitrile, neoprene solutions, polyurethanes
Cellular glass	Latex hydraulic cements, bitumen/rubber solutions and emulsions, bitumen modified polyurethanes, epoxides, silane-modified polymers, silicone polymers
Calcium silicate, perlite	Sodium silicate

NOTE The adhesive groups shown here are indicative only, and in no way preclude selection of alternative materials recommended by the adhesive or insulant manufacturer.

10.1.3 Adhesive strength

*NOTE 1 Properties which might affect the behaviour of the adhesive after installation are described in **10.1.3** and in **A.1**.*

The adhesive strength should exceed the cohesive strength of the insulating material by a safe margin under all conditions of service.

NOTE 2 High strength of adhesive is not usually the most important requirement because of the low bulk density and loose bonding of many insulating materials.

For materials of higher bulk density and strength, stronger adhesives should be used, and these should be adequate to carry the required load with an ample margin of safety.

NOTE 3 The main components of adhesive strength are those relating to tensile, shear, and peeling forces; peeling forces are usually the most destructive and they are a frequent cause of failure. For example, if the layer of adhesive is too thin for bonding distorted insulation boards to metal surfaces, e.g. metal ducts, the resulting insufficient area of adhesive contact can be inadequate to resist the severe peeling forces generated by thermal movement, especially at the edges of the areas of contact.

NOTE 4 As the cross-sectional area of the ducting increases, so does the effect of mechanical vibration. The cross-section of the ducting can be affected by mechanical vibration.

Where permanent bond strength is important, the effect of "ageing" due to heat should be taken into account; this can be significant in reducing the acceptable maximum service temperature. However, long-term performance of adhesives cannot be assessed in isolation; the whole insulation system should be assessed and documented, especially the behaviour of the insulating material itself.

10.1.4 Mechanism of curing

All solvents, aqueous or organic, should be allowed to cure in accordance with manufacturer's instructions and should be allowed to escape from the assembly; failure to do so can cause application difficulties and service failures.

NOTE 1 This is especially important if foil-faced slab insulation has been bonded to the duct work and insufficient time has been left to allow the adhesive-carrying solvent to dry completely before the vapour barrier is completed with, for example, self-adhesive foil tape.

In general, solvent-based or water-based adhesives should be used where one of the contact surfaces is porous; in this case the adhesive may be applied to one surface and the bond made immediately or after a short "open-time" during which the adhesive develops "grab".

Where chemically curing adhesives are used, two-component adhesives should be mixed completely according to instructions; part mixing of components for small jobs normally results in a failed bond. Most assemblies should be supported until sufficient strength has developed.

*NOTE 2 For further information on adhesives used for curing, see **A.2**.*

10.2 Mechanical securements

10.2.1 The securing materials in this category generally should be classified as welded attachments, adhesive attachments, bolted fittings, or banding and wire securements. For the application methods of securement, see Clause **27**.

10.2.2 Designers should determine and specify appropriately the need for insulation supports (see **4.2)**. The requirement for securement and type of securement for a particular application will vary depending on the type, form and density of the insulation material (see Clause **27**). If available, the securement manufacturer's instructions should be referred to and followed. The insulation manufacturer should also be consulted. Where welded attachments are specified, this should be clearly identified so they can be attached prior to final stress relieving and completion of the engineering of the equipment.

10.2.3 Bimetallic contact between metals of appreciably different electrochemical properties should be avoided (see **8.3.4**).

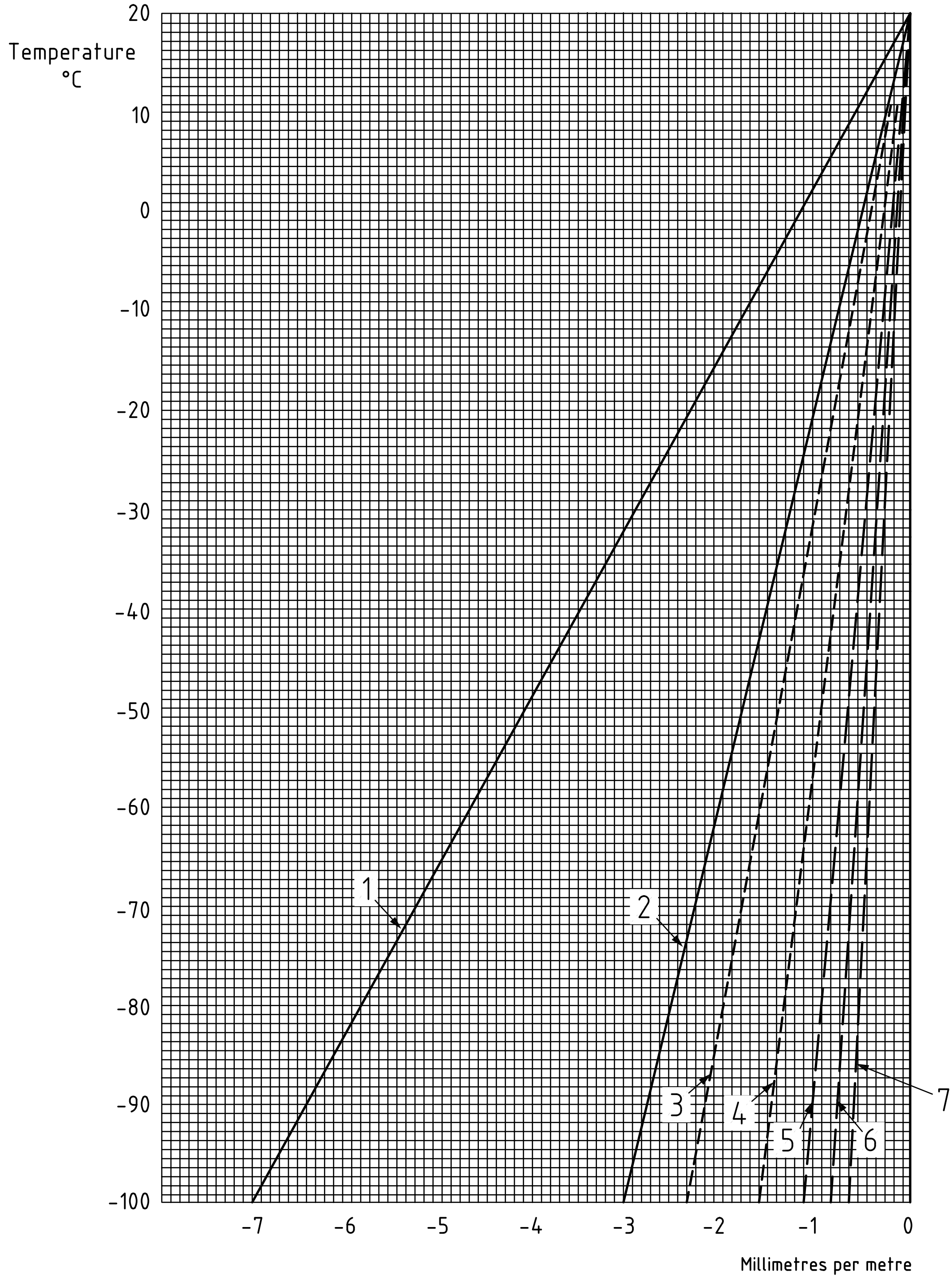
10.2.4 On vertical piping, or vertical and downward-facing vessels and equipment, support attachments should be appropriate to the pipe/vessel/duct size and service, see **7.8.2** and manufacturer's instructions. Any penetration of ventilation ductwork should be sealed.

NOTE Securements that may be considered include welded lugs, self-adhesive hangers and retaining washers, adhesive fixed perforated base hangers and retaining washers, self-drilling hangers, banding and lacing wires, insulation hangers, additional mechanical fixings or a combination of these.

10.2.5 Where the use of adhesive attachments is being considered, substrate type, weight of the insulation system, possible effects of vibration, ambient conditions, service temperature along with the application ambient temperature and climatic limits and the cure time of the adhesive should be taken into account.

*NOTE Welded attachments can be in the form of cleats, angles, pads, studs, bolts, nuts, etc., that provide support for bolted fittings and permanent datum positions relative to each other. The spacing of these attachments can be varied locally to control thermal movement (see **27.7.2**, **29.1.3** and Figure 3 to Figure 11).*

Figure 4 **Linear thermal movement of various materials between temperatures of 20 °C and –100 °C**



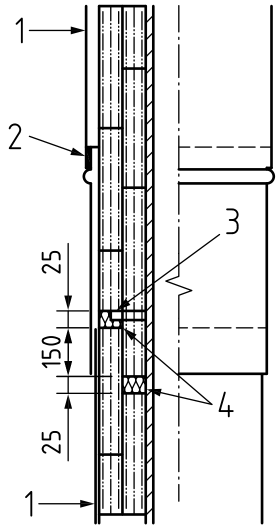
Key

1	Polyurethane and polyisocyanurated (foamed)	4	Austenitic stainless steel
2	Phenolic foam	5	Carbon steel
3	Aluminium	6	Cellular glass insulation
		7	Mineral wools

NOTE 1 The linear thermal movements shown are for unrestrained material at a temperature, which is uniform across the section.

NOTE 2 Refer to manufacturer's data for specific values of linear coefficient of expansion/contraction.

Figure 5 **Typical compression/support joint (for use at 5 °C or above)[A) B)]**



Key

1 Metal cladding

2 Butyl sheet

3 Insulation support ring

4 Mineral fibre or other flexible insulation tightly packed

Expansion joint spacing:

Up to 370 °C: 4 500 mm

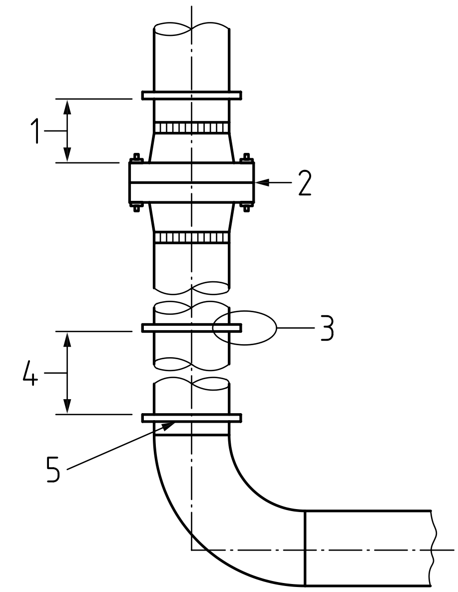
371 °C to 480 °C: 3 600 mm

481 °C to 650 °C: 2 700 mm

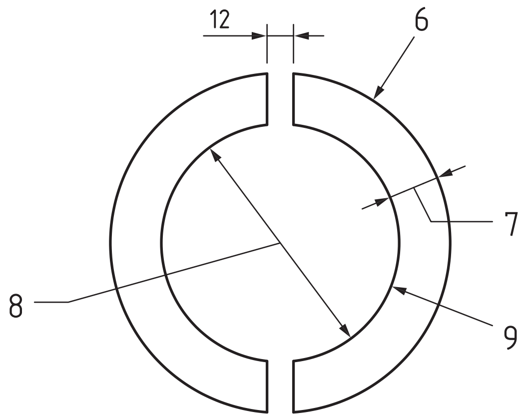
A) Expansion joints in vertical pipework should be positioned directly below the insulation support ring.

B) For operating temperatures above 480 °C, circumferential expansion joints should be installed.

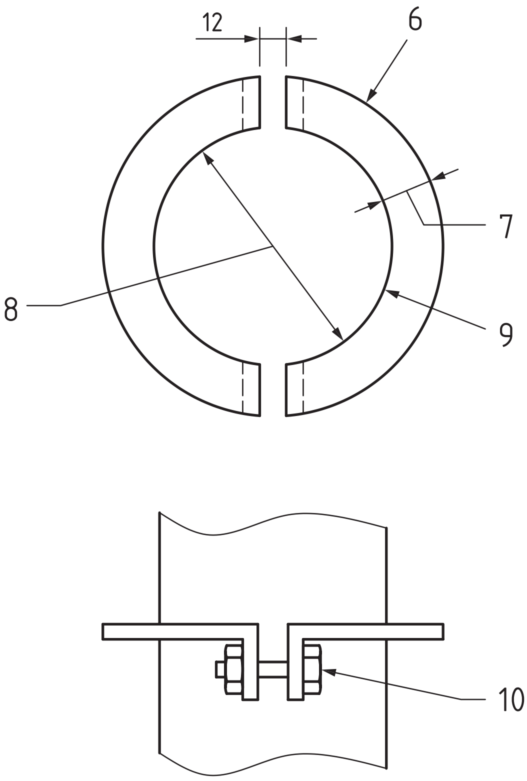
Figure 6 **Typical cladding and/or insulation support for vertical pipework – Spacing of joints (hot insulation)**



a) Piping insulation support ring detail



b) Welded support ring joint detail A



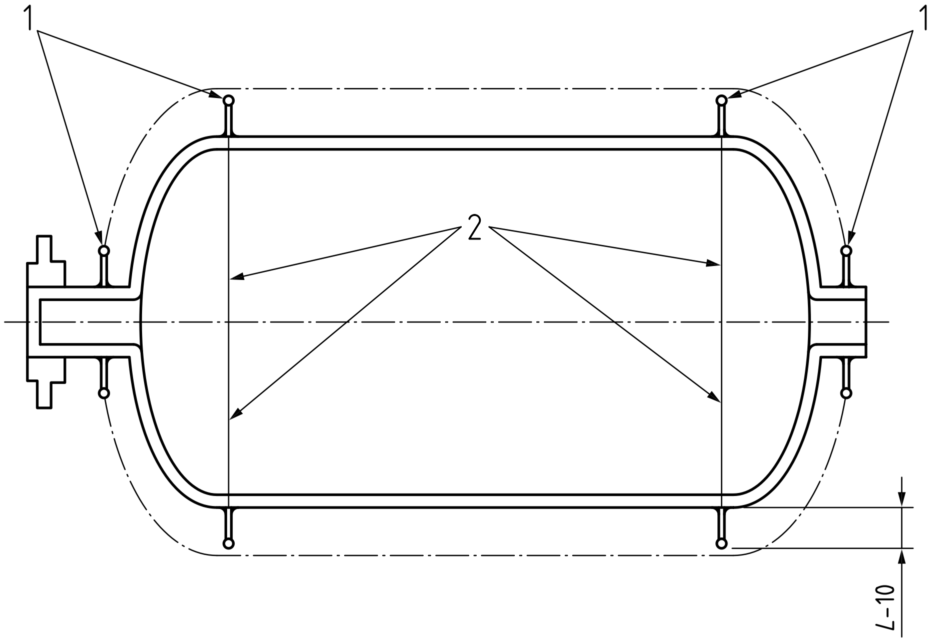
C) Support bolted to pipe where welding not permitted

Key

1 Stud bolt length +1” (25 mm), 2” (51 mm) minimum above
2 Flange weld
3 See Figure 6b)
4 Every 10’ (3 m)
5 Support ring 2” above elbow weld
6 6 mm steel plate
7 ⅔ of insulation thickness
8 Outside diameter of pipe
9 Insulation ring made by fabricator or strapped on in field
10 ½" stainless steel bolts with nuts

Figure 7 **Typical methods of insulating horizontal vessels**

Dimensions in millimetres



Key

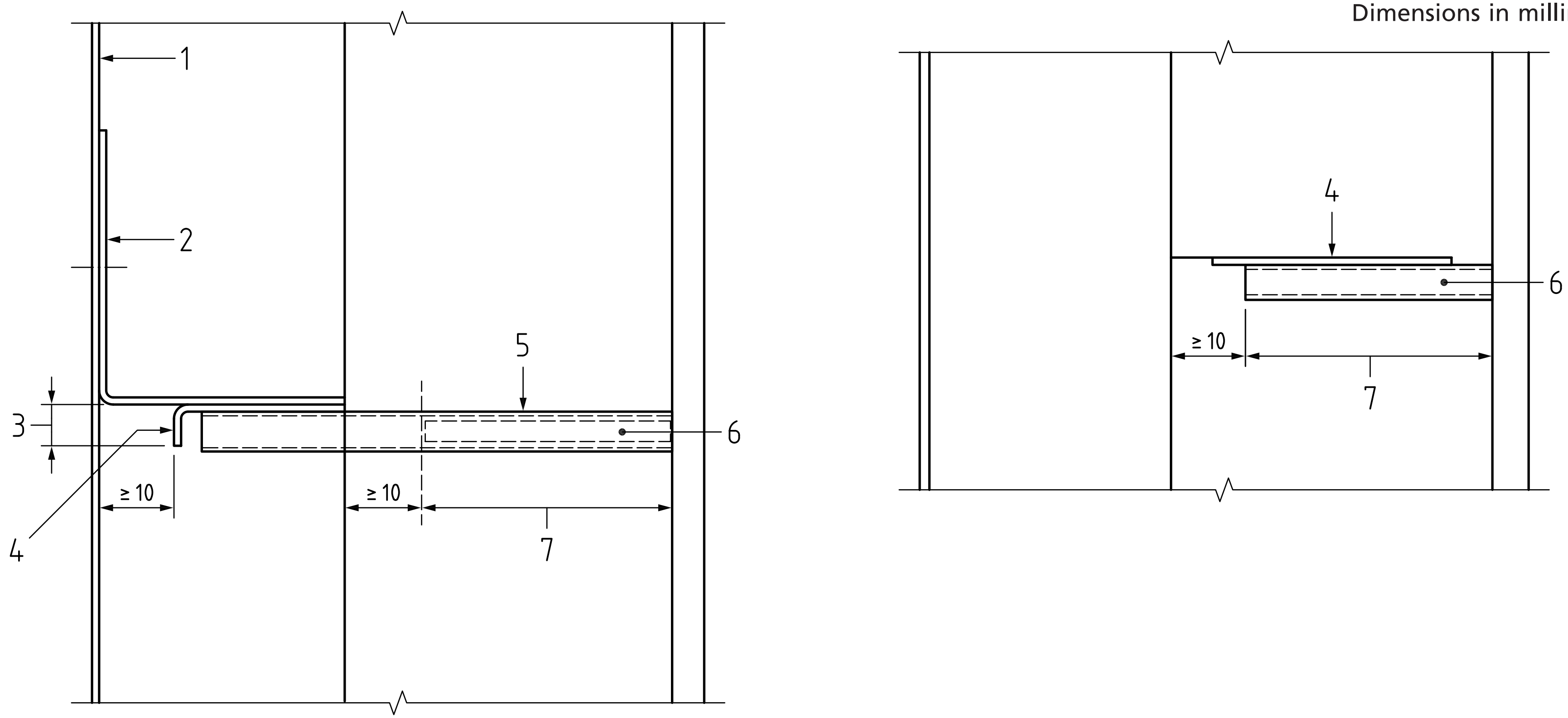
1 Type 1 or 3 ring

2 Tan line

L = Insulation thickness

Figure 8 **Typical cladding and/or insulation support for vertical pipework – Support arrangements (hot insulation)**

Dimensions in millimetres



Key

1	Cladding	5	10 mm nominal bore tube (over stud)
2	Angle cleat	6	Stud
3	5 mm (typical)	7	Stud length
4	Support collar		

NOTE Angle cleats of the same material as the cladding are riveted to the cladding. Minimum of 4 cleats per ring, maximum distance between centres of cleats 230.

Width of cleats as follows.

Insulation outer diameter	*150 to 200*	*200 to 300*	*Above 300*
Cleat width	*20*	*25*	*35*

Figure 9 **Typical insulation supports for vessels** *(1 of 3)*

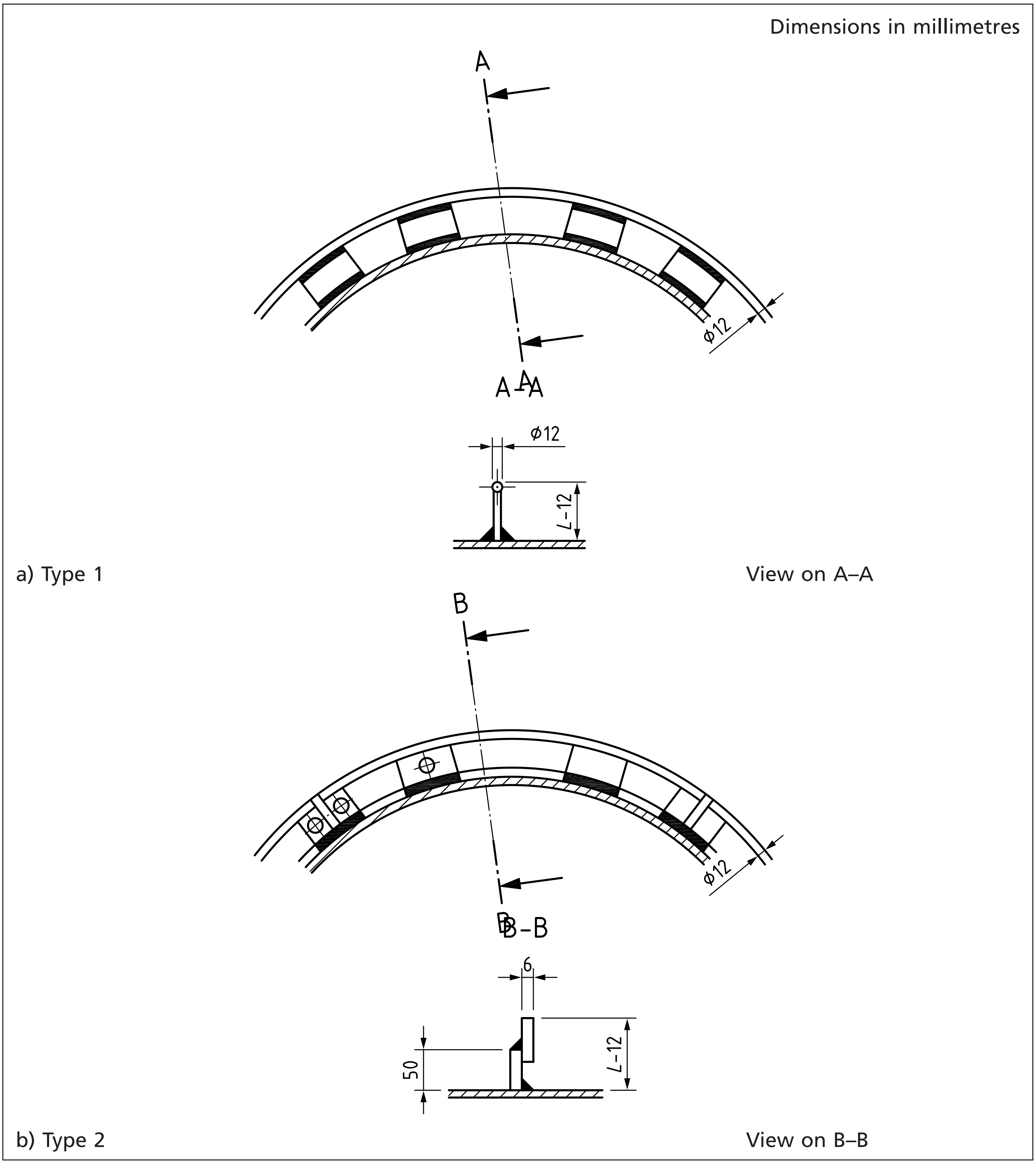
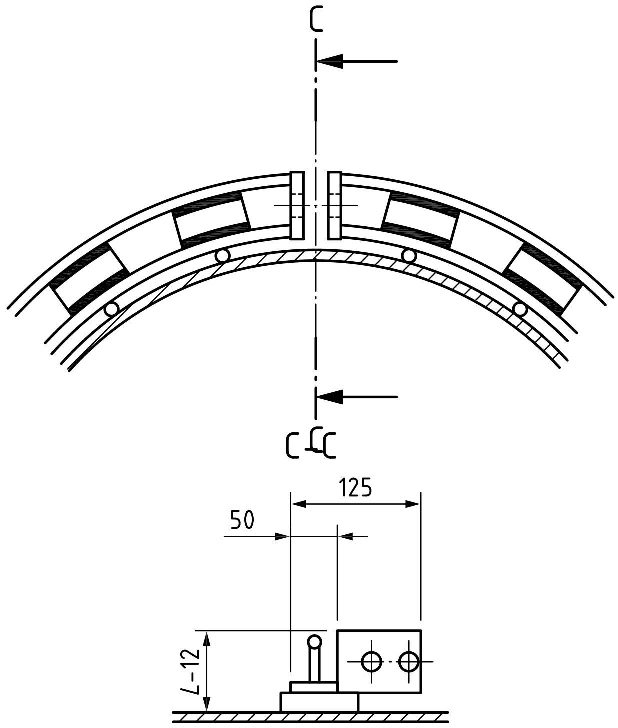
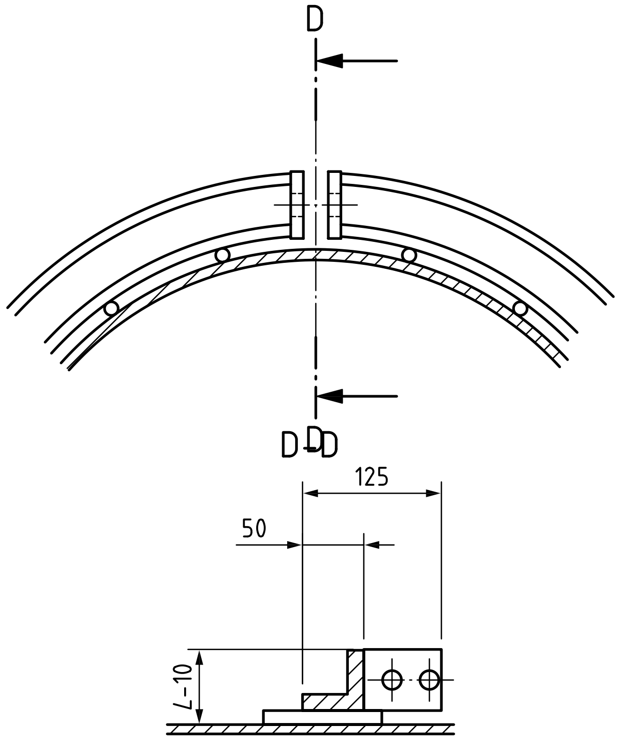


Figure 9 **Typical insulation supports for vessels** *(2 of 3)*

Dimensions in millimetres



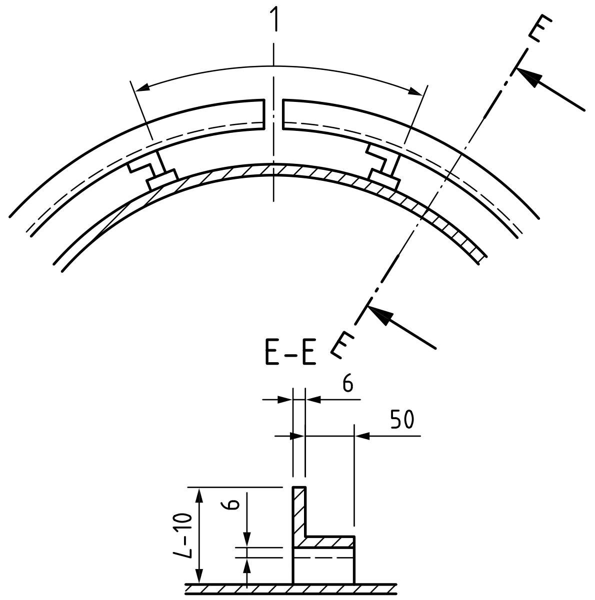
c) Type 3 (clamped) View on C–C



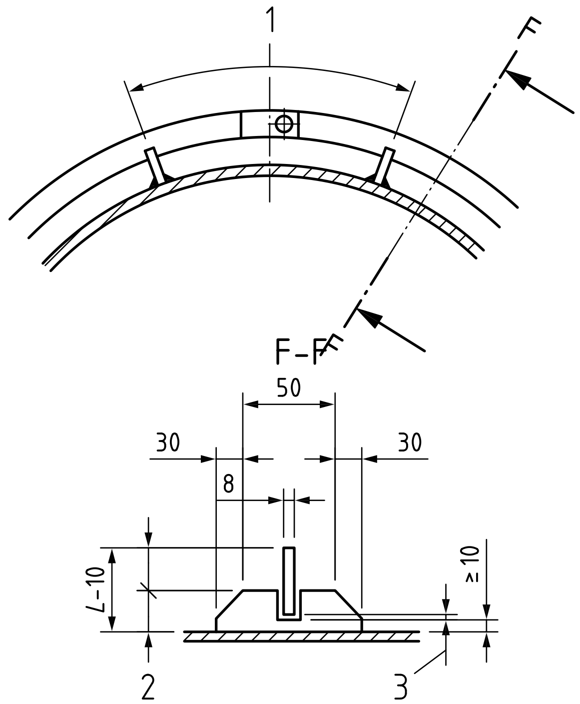
d) Type 4 (clamped) View on D–D

Figure 9 **Typical insulation supports for vessels** *(3 of 3)*

Dimensions in millimetres



e) Type 5 (*L* > 100) View on E–E



f) Type 6 View on F–F

Key

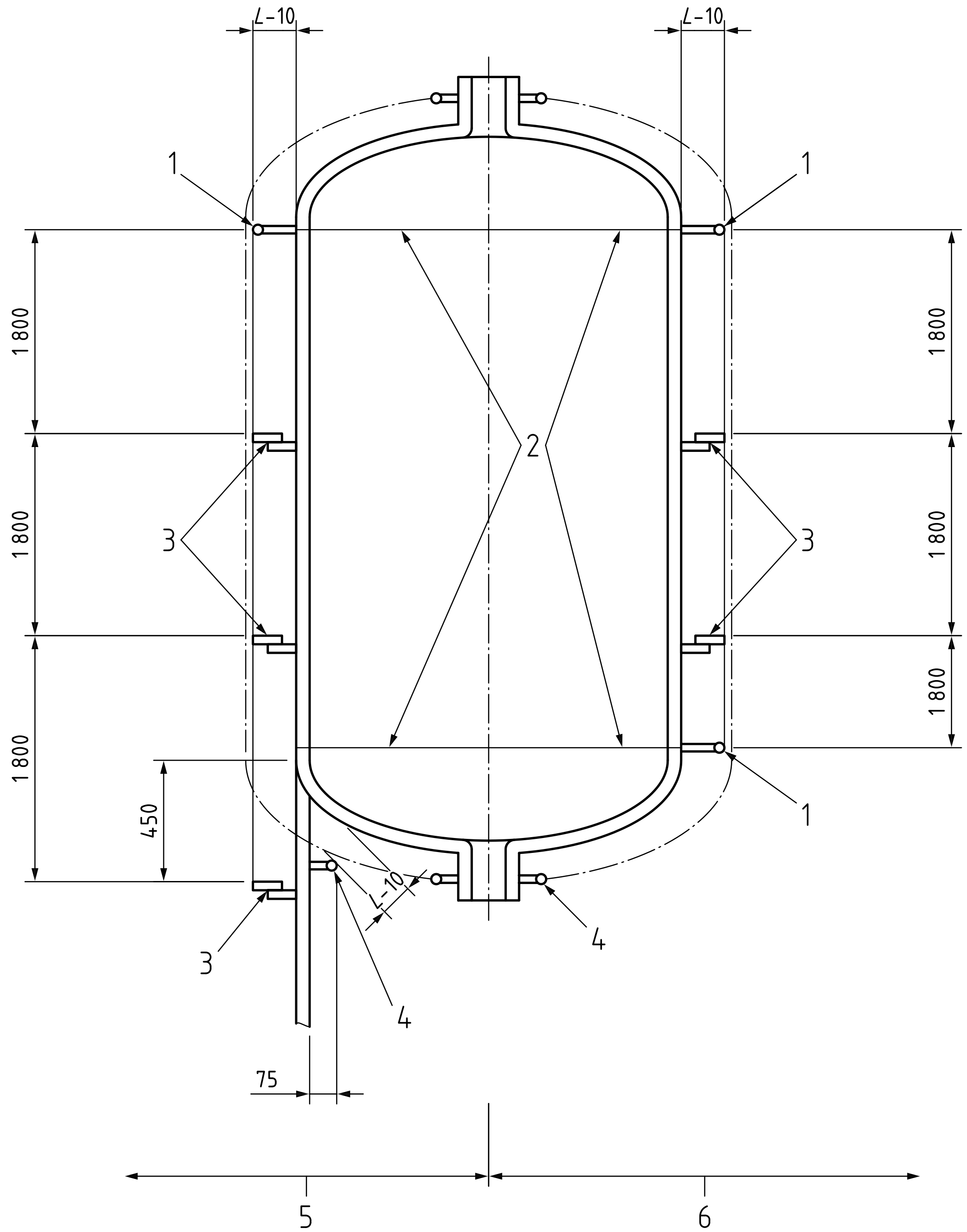
1 600 mm pitch

2 *L* -10 or 50 mm, whichever is smaller

3 Clearance after expansion

Figure 10 **Typical methods of insulating vertical vessels**

Dimensions in millimetres



Key

1 Type 1 or 3 ring

2 Tan line

3 Type 2 or 4 to 6 inclusive

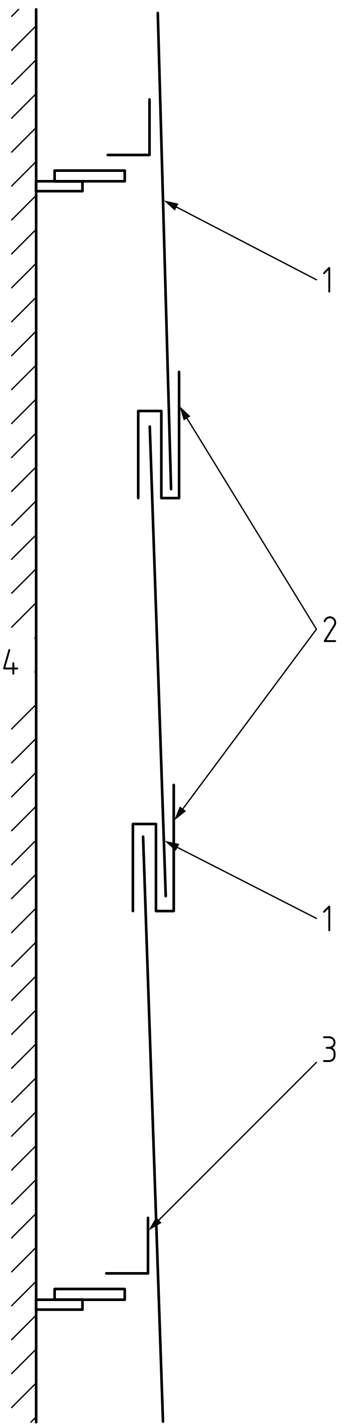
4 Type 1 ring

5 Vertical vessel with skirt support

6 Vertical vessel with leg or bracket support

L = Insulation thickness

Figure 11 **Method of supporting cladding**



Key

1 Cladding

2 'S' clip: to support one sheet of cladding from the one below [A)]

3 Angle bracket: to support cladding from the insulation supports. Angle brackets to be of the cladding material [A)]

4 Shell

[A)] There should be a minimum of two per sheet.

10.2.6 Attack by liquid metal should be prevented (see **8.5**).

10.2.7 Site welding of securing and fixing devices should not be undertaken without first consulting the client, the contractor and sub-contractors (referred to as the purchaser).

NOTE On large areas of equipment, e.g. oil storage tanks, the attachments provide a secure base for secondary angle rings, etc.; the spacing is determined by the maximum permitted span under wind loading conditions for the cladding used.

10.2.8 For large tanks, which can be subjected to significant wind loadings, bolted fittings should only be used with attachments that are welded or fastened by means that provide equivalent restraint.

NOTE Bolted fittings, whether plain or spring-loaded, if not used in conjunction with a welded attachment on a vertical surface, are likely to slip and become ineffective in their control of the insulation system.

10.2.9 The size and spacing of banding and wire securements should depend on the materials chosen, on the design parameters of the insulation system (see **27.1.1**) and manufacturer's instructions.

NOTE Banding and wire securements are used mainly to hold materials firmly to the plant to be insulated; they can be of metal, fabric, plastics strip, etc.

10.2.10 When fixing attachments by welding, brazing, etc., metallurgical damage should be avoided. The conditions recommended in application standards, e.g. BS EN 13480 (all parts), should be followed rigidly.

10.3 Combination

In certain circumstances, mechanical fixing devices for cladding may be attached by the use of adhesives; mechanical strength should be assessed and documented, especially for large tanks where the cladding can be subjected to substantial wind forces. The manufacturer's instructions should be followed to get the optimum cure (see **27.6.5**).

10.4 Insulation hangers

Once the hangers are correctly assembled and positioned, the insulation should be impaled on the spindles and retained in position with a self-locking washer. The insulation system should be used strictly in accordance with the manufacturer's instructions. The weight of the insulation and environmental temperature factors, such as solar gain (a particular problem associated with external cladding), should be identified and the insulation system selected or rejected accordingly. (Also see **27.6.6**.)

NOTE 1 A range of insulation hangers is available consisting of a metal or plastics base, to which a spindle is attached. The base may be perforated for attachment to substrates with a separate high-performance adhesive or supplied plain with a self-adhesive pad depending on application. Self-drilling insulation hangers complete with self-locking washer are also available.

NOTE 2 Insulation hangers are sometimes referred to as stick pins.

11 Selection of vapour barriers

NOTE The term vapour barrier is used to describe materials that are vapour retarders to varying degrees of permeance.

11.1 General

11.1.1 The designer of pipework, ductwork, associated equipment and other industrial installations should design the insulation system configuration appropriately to allow effective sealing of the vapour barrier, particularly at penetration points. The designer should also take into account localized environmental and installation conditions and the ability for the material to be effectively sealed around penetrations. The materials for use as vapour barriers should be assessed, documented and selected depending on the type of equipment being insulated, the design conditions, the type of insulant being used and the environmental conditions during application and service.

11.1.2 The vapour barrier should be used to minimize the ingress of water vapour into the insulating material. The barrier should always be applied to the warmer surface of the material (see **4.7.1**), taking the form of a coating or sheet material resistant to the passage of water vapour, i.e. of low permeability. The sealing of joints and overlaps should be effective, otherwise the vapour barrier becomes compromised and rendered ineffective (see Annex B). Insulation system design should ensure that manufacturer's recommendations can be followed. The vapour barrier should not reduce the fire performance of the complete insulation system below specified limits.

11.1.3 Self-adhesive foil tape for heating, ventilation and air-conditioning (HVAC) applications should be used for effective sealing of foil vapour barriers, but it should be verified with the tape supplier that it is compatible with the foil and fit for purpose.

NOTE 1 Where poor adhesion occurs due to surface contaminants, application of extra adhesive might be necessary.

NOTE 2 For further information on the relationship between water vapour pressure and water vapour barriers, see Annex B.

NOTE 3 Unless it is possible for moisture to be re-evaporated, it can be absorbed into permeable insulating material that might be applied to the cold surface, increasing the thermal conductivity of that material. This impairs its insulating properties and creates a risk of corrosion under insulation.

11.1.4 Unless the insulation has sufficient integral vapour resistance and the joints remain sealed throughout the lifetime of the installation, all insulation on plant working any time at sub-ambient temperatures should have an additional vapour barrier layer over the outer (warm face) surface. This barrier should be resistant to the passage of water vapour and it should be applied to the dry insulation immediately after the latter has been fitted. The properties of the vapour barrier should have attained their optimum values before the plant is operated.

NOTE The effectiveness of the vapour barrier is expressed in terms of the rate at which water vapour is transmitted through it under defined conditions, e.g. by a "permeability" value or a "permeance" value. Permeability relates to the rate of transmission through unit thickness (normally 1 m) of the material whereas permeance relates to the total rate of transmission through the actual thickness of a particular material, as applied. Whereas "permeability" is a characteristic of a given material, "permeance" relates only to a particular layer of known thickness after application. Typical values for some vapour barrier layers are shown in Table 6 and conversion factors are shown in Table 7.

11.1.5 Where insulation is installed over porous structures, e.g. concrete, the porous surface should be sealed.

11.1.6 For below ambient service temperature, multiple vapour barriers may be necessary; manufacturers' advice should be sought.

11.1.7 For below ambient operation, the vapour barrier layer should not be exposed to mechanical damage.

11.1.8 If a weatherproof outer finish is used, its emissivity should be assessed and documented. Vulnerable vapour barriers should be mechanically protected.

NOTE A low-emissivity surface reduces solar absorption. However, this increases the chance of surface condensation compared with a high-emissivity finish on a below ambient insulation system. In many humid climates, condensation is a more onerous problem than heat gain and so a high-emissivity finish is favoured.

11.1.9 The compatibility of the vapour barrier material with the chosen insulation should be identified and the material accepted or rejected accordingly, e.g. solvent-based materials should not be used directly over polystyrene.

Table 6 **Typical values for water vapour permeance**

Material	**Thickness** mm	**Permeance (maximum)** kg/(m² s Pa) SI unit	**Permeance (maximum)** g/(m² 24 h mmHg) metric perm
(A) Liquid-applied			
(1) Emulsion-based			
Bitumen emulsion	3.2	4.601×10^{-11}	0.530
Rubber/bitumen emulsion	3.2	3.038×10^{-12}	0.035
Homopolymer emulsion	0.4 to 1.6	5.703×10^{-11} to 2.900×10^{-11}	0.657 to 0.334
Copolymer/polymeric emulsion	0.8	7.987×10^{-12}	0.092
(2) Solvent-based			
Bitumen mastic	0.8 to 3.2	1.997×10^{-13} to 5.990×10^{-13}	0.002 3 to 0.006 9
Polymeric mastic	0.5 to 3.2	1.701×10^{-11} to 1.937×10^{-12}	0.196 to 0.029
Elastomeric mastic	1.6	2.672×10^{-12}	0.040
(3) Non-solvented			
Epoxy resin	2	3.125×10^{-12}	0.036
(B) Dry membrane/sheet			
(1) Aluminium foil-based			
Foil/kraft (FK)	0.008 (foil)	2.396×10^{-11}	0.276
Foil-scrim-kraft (FSK)	0.008 (foil)	2.396×10^{-11}	0.276
Foil polyethylene-glass reinforcement	0.02 (foil)	1.500×10^{-12}	0.009
Foil	0.02 to 0.05 (foil)	7.813×10^{-14}	0.000 9
(2) Compounded sheeting			
Multilayered laminate	Plain 0.18/ stucco 0.36	0.00	0.00
Polyisobutylene (PIB)	0.8	1.476×10^{-12}	0.017
Rigid PVC (UPVC)	0.35	1.997×10^{-12}	0.023
Elastomeric, fire retarded	0.06	1.476×10^{-12}	0.017
(3) Single polymer sheeting			
Polyethylene	0.05	3.073×10^{-12}	0.046
Polyester	0.025	3.073×10^{-12}	0.046

Table 7 **Water vapour permeance conversion**

	kg/(m^2 s Pa) SI unit	g/(m^2 24 h mmHg) metric perm	gr/(ft^2 h inHg) US perm	lb/(ft^2 h atm) (see Note 2)	gr/(ft^2 h mbar) (see Note 3)	g/(s MN)
kg/(m^2 s Pa) SI unit	1	1.152×10^{10}	1.749×10^{10}	7.471×10^{7}	5.161×10^{8}	1.000×10^{9}
g/(m^2 24 h mmHg) metric perm	8.681×10^{-11}	1	1.517	6.486×10^{-3}	4.481×10^{-2}	8.681×10^{-2}
gr/(ft^2 h inHg) US perm	5.719×10^{-11}	6.590×10^{-1}	1	4.275×10^{-3}	2.951×10^{-2}	5.719×10^{-2}
lb/(ft^2h atm) (see Note 2)	1.339×10^{-8}	1.542×10^{2}	2.339×10^{2}	1	6.909	1.339×10^{1}
gr/(ft^2 h mbar) (see Note 3)	1.937×10^{-9}	2.233×10^{1}	3.388×10^{1}	1.447×10^{-1}	1	1.937
g/(s MN)	1.000×10^{9}	1.152×10^{1}	1.749×10^{1}	7.471×10^{-2}	5.161×10^{-1}	1

NOTE 1 To convert units in the first column to the units shown in the heading of the following columns, multiply by the factor given at the intersection of the appropriate row and column.

NOTE 2 This is the term sometimes used by the building industry.

NOTE 3 The symbol "gr" refers to grains (1 gr = 15.4 g).

11.1.10 The vapour barrier should be selected from the following materials with any joints sealed in accordance with manufacturer's recommendations.

a) Wet-applied vapour barriers comprising cut-back bitumens, bitumen emulsions with or without elastomer latex, vinyl emulsions, and solvent-based polymers. They may be reinforced with cotton scrim cloth or open-mesh glass fabric.

b) Neutral petrolatum compound or sealing tape based on synthetic fabric impregnated and coated with neutral petrolatum compound. They can be used for sealing awkward profiles.

c) Elastomer sheets. They can be folded to provide for contraction and other movements whilst maintaining good resistance to the transmission of water vapour; joints should be sealed with an adhesive and the overlaps should be at least 40 mm.

d) Polyvinyl chloride, polyethylene, polyisobutylene, or other plastics tapes or sheets. They can be used on insulated pipes.

e) Epoxy and polyester resins. They provide resistance against mechanical damage, together with protection against the weather and chemical spillage.

f) Metal foils. If used alone, they should be durable or laminated to a suitable reinforcing substrate.

g) Polymer finishes such as silane-modified (MS) polymers and silicon polymers.

h) Insulation materials with a factory-applied vapour barrier.

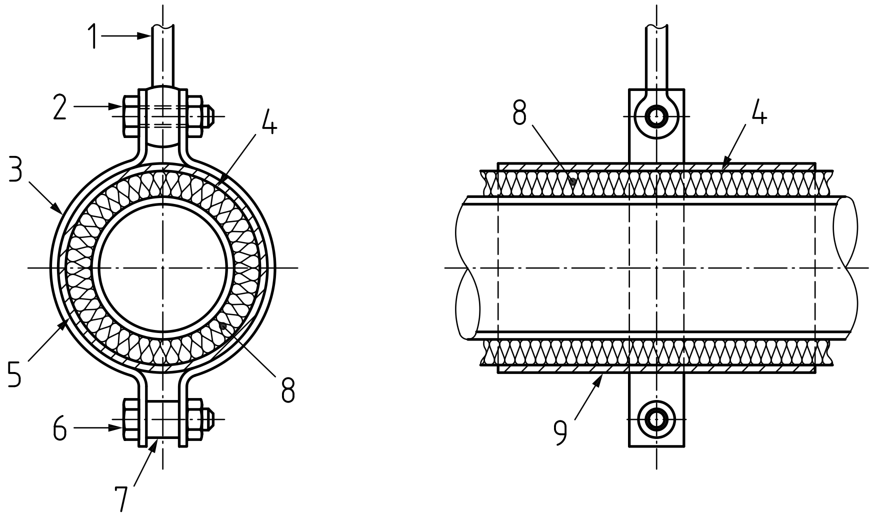
i) Aluminium and polyester layered laminate with a cold weather acrylic pressure sensitive adhesive. They can be used for insulation, cladding and jacketing to provide resistance against mould, UV and the weather.

11.1.11 If the fire performance characteristics of the insulation system used for cold work are not sufficient for the given application, an additional finish should be used, e.g. sheet metal, fire-resistant mastic, intumescent epoxy, or another type of vapour barrier suitably protected.

11.1.12 Before the vapour barrier is applied, the insulant should be smooth and regular with all surfaces carefully butted together. Any adhesives or joint sealants should be fully cured and installed in accordance with manufacturer's recommendations. If the vapour barrier is a wet-applied coating or mastic, all corners on the insulant should be radiused.

11.1.13 For below ambient applications, the supports for pipes and vessels should be external to the vapour barrier. The insulation inside the vapour barrier should be load bearing and of the same or compatible material, see Figure 12 to Figure 15. Support insulation should be protected from environmental conditions until the vapour barrier is complete. Wooden blocks should not be used for below ambient applications. Where the load bearing insulation differs from the general insulation, an adhesive compatible with both materials should be used where adhesive is specified by the adhesive manufacturer and/or the manufacturer of the insulation or load bearing insulation.

Figure 12 **Preferred option – Hanger incorporating load-bearing insulation (for pipes operating above or below ambient temperature)**[A)]



Key

1 Sling rod

2 Load bolt

3 Steel pipe

4 Vapour barrier

5 Steel sheath (split)

6 Clip bolt

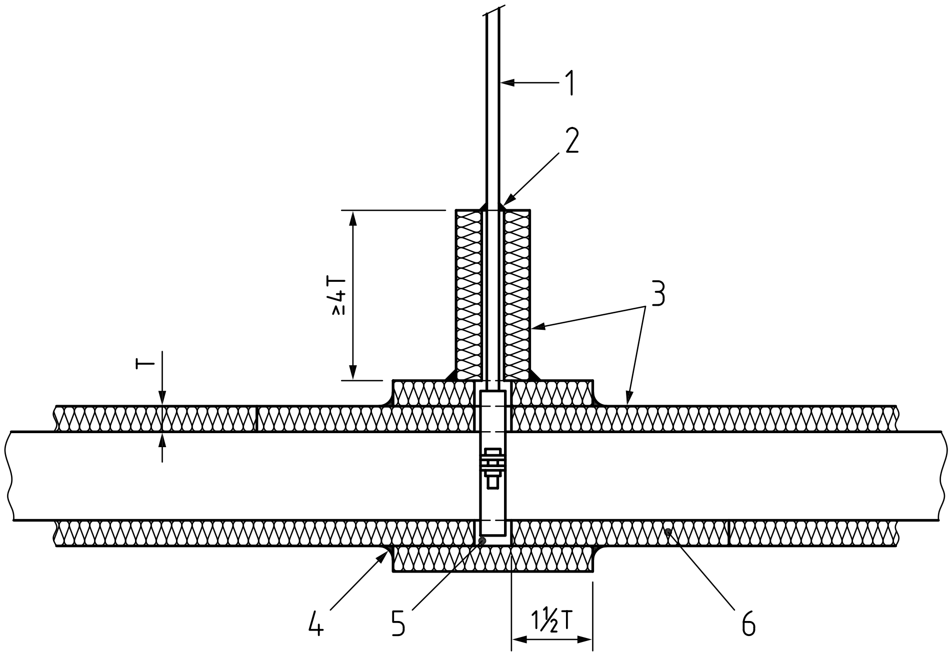
7 Distance piece

8 Load-bearing insulation

9 Load-bearing steel sheath

A) Wood blocks should not be used.

Figure 13 **Non-preferred option – Hanger in direct contact with pipe (not for pipes operating below ambient temperature)[A)]**



Key

1 Hanger rod

2 Flash finish around hanger rod

3 Finish

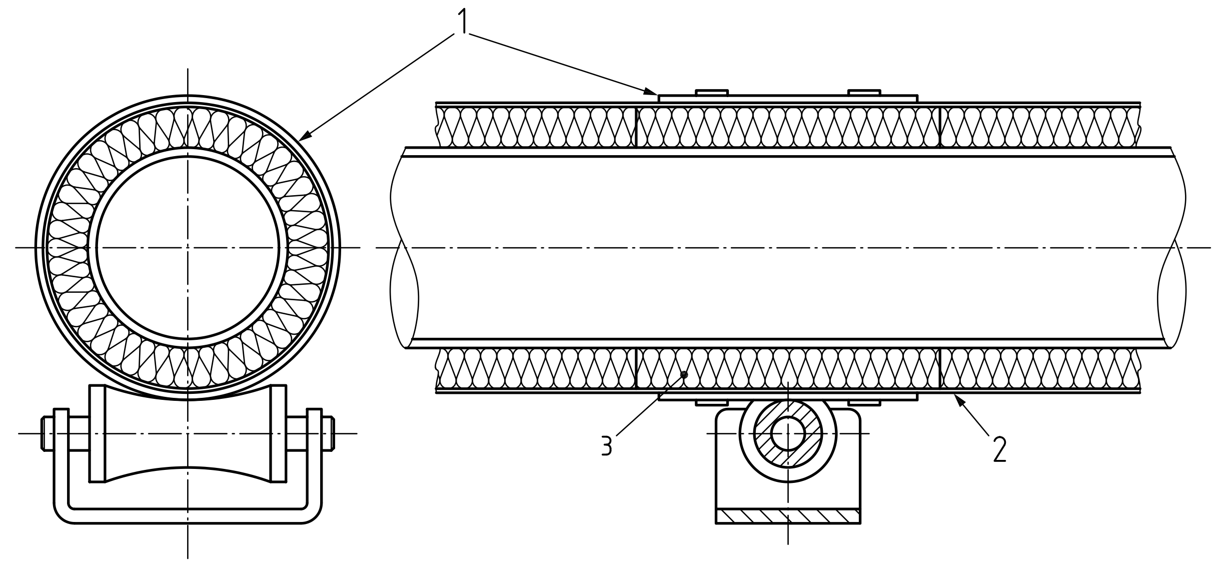
4 Heavy fillet of caulking mastic

5 Flexible insulation

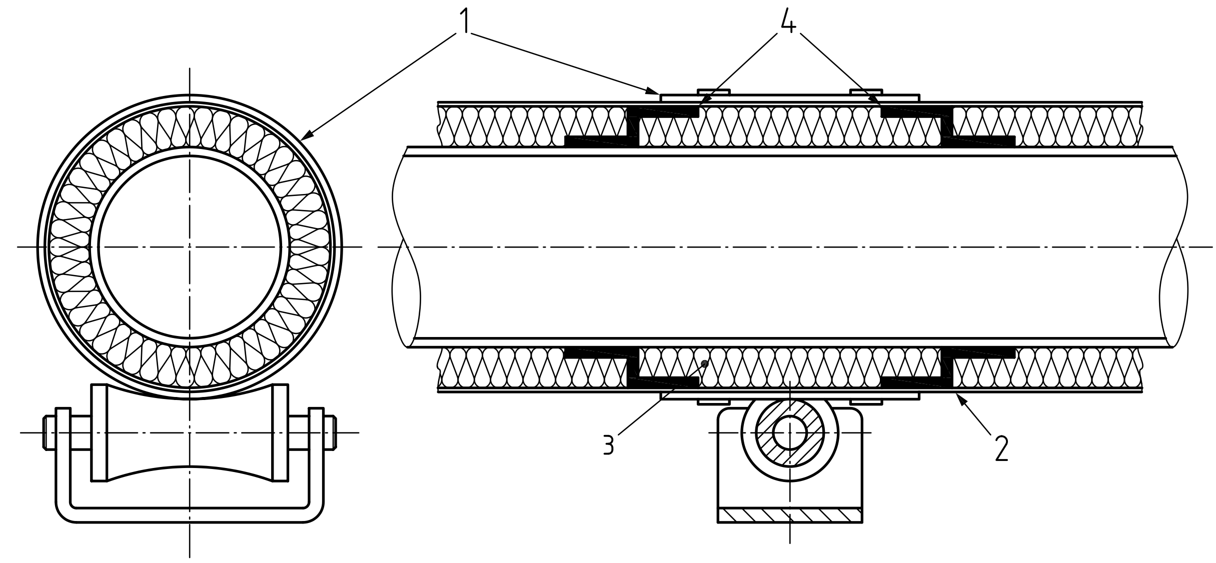
6 Insulation

A) Wood blocks should not be used.

Figure 14 **Typical roller support incorporating load-bearing insulation**A)



a) For pipes operating below ambient temperature



b) For pipes operating above ambient temperature

Key

1 Steel casings secured by bands or clamps

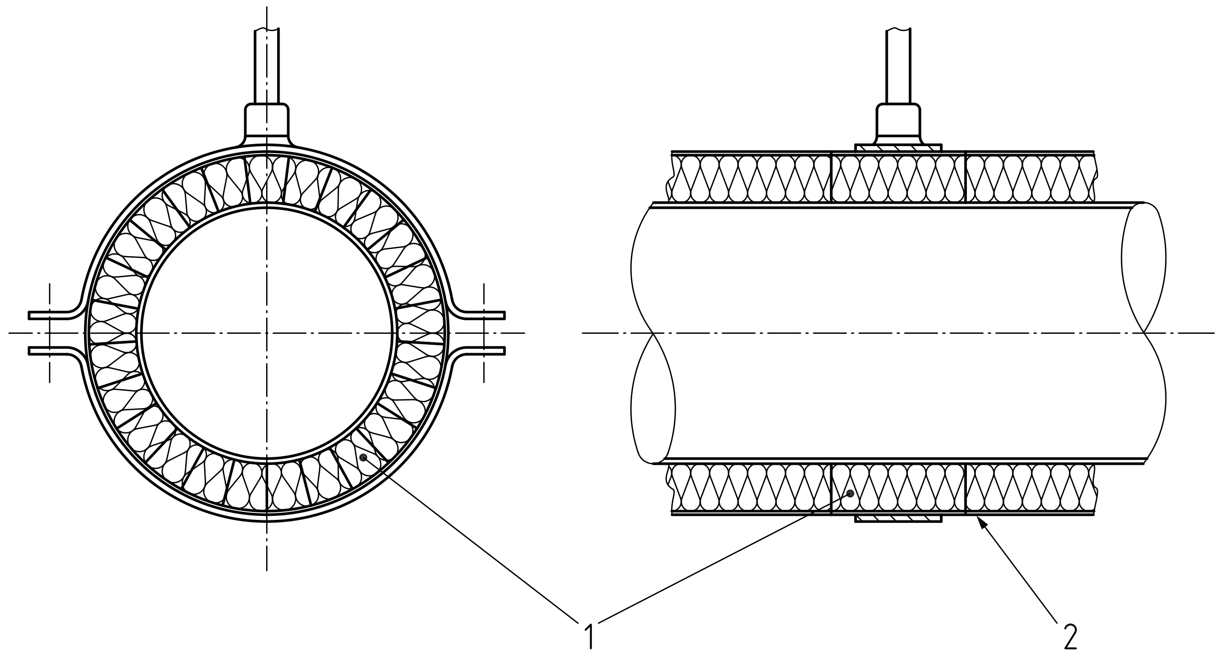
2 Insulation finish continuous through steel casings

3 Pipe support incorporating load bearing insulation insert. Insert as supplied complete with vapour barrier steel casings and bands

4 Vapour barrier

A) Wood blocks should not be used.

Figure 15 **Typical support for circular ducting incorporating load-bearing insulation (operating above or below ambient temperature)**[A)]



Key

1 Segmented strip incorporating load-bearing insulation segments bonded to flexible membrane (usually reinforced foil)

2 Insulation finish continuous through support bracket

A) Wood blocks should not be used.

11.1.14 For maintenance purposes where insulation is removable, e.g. at flanged joints, at manholes, the main insulation should be cut short of the fitting and the vapour barrier sealed directly to the pipework or shell of the vessel. The removable portion of the insulation should be fitted as a separate item with its vapour barrier overlapping and sealed to the main vapour barrier.

11.1.15 Where the service temperature of the plant cycles above and below the temperature of the ambient air, the vapour barrier/breather system should be designed to take into account the maximum and minimum temperatures, the time periods over which the plant-temperature cycles and the type of insulant used.

11.1.16 The vapour barrier should be installed over the insulation on all plant working at temperatures below the ambient air.

NOTE Pipework and equipment essentially provides a non-permeable base surface that, if excessive accumulation of water is to be avoided, theoretically requires the lowest possible permeance for an insulation system. However, constraints such as combustibility, durability and chemical resistance often preclude the selection of components with the lowest water vapour permeance. Field experience often shows that a selection of mastics and coating compounds, in conjunction with insulating materials of adequately low permeance rating, can give good practical service provided that they are associated with good joint-sealing technique and, especially for very low temperatures, with the use of mid-layer sealants or vapour barriers.

11.1.17 The relevant dry finished thickness of the vapour barrier layer should be specified at the same time as the claimed permeance values. Also, because the method of test can introduce substantial variations in permeance values, the relevant method used should be documented to substantiate claims for permeance values.

NOTE Typical values for the water vapour permeance of some materials are in Table 6.

11.2 Vapour barriers for use over insulation applied to surfaces below dew-point

Because it is essential to prevent the condensation of moisture with the consequent risk of ice formation within the insulation material in zones that are below freezing point, a vapour barrier should be used.

NOTE 1 The condensation of moisture within the insulating material can lead to eventual saturation of the material, with possible resultant mechanical and physical deterioration within the insulation system, and risk of corrosive attack on the insulated metal surface.

The barrier should not be used as the exposed surface finish if it is likely to be damaged during service.

*NOTE 2 Even penetration by pin-holes impairs the effectiveness of the vapour barrier (see **11.1**).*

12 Selection of finishing materials, including ultimate treatment of finish

12.1 General

12.1.1 The properties of thermal insulating materials should influence the choice of protective covering, for example, a wet applied coating should have a firm base to which it can be applied effectively.

NOTE If self-supporting sheet material is used, insulation materials of lower compressive strength may be used.

12.1.2 A vapour barrier should be used for the insulation of plant at sub-ambient temperatures.

12.1.3 At sub-ambient temperatures, both the insulating material and the finish should be of a type that does not require heat for drying out.

12.1.4 To exclude all moisture from the insulation system, only dry materials should be used and they should be maintained dry before the vapour barrier layer is applied.

12.1.5 The joints of sheet finishing materials should be sealed, especially those used for outdoor work.

12.1.6 Overlaps should be arranged to shed water or other liquid spillage, and it may be necessary to protect the inner surface of metal covering to avoid corrosive or galvanic action from condensed moisture.

12.2 Classification of finishing materials

Finishing materials should be classified under the following six broad categories.

a) Sheet materials, e.g. metal, plastics sheet, insulation board, metal foils (or foil laminates), woven mesh. Sheet metal may be profiled or flat sheet of aluminium or steel with or without anti-corrosion finish.

b) Synthetic sheet materials, e.g. ethylene propylene diene monomer (EPDM), UV-cured glass reinforced plastic (GRP), glass reinforced epoxy (GRE), chloro-sulphonated polyethylene, polyisobutylene (PIB), multi-layered aluminium laminate.

c) Liquid solutions and dispersions, e.g. weatherproofing and decorative coatings (organic solvent or water-based). They may be applied manually or by spray-gun.

d) Polymer coatings, e.g. silane-modified polymers, silicone.

e) Dry mixtures brought to paste consistency with water, e.g. hard-setting composition, self-setting cement, gypsum plaster.

f) Woven or knitted fabrics, roofing felt, or fibrous sheet materials that can be based on cotton, jute, organic polymer, or glass fibre. These materials may be further treated with a decorative solution or dispersion for identification or surface protection.

NOTE The materials in e) and f) are becoming less frequently used.

12.3 Reasons for use of finishing materials

The following reasons should be referred to when selecting finishing materials:

a) to protect against water, ice, snow, airborne deposits, sunlight or ozone;

b) to minimize the risk of corrosion to the substrate;

c) to protect against mechanical damage;

d) to constrain the insulation;

e) to help to identify the pipe or vessel, in accordance with BS 1710;

NOTE 1 This can be achieved by painting, either with a characteristic colour or with coloured bands at intervals. This identification can also be used to indicate the direction of flow for the fluid contents.

f) to protect against excessive moisture, corrosive vapour, etc. in the atmosphere;

g) to protect against spillage of oils and other flammable liquids;

h) to influence thermal efficiency of the insulation system;

NOTE 2 The significance of the influence varies depending on the conditions and the environment.

i) to improve appearance or to provide a surface that can be cleaned easily;

j) acoustic barrier material;

k) to influence the surface temperature of the insulation for reasons of condensation control and personal protection;

l) to retard, or if possible to prevent, the spread of flame; and

m) to protect against chemical attack, vermin, and mould growth.

12.4 Typical uses for finishing materials

12.4.1 General

The characteristic properties of the six main types of finishing materials (see **12.2**) should be referred to when choosing an insulation system for particular applications.

12.4.2 Sheet materials

The following points should be taken into account when using sheet materials.

- Rigid finishing materials may be used for their resistance to mechanical damage in at-risk areas. Where aluminium is used, it should be isolated from dissimilar metals.

- Profiled sheet metal may be used to give increased rigidity, while permitting lateral expansion movement. If there is a danger of condensation on the inner surface of the metal that is in direct contact with the insulating material, the contact surface should be protected with a coating before site application.
- Metal foils may be applied over insulation on pipework, particularly where they are not vulnerable to mechanical damage, but where an attractive appearance is required.
- Organic polymer films may be used for similar purposes and may be combined with metal foil, e.g. polyethylene-backed aluminium foil, to give improved durability. They should be secured to the surface of the insulating material by means of an adhesive.
- Glass reinforced plastic may be used to give a tough board-like finish of limited flexibility in thin sheet form.

12.4.3 Synthetic sheet materials

The following points should be taken into account when using synthetic sheet materials.

- Synthetic sheet materials, see **12.2**b), may also be used for their resistance to mechanical damage in at-risk areas as an alternative to traditional sheet metal cladding on pipes, ducts, tanks and vessels. They should be applied in accordance with the manufacturers' instructions. They should not be applied where there is contact with hot surfaces, e.g. at terminations, name plates or around insulation penetrations that are above the maximum manufacturers' recommended temperatures.

  NOTE These materials can be particularly effective as a cladding for sealing around complex configurations.
- Chloro-sulphonated polyethylene sheet is flexible and may be applied over flexible insulation.
- Ultra-violet cured glass reinforced plastic may be used to give a tough board-like finish of limited flexibility in thin sheet form.
- Aluminium foil laminates in sheet or self adhesive format may be used as a vapour barrier.

12.4.4 Liquid solutions and dispersions

The following points should be taken into account when using liquid solutions and dispersions.

- Solutions or dispersion coatings may be used for mechanical protection or for weatherproofing. They may also be self-coloured for decorative purposes when applied over the finishes indicated in **12.2**e). Alternatively, they may be applied over the sheet materials of the type described in **12.2**f).

  NOTE 1 They may be of bituminous or polymeric plastics compounds, varying in consistency from a heavily filled viscous mastic designed for trowel application to a mobile liquid for application by brush or spray-gun.
- Aqueous dispersions/solutions in organic solvents should be applied by brush or spray-gun.

  NOTE 2 After drying, aqueous dispersions can give films that are permeable to water vapour (the so-called "breather coats"), whereas solutions in organic solvents can give dry films of low permeability.

  NOTE 3 Thickness can vary according to the degree of protection required, but the final dry films for most normal coatings are likely to be about 1 mm or less. Mastics, which are heavy dough-like products of asphalt, bitumen, or polymeric *plastics compounds, are used mainly as "high-build" coatings, usually thicker than 1 mm. All of them may be reinforced with short man-made mineral fibres to give increased durability.*

- For heavy-duty weatherproofing, the finishing material should be applied in two layers with open-mesh reinforcement to give a final dry thickness of 1 mm to 2 mm. The two coats should be of different colours to indicate correct application.

  *NOTE 4 There is an extensive range of flexible protective sheet finishes based on some form of textile product, e.g. woven glass fabric or cotton fabric [see **12.2**f)].*

12.4.5 Polymer coatings

The following points should be taken into account when using polymer coatings.

- Polymer coatings such as silicones and silane-modified polymers may be both site-applied and factory pre-applied without reinforcement scrim and can be used for a wide range of hot and cold temperatures. Since they may be used for both jointing and coating, they allow application without secondary jointing adhesives or tapes and so allow a continuous finish across joints, reducing risk of sealing failure. They may also be used for coverage of irregular surfaces, including bends.

NOTE Their permanent flexibility and elongation properties allow them to be used for terminations and to absorb a degree of thermal expansion/contraction movement.

- They are generally solvent-free products so shrinkage and age-hardening ought to be avoided.

12.4.6 Dry mixtures brought to paste consistency with water

The following points should be taken into account when using dry mixtures brought to paste consistency with water.

- Dry mixtures brought to paste consistency may be used for coverage of irregular surfaces, including bends, for hot work and as joint filler. It may be reinforced with expanded metals or open weave glass mat.
- It should be dried out in situ.

12.4.7 Woven or knitted fabrics

The following points should be taken into account when using woven or knitted fabrics.

- Flexible sheet materials of organic polymeric compound, e.g. flexible polyvinyl chloride or polypropylene, may be used as integral dry finishes over pre-formed pipe sections. They should be secured to the outer surface of the insulating material with an adhesive. They may also be applied as an outer covering to improve the finished appearance of the insulating material.
- After application to the surface of the insulating material, the woven or knitted textile fabric may be treated with a polymeric plastics coating by brushing or by spraying; this coating can act both as an adhesive and a self-coloured decorative finish.

12.5 Finishes for refrigeration work

Where the selected finish is inadequate as a vapour barrier, an additional vapour sealing layer should be applied.

For dry sheet finishes all joints and overlaps should be sealed. Advice should be obtained from the manufacturers concerned regarding the choice and method of application of vapour barrier material (see Clause **11**).

12.6 Finishes to improve fire protective properties

NOTE Many finishes in common use are non-combustible, e.g. glass fabric, metal cladding and foil-face mineral fabric. These provide a good degree of protection against fire, but they cannot prevent an involvement of combustible materials in a developed fire or the production of smoke in the earlier stage of a fire, thus obstructing a means of escape and creating a fire-fighting hazard. Oil-resisting compounds are often used to protect insulating material against the spillage of flammable liquids, which could be absorbed in porous materials and so create a fire hazard.

12.6.1 Finishes should display an appropriate level of fire and smoke performance for the locations, environments and fire hazards to which they are likely to be exposed. Attention should be given to areas remote from fire danger such as escape routes and ceiling voids. Manufacturers should be consulted with regard to choice, permanence of effectiveness and method of application (see also **7.9**).

NOTE The results obtained from the surface-spread-of-flame test, for the same applied finish, vary in practice depending on the insulation system used. General guidance on the effect of thermal characteristics on the performance of assemblies is given in BS 476-6:1989+A1, Appendix B and BS 476-7:1997, Appendix B.

12.6.2 Steel cladding should be used in preference to aluminium where there is a risk of development of fires due to the low melting point of aluminium.

12.7 Finishes for use over pipes in enclosed spaces, ducts, subways and beneath buildings

Finishes should be chosen from those recommended in **12.4** (see also BS EN 13599 and BS EN 13941. The fire and smoke hazard presented by some finishes should be assessed and documented, particularly when the ducts are used for the passage of air or when subways are used as a means of escape for personnel.

12.8 Ultimate treatment of finish

12.8.1 General

Where necessary, the need for additional treatments for the finishes recommended in **12.4** should be assessed and documented, e.g. for identification purposes, for colour blending with the environment or to provide additional corrosion and chemical resistance.

12.8.2 Painting

NOTE The distinction between paints, polymeric coatings and mastics is primarily one of application consistency and dry film thickness. Paints are generally more fluid and of lower "build" than polymeric plastics coatings and mastics, but they are used widely to confer extra protection, to provide a smooth outer surface, and to improve the final appearance.

12.8.2.1 Painting as a final finish

The application of a paint or coating should not diminish its resistance to fire.

No aluminium paint, whatever its base, should be used in flammable atmospheres if the painted surface is likely to be heated to a temperature of 150 °C or above.

NOTE Below this temperature, aluminium paint may be used on ferrous metals, even when the surrounding atmosphere can be flammable.

12.8.2.2 Indoor applications

NOTE Paint may be used over indoor finishes to provide a smooth surface and can serve the dual purpose of identifying the contents of pipes by colour (see BS 1710). Tinted coatings are also available.

Hard-setting composition, self-setting cement, gypsum plaster, and all woven fabrics applied directly to the insulating material, may receive an initial coat of size or copolymer emulsion coating that should be allowed to dry before the paint is applied, in a minimum of two coats.

12.8.2.3 Outdoor applications

NOTE 1 Paint or polymer coatings may be applied for decorative and protective purposes.

Bituminous-based paints should be used over bituminous weatherproofing finishes, including roofing felt, using an intermediate coat of aluminium sealer containing flake aluminium. Polymeric primers should be used for self-setting cement finishes due to possible alkaline reaction (see **30.4.3** and **31.4.2**).

NOTE 2 Paints based on chlorinated rubber, epoxy-resin or polyurethane provide good protection over many insulation finishes, particularly in corrosive atmospheres.

NOTE 3 Aluminium and galvanized mild steel might require a primer before the application of certain undercoats and gloss paints.

12.9 Identification of the contents of an insulation system

Methods of identification of pipe lines and services should be in accordance with BS 1710.

NOTE BS 1710 provides examples of colour identification and suggests methods for incorporating ground colour, bands and indications of direction of flow, etc.

13 Selection of thermal insulation systems

13.1 General

The components of the insulation systems for pipework to flat surfaces (e.g. air ducts, gas flues, walls of drying ovens, walls of large boilers), and to vessels, tanks and large curved surfaces should conform to the specific requirements of use.

For example, different types of insulation system might be required for the following applications and should be designed for their specific uses:

a) refrigeration;

b) chilled and cold water supplies, industrial use;

c) central heating, air conditioning, and domestic hot and cold water supplies;

d) warm/hot process pipework and equipment;

e) cold process pipework and equipment;

f) dual-temperature insulation systems, e.g. refrigeration with occasional use at higher temperatures; and

g) heat transfer fluid insulation systems.

13.2 Optimum efficiency

The designer of the thermal insulation system should ensure that optimum efficiency is derived from all components, while taking into account any limitations imposed by the purchaser. There should be quality control at all stages of manufacture of materials and at all stages of their storage and application at site.

NOTE The required life of the insulation systems affects the annual cost and hence the environmental thickness. If the plant has only a short life, an inexpensive insulation system might be adequate; if the plant has a longer life, a more expensive insulation system with longer life can be more economical.

When the technical requirements of the application have been met, the total cost (as distinct from the initial cost) during the life of the insulation should be the prime consideration (see **4.3** for environmental thickness).

13.3 Extent of insulation system

A thermal insulation system should include the following:

a) attachments to the surface to be insulated;

b) initial protection of the surface to be insulated (see Clause **8**);

c) means of securing the insulation system to attachments or to the surface directly;

d) the types and thicknesses of the insulating materials to be used;

e) vapour barrier;

f) reinforcing materials;

g) protection against weather; and

h) protection against mechanical damage.

13.4 Determining factors

13.4.1 Temperature

Thermal insulation on plant operating at temperatures below the dew-point of the surrounding air should be kept dry, both before and after application. Some form of vapour barrier should be used. For elevated temperatures, the insulating material should be resistant to the highest temperature involved under service conditions.

13.4.2 Mechanical stability

At all times, the insulation system should be resistant to vibration, mechanical damage and thermal movement, and it should retain its effectiveness and stability in service.

The insulation system, including the insulating material, the method of fixing, and the finishing material, should be capable of giving effective service during its design life.

NOTE This is of special importance for certain plant in which access for repair work can be difficult.

13.4.3 Resistance to degradation

The insulation system should be resistant to degradation from a wide variety of situations, e.g. UV, humidity, fire, chemical attack, vermin, microbiological attack.

13.4.4 Thermal efficiency

The design calculations and assessment of thermal efficiency should be applied to the complete insulation system. Manufacturer's information on product performance under the design conditions specified in Clause **5** should be applied to the insulating material. The designer should ensure the efficiency of the complete insulation system. The effect of penetrations such as thermocouples, man ways, gantry and walkway supports and any thermal bridges such as cladding supports should be assessed and taken into account. The effects of joints, layers and termination points in the insulation should also be assessed for their effect on efficiency.

13.4.5 Type and dimensions of the plant to be insulated

The insulation system should be selected for its compatibility with the size, complexity and configuration of the plant. Particular care should be taken with large flat areas, especially when elevated temperatures can cause extensive thermal movements.

13.4.6 Compatibility of the components of the insulation system

Adhesives and finishing compounds that are not compatible with other materials in the insulation system should not be used as they can cause corrosion or material deterioration.

In addition, other corrosion problems should be avoided, e.g. electrochemical action between dissimilar metals under conditions of high humidity.

13.4.7 Total weight of the insulation system

The total weight of the insulation system should be calculated at the design stage to ensure adequate support is provided.

13.4.8 Space for insulation system

Sufficient space should be provided during plant design to enable the chosen insulation system to be correctly installed and maintained at the specified thickness.

13.4.9 Potential hazard to health

It should be ensured that the insulation system selected is safe, incorporating the need for subsequent removal of the insulation. An assessment should be made based on the manufacturer's health and safety data sheet for all materials.

NOTE Attention is drawn to the COSHH Regulations [4] and the Chemicals (Hazard Information and Packaging for Supply) Regulations [5].

> **WARNING.** Certain types of fibrous insulating materials, notably asbestos and refractory ceramic fibre, and certain finely divided aggregate such as crystalline silica, can be a hazard to health when inhaled into the lungs.

13.4.10 Corrosion hazards

Precautions should be taken to minimize risk of corrosion to substrate (see Clause **8**). The risk of corrosion should be assessed with regard to operating and environmental conditions, the type of surface to be insulated and the type of insulation including protective finishes.

NOTE Insulating materials can contain soluble salts.

13.4.11 Fire hazard

The operating conditions, environmental conditions and the insulation system as a whole, including ancillary materials and finishes (see BS 5422 and BS 5908) should be assessed for fire hazards and precautions taken accordingly.

13.4.12 Environmental aspects

*COMMENTARY ON **13.4.12***

All thermal insulation products give enormous benefits to the environment because of the saving in the use of fuels resulting from their use.

The consumption of resources and energy and the consequent pollutant emissions associated with a typical product in a heating and ventilation application over its life cycle are usually only a tiny fraction (0.1% to 0.01%) of those saved by its use.

The life cycle phases of an insulation product over which resources are consumed are: pre-production, manufacture, installation, delivery to site, installation and maintenance and end of life.

NOTE 1 The life cycle analysis of the insulation system may be considered as part of the environmental evaluation (see BS 5422).

NOTE 2 Under the terms of the Montreal Protocol as enforced under EC Reg 1005/2009 [15], neither chlorofluorocarbons (CFCs) nor hydrochlorofluorocarbons (HCFCs) are permitted in the production of thermal insulation in the EU.

All insulation and ancilliary materials should be applied in accordance with the suppliers' instructions, taking into account their health and safety material data sheets. With solid materials, the spread of dust and debris from offcuts should be avoided with active maintenance. Spill kits should be available to control and manage spillages of liquids and to prevent them entering the drainage systems. All waste materials, including packaging and containers, should be disposed of.

NOTE 3 Attention is drawn to the Collection and Disposal of Waste Regulations 1988 [6].

Section 3: Site considerations

14 Basis and method of presenting schedule of work for agreement between purchaser and contractor

14.1 Before work at site begins, the "purchaser" (who could be the client, the main contractor or sub-contractors) should provide the contractor carrying out the insulation work with a clear programme indicating when the site is available and a completion date for each section of the work to allow enough time to mobilize to site with the appropriate materials and personnel. At the enquiry stage, the purchaser should indicate any special conditions known to exist. The contractor should submit to the purchaser a corresponding document giving an assurance to meet the agreed programme dates and that adequate materials and labour are available. If initial programme dates are later amended by the purchaser, they should immediately inform the contractor to adjust the execution of work to conform to the required sequence. If the contractor is unable to comply with the programme, they should inform the purchaser at the earliest possible date.

14.2 The purchaser and contractor should assess and document their responsibilities regarding supply or application of insulation-securing attachments and any necessary preparation of surfaces, e.g. removal of oil, grease and rust, painting, application of securing attachments before stress relieving.

14.3 Where areas of plant to be insulated are to be left bare for a period, e.g. to make provision for inspection or tests to be carried out later, this should be indicated to the contractor at the tender stage. Temporary terminations in the insulation system should be sealed. Before work at site begins, precise details of such omissions should be provided by the purchaser to the contractor.

14.4 Where the satisfactory application of insulating and finishing materials can be dependent on weather conditions, including frost, rain, ambient air-temperature and humidity, the work area should be protected and manufacturers' installation instructions should be consulted. The protective arrangements should be agreed with the purchaser.

14.5 For the contractor to operate on an efficient and economical basis, complete sections of plant should be released for insulation installation and any limitations of access should be notified.

14.6 The contractor's tender and purchaser's subsequent requisition should contain a clear description of the extent of work covered by the contract. If the contractor is requested at site to carry out work outside the scope of the contract, immediate discussion regarding responsibility should be arranged with the purchaser. The additional work should not be undertaken until written instructions have been issued to the insulation contractor. Any additional cost should be agreed at the same time.

14.7 If a contractor is called upon to repair or modify previously completed work, the purchaser and contractor should immediately agree to a procedure for carrying out the additional work. It is customary for extra work of this nature to be executed on a "time and material" basis; the contractor should submit weekly sheets to be certified by the purchaser if such a procedure is adopted. The "time and material" sheets should contain a description of the work carried out, together with precise details of materials used and hours worked.

14.8 Before work at site begins, the purchaser and contractor should be in complete agreement regarding the extent of a contract working week, working conditions for personnel and all other items that affect the maintenance of previously approved programming.

14.9 There should be agreement between the purchaser and contractor on the need for and protection of completed work after handover.

NOTE There can be issues when finishing activities such as commissioning and scaffold dismantling damage the completed insulation system.

15 Packaging and transport to site

15.1 Methods of packing

Insulating materials should be packed in cartons, crates, bags or shrink film wrapping to minimize mechanical damage and to avoid contamination.

15.2 Protection against crushing

Stacking of packed insulation should be limited in accordance with the nature of the material and manufacturer's recommendations (see **17.3**, **17.4**, **17.5** and **17.6**).

15.3 Packing of plastic compositions and finishing compositions or cements

Packing of compositions should take into account the bulk of the material to ensure that the size of bags is convenient for handling.

15.4 Methods of identification of packages

All forms of packaging for insulating materials should be carefully marked. The marking should indicate the type of material and the size, thickness, quality and quantity contained in each package. Where required by the purchaser, the manufacturer's identification reference should be shown.

Where required by the purchaser, the packages should be marked to show the particular section of plant on which the contents are to be applied. All packages should clearly show the purchaser's contract number and supplier's identification number. Where possible, each consignment should be readily identifiable against the names of the consignee and the consignor.

The total weight of the materials should be recorded on the outside of the packages to enable the contractor to adequately assess the manual or mechanical handing requirements.

Products should conform to the relevant European standard (see Table 1 to Table 4 as appropriate).

NOTE Such products display a CE mark as a declaration of conformity to the relevant standard.

16 Labour and supervision

The contractor should provide labour trained and skilled in the use and application of the materials and equipment they are required to handle for a specific contract. At the enquiry stage, the purchaser should indicate any special labour conditions known to exist.

When issuing the enquiry, the purchaser should indicate the level and method of supervision expected from the contractor.

17 Provision of storage space, protection and safety during storage

17.1 Space should be provided for the contractor to store insulation and ancillary materials.

17.2 All materials should be stored in a dry atmosphere undercover. Manufacturer's storage instructions should be consulted in case of special requirements.

17.3 Stock rotation should be employed so that the first material supplied to site is the first to be used.

17.4 Cartons or packs containing slab insulation should be stored on a flat surface.

17.5 Bags containing mattress insulation should be stacked flat in accordance with manufacturer's instructions.

*NOTE Referring to **17.3**, **17.4** and **17.5**, stacking height is limited to prevent damage to the lower layers.*

17.6 Sheet metal should be delivered as single sheets, coils or in stacks, dependent on the type of handling facilities in the stores. The first layer of sheets not exceeding 0.5 tonnes or the first stack should be stacked on a pallet board. The second and subsequent layers or stacks should be supported on timbers, which should be spaced at not more than 600 mm between centres.

17.7 Sheet edges should be examined at least monthly to see if any discoloration has taken place. If discoloration occurs, the faces of the sheets should be examined and, if necessary, dried and re-stacked.

17.8 When storage for longer than three months is considered, the supplier should be consulted for recommendations on packaging the sheets before storage.

17.9 Adhesives, coatings and mastics should be stored undercover in a dry atmosphere in accordance with manufacturer's instructions. The shelf life and the recommended storage condition should be maintained, particularly with two-part adhesives, mastics, coatings or foam systems.

18 Provision of power, water, light, heat and accommodation for personnel

*NOTE 1 The provisions of Clause **18** may be varied by local agreement.*

NOTE 2 Attention is drawn to the Construction (Design and Management) Regulations [16].

18.1 Power and water

Connection to the supply and the provision of transformers and cables should be provided by, and be at the expense of, the main contractor.

NOTE Power and water are normally supplied free of charge by the purchaser or main contractor.

18.2 Light and heat

General lighting and heating should be provided by the purchaser or the main contractor. The provision of local lighting and heating should be subject to prior agreement. Heat for drying out plastic composition should be provided free of charge by the purchaser or the main contractor.

18.3 Accommodation and storage

Site offices and storage facilities should be provided by the contractor on a site made available by the main contractor or the purchaser. Toilets and washing facilities should be provided by the main contractor or the purchaser. Provision of site accommodation and storage should be stipulated at tender stage. Canteen facilities should be the subject of prior arrangement.

19 Provision of access equipment

It should be stipulated at tendering stage who is responsible for providing access equipment.

NOTE Attention is drawn to the Construction (Design and Management) Regulations [16].

20 Responsibility for studs, cleats, etc.

Responsibility for the supplying and/or fixing of these attachments should be by agreement at the tendering stage between the contractor and the main contractor or purchaser.

21 Observance of site safety and security regulations

The purchaser should notify the contractor of any local site safety and security regulations.

A safe working area should be defined and agreed between the main contractor or the purchaser and the contractor if other work is proceeding on site.

NOTE 1 Fires have occurred during site work involving storage and use of insulation and ancillary materials, including packaging.

NOTE 2 Guidance notes are issued by the HSE, which are periodically updated and give practical guidance on many aspects of fire safety.

22 Protection of adjacent equipment and surfaces

The protection of equipment and surfaces should be agreed with the main contractor. Items of a fragile nature should not be installed before insulation is applied.

23 Clearing waste material from site

Waste material arising from the insulating work should be removed by the contractor. Where required, insulation waste should be segregated and kept free from contamination. The installation should be kept clean and tidy at all times during the course of the contract, and left so on completion.

24 Health considerations

The contractor should take all necessary safety precautions for the materials in use and should advise the main contractor or purchaser when any health hazard exists (see **7.11**).

In addition, allowance should be made for the variation in ambient environmental conditions.

Reference should always be made to the appropriate supplier's health and safety material datasheets.

Section 4: Application methods

25 Methods of application and practical consideration

25.1 Insulating materials should be kept dry in store and during erection.

25.2 Apart from certain load-bearing materials, most types of insulating materials should be supported or reinforced when applied; they should also be secured to the surface to be insulated. For these reasons, where necessary, fixing accessories should be attached to the piping or equipment before application of the insulating material begins.

25.3 To maintain the thermal efficiency of the insulation systems, all insulating materials, however fixed, should be in close contact with the surfaces to which they are applied unless an air space is specially required, e.g. for acoustic purposes.

25.4 Where the main insulation consists of pre-formed or flexible material, all edges or ends should be closely butted; for multilayer work all joints should be staggered.

25.5 Insulation work should be carried out with the plant off-load.

NOTE In certain situations, it might not be practicable to carry out the installation with the plant off-load. In these situations, special measures might need to be taken. It might be possible to apply finishing material at service temperatures with the manufacturer's advice.

25.6 Before any section of the insulation work on piping, vessels or ductwork begins, all hangers, brackets, pipe clips, trace-heating, etc. should be in position and the necessary acceptance tests for pressure/vacuum, etc. should have been carried out.

25.7 The junction between removable and permanent insulation should be arranged so as to be readily discerned, e.g. by identification signs.

25.8 The design of plant and pipe layout should ensure that, when insulating complicated plant, safe access is provided.

25.9 The plant designer should allow a minimum clearance of 50 mm beyond the full extent of thermal movement between insulated plant and structural, or other, surfaces. Where the shielded depth is greater than 300 mm, there should be sufficient clearance for working access.

25.10 Where pipe banks against walls or ceilings are involved, the designer should take into account the sequence of the fixing of the insulating material and its finish, and should make all necessary provisions to ensure application is possible.

26 Surface preparation and accessories

NOTE Accessories comprise attachments, insulation supports, securing devices and reinforcement.

26.1 Surfaces to be insulated should be clean, dry and free from grease, dirt, loose rust, scale or any contaminants. Usually the surface should be coated (see Clause **8**). This coating should not be applied until all welded attachments have been fixed in position. However, where the coating has to be removed for the welding of additional attachments, the coating should be made good before the application of the insulation.

26.2 Other forms of surface protection should be provided for specific situations, e.g. wrapping austenitic stainless steel surfaces with aluminium foil to protect against stress corrosion (see **8.4**).

27 Securements

27.1 General

27.1.1 Unless the insulating material can be secured directly to the surface to be insulated, e.g. by means of adhesive (see **10.1**, **27.2** and **28.3**), some form of mechanical accessory should be used to secure it to the permanent attachments. The type of securement chosen should be compatible with the specified insulation material and in accordance with the manufacturer's instructions.

*NOTE Tie wires, lacing wire, washers, clips, or nuts are the most common securement associated with the types of attachment and supports described in **27.6** and **27.7**.*

27.1.2 When using bands, wire, pins/hangers or any other means to mechanically secure insulation to a surface, it should be ensured that the water vapour barrier is not damaged.

27.1.3 The vapour barrier should be maintained at all times and might require an effective foil taping over impalement locations to provide continuity.

27.1.4 Flexible insulating mattresses that have wire mesh covering integral in their construction, and have inter-surface ties, should be impaled over the main attachments and further secured by tightly fastening together adjacent edges of the outer covering mesh. The lacing wires for this purpose should be of similar metal and diameter to that used for the wire mesh. If a final covering of aluminium sheet is to be applied, direct contact between dissimilar metals should be avoided (see **8.3.4**).

27.1.5 If split-pin or fork-stud attachments have been used, the insulation should be secured by bending the prongs of the fork arrangements either through and over reinforcing mesh or through washers. Typically, the prongs of the pins/hangers or studs should be 3 mm in diameter or 3 mm^2 and the lengths should be such that the prongs can be depressed below the outer surface of the insulating material.

NOTE Washers can be 50 mm square, cut from expanded metal; approximately 10 mm mesh and 0.6 mm metal thickness are commonly used.

27.2 Adhesives and fastenings

27.2.1 Adhesives may be used to form a bond between adjacent insulation elements or the insulation and the surface to be bonded; adequate "open time" should be allowed for evaporation of the solvent before making a bond between materials of low permeance.

NOTE Most adhesives form a bond by evaporation of solvents, which can be flammable and toxic; water-based adhesives are slow drying.

27.2.2 If adhesives are used as an aid to erection, mechanical support should be provided. The manufacturer's advice on the effective temperature range of the adhesive should be sought as many adhesives do not continue to operate effectively at very low temperatures.

27.2.3 Wherever possible, and where recommended by the manufacturer, additional mechanical support should be used in the form of banding, insulation hangers or self-adhesive tapes.

27.3 Self-adhesive foil tapes

COMMENTARY ON ***27.3***

If the insulation is not installed properly using the correct securements, the insulation product can sag or become detached from the underlying surface, and can suffer from the effects of vibration.

Additionally, this can result in stresses placed on any aluminium foil tape being used. This can lead to mechanical failure between the tape and the foil covered surface of the insulation, damaging the integrity of the vapour barrier and the thermal efficiency of the insulation system.

27.3.1 Before using self-adhesive foil tape for securement, the following should be considered:

- insulation material density and thickness;
- self-adhesive foil tape strength, width and thickness, and temperature range;
- indoor and outdoor environmental conditions; and
- pipe and ductwork vibration.

27.3.2 Self-adhesive foil tape applied to circumferential joints for securement should be overlapped on to itself by a minimum of 75 mm.

27.3.3 The minimum thickness of self-adhesive foil tape used for securement purposes should be not less than 30 micron and should have a temperature range suitable for the application it is being used for.

27.3.4 Both the insulation and foil tape manufacturers' advice should be sought before using self-adhesive foil tape as a sole means of securement.

27.3.5 All surfaces should be clean and free of dust, scale, oils and other contaminants before the application of the self-adhesive foil tape.

27.4 Securement (wires and banding)

NOTE Methods include tie wires, lacing wire, bands, clips washers, nuts, etc.

27.4.1 Lacing wire

27.4.1.1 The sizes of wire should be 1 mm diameter for general use, or 1.5 mm for heavier use. For refrigeration work, plastics tapes should be used instead of wires. Other soft wires should be used for special applications.

NOTE Lacing wire and tie wire is normally made of galvanized soft iron, but one of the soft alloy-steels might be required for special chemical resistance or for use at elevated temperatures (see ***8.3*** *for temperature limitations).*

27.4.1.2 Lacing wires should be fastened either by wrapping them around each attachment or by means of nuts, clips or washers at each fixed point.

27.4.1.3 Where lacing wire is used, it should be applied so as to avoid cutting into the insulation material. If this is not possible, an alternative approach should be used.

27.4.1.4 Lacing wire that is likely to be in direct metallic contact with a final cladding of aluminium sheet should be coated with a plastics material to avoid bimetallic corrosion in the locations of contact.

NOTE Alternatively, aluminium or stainless steel securing materials may be used.

27.4.2 Bands

Bands should be corrosion-resistant, either due to the nature of the metal or by a surface treatment. If aluminium sheet has been used as the outer covering for the insulation, only aluminium or stainless steel bands should be used.

Plastics bands should be sufficiently robust to withstand prolonged conditions of service.

Where the insulation is to be clad, the securements to the pipe should only be used on the insulation if it is to be left unclad for a lengthy period of time.

NOTE Additional securements may be necessary in specific circumstances.

Self adhesive tape should not be used as a sole means of support unless recommended by the insulation's manufacturer. Additional mechanical support should be used with a minimum of two bands per section.

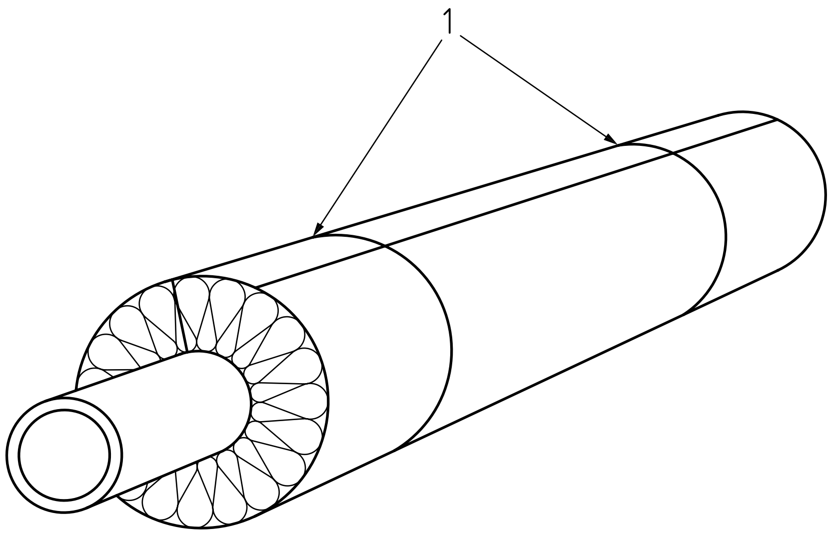
27.4.3 Pipe insulation

Pipe sections with an inner diameter of 89 mm or larger should be secured by lacing wire or metal bands, at least two bands used per section, one used at maximum 450 mm centres per section, see Figure 16. The lacing wire or bands should be positioned not less than 50 mm from the end of each section.

Also, at pipe supports and valves, the pipe section should also be secured by lacing wire or metal bands.

NOTE Some insulation materials might be damaged by lacing wire; refer to insulation manufacturer's instructions.

Figure 16 **Banding**



Key

1 Lacing wire or banding

27.4.4 Large flat surfaces

NOTE 1 For large flat surfaces, the insulating materials may be secured by impaling it over the studs or cleat attachments using lacing wire (where appropriate) to hold it in position.

If lacing wire is used, it should be wrapped round the main attachments and crossed for tensioning.

NOTE 2 With flexible fibrous mattresses enclosed in wire mesh, the outer mesh to the individual attachments may be tied to achieve securement.

The vapour barrier should be maintained at all times and might necessitate an effective foil taping over impalement locations to provide continuity.

NOTE 3 This may be improved by double layering by creating an X-shape of foil taping over impalement locations.

27.4.5 Cylindrical surfaces

NOTE For cylindrical surfaces, the complete insulation system may be secured with circumferential bands that can be tensioned over the outer surface. Wire netting over some insulating materials may be used to serve the same purpose provided that the edges are laced tightly together.

Separate securing accessories might not be necessary if an integral sheet finish is arranged so that an edge overlap can be secured by means of adhesive.

27.4.5.1 Circular ducts

Circular ducts should be secured by lacing wire or circumferential metal bands. The securements should be positioned not less than 100 mm from the circumferential joint with a minimum number of three securements per length of flexible insulation, as follows.

- For flexible insulation the securement centres should be at a maximum of 400 mm.
- The securement should not be over-tightened as thickness reduces the thermal efficiency of the insulant.
- Additional measure may be necessary to prevent sagging.

27.4.5.2 Large cylindrical vessels

Metal bands for large vessels should be of adequate width and thickness to provide stability to the insulation system under the conditions of service specified in accordance with Clause **5**.

27.5 Reinforcement

27.5.1 The main uses for the metallic reinforcement are with spray-applied fibrous insulation, wet-applied finishing compositions and wet finishing cements, but they should also be used for retaining dry fibrous insulation and various types of pre-formed materials.

NOTE 1 The most commonly used reinforcing materials are galvanized wire netting or one of the various types of expanded metal, but open-mesh woven glass fabric may be used for certain applications, e.g. the reinforcement of weatherproofing compounds.

NOTE 2 Where wire mesh is used, the mesh size of wire netting can be either 25 mm or 40 mm, with wire of 1 mm diameter; the mesh may be reduced for use over flexible fibrous materials.

NOTE 3 Expanded metal can vary from 12 mm to 50 mm across the short dimension of the mesh, with thickness of metal which can vary between 0.5 mm and 1.6 mm.

27.5.2 Galvanized steel reinforcing mesh and securing devices should not be subjected to temperatures in excess of 65 °C under conditions of possible high humidity. Heat-resisting alloy should be employed for all service temperatures in excess of 400 °C. For intermediate temperatures, carbon steel may be used, but it should be coated for protection against corrosion during storage and before application on site (see **8.3.1**).

27.5.3 Where substantial mechanical strength is required, e.g. for resistance to compression, square-pattern reinforcing mesh should be used, which can vary, according to the requirements, from strands of 2 mm diameter at 40 mm spacing to strands of 6 mm diameter at 100 mm or 150 mm spacing.

NOTE 1 The component wires may be welded together at the crossing points.

NOTE 2 Material of square mesh pattern is likely to distort on expansion at elevated temperatures if it is secured rigidly to attachments on the insulated surface.

27.5.4 Where metal reinforcement is to be located over the outer layer of insulating or finishing material and is likely to be in direct contact with cladding of a dissimilar metal, precautions should be taken to avoid electrolytic corrosion action, e.g. by the use of a coating on the inner face of the cladding or on the reinforcing metal.

27.5.5 Where mechanical strength is required, e.g. for puncture resistance, open-weave glass or polyester cloth or scrim should be embedded between layers of weatherproof or vapour-proof mastics.

27.6 Mechanical securements (attachments)

27.6.1 Attachments should be used either for the direct support of insulating materials or as fixtures to which insulation supports may be secured, e.g. by bolting (see Clause **20**).

NOTE Some types of fittings may be fixed to the surface with an adhesive subject to temperature limitations. Attachments for welding may be flat or angle cleats, pipe bosses, threaded pillar nuts, washers or nuts welded "on edge", or studs of various kinds, e.g. round, flat, split pins, fork studs. The term "attachment" is used for any anchor fitting fixed permanently to the surface to be insulated, usually by welding.

27.6.2 The contact area for application of stud-welded attachments should be related to the thickness of metal to which each one is to be applied so as to avoid lack of fusion, undercutting or over-penetration. If the metal of the surface to be insulated is of such thickness that it cannot be adequately heated during welding, local supplementary heating should be applied.

NOTE Attachments for application by welding gun can have flux in the contact end or edge, but pins/hangers of 3 mm diameter can usually be gun welded without flux.

27.6.3 Where angles, flat cleats and similar large attachments are used, they should be secured by electric arc welding or gas welding. A procedure appropriate to the materials, the thickness of the component and that of the attachment should be used. Pins/hangers and studs should be attached using a gun welding system.

27.6.4 For surfaces on which site-welding of attachments is not recommended, e.g. for certain types of alloy-steel, or where subsequent internal temperature and pressure could be a hazard, metal pads may be welded in appropriate locations. These should be applied during manufacture of the equipment at the works and require subsequent stress relieving; the attachments should be fitted to the pads at site (see Figure 10).

27.6.5 For the choice and methods of attachment of plastics or metal support clips with an adhesive, the adhesive manufacturer's literature should be consulted.

NOTE These clips are usually formed with an integral perforated flat base that allows penetration of the adhesive through to the upper surface.

27.6.6 Where adhesive insulation hangers are applied to flat smooth surfaces, e.g. galvanized metal or plastics ducting, the surface should be free from contaminants, scale or oxidants. The weight and type of materials to be secured should be considered along with service temperature and application ambient temperature limitations including cure times of any adhesives used. None of these limitations should be exceeded and the adhesive insulation pin manufacturer's instructions should be referred to. The possible effects of vibration, ambient conditions, weight of insulation and orientation of equipment when using any adhesive insulation pins/hangers should also be taken into account. Consideration should be given to attaching adhesive insulation hangers (metal) on side walls and undersides of ductwork with a self-sealing pop rivet of compatible material (metal) to additionally secure the insulation hanger in the event of moisture attack or vibration loosening the adhesive backed insulation hanger from the surface.

NOTE 1 This is common practice in the industry with insulation hangers (metal) so long as self-sealing pop rivets are used, not impacting with duct pressures and air leakage.

NOTE 2 Caution is advised when proposing the use of self-adhesive insulation hangers in place of perforated plate pins and separate adhesive.

27.6.7 Split pins, fork studs and similar fastenings should follow the recommendations for studs, see **27.6.1** to **27.6.6**; the contact area should not exceed 80 mm^2.

27.6.8 When welding, the difference in thermal expansion between the welded contact edge and the free edge should be assessed and, if it is significant, distortion of the attachment should be avoided by the introduction of saw cuts at intervals along the free edge; these cuts should penetrate to a distance of approximately half the width of the attachment.

NOTE 1 Typical attachments for gun welding are plain pins of 3 mm diameter, end-fluxed studs of 10 mm diameter (plain or threaded), flat cleats 12 mm wide and 3 mm thick (or similar angle-welded on edge), threaded pillar nuts up to 12 mm diameter, etc.

*NOTE 2 The use of hand-welding technique can enable the application of attachments with larger contact areas than those indicated in **27.6.7**. With relatively long angles or cleats, intermittent (stitch) welding may be used.*

27.6.9 To avoid mechanical damage to the stud during transit or during erection of the plant, a thick threaded nut should be welded on to the surface to be insulated, providing a fixture into which a threaded stud can be screwed at a later stage.

27.6.10 The locations of attachments should be determined by calculating the weight of insulation to be attached, as well as on the size and orientation of the surface and on the degree of vibration to which the plant can be subjected under service conditions. There should be a row of attachments parallel to each edge and to each stiffener or flange, and at a distance of 75 mm to 150 mm away from the edge; alternate rows may be offset by 50% of the spacing, depending on the dimensions of the material used. For large surfaces, average spacings should be:

- vertical surfaces: 450 mm square spacing;
- upward-facing surfaces: 600 mm square spacing; and
- over-hanging and downward-facing surfaces: 300 mm (maximum) square spacing.

27.6.11 Welded attachments should penetrate into the insulating material only to the minimum extent necessary to provide support. The cross-sectional area of the attachments should be the minimum consistent with the required mechanical strength to avoid excessive heat transfer or cold bridging by metallic conduction.

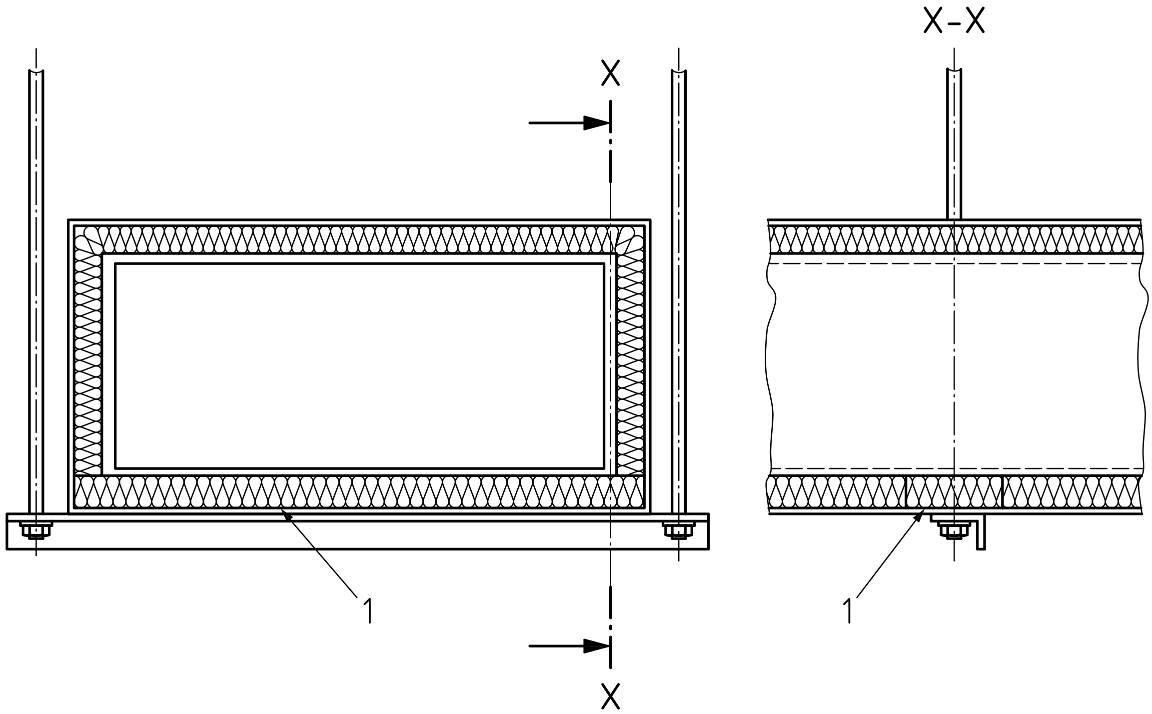
27.6.12 Welded attachments can tear the insulation or finish due to being subject to the same extent of thermal movement as the insulated surface; this should be avoided, e.g. by using expansion or slip joints.

27.7 Insulation supports

27.7.1 Distinction between the main supports for the plant or equipment and those required only to support the thermal insulation together with any associated finish should be identified and documented. Supports for the plant and equipment, e.g. pipe supports and hangers, should be capable of bearing the distributed load of the equipment itself while permitting thermal movement.

*NOTE They may be isolated from direct metallic contact with the surface of the plant, e.g. by compression-resisting insulating material, or they may be in direct contact with the plant surface while being enclosed inside the thermal insulating material (see Figure 12 to Figure 15, Clause **11**; Figure 16 to Figure 18, Clause **27**). Where supports are in direct contact with plant, thermal bridging might occur (see **27.6.11** and **27.7.10**) and additional measures for personal protection and process efficiency might be required.*

Figure 17 **Typical support for rectangular ducting incorporating load-bearing insulation (operating above or below ambient temperature)[A)]**

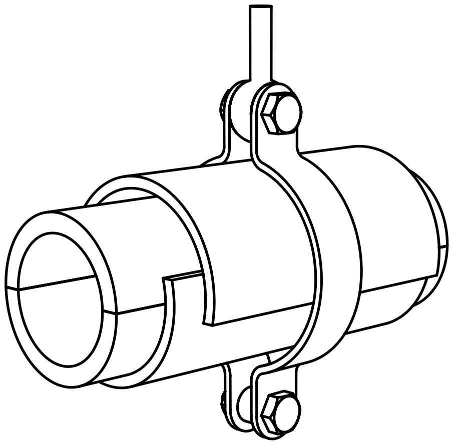


Key

1 Duct support load-bearing insulation insert supplied with facing of reinforced foil to match the duct insulation. Insulation finish to be continuous through the support.

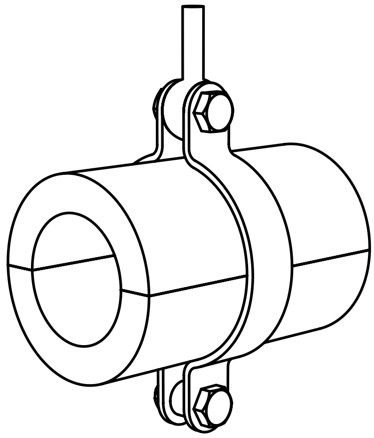
A) Wood blocks should not be used.

Figure 18 **Typical proprietary support inserts**[A)]



a) Support sleeve

NOTE 1 The sleeve, when in position as shown, effectively spreads the supported load. High-density load-bearing insulation, supplied in two halves with foil covering.



b) Load-bearing insulation

NOTE 2 High-density load-bearing insulation, supplied in two halves with foil covering.

A) Wood blocks should not be used.

27.7.2 Unless otherwise recommended, supports for insulation and any associated cladding should only have to bear relatively light loading; they may consist of metallic flat bars, rings, part rings, varying lengths of angle, or studs.

NOTE Additional support might be required to withstand wind loading.

27.7.3 Flat bars, rings and angles should rest on stud or cleat attachments welded in the appropriate locations to the surface to be insulated (see Figure 7, Figure 9a and Figure 10). Where used, angle supports should be bolted to the welded attachments on the plant, or they should rest loosely on top of floating flat rings.

*NOTE In the latter arrangement, short angle pieces may be used to secure external metal cladding to which they are fastened, either by bolts or rivets (see Figure 5 to Figure 11, **8.3.4** and Clause **20**).*

27.7.4 Stud-type supports may be used for pre-formed or flexible insulating mattresses; they should serve as suspension points for the metal-mesh covering of spray-applied insulation (see Figure 6 and Figure 8, and **27.4.4**).

NOTE The studs can be in the form of attachments welded directly to the plant, e.g. split pins, fork studs or plain studs, or as threaded studs screwed into nuts that are themselves welded to the surface to be insulated.

27.7.5 Alternatively, especially for vertical alloy-steel pipework, the studs may be welded radially to a ring that can be clamped around the pipe at the required vertical intervals. As these rings can slip downwards under service conditions, support lugs or pads for the rings should be welded on to the pipe at the manufacturer's works, to be followed by any necessary stress-relieving process.

27.7.6 Studs should not be greater than 10 mm in diameter, or equivalent contact area, for gun welding. Angle cleats and flat bar should normally be approximately 5 mm to 10 mm thick, depending on the weight of insulation (and finish) to be supported; widths can be about 75 mm, varying according to the total thickness of insulation to be supported.

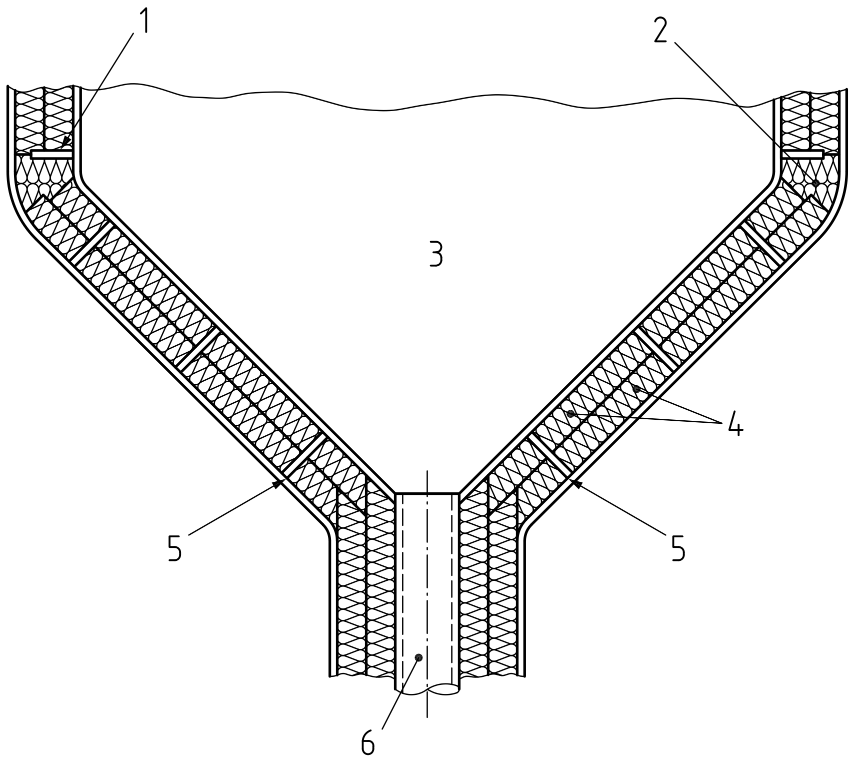
NOTE These studs may be welded directly to the surface of the plant or threaded for screwing into corresponding nuts that are themselves welded to the surface to be insulated.

27.7.7 Support angles should not penetrate the insulation to a distance greater than its total thickness less 10 mm unless through-metallic connection between cold and hot surfaces of the insulation can be avoided by interposing a pad of insulating material between the inner welded supporting angle and the insulation support system.

NOTE This is of particular importance with insulation over refrigerated plant, or when the external finish over hot insulation is of sheet metal.

27.7.8 On large diameter tanks, the cladding from the tank surface should be directly supported to accommodate wind loading considerations (see **29.3.2.7** and Figure 10, Figure 19 and Figure 20).

Figure 19 **Typical method for insulating vessels with conical bottoms[A)]**



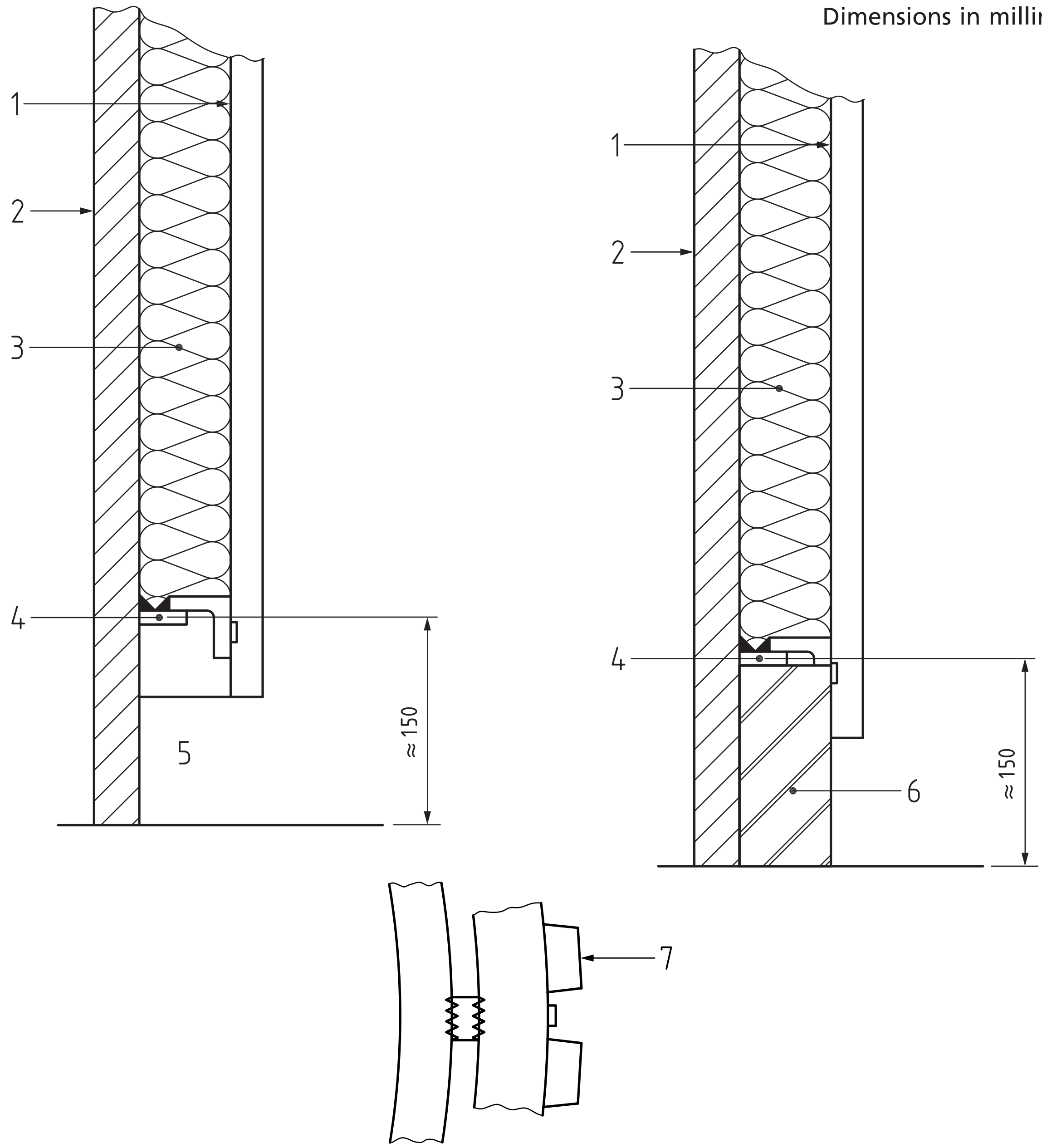
Key

1 Insulation support ring in segments welded or adhered to vessel
2 Compatible insulating material
3 Vessel
4 Insulation slabs or lags
5 Studs or cleats welded or adhered to vessel
6 Pipe

[A)] All spaces should be filled with compatible insulation material.

Figure 20 **Typical arrangement showing termination of insulation adjacent to the tank bottom with the bottom left uninsulated for ease of inspection**

Dimensions in millimetres



Plan view

Key

1 Cladding
2 Tank shell
3 Insulation
4 Supporting ring
5 Uninsulated area
6 Cellular glass
7 Profile cladding

27.7.9 On vertical surfaces, provision should be made for insulation supports (e.g. flat bars, angles or studs as may be agreed; see **10.2**) to take the dead weight of the insulation. These supports should project halfway through the insulation thickness or, for multilayer work, to a line halfway through the thickness of the outer layer.

27.7.10 To reduce heat transfer and cold bridging to a minimum, the cross-sectional area of each insulation support should not be greater than that necessary to achieve the required mechanical stability.

27.7.11 Additional supports should be used for the insulation on the ends of vessels of over 1.5 m diameter. Pins/hangers of 5 mm diameter should be provided on a triangular pitch of approximately 300 mm. The length of the pins should be equal to the thickness of insulation except on the bottom of vessels where the bottom is protected by a skirt, in which case the pins/hangers should be 10 mm longer than the thickness of insulation. Horizontal vessels of 2.0 m diameter or greater should have attached a type 1 insulation support on their longitudinal centre line. The method of attachment should be specified on the drawing or data sheet (see Figure 7, Figure 9b and Figure 10).

28 Cold insulation – Application for systems operating in the temperature range –100 °C to ambient temperature

28.1 General

28.1.1 The outer surface of the insulation used on systems operating at below ambient temperatures should be protected by a continuous water vapour barrier. The vapour barrier should not be pierced or compromised by supports. At discontinuities and at points where the insulation system terminates, the vapour barrier should be returned to the surface being insulated to prevent entry of moisture at the edges of the insulation (see also Clause **11**).

28.1.2 Where the total thickness of insulation to be applied exceeds 50 mm, the insulation should normally be applied in multiple layers, each no thicker than 50 mm. As some materials are suitable for applying in single or multiple layers of greater than 50 mm, manufacturer's advice should be sought. All joints between adjacent layers of insulation should be staggered. 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, at least 200 mm (see Figure 1).

28.1.3 In addition to the recommendations in Clause **27**, metal surfaces operating below the dew-point might require anti-corrosion coating, which should be thoroughly dry before the insulation is applied. The initial protective layer should be compatible with any adhesive joint sealant and vapour barrier used. Where applicable, it should also be resistant to steam-purging temperatures.

NOTE The treatment may consist of coating with paint, bitumen or weatherproof polymer solution, or wrapping with self-adhesive PVC, polypropylene pipe-wrap tape or wax-impregnated cotton tape.

28.1.4 Insulation should be carried out on surfaces above the dew-point temperature of the ambient air at the time of application. If surfaces are below the dew-point temperature or below freezing, the surface should be de-iced and wiped dry before the insulation is applied. As this practice is likely to result in moisture in the insulation system that impairs thermal performance and could cause corrosion, it should only be used where unavoidable or as a temporary measure.

28.1.5 The manufacturer's recommendations should be followed, particularly in respect of the following:

a) the suitability of all materials for the design conditions under which the plant operates, including purging and steam cleaning where the material can occasionally be subjected to elevated temperatures; and

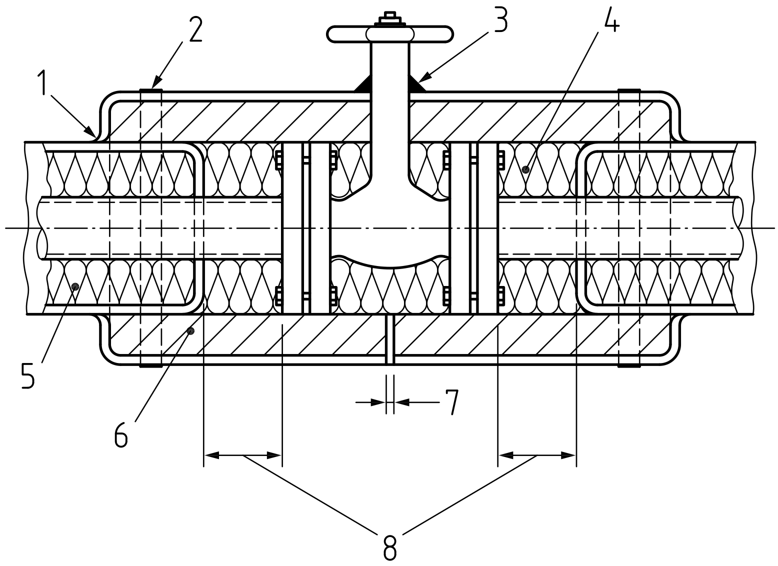
b) the compatibility of adhesives, pipe coatings, joint sealant and vapour barrier coatings with insulating material, mechanical supports, and with each other where applicable.

28.1.6 Where possible, skewers should be avoided. Where used, they should remain within the insulation to avoid compromising the vapour barrier.

28.1.7 Where two or more layers of insulating material are required (see **28.3.1**) and the service temperature is below –20 °C, the insulating material should not normally be bonded to the vessel or pipework with adhesive, although subsequent layers may be bonded to the previous layer. Where a vapour tight or air tight seal is required, joint-sealer mastic should be applied according to the manufacturer's recommendations (see also **28.1.5**).

28.1.8 The vapour barrier should be designed as an integral part of the insulation system and applied as soon as possible so as to keep the insulation dry (see Figure 21 and Figure 22). The vapour barrier should not be used as the final surface finish if it is likely to be easily damaged.

Figure 21 **Typical method of insulating a valve where metal cladding is not required**



Key

1 Tape under vapour barrier composition at circumferential and longitudinal joints (to aid removal of flange cover). Glass cloth to be left clear of tape

2 Metal band

3 Mastic seal

4 Space for the withdrawal of bolt, packed with loose filled insulation plastic composition for hot work, or alternatively, granulated insulation filled non-setting mastic for cold work

5 Insulation

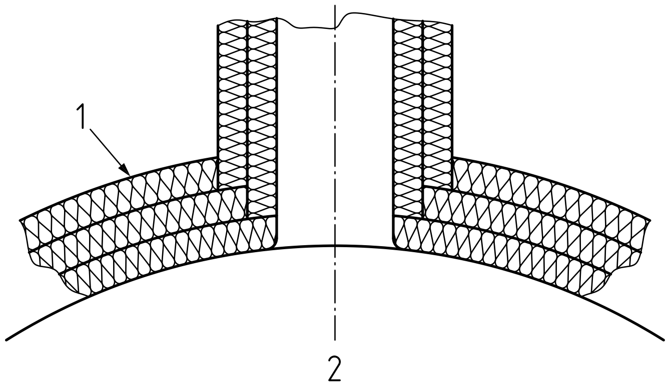
6 "Oversized" pre-formed pipe section [A)]

7 Ø5 mm drain hole for hot work only

8 Clearance to permit bolt withdrawal without disturbing the pipe insulation

[A)] "Oversized" insulation sections should not be adhered to pipe or vessel insulation, but secured with bands. Cold work should be finished with a reinforced vapour composition.

Figure 22 **Typical method of insulating branches of vessel for cold work showing layered junction**[A)]



Key

1 Vapour barrier

2 Vessel

A) Flanges should be insulated.

28.1.9 Where insulants of an abrasive nature are to be used (e.g. cellular glass), applying an anti-abrasion bore coating to the inner face of the insulant should be considered.

28.2 Contraction joints

28.2.1 Where the insulating material is not sufficiently compressible to accommodate the differential thermal movement, contraction joints should be used. Detailed guidance on requirements for contraction joints should be sought from manufacturers. (See Figure 3.)

NOTE 1 Insulating materials for use at sub-ambient temperatures can have coefficients of thermal movement that not only vary with different materials, but also differ appreciably from the corresponding movements of the pipe or item of equipment to which they are fitted.

NOTE 2 The contraction joints can take the form of a 10 mm gap in insulation that is packed with a flexible insulant; see Figure 3a).

28.2.2 Contraction joints should be provided immediately below insulation support rings on vertical pipes and at intervals on horizontal pipes. Joint intervals, the width of the joint and the extent of compression of the compressible material, should take into account the pipe material, the insulation material and the difference in temperature between ambient and service temperature. The joints should be covered with a pre-formed insulation fastened at one side of the joint only. The design of the vapour barrier should accommodate movement of this joint (see also **28.2.3**, Figure 3 and Figure 4).

28.2.3 The insulation should be cut and fitted accurately. Pre-formed bends of insulating material should be used to ensure accurate fit without open joints. Leaving gaps in joints to be filled with plastic composition or rough slivers of insulation should be avoided.

NOTE Contraction joints might be required because of the differing rates of thermal movement between the equipment and various types of insulating materials. See Figure 4 for some values relating to typical materials in the temperature range 20 °C to –100 °C.

28.2.4 Where the service temperature is very low or where there are appreciably large fluctuations of temperature, and depending on the type of insulating material and the configuration of the insulation system, contraction/expansion joints of the type shown in Figure 5 should be used.

28.3 Typical erection methods

28.3.1 Using pre-formed insulating materials

Two-layer construction with pre-formed insulating materials should normally be used for surfaces operating at temperatures below –10 °C; all joints should be staggered. There are some specific exceptions for double layering for certain materials, so the manufacturer/contractor/applicator should be consulted.

28.3.2 Using solvent-based adhesives

Solvent-based adhesives can be based on bitumens, resins or rubbers; they should be applied by brush or trowel. Where necessary, time for partial curing should be allowed in accordance with the manufacturer's instructions before the bond is made.

Compatibility of the solvent with the insulating material and substrate should be checked (e.g. polystyrene/protective coatings/plastics substrates, etc.).

The piece of insulating material should be positioned precisely where an impact type of adhesive is used.

NOTE Some adhesives permit the piece of insulating material to slide before final adhesion.

28.3.3 Using bedding compounds

These non-hardening substances are generally based on fully saturated petroleum hydrocarbons containing inert siliceous fillers, resins or bitumens; they should be used to eliminate air voids and permit insulating materials to be stripped without damage and reused. The compounds should be used for bedding the insulating material against the substrate and may be palmed on by a glove-protected hand or applied by trowel so that all joints are fully sealed. When using this method of erection, the insulating material should be securely held by mechanical means (see **27.2.2**).

28.3.4 Dry erection

NOTE Certain insulating materials may be applied without the use of adhesive in accordance with manufacturer's advice. This method is particularly useful for installing foil covered insulation to pipelines between ambient and 0 °C.

All joints should be sealed to maintain a continuous vapour barrier. The pre-formed sections should be installed with all joints tightly butted and held in place by compatible self-adhesive tape or metal bands at 300 mm centres.

28.3.5 Vessel supports

Vessel supports should be subject to similar recommendations as apply to pipes.

NOTE Vessel supports can be subject to the same recommendations as pipes because they are a similar shape, but where they do not have the same physical properties, erection methods will differ slightly.

28.4 Pipework and fittings

28.4.1 General

Pipework should be insulated in accordance with the general installation principles in **28.1**, **28.2** and **28.3**. Advice from the manufacturer should be obtained regarding the type and suitability of their product for the diameter and service temperature of the pipe.

28.4.2 Pipework

NOTE When insulating pipework, pre-formed insulating material is usually preferred although insulation foamed in situ might also be appropriate.

28.4.2.1 Pre-formed insulating material

28.4.2.1.1 General

Small diameter pipe should be insulated with insulating material pre-formed into appropriately dimensioned sections. Large diameter pipes should be insulated using matt slotted slabs, radiused and bevelled lags, or flexible sheet material. Pre-formed sections should be erected as recommended in **28.3.1**.

28.4.2.1.2 Cellular glass

Cellular glass sections not secured to the pipe by adhesives should normally have a bore coating to act as an anti-abrasive lining; this bore coating should be factory applied. If site applied, it should be allowed to dry before the section is fitted.

28.4.2.1.3 Elastomeric foam

When using elastomeric materials on pipework operating at temperatures down to –40 °C, the use of bedding compounds as described in **28.3.3** is not necessary and the use of mechanical fixings as described in **27.2.2** should be avoided.

Pipe insulation materials should be installed in un-slit tubular form whenever possible.

All seams and joints should be fitted under slight compression.

Elastomeric materials should be bonded directly to pipework operating at line-temperature down to –40 °C contrary to the general rule for other types of insulation indicated in **28.2**.

28.4.2.2 In situ foam

28.4.2.2.1 General

In situ moulded or dispensed PUR/PIR foam should be applied by the following methods:

a) injecting into a temporary mould around piping or equipment;

b) injecting or pouring into an installed metallic cladding that acts as primary vapour barrier; and

c) sprayed foam for specialist activities such as on tank walls or shop fabricated piping systems.

Pouring should only be used for emergency maintenance if injection equipment is not directly available.

Subclause **28.4.2.2.1**(a) is normally the preferred method for dispensed PUR/PIR foam as the foam quality and effectiveness of the filling can be checked after removal of the mould. Subclause **28.4.2.2.1**(b) should only be used for items that need to be removed for shutdowns such as valve boxes and flange boxes, or for items of particular complexity.

28.4.2.2.2 In situ foam injection application method [28.4.2.2.1a) and 28.4.2.2.1b)]

For **28.4.2.2.1**a) and **28.4.2.2.1**b), the foam injection process should be carried out in accordance with the manufacturer's recommendations. Atmospheric site conditions, including relative humidity, maximum and minimum temperatures, should be provided to the manufacturer for ensuring the performance of the injection foam (PUR/PIR). The product should be delivered on site in two components ready for use.

Pre-formed spacers of PUR/PIR half-pipe sections, with a minimum density of 40 Kg/m^3, should be used to form appropriate compartments to control the in situ foaming operation. Spacers should be fastened securely with stainless steel bands, filament tape or suitable adhesive. The pre-formed spacers should be sited taking into account the location of supports, welds, auxiliaries, etc. and the dimensions of the formwork.

The metal cladding mould should be installed with overlaps of at least 50 mm over the pre-formed spacers with temporary bands; vapour barrier cladding should be installed with bands and with all joints and overlaps sealed. Sufficient injection and de-aeration holes should be provided to ensure proper injection and to prevent trapping air pockets and causing voids.

Clamps, banding or special tools should be fitted over the metallic cladding to withstand the pressure loads from foam expansion.

Appropriate fire performance of the product or system should be identified for this insulation system.

28.4.3 Pipe bends

28.4.3.1 Pre-formed insulating material

Bends should be insulated with pre-formed bends. Where pre-formed bends are not available, bends should be cut lobster-back (mitred) fashion and secured, as for straight piping, with one tie per segment. Any gaps that appear between mitred segments should be filled with material compatible with the pre-formed material.

28.4.3.2 Elastomeric foam

When insulating large diameter pipe (≥89.9 mm) using elastomeric foam, the bends should be insulated using pre-formed flexible sheet material. This sheet should be cut according to a "two-piece" pattern, and adhered using a compatible vapour sealing adhesive. The manufacturer's advice should be sought.

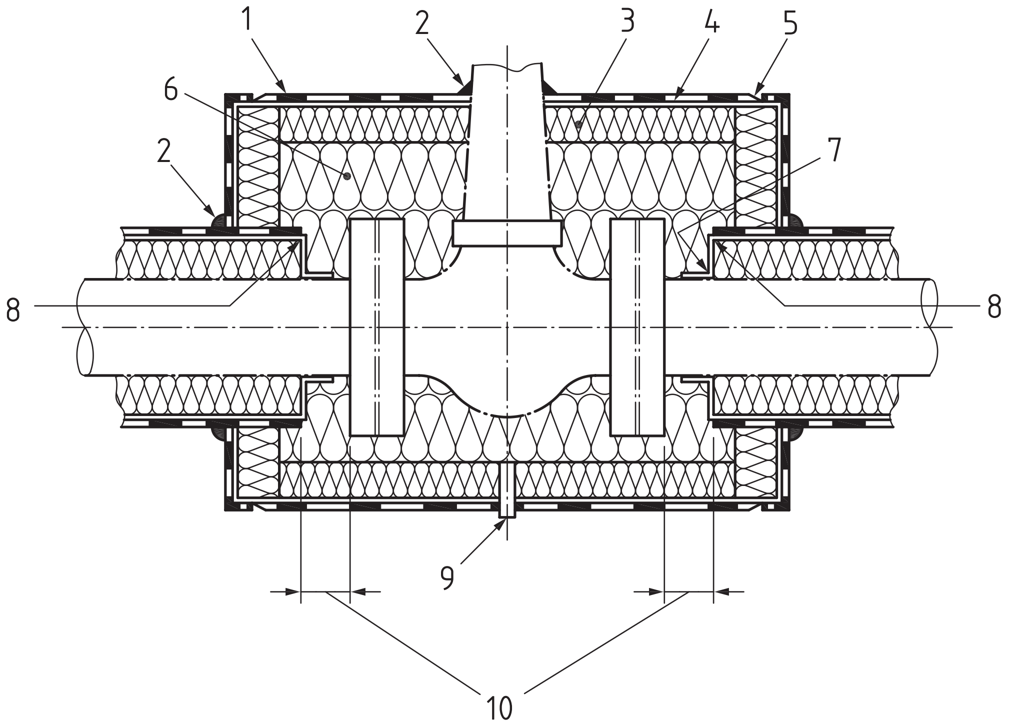
28.4.4 Flanges, valves and other fittings

28.4.4.1 General

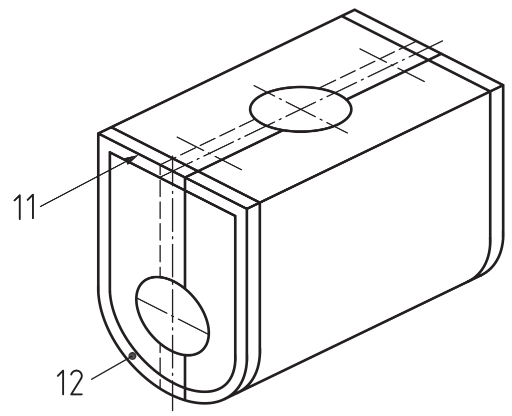
Provision should be made to allow the removal of bolts. Fittings should be insulated with moulded or prefabricated flange/valve boxes. Where unavailable, they should be insulated with oversize sections of the same material and thickness as the insulation on the adjacent pipework (see Figure 23, Figure 24 and Figure 25).

Cavities formed between the insulation and the fitting should be filled with insulation material or non-setting compound or a mixture of both, which should be easily removable for access purposes.

Figure 23 **Pre-fabricated valve box in single-layer insulation system**



a) Cross-section showing details of construction



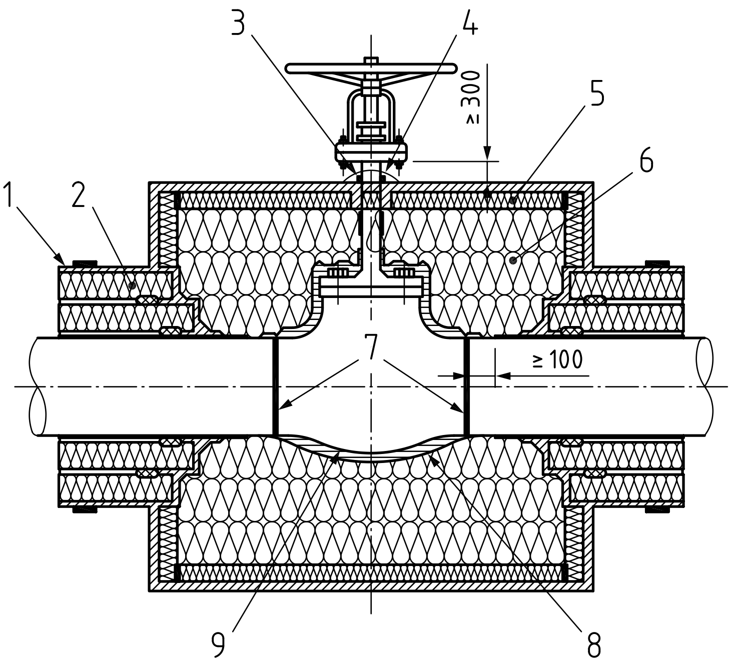
b) Toggle clips used to join the two halves

Key

1 Lockformed joint
2 Mastic seal
3 Insulation
4 Vapour barrier for cold work
5 Cladding
6 Space usually filled with insulation for cold work
7 End capping for hot work stopped short of pipe
8 Vapour stop
9 Ø5 mm drain hole for hot work only
10 Clearance to permit bolt withdrawal without disturbing pipe insulation
11 Top to cover sloped for drainage (external only)
12 Lockformed joint

Figure 24 **Valve box, dual layer cold pipework using rigid insulation with non-metallic coating**

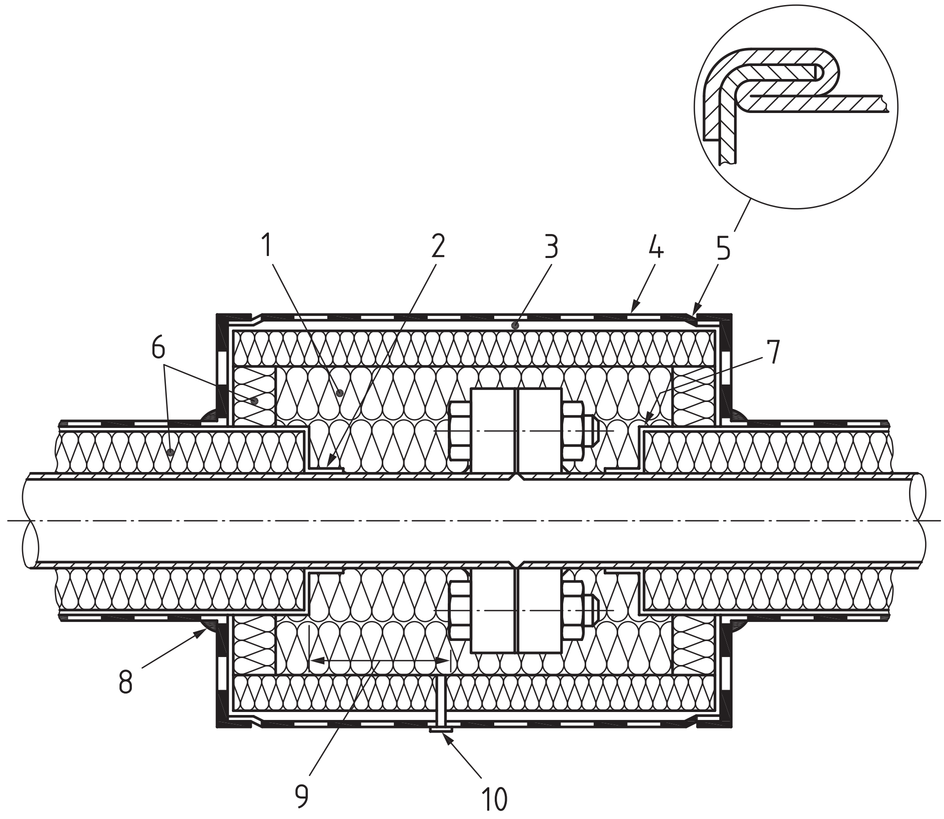
Dimensions in millimetres



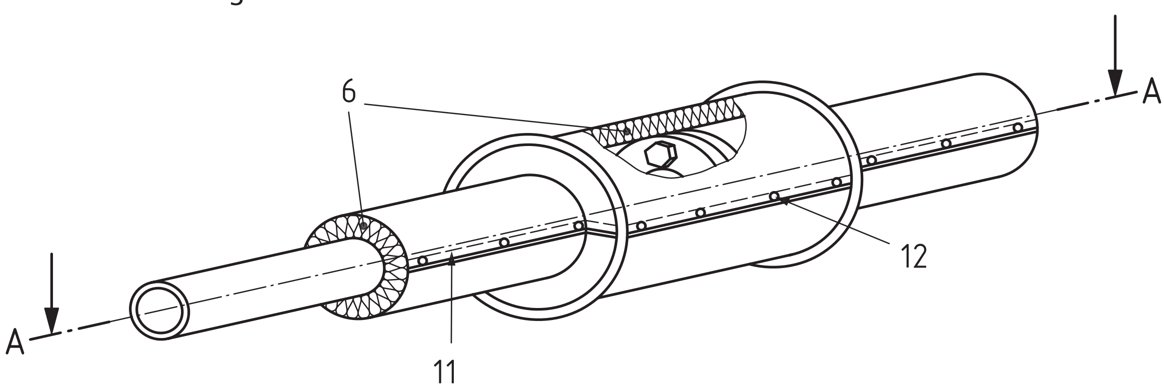
Key

1 Non-metallic coating
2 Insulation
3 Sealing mastic
4 Extended stem
5 Prefabricated insulation box
6 Glass wool
7 Test welds before insulation
8 Foil tape
9 Fibreglass blanket

Figure 25 **Pre-fabricated flange box in single-layer insulation system**



a) Cross-section showing details of construction



b) Detail of covering

Key

1 Space usually filled with insulation for cold work
2 End capping for hot work stopped short of pipe
3 Vapour barrier for cold work
4 Cladding
5 Lockformed joint
6 Insulation
7 Vapour stop
8 Mastic seal
9 Clearance to permit bolt withdrawal without disturbing pipe insulation
10 Ø5 mm drain hole for hot work only
11 Overlap
12 Self-tapping screws or toggle fasteners

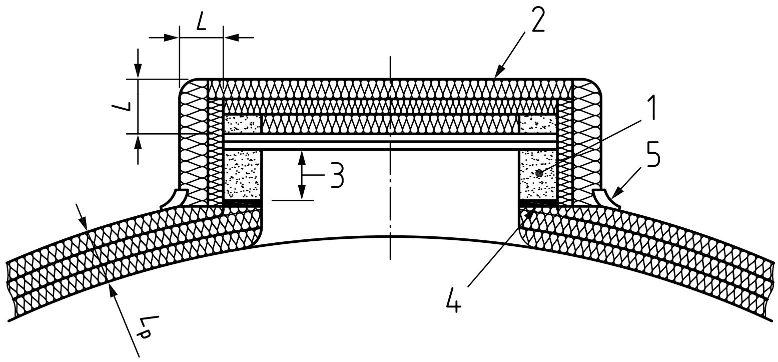
28.4.4.2 Fixing

The individual pieces should be jointed with adhesive and may be reinforced, e.g. by temporary fixing bands. Covers that are to be removable should not be fixed permanently to the main insulation, but should be separately secured.

28.4.4.3 Vapour sealing

The insulation system should be vapour sealed to ensure that the flange or valve insulation can be removed without damage to the vapour barrier on the adjacent pipework (see Figure 18, Figure 19 and Figure 26).

Figure 26 **Typical method of insulating manhole (cold work)[A)]**



Key

1 Space filled with insulation for coldwork

2 Reinforced vapour barrier

3 Clearance to permit bolt withdrawal without disturbing vessel insulation

4 Sealing ring

5 Sealing strips

A) The integral manhole cover is built up from sections glued together; to facilitate removal, the cover should not be adhered to the vessel insulation.

28.4.4.4 External finish

NOTE The external finish of valve, flange and other fitting covers may differ from that used for insulation on adjacent pipes.

The contractor should ensure that the external finish of fitting covers is appropriate for the location in which it is to be sited, e.g. fitting covers used externally should be UV and weather resistant. The possible effects of the medium in the pipe on the finish should be considered.

28.4.4.5 Fitting covers directly fabricated from insulation material

The water vapour permeability of the fitting cover should be no higher than that of the insulation system applied on all other pipework; the insulation thickness should not be less than that used on all adjacent pipework.

NOTE 1 Pre-formed rigid or flexible sheets of insulating material can often be directly fabricated into covers for valve, flange or other fittings.

*NOTE 2 Coverings might still be required, see **28.4.4.4**.*

28.4.5 Pipe supports

Pipe support brackets for cold lines should not be attached directly to the pipe.

Pipe support brackets should be clamped over the exterior of load-bearing insulation pipe support inserts installed to support the weight of the pipeline as shown in Figure 12 to Figure 15 and Figure 17. The load bearing insulation pipe support inserts should be of the same material, or compatible with, the thermal insulation on the pipework.

The thermal resistance of the insulation at the pipe support should be adequate for the design conditions.

The exposed ends of pipe supports should be protected until the completion of the insulation system.

Wooden pipe supports should not be used.

28.5 Vessels and large curved surfaces

For general considerations, the recommendations in **28.1** should be followed.

NOTE The types of insulating materials normally specified for low-temperature applications are available in a range of physical forms which may be used for curved surfaces, but pre-formed insulation is most commonly used, such as radiused and bevelled lags, plain lags or slotted slabs with the slots on the inner face. Other types of insulation may be applied as loosefill granules, foam in situ or sprayed (see Figure 22, Figure 26 and Figure 27).

Each layer should be firmly secured either by adhesive or bands or a combination of both. Insulation slabs should be evenly supported at not more than 400 mm centres or in accordance with the manufacturer's recommendations. Thin clips may be used to hold second and subsequent layers to the first.

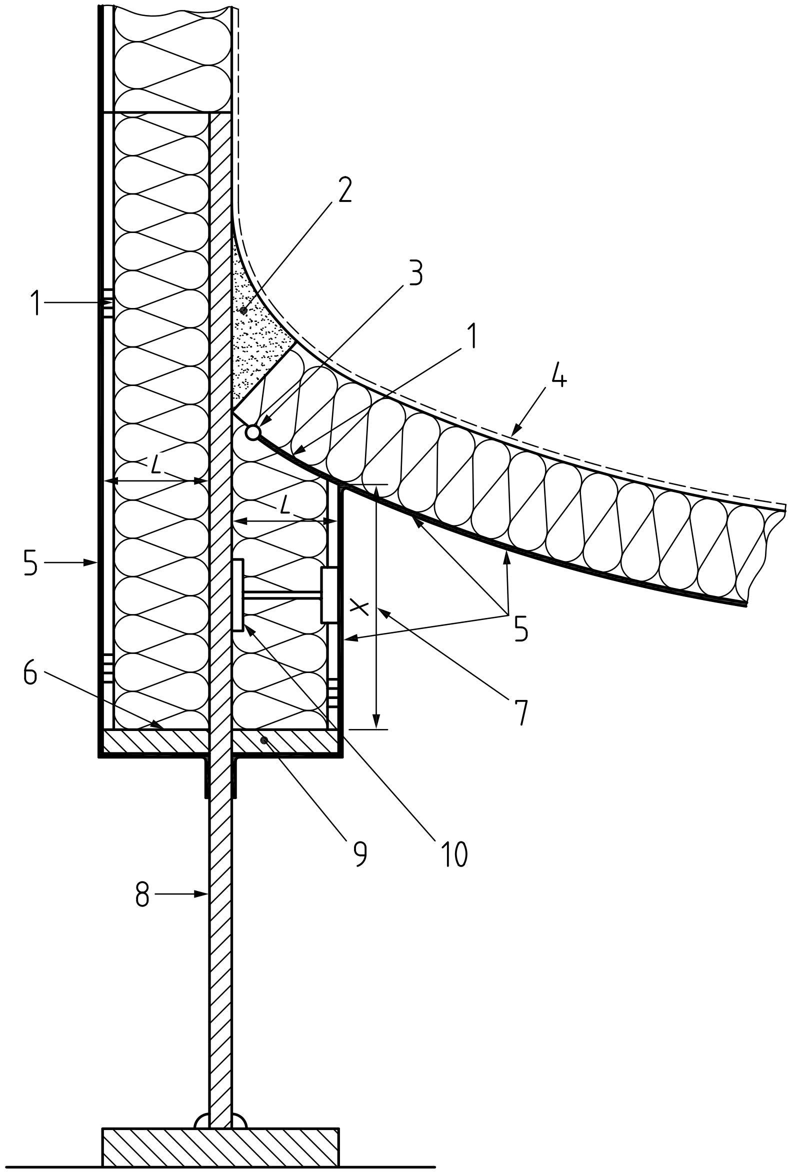
Where banding is impracticable, slabs should be impaled on studs that partially penetrate the thickness of insulation.

Load-bearing supports are generally recommended for vertical and downward-facing surfaces. The vapour seal should be continuous over all such supports.

Where differential movement between vessel and insulating material occurs, expansion/contraction joints should be used; the positions of these should be marked off before erection of the insulation begins to ensure there are no conflicts with penetrations from the vessel. Flexible vapour-tight cover strips should be provided. Before the erection of the main body of insulation, all protruding pipe stubs, fittings, manhole necks, etc., should be insulated.

The insulation should extend down any vessel skirt or legs or cradle for a distance not less than four times the thickness of the insulation on the vessel, measured from the surface of the insulation.

Figure 27 **Typical method indicating the extent of insulation on vessel skirt**



Key

1	Banding (under vapour barrier)	7	*X* = *L* × 4 (minimum) ideally to a point where the temperature of the metal skirt is above the ambient dew-point
2	Space filled with insulation		
3	Securing ring		
4	Vessel	8	Vessel skirt
5	Vapour barrier	9	Insulation support (if possible)
6	Flexible sealant	10	Insulation pins/hangers welded or adhered to skirt

28.6 Storage tanks

28.6.1 General

Base, sidewalls, roof and protrusions should be insulated and there should be a continuous vapour barrier over the outer surface of the insulation (see Clause **4**).

28.6.2 Corrosion protection

Corrosion protection should be in accordance with the recommendations in Clause **8** and **28.1.3**.

28.6.3 Nozzle connections and manholes

The vapour barrier over the nozzle connections and manholes should be integral with the vapour barrier on the shell and roof.

28.6.4 Base of tank

The base of the tank should be insulated to prevent frost heave.

NOTE The insulation may be used alone, or in conjunction with a heating system.

The insulation should have load-bearing properties to support the weight of the tank and contents unless the tank is adequately supported.

The base insulation system should be designed to ensure a continuous vapour barrier can be provided between the base insulation and shell insulation.

28.6.5 Shell and roof of tank

Insulation systems should include:

a) pre-formed slabs of materials (see Table 3 and Table 4) applied with vapour barriers;

b) sprayed polyurethane with a vapour barrier; and

c) foaming in situ of polyurethane or isocyanurate into a cavity formed by metal cladding or plastic sheet.

NOTE Double-skinned tanks are used for the storage of cryogenic liquids, therefore insulation for these tanks is usually perlite applied as a loosefill between the two skins.

28.7 Air-conditioning ductwork operating below ambient temperature

NOTE 1 Whilst this subclause refers specifically to ducts carrying air below the temperature of the surrounding air, ventilation or air-conditioning ducts can carry air for both heating and cooling.

*NOTE 2 Subclause **28.7.1.1** does not apply to the installation of pre-insulated ductwork. Where installing pre-insulated ductwork, only **28.7.3.1** and **28.7.3.2** apply.*

28.7.1 General

28.7.1.1 Air-conditioning ductwork operating below ambient should be insulated in accordance with **29.4** (see BS 9999 for fire performance requirements, and **7.9** and **12.6** for fire hazards).

28.7.1.2 Fresh-air ducts and exhaust ducts carrying cold air should be insulated to prevent condensation. The insulation should be continuous over the whole length of the duct, including fans, heat exchangers and filter casings carrying cold air.

28.7.1.3 Materials suitable for the insulation of ducts should be used (see Table 1 and Table 2).

28.7.1.4 Insulation over 50 mm thick should normally be applied in two layers and should have staggered joints. Manufacturer's guidance should be sought.

28.7.1.5 Materials that are suitable for insulating ductwork operating in this temperature range should be used (see Table 3 and Table 4).

28.7.1.6 For ductwork located externally to buildings, metal surfaces should be given corrosion protection before the application of pre-formed insulation and a waterproof finish. Termination points should be sealed, i.e. inspection doors, expansion joints, etc.

28.7.2 Fixing and adhesion

*NOTE 1 The insulating material may be secured to the surface of the duct with an adhesive (see **27.2**). Where necessary, this may be supplemented by plastics or welded-metal pins/hangers or studs on a base plate that can be attached firmly to the duct by an adhesive, by welding, or by the use of bands on non-rectangular ducting.*

*NOTE 2 Cylindrical and flat-sided ducting insulation may be attached using banding with corner angle protection on flat sided ducts, suitable adhesive subject to temperature and weight limitations, mechanical fixings, or adhered fixings subject to temperature and weight limitations, see Clause **27**.*

For vertical ducts where there can be danger of settlement, stud attachments should be provided, either by welding to the surface of the duct or with an adhesive (subject to temperature limitations).

28.7.3 Vapour barriers and finishes

28.7.3.1 A finish for indoor ducting can provide an adequate vapour barrier for the design conditions; it should be robust enough to withstand mechanical damage or cleaning, and where necessary, have a visual appearance compatible with the location.

28.7.3.2 Ductwork situated outdoors should have a weatherproof finish.

28.7.3.3 Insulation may be used with a factory-applied vapour barrier adhered to its surface. All joints in the vapour barrier should be sealed, either by bonding the overlaps, where provided, with adhesive or by sealing with matching self-adhesive tape.

28.7.3.4 Where plain un-faced slabs are used and wrapped with the vapour barrier facing on site, the overlaps of the facing should not be directly over the joints in the slabs.

28.7.3.5 Conditions encountered on many sites where insulation is applied should be assessed and documented as they can be adverse to the successful adhesion of self-adhesive tapes, which can delaminate. Where applicable, this problem should be prevented by priming the surface of the vapour barrier jacket with a thin brush coat of a compatible contact adhesive before application of the tape.

28.7.3.6 Where insulation is to be secured and protected by means of a polymeric vapour barrier coating, this should be applied in two coats and reinforced with a membrane of cotton or open-weave glass fabric between coats, the first coat being used to adhere the membrane to the insulation.

NOTE Different colours may be used to ensure coverage of each layer. Alternatively polymeric wraps including GRP, flexible non-reinforced polymeric coatings may be used.

28.7.3.7 Where a protective finish has been applied to the substrate of the duct, it should be ensured that it is not damaged. If it is damaged, the contractor should notify the purchaser (the client, the contractor and sub-contractors) so that the coating can be made good before insulation is applied. If the insulation is to be adhered to the ducting, the compatibility between the adhesive and the protective coating or the fabric of the duct should be checked with the adhesive manufacturer.

28.7.4 Flanges, stiffeners and other fittings

28.7.4.1 The insulation and finish should terminate clear of access openings and hinged or removable doors.

28.7.4.2 Flanges and stiffeners should be covered either with insulated box-type fittings or by increasing the general thickness of insulation to give at least 5 mm cover (see BS 5422 for thickness).

28.7.5 Fire dampers and fire stopping

28.7.5.1 The insulation and finish should terminate clear of instruments, detectors, and damper operating gear and accessories to permit free opening and closing of the dampers.

28.7.5.2 Where there are fire dampers within ducts, combustible thermoplastic insulation should stop approximately 1 m clear of the damper (which could become very hot in a fire) to prevent excessive radiation of heat to the insulation on the side remote from the fire, so preventing the damper from performing its fire-separating function. Ductwork should be protected in accordance with BS 9999.

28.7.5.3 The problem of fire hazard for air-conditioning ductwork should receive careful assessment and documentation. A fire stop should be provided at each wall penetration. Recommendations given in BS 5422, BS 9999 and *Approved Document B (Fire safety) – Volume 2 – Buildings other than dwellinghouses* [17] should be followed (see also **7.9**).

28.7.6 Pre-insulated ductwork

The properties of pre-insulated ductwork vary according to manufacturers' design and recommendations, e.g. phenolic foam and mineral fibre to BS EN 13403; therefore, installation should be in accordance with manufacturers' literature and fabricated/installed by competent and trained persons.

NOTE As such, no general recommendations can be made.

Air-conditioning ducts constructed from thermal insulating material, e.g. boards or faced slabs, might not require supplementary insulation, but reference should be made to BS 5422 for total insulation requirements.

28.7.7 Internal ductwork lining

NOTE Where insulation is located inside air-conditioning ductwork, this might be for acoustic purposes beyond the scope of this British Standard and it might be necessary to seek specialist acoustic advice.

28.7.7.1 The presence of internal insulation alone might not be sufficient to meet heat loss/gain targets and additional external duct insulation might be necessary; it should be ensured that the total thickness of insulation applied is sufficient to meet all design considerations.

28.7.7.2 Where the risk of fibre erosion exists, the internal insulation should be covered by a plastics film, glass scrim fabric, glass staple tissue, neoprene-coated glass-fibre mat, perforated sheet metal or perforated board. Where plastics film or neoprene-coated glass-fibre mat is used, fire performance requirements should be assessed and documented.

28.7.7.3 Consideration should be given to the methods and effects of cleaning the inside of the ductwork on internal linings where they are adopted.

28.7.7.4 For conditions of high air velocity, only sheet metal covering backed by film should be used. The leading edge and all joints should be sealed to prevent pick-up of the fibres by the air flow.

NOTE 1 It might be necessary to consider the acoustic impact of covering insulation within ductwork.

NOTE 2 Cellular glass duct linings are generally coated with an appropriate render and scrim to create a smooth reinforced surface.

28.8 Flat and irregular surfaces (including machinery)

For general recommendations **28.1** should be followed. For erection against flat surfaces the basic recommendations given in **28.5** should be followed.

If intricate shapes are to be boxed-in with board or slab insulation materials, they should be jointed with adhesives and may be reinforced with skewers or clips.

For the erection of cold boxes, a supporting structure should be used. The insulation manufacturer's advice should be sought if free-standing panels are to be used.

NOTE Alternatively, most pre-formed slabs may be laminated to a variety of facing materials to form large panels that can be used to clad a structure.

29 Hot insulation – Application for systems operating in the temperature range above ambient to +870 °C

29.1 General

29.1.1 Application

Where the total thickness of insulation to be applied exceeds 100 mm, the insulation should normally be applied in multiple layers, each no thicker than 100 mm. Manufacturer's advice should be sought as some materials are suitable for applying in single or multiple layers of greater than 100 mm. All joints between adjacent layers of insulation should be staggered. Longitudinal joints in pipe sections should be staggered by 90°, but should be staggered by at least 45° where this is not practicable. 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 (see Figure 1), but should be staggered by at least 200 mm where this is not practicable.

29.1.2 Attachments

Apart from certain load-bearing materials, most types of insulating materials require support or reinforcement when applied and might require securing to the surface to be insulated; fixing accessories should be attached to the plant before application of the insulating materials begins (see **10.2**).

29.1.3 Provision for differential thermal movement

Due to the difference in expansion coefficients of metals and insulating materials, necessary allowance should be made for the differential movements between the hot surface, the insulant and the finish.

Such allowances should be accommodated by expansion joints inserted at the intervals specified in Table 8.

Table 8 **Expansion gaps**

Temperature °C	**Spacing intervals** m
<200	5
200 to 300	4
300 to 400	3
>400	2

Where insulation is applied in multilayers, expansion joints in each layer should be staggered.

At the junction between pre-formed insulating materials and fixed steel work, the joint area should be packed with mineral fibre to accommodate differential thermal movement.

NOTE 1 With a metal finish it is usual to fit sliding joints.

When a plaster-type finish is applied, an expansion joint should be provided by cutting at a circumferential joint in a single layer or in the outer layer of a double-layer insulation system. These joints should be covered with glass-fibre cloth, secured in place.

NOTE 2 As a rough approximation, radial expansion of pipes and vessels covered with plaster-type finishes is acceptable without longitudinal expansion joints if the value of "D – t" is less than 250 for pipes or vessels up to 1.5 m in diameter over the insulation, or 500 if over 1.5 m, where "D" is the diameter in metres and "t" is the temperature in degrees Celsius.

29.1.4 Sliding and bellows expansion joints, and corrugated piping

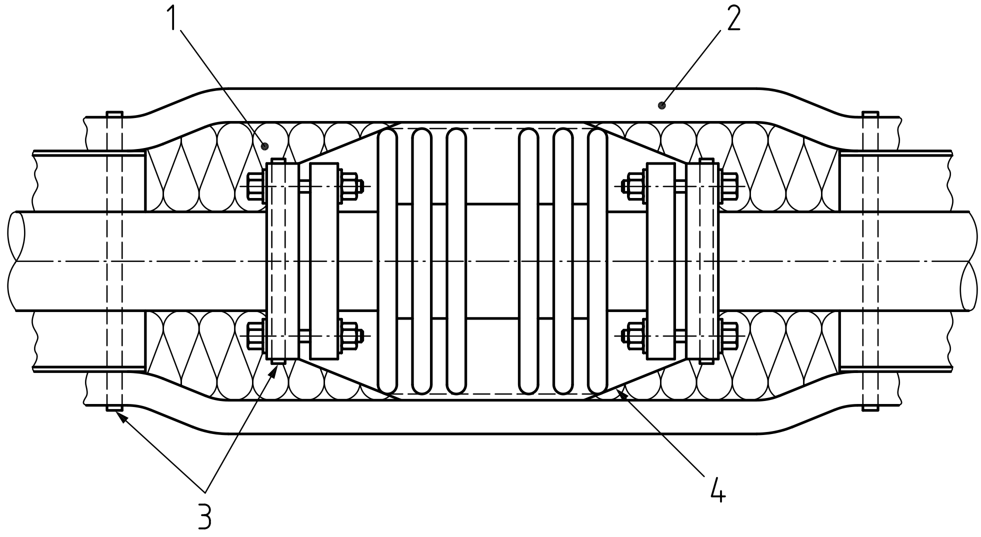
The insulation should not interfere with the operation of the expansion joints.

NOTE For this reason, the bellows or joint is usually fitted with a metal cage, fastened at one end only, on which the insulation can be secured.

Tie rods, etc., should not be enclosed within the insulation as they can attain too high a temperature and cannot be adjusted (see Figure 28 and Figure 29).

Corrugated piping should be insulated as plain piping. Expansion bellows pieces are frequently left un-insulated for metallurgical considerations, but, where required, they should be insulated as shown in Figure 28 and Figure 29, with external protection as necessary.

Figure 28 **Typical method of insulating high temperature expansion bellows**



Key

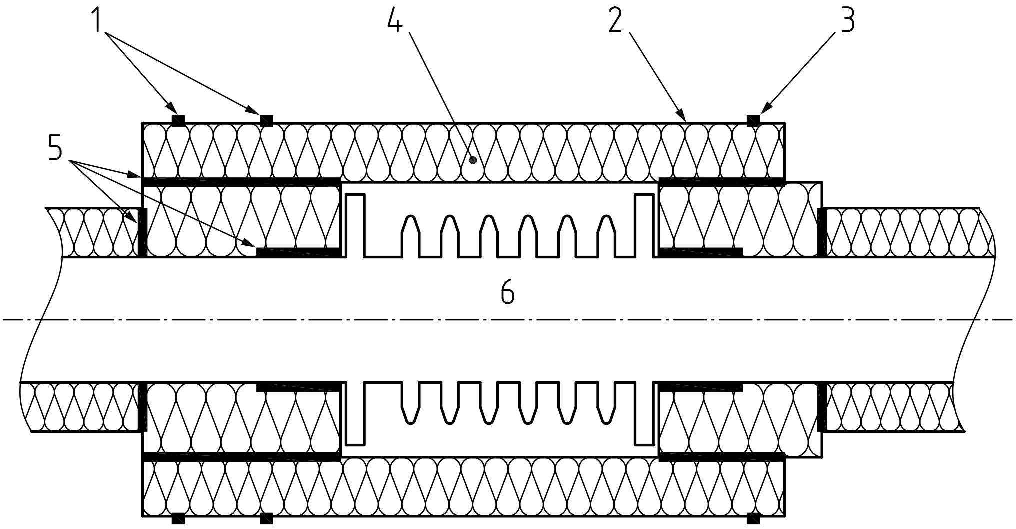
1 Bolt withdrawal space filled with mineral-fibre

2 Material-fibre mattress

3 Securing bands

4 Metal gauze or knitted wire

Figure 29 **Typical method of insulating cold temperature expansion bellows**



Key

1 Retaining band (e.g. 316 stainless steel banding, 13 mm wide × 0.5 mm thick)

2 Butyl non-hardening mastic

3 Retaining band, should allow sliding movement of insulation layer 2 over layer 1

4 Insulation

5 Mastic

6 Bellows

29.2 Pipework

29.2.1 General considerations

Insulation of pipework should be carried out with pre-formed materials. Where the pipe diameter is too large for pre-formed pipe sections to be used, the pipe should be covered as far as practicable by building up with radiused and bevelled lags or flexible materials.

Where it is necessary to dismantle pipework, this should be done with minimum disturbance of insulation. Permanent insulation should end sufficiently far from flanges and fittings to enable bolts to be withdrawn. Flanges should be insulated with pre-moulded material, jackets or insulated boxes that can be removed for maintenance (see Figure 21, Figure 23, Figure 24 and Figure 25 for methods of arranging this).

The junction between removable and permanent insulation should be made readily discernible, e.g. by painting the end or by laying a textile fabric over the end of the permanent insulation.

It is essential that valves, flanges and fittings are insulated to the same standard as the rest of the insulation system to minimize heat loss (see Figure 23). Irregular surfaces are difficult to insulate; where it is necessary to remove and replace the insulation for inspection purposes, moulded sections should be used as much as practicable for minimum wastage of material. The insulation should be finished so that there is free access to instruments. All thermometer pockets, including the boss and welded pad, should be insulated.

Valves should be specified by the mechanical contractor to be fitted with extended spindles and handle designs, which allow for the full insulation thickness to be applied.

For some superheated steam installations, pressure-gauge pipework should be insulated from a reasonable distance from the tapping point to avoid pressure loss due to cooling.

Where pipework is outdoors or in areas of likely spillage, the insulation at valves and flanges should be sealed. The permanent insulation either side of the removable valve or flange box should be sealed to prevent liquid ingress when the box is removed. All joints should be offset where possible (see Figure 1).

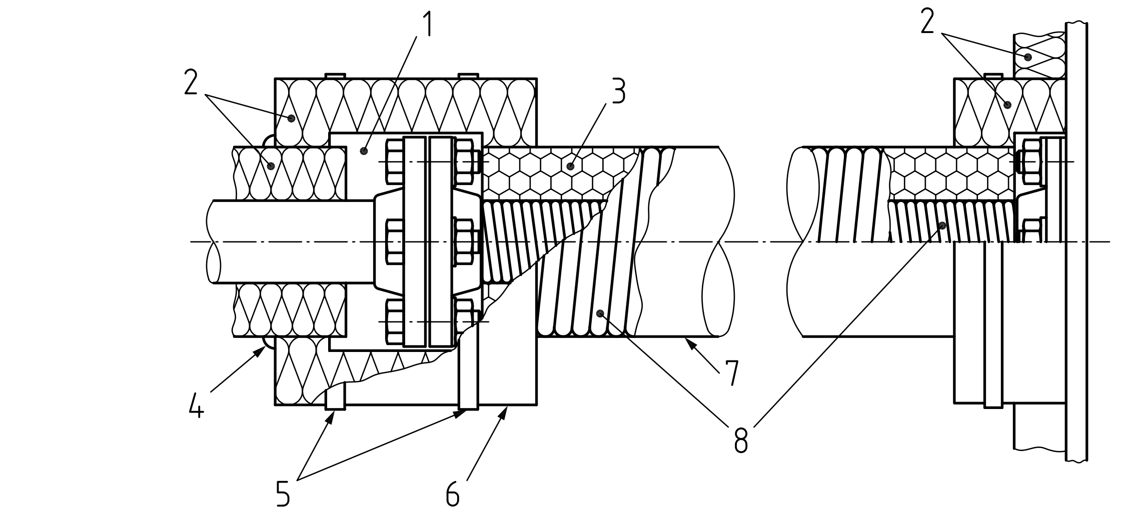
Hangers and supports should be insulated from the pipe surface (see Figure 18). Where pipework is outdoors or in areas of likely spillage, the surface should be sealed to prevent liquid ingress.

NOTE Methods for insulating hot pipes using direct-contact support or insulation rings are shown in Figure 12 to Figure 15 and Figure 17.

Flexible piping, other than corrugated piping for steam services, should be insulated as shown in Figure 30.

Pipe systems should be tested for leak tightness and the insulation should not be finally secured over joints until the system has proved to be leak-free under operating conditions. Temporary seals should be provided to the exposed ends of the insulation. To facilitate regular inspection of welds and bolted joints, removable portions of insulating and finishing materials should be provided in the appropriate locations.

Figure 30 **Typical method of insulating flexible pipe**



Key

1 Space for withdrawal of bolt	5 Securing bands
2 Insulation	6 Flange cover
3 Flexible insulation	7 Glass cloth
4 Mastic seal	8 Flexible pipe

29.2.2 Pre-formed materials

Pre-formed pipe sections should conform to the appropriate British Standard. They should be fitted closely to the pipe, and any unavoidable gaps in circumferential or longitudinal joints should be filled with compatible insulating material. Where there is more than one layer of insulating material, all joints should be staggered (see Figure 1).

Each section should be held in place by circumferential bands or wires (see **27.4.1**, **27.4.2** and **27.4.5**) at not greater than 450 mm spacing and not nearer than 50 mm to the end of the section. Over-tightening of bands or wires should be avoided to prevent cracking of rigid material or opening of joints of flexible material. After tightening, the ends should be pressed on to the insulating material. The choice of material for the bands or wire and its corrosion protection should be assessed and documented based on the environmental conditions and applied finish (see **25.6** for leak testing).

Sections held in position and covered by a fabric should be secured with an adhesive. The edge of the fabric should overlap by at least 25 mm. Where adhesive tape is used, it should be at least 50 mm wide applied centrally to the joint and overlapping itself by at least 50 mm at the termination.

*NOTE 1 Alternatively, with a fabric or sheet outer finish, the whole may be secured by circumferential bands (see **27.4.2** and **27.4.5**).*

Sections that are split down one side only should be sprung on to the piping and secured. Certain types of pipe sections can be secured by corrosion-resisting staples at the joints; these staples should be not further apart than 100 mm.

For vertical and near vertical piping, downward displacement of the insulating material should be prevented by the use of supports, which can be in the form of metal rings, part rings, or studs (see **27.7.2** and **27.7.3**). These supports should be located at intervals of not more than 5.0 m and there should be a support immediately above each expansion break in the insulation (see **29.1.3**).

*NOTE 2 For extent of penetration of the supports, see **27.7.7**. For extent of penetration of the welded attachments, see **27.6.11**. Where stud-type supports are welded radially to a separate ring that might be clamped around the pipe, see **27.7.4** for the need for welded pads on the pipe.*

29.2.3 Flexible materials

29.2.3.1 Fabric-covered mattresses should be made from a flexible medium and filled with a filling that contains a minimum of dust or foreign matter. The hem of the fabric cover should be folded twice before sewing. The inner faces of mattresses and the filling should be suitable for continuous exposure to the temperature at the hot face of the equipment. The outer face of the mattress should be suitable for continuous exposure to environmental conditions. The edges of mattresses should overlap adjoining insulation and be bound with tie wires fixed to hooks and eyes/discs, velcro fastenings or glass rope ties. Air spaces should be kept to a minimum and there should be no free passages from hot surface to atmosphere. The filling material should be prevented from packing down by quilting as necessary. Mattresses faced with metal mesh should conform to BS 3958-3. Strip and rope material should be wrapped spirally around the surface, successive layers being applied to opposite hand. The ends of this material should be firmly secured and all tie wires buried. Flexible materials should not be unduly compressed. Where insulation is fitted in two layers, the layers should be staggered.

29.2.3.2 Flexible insulating blankets or mats should be secured with circumferential bands of metal or plastics strip, as described in **27.1.1**, with the exception of circumferential tie wires, which may be used when the ultimate finish is to be of sheet metal. Securing bands should be of compatible material or isolated from the jacketing.

29.2.3.3 For vertical and near-vertical piping, downward displacement of flexible insulating materials should be prevented. While support from below is suitable for many pre-formed materials, flexible insulating materials should be suspended from above.

29.2.4 Foamed in situ

Foamed in situ insulation should be applied in accordance with **29.3.6**.

29.2.5 Sprayed insulation

Spray-applied insulation should only be used for piping greater than 300 mm nominal size and there should be good all-round access.

NOTE 1 Excessive amounts of material might be required due to overspray. Overspray can be reduced when used on larger-diameter pipes or flat surfaces by erecting temporary wind shields.

Adjacent equipment should be protected from overspray.

*NOTE 2 For more details of the application of sprayed insulation, see **29.3.7**.*

NOTE 3 Some variation in the thickness and the quality of the surface finish is inevitable.

29.2.6 Loosefill insulation

Loosefill requires a permanent casing and the filling should be poured, blown or packed to the density required by the declared value of the thermal conductivity; baffle plates should be fitted as necessary to prevent settling. Some settlement can occur with some materials, but this should not be greater than 10% and arrangements should be made to enable the insulation to be topped up within six months of completing the initial application.

29.2.7 Insulating concrete

NOTE This type of material consists of an insulating aggregate bonded in situ with either Portland cement or high alumina cement. The insulating aggregate can be an expanded natural mineral or granular expanded clay brick.

29.2.7.1 For highly porous pre-fired brick aggregates, the aggregate should be soaked in water for 12 hours and then quickly drained before being mixed with the cement and the measured amount of water for use. Insulating concrete should not be used where the impinging gas contains entrained solids due to their abrasive action.

NOTE The chief use with pipes is to protect the metal from excessive temperature, either as a lining for the conveyance of hot gas or over the outer surface when the metal of the pipe is to be shielded from the impact of hot gas.

29.2.7.2 Linings for large pipes should be anchored by Y-studs or V-anchors welded to the inner surface; for horizontal pipes, the upper curved surface should have studs at a closer pitch than those over the lower surfaces. Externally shielded pipes should have either plain or Y-type securing studs welded to the surface. In both cases, the concrete should be reinforced additionally by expanded metal or other metal mesh reinforcement secured to the studs at a short distance from the surface to be shielded.

29.2.7.3 The concrete for lining pipes should be applied by hand trowelling, spray-gun or, in certain specialized cases, by centrifugal spinning.

NOTE For exterior treatment the principal method is to apply the material by hand trowel.

29.2.7.4 After application, the insulating concrete should be cured by maintaining in a moist condition (e.g. by covering with wet sacks, spraying with water) for 24 hours. The initial heating should be relatively slow (see manufacturer's instructions and also **29.3.9**).

29.2.8 Pipes with trace heating

29.2.8.1 General

The following trace heating methods should be assessed and selected or rejected accordingly:

a) external pipe tracing, in which a small-bore heating pipe is placed close to the main pipe;

b) electrical tracing, in which an electrically heated tracing tape or cable is wound around the outside of the pipe or clipped immediately below and in contact with it;

c) jacketing, in which the main pipe is fitted with a jacket through which heating fluid is passed;

d) lancing, in which a small-bore heating pipe is inserted inside the main pipe; and

e) extruded pipe that has its own integral heating pipe in its wall.

29.2.8.2 Application of insulation to pipework heated by external tracing pipe

Before application of insulation, the product pipe and tracer pipe should be wrapped together with aluminium foil not less than 0.06 mm thick (see Figure 31 and Figure 32).

NOTE 1 The principal mode of heat transfer between the external tracer pipe and the heated pipe is by direct conduction.

NOTE 2 The following methods may be used to increase the effectiveness of heat transfer:

a) maintaining a hot air space inside the insulation cover to increase the heat transfer area;

b) maintaining direct contact between the tracer pipe and the main pipe by wiring or strapping at intervals; and

c) using heat-conducting cement to increase the contact area between the tracer and heated pipe.

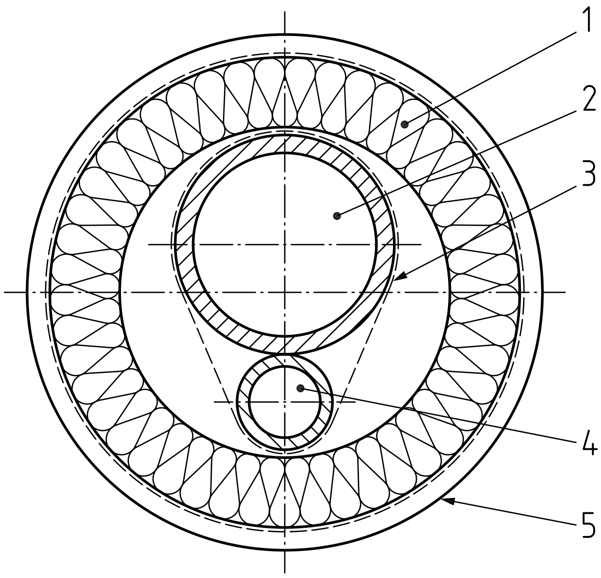
When corrosive action between fluid and main pipe is liable to occur at local hot spots, spacers of low conductivity should be fitted between tracer and heated pipe to prevent direct contact between tracer and main pipe.

NOTE 3 This can decrease the effectiveness of heat transfer.

The tracer pipe itself should be looped out and jointed near the main pipe flanges, e.g. by a compression fitting. The exposed length of tracer should be insulated.

Leak testing should be satisfactorily completed before the application of thermal insulation.

Figure 31 **Typical method of insulating steam traced pipe**



Key

1 Pipe section insulation

2 Main pipe

3 Aluminium foil >0.06 mm

4 Tracer

5 Finish as required

29.2.8.3 Electrical tracing

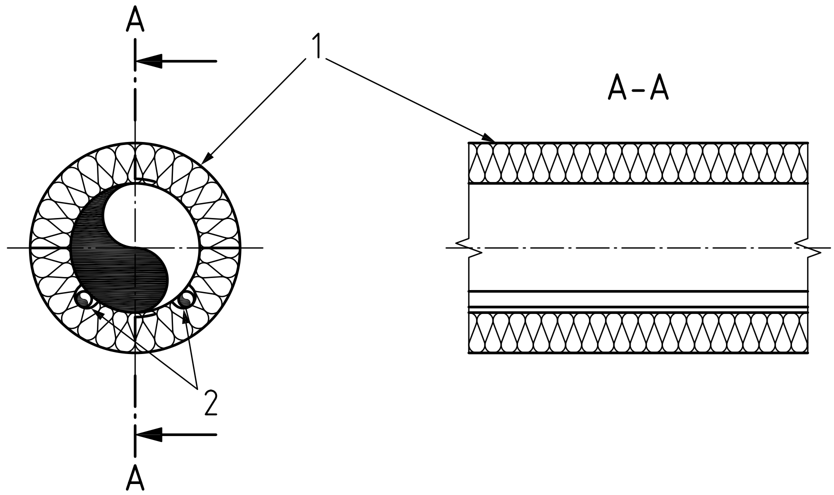
Electrical tracing should always be applied and insulated in accordance with the tracing manufacturer's instructions.

Mechanical damage should be avoided and the heater tape should be protected from water or chemical spillage. Pre-formed insulation of the correct inner diameter should be applied to fit over the tracing cable on the pipe. Where live electric tracing cables are buried in the insulation, a warning notice should be placed on the outside.

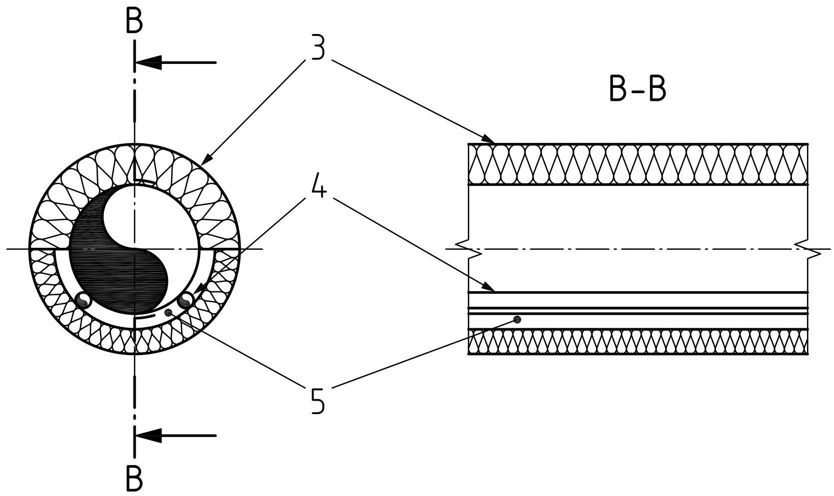
Compatibility of heat tracing material with the pipes should be ensured (refer to Table 10 for further details of compatibility of materials).

Copper-sheathed insulated cable should not be installed in direct contact with galvanized steel.

Figure 32 **Typical method of insulating electrically traced pipe**



a) End view – Section A



b) End view – Section B

Key

1 Insulation

2 Insulation grooved to accept tracers

3 Insulation (full thickness top half only)

4 Tracer lines

5 Void bottom half (may be filled with blanket insulation)

29.2.8.4 Application of insulation to pipework heated by jacketing, lancing or integral heating

These systems require no special technique and should be insulated as normal pipework. Leak testing should be satisfactorily completed before the application of thermal insulation.

29.2.9 Piping bends

Bends should be insulated to the same specification as the adjacent straight piping. Pre-formed bends may be used, but where unavailable, site-mitred segments should be used. Any other avoidable gaps that might appear between mitred segments should be filled with compatible material. Where plastic composition is to be used, the danger of moisture-induced, stress-corrosion attack on austenitic steels should be assessed and protected against, see **8.4.1**.

29.2.10 Flanges, valves and other fittings on hot piping

29.2.10.1 General

Valves and flanges should be insulated, but where hidden flange leakage can cause a possible fire or other hazard, e.g. with oil lines, or where repeated access makes it uneconomical, insulation may be omitted. For example, for hot hydrogen duty, a simple sheet-metal shroud should be placed over the flanges to protect them from thermal shock due to changes in atmospheric conditions, whilst permitting access for safety, etc.

Drain points should be considered, particularly for hot-oil systems.

*NOTE Five common methods adopted are described in **29.2.10.2** to **29.2.10.6**.*

29.2.10.2 Pre-formed flange and valve insulation covers

Where possible, flanges and valves should be insulated by pre-formed covers (see Figure 20).

29.2.10.3 Flange and valve boxes

Flange and valve boxes should be selected from the materials described in **30.1** and **31.1** and lined with pre-formed rigid or flexible insulating material, which is mechanically secured to the box. Direct contact between the metal of the box and the insulated metal surface should be avoided (see Figure 21, Figure 23, Figure 24 and Figure 25).

29.2.10.4 Mattresses

NOTE These consist of a glass or silica fibre cloth envelope packed with loosefill insulating material (see Figure 28 and Figure 29).

Where a cloth needs to be weather-resistant for external use, it should be impregnated with weather-resistant material.

29.2.10.5 Oversized sections

The insulation should be built up with collars of pre-formed material on each side of the flange, leaving space for withdrawal of the bolts and a length of large bore section applied over the outside of the collars to bridge between them and cover the flange (see Figure 22).

29.2.10.6 Plumber's joint

NOTE This may be achieved by the application of plastic composition over flanges or valves, after the insulation on adjacent piping has been finished.

The insulation systems referred to in **29.2.10.2** to **29.2.10.5** should be used.

29.2.11 Plastic composition

29.2.11.1 All plastic compositions should be mixed with clean, fresh water. Before application of plastic composition, the piping should be heated to a minimum temperature of 65 °C. This temperature should be increased progressively with the application of subsequent layers of plastic composition. A preliminary coating of keying composition should be applied and allowed to dry.

The composition should be applied by hand in layers, each layer being allowed to dry before successive applications are made. The first layer should be between 12 mm and 25 mm thick. Remaining layers should be up to 25 mm thick. The surface of each layer should be roughened by hand to provide a key for the next layer. The surface of the final layer should be smoothed off.

29.2.11.2 Plastic composition materials might not require securing attachments on pipework, but reinforcing metal mesh should be provided over the first 25 mm of thickness and subsequently at each 50 mm increment of thickness and over the final surface.

NOTE The final layer is for the purpose of reinforcing the finishing cement.

29.2.11.3 For thicknesses greater than 50 mm on pipes for 150 mm nominal size and over, an intermediate reinforcing layer of metal mesh should be used, as detailed in **27.5**, taking into account the temperature limitations of galvanized wire mesh. This layer should be independent of any finishing reinforcement. For pipes less than 150 mm nominal size, the reinforcing of the first layer can suitably be wire of 1.0 mm to 1.5 mm diameter and should be wrapped spirally at 75 mm centres.

29.3 Vessels and large curved surfaces

29.3.1 General considerations

The need to dismantle associated pipework and inspection covers should be anticipated and permanent insulation should end sufficiently far from flanges and fittings to enable bolts to be withdrawn. Removable portions of insulating and finishing materials should be provided in the appropriate locations to allow regular inspection of welds and bolted joints. The junction between removable and permanent insulation should be made readily discernible, e.g. by painting the end of the permanent insulation, by laying a textile fabric over the end. For external applications or where fluid spillage is likely, the permanent insulation should be terminated with a finish to prevent fluid ingress while removable sections are not in place.

Manhole covers should be insulated separately and the insulation value should not be less than that provided on the main body of the vessel, see **8.2.1.8**. The support and retention of cladding for vessels and columns should be capable of withstanding wind loads.

29.3.2 Storage tanks

NOTE See also Clause ***10****.*

29.3.2.1 Corrosion protection

As the presence of insulation prevents inspection of the tank, the surface should be prepared and painted before the insulation is applied. The tank shell, roof (where insulated) and welded attachments should be dry, free from grease and loosely adhering particles, and painted to a specification agreed by the purchaser.

Although painting cannot be part of the insulation contract, the insulation contractor should avoid damaging any paintwork and should report any damaged areas to the purchaser, who should make good before insulation is applied.

If the insulation system involves the foamed in situ technique or the spraying of polyurethane foam, the paint system should be compatible with the foam system and unaffected by any foaming reaction or in-service condition. Where foam insulation incorporates fire-retardant formulations, the insulation system should be protected against the possibility of halogen-induced accelerated corrosion (see Clause **8**).

29.3.2.2 Nozzle connections and manholes

The tank design should include sealing discs fitted to all nozzles and protrusions on shells and roofs to ensure an adequate weatherproof seal can be made.

29.3.2.3 Stairway connections

The inner stringer of double-stringer staircases should be spaced away from the tank at a distance sufficient to ensure a gap of not less than 75 mm between it and the outer face of the insulation system. Stairways with treads welded directly to the shell should not be specified for insulated new tanks.

With such stairways on existing tanks, a weather shield should be provided beneath the treads with dimensions to ensure adequate weather-protection of the insulation.

29.3.2.4 Base of shell

A supporting ring should be welded to the tank at not less than 150 mm from the tank base to keep the insulation clear of standing liquids. The width of the ring should be equal to the specified thickness of insulation, but should be profiled to avoid creating a water-trap lip before and after installation of insulation.

Unless the heat losses produced exceed the specification, the insulation should terminate approximately at the ring to minimize the rise of corrosion at the bottom of the tank (see Figure 20). Where the heat losses exceed the specification, cellular glass slabs adhered with bitumen-polyurethane adhesive or other adhesives to a minimum height of 150 mm should be used for insulation of the tank shell below the lowest horizontal support.

29.3.2.5 Insulation support rings

Insulation support rings should be provided at regular intervals determined by the compressive strength of the insulation. The width of support rings should be to half way through the thickness of the outer layer of insulation.

29.3.2.6 Cladding securement

On tanks with a diameter of less than 10 m, the secure attachment of insulation and cladding should usually be achievable by simple methods such as banding.

For storage tanks with a diameter 10 m greater and small tanks adjacent to other tanks, structures or buildings, the securing and retention of the insulation material and its protective cladding can become problematic; wind loading and associated vacuum effects, differential thermal expansion and hydraulic pressure expansion should be assessed and precautions taken accordingly.

The design and application of insulation and cladding systems for these tanks should be in accordance with BS EN 14015:2004, Annex Q, while following the insulation practices described in this document.

29.3.2.7 Roof insulation

The shell and roof insulation should be segregated to minimize the effect of any water ingress to the insulation system.

Where the tank roof is designed to project beyond the tank shell, the projection should be not less than the thickness of the insulation system plus 50 mm.

Where the roof does not project an adequate distance beyond the tank shell, this protection should be provided as part of the insulation system.

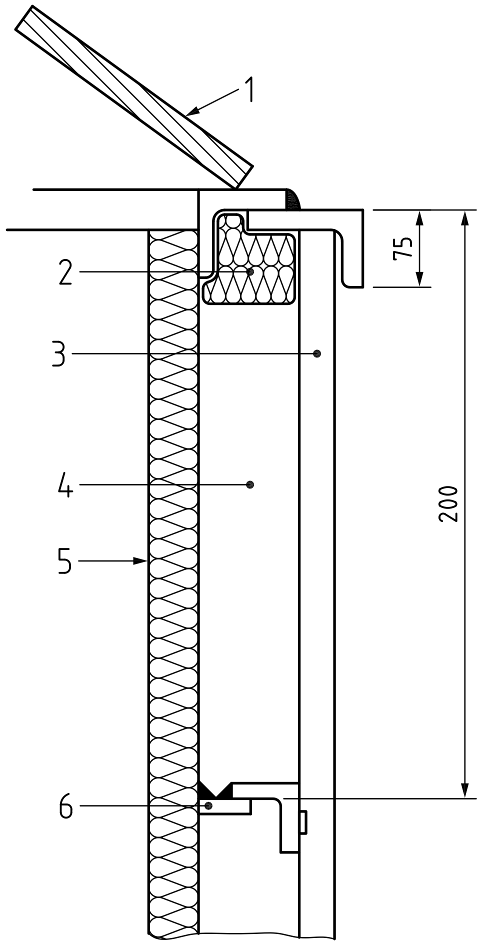
NOTE 1 An expansion/contraction joint might be required at the wall/roof interface when using rigid insulation materials.

For access areas, load-bearing insulation should be used to reduce risk of damage to the weather-proofing system and insulation.

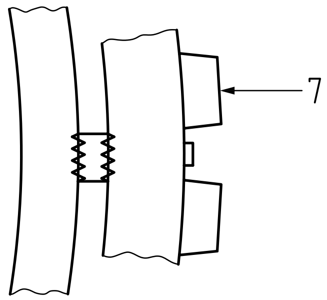
NOTE 2 For "shell only" insulation, see typical detail of roof termination in Figure 33.

Figure 33 **Typical arrangement showing termination of insulation adjacent to the tank roof**

Dimensions in millimetres



a) Cross-section



b) Plan view (through 6)

Key

1 Roof plate
2 Expansion contraction joint filled with compressible insulation
3 Cladding
4 Tank shell
5 Insulation
6 Supporting ring
7 Profile cladding

29.3.3 Pre-formed materials

NOTE Pre-formed materials may be cut to fit irregular contours. Alternatively, material may be used to provide a regular foundation (see Figure 28 and Figure 29).

All cut faces should be clean and adjacent edges should be butted. For multilayer applications, joints should be staggered.

29.3.4 Plastic composition

Application and reinforcement should be in accordance with **29.2.11**.

29.3.5 Flexible materials

Adjacent edges of flexible insulation should be secured in close contact with each other. Gaps should be kept to a minimum and there should be no free passages from hot to cold surface. Insulation should be secured in accordance with **27.1.4**.

29.3.6 Foamed in situ

NOTE 1 In situ foaming may be used where complicated shapes are involved, where the number of joints has to be kept to a minimum, or where the insulation is required to contribute to the strength of the structure.

Rigid polyurethanes or polyisocyanurates, if selected, should not be used in applications above their maximum service temperature (see Table 3 and Table 4). For polyisocyanurate, the cavity should be maintained at temperatures in excess of 25 °C to enable the chemical reaction to be completed. A liquid or froth mixture should be poured or injected into a cavity made by fitting shuttering around the equipment.

NOTE 2 The mixture reacts chemically to produce an expanding foam that subsequently sets to a rigid mass.

The rate of expansion of the foam may be varied by the formulation and should be discussed with the manufacturer.

NOTE 3 Considerable pressure can be exerted by the rising foam on the shuttering and, although this can be reduced by dispensing the foam in small amounts, it might be necessary to constrain the assembly.

In very cold weather, the metal surfaces should be warmed.

Extremely efficient insulation can be obtained using this method, but as it involves carrying out a manufacturing process, often under difficult site conditions, competent technical supervision is essential and should be continuous. The purchaser should check that the contractor provides this supervision. As the insulation itself cannot be subject to the same degree of quality control as pre-formed materials, particularly where permanent shuttering is used, there should be adequate access for inspection and regular test samples should be made. Where foaming is more or less continuous, test samples should be taken on an hourly basis.

NOTE 4 With intermittent foaming, fewer samples might be needed but the quality of the foam can be adversely affected.

At least one sample should be made at the beginning of each session of work. Samples should be prepared in test cavities of similar thickness to the application and suitably jigged so that the density and cell structure can be assessed. Samples should be prepared in polyethylene bags so that surface faults in the foam can be readily observed. After allowing the sample to cool for about 15 minutes, it should be examined internally to assess the visual quality of foam. The sample should contain no un-reacted materials and be of uniform texture, free from voids and shrinkage. When the foam components are being metered and mixed mechanically, the equipment should be thoroughly checked each day before work begins.

Where in situ foaming is used for items where the insulation has to be removed from time to time, the inner surface should be lined with a material such as polyethylene sheet. To prevent the foam filling behind protuberances such as flanges, making removal difficult, such points should be packed out with loosefill material before applying the lining sheet. Where pre-formed material is used for removable areas, the junction between pre-formed and in situ foam should be broken; a separating agent such as polyethylene sheet or aluminium foil should be inserted.

Special safety precautions should be taken when working with polymeric foam components. Stock drums should be protected against excessive heat and against water. For work in confined spaces with certain types of isocyanate or for work done with certain types of mixing head, fresh-air masks or hoods should be worn; air extraction equipment might also be necessary (see **7.11**).

Heat (e.g. from welding) should not be applied to metal coated with polyurethane foam, as toxic gases can be generated and fire can propagate between the vessel and cladding. Precautions should be taken to ensure that chimneys, ventilation passages, etc., have not become blocked with foam.

29.3.7 Sprayed insulation

29.3.7.1 General considerations

Spray-applied insulation to large areas should be applied where the problem of overspray is minimal and full advantage can be taken of the rapid method of application. Access should be good and made by the use of powered cradles. Where scaffolding is used, it should be set at a sufficient distance from the vessel to allow application of the full thickness of insulation and to avoid masking the surface from the spray.

29.3.7.2 Mineral fibre

NOTE This consists of a mixture of milled mineral fibre and hydraulic binders.

Mineral fibre should be applied by spraying together with jets of atomized water and pressing back to the thickness and density required. Metal surfaces may be primed and the mineral fibre should be sprayed on before the primer has dried.

29.3.7.3 Spray-applied rigid organic foam (polyurethane or isocyanurate)

The techniques and hazards involved with these materials are such that only skilled and experienced operators should be employed. When choosing these insulation systems, fire problems should be assessed and documented. It is essential that substantial protection is provided from the weather and in very cold weather some heating might be necessary. The metal surface should be free of moisture, grease and dust that could impair the adhesion of the foam. A primer should be applied, which should be left to dry before any spraying is carried out.

NOTE Failure of the foam to stick to the metal might not be evident immediately and is not readily detected by eye because of the uneven finish of the surface of the foam. It can be detected by tapping the foam, which gives a distinctive hollow sound if it is not stuck to the metal. This technique is not as wholly reliable as differing densities of foam can give different sounds. Adhesion tests might be required in specific instances. It is impossible to achieve an absolutely even thickness with a perfectly smooth surface, but a skilled operator in good conditions can produce a reasonably consistent coating and finish. Surface irregularities in the metal, such as welds, can be exaggerated by the foam. At surface irregularities and where the foam is uneven or rough, it might be necessary to trim the foam before any ultraviolet protection or finishing coat is applied.

The trimming of foam leaves a cut-cell surface, which should be sealed. Supervision, sampling and checking of equipment should be in accordance with **29.3.6**.

Sprays or foams should be applied in accordance with BS 5241 (all parts) and BS 7021. Corrosion from water ingress in sprayed foam should be protected against (see Clause **8**).

29.3.8 Loosefill insulation

Loosefill insulation should be applied in accordance with **29.2.6**.

29.3.9 Insulating concrete

Concrete insulation should be applied in accordance with **29.2.7**, but unless the thickness of concrete to be applied is structurally sound, the linings of cylindrical vessels should usually be adequately reinforced, e.g. with heavy hexagon strip mesh, expanded metal, square road mesh. Reinforcement should be welded to studs or other spacers that, in turn, are secured to the surface to be protected. Mesh reinforcements should be used where insulating concrete is applied to external surfaces of cylindrical vessels, e.g. fire protection of oil tanks, except for thicknesses over about 75 mm, which can be retained by Y-studs only.

NOTE At the upper temperature limit covered by this British Standard, i.e. 870 °C, insulating concretes are likely to show mechanical weakness owing to the loss of strength of the hydraulic bond.

Under conditions of soaking heat at temperatures over approximately 260 °C, adequate reinforcement should be provided as the hydraulic bond can lose strength, which can lead to rapid failure.

After application, the insulating concrete should be cured by maintaining it in a moist condition (e.g. by covering it with wet sacks, spraying it with water for 24 hours). The initial heating should be relatively slow (see manufacturer's recommendations).

29.4 Air ducts and gas flues

NOTE 1 There are three different types of air duct: warm, chilled or dual purpose as defined in BS 5422.

*NOTE 2 For the purposes of **29.4**, a duct is a rectangular or cylindrical conveyance system through which cold or hot air is passed from one location to another. A flue is used similarly for the conveyance of the products of combustion, usually designated as flue gas, or more simply as gas. Both air ducts and gas flues can be located inside a building, or they can be partly or wholly outdoors and exposed to the weather.*

29.4.1 Air ducts (building services)

29.4.1.1 Insulation should be applied to ductwork, fans, heat exchangers, filter casings, etc., carrying conditioned air. Fresh-air ducts and exhaust ducts carrying hot air should be insulated to prevent excessive heat gain, either to the contained air or to the surrounding space. Plenum heating ducts should be insulated for personnel protection and for heat conservation.

*NOTE For additional information, see **4.1** and BS 5422 for recommended thicknesses. For clearances at instruments, detectors, dampers, and hinged and removable doors at access openings, see also **28.7.2** Note 1, **28.7.4.1** and **28.7.5**.*

29.4.1.2 Insulation should be applied to ductwork in accordance with **28.7**.

29.4.1.3 Thicknesses of thermal insulation should be in accordance with BS 5422 or, where specific requirements are stated, calculation should be in accordance with BS EN ISO 12241. When transient working temperatures are below the dew-point of the ambient air, insulation thicknesses should be sufficient to prevent surface condensation.

29.4.2 Hot air ducts (industrial applications)

29.4.2.1 Insulation should be applied to conserve heat. Insulation thickness varies with service temperature, but less than 50 mm thickness should not normally be used. For insulation thicknesses greater than 75 mm, the insulation should normally be applied in multilayers with all the joints in the consecutive layers staggered. Manufacturer's advice should be sought as some materials are suitable for applying in single or multiple layers of greater than 50 mm.

NOTE Typical duct-air temperatures are normally in the range 50 °C to 500 °C.

29.4.2.2 The insulating material should be pre-formed slabs of calcium silicate, perlite or inorganically-bonded man-made mineral fibre, or cellular glass. Alternatively, man-made mineral-fibre mattresses and blankets may be used, but excessive compression of the insulant should be avoided. The recommended upper temperature-limit of the insulating material, in particular for that in immediate contact with the hot surface, should not be exceeded. All materials used should not constitute a fire hazard (see **7.9** and BS 5422).

NOTE Organically-bonded man-made mineral-fibre slab may also be used, but loss of the organic binder reduces its compressive strength (if this property is required) when operated above a temperature of approximately 230 °C.

29.4.2.3 The insulation material should be firmly secured to the duct with fork ties, split pins or solid studs, over which the insulation is impaled. Where a rigid slab material, e.g. calcium silicate is to be installed, the insulant should be predrilled to avoid cracking the insulant during installation. The fixings should be welded to the duct at the pitch recommended in **27.6.10**. Where fork ties or split pins are used, they should penetrate through the insulant and be bent over washers in accordance with **27.6.7**. Solid stud fixings should be restricted for use with easily compressible insulants or where a space is present between the metallic cladding and the insulant. For stainless steel, "push-fix" washers should be applied to the studs to retain the insulant. Austenitic steel lacing wires should be installed crossing each slab twice and secured behind the washers. Certain insulants are susceptible to damage from lacing wires and manufacturer's advice should be sought. Alternatively, a wire mesh should be installed where a wet finish is to be applied or where a high degree of stability is required. When a metallic cladding is to be installed, the fixings should, where possible, lie within the thickness of the insulation to avoid metal to metal contact.

29.4.2.4 Wet-applied finishing compositions should be reinforced normally by woven wire mesh, as described in **29.4.2.3**, or by expanded metal mesh on suspended surfaces (see **27.5.1** and **30.1**). Hard-setting compositions reconstitute in the presence of water and should not be used for outdoor applications or where water leakage is likely to occur. Where additional protection is required, a breather type polymeric coating reinforced with open-mesh glass cloth should be coated over the finish.

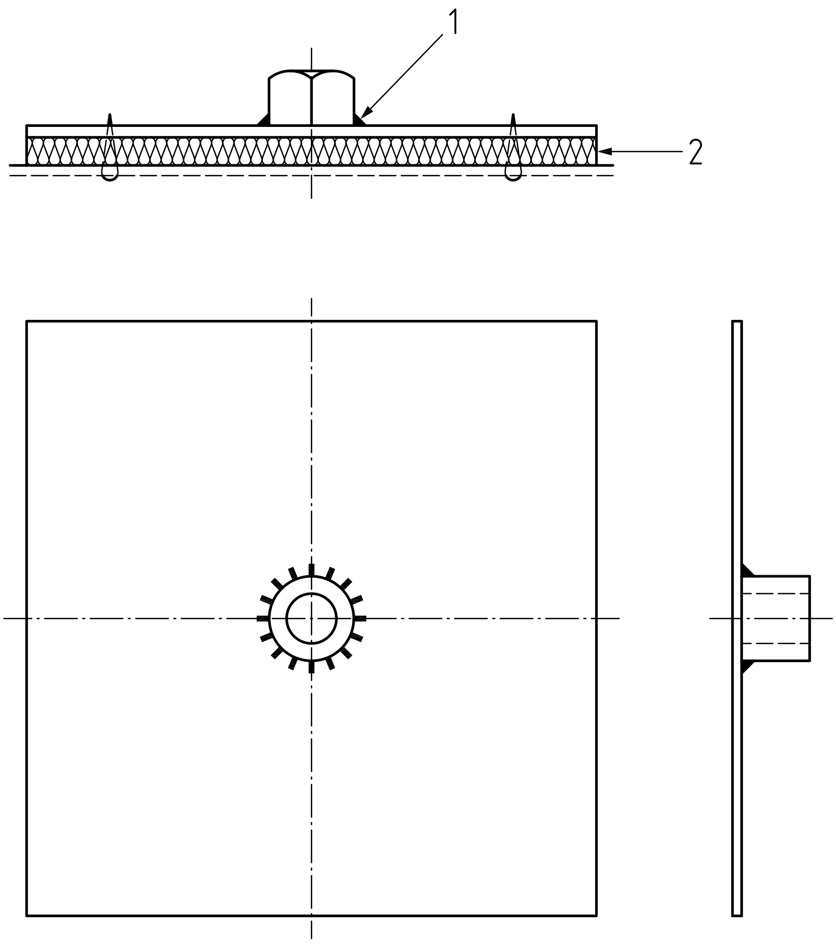
NOTE Two main types of wet-applied finishing compositions are available, self-setting cements and hard-setting composition.

29.4.2.5 Although there are a number of finishes which may be used on outdoor hot-air ducts, metallic cladding should be used because it provides fire resistance and good mechanical and weather-protection. Water ingress into the insulation should be prevented because this significantly increases the weight on the duct, increases thermal losses and can give rise to an enhanced rate of corrosion of the plate-work and fixings. Where self-setting cement is to be used on an outdoor duct, it should be finally treated with a weatherproofing finish. The coating should be vented or a compound should be used that permits the escape of any trapped moisture when the duct is first heated for service (see **31.5.4**). Where no provision has been made in the design of the duct for run-off water, it can be necessary to build-up a slope when applying the required thickness of slab insulation; a slope of 1:25 should be suitable for most applications.

29.4.2.6 Where a metal outer finish is to be installed, it should be supported on insulated plates mounted on threaded studs or insulated angle cleats or rails (see Figure 34). The insulation support system should be designed to allow for differential expansion so that these retention systems can move with the thermal movement of the duct. To accommodate this, a slippage arrangement on the retention system or expansion folds in the metal finish should be provided.

NOTE Profiled sheet accommodates the movement in one direction and overlaps cater for the other movement (see Figure 35).

Figure 34 **Insulated support plate for metal cladding – 150 mm square**



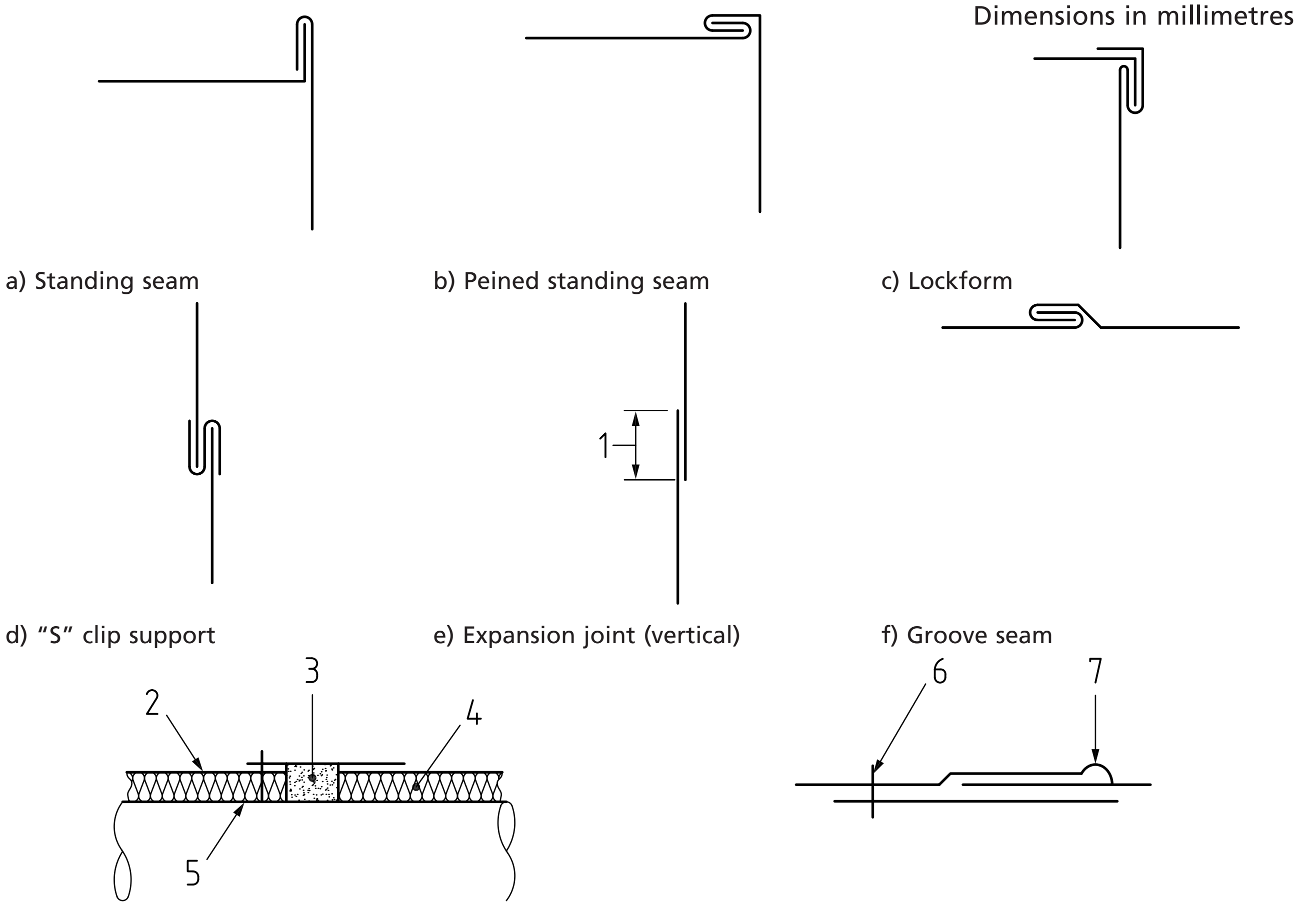
Key

1 Nut weld to support plate

2 Insulating pad

Figure 35 **Typical joints in sheet metal**

Dimensions in millimetres



a) Standing seam b) Peined standing seam c) Lockform

d) "S" clip support e) Expansion joint (vertical) f) Groove seam

g) Expansion collar h) Expansion joint (horizontal)

Key

1 ≥50 mm designed expansion
2 Metal cladding
3 Flexible material
4 Rigid insulation
5 Pipe wall
6 Rivet
7 Swage

29.4.2.7 To create a "straight line" appearance, a rail system for the retention of the metal sheets should be used. The rail should be stood-off from the duct surface sufficiently to clear the majority of the stiffening members.

NOTE This obviates the use of box sections to a large extent and provides a cleaner appearance.

29.4.2.8 Outdoor hot-air ducts should have all joints in the metal sheets sealed with a non-setting weatherproof sealing compound. Where practicable, the roofing sheets should be extended over the sides to form eaves. Where profiled sheet is used, it is important that proprietary filler blocks should be used to close the openings.

29.4.2.9 The insulation and finishing material should finish clear of any instruments, detectors, damper operating gear and accessories to permit free access and movement. They should also finish clear of any access openings and doors (see **28.7.2** Note 1, **28.7.4.1** and **28.7.5**). Where necessary, weatherproofing should be provided for outdoor installation. Where an acoustic barrier of a combustible nature is applied over the insulant, it should be kept clear of hot moving parts such as damper spindles.

29.4.2.10 The thickness of metal cladding, where used, should be in accordance with Table 9.

Table 9 **Thickness of metal cladding**

Type of area	Protected mild steel		Aluminium		Stainless steel	
	Flat mm	Profiled mm	Flat mm	Profiled mm	Flat mm	Profiled mm
Large flat areas over flexible insulation	1.2	0.8	1.6	0.9	1.0	0.6
Smaller flat areas over flexible insulation, or large areas over pre-formed slabs (including large curved surfaces)	1.0	0.8	1.2	0.9	0.8	0.5
Removable insulated manhole and door covers	1.6	—	1.6	—	1.0	—
Flange and valve boxes	As metal on adjacent pipe					
Pipes with an insulated diameter of more than 450 mm	1.0	—	1.2	—	0.8	—
Pipes with an insulated diameter of 150 mm to 450 mm	0.8	—	0.9	—	0.6	—
Pipes with an insulated diameter of less than 150 mm [A)]	0.6	—	0.7	—	0.5	—
Recommended thickness for reinforcing plates and where foot traffic is likely						
For flat surfaces, large curved areas and pipes with an insulated diameter of 450 mm or more	1.6	—	1.6	—	1.0	—
For pipes with an insulated diameter of less than 450 mm	1.0	—	1.2	—	0.8	—
Recommended thickness where no mechanical damage is likely						
For pipes with an insulated diameter of less than 1 000 mm	0.3	—	0.3	—	0.3	—
For pipes with an insulated diameter of 1 000 mm or more	0.4	—	0.4	—	0.4	—

[A)] For insulation diameters of 150 mm or less, the thickness of reeded aluminium should be not less than 0.25 mm. For insulation diameters in excess of 150 mm, it should be 0.4 mm or greater.

29.4.2.11 Stiffeners that project beyond the main line of the insulation should be covered with not less than 25 mm or half the full thickness of the main insulation, whichever is the greater, built up so as to enclose the metal of the stiffeners completely. The finish should be the same as for the main area of the duct.

29.4.2.12 Where metal cladding can be in direct contact with the securing wire or reinforcing mesh, precautions should be taken to avoid the possibility of electrochemical corrosion that could result from direct contact between dissimilar metals under humid conditions (see **8.3.4**).

29.4.2.13 For certain types of application, e.g. close spacing of stiffeners, a rigid square mesh may be mechanically fixed over the outerline of the stiffeners, which is used as a substrate for the insulant; adjacent edges should be securely laced or welded together to form a firm base for the insulation material. The air space formed beneath the insulation should be sealed to restrict ingress and egress of air. A convection barrier should be used at intervals between the duct surface and the mesh.

NOTE This arrangement permits the application of metal cladding with a uniform exposed surface over the whole insulated duct.

29.4.3 Gas flues, flares and exhausts

*COMMENTARY ON **29.4.3***

Attention is drawn to the Dangerous Substances and Explosive Amospheres Regulations [18], where the risk of contact of combustible gases with hot surfaces is to be considered.

Gas temperatures are likely to be within the range 140 °C to 600 °C although in some cases higher temperatures can be encountered.

Due to the requirements for optimum use of energy, gas flues can be associated with some form of heat exchanger, e.g. air heater, so that the resulting gas temperature might be as little above the dew-point of the gas as can be practicable. At low load and with a low rate of gas flow, any deficiency in the insulation system can result in acidic condensation within the flue.

This condition is most aggressive when the gas is derived from the combustion of fuels with a high sulfur content.

29.4.3.1 The insulation system should be designed to maintain the gas temperature above the dew-point of the flue gas.

NOTE Depending on the method of operation of the plant, e.g. overnight or weekend shutdown, the thickness of the insulating material may be increased to avoid the entrained gases condensing out, which affects the thermal capacity and thermal conductivity of the insulation system.

29.4.3.2 The insulation system used should be chosen taking into account the design of the flue and, in particular, the method of construction and the size and position of stiffening members incorporated to reduce vibration and provide structural stability to the structure. The insulation system on all roofs where a metallic cladding is not separately supported should be compression-resistant to reduce potential damage during service. Where access is required on a regular basis, e.g. tapping points, a separately supported walkway should be installed or additional supports should be incorporated in the design of the insulation system.

29.4.3.3 The metal temperature of a carbon steel flue should be restricted to 460 °C to avoid scaling (see **8.3.1**). Precautions should be taken to protect the metal at higher gas temperatures, e.g. the use of heat-resisting alloy-steels instead of carbon steel, internal protection with abrasion-resistant insulating materials. Under certain conditions, it might be necessary to apply all, or most, of the insulating material on the inside of the flue, in which case, precautions should be taken to protect the inner surface of the material from erosion, etc., e.g. by covering the exposed inner surface with a thin protective sheet of stainless steel, high-nickel alloy or ceramic fibre board.

29.4.4 Metal chimneys

A mild-steel chimney should be insulated externally to assist the velocity of the gas by maintaining the internal temperature and preventing internal corrosion, particularly when the products of combustion are from firing fuels with a high sulfur content.

NOTE 1 A double-skin construction with an annular closed air space, is effective but costly. The annular space can be divided into sealed compartments or it can be filled with mineral fibre as mattress or flexible slab, or loosefill material, e.g. perlite (see BS EN 1856-1).

Alternatively, closed compartments with single-skin chimneys can be formed in situ by using thick bands of woven glass fibre tape, which should be wrapped at intervals with plain sheet metal of a suitable thickness applied over the whole outer area of the chimney to form an annular space

NOTE 2 The dimensions of the annular space are governed by the thickness and position of the glass fibre bands.

This should be secured with external tensioning bands of stainless steel clamped circumferentially over the location of the fabric bands. Self-tapping screws or blind pop rivets should be used to close the vertical overlaps. Flat S-shaped clips should be used to prevent downward movement of the sheets, each of which should overlap the one immediately below. Where more effective insulation is required, the whole chimney should be insulated with man-made mineral fibre. Studs should be fixed to the chimney and the insulating material should be secured with plastics coated wire mesh for an outer finish of aluminium or galvanized wire mesh if the finish is to be galvanized steel sheet. For this type of construction an insulated suspension system for attachment of the metal finish should be provided.

Personnel should be protected from accidental contact with hot metal (see **4.5**).

29.5 Flat and irregular surfaces (including machinery)

29.5.1 General considerations

All insulating materials, however fixed, should be in close contact with the surfaces to which they are applied unless an air space is required for special reasons. Where the main insulation consists of pre-formed or flexible material, all edges or ends should be closely butted; for multilayer work all joints should be staggered. Where possible, pipes adjacent to flat surfaces should be insulated separately.

The insulation should be secured in accordance with **27.4**.

NOTE 1 For large cylindrical or overhanging surfaces, securing bands may be applied.

Mountings on boilers and vessels, etc., should be insulated separately.

NOTE 2 This provides easy access to the mountings without disturbing the main plant insulation.

29.5.2 Pre-formed materials

These should be neatly fitted and secured in position by pinning, banding, or wiring, any gaps at the joints being filled with either plastic composition or loosefill insulating material.

29.5.3 Plastic composition

Plastics composition should be applied in accordance with **29.2.11.1** and reinforced in accordance with **29.2.11.2**.

29.5.4 Flexible materials

Flexible materials should be applied in accordance with **29.3.5**.

29.5.5 Foamed in situ

Foamed insulation should be applied in accordance with **29.3.6**.

29.5.6 Sprayed insulation

Sprayed insulation should be applied in accordance with **29.3.7**.

29.5.7 Loosefill insulation

Loosefill insulation materials should be applied in accordance with **29.2.6**.

29.5.8 Insulating concrete

Insulating concrete should be in accordance with **29.2.7** and **29.2.8**, but, as certain flat surfaces, e.g. floors, roofs and walls of some furnaces, drying ovens, can require the casting of appreciable thicknesses of insulating concrete, some variation of technique might be necessary.

If the surface area of the insulating concrete is large, it should be divided into panels to allow for differential expansion under service conditions.

Insulating concretes should not be exposed directly to conditions of abrasion, particularly when the hydraulic bond has been weakened at temperatures over approximately 260 °C.

NOTE These materials can retain water over long periods and exposure to moisture, even after drying, can lead to dimensional changes. Normally, contained water can be removed by careful and slow heating but, where such heating is not practicable, the retention of water can give rise to corrosion below ground level.

Specialist advice should be obtained with regard to the need for anchorage and reinforcement systems.

30 Indoor finishes and their methods of application

*NOTE See **7.9** for fire performance of insulation systems as installed.*

30.1 Sheet metal

*NOTE 1 For the reasons indicated in Clause **12**, and particularly where insulation is liable to damage by oil or water, or where additional resistance to mechanical damage is necessary, the finish may consist of flat or profiled metal cladding. The thickness of the finish may be increased by using reinforcing plates (see **30.1.5**).*

NOTE 2 Profiled cladding is particularly advantageous on tanks with diameter greater than 10 m.

30.1.1 Untreated mild steel gives corrosion problems, and should therefore be protected, e.g. coated with zinc, aluminium, zinc/aluminium alloy, enamel, ceramic, plastics finishes. It should not be used unless both inner and outer surfaces are painted (see Clause **8**). Where coated steels are used, the minimum coating weight (including both sides) should be as follows:

- galvanized 275 g/m^2;
- zinc/aluminium alloy 185 g/m^2; and
- aluminized 240 g/m^2.

30.1.2 Corrosion-resisting alloy-steels are expensive, but they should be used where their resistance to corrosion and aesthetic appearance justifies the increased costs.

30.1.3 Aluminium, being relatively soft, should not be used for protection in areas which might be exposed to substantial mechanical damage, particularly when it is applied over flexible insulating material. As flat sheets of polished aluminium tend to emphasize areas of minor damage through reflection of light, the reflecting surface, particularly with large flat areas, should be broken up by the use of ribbed sheet or material with an embossed “stucco” finish.

NOTE Sheets with box, ribbed or reeded profile have greater intrinsic resistance to deformation than flat sheet.

30.1.4 When selecting the material for metal cladding, the compatibility of the metal with the insulation should be confirmed with the manufacturers. Direct contact between dissimilar metals should be avoided (see **8.3.4**), although in dry conditions, painting the contact surfaces can provide sufficient protection.

30.1.5 Where aluminium sheet is to be used under conditions of high humidity, e.g. in paper mills or in aggressive environments, surface-protected material for outdoor application should be used (see **31.1**).

NOTE Aluminium sheet is available with a factory-applied moisture barrier.

30.1.6 In flammable environments, e.g. those covered by the Petroleum Act [7], all metal cladding and all wire netting at flanges, pumps, etc. should be bonded and earthed in accordance with BS EN 62305 (all parts) using stainless steel wire or bands.

30.1.7 As aluminium can be corroded by certain insulants, e.g. calcium silicate, the inner surface of the cladding should be painted with a protective coating or pipe-wrap tapes applied for corrosion protection, see **8.2.2**.

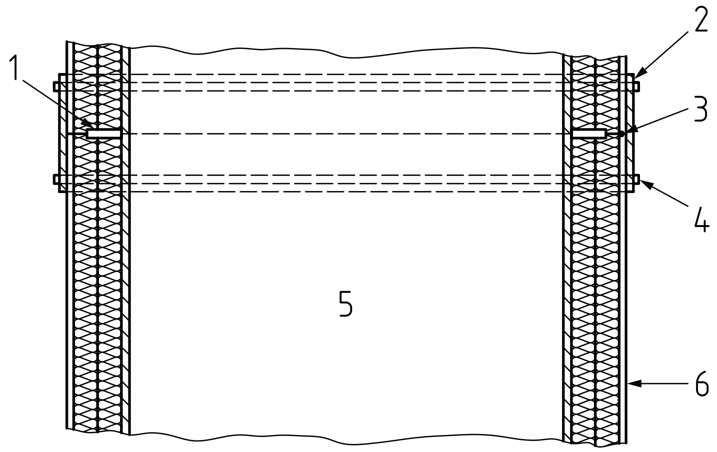
30.1.8 The thicknesses in Table 9 should be used for general conditions, although special applications might require variation from the normal. Where the underlying insulation is easily compressible, the insulation system as installed should be protected to withstand anticipated mechanical abuse even if this necessitates an increase in the metal thicknesses in Table 9.

NOTE The use of relatively hard corrosion-resisting steels or hard aluminium alloys can justify some reduction in these thicknesses.

30.1.9 Adjacent edges of metal sheet may be secured together by folded joints or by plain laps (see Figure 36); for lapped joints, each sheet should cover the adjacent sheet by a minimum of 40 mm and the securing screws or rivets should be located at not greater than 150 mm spacing both for flat areas and for the longitudinal spacing on pipes. For the circumferential laps on the pipes, it might be sufficient to locate the screws or rivets on the lines of quarter segments, i.e. four in the circumference, but one circumferential joint should be left free at intervals to allow for longitudinal expansion movement (see **29.1.3**).

*NOTE Lapped joints may be secured with self-tapping screws or pop rivets, but they do prevent expansion movement. Bands may be used as an alternative to rivets and screws (see **27.4**). With folded joints, separate securing attachments are not required for cylindrical surfaces, as they have the advantage of allowing some expansion movement, see Figure 35.*

Figure 36 **Typical expansion joint between hot vessel and self-setting cement covering**



Key

1 Insulation support rings in segments

2 Glass cloth 200 mm wide

3 Expansion cut in finish

4 Metal bands

5 Vessel

6 5 mm thick-setting cement finish

30.1.10 Arrangements should be made to secure the metal finish over the insulation or direct to the insulated surface to ensure that "through" metal connection between the insulated substrate and the outer metal cladding is reduced to a minimum.

30.1.11 For long sections of vertical pipework, the cladding should be supported from attachments on the pipe (see **27.6** and **29.1.3**). Adjacent sheets should be firmly attached to each other. Free-lapped joints should be fitted between the fixed points to provide for differential expansion. Overlaps should be adequate to cater for the expected expansion movement plus the standard lap, see **30.1.10** (Figure 6 and Figure 35).

30.1.12 For flat surfaces and for large irregular curved surfaces, the outer sheet metal should be secured to the insulated surface with studs or insulation support plates (see Figure 34) or expansion channels designed to accommodate differential expansion movement while reducing "through" metallic contact to a minimum.

NOTE Positive fixing at the centre of each sheet might be the best arrangement for large flat surfaces as it permits expansion movement round the periphery by means of folded joints.

30.1.13 As polished metal finish can give surface temperatures higher than those for non-metallic finishes under the same conditions, it should be assessed and accepted or rejected accordingly.

NOTE The heat loss from the polished surface can also be lower than that from a non-metallic surface.

30.1.14 To avoid direct contact between dissimilar metals, precautions should be taken against electrolytic corrosion for all materials, particularly for plant within 10 km of the sea. It is essential that galvanized or aluminized mild-steel sheets are secured with cadmium-plated, galvanized or aluminized mild steel or stainless steel attachments, or aluminium sheets with aluminium or stainless steel attachments (see Table 10).

NOTE 1 Cadmium-plated or galvanized mild-steel attachments for aluminium sheet may be used to achieve satisfactory results under dry conditions.

NOTE 2 Alternatively, the securing attachment can be isolated from the outer cladding sheet with a non-metallic washer.

*NOTE 3 Although austenitic stainless sheet is not close to aluminium in the electrochemical scale, in practice it is found to have an oxide surface film that permits contact without serious bimetallic corrosive effect (see also **8.3.4**).*

Table 10 **Compatibility between screws/rivets and cladding material**

Cladding	**Screws/rivets**		
	Galvanized (zinc or cadmium) minimum coat 25 micron	**Aluminium**	**Stainless steel**
Galvanized, aluminized or zinc/aluminium alloy	Recommended	Not recommended	Recommended
Aluminium	Not recommended	Recommended	Recommended
Stainless steel	Not recommended	Not recommended	Recommended

30.2 Aluminium foils and laminates and synthetic sheet materials

NOTE 1 Plain aluminium foil or reinforced aluminium foil laminates may be pre-applied to insulation material by the insulation supplier/manufacturer.

These facings should not require further finishing and may be used as dust and/or vapour barriers in areas where there is little risk of mechanical damage, e.g. on pipework at high level, in services ducts.

NOTE 2 Where there is risk of damage, a laminate specifically designed for this purpose may be used.

Where the use of aluminium foil is essential to the proper functioning of the insulation system, e.g. vapour barriers, the foil should be protected from mechanical damage (see also **28.1.8**).

Longitudinal overlaps on pipe sections should be secured with adhesive or compatible self-adhesive tape. Circumferential joints on pipe sections and all joints between abutting slabs and mats should be sealed with compatible self-adhesive tape, see **27.3.2**.

The integrity of the vapour barrier should be ensured, particularly for chilled or cold water services.

30.3 Mastic and coating finishes

30.3.1 The technique of application, e.g. by brush, hand or spray, should depend on size, location, risk of overspray and any possible need to permit evaporation of a solvent. The contractor should consult the manufacturer of the material on the details of the procedure to be followed on any special equipment required and safety precautions to be taken.

30.3.2 Selection of mastic and coating finish should depend on whether it can be applied direct to the insulant, or whether it needs to be used in conjunction with open-weave glass-cloth, cotton scrim or canvas and the degree of protection required.

NOTE Mastic and coating finishes based on ingredients such as bitumens, resins or polymers can be of three types: water-based (emulsions), solvent-based and solvent-free.

30.3.3 Water-based materials should be protected from frost during storage. It is essential that they are not applied when the ambient or surface temperature is below 5 °C, or when freezing conditions are expected within 24 hours of application.

NOTE These materials are non-flammable during application. However, some water-based mastics are available with special antifreeze ingredients allowing application in freezing conditions.

30.3.4 Solvent-based mastics and coatings can withstand freezing, but for best results they should not be applied at temperatures below 5 °C. Most of them thicken considerably at low temperatures, rendering application by spraying particularly difficult; for winter use, enclosed storage at a minimum of 10 °C should ensure easy application. Many contain highly flammable solvents and precautions should be taken. Solvent vapours in fairly low concentrations can cause narcosis, so adequate ventilation should be ensured whenever solvent-based materials are applied.

30.3.5 Solvent-free materials, such as epoxies or urethanes, should be used where, for example, particular chemical resistance is necessary.

NOTE Silane-modified polymers and silicone polymers are strong and flexible; they may be used to seal and to joint the insulation by pre-applying to rigid insulation.

30.4 Hard-setting composition, self-setting cement and gypsum plaster

30.4.1 General

Materials conforming to BS 3958-6, i.e. hard-setting composition, self-setting cement and gypsum plaster, which are prepared for use by the application of water, should be selected for indoor finishes.

Provision should be made for tying back any reinforcement for the finishing cement.

30.4.2 Hard-setting composition

*COMMENTARY ON **30.4.2***

*Hard-setting composition is mixed with water to the manufacturer's instructions and applied over a reinforcement of wire netting or expanded metal (see **27.5**).*

On small bore pipes where the outside diameter of insulation does not exceed 100 mm, the reinforcement can consist of 1 mm diameter wire spirally wound at maximum 75 mm pitch.

Hard-setting composition is a clay-based product and may be applied over pre-formed or plastic insulation on installations where heat is available for drying out.

Hard-setting composition should be applied in two layers to give a final thickness of approximately 10 mm, the first layer being left rough to act as a key for the second layer. The final coat should be trowelled to a smooth finish.

NOTE When dry, the hard-setting composition may be painted with emulsion paint, undercoat and gloss paint or PVA-based coatings.

30.4.3 Self-setting cement

NOTE Self-setting cement is a hydraulic setting Portland cement-based product for application over pre-formed, plastics or sprayable insulation possessing the property to absorb the excess water from the wet mix.

Self-setting cement should be mixed with water to the manufacturer's instructions and applied over a reinforcement of wire netting, expanded metal or wire, see **30.4.2**.

Self-setting cement should be applied in one layer to give a final thickness of approximately 5 mm and should be trowelled to a smooth finish. Expansion grooves should be cut through the self-setting cement and reinforcement mesh before the cement has taken its hydraulic set to minimize the risk of cracking, which can be caused by differential thermal expansion between substrate and finish.

The application of self-setting cement should be carefully planned to ensure work is finished off at an expansion joint or some other termination point as wet cement does not readily join up with cement already dried (see **29.1.3** and Figure 36). When dry, self-setting cement may be painted with PVA-based coating, chlorinated rubber paint or gloss paint applied over an alkali-resistant primer.

30.4.4 Gypsum plaster composition

NOTE 1 Although no longer commonly used, gypsum plaster composition is a hydraulic setting calcium sulfate hemihydrate-based product for application over non-absorbent materials, e.g. expanded plastics, cork, resin-bonded mineral wool, where the temperature on the gypsum plaster does not exceed 50 °C under operating conditions.

Gypsum plaster composition should be mixed with water to the manufacturer's instructions and applied over a reinforcement of wire netting, expanded metal or wire, see **30.4.2**. Gypsum plaster composition should be applied in one layer to give a final thickness of 5 mm and should be trowelled to a smooth finish.

NOTE 2 When dry, gypsum plaster composition may be painted with emulsion paint, undercoat and gloss paint or PVA-based coatings.

30.5 Non-metallic sheet

30.5.1 Flexible plastics and elastomer sheets can be adhered direct to the insulation; an adhesive recommended by the manufacturer should be used or they should be solvent-welded to themselves using a "solvent welding agent". Adhesives or solvents should be checked for compatibility with the insulation especially where cellular plastics or expanded rubber insulation is to be applied. The manufacturer's directions for drying time, or "open time" for contact adhesives, should be closely followed so as to achieve good adhesion without trapping solvent in the insulation (see also **30.3.4** for safety recommendations in the use of solvent-based materials). All joints should have an overlap of at least 50 mm and, where practicable, the joints should be made so as to shed water. Where used over a foamed or expanded polymer insulation that can shrink, adhesive should terminate at least 25 mm on each side of all insulation joints to avoid splitting the sheets. Most types of elastomer sheets are non-porous and therefore the insulation and any smoothing finish should be thoroughly dry before the outer sheeting is applied. On bends and at changes of surface direction, the sheet should be cut to achieve a close fit, free from gaps or wrinkles (alternatively, tape may be used as described in **30.5.6)**. Where the insulation stops short for flanges, valves, etc., particularly on cold insulations, the sheet should be brought over the end and sealed to the metal surface if the service temperature permits.

30.5.2 Where rigid plastics (PVC) sheeting is used, it is usually pre-curled to facilitate fitting over pipe sections and should not be less than 0.35 mm thick. Longitudinal and circumferential joints should be overlapped by 50 mm and longitudinal overlaps should be neatly secured at 150 mm centres with plastics rivets. Alternatively, for cold work or where a hygienic finish is required, the joints should be continuously bonded with a specially formulated solvent; they may be finished with matching PVC tape. Where hot work is involved, the plastics sheets should not be subjected to excessive temperatures where the equipment is in use.

NOTE Bends and tees may be finished with purpose-made fittings, which are usually an integral part of the cladding system.

30.5.3 Ultra-violet cured GRP is a flexible product when first installed and hardens in the presence of UV light; it does not require the use of adhesive, but should be installed on to a dust free substrate.

NOTE Aluminium foil is a suitable substrate.

30.5.4 Chloro-sulphonated polyethylene is a flexible product, which is wrapped around the insulation material and should be overlapped using contact adhesive and additional sealant.

30.5.5 Where insulation might have to be removed periodically, such as at flanges and manholes, it should be independently installed. The permanent insulation should be sealed effectively to the pipe or equipment.

30.5.6 Aluminium foil tape [2)] may be used on pipelines, especially those of small diameter, if there is sufficient clearance between the pipe and other equipment to permit the wrapping operation to be carried out. The tape should be spirally wrapped over the insulation with an overlap of at least 50% between successive wraps. At the ends of insulation, the tape should be double-wrapped and banded to prevent unwrapping. On vertical and inclined pipes, the wrapping should start from the bottom so as to prevent the ingress of moisture running down the surface.

30.6 Textile fabrics

NOTE These materials are not in common use.

30.6.1 Lightweight canvas and bands

These comprise pipe sections encased in cotton canvas, approximately 100 g/m², which should be attached with an adhesive. The insulation should be further secured in the fitting of metal bands at not more than 450 mm centres and not more than 50 mm from the end of the pipe section. If the surface is to be treated, one coat of primer should be used followed by two coats of paint or insulation coating compound. Alternatively, a polymer emulsion adhesive/insulation coating can be used, which should be adhered to the canvas and coated in one operation.

30.6.2 Heavy fabric wrappings

These comprise a layer of heavy cotton canvas, approximately 270 g/m² or heavier, or where a non-combustible or rot-proof finish is required, a layer of glass cloth should be applied over the wired-in-place sections.

NOTE It is not usual to secure heavy fabric covering with an adhesive during works' manufacture of pre-formed insulating material. This type of fabric is applied during erection on site and is usually secured by stitching.

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2) BS 5970:2001 referred to this as plastics tape.

It provides a more durable finished surface than that described in **30.6.1**; additional securing bands should not be required.

31 Weather-resistant finishes

*NOTE See **7.9** for fire performance of insulation systems as installed.*

31.1 Sheet metal

31.1.1 The recommendations given in **30.1** apply also for sheet metal finishes for outdoor installations, but protective measures should be taken to prevent electrolytic corrosion. Ingress of water should be prevented and the metal itself should be suitable for the conditions of service and environment. Plain lapped joints should be arranged to shed water and sealed effectively within the overlap of the joint. The seal should be formed by filling the lapped joints with polymer mastic, which may be in flexible strip form, gun extruded or impregnated tape between the sheets of each joint; the tape can be impregnated with petroleum jelly, soft bitumen, or similar water-resisting material. The joint should be selected from one of the types shown in Figure 35. Blind rivets or screws should be spaced not more than 100 mm apart.

NOTE Upstanding seams may be used to prevent water penetration at joints over flat or large curved areas. The seam may be sealed by using a U-shaped cover strip or a lock form joint.

31.1.2 The normal overlap for profiled sheets with a sealant, as in **31.1.1**, might be adequate to avoid water penetration, but arrangement should be made to retain the lapped surfaces in close contact without penetrating the sheets, e.g. with banding.

31.1.3 As the metal cladding can be exposed to wide variations of atmospheric temperature, provisions for thermal movement should be made and “through” metal connections with the insulated substrate should be restricted (see **29.1.3**, Figure 6 and Figure 8).

NOTE Although hot-dipped galvanized sheet can resist weather conditions for appreciably long periods, painting or other protective treatment over the outer exposed surface might be necessary after extended service, depending on environment and longevity required of the insulation system. Plastic- or powder-coated steel, zinc aluminium alloy and alloy-steel do not usually require additional surface treatment.

31.1.4 Aluminium sheet can develop irregular white areas of oxide film after a period of exposure to outdoor weather conditions; to avoid this, material that has received a chemical or electrolytic treatment should be used, e.g. anodized, surface treatment. Aluminium should be isolated adequately from direct contact with dissimilar metals by using an integral moisture barrier to back weatherproofing tape or elastomer strip.

31.1.5 Where exposure to high wind is probable, the cladding should be retained by banding with all overlaps mechanically secured. Support should be designed to accommodate suction forces.

31.2 Synthetic sheet materials

Synthetic sheet materials should be used in accordance with **12.4.3**.

31.3 Non-metallic sheet

NOTE 1 These products fall under a general heading of polymeric systems and typically include neoprene, UV-curing GRP, acrylics and PVC sheeting.

If selected, proprietary systems should be installed in accordance with the manufacturer's instructions.

Laps should be arranged to shed water and should be sealed with an adhesive, cover strip, sealing bead, etc. All joints should be overlapped or a cover strip applied, typically by 50 mm to 75 mm.

NOTE 2 Some sheet materials might require additional mechanical support to prevent sagging.

*NOTE 3 The general considerations in **30.3** apply.*

31.4 Self-setting cement

31.4.1 Self-setting cement can be exposed to outdoor weather conditions without further protection, but as it is not impervious to water and possesses low flexibility, it should be protected with a coating.

31.4.2 The porosity of self-setting cement can be reduced by the application of surface coatings; however, the cement should be fully dry before weatherproofing coatings are applied to avoid any possibility of the coatings blistering.

31.4.3 A continuous layer of cement may be applied over large areas unless high differential movements are expected. Covers over projecting stiffeners should be used to take up expansion movement; for greater differential temperatures, grooving of the cement whilst in green condition might be necessary. Bands of fabric should be treated with a water-resistant coating to weatherproof the grooves for pipework, but for flat surfaces it might be necessary to apply an overall weatherproof coating to prevent penetration of water into the expansion grooves.

31.5 Weatherproofing compounds

31.5.1 General considerations

The application of weatherproofing compounds should be dependent on the basic surface to which the compound is to be applied, as follows:

a) direct application over the insulating material;

b) application over a finish of hard-setting composition; or

c) application over a finish of self-setting cement.

NOTE 1 For each type of application, the weatherproofing finish can be either solvent- or water-based. Water-based materials are susceptible to wash-off by rain until integrally dried; prolonged drying time can be expected in periods of continuous high humidity and/or low temperature.

Most manufacturers' data sheets quote drying times for standard temperature and humidity conditions only so manufacturer's should be consulted if the conditions are outside this range. For hot insulation work with water-based finishes, it can be necessary to delay application of the finish until heat is available, which should be used to dry out both insulation and finish, dependent on the water content in the insulant and on the ambient conditions. The erection of temporary shelter to protect surfaces during application and drying can be required; airflow should not be restricted during this period.

NOTE 2 Solvent-based materials, though less sensitive to inclement weather immediately following application, quickly form a relatively impervious layer and can trap water in the insulation substrate. This can result in blistering of the finish when hot plant is commissioned or when plant is exposed to solar heating.

Aqueous dispersion coatings should be used to avoid blistering as it allows passage of moisture vapour but is weather-resistant. However, the insulation should be kept dry both in storage and during application.

NOTE 3 Fabric reinforcement of finishes may be used and good workmanship at insulation joints, incorporating a joint sealant where necessary, is essential if cracking is to be avoided.

NOTE 4 With water-based and solvent-based coatings, the applied wet film thickness is greater than the final dry thickness due to solvent or water loss. Dependent on the elasticity and tensile strength of the chosen compound, it can be expected that gross cracking of the insulant or finishing cement, due to excessive vibration or inadequate provision of expansion joints, transmits to the weather-resistant layer. Reinforcement with glass fabric or other membrane can eliminate or reduce the incidence of cracking, according to the severity of service.

NOTE 5 Where the surface is black or a dark colour, higher surface temperatures can occur in direct sunlight.

31.5.2 Direct application over insulating material

This method may be used for insulation over pipes or ducts of relatively small diameter, or over flat surfaces of small area.

Where applying water-based and solvent-based coatings to the outer surface of resin-bonded mineral wools (glass or stone) or pre-formed materials, which have a fairly rigid uniform shape and outer surface, they should be treated with a minimum of two brush coats of a flexible weather coating, embedding an open-weave glass cloth or rot-proofed hessian in the surface of the first coat.

31.5.3 Application over a finish of hard-setting composition

As the surface of hard-setting composition can be dusty, a thin primer coating should be applied to the outer surface before applying the weather-resistant finish. The primer should be compatible with the hard-setting composition and weather-resistant finish.

31.5.4 Application over a finish of self-setting cement

As the dry surface of self-setting cement is relatively dust free, weatherproofing compounds normally adhere directly to the surface; the surface should be treated with two brush coats of a weather-resistant compound or by spraying if permitted on site. If substantial thermal movement is expected, which can cause cracking of the cement, an open-mesh glass-fabric reinforcement should be embedded in the wet surface of the weatherproofing compound.

32 Ultimate treatment of finish painting

Where paints are used, they should be suitable for service and environment; their method of application should be discussed at the beginning of the design stages with the paint manufacturers. Heat-resistant paints should be used for surfaces at elevated temperatures. All paints should be applied strictly in accordance with manufacturer’s instructions.

33 Inspection and testing of the insulated system materials before and during installation

There is a joint responsibility between the client, the contractor and sub-contractors (referred to as the purchaser) to arrange for the inspection of all building services and equipment, which should include checking of insulation, cladding and ancilliary materials and specific application procedures before and during progress of the insulation work. The purchaser or purchaser's nominated inspection authority should have free access, at all reasonable times, to those parts of the sites carrying out the work for the specific contract. The purchaser should be allowed to select samples from the materials to be applied, to reject any materials or workmanship that do not conform to the relevant specification and to carry out acceptance tests to the purchaser's satisfaction.

Approval by the purchaser, purchaser's nominated inspection authority or a waiver of inspection should not relieve the contractor of responsibilities for the design and, where applicable, materials or workmanship. The contractor should co-operate and provide the opportunity for this inspection to be carried out.

Finishing materials should be inspected for quality and thickness, either before or during application, dependent upon the particular type of finish used.

Inspection should be carried out after each stage of work has been completed and before the next stage has started. The contractor should give the purchaser or purchaser's nominated inspection authority reasonable notice of stage completion to avoid disruption and to maintain continuity of work.

The contractor's site organization should be such that there is a regular and systematic supervision of the work by experienced, competent staff.

Until final acceptance of the installation by the purchaser, the contractor should make good any damage to the insulation and pay the cost incurred, unless caused by third parties or an extraneous source, so that installation is handed over in the specified condition. The responsibility for the weather protection of the incomplete insulation system should be agreed between the purchasers before any work begins. In addition, storage should be in accordance with Clause **17**.

Where the purchasers require the contractor to leave certain elements uninsulated until system testing is completed, such as valves and flanges, the purchasers should agree the method of temporary sealing of the exposed edges of the insulation to prevent accidental ingress of water or other liquids or contaminants.

Where required, a removable section of insulation and finish can be installed for inspecting insulated surfaces; however, the need for this should be considered in conjunction of the risk of water or water vapour ingress at the edges of this removable section and resultant corrosion risk. This should be agreed between purchasers before any work begins.

Section 5: Post-installation inspection and maintenance

34 Maintenance

34.1 General

Before completion, the "purchasers" should discuss the procedures and requirements for routine periodic inspection and maintenance of the complete insulation system.

NOTE 1 This is to ensure that the initial performance of the materials are maintained and the methods of repair and replacement to be carried out if damage occurs or during service or overhaul are established.

It should be made clear that early identification of system breakdown and prompt repair action is essential to minimize the risk and effect of corrosion under insulation.

Inspection of the external surface of the insulation system, the cladding or coating, should include signs of cracking, tearing, distortion, damage, opening of seams, sealant breakdown, loss of screws or tearing of rivets, corrosion, evidence of hot spots on high-temperature plant or condensation/ice build-up on low-temperature plant. Where inspection of the external surface shows any signs of the defects listed, the external finish should be removed to enable an inspection of the insulation and/or fixing attachments and reinforcement; selective random removal of external claddings might be specified. Where defects are discovered, remedial treatment to insulation, fixing attachments, reinforcements and cladding, where applicable, should be carried out without delay to avoid further deterioration of the insulation system.

Where non-destructive testing (NDT) techniques are used, they should only be carried out and results interpreted by suitably trained personnel.

NOTE 2 To assist routine inspection of insulation in service, NDT methods, such as thermal imaging or flash radiography, can be used.

The purchaser should ensure that only suitably qualified operatives are employed for the dismantling of existing insulation and also for the re-insulating process when repairs or modifications are to be carried out to the plant.

NOTE 3 Before any work begins, a risk assessment should be completed, which can lead the purchaser to refer to the MSDS (material safety data sheet) or COSHH [4] normally located in the OMM (operation and maintenance manual).

34.2 Inspection, maintenance and sealing of insulation containing asbestos

34.2.1 Inspection and maintenance

NOTE 1 Attention is drawn to the Control of Asbestos Regulations [8] for managing asbestos containing materials. The Control of Asbestos Regulations [8] require that all insulation and insulation coatings containing asbestos are inspected regularly and maintained.

WARNING. If installation containing asbestos is damaged, it can cause a serious and immediate health concern.

Specialist advice should be sought. All insulation containing asbestos should be inspected and maintained to ensure that the surface condition remains sound, undamaged and free from loose adhering fibre. Where there is foreseeable risk of abrasion or of physical damage, preventative action should be taken. The choice of protection should depend upon the location and circumstances.

NOTE 2 When access is required to areas where asbestos insulation is present, mechanical protection for the insulation system might be necessary to prevent damage by plant, equipment or workers.

NOTE 3 The owner/manager of the site is required to make the contractor aware of the presence of any asbestos-containing materials that they could encounter in the course of their work.

34.2.2 Encapsulating or sealing

NOTE Attention is drawn to the Control of Asbestos Regulations [8] and the associated HSE document "Working with materials containing asbestos – Control of Asbestos Regulations 2006 – Approved Code of Practice and guidance" [19].

WARNING. If installation containing asbestos is damaged, it can cause a serious and immediate health concern.

Where damage or abrasion has occurred to thermal insulation or where the surface has become friable with loose asbestos fibre adhering to the surface, one of the following treatments should be adopted:

a) cover with paint or a sealing solution by brush or spray application;

b) cover with woven cotton or glass fabric, and paint;

c) cover with a layer of hard-setting composition or self-setting cement, coated where necessary;

d) cover with plain or coated glass cloth;

e) cover with plastics sheet or encapsulate in plastics compound;

f) cover with sheet metal or metal foil; or

g) cover with non-metallic cladding such as UV cured glass reinforced plastic (GRP).

Overlaps of sheet materials should be sealed. The sealing or encapsulation method should be selected dependent upon the location, environment and the degree of mechanical protection required. The surface treatment, particularly the application of paints or sealants, should be such that the resistance to surface-spread-of-flame and reaction to fire characteristics is not reduced.

34.3 Stripping old insulation containing asbestos

NOTE Attention is drawn to the Control of Asbestos Regulations [8] and its Approved Code of Practice, "Working with materials containing asbestos" [19] for removal of insulating materials containing asbestos. The Control of Asbestos Regulations [8] require that all insulation and insulation coatings containing asbestos are inspected regularly and maintained.

WARNING. If installation containing asbestos is damaged, it can cause a serious and immediate health concern.

Guidance notes issued by HSE, which are periodically revised and updated, should be referred to for practical guidance on many aspects of asbestos removal (see also **7.12**).

35 Guarantees

Any defects arising from faulty materials or workmanship during this period should be rectified by the contractor, free to the purchaser.

NOTE Invitations to tender usually include a clause that requires the contractor to guarantee materials, workmanship and, where required by the purchaser, performance guarantees for a given period.

A purchaser's enquiry document should state any intention to retain an agreed percentage of the total value of the work for an agreed period after the work has been completed.

Annex A (informative) Adhesives

A.1 Service properties

A.1.1 Application characteristics

Important properties that affect the selection of adhesives are as follows:

a) application method, i.e. suitability for brushing, spraying, etc.;

b) coverage;

c) early development of adhesive strength ("grab or green strength"); and

d) degree of absorption with porous insulating materials.

Other properties that might affect the use of insulation are as follows:

1) flashpoint;
2) toxicity;
3) temperature and humidity range (for application);
4) vibration;
5) viscosity;
6) orientation of equipment;
7) weight of insulation being adhered;
8) range of bonding times;
9) curing time;
10) storage conditions and shelflife;
11) compatibility with insulation and equipment, e.g. to prevent corrosion potential, such as the presence of chlorides on stainless steel, the nature of any solvent, or resistance to chemicals;

    NOTE Slow loss of water can give rise to corrosion; alkaline adhesives, e.g. sodium silicate, can attack aluminium, man-made mineral fibres and cellular glass. Polystyrene is susceptible to attack by certain solvents.

12) possible environmental impacts; and
13) possible corrosive attack.

A.1.2 Temperature limits

There are limiting-temperatures between which an adhesive remains effective without significant loss of bond strength. Most adhesives for thermal insulation have service temperature limits within the range –40 °C to 120 °C. Exceptions to this might include specific grades of silicone, silane-modified and sodium silicate adhesives.

Below a temperature of about –40 °C, most adhesives undergo dramatic loss of flexibility. In particular however, silane-modified adhesives are an exception to this due to excellent low and high temperature flexibility and bond strength properties. When bond failure occurs, it is usually manifested as shearing of a relatively brittle (though stronger) layer away from a comparatively weak insulating material; part of the insulating material tends to remain attached to the adhesive so that the mode of failure relates to the cohesion of the insulating material.

For service temperatures of above 150 °C, the most widely used adhesives are based on filled sodium silicate solutions, which are not resistant to water or high humidity. Where assessing required service temperatures, there can be periodic departures from the assumed conditions, e.g. through steam-cleaning requirements, variations of boiler operation. High-temperature silicones and silane-modified polymer adhesives are effective adhesives for cellular glass at elevated temperatures.

NOTE For limitations on high temperature adhesives, refer to manufacturer's instructions.

A.2 Curing

A.2.1 Solvent-based adhesives

The curing or setting process is of fundamental importance to ensure the successful use and performance of adhesives.

NOTE 1 Most insulation adhesives form a bond by the evaporation of organic or aqueous solvents or by the absorption of water into porous contact surfaces with subsequent evaporation. Whilst many of these adhesives have an additional curing phase due to cross-linking, this cannot properly take place before solvent loss.

The thickness of applied wet film and porosity of the contact surfaces are major determinants in establishing an application technique.

NOTE 2 The wet film thickness, when related to the solids content of the adhesive, shows the proportion of solvent that has to be lost; increasing the thickness generally increases the drying time disproportionately, e.g. bonding two relatively impermeable materials and applying double the recommended thickness can extend the curing period from hours to days or even preclude any possibility of the adhesive ever curing.

With two non-porous contact surfaces, certain adhesives may be applied to both surfaces and the bulk of the solvent left to evaporate for a period up to the maximum specified by the bonding time range before closure is made; good operator skill and strict compliance with manufacturers' instructions are likely to ensure success.

A.2.2 Water-based adhesives

Water-based adhesives are generally only used where one of the contact surfaces is porous; the adhesive may be applied to one surface and the bond made immediately or after a short "open-time" during which the adhesive develops "grab".

With two non-porous contact surfaces, certain adhesives may be applied to both surfaces and left to evaporate for a period up to the maximum specified by the bonding time range before closure is made; good operator skill and strict compliance with manufacturer's instructions are likely to ensure success.

Some water-based gap-filling adhesives with high solids content or heavily filled solvent may be used to bond relatively impervious insulants with the assembly supported or shored for a prolonged period whilst cure is developed. This technique relies on solvent loss through edges and joints, together with a slow loss through the insulant; good operator skill and strict compliance with manufacturer's instructions are likely to ensure success.

A.2.3 Chemically curing adhesives

These are generally set by a chemically activated cross-linking process and are increasingly used for insulation work. They are usually two-component materials based on epoxies or polyurethanes and modifications of these with other polymers. Their use is generally indicated for heavy-duty bonding of impermeable materials. Some types can contain a small proportion of volatile solvent to facilitate application, but this has little effect on curing times. They are frequently available as a combined joint-sealant/adhesive; some polyurethane versions are especially useful for low-temperature work.

A.2.4 100% solids adhesives

Where neither a solvent or water carrier is present, the adhesive can be classified as a 100% solids adhesives. Typical examples include hot melt adhesives, epoxies, high specification silicones and silane-modified polymer adhesives. Some of these materials are available as one and two part adhesives. Where they are required to be mixed, refer to manufacturer's recommended mixing ratios and instructions.

A.3 Types and typical properties

A.3.1 General

The materials referred to, with summaries of properties, in **A.3.2** to **A.3.12** are not an exhaustive list; the particulars are for guidance only. More detailed information can be obtained from the manufacturer, paying particular attention to the suppliers' health and safety data sheet.

All the adhesives listed are based on natural or synthetic resins, rubbers, or other polymers, which are formulated into adhesives in a variety of ways. Other ingredients, such as fillers, plasticizers, anti-oxidants, tackifiers, etc., are added to achieve the required properties and working characteristics. The quality and properties can vary widely between adhesives of nominally similar type making it essential to specify requisite application and service properties when selecting an adhesive.

A.3.2 Bitumens

These are low-cost thermoplastic materials of mineral origin, generally of dark colour and with poor elasticity and strength. At service temperature they can be brittle or soft, depending on the compound used. They adhere to many types of surface, including concrete, glass, metal and felt and may be used in applications where low stresses are encountered. Reinforcement with mineral fibre or with metal mesh gives improved strength. They have good resistance to water and to alkalis, but oils and many solvents can cause softening. The addition of rubber improves the flexibility and the bond strength.

WARNING. They are flammable, of low acute toxicity, and can have an odour. Pitch and bitumens can be harmful to the skin as a result of their content of polycyclic aromatic hydrocarbons.

The commercial products can be supplied as aqueous emulsions or as "cut-backs" with organic solvents.

A.3.3 Epoxy-resins

These are two-part adhesives that can be formulated to cure at ambient temperature. High bond strengths are obtainable, but they have a limited "pot life", low flexibility and poor impact strength. The flexibility may be improved by modification with polyamides or polysulfides, but even these modified compounds are brittle below temperatures of about –25 °C. Bond strengths up to temperatures of 100 °C are satisfactory for all normal purposes.

Epoxy-resins have excellent resistance to oils and mould growth, with good resistance to water, alkalis and solvents. Their main advantages are low-volume shrinkage, no evolution of volatiles during cure and that they only require contact pressure. They have good electrical insulating properties and they can be useful in gap-filling applications. Epoxy-resins themselves are non-toxic and non-flammable, but they can cause dermatitis. The solvents in the resin adhesive can be toxic, and inhalation of spray can be harmful.

A.3.4 Natural rubber

Cements based on natural rubber are available in a range of colours, depending on the rubber stock and the filler used. They can have flammable or non-flammable solvents. Adhesives are also available on a basis of rubber latex and these are relatively non-toxic; they can be cured as a one-component cement at room temperature. Solvent-based cements may be vulcanized or cured with a second component. Unvulcanized bonds lose much of their strength at a temperature of 50 °C, but vulcanized bonds are normally satisfactory up to a temperature of 100 °C; the bonds of both types become brittle at a temperature of about –35 °C. Natural rubber has good resistance to water and to mould growth, but poor resistance to oils and organic solvents.

A.3.5 Neoprene-phenolic

These adhesives may be used as unvulcanized dispersions to give good bonds up to a temperature of 100 °C (or 140 °C intermittently); two-part mixes can have higher resistance to heat. The bonds become brittle at a temperature of about –55 °C, but the resistance to water, mould growth and some oils and solvents is excellent. The adhesives can contain either flammable or non-flammable solvent, with varying toxicity, and some grades can meet the class 1 spread of flame requirement as defined in BS 476-7.

A.3.6 Nitrile-phenolic

The properties of nitrile-phenolic adhesives are similar to those of neoprene-phenolic type, but the cured adhesives have higher resistance to heat. Bonds become brittle at a temperature of about –40 °C, but the resistance to water, oils, and to mould growth is excellent.

A.3.7 Emulsion polymers – PVA/VaVeova, etc.

A comprehensive range of water-based emulsions is available, including copolymers and terpolymers containing ethylene vinylacetate (EVA), vinylchloride (VC) and acrylics; they comprise a useful range of adhesives.

A.3.8 Styrene-butadiene-based (SBR) cements

These are an important class of adhesives. They can contain either flammable or non-flammable solvent and are normally combustible when dry, although the resistance to spread of flame can be improved. Their resistance to heat is similar to that of adhesives based on natural rubber.

A.3.9 Silane-modified polymer technology

These comprise a range of adhesives with differing high performance characteristics. The types used most frequently for bonding insulating materials have an excellent blend of strength and flexibility, even at low temperatures. These materials are often recommended for use as dual joint-sealant/adhesives and they can be compounded to give vapour barrier properties. The cure times are generally low, as they have no carrier (solvent or water), and they can be used in the widest variety of insulation applications.

A.3.10 Polyurethanes

These comprise a wide range of adhesives with differing characteristics. The types used most frequently for bonding insulating materials are the two-component adhesives that cure by chemical reaction; they have a high solids content (over 95%) and show an excellent blend of strength and flexibility, even at relatively low temperatures. Their main service range is –40 °C to 100 °C, and they are normally flammable in the wet state. These materials are often recommended for use as dual joint-sealant/adhesives and they can be compounded to give vapour barrier properties.

A.3.11 Silicones

High-temperature silicones are effective adhesives for cellular glass at elevated temperatures.

A.3.12 Bitumen-polyurethanes

These are two component bitumen-polyol adhesive cured by chemical reaction. They particularly give flexible bonding for materials with different thermal expansion coefficients including a wide range of substrates such as steel, aluminium and concrete. They are also used as a coating compound against moisture. They can absorb mechanical and thermal stress at a service range of –55 °C to 120 °C with cellular glass, depending on application and substrate.

Annex B (informative) Water vapour pressure and the relation to water vapour barriers

The amount of water vapour able to be retained in air is dependent on the temperature of the air; it reduces as the temperature of the air decreases. When the temperature falls to the dew-point, water vapour condenses as the air is no longer able to retain the same quantity of water in the vapour phase.

The amount of water vapour able to be retained in the air is also dependent on the atmospheric air pressure. Air under lower atmospheric pressure has less capability to retain water vapour than air under higher atmospheric pressure and as a result the dew-point temperature increases as the atmospheric pressure decreases. This might be important for calculating insulation requirements for applications at particularly high altitudes.

Water vapour is a gas that naturally diffuses from areas of high concentration to areas of low concentration. This diffusion creates a partial water vapour pressure gradient in the air.

Since the partial water vapour pressure of the air is related to the actual moisture content of the air, and cooler air has a much lower actual moisture content than hotter air, the pressure gradient often forces water vapour towards cold surfaces.

EXAMPLE

With air at a temperature of 20 °C (dry-bulb) and a relative humidity of 52.6%, water vapour exerts approximately the same pressure (1 230 N/m²) as air at 10 °C and a relative humidity of 100% (i.e. saturated); the dew-point in each case is 10 °C and the actual moisture content is approximately 0.007 67 kg/kg dry air.

The partial water vapour pressure of air next to a cold metal surface at a temperature of –17 °C is 125 N/m².

The partial water vapour pressure difference can be calculated as 1 230 – 125 = 1 105 N/m².

NOTE 1 This example assumes a barometric pressure of 1 013 mbar [3].

If, in this example, insulation were to be applied to the cold metal surface, the partial water vapour pressure of 1 105 N/m² is exerted on the surface of the insulation. Without adequate resistance against the ingression of water vapour, this partial water vapour pressure forces water vapour into the insulation structure where it condenses and potentially freezes if the plant temperature is below 0 °C.

The thermal conductivity of water is about 20 times that of a typical good-quality dry insulating material, and that of wet ice can be up to 3.5 times that of water. This means that internal condensation and ice formation appreciably reduces the effectiveness of the thermal insulating material. Additionally, the increase in volume of the moisture on freezing can disrupt the physical structure of the thermal insulating material.

The level of protection necessary against water vapour ingress is dependent on the partial water vapour pressure. Insulation materials and covering foils with low water vapour permeabilities (known as water vapour barriers) may be applied.

NOTE 2 As the partial water vapour pressure increases, water vapour can be forced through materials of lower permeability. Water vapour barriers exhibiting lower permeabilities are therefore required for insulation used on colder surfaces.

Insulation materials that consist substantially of closed-cells possess a high resistance to the passage of water vapour. This level of resistance is likely to prove sufficient to prevent water vapour migrating through the insulation along the partial water vapour pressure gradient though, if there is any reason to doubt this, it is sensible to check suitability for use with the manufacturer.

Open-cell insulants and loosefill porous materials are readily permeable to water vapour and require an externally applied water vapour barrier to prevent water vapour ingress.

Insulation materials that consist substantially of closed-cells possess a higher resistance to the passage of water vapour, but open-cell insulants and loosefill porous materials are readily permeable to water vapour.

NOTE 3 Even with materials that have good resistance to the transmission of water vapour, differential movement of plant and insulation can cause joints in the latter to open, allowing moisture to penetrate towards the underlying surface. Joint-sealing compounds can also fail to exclude water vapour completely, in which case the contained water or ice can form strongly conducting paths from the surface of the plant to the ambient air.

[3] 1 mbar = 100 N/m² = 100 Pa.

Annex C (informative) Water vapour diffusion resistance ratio (μ value)

In addition to the units for vapour permeance shown in Table 7, there are other related measures in common use that communicate similar, though not directly comparable, information.

The water vapour diffusion resistance factor, referred to as the μ value, is defined as a ratio of the water vapour diffusion coefficient of the material itself and the water vapour diffusion coefficient of air. As such the μ value is a dimensionless characteristic, which becomes larger as the resistance to water vapour permeability increases.

Unlike water vapour permeance values, which are specific to the thickness of material or film tested, the μ value is an inherent material property independent of material thickness. Hence increasing the thickness of a material increases its overall resistance to water vapour diffusion, but the stated μ value remains the same.

The μ value for a given material is determined by experimentally obtaining the water vapour permeability and dividing by the water vapour permeability which is exhibited by the same thickness of air.

Multiplying the μ value by the material thickness gives a thickness of static air that provides an equivalent water vapour diffusion resistance:

$S_d = \mu \cdot d$

EXAMPLE

A film with a μ value of 1 000 and a thickness of 1 mm has a total water vapour resistance equivalent to a film with a μ value of 10 000 and a thickness of 0.1 mm. In both cases, the total water vapour resistance is equivalent to that which is provided by 1 m of static air:

1 000 × 0.001 = 1 m

10 000 × 0.000 1 = 1 m

See Table C.1 for further detail.

Table C.1 **Water vapour diffusion resistance ratio (μ value)**

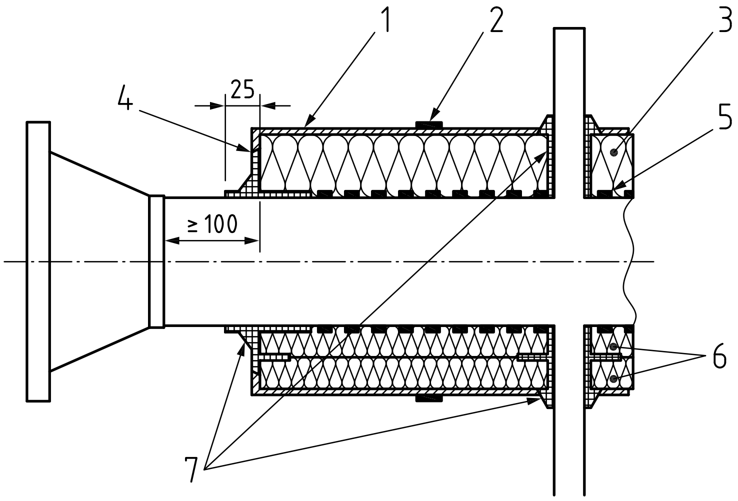
μ value	**Thickness** mm	**Equivalent air layer thickness** (S_d) m
10 000	5	5
10 000	10	10
10 000	20	20

Annex D (informative) Examples of termination methods

Figure D.1 and Figure D.2 show examples of termination methods for hot pipework and cold pipework using rigid insulation.

Figure D.1 **Termination method, hot pipework using rigid insulation**

Dimensions in millimetres



Key

1 Factory applied polymer coating

2 Stainless steel band (where specified)

3 Insulation

4 Site applied polymer coating

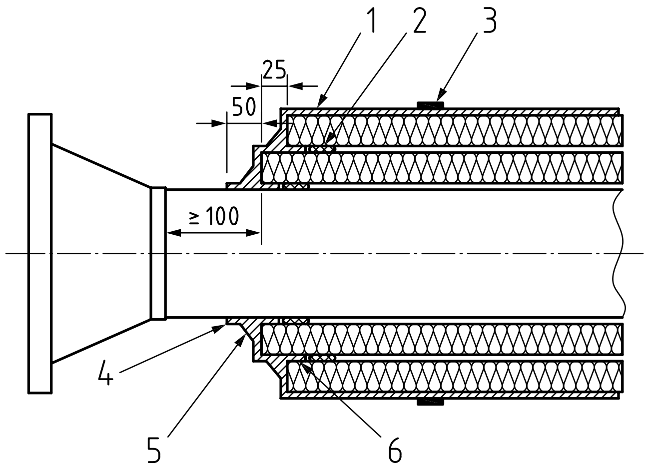
5 Factory applied reinforced coating for high-temperature single-layer applications

6 Double-layer system for extreme temperatures (with factory applied reinforced coating if specified)

7 High-temperature rated silicone sealant fillet bead and end coating (site applied)

Figure D.2 **Termination method, dual-layer cold pipework using rigid insulation**[A)]

Dimensions in millimetres



Key

1 Polymer vapour retarder (factory applied)

2 Butyl mastic bead (approximately Ø8 mm)

3 Stainless steel band

4 Polymer site applied to exposed insulation and pipe to create flexible seal

5 Polymer fillet bead (site applied)

6 Polymer site applied bead (approximately Ø8 mm)

A) Longtitundinal joints of inner and outer sections sealed with non-metallic coating at the end of the section termination and with bead of butyl mastic to create vapour-tight system.

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