

Australian Standard[®]

**Thermal insulation of pipework,
ductwork and equipment—
Selection, installation and finish**

This Australian Standard was prepared by Committee ME/77, Thermal Insulation Mechanical Services. It was approved on behalf of the Council of Standards Australia on 16 August 1996 and published on 5 January 1997.

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Association of Consulting Engineers Australia
Australian Chamber of Commerce and Industry
Australian Institute of Refrigeration, Air Conditioning and Heating
Institution of Engineers, Australia
Master Plumbers and Mechanical Services Association of Australia
Metal Trades Industry Association of Australia
Thermal Insulation Contractors Association of Australia
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**Thermal insulation of pipework,
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Selection, installation and finish**

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PREFACE

This Standard was prepared by the Standards Australia Committee ME/77, Thermal Insulation Mechanical Services.

The objective of this Standard is to provide good practice procedures relating to the installation of insulation to mechanical services for use by designers, specifiers, regulators and inspectors of these systems. The Standard outlines requirements and guidelines for the process of selecting and installing thermal insulating systems for mechanical plant and services operating in the range of -75°C to $+800^{\circ}\text{C}$.

The term 'informative' has been used in this Standard to define the application of the appendix to which it applies. An 'informative' appendix is only for information and guidance.

During the development of this Standard cognizance was taken of the technical requirements and contents of BS 5970, *Code of practice for thermal insulation of pipework and equipment (in the temperature range -100°C to $+870^{\circ}\text{C}$)*.

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STANDARDS AUSTRALIA

Australian Standard

**Thermal insulation of pipework, ductwork and equipment—
Selection, installation and finish**

SECTION 1 SCOPE AND GENERAL

1.1 GENERAL

1.1.1 Scope This Standard deals with the selection, installation and finish of thermal insulation for pipework, ductwork, tanks, vessels and equipment in the temperature range -75°C to $+800^{\circ}\text{C}$ but excludes manufactured pre-insulated equipment, structural insulation of buildings and cold stores, fireproofing structures, refractory linings of plant, airborne installations and all external underground mains.

NOTES:

- 1 The Standard may be found to be generally applicable to the insulation of road and rail transport vehicles and of some assistance in marine insulation.
- 2 Appendices to the Standard provide guidance on inspection, testing and maintenance (Appendix A), protection against condensation (Appendix B), protection against corrosion (Appendix C) and relevant Australian Standards on insulation materials (Appendix D).

1.1.2 New designs and innovations Any alternative materials, designs, methods of assembly, and procedures that do not comply with specific requirements of this Standard, or are not mentioned in it, but give equivalent results to those specified, are not necessarily prohibited.

1.2 REFERENCED DOCUMENTS The following documents are referred to in this Standard:

AS

- | | |
|------|--|
| 1345 | Identification of the contents of piping, conduits and ducts |
| 1530 | Methods for fire tests on building materials, components and structures (series) |
| 2124 | General conditions of contract |
| 2352 | Glossary of terms for thermal insulation of buildings |
| 2545 | Subcontract conditions |
| 4254 | Ductwork for air-handling systems in buildings |
| 4300 | General conditions of contract for design and construct |
| 4303 | General conditions of subcontract for design and construct |

ASTM

- | | |
|------|---|
| C236 | Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box |
| C739 | Specification for Cellulosic Fibre (Wood-Base) Loose-Fill Thermal Insulation |

1.3 DEFINITIONS For the purposes of this Standard, the definitions given in AS 2352 and those below apply.

1.3.1 Castable cement insulating material—thermal insulating material in loose, dry form that is prepared for application as a paste or dough, usually on site, and is dried, naturally or artificially, in situ to form a continuous insulating layer.

1.3.2 Coating—an aqueous dispersion or solution in organic solvent of a polymeric plastic compound, of consistency suitable for application by brush or spray. The coating usually dries in situ by evaporation of the liquid carrier.

1.3.3 Finishing materials—all materials used for covering thermal insulation for weather proofing, protection from mechanical damage or decoration, whether applied in a factory or on site.

1.3.4 Flexible insulating material—thermal insulating material that, lacking rigidity, tends to drape or to conform to the shape of the surface against which it is laid.

1.3.5 Gypsum plaster—finishing material supplied in loose dry form that is prepared for application by mixing with water. It will dry in situ without the application of heat. Normally the material is based on calcined gypsum with fibre reinforcement.

1.3.6 Hard-setting composition—finishing material supplied in loose dry form that is prepared for application by mixing with water and is dried in situ by the application of heat.

1.3.7 Mastic—a protective finish of relatively thick consistency and with some degree of permanent flexibility, suitable for application to thermal insulation or other surfaces, usually by spray or trowel, in heavy layers of thickness greater than 1 mm.

1.3.8 Metal cladding, sheathing—sheet metal fitted as a protective finish over insulation.

1.3.9 Mineral fibre—inorganic fibrous material from rock, slag, glass or ceramic origin, but excluding asbestos.

1.3.10 Plastic insulating and finishing materials—a wide group of compounds, substantially organic, usually based on synthetic polymers or on modified polymers of natural origin.

1.3.11 Preformed insulating material—thermal insulating material that is prefabricated in such a manner that at least one surface conforms to the shape of the surface to be covered and that, when handled, will maintain its shape without cracking, breaking, crumbling or permanent deformation.

1.3.12 Self-setting cement—finishing material supplied in loose dry form that is prepared for application by mixing with water. It will dry in situ without the application of heat and normally will give a harder finish than hard-setting composition. Normally the material contains Portland cement.

1.4 EXCHANGE OF DESIGN DATA

1.4.1 Information to be supplied by the purchaser The purchaser should state either—

- (a) precise details of the insulation requirements; or
- (b) the service conditions for which the insulating materials are required so that the insulating contractor can make recommendations.

In the case of (b) the purchaser should provide the relevant information required by Clauses 1.4.2 to 1.4.8.

1.4.2 Preparation of surfaces Special requirements, e.g. for the removal of works-applied protective paint or lacquer, or for the application at site, of paint or other protective coating to the surface to be insulated, should be clearly stated.

1.4.3 Plant details Full details of the plant to be insulated indicating operating temperature and site location.

1.4.4 Types of fittings and supports Types of fittings and supports should be specified and whether or not these are to be provided by the purchaser.

1.4.5 Type of insulation Information on the following should be supplied:

- (a) Main insulation for each portion of plant, e.g. preformed, castable composition, flexible, loosefill, insulating concrete.
- (b) Insulation for bends, flanges, valves, hangers and other fittings.

1.4.6 Type of finish Requirements for type of finish should be supplied e.g. hard-setting composition or self-setting cement, weatherproofing compound or sheet metal.

1.4.7 Special service requirements Any special service requirements should be supplied e.g. resistance to compression, resistance to fire or resistance to abnormal vibration. If there is any special hazard from contact with chemicals or oils on the plant, attention should be drawn to this.

1.4.8 Basis on which the thickness of insulation is to be determined Considerations should be as follows:

- (a) Specified temperature on outer surface of insulation system.
- (b) Specified heat loss per unit dimension, linear or superficial.
- (c) Economic thickness.
- (d) Specified conditions of temperature for the surfaces to be insulated.
- (e) Specified conditions of fluid at the point of delivery.
- (f) Special thickness requirements.

1.4.9 Information to be supplied by the manufacturer or contractor Information should include:

- (a) The manufacturer's declared value of thermal conductivity (k) and thermal resistance (R) appropriate to the temperature of use, plus the corresponding bulk density. 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 stated.
- (b) Limitations of use, physical and chemical.
- (c) The overall thickness, with details of the thickness of the individual layers.
- (d) Information regarding the surface preparation.
- (e) The appropriate Section of this Standard with which the following are in accordance—
 - (i) insulating material (Section 2);
 - (ii) fixing devices and reinforcement (Section 6);
 - (iii) finishes (Sections 5 and 7).

1.4.10 Drawings If required, the insulation contractor should provide drawings showing details as follows—

- (a) type and spacing of required insulation attachments;
- (b) particular methods to be adopted when applying material; and
- (c) any special design that the contractor may wish to be considered;

1.5 PRACTICAL DESIGN CONSIDERATIONS

1.5.1 General Thermal insulation for plant and equipment is too often considered at so late a stage in the design and erection sequence that the insulation contractor has to submit a scheme under pressure of time. The ultimate cost of insulation should be an important factor but it is by no means the only one, and the wise purchaser will base his considerations on having the right material in the right amount and in the right place.

Purchase, delivery and application at the right time are not the main concern of this Section but guidance is given for assessing the influence that design considerations will have on the choice of the right material in the right amount. It is unlikely that any problem will arise for which all the factors discussed here will need to be considered but every factor is dealt with in sufficient detail to ensure that it will be of practical value when required.

1.5.2 Clearance between insulation and the surrounding surfaces One of the chief problems when insulating complex plant is to provide for adequate access, and it is of prime importance that this shall be taken into account when designing the plant and pipe layout.

A minimum clearance of 25 mm beyond the full extent of thermal movement shall be allowed between insulated plant and structural or other insulated surfaces, except where the shielded depth is greater than 300 mm. In such cases, or where pipe banks against walls or ceilings are involved, the designer should envisage the sequence of the fixing of the insulating material and its finish and make all necessary provision.

1.5.3 Provision for differential thermal movement

1.5.3.1 Hot surfaces Due to the difference in expansion coefficients of metals and insulating materials it is necessary to make allowance for the differential movements between the hot surface, the insulant and the finish.

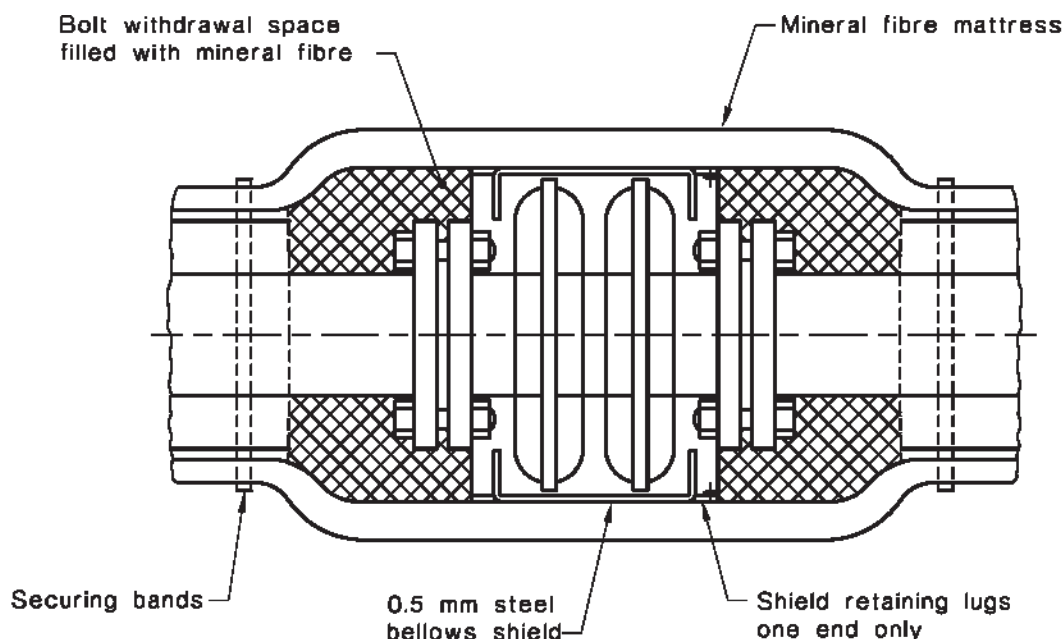
As a guide such allowances or expansion joints should be inserted at the following intervals:

Temperature °C	Spacing intervals m
Up to 200	5
200 to 300	4
300 to 400	3
Over 400	2

If heat-loss or personnel protection are critical considerations preformed sections or flexible insulation shall be applied in two (or more) layers and joints in individual layers shall be staggered.

At the junction between preformed cementitious insulating materials and fixed steelwork, the joint area shall be packed with mineral fibre or other compressible insulant to accommodate differential thermal movement. With a metal finish it is customary to fit sliding joints. When a plaster-type finish is applied, an expansion joint shall be provided e.g. by cutting at a circumferential joint in a single layer or in the outer layer of a double-layer system. These joints shall be covered e.g. with mineral-fibre cloth, secured in place, or as a muff in the same way as at a flange. Radial expansion of pipes and vessels covered with plaster-type finishes is acceptable without longitudinal expansion joints if the value of $D \times t$ is less than 250 for pipes or vessels up to 1.5 m in diameter over insulation or 500 if over 1.5 m. (D is diameter in metres and t is temperature in °C.)

1.5.3.2 Sliding and bellows expansion joints The insulation shall not interfere with the operation of the expansion joints. 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. Mild-steel tie rods, or similar, shall not be enclosed within the insulation where they may attain too high a temperature or cannot be adjusted. See Figure 1.1.



NOTE: Steel cover to overlap bellows by 40 mm at each end. Cuts to be made in the cover and lugs bent over to locate the cover. The purpose of the shield is to permit free movement of the bellows.

FIGURE 1.1 TYPICAL METHOD OF INSULATING EXPANSION BELLOWS

1.5.3.3 Cold surfaces Insulating materials for use at subambient temperatures may 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. In some cases the insulating material will be sufficiently compressible to accommodate this differential movement but, with long straight lengths at extreme temperatures or with non-compressible insulation, contraction joints will be required. These may take the form of a 12 mm gap in the insulation that is packed with a flexible insulant (see Figure 1.2). Contraction joints shall be provided immediately below insulation support rings on vertical pipes and at suitable intervals on horizontal pipes. Joint intervals shall be chosen with due regard to the pipe and insulation materials and the operating temperature. The joints shall be covered with a preformed insulation fastened at one side of the joint only. The design of the vapour seal shall accommodate movement of this joint. See Figure 1.2.

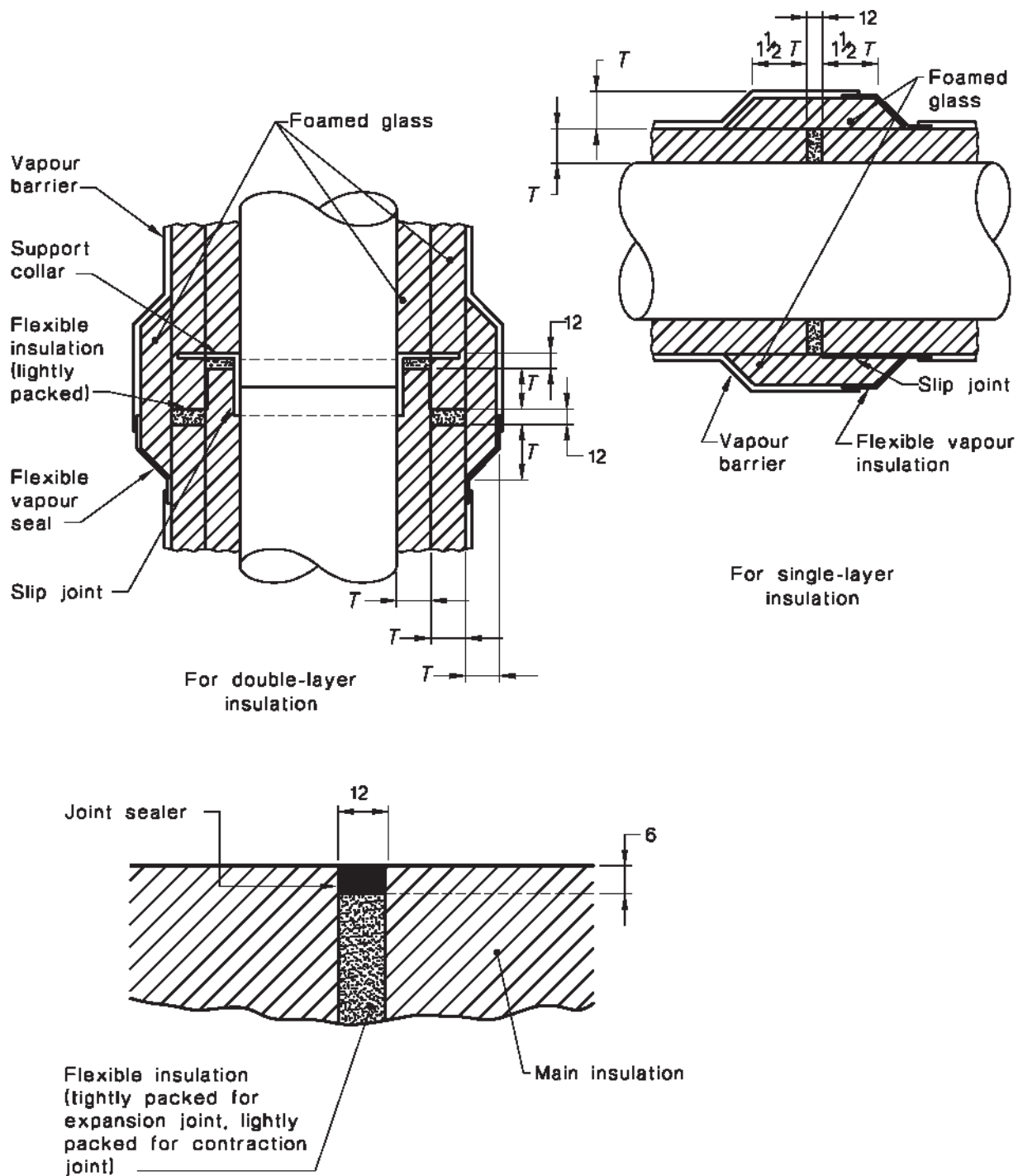
NOTE: In the unlikely event that plastic pipe requires thermal insulation, attention is drawn to the fact that the thermal expansion coefficients are generally much higher than those of metals.

1.5.4 Insulation support On vertical surfaces provision shall be made for insulation supports to take the dead weight of the insulation to prevent settlement and cracking. These shall project halfway through the insulation thickness or in the case of multilayer work to a line halfway through the thickness of the outer layer.

NOTE: These supports may take the form of flat bars, angles or studs as may be agreed. Where such supports are in the form of clamps it is important to ensure that clamps are of the same material as that of pipes so that an adequate clamping force is maintained throughout the operating temperature range of the system.

Provision shall be made for tying back any reinforcement for the finishing cement.

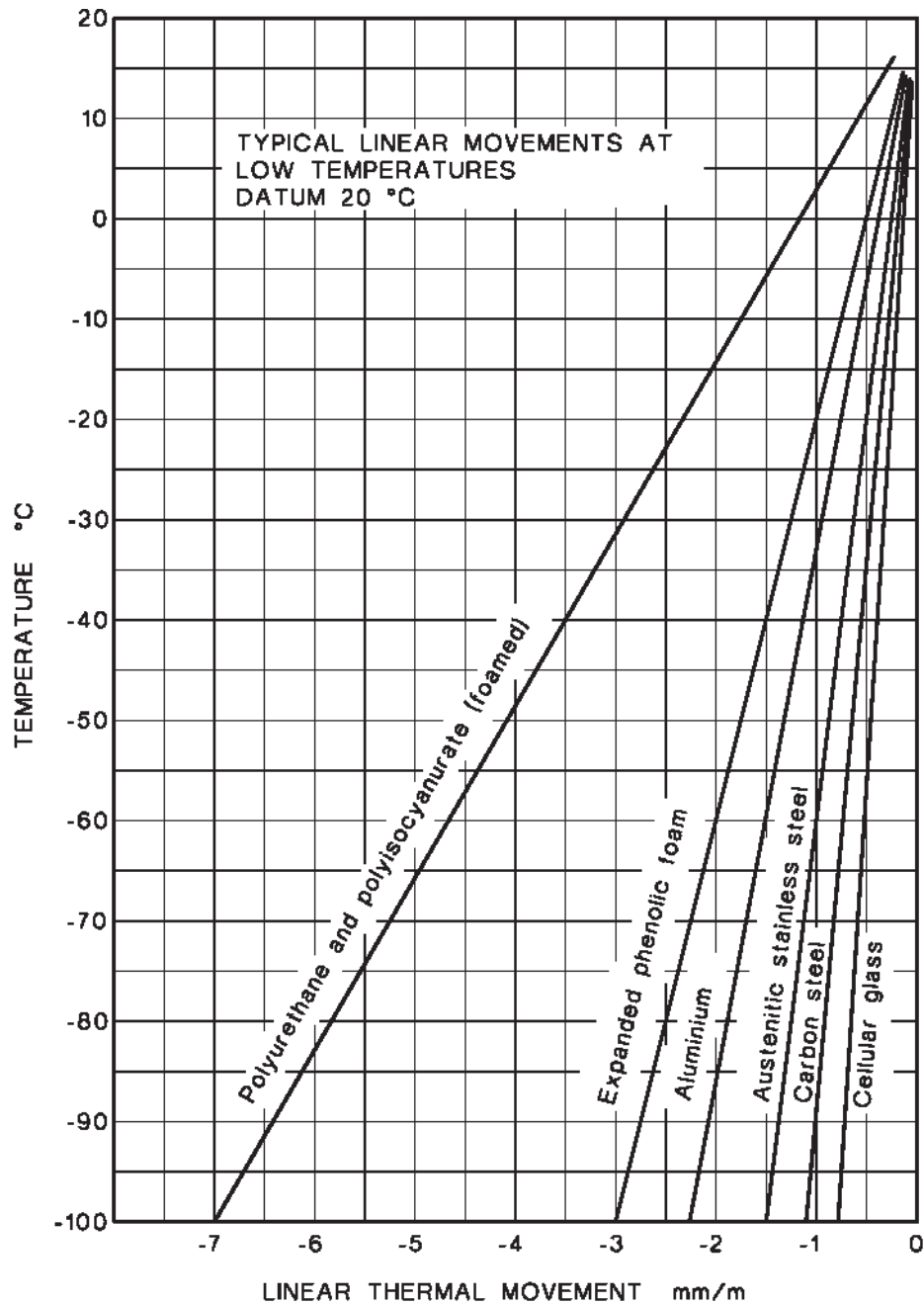
NOTE: Clay-based compositions, bitumen emulsions and other similar finishes should only be applied to hot plant when heat is available for drying out the whole insulation from within.



(a) Typical contraction joints in insulated piping (refrigeration)

DIMENSIONS IN MILLIMETRES

FIGURE 1.2 (in part) CONTRACTION JOINTS: LINEAR THERMAL MOVEMENT OF MATERIALS



(b) Linear thermal movement of various materials between +20°C and -100 °C

FIGURE 1.2 (in part) CONTRACTION JOINTS: LINEAR THERMAL MOVEMENT OF MATERIALS

1.5.5 Insulation of pipes in ducts and subways Pipes in internal ducts and trenches shall be insulated after hydraulic testing and, in the case of pipes for heating services, before heating is commenced.

Insulation is recommended for steam, condensate, heating and hot-water supply mains, in order to conserve heat and to avoid high ambient temperatures. It is not usually necessary to insulate cold water pipes, fire mains, or similar, against frost when they are enclosed in a duct, unless insulation is required to prevent surface condensation.

For hot-water heating, and for steam, hot-water and cold-water services, effective insulation may be provided by using preformed or flexible insulating materials.

To prevent condensation of moisture, insulation and adequate vapour seal are required for chilled-water and refrigeration pipes.

For internal ducts where the pipes are hidden from sight, it may not be necessary to apply further finish. Where a neater appearance is required it may be finished with textile fabric or with a thin sheet material. Painting of the finished surface may be necessary, and identification shall be provided in accordance with AS 1345.

NOTE: Where pipes are to run underground external to buildings consideration should be given not only to the insulation required but also to the protection necessary to prevent the penetration of groundwater to the insulating material and the pipe. Advice should be sought on the extent of water penetration so that consideration can be given to the protection methods to be used for protecting the insulation.

1.5.6 Insulation for airconditioning ductwork Ventilation or airconditioning ducts carry air for both heating and cooling. Such ducts are usually constructed of galvanized sheet metal, reinforced plastic sheet, or made from rigid insulation material and are located in false ceilings, voids, subways, rooms or workshops, or even on roofs and therefore in the open atmosphere. Where a special coating is provided to protect the duct against deterioration, care shall be taken to protect this coating. Where damage has occurred the coating shall be replaced or repaired.

1.5.7 Fire hazards

1.5.7.1 Insulating materials Not all the thermal insulating materials in common use are non-flammable. Some of them are entirely of organic composition and thus may constitute a fire hazard, or they may emit smoke and toxic fumes. Designers of thermal insulation systems shall therefore consider the process conditions and the plant arrangement before deciding whether or not the proposed thermal insulating material might contribute to the spread of fire, however initiated, and they shall vary their choice of material accordingly.

In the absence of special requirements, the characteristics of thermal insulating systems with respect to fire shall be determined in accordance with standardized test methods such as AS 1530 series.

1.5.7.2 Ductwork systems Materials for use with ventilation and airconditioning ductwork shall be in accordance with AS 4254.

1.5.7.3 Finishing materials Some protective finishes in common use are flammable and may produce substantial quantities of smoke on ignition, e.g. bituminous compounds, many plastic polymers, some impregnated cloth and tapes, as well as cotton cloth or bandages. These materials are generally safe for use in the rare situations where there is no fire hazard of any sort but they shall not be used for pipework of plant that may be exposed to fire hazard. There are fire-retarding compounds and anti-oxidant materials that may be applied to flammable finishes, but it should be noted that the protection afforded by such compounds is usually of short duration and that they afford temporary rather than permanent protection.

1.5.7.4 Aluminium paint Some protective and finishing materials, although not in themselves normally considered to be a fire hazard, may become so under certain conditions. Thus aluminium paint based on nitrocellulose shall not be used in flammable atmospheres if the painted surface is likely to be heated to a temperature of 150°C or over. Below this temperature, aluminium paints, except those based on nitrocellulose, may be used on ferrous metals, even when the surrounding atmosphere may be flammable.

1.5.7.5 Aluminium cladding Under certain conditions, aluminium cladding may constitute a hazard e.g. in the event of fire in a large process plant where it is possible for the aluminium to melt and ignite. In a major fire molten incandescent aluminium can be scattered over a wide area. Where such a fire risk is present aluminium cladding shall not be used.

1.5.7.6 Galvanized sheet In the event of a fire in the vicinity of the insulated plant, molten zinc from galvanized accessories can drop onto and penetrate, austenitic steel pipework or plant immediately below. If the pipes or plant contain flammable chemicals a serious fire hazard may result. Where such a fire risk is present galvanized sheet shall not be used.

1.5.7.7 Internal self-heating Some insulating materials that contain organic bonding agents which, although generally suitable for the service temperatures anticipated, may in fact constitute a fire risk through a phenomenon of internal self-heating. Evidence of this self-heating may be a transient rise in temperature above the theoretical value for specific locations within the insulation system. This hazard may be accentuated if air can enter into material of low bulk density, or by convection currents induced with insulated vertical pipework. The phenomenon is a complex one, being 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 may constitute a fire hazard, particularly if the surrounding atmosphere is flammable or if there are flammable materials in the immediate vicinity.

It has been observed that the factors influencing the initiation of a self-heating reaction include:

- (a) The type and physical state of thermal insulating material and spillage material.
- (b) The concentration and quantity of spillage material.
- (c) The shape and dimension of the hot face and of the thermal insulation.
- (d) The temperature of the inner surface of the insulation material.
- (e) The facility 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.
- (f) The ready availability of a source of air, i.e. either entrained or external when there is no surface seal.

Where an identifiable risk is present from a combination of the above factors, such organic bonding agents shall not be used.

1.5.7.8 Earthing In flammable atmospheres, particularly with long runs of insulated pipework, external metal cladding shall be connected to earth in order to avoid possible build-up electricity.

1.5.7.9 Secondary contamination A number of dangerous fires have occurred in situations where non-flammable insulating materials have become accidentally contaminated by oil, chemical or other spillage. The chemical and physical processes involved are complex so that conditions could be hazardous without this fact being recognized.

Three distinct situations have been observed following the spillage of contaminant on to heated thermal insulation. These are as follows:

- (a) No reaction.
- (b) A small rise of temperature within the body of the insulating material, followed by a slow decline of temperature.
- (c) A small rise in temperature, followed by a period of steady temperature and then by a relatively rapid rise to values associated with combustion. At this stage fire may be initiated if flammable materials are present. In other circumstances the thermal insulating material may smoulder or even glow with heat and thereby constitute a source of ignition for other materials in the vicinity. This sequence of temperature rise may be initiated even though the insulated hot-face temperature is well below the flashpoint of the spillage material.

1.5.7.10 Storage The consequences of fire in an insulation system are most dangerous in locations where highly flammable or low-flash-point materials, or both, are stored or processed, i.e. areas normally classified as flameproof. In these circumstances the choice of an insulation system should be preceded by self-ignition experiments in a laboratory.

1.5.7.11 Protection An impervious finish shall not be relied on to provide protection against an otherwise dangerous combination of insulating material and spillage material, since the finish may be rendered ineffective by accidental, and possibly unobserved, mechanical damage.

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

1.5.7.12 Maintenance In all circumstances it is important to aim for a high standard and vigilance of plant maintenance to minimize the risk of accidental contamination by spillage or leaks.

1.5.7.13 Fire retardants Fire precautions may also be applied to limit the heat gain of vessels containing volatile and flammable liquids, and to delay any dangerous temperature rise in structures that could be exposed to conditions of fire. Spray-applied vermiculite products and spray-applied mineral fibres are typical materials for this type of application.

1.6 TEMPERATURE CLASSIFICATIONS For the purposes of this Standard systems have been classified in accordance with normal operating temperature as follows:

- (a) *Low temperature*—systems operating in the temperature range of -75°C to $+10^{\circ}\text{C}$.
- (b) *Medium temperature*—systems operating in the temperature range of $+10^{\circ}\text{C}$ to $+300^{\circ}\text{C}$.
- (c) *High temperature*—systems operating in the temperature range of $+300^{\circ}\text{C}$ to $+800^{\circ}\text{C}$.

NOTE: Some systems may have cyclic operation characteristics i.e. they may operate between the temperature ranges classified. In these cases the requirements and recommendations for both operating temperature ranges should be followed.

1.7 CONTRACTS Contracts and subcontracts should be in accordance with AS 2124, AS 2545, AS 4300 and AS 4303 as applicable.

SECTION 2 SELECTION OF INSULATING MATERIALS AND SYSTEMS

2.1 CHARACTERISTICS OF INSULATING MATERIALS

2.1.1 Thermal conductivity and thermal resistance A low thermal conductivity (k) is desirable to achieve a maximum resistance to heat transfer or a high thermal resistance (R). Therefore, for any given thermal resistance or R value, a material of low thermal conductivity will be thinner than an alternative material of high conductivity. This is of particular advantage for pipes because thinner layers of insulation reduce the surface area emitting heat and also reduce the area of the outer surface that will require protection.

The thermal conductivities of most insulating materials vary with temperature and with bulk density, so that both these factors must be considered. Figure 2.1 shows the typical relationship between thermal conductivity and service temperature for some typical insulation materials. It is the normal practice of manufacturers to provide tables or graphs showing thermal conductivities for each of their standard products at a range of hot-face temperatures together with the relevant cold-face temperatures used for the tests. The information shall also include the bulk density for each material tested. Materials for use under hot conditions should be tested with a cold-face temperature in the range 10°C to 50°C. Materials for use at temperatures below about 5°C should be tested with one face at or near to the required low temperature, with the other face within the range 5°C to 20°C.

Although, under service conditions for insulating materials at elevated temperatures, the outer exposed surface may reach a temperature above that quoted for the test, the figures for any calculation of heat flow may be based on those published by the manufacturer. Provided that the outer surface temperature does not exceed 50°C, the resultant error is likely to be less than 5%.

For very high cold-face temperatures, which could apply, with the inner layer of composite insulation or with materials exposed to high ambient temperatures on the exposed surface, special calculations are required. These may involve reference to 'mean' temperatures, i.e. the arithmetic mean between the hot-face and cold-face temperatures of test; to avoid confusion, either the corresponding hot-face or cold-face temperature should also be quoted.

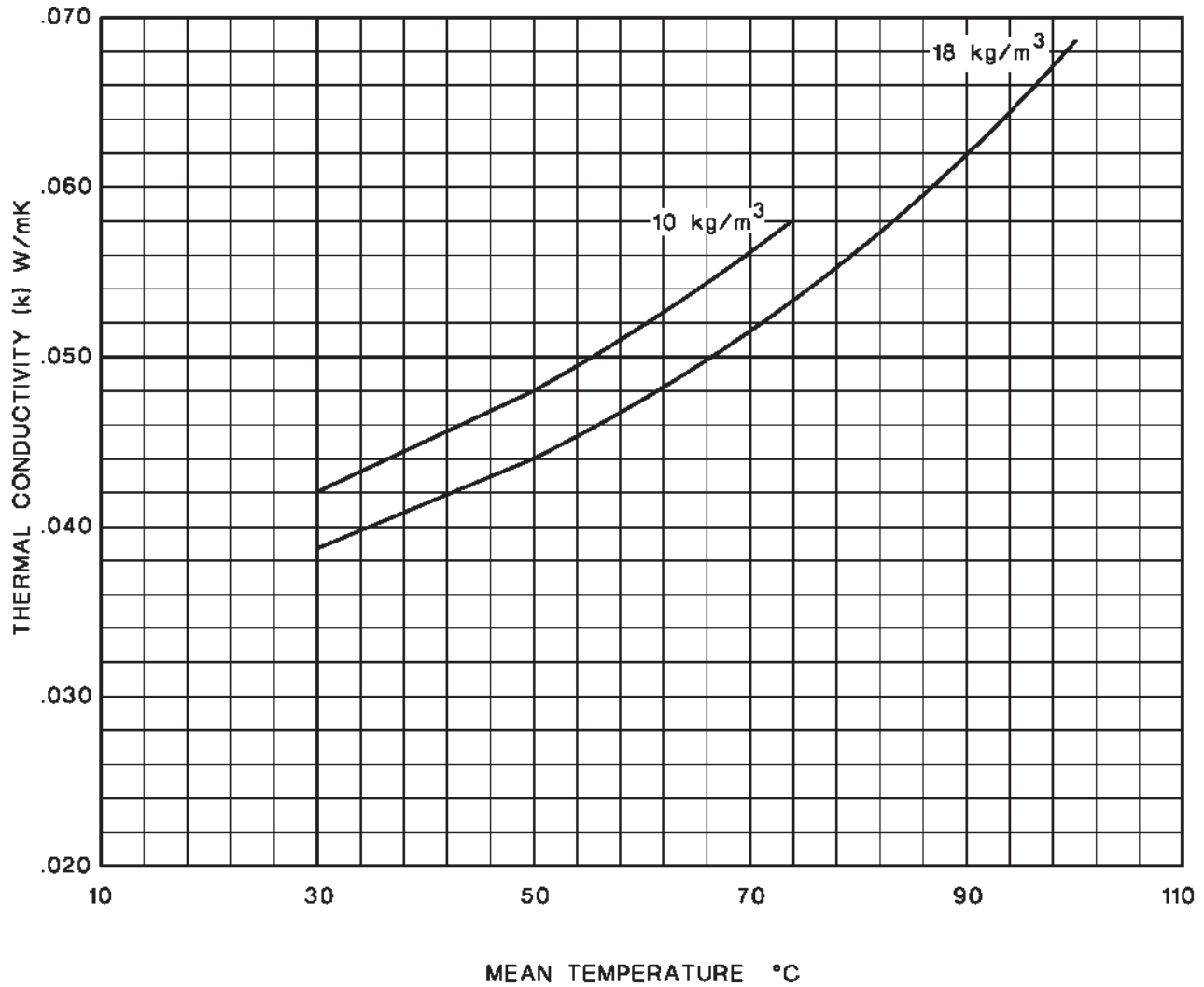
2.1.2 Physical forms Insulation is usually supplied in one of the following forms:

- (a) Preformed (slabs or sections).
- (b) Loosefill.
- (c) Flexible.
- (d) Castable composition.
- (e) Blanket.
- (f) Sprayed.
- (g) Powder.
- (h) Metallic.

Each of these 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 guidelines on typical properties of common insulating materials see Table 2.1. Some of these materials may be used in a vacuum-type insulation system.

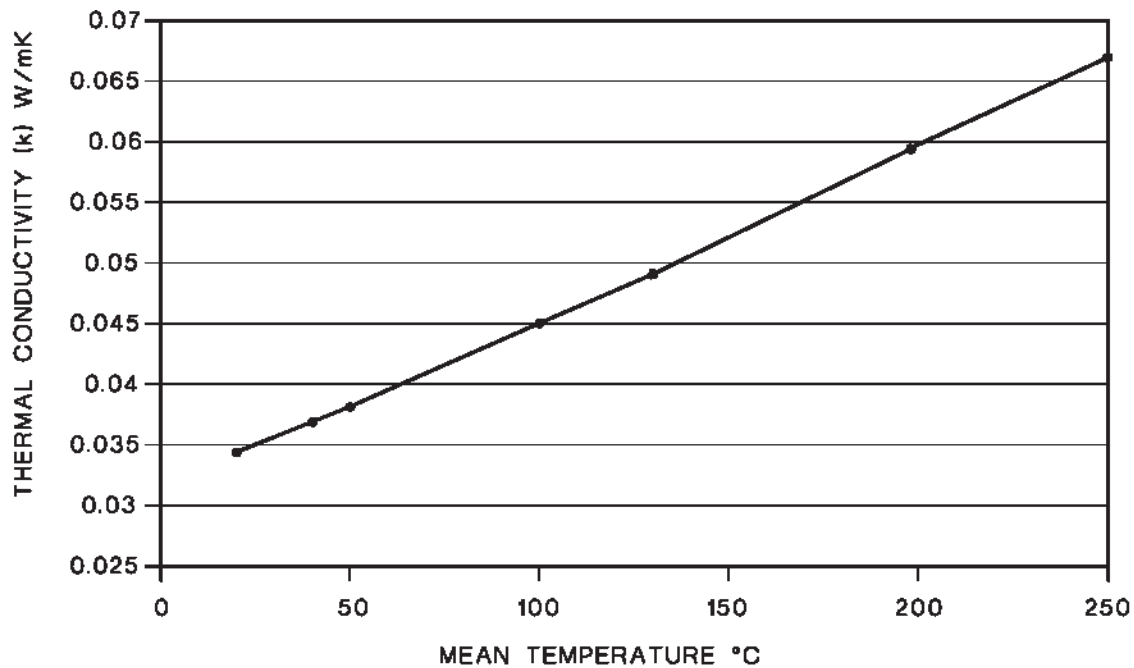
Information given in Table 2.1 is for guidance only. Actual product data may vary widely from that shown in this Table and this information shall at all times be obtained from the manufacturer, an accredited testing laboratory or actual representative samples of material.



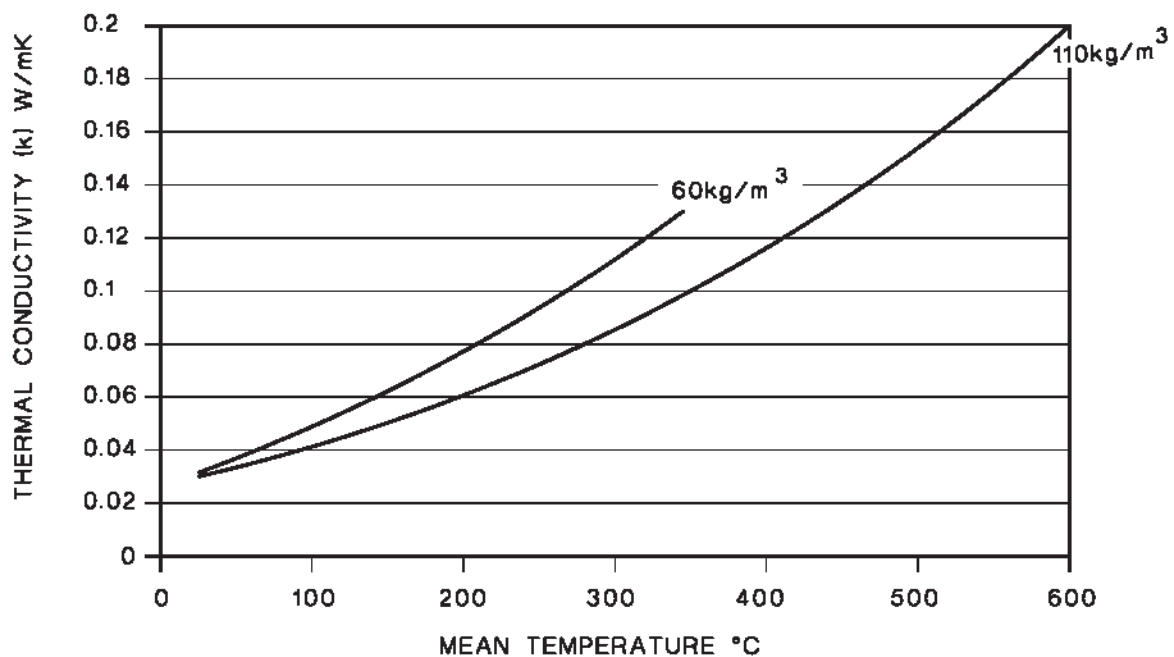
[a] Glasswool insulation

NOTE: This information is for guidance only. For design purposes the actual product data should be sourced from the manufacturer.

FIGURE 2.1 (in part) TYPICAL RELATIONSHIP BETWEEN THERMAL CONDUCTIVITY AND SERVICE TEMPERATURE FOR TYPICAL INSULATING MATERIALS



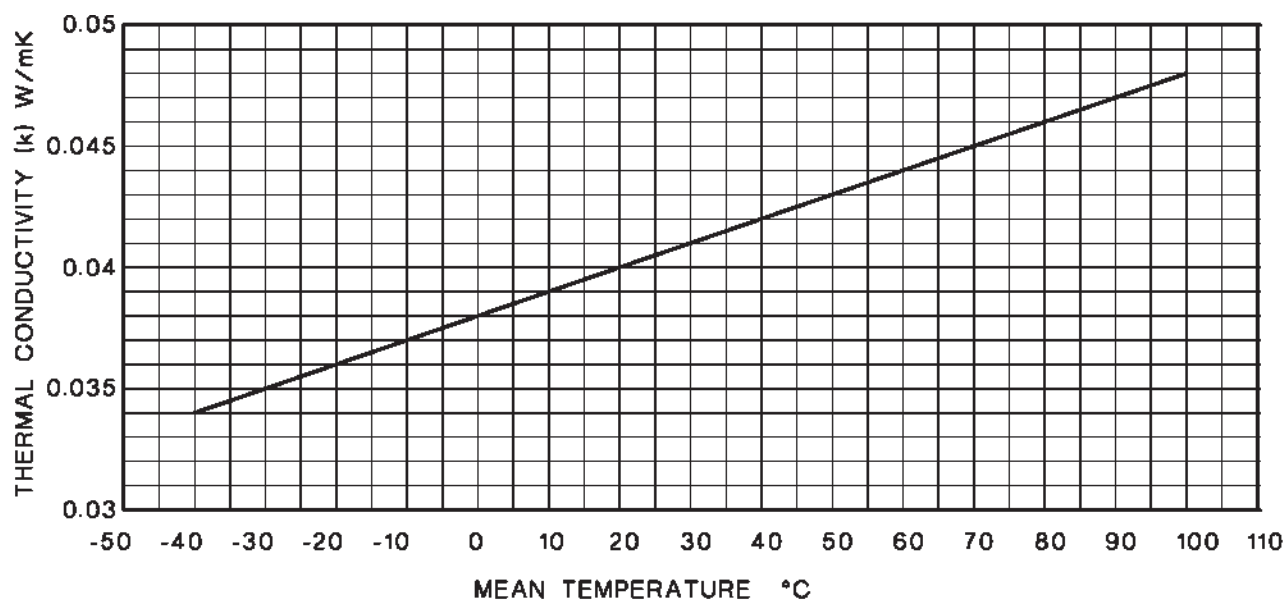
(b) Glasswool insulation



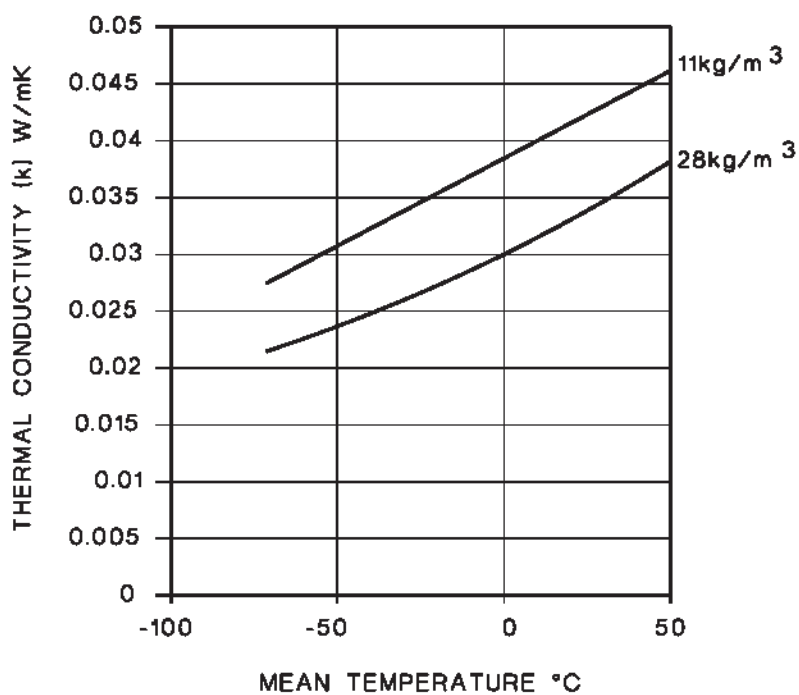
(c) Rockwool insulation

NOTE: This information is for guidance only. For design purposes the actual product data should be sourced from the manufacturer.

FIGURE 2.1 (in part) TYPICAL RELATIONSHIP BETWEEN THERMAL CONDUCTIVITY AND SERVICE TEMPERATURE FOR TYPICAL INSULATING MATERIALS



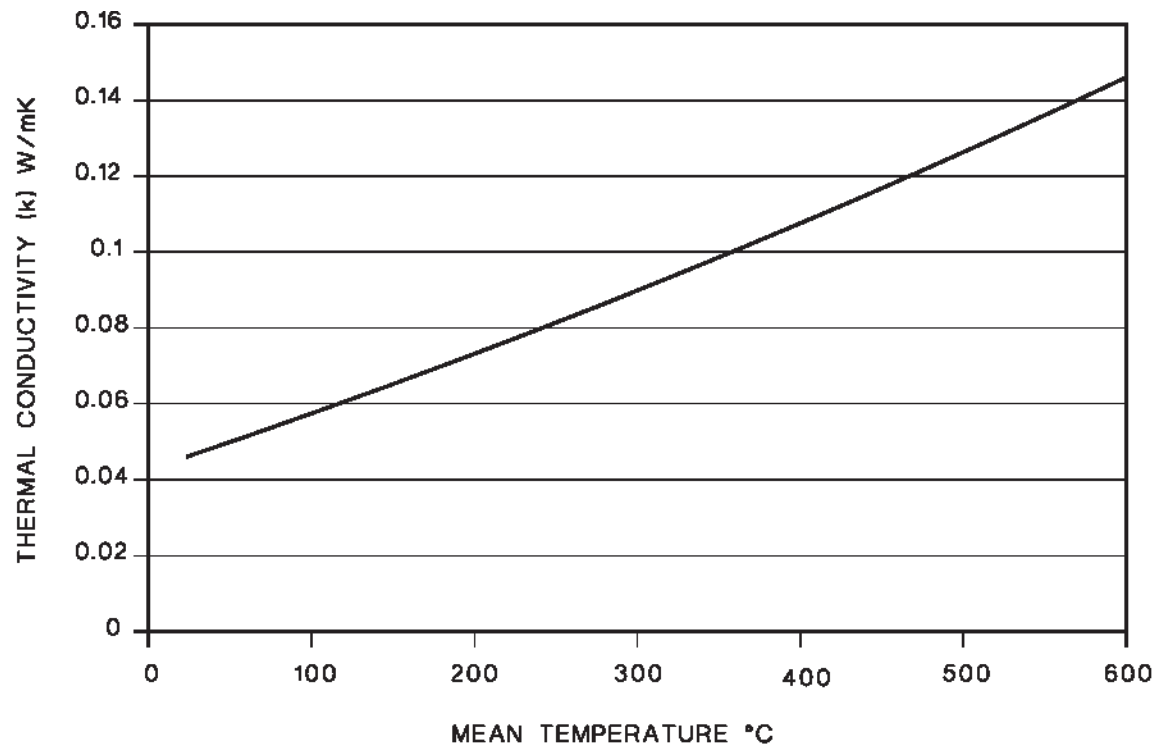
(d) Nitrile rubber



(e) Polystyrene insulation

NOTE: This information is for guidance only. For design purposes the actual product data should be sourced from the manufacturer.

FIGURE 2.1 (in part) TYPICAL RELATIONSHIP BETWEEN THERMAL CONDUCTIVITY AND SERVICE TEMPERATURE FOR TYPICAL INSULATING MATERIALS



(f) Calcium silicate insulation

NOTE: This information is for guidance only. For design purposes the actual product data should be sourced from the manufacturer.

FIGURE 2.1 (in part) TYPICAL RELATIONSHIP BETWEEN THERMAL CONDUCTIVITY AND SERVICE TEMPERATURE FOR TYPICAL INSULATING MATERIALS

TABLE 2.1
TYPICAL PROPERTIES OF INSULATING MATERIALS
LOW TEMPERATURE RANGE

Material	Physical form	Type	Typical temperature range °C	Typical bulk density range kg/m ³	Typical thermal conductivity range W/m K
Mineral wool (glass)	Resin-bonded slabs/lags Preformed pipe sections Flexible mats Lamella mat Board	Fibrous	<230 <450 <230 <230 -50 to +450	15 to 100 60 to 100 15 to 35 20 to 40 48 to 60	0.02 – 0.1 (Refer to Figure 2.1 (a & b))
Mineral wool (rock)	Loose wool Resin-bonded slabs/lags Preformed pipe sections Flexible mats Wired mattresses Lamella mat Pipe section mat Inorganically bonded slabs/lags	Fibrous	<850 <850 <750 <230 <850 <230 <650 <1100	50 to 150 20 to 200 80 to 150 Up to 45 90 to 130 30 to 48 140 240 to 250	0.03 – 0.2 (Refer to Figure 2.1(b))
Cellulose	Loose fill	Fibrous	<90	30 to 50	0.04 – 0.05
Polyester	Batt Rigid board Blanket	Fibrous	160	8 to 60	0.04 – 0.10
Cork	Rigid board Pipe section Loose fill	Cellular	<90	100 to 200	0.04 – 0.05
Phenolic foam (open cell)	Pipe sections Rigid boards	Cellular	-180 to +120	30 to 50	0.04 – 0.05
Nitrile rubber (closed cell)	Sheets and pipe sections	Cellular	-50 to +100	56 to 110	0.03 – 0.05 (Refer to Figure 2.1(d))
Polyethylene (closed cell)	Sheets and pipe sections	Cellular	-50 to +100	24 to 48	0.04 – 0.06
Cellular glass	Rigid board Block and pipe sections	Cellular	-270 to +500	120 to 150	0.05 – 0.15
Polystyrene (extruded)	Board and pipe covering	Cellular	-50 to +80	29 to 56	0.02 – 0.04 (Refer to Figure 2.1(e))
Polystyrene (expanded)	Board and pipe covering	Cellular	-50 to +80	16	0.02 – 0.04
Polyurethane	Batt Rigid board Blanket Pipe section Loose fill	Cellular	-50 to +104	24 to 80	0.02 – 0.05
Polyisocyanurate	Board and pipe covering	Cellular	-180 to +150	32	0.02 – 0.04
Urea-Formaldehyde	Rigid boards	Cellular	<100	10 to 16	0.03 – 0.05

(continued)

Material	Physical form	Type	Typical temperature range °C	Typical bulk density range kg/m ³	Typical thermal conductivity range W/m K
Gypsum pellets	Loose fill	Granular	<430	320 to 480	0.06 – 0.16
Insulating compositions	Castable cement composition	Granular	<1500	250 to 1100	N/A
Vermiculite	Loose fill	Granular	<1100	50 to 150	0.06 – 0.25
Vermiculite cement	Sprayed	Granular	<1100	320	0.07 – 0.25
Vermiculite/sodium silicate	Slabs	Granular	<1000	450	0.07 – 0.25
Calcium silicate	Plastic composition Slabs/lags Preformed pipe sections	Granular	<1000 <1000 <800	160 to 320 160 to 320 190 to 260	0.05 – 0.25 (Refer to Figure 2.1(f))
Perlite (expanded)	Loose fill	Granular	<870	40 to 150	0.04 – 0.20

N/A = Not available

NOTES:

- 1 Typical properties listed in Table 2.1 are for information only. Actual product data for design purposes should at all times be sourced from the manufacturer.
- 2 The lower limiting temperature of insulating materials is dependent on several factors and the manufacturers should be consulted.
- 3 The thermal conductivities of some foamed cellular materials, especially plastic, may increase with age as the gaseous content of the cells, diffuse out of the cells and is replaced by air. For design purposes, only aged values of conductivity should be used.

2.1.3 Bulk density The bulk density for most thermal insulating materials falls within the range 16 kg/m³ to 320 kg/m³ and their effectiveness depends essentially on the large numbers of minute air or gas cells that they contain and that retard transfer of heat by conduction, convection and radiation.

Low bulk density may result in low compressive strength, in which case the material will not be suitable for load-bearing purposes.

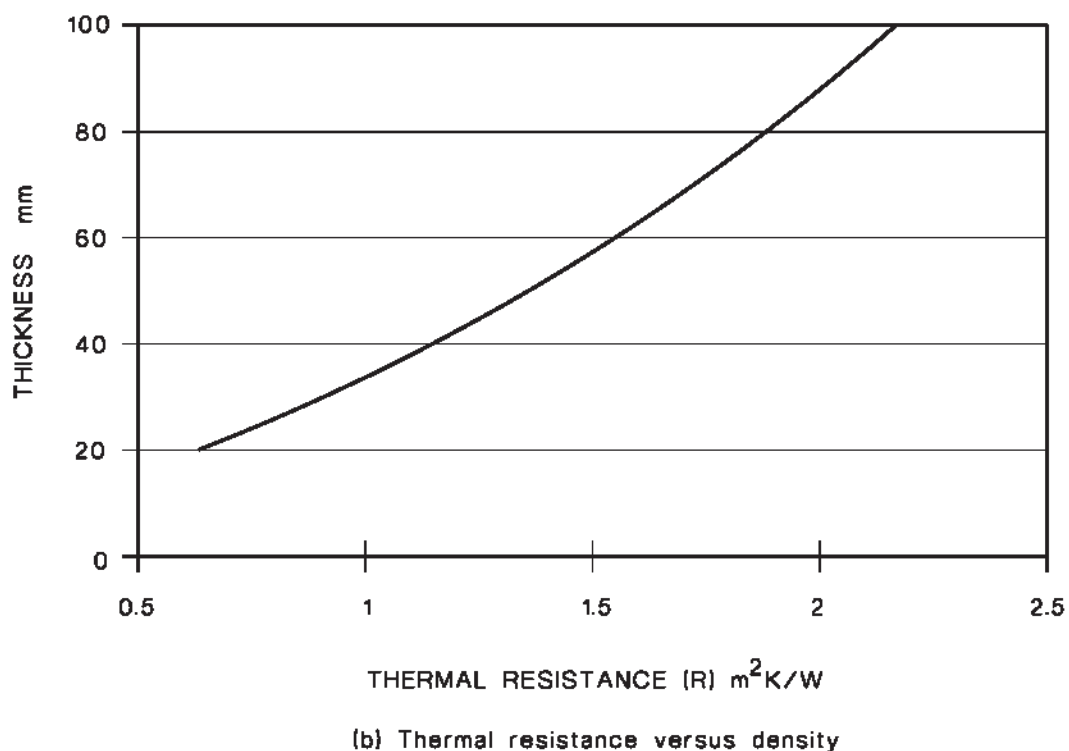
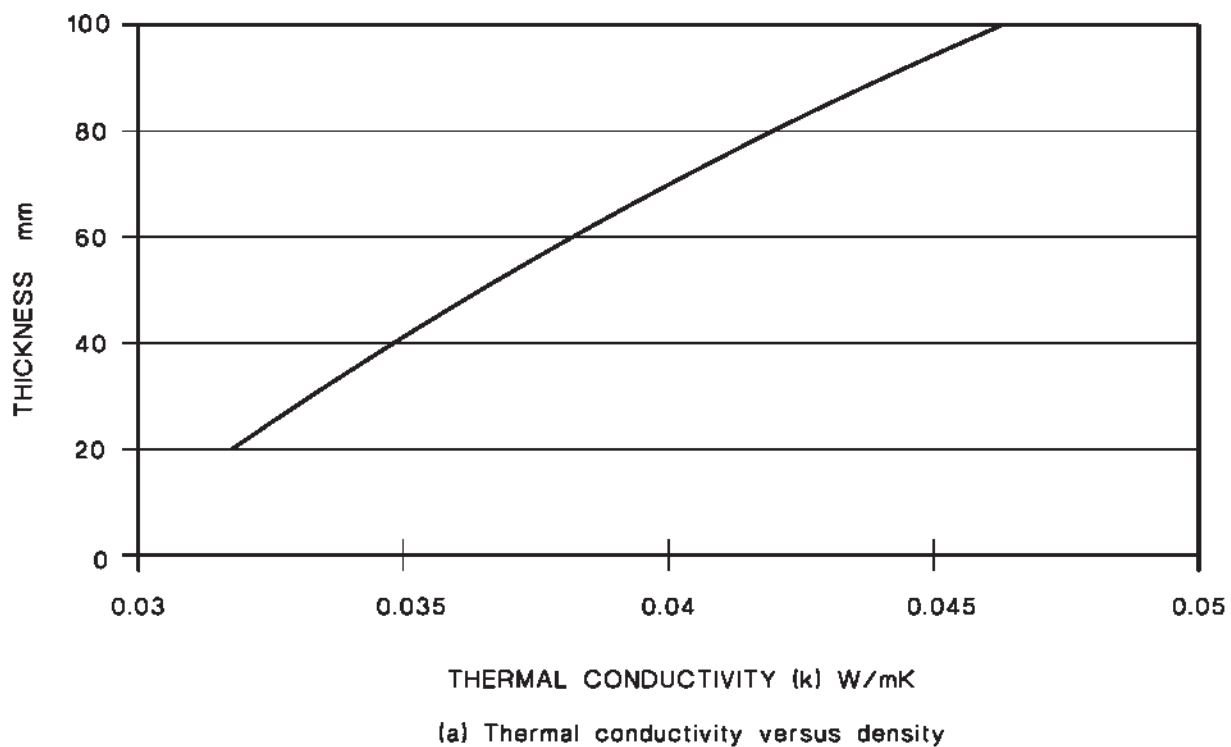
As a general rule, increase in bulk density is associated with reduction in the size of the contained air or gas cells and this tends to maintain effectiveness of insulation at the higher service temperatures.

Figure 2.2 shows the typical relationship between density and thermal conductivity or thermal resistance.

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

2.1.4 Suitability for service temperature The temperature at which the material is used shall be within the range for which it will provide satisfactory long-term service under conditions of normal usage. See Table 2.1 for a guide to approximate operating temperatures.

For materials to be used at temperatures below about 10°C, attention shall be paid to the relevant limiting minimum as well as to the limiting maximum temperatures, and to the effects of possible excessive shrinkage, embrittlement, and porosity, in addition to resistance under conditions of occasional heating for defrosting purposes.



NOTE: These graphs were obtained by compressing a 100 mm (1000 g/m²) thick sample and determining the k or R values at successive thicknesses.

FIGURE 2.2 TYPICAL RELATIONSHIP BETWEEN DENSITY AND THERMAL CONDUCTIVITY OR THERMAL RESISTANCE

For materials to be used at elevated temperatures it will be necessary to consider the many factors that may result in deterioration under conditions of service. These include linear shrinkage under heat, loss of compressive strength and of weight during heating, and the effects of vibration and possible self-heating phenomena. In establishing maximum operating temperatures for preformed high-temperature insulation, particularly that in the form of pipe sections, the ability of the insulation to withstand moderate loads and vibration whilst in service should be considered. Some knowledge of the compressive strength both before and after heating may be of value. Additionally, the effect of long-term heating should be studied.

Where the compressive strength in service undergoes significant reduction, as in the case of bonded mineral wool due to volatilization of the organic binders at temperatures above about 260°C, it is necessary to support and protect the insulating material. Metal cladding (see Table 7.1) is convenient for this purpose. Where additional strength is required, the metal cladding shall be supported from the pipe independently of the insulation, e.g. by insulated metal spiders or by suitable loadbearing insulation.

The appropriate tests should be carried out by the manufacturer or an accredited test laboratory and the results used to compile a report on suitability for particular applications. Judgement is then needed in selecting specific materials for specific conditions of use.

2.1.5 Thermal expansion Most thermal insulating materials have a lower thermal expansion coefficient than metals. Differential thermal movement between the insulated surface, insulation and outer finish shall be considered.

2.1.6 Resistance to compaction Loosefill material and unbonded mattresses are liable to compact under the influence of vibration and thermal cycling. Insulation materials may also be compacted by inappropriate installation methods. This compaction causes a decrease in the thermal resistance (R) of the material due to a decrease in the insulation thickness a typical relationship between insulation thickness and corresponding R value is illustrated in Figure 2.3.

2.1.7 Resistance to vapour penetration and absorption Whilst closed-pore materials, e.g. cellular glass may have low vapour permeability characteristics, open-pore and fibrous insulating materials can absorb considerable quantities of condensed vapour which will adversely affect the thermal conductivity and the effectiveness of the insulation.

Insulation applied to cold surfaces has to be protected from vapour penetration that gives increased conductivity. If vapour is allowed to penetrate and freeze, the cells of the insulation may rupture and permanently damage the material. It is an advantage if the material itself is of low vapour permeability.

2.1.8 Mechanical strength and durability

2.1.8.1 Mechanical strength Generally, insulating materials are mechanically weak and strength normally decreases after heating. The finish applied frequently affords some protection against mechanical damage, but the insulation itself shall be strong enough to withstand reasonable handling. Strength and abrasion resistance shall be related to the work and material in question, and have to be taken into consideration at the design stage.

2.1.8.2 Durability The durability of an outdoor insulation system may be important. For instance, shrinkage in sunlight or breakdown by frost may have serious consequences. Insulation materials shall not be used outdoors unless adequately protected or intrinsically able to withstand the conditions.

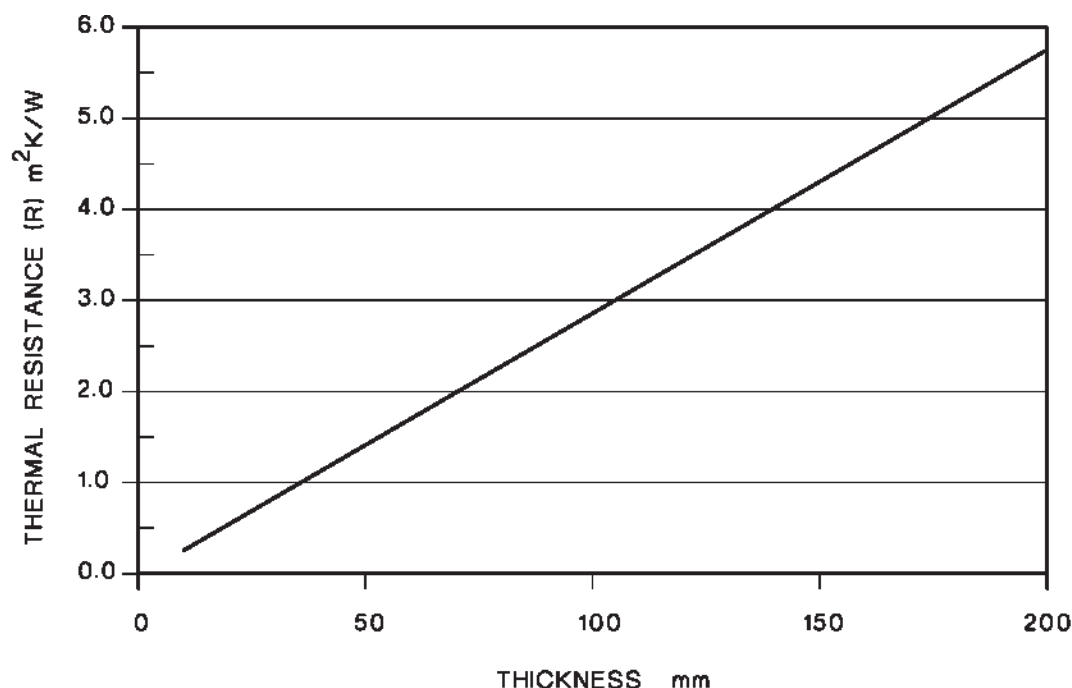


FIGURE 2.3 TYPICAL RELATIONSHIP ILLUSTRATING LOSS IN R VALUE WITH LOSS IN THICKNESS FOR COMPRESSIBLE INSULATION

2.1.9 Fire and explosion hazards Whilst it is usually desirable that insulation be non-combustible there may be areas where such materials are not necessary, in which case some relaxation could be considered. The relevant building and fire authorities shall be consulted. The fire hazards, whether caused by quantity of combustible material, susceptibility to ignition, ease of surface spread of flame, or quantity of smoke or toxic gas produced in a fire may be influenced considerably by the protective coating and associated materials, e.g. adhesives, vapour barriers and sealants. Many insulating materials are practically free from risk, but if inadequately protected can absorb quantities of oil or similar that may ignite spontaneously.

The production by the insulation and associated materials of large quantities of smoke or toxic gases is particularly hazardous within staircases and other shafts, corridors and enclosed escape routes in a building, or within ventilation ducts and ceiling voids used as ventilation ducts.

In certain areas of high fire (or explosion) risk, e.g. where powerful oxidizing agents are handled, the insulation shall not contain any organic matter.

2.1.10 Resistance to vermin and fungus The resistance of insulation to vermin, insects and fungal growth can be important, particularly in cold stores or food factories. Insulation surfaces likely to become wet shall not be finished with materials that may be attacked by these agencies. Finishing with non-absorptive materials is required for severe cases. ASTM C739 includes a test method for the fungi resistance of some insulation materials.

2.1.11 Health hazards

2.1.11.1 General Respirable dust and fibre particles from insulating materials containing asbestos, silica, etc., may enter the bronchial passages and cause lung diseases. Because of this risk to health where materials are manipulated, e.g. mixed, handled or removed, adequate work methods and protective equipment shall be used. Insulating materials maintained in good order and stable condition are likely to present only a low degree of risk.

2.1.11.2 Removal The risks to health associated with the removal of thermal insulation containing asbestos are particularly well-known, especially when crocidolite (blue asbestos) is encountered. Diseases that have been related to asbestos are asbestosis, lung cancer and mesothelioma.*

Before any stripping work is carried out it is necessary to determine what type of insulating material is involved. Although the presence of crocidolite is sometimes discernible by its rich lavender-blue colour, it is not correct to rely on this test alone. It is always necessary to obtain positive analysis by a responsible laboratory.

2.1.11.3 Asbestos disposal For disposal of any waste asbestos the respective State or local council requirements shall be referenced.

2.1.11.4 Fibrous materials Many fibrous insulating materials can cause skin irritation. Normally this is associated with the coarser fibres, although the same materials of smaller fibre diameter may cause this irritation. The use of barrier creams and the provision of adequate washing facilities will help reduce the incidence of skin irritation, but tight clothing, e.g. round the neck and at the wrists, may trap fibres and thus increase local irritation.†

2.1.11.5 Cements Certain finishing cements are strongly alkaline when wet and may cause skin irritation. Gloves shall be worn when handling these materials.

2.1.11.6 Chemicals Chemical fumes from the components of some insulating materials, e.g. foamed urea-formaldehyde, phenol-formaldehyde resins, isocyanides and polyurethane 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. Suitable respiratory protective equipment shall be used and, particularly in confined spaces, air-supplied hoods or respirators are required for many materials, especially isocyanides and epoxy-resin compounds.

Contact with certain resinous coatings, adhesives and epoxy-resins components can cause dermatitis, which may occur after brief contact, or long exposure leading to allergy. Associated solvents may cause damage to the eyes and skin irritation. Goggles and gloves shall be worn when necessary.

2.1.11.7 Castable cement Attention is drawn to the possible danger of skin irritation when using castable cement. Materials with a high free-lime content require particular care.

2.1.11.8 Adhesives Adhesive users and specifiers shall 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 must be obtained for study.

* Attention is drawn to *Asbestos: Code of Practice and Guidance Notes*.

† Attention is drawn to *Synthetic Mineral Fibres — National Standard and National Code of Practice* issued by the National Occupational Health and Safety Commission.

2.1.11.9 Polymeric foam Special safety precautions shall be observed when working with polymeric foam components. Stock drums shall be protected against excessive heat and against water. With certain types of polyisocyanate, for work in confined spaces, or for work done with certain types of mixing head, it is essential to wear fresh-air masks or hoods.

Care must be taken if heat (e.g. from welding) is to be applied to metal coated with polyurethane foam, as toxic gases can be generated. Also, precautions shall be taken to ensure that chimneys or ventilation passages, do not become blocked with foam.

Special safety precautions shall be observed when spraying polymeric foams and a fresh-air mask or hood shall be worn. Other personnel shall be kept from the vicinity of the spraying and no-one without a mask shall approach within 12 m of spraying operations.

2.1.12 Optimum heat capacity As the heat capacity (alternatively thermal capacity) of an insulating material varies according to its bulk density, this thermal property shall be expressed in terms of heat capacity per unit mass (alternatively specific heat capacity). This value is expressed in J/(kgK). It should be noted that the value will vary with mean temperature even though it is given in terms of unit increment of one kelvin.

An insulating material of low thermal capacity will absorb relatively small quantities of heat with increase of temperature and consequently, under fluctuating temperature conditions, it will be associated with rapid heating and cooling. Conversely, a material of high heat capacity will tend to impart thermal stability to an insulated system.

For certain applications it may be convenient to refer to 'heat capacity' per unit volume, J/(m³K), but this value will be typical only for a representative product, i.e. at a specific bulk density.

2.1.13 Freedom from objectionable odour It is of particular importance that insulating materials for use in food factories, canteens or buildings in which food is processed or served, shall be free from objectionable odour. ASTM C739 contains a test method for the determination of odour emissions from some insulating materials.

2.1.14 Chemical resistance Thermal insulation used in process plants shall not react with chemicals present.

2.2 SELECTION OF THERMAL INSULATING SYSTEMS

2.2.1 Optimum effectiveness The use of thermal insulation should be so arranged that the optimum effectiveness is derived from all components of the complete system, bearing in mind any economic limitations that may be imposed by the purchaser.

The required life of the insulation system should be considered because this affects the annual cost and hence the economic thickness. If the plant has only a short life, a cheap insulation system may be adequate. If the plant has a longer life, a more expensive insulation system with longer life may be the 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 installation is the prime consideration.

Maintenance costs can be significant in the total cost of an insulating system. These costs should be minimized by the correct selection of materials and finishes and by attention to detail in the layout of the system. Particular attention should be given to the accessibility of removable sections, valves, or similar, and the protective systems used in inaccessible locations such as ducts.

2.2.2 Extent of system Thermal insulating system shall be understood to include the following:

- (a) The required attachments to the surface to be insulated.
- (b) Means of securing the insulation system to those attachments, where appropriate, or to the surface directly.

- (c) The types and thicknesses of the insulating materials to be used.
- (d) Means of protecting the insulating material, other than the outer finish, e.g. fire retardant or vapour barrier. This includes initial protection of the surface to be insulated, e.g. from corrosive attack and joint sealants.
- (e) Reinforcing materials.
- (f) Finishing materials.

2.2.3 General Consideration should be given individually to systems for pipework, to flat surfaces (e.g. air ducts, gas flues, walls of drying ovens, walls of large boilers, and similar), and to vessels, tanks, and large curved surfaces.

The components of the system should be appropriate to the specific requirements of use. Generally, materials to be exposed to outdoor weather will differ from those used indoors, if only in the type of finish employed. Different types of system are likely to be required for the following ranges of application:

- (a) Refrigeration (-75°C up to $+5^{\circ}\text{C}$).
- (b) Chilled and cold water supplies ($+5^{\circ}\text{C}$ up to 50°C).
- (c) Central heating, airconditioning, and domestic hot and cold water supplies (10°C up to 110°C).
- (d) Process pipework and equipment (from ambient temperature up to 800°C).
- (e) Dual temperature systems, e.g. refrigeration with occasional use at higher temperatures (-75°C up to $+50^{\circ}\text{C}$).

2.2.4 Facts for consideration

2.2.4.1 Temperature Thermal insulation on plant operating at temperatures below the dewpoint of the surrounding air has to be kept dry, both before and after application. This means that some form of vapour barrier is essential. For elevated temperatures the insulating material shall be adequately resistant to the highest temperature involved under eventual service conditions.

2.2.4.2 Mechanical stability The system, including the insulating material, the method of fixing, and the finishing material, shall be capable of giving effective service during the required life period of the installation. This is of special importance for plant in which access for repair work may be difficult. At all times the system should have good resistance to vibration, mechanical damage and thermal movement, and it should retain its physical effectiveness and stability in service.

2.2.4.3 Resistance to degradation This requirement can have wide implications, from resistance to vermin and fungoid attack and to freedom from fire hazard. Also it will include resistance to the required environmental conditions, e.g. adequate weather resistance for outdoor service as well as resistance to accidental spillage of oils or other chemicals. The insulating material itself shall not tend to dissociate or to disintegrate under specified service conditions.

2.2.4.4 Thermal effectiveness A low thermal conductivity figure for one test sample may not be a reliable guide to the thermal effectiveness of a complete insulation system during prolonged periods of service. ASTM C236 outlines a test method which may be used to determine the performance of insulation system assemblies.

2.2.4.5 Quality control There should be adequate quality control at all stages of the manufacture of materials and at all stages of their application at site.

2.2.4.6 *Type and dimensions of the plant to be insulated* The size and configuration of the plant will have an important bearing on the suitability of a particular insulating material, as well as on the reinforcement, means of securing, and type of finishing material to be used. Particular care will be required with large flat areas, especially when elevated temperatures may cause extensive thermal movements.

2.2.4.7 *Compatibility of the components of the system* Care shall be exercised to avoid the use of solvent-based adhesives or polymeric finishing compounds where these may attack the main insulating material, e.g. polystyrene. Corrosion problems shall be minimized, e.g. those caused by electrochemical action between dissimilar metals under possible humid conditions.

2.2.4.8 *Total weight of the system* Although substantial thicknesses of insulating material may be desirable for energy saving, consideration shall be given to the resultant need to provide additional supports, especially if a heavy metal finish is to be used for mechanical protection. On the other hand, a fibrous or exfoliated loosefill insulating material of low bulk density, with a lightweight finish, may tend to disintegrate or to settle under service conditions where there is substantial vibration, caused e.g. by road vehicles. Such materials shall not be used when it is known that these conditions will render them ineffective under normal service conditions.

2.2.4.9 *Corrosion hazards* As no insulating materials, with the possible exception of multiple-foil stainless steel, are substantially free from soluble chlorides, adequate protective measures shall be adopted as an essential part of the insulation system when the surface to be insulated is sensitive to chloride attack, e.g. austenitic steels. In such cases these precautions may include covering the surface with aluminium foil, or treatment with suitable protective compound.

SECTION 3 SELECTION OF SECURING MATERIALS

3.1 GENERAL Insulation systems may be secured by means of adhesives, by mechanical means, or by a combination of both.

Factors which shall be considered when selecting securing materials include:

- (a) Type of insulation to be secured.
- (b) System operating temperature.
- (c) Site configuration and access for installation.
- (d) Type of plant to be insulated.
- (e) Thermal expansion of plant and insulation.
- (f) Thermal bridging possibilities.
- (g) Ambient temperatures and conditions.
- (h) Local fire hazards.
- (i) Local conditions, e.g. vibrations.
- (j) Occupational health and safety considerations.

3.2 ADHESIVES

3.2.1 General Adhesion depends on molecular forces and, because the surfaces in thermal insulation systems are often rough and irregular, adhesives used for these systems require special gap-filling properties. Compatibility with the surfaces involved is also important and particular insulating materials may require specific adhesives. Fluid primers may be required to assist penetration and wetting, particularly when it is necessary to bond or to consolidate friable surfaces.

In addition to gap-filling capability, correct viscosity is also important. Adhesives of nominally similar type may differ in their resistance to water, in their behaviour under conditions of fire, and in their resistance to temperature variation.

3.2.2 Classification according to use Adhesives for insulation may be classified as follows:

- (a) *Insulation bonding adhesives* Used for securing preformed 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 characteristics, i.e. they are of high build and have high solids content.
- (b) *Facing and film-attachment adhesives* Used for attaching flexible laminates, foils and plastic films to thermal insulation, and for bonding the overlaps of these materials. This group includes a wide range of products, generally of consistency suitable for brush or spray application. They are chosen for economy and for ease of application. For plastic films in particular, the long-term compatibility with the chosen adhesive shall be established at the design stage.

Obviously some overlapping occurs in the above groups, which are intended to illustrate the primary function, i.e. that of adhesive. Good design practice frequently permits economical brush or spray-type adhesives to be used for attachment of insulating materials when existing features of the design can be employed to provide back-up mechanical support, such as metal banding or a strong fabric-reinforced mastic finish.

3.2.3 Application characteristics Important properties that affect use are—

- (a) build, i.e. ability to resist sagging or similar;
- (b) consistency, i.e. suitability for brushing, spraying, or similar;
- (c) coverage;
- (d) solids content (influencing the ease with which solvents or water are lost); and
- (e) degree of absorption with porous insulating materials.

Other properties that may require consideration are flashpoint, toxicity, temperature and humidity range (for application), range of bonding times, curing time, stability in storage, possibility of corrosive attack and danger from attack by solvents. (Slow loss of water can give rise to corrosion; alkaline adhesives, e.g. sodium silicate, can attack aluminium and glass fibre; organic foams, especially polystyrene, are susceptible to attack by certain solvents.)

3.2.4 Temperature limits There are limiting temperatures between which an adhesive will remain effective without significant loss of bond strength. Most adhesives for thermal insulation have service temperature limits within the range -50°C to $+120^{\circ}\text{C}$, although many special adhesive/insulation combinations can be used outside this range.

Below about 0°C most adhesives undergo dramatic loss of flexibility. When bond failure occurs it is most often manifested as shearing of a relatively brittle (though stronger) layer away from a comparatively weak insulating material. Usually part of the insulating material remains attached to the adhesive, so that the mode of failure relates to the cohesion of the insulating material. With the exception of some very sophisticated and expensive adhesives, most products that have the required flexibility at low temperatures do not have sufficient bond strength at normal ambient temperatures.

Above service temperatures of about $+150^{\circ}\text{C}$, the most widely used adhesives are based on filled sodium silicate solutions, which are not resistant to water or high humidity. When assessing the required service temperatures, attention shall be given to the possibility that there may be periodic departures from the assumed conditions, e.g. through steam-cleaning requirements or variations of boiler operation.

3.2.5 Adhesive strength Because of the low bulk density and loose bonding of many insulating materials, high strength of adhesive is not usually the most important requirement. However, the adhesive strength has to exceed the cohesive strength of the insulating material by a safe margin under all conditions of service. For materials of higher bulk density and strength, stronger adhesive will be required, and these have to be adequate to carry the required load with an ample margin of safety. The main components of adhesive strength are those relating to tensile, shear, and peeling forces; the latter are usually the most destructive and a frequent cause of failure. For example, if the layer of adhesive is too thin for bonding slightly distorted insulation boards to metal surfaces, e.g. metal ducts, the resulting insufficient area of adhesive contact may be inadequate to resist the severe peeling forces generated by thermal movement, especially at the edges of the areas of contact. Under typical conditions this type of failure is accentuated after an initial period as the stresses are propagated by cantilever and other effects.

Where permanent bond strength is important, the effect of ageing due to heat must be taken into account. This may be of significance in reducing the acceptable maximum service temperature. However, long-term performance of adhesives cannot be assessed in isolation; the whole system has to be considered, especially the behaviour of the insulating material itself.

3.3 MECHANISM OF CURING

3.3.1 Solvent-based adhesives Appreciation of the curing or setting process is of fundamental importance in ensuring the successful use and performance of adhesives.

Most insulation adhesives form a bond by the evaporation of organic or aqueous solvents or by the absorption of water into porous adherents with subsequent evaporation. Whilst many of these adhesives have an additional curing phase due to cross-linking, this follows solvent loss and cannot properly take place before that occurs.

Failure to ensure that all aqueous or organic solvent can escape from the assembly is the most frequent cause of application difficulties and service failures.

Thickness of applied wet film and porosity of the adherents are major determinants in establishing an appropriate application technique. The wet film thickness, when related to the solids content of the adhesive, shows the proportion of solvent that has to be lost and increasing the thickness generally increases the drying time disproportionately, e.g. bonding two relatively impermeable materials and doubling the recommended thickness could extend the curing period from hours to days or even preclude any possibility of the adhesive ever curing.

In general, solvent- or water-based adhesives are used where one of the adherents 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'. This technique is referred to as 'one-way wet stick'.

With two non-porous adherents 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. This procedure is often called the 'two-way dry stick'.

Some waterbased gap-filling adhesives with high solids content, or heavily filled solvent may be used to bond relatively impervious insulants provided the assembly is 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. Again considerable skill and adherence to manufacturers' instructions are required for trouble-free application.

3.3.2 Chemically curing adhesives These adhesives, generally set by a chemically activated cross-linking process, are increasingly used for insulation work. Usually consisting of two-component materials based on epoxies or polyurethane and modifications of these with other polymers, their use is generally indicated for heavy-duty bonding of impermeable materials. Some types may 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 which some polyurethane versions are especially useful for low-temperature work. Complete mixing of two-component adhesives according to instructions is essential; part mixing of components for small jobs will normally result in a failed bond. Most assemblies need to be supported until sufficient strength has developed.

3.3.3 Hot melt adhesives These are applied as hot viscous liquids and form a bond by solidification on cooling to ambient temperatures. As no solvent loss is required they are useful for bonding non-porous adherents but most types are restricted to a comparatively narrow range of service temperature. These adhesives shall not be used for interface temperatures above 40°C.

3.4 MECHANICAL SECUREMENTS

3.4.1 General The securing materials under this heading generally can be classified as welded attachments, bolted fittings, or banding and wire securements. Care is required to avoid bimetallic contact between metals of appreciably different electrochemical properties.

3.4.2 Welded attachments Welded attachments are used mainly on the vertical faces of piping, or vertical and downward-facing vessels and equipment. They may be in the form of cleats, angles, pads, studs, bolts, nuts and the like that provide support for bolted fittings and permanent datum positions relative to each other. The spacing of these attachments may be varied locally to control thermal movement. Care is required to avoid danger from attack by liquid metal.

Site welding of securing and fixing devices shall not be undertaken without prior consultation with the purchaser, owner or designated agent.

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

3.4.3 Bolted fittings Bolted fittings are used mainly in conjunction with welded attachments and they can be in the form of angle rings, flat rings and the like as such they provide the horizontal support for insulating and cladding materials. Bolted fittings, whether plain or spring-loaded, must be used in conjunction with a welded attachment on a vertical surface, as they are otherwise likely to slip and become ineffective in their control of the insulation system.

3.4.4 Banding and wire securements Banding and wire securements are used mainly to hold materials firmly to the plant to be insulated. They may be of metal, fabric, plastic strip, etc. The size and spacing of these securements will depend on the materials chosen and on the design parameters of the insulation system.

NOTE: When fixing attachments by welding, brazing and the like, it is important that metallurgical damage be avoided.

3.5 COMBINATION In certain circumstances, mechanical fixing devices may be applied with the use of adhesives. In such cases mechanical strength is very important, especially for large tanks where the insulation may be subjected to substantial wind forces.

SECTION 4 VAPOUR BARRIERS

4.1 GENERAL A vapour barrier is defined as a hermetic, continuous membrane installed on the warm side of a thermal insulation system.

The environment in which the thermal insulation system will operate may contain a range of vapours which, in the absence of an effective vapour barrier, may penetrate the insulation and condense on the insulated surface.

4.2 CONDENSATION AND FREEZING Water vapour is of most common concern, and although the following Section refers to water vapour, it is relevant to other vapours. Condensation of water will occur on surfaces at temperatures below the atmospheric dewpoint, due to water vapour drawn towards the cold surface as a result of difference in partial vapour pressure between the air at ambient temperature and that at the temperature of the cold surface. Unless it is possible for this moisture to be re-evaporated, it can be absorbed into any permeable insulating material that may be applied to the cold surface, thus increasing the thermal conductivity of that material, with impairment of its effectiveness.

Where the system is operating at temperatures below freezing point, freezing of condensation may damage the insulation system. Where cyclic or intermittent operation occurs repeated freezing and defrosting of condensation will damage the insulation system.

4.3 REQUIREMENTS FOR A VAPOUR BARRIER Since it is essential to prevent the deposition of moisture, with the consequent risk of ice formation within the insulating material in those zones that are below freezing point, the use of an effective vapour barrier is an important technical requirement. The deposition of moisture within the insulating material could lead to eventual saturation of the material, with possible resultant mechanical and physical deterioration within the insulation system, and the risk of corrosive attack on the insulated metal surface. The barrier shall not be used as the exposed surface finish if it is likely to be damaged during service.

NOTE: Even penetration by pinholes will impair the effectiveness of the vapour seal.

4.4 VAPOUR BARRIERS FOR USE OVER INSULATION ON SURFACES ABOVE DEW POINT If the cold surface is at temperatures below the atmospheric dewpoint for short periods only, any deposited moisture may evaporate later, in which case the use of a vapour barrier may not be essential, or a surface breather coat may be adequate.

It should be noted that the atmospheric dew point is likely to vary from day to day in accordance with the relative humidity. Account shall be taken of this likely variation when the requirements of vapour protection are under consideration.

4.5 FACTORS WHICH MUST BE CONSIDERED Factors which shall be considered include:

- (a) The saturation or dew point temperature or each of the vapours present in the operating environment.
- (b) The ability of a particular vapour barrier membrane to resist penetration by a particular vapour.
- (c) Given that there will be some measurable penetration of the membrane by the vapour, what may be the effective life of the insulation system.
- (d) What effect the vapour or the condensate has on the safety of the workplace, or on the health of those working in the vicinity.