



RP 52-1

THERMAL INSULATION

April 1997

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BP GROUP RECOMMENDED PRACTICES AND SPECIFICATIONS FOR ENGINEERING			
Doc. No. RP 52-1		Issue Date	April 1997
		Latest Amendment Date	
Document Title			
THERMAL INSULATION			
APPLICABILITY			
Regional Applicability:		International	
SCOPE AND PURPOSE			
This document specifies BP general requirements for the external thermal, and combined thermal and acoustic, insulation of equipment, pipework, valves and fittings in the temperature range of -180°C to +800°C.			
AMENDMENTS			
Amd	Date	Page(s)	Description
CUSTODIAN (See Quarterly Status List for Contact)			
Materials & Inspection			
Issued by:- Engineering Practices Group, BP International Limited, Research & Engineering Centre Chertsey Road, Sunbury-on-Thames, Middlesex, TW16 7LN, UNITED KINGDOM Tel: +44 1932 76 4067 Fax: +44 1932 76 4077 Telex: 296041			

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FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory Volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory Volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Recommended Practice

This Recommended Practice gives guidelines for both maintenance and project thermal insulation requirements, based upon the experience of both BP and other companies. This information is not contained in any other formal documents, or industry wide standard.

In particular, external codes do not give guidance on the pre-treatment, application and finishing aspects that are so important to satisfactory insulation. In addition, it is clearly important to encapsulate the BP Group's experience of successful (and to warn of unsuccessful) insulation practice.

Application

Text in *italics* is Commentary. Commentary provides background information which supports the requirements of the Recommended Practice, and may discuss alternative options. It also gives guidance on the implementation of any 'Specification' or 'Approval' actions; specific actions are indicated by an asterisk (*) preceding a paragraph number.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP RPSE's, to assist in the process of their continuous improvement.

For feedback and further information, please contact Standards Group, BP International or the Custodian. See Quarterly Status List for contacts.

Changes from Previous Edition



The document has been updated to include application within BP Chemicals. Principally, several new Tables and Figures have been added.



1. INTRODUCTION

1.1 Scope

This Recommended Practice specifies BP general requirements for the external thermal, and combined thermal and acoustic, insulation of equipment, pipework, valves and fittings in the temperature range of -180°C to +800°C.

Insulation for both onshore and offshore use is specified for the following purposes:-

- (a) Saving of energy by reducing the transfer of heat.
- (b) Maintenance of process temperatures.
- (c) Prevention of freezing, condensation, vaporisation or formation of undesirable compounds such as hydrates and halides.
- (d) Protection of personnel from injury through contact with cold and hot equipment.
- (e) Prevention of condensation on the surface of equipment conveying fluids at low temperatures.
- (f) Reduction of pressure relief loads in event of fire.

This latest revision of BP Group Recommended Practice 52-1 incorporates BP Chemicals Insulation Specifications, and much of the BP Chemicals experience together with individual Project and site specifications from across the BP Group. It deals with all aspects of materials, design and installation of insulation. A number of figures have been added to illustrate principles described.

Buried insulated pipework is excluded, as a special case demanding a completely different approach to that described in this document. The role of thermal insulation in passive fire protection is not specifically addressed in this Recommended Practice, and BP Group [RP 24-1](#) and BP Group [RP 24-2](#) should be consulted for further details.

This Recommended Practice addresses the key factors which have to be addressed with any insulation system, namely:-

- Why and where insulation is needed;
- The types of insulation available and how to decide which to use;
- The determination of insulation thickness;
- The accessories used to install lagging, e.g. supports, fasteners, cladding etc.;
- The prevention of under-lagging corrosion by proper surface preparation and painting;
- Weatherproofing to avoid the ingress of water

Verification of the vendor's quality system is normally part of the pre-qualification procedure, and is therefore not specified in the core text of this specification. If this is not the case, clauses should be inserted to require the vendor to operate and be prepared to demonstrate the quality system to the purchaser. The quality system should be based upon the principles of [BS 5750](#), [EN 29000](#) or [ISO 9000](#) and should ensure that the technical and QA requirements specified in the enquiry and purchase documents are applied to all materials, equipment and services provided by sub-contractors and to any free issue materials. A typical quality plan format is included in this document - see Table 9.

Further suggestions may be found in the BP Group RPSEs Introductory Volume.

2. MATERIALS

2.1 Insulation Materials

- 2.1.1. The use of asbestos as an insulation or contained in cements, vapour barriers and mastics etc., is not permitted under any circumstances.

Where it is necessary to interface the new insulation system with an existing system utilising asbestos, the precautions laid down in the Asbestos Research Council recommendations shall be followed.

- 2.1.2. Insulation materials shall be odourless at operating temperature, mould and vermin proof, non-injurious to health and non-corrosive to steel. Total halides shall not exceed 15 ppm.

- 2.1.3. The important properties of the most common insulating materials are listed in Tables 1A, 1B, and 1C. Where available, standards appropriate to these materials are also listed.

For practical reasons it is convenient to separate materials into those used mainly above ambient and those used below ambient. Materials used where operating temperatures are below the dew point of ambient temperature air generally have a closed cell structure which helps to prevent water ingress and condensation.

- * 2.1.4. Water repellent mineral wool shall be tested for water retention on partial and total immersion. The maximum acceptance values for water retention for preformed pipe and slab are shown in Table 1A. Water retention figures for mineral wool loose fill and mattresses shall be subject to approval by BP.

Above 250°C, water repellency is lost as the added resin binder decomposes. There is always a premium to be paid for water repellency, particularly in the temperature range 200 - 250°C. Therefore, the maximum test temperatures for the procedures (described in [BS 2972](#) Part 12) may be reduced in line with the conditions of the application.

- 2.1.5 Details of the flammability of the material and of any toxic fumes which may be given off in a fire shall be available for consideration when choosing the material. Any material chosen shall meet the flamespread requirements of [BS 476](#) Part 7, Class 1 (or equivalent, e.g. not more than 4 according to [ASTM E84](#)) for limitation of flame spread.

2.2 Sheet Metal Cladding

- 2.2.1 Sheet metal cladding may be flat, corrugated, reeded or troughed.

Typically, cladding will be flat for pipework, vessels, heat exchangers, and other process equipment. Corrugated or profiled sheet will be used for tankage, and major columns and towers, where improved strength may allow the use of thinner section cladding.

- 2.2.2 The material used for sheet metal cladding shall be either:-

- (a) Stainless steel [ASTM A167](#) Types 304 or 316;
- (b) Hot dip galvanised mild steel with coating thickness of 270 g/m² or 350 g/m² (to [ISO 3575](#), [BS 2989](#), or [ASTM A526](#));
- (c) Hot dip coated aluminised (low silicon) mild steel with a coating thickness of 230 g/m² (to [ISO 5000](#), [BS 6536](#) or [ASTM A463](#));
- (d) Mild steel hot dip coated with an alloy of zinc and aluminium with a coating thickness of 180 g/m² (to [ISO 9364](#), [BS 6830](#), or [ASTM A792](#)).
- (e) Aluminium [ASTM B209](#) Type 3003 or 5005 with minimum thickness 0.4 mm.

The selection of stainless steel will normally incur a significant cost penalty and should only be considered for the harshest environments, where optimum corrosion resistance is required. [ASTM A167](#) Type 316 stainless steel should be chosen ahead of [ASTM A167](#) Type 304, where enhanced resistance to crevice corrosion is required.

For galvanised steel cladding the life span in any one specific environment will be directly related to the thickness of the zinc coating. The appropriate thickness should therefore be specified according to environmental conditions and lifespan required.

For aluminised steel there is evidence to show that the presence of silicon is detrimental to the corrosion protection afforded by the aluminium alloy layer. In aggressive environments, such as those found at coastal sites, or offshore, this can result in the onset of rust spots and/or rust staining at a very early stage. While this is unsightly, it does not normally lead to rapid perforation of the cladding. However, it is likely to have a detrimental effect upon the long term performance.

Where optimum corrosion resistance is required from aluminised steel cladding, a coating of commercially pure (99%) aluminium to [ASTM A463](#) Type II should be specified.

Of the cladding materials available aluminium is the most susceptible to mechanical damage. In addition, it can be problematic in hydrocarbon fire situations. Burning aluminium can result in incandescent droplets spreading the

fire. In addition, melting of cladding also exposes the insulation to any fire fighting water jet, and so increases the likelihood of insulation falling off and exposing the pipe or equipment directly to the fire. Aluminium cladding should not generally be used on hydrocarbon or flammable material processing units, especially inside battery limits, or tankage with hazardous contents. Aluminium cladding should not be used in special fire risk areas, as defined by BP Group [RP 44-7 Plant Layout](#).

All of these aspects must be addressed before specifying the cladding material.

- 2.2.3 The minimum thicknesses for sheet metal cladding shall be as given in Table 2.

Thinner sheet has been used over rigid insulation, e.g. calcium silicate. This thinner sheet is generally easier to form and to seal.

2.3 Fastenings

- 2.3.1 Banding for securing insulation and cladding shall be stainless steel [ASTM A167](#) Types 304 or 316, with dimensions as in Table 3. The same stainless steel banding shall be used for S and J clips and for breather springs when they are required for securing cladding.

Alternatively where corrosion of cladding beneath banding is considered a problem, for example due to galvanic incompatibility, stainless steel bands with PVC or PVF (10 microns minimum thickness) coated faces may be used.

- 2.3.2 For securing foam slabs or preformed sections beneath vapour barriers, fibre reinforced adhesive tape or woven polypropylene or polyester bands shall be used. Adhesive tape shall be pressure sensitive water repellent vinyl tape, 25 mm wide for < 450 mm OD (over insulation), 50 mm wide above this. Woven polypropylene and polyester bands shall be of minimum dimensions 13 mm wide x 1.0 mm thick.

- 2.3.3 Binding wire for securing insulation shall be stainless steel [ASTM A167](#) Type 304, 0.9 mm diameter, annealed.

- 2.3.4 Welded studs for insulation support shall be M6 to M10 diameter with one end screwed to accept spring type nuts and a 50 mm square plate washer or other proprietary cleat.

- 2.3.5 Screws for securing cladding shall be 13 mm or 19 mm long No 10 or No 14 sized. Zinc plated (for example to [BS 1706](#), Class A passivated) hardened steel screws shall be used for galvanised or aluminised steel sheet. Stainless steel screws shall be used for aluminised sheet or stainless steel sheet. All screws shall be provided with neoprene or nylon washers. Screws shall not be used to fix cladding on cold insulation where the vapour barrier is likely to be perforated.

- 2.3.6 Blind pop rivets for securing cladding shall be stainless steel [ASTM A167](#) Type 304, and shall be 3 to 5 mm diameter x 9 mm long. All rivets shall be self sealing for water resistance.

- 2.3.7 Toggles for closing and securing boxes and covers should be quick release, shackle type locks in stainless steel.

2.4 Other Materials

- 2.4.1 Wire mesh reinforcement used for example to reinforce cements and fibre mattresses, shall be stainless steel [ASTM A167](#) Type 304 with 25 mm mesh, with 0.8 mm diameter wire.
- 2.4.2 Expanded metal reinforcement used for example to reinforce cements, as well as for personnel protection cages and screens, shall have a maximum mesh size of 9 mm x 25 mm and a minimum metal thickness of 0.46 mm. It shall be either galvanised mild steel, or stainless steel [ASTM A167](#) Type 304 for stainless steel pipework.
- 2.4.3 Glass fibre matting or cloth reinforcement shall have nominal weight between 200 g/cm² and 415 g/cm², 0.17 mm and 0.40 mm thick respectively. When used to separate dissimilar metals, glass webbing tape shall be fabricated from E-glass and may be rubberised.
- 2.4.4 Hard, self setting cements (or 'plastic compositions') shall be reinforced with galvanised wire mesh or suitable temperature resistant fibres.

Such materials may be used over rigid insulation where the geometry of the insulated equipment precludes the use of metal cladding, or where the particular equipment is sheltered from the weather. They may be used over flexible insulation providing they are well supported by expanded mesh metal reinforcement.

Typically, a reinforcing mesh shall be provided on top of the first 25 mm of thickness and subsequently at each 50 mm increment. A final layer of mesh on the outer surface shall also be applied for laying a cement finish. Exterior applications of this type of insulation require waterproofing. Cementitious finishes have limited impermeability to moisture and so a protective weatherproof coating is required in exterior locations. At any transition from metal cladding to a cementitious finish, the metal cladding shall overlap the cementitious finish by a minimum distance of 200 mm and the joint fully sealed with elastomeric sealant. Cement finish must not be used in fire exposed or high traffic areas, and it should not be considered as fire-proofing.

- 2.4.5 When specified for the protection of stainless steel beneath insulation against chloride attack, aluminium (99% pure) and steel foils shall have a minimum thickness of 0.06 mm.
- 2.4.6 Preformed butyl mastic strips used to seal cladding joints shall be at least 3 mm thick and 25 mm wide.
- 2.4.7 Elastomeric coatings for cellular glass, mastic coatings for weather proofing cement finishes, and adhesives for foam insulation shall be as

recommended by the insulation manufacturer as being compatible with the insulating material.

Typical properties of mastics, coatings and vapour barriers are described in detail in [BS 5970](#) and [ASTM C647](#) and [C755](#). Where there is a likelihood of the process fluid coming into contact with the vapour barrier, at sampling points for example, the vapour barrier shall be chemically resistant to such fluids.

2.4.8 Webbing tape used to prevent metal-metal contact and provide a thermal break, typically at nozzles, flanges and around box covers, shall be glass fibre texturised yarn, treated with waterproof sealant to prevent wicking. This tape shall typically be 3 mm thick and 50 mm wide.

2.4.9 Adhesives used for bonding together sections of insulation shall be compatible with the insulating material(s) being joined and shall be suitable for the full operating temperature range.

2.5 Storage and Handling of Materials

2.5.1 The main objective shall be to maintain insulating materials in their factory dry condition until permanent and final weather protection is fitted. Insulation must be protected and sealed to prevent contamination by water and salts prior to and during application.

2.5.2 All products employed shall be properly packaged, and identified by manufacturer, type, batch number and date of manufacture. Packaging for insulation shall consist of wrapped or pre-shrunk polythene, or weather-proof cartons or containers.

2.5.3 If removed from its original packaging, e.g. partially used cartons, insulation shall be placed in sealed polythene bags with identifying labels.

2.5.4 Materials shall be stored under cover until required for use. Materials which become wet or contaminated with dirt or other extraneous matter shall not be used.

2.5.5 Materials shall always be stored, handled and applied in accordance with manufacturer's instructions, giving due regard to the materials, health and safety recommendations and COSHH requirements.

2.5.6 Insulating materials shall remain in their packaging until immediately before use, and a minimum of handling shall be employed during application. The interval between application of the insulation and weatherproofing should then be kept as short as possible. Where immediate application of the weatherproofing is impractical the insulation shall receive adequate temporary weather protection.

Irrespective of whether a temporary enclosure is being employed, the insulation shall be protected against ingress of water at all times.

The enclosure will normally consist of a structural frame clad in a strong, water proof membrane designed to withstand prevailing winds. Attention must be paid to flame retardance requirements. Partially installed insulation should be completely wrapped and sealed in heavy gauge polyethylene sheeting or other material impermeable to moisture.

3. GENERAL PRINCIPLES AND REQUIREMENTS

3.1 General

3.1.1 Thermal insulation shall only be applied where safety or process requirements dictate. If heat loss is acceptable, if equipment is located in a non-hazardous area, or if heat loss is desired, personnel protection shall be provided by secure metal mesh guards, stood off by at least 75 mm from any hot surface. Every effort shall be made to minimise the use of insulation for personnel protection, especially for surfaces with operating or intermittent temperatures below 150°C, where corrosion under insulation is known to be a particular problem. Surfaces at operating temperatures above 65°C which could be touched in the course of normal operating duties shall be considered for personnel protection measures. Prior to the commencement of the work the Contractor shall provide project specific drawings and/or sketches of his proposed insulation and weatherproofing details for: piping valves, tees, bends, caps, reducers, expansion joints, vessels etc.

Excluded from these requirements are surface temperatures in excess of 65°C caused solely by local climatic conditions. No low temperature limitation is given for personnel protection since it is considered that equipment operating below ambient will be insulated to prevent condensation and thus personnel protection will be provided.

3.1.2 A thermal insulation design shall consist of a structure with the following components:-

- Surface preparation and coating;
- Insulating layer, with appropriate support and securement;
- Vapour barrier for cold insulation;
- Cladding, for mechanical protection or water shedding function, with appropriate support and securement.

The general requirements for each of these layers are outlined in this section.

Particular consideration must always be given to the requirements for weather proofing and sealing of external cladding, and for maintaining the vapour barrier around cold insulation.

- 3.1.3 Where vessels or other items of equipment are to be insulated, it is important that the designer is made aware of the need for thermal insulation and the specified insulation thickness at an early stage in the design.

Nozzles, manways, etc., must be designed with sufficient length to allow flange joint make-up on site without the need to disturb the thermal insulation local to the flange. Also the design must incorporate insulation support rings and nozzle insulation sealing rings or discs where these are considered necessary. See Figure 19.

Also, ladders, platforms etc, which will be outwith the insulation, should be thermally isolated from the vessel or tank etc, using insulating blocks at fixing and/or contact points.

In general, all protrusions from the surfaces of equipment, vessels, tanks and spheres should be insulated completely or to a maximum practicable extent.

- 3.1.4 All materials used in thermal insulation systems shall be compatible with all other materials with which they have contact. They shall be suitable for the operating and design temperature range, and for the maximum emergency temperature. The full operating temperature range shall be stated for each recommended material. Account shall be made for any requirements for elevated temperature during steaming out, cleaning and flushing operations.

- 3.1.5 Selection of materials shall be generally dictated by availability, economics, local contractor experience, and operating and safety requirements

- 3.1.6 Where required, box covers as illustrated in Figures 1 and 16 shall normally be used to insulate flanged joints and valves. Such items may also be constructed to insulate several small items of equipment confined within a small space. As appropriate, covers shall be designed to be weatherproof or to maintain the integrity of the vapour barrier. Box covers shall be built in at least two parts, each weighing no more than 25 kg (55 lb), using the same grade of metal specified for the cladding of the adjacent pipework. Covers shall accommodate landing collars and shall be packed with loose fill or other suitable insulating material. When weatherproofing is required, box covers shall be designed such that the top plate sheds water, and joints shall be of a lockform design incorporating an elastomer sealant. The box shall be closed using toggle clips, and any sealant used on the closure surfaces shall be completely replaced whenever the cover is removed or opened for any reason. Removal of the cover should not compromise integrity of adjacent insulation. Where the insulation of flanges is required, removable boxes shall also be used to facilitate the withdrawal of spades without disturbing the existing insulation on the adjacent pipework.

Cold boxes may employ foamed in situ insulation with polyurethane foam, with an approved release agent coated onto the inside of the box. The foam is injected using portable kit through holes in the box which are sealed after use with a suitable plug.

- 3.1.7 Where possible, galvanic corrosion shall be avoided by ensuring that there is no chance of direct contact between items made of dissimilar metals.
- 3.1.8 Galvanised components and other materials containing metals likely to cause liquid embrittlement shall not be used where there is a risk that they will come into contact with austenitic stainless steel or nickel alloy pipework or equipment at temperatures above 350°C, either through fire or normal operation. Zinc based paints should not be used at elevated temperatures for similar reasons.
- * 3.1.9 Insulation design will be based on engineering data provided by BP, which will include either a precise definition of requirements, or sufficient operating conditions to allow accurate selection of materials and procedures. Drawings and procedures to be submitted for BP approval.
- 3.1.10 Insulation shall be taken over any nameplate without a break, with no attempt being made to clear round and seal. Before insulation work is commenced a certified copy or rubbing shall be made of the nameplate and retained in the plant records. A duplicate of the nameplate shall be attached by suitable means to the outside of the cladding at an equivalent location to the original. Where warning notices occur, these shall also be copied onto the outside of the cladding.
- 3.1.11 For the purpose of measuring vessel shell or pipe thickness in service, removable sections of cladding and insulation shall be provided. The design of these sections shall not compromise the continuity of the vapour barrier in cold applications, and weatherproofing in external applications.
- Several proprietary systems are available for accessing plugs and ports. For items of equipment which are frequently disturbed for inspection and/or maintenance, suitably well fitting insulation blankets may be used beneath fully sealed metallic cladding.*
- 3.1.12 Several techniques are available for the non-intrusive inspection of insulated plant and equipment in service: thermography can locate positions of excessive heat transfer due to wet or absent insulating material; neutron backscatter can establish the presence of water in the insulation; and flash radiography can establish the presence of corrosion under the insulation on pipework. To determine the fitness for purpose of insulated plant and equipment, one or more of the above techniques should be used in conjunction with a criticality assessment system and

detailed visual inspections following selective removal of the insulation and cladding.

- 3.1.13 The requirements for insulation supports on vertical lines and vessels may be relaxed in the case of foamed in-situ insulation, where it can be adequately demonstrated that the foam adheres firmly to both the pipe or vessel wall and the external cladding, and will not disbond and slip with time due to thermal movement.
- 3.1.14 Corrosion under insulation continues to be a major issue, and in order to minimise the effects of CUI, it is imperative that sufficient, detailed consideration is given, firstly, to surface preparation as laid out in section 3.5, and, secondly, to routine inspection, visual or otherwise, of insulation once installed.
- 3.1.15 Clearance between outside of insulation and adjacent piping, equipment or structural members shall be maintained at 25 mm (hot)/50 mm (cold) for pipework, vessels and equipment and at 100 mm for tanks and spheres. Clearances shall take into account fireproofing and insulation applied to adjacent piping, equipment or structural members.
- * 3.1.16 Insulation of equipment in oxygen service shall employ materials which are inorganic and free from contamination by any organics and shall be subject to approval by BP.
- 3.1.17 Insulation employing rigid insulating materials shall be designed so as to maintain integrity through thermal expansion and contraction. This shall normally be achieved by incorporating expansion or contraction joints of loose fill material adjacent to insulation supports, as illustrated in Figures 2 and 3.
- Typically, expansion and contraction joints should be 25 mm wide and on the underside of each support ring on vertical vessels or item of equipment, and at 3m intervals on horizontal items. Tanks may have expansion joints 500 mm wide at 15 m centres circumferentially around the tank, secured by banding around the whole circumference. Contraction joints are typically insulated using loose fill glass fibre material, which in the case of cold applications is completely covered and sealed by a flexible membrane, e.g. butyl rubber sheet, suitably bonded to adjacent insulation to maintain the vapour barrier*
- 3.1.18 The use of footbridges shall be considered for the protection of thermal insulation, particularly when non-rigid insulation materials are used and on major thoroughfares.
- 3.1.19 All insulation installation work shall be carried out at ambient temperatures of <37°C (<100°F), in dry and frost free conditions. Cold service insulation shall be applied above the dew point of atmospheric air.

- 3.1.20 Insulation work shall normally be carried out after hydrostatic testing and inspection.

At very least, all joints shall be left uninsulated until testing is completed. Adequate precautions must be taken to ensure that the previously installed thermal insulation does not sustain damage or become soaked with water as a consequence of hydrotesting operations. The extent of any damage or soaking shall be reviewed and the thermal insulation replaced where water contamination has occurred.

- 3.1.21 The application of thermal insulation to plant and equipment shall be inspected at every stage to ensure the quality of the workmanship. The extent of this inspection will be defined in the contractors Quality Plan.

3.2 Selection of Insulating Material

- 3.2.1 In general, the insulating material selected shall have an adequately low thermal conductivity, and sufficient physical and mechanical integrity for the installation envisaged compatible with economic considerations. The material should be capable of retaining adequate properties for service under the expected conditions for the required plant life.

In the selection of materials, attention must be paid to the possibility of the line or vessel requiring steaming out, in which case the hot face temperature of the insulation and the stability of any adhesives used should also be considered.

- 3.2.2 Materials for hot insulation should be selected from the general range listed in Tables 1A and 1B. They shall not be used at temperatures exceeding those recommended for satisfactory continuous use, either in these Tables or by the manufacturer.

Water repellent mineral wool is the preferred material for hot insulation, consisting of processed long fibres bonded with a binder suitable for the intended operational temperature range. It is available in several forms including: pipe sections with bonded reinforcing mesh; flexible blankets supported on at least one side with stainless steel wire mesh, secured with stainless steel stitching; and loose fill material for flexible packing.

Other materials may be selected for specific services. For example, calcium silicate is good for high temperatures, for fire protection, and in areas of high maintenance traffic. Cellular glass is good for applications where leakage or spillage is likely.

Organic insulating materials should not be used at temperatures above the limits stated in Table 1C, since there is evidence to show that acidic species and aggressive ions, in particular chlorides, can be leached out by exposure to water at elevated temperatures.

- 3.2.3 Insulating materials for below ambient temperatures shall be selected from Table 1C. When employed in cold insulation, all these materials shall always be used in conjunction with a suitable vapour barrier.

Polyurethane and polyisocyanurate (low flame spread) foams and cellular glass are the preferred materials for cold insulation. These options are easy to seal and join, and due to their closed cellular nature provide inherent obstruction to water

transport through any insulating layer. Phenolic foams have the best fire resistance of all of the organic insulating materials, but cannot be foamed in situ.

- 3.2.4 Materials other than those listed in Tables 1A, 1B and 1C may be used, where their physical properties, chemical properties, and/or cost offer significant and demonstrable advantages to BP over those listed.

- 3.2.5 Where possible, for ease of installation, preformed insulating materials shall be used for hot applications, and either preformed or in-situ foamed materials for cold service.

Other methods may be acceptable as alternatives. For example, insulation may be provided using a double skin filled with a granular loose fill material such as perlite or vermiculite. Flexible blankets have advantages for complex geometries and for regularly disturbed insulation.

- 3.2.6 Where they can be shown to be economically advantageous and suitable for the operating temperature range, sprayed or foamed-in-situ materials may be used in preference to preformed sections. They shall have equivalent properties to preformed material. For quality control purposes, samples shall be taken during application, in order to confirm that physical, mechanical and fire resistance property requirements are being achieved.

BS 5241 and ASTM C1029 contain detailed information regarding on-site foamed-in-situ or sprayed polyurethanes and polyisocyanurates.

- 3.2.7 Where shown to be more economical or technically advantageous, the insulation shall consist of two or more layers of dissimilar materials, provided their respective service temperature limits are appropriate for the duty.

Examples of this requirement might be where pipework or equipment may reach a temperature of, say, 260°C or more. Above this temperature pre-formed sections, which may contain a resin binder, may lose some of their binder by volatilisation and, if the line or equipment is subject to vibration, the material may partially collapse. Consideration should be given to using a ceramic fibre (e.g. Kaowool) or calcium silicate, depending on surface temperature, as an inner layer. High density mineral wools having inorganic binders are also available.

- 3.2.8 Where thermally insulated items of plant and equipment also require passive fire protection, consideration should be given to selecting a material which is suitable for both duties. If this is inappropriate then the insulating and fire proofing materials shall be compatible. The thermal insulation properties of the fire proofing should be taken into account when determining the insulation thickness.

3.2.9 Insulation applied as a hard setting plastic composition shall only be used where other forms are impractical and where heat is available at the time of application for drying out.

3.2.10 Polyurethane insulation shall not be used on pipework or equipment located in confined spaces. It may be used in hydrocarbon process areas, in which case self-extinguishing grades will be required.

Foamed plastics are excluded for use in confined spaces because, in the event of a fire, smouldering or burning plastics like many other organic materials may give off carbon monoxide and dense smoke. Polyisocyanurate is the flame retardant version of polyurethane and emits far less smoke when it burns than polyurethane.

3.3 Determination of Required Thickness of Insulation

* 3.3.1 The contractor shall confirm to BP by the presentation of calculations that the thicknesses quoted are satisfactory for the particular process involved. Minimum thickness shall be determined using normal operating temperature, and shall be governed by the insulation requirements and the established thermal conductivity of the insulating material.

3.3.2 For hot insulation, the insulation thickness shall be calculated according to process or personnel protection requirements.

Calculation methods employed should follow the principles laid out in [BS 5422](#). Tables 4A and 4B show typical thicknesses of mineral wool required for hot insulation and personnel protection respectively, employing commercially available thicknesses of insulation. These tables employ a mineral wool 90 - 100 kg/m³ up to 400°C, 144 kg/m³ above this, and for personnel protection the maximum outer surface temperature is generally limited to 60°C. Similar tables can also be constructed for other insulation materials and for applications where only process requirements need to be taken into account. Surface finish has an effect on the insulation thickness required, and if cladding is given a coat of paint or, where suitable, a non-metallic finish, generally a thinner layer of insulation is required. Thickness may vary in any given application, e.g. tall towers, so long as at any point the thickness applied is equal to or exceeds the thickness dictated by the operating temperature at that point.

3.3.3 For cold insulation, the insulation thickness shall be calculated to ensure condensation will not form externally due to predicted atmospheric conditions and the line operating temperature. Tables 6 and 7 give typical thicknesses for cold insulation using organic foams for operating temperatures down to -160°C for pipework and vessels respectively. The thicknesses given in the Tables are those required to prevent the formation of condensation on insulated surfaces at ambient conditions of 20°C and 85% relative humidity.

For lower temperatures, such as in LNG installations, specific calculations of the required insulation thickness should be made in accordance with [BS 5970](#).



The minimum (economic) thickness of insulation for cold piping and equipment will be that required to satisfy the permissible heat gain limits of the process or system based upon the running costs and size of the refrigeration equipment required.

- 3.3.4 When insulation is required for more than one purpose, the more extreme requirement shall be the basis for selecting the total insulation thickness.

3.4 Combined Thermal and Acoustic Insulation

- 3.4.1 Where insulation is required for both acoustic and thermal insulation the same materials shall be used to meet both requirements wherever this is practicable.

For further information, [EEMUA Publication 142](#) should be consulted.

- 3.4.2 For combined thermal and acoustic service, ceramic fibre or mineral wool mattresses or flexible sections of materials listed in Table 1B shall be used.

Materials for combined acoustic and thermal service normally contain long strand fibres without resin bonding and with a density of 64 to 160 kg/m³. Materials outside this range may be used if adequate data on their acoustic properties are provided. Normal sheet metal cladding is used, secured so that it does not touch the equipment or piping at any point.

- 3.4.3 Multi-layer structures shall be employed where ceramic and mineral wool are unsuitable for direct insulation. In such instances no credit for noise reduction shall be given to other layers introduced. The fibre layer shall always be on the outside.

Where it is necessary to apply acoustic insulation over cold insulation, the acoustic service materials shall be applied over the cold insulation material and vapour barrier. In addition there may be a requirement to apply a further vapour barrier to the outer face of the acoustic insulation. Hot insulation with face temperatures above those acceptable for ceramic or mineral fibres should have calcium silicate as the first, innermost layer.

3.5 Surface Preparation and Protective Coating Application

- 3.5.1 Before the application of any insulation, all carbon, low alloy and stainless steel piping and equipment shall be protected against corrosion, in the event that the insulation becomes wet, by appropriate surface preparation and coating application.

- * 3.5.2 All carbon and low alloy steel surfaces operating below 350°C shall be prepared and painted in accordance with the Project painting specification or BP Group [GS 106-2](#). The coating system shall be suitable for the full operating temperature range and shall be applied in accordance with the coating manufacturer's recommendations. The coating shall be fully dry prior to insulation being applied. The

Insulation Contractor shall ensure that the Painting Contractor has signed all the relevant documentation showing compliance with the project painting specifications and this documentation has been approved by BP.

- 3.5.3 There shall be a requirement to protect austenitic stainless steel pipework and equipment against chloride attack. Austenitic stainless steel pipework and equipment operating at temperatures up to 500°C shall normally be wrapped in aluminium foil. For temperatures above 500°C, stainless steel foil of a grade compatible with the pipework or equipment shall be used. Individual pieces of foil should have a minimum of 50% overlap.

Consideration should be given to washing austenitic stainless steel surfaces with demineralised water and the use of gloves by erectors to prevent contamination by perspiration.

Protective paint systems and coatings may be employed as an alternative to foils. They should be free from low melting point metal pigments (e.g. lead, zinc, tin and copper), have a halide content less than 100 ppm and be suitable for the full operating temperature range. Surface preparation and coating application shall be fully in accordance with the manufacturer's instructions.

3.6 Application and Securement of Insulating Layer

- 3.6.1 Insulation and cladding shall be properly supported and secured, and specific attention shall be given to relevant methods at the process equipment design stage. See Figure 19.

- 3.6.2 Individual pieces of insulating material shall fit closely together and to the surfaces being insulated. The least number of pieces possible shall be used. Gaps or cavities shall be avoided as far as possible by trimming the insulation to fit. Adjacent sections of rigid cold insulation materials shall be buttered together with a flexible joint sealant.

Close fitting insulation and a layer which is complete and free from holidays will clearly provide the best insulating performance. Good contact to surfaces requires consideration of actual pipe OD dimensions. Where gaps or cavities cannot be avoided, loose-fill or trowelled-in material having comparable thermal insulation properties to the main material should be used as fillers to ensure adequate insulation.

- 3.6.3 Preformed cold insulation material under vapour barriers shall be secured to pipework by means of plastic banding or self adhesive tapes. These shall be fitted to all circumferential joints, at a maximum pitch of 450 mm with at least 2 bands per section of insulation.

- 3.6.4 Multi-layer structures of insulating material shall be used when the total thickness of insulation exceeds 70 mm in the case of pipework, and 75 mm in all other applications. Layers should be selected to be

approximately equal in thickness and no single layer shall exceed these maximum thicknesses, as illustrated in Table 8.

- 3.6.5 All multi-layer insulation shall have the individual layers secured by banding, wires or by self adhesive tapes and all longitudinal and circumferential joints shall be staggered, by approximately 50% of lag or section size.
- 3.6.6 Prior to application of insulation all surfaces shall be clean, dry and free from frost, grease and dirt.
- 3.6.7 Where foamed glass insulation is used, equipment surfaces shall be protected from damage due to abrasion and freeze/thaw action by anti-abrasion or surface sealing compounds. Anti-abrasion and sealing materials shall be compatible with the insulation and be applied in accordance with the manufacturer's instructions.
- 3.6.8 Where the shape of the equipment makes the fitting of rigid section impractical, insulation in a mouldable form may be applied, provided that the heat is available at the time of the application for drying out. A reinforcing mesh should be provided over the first 25mm (1") of thickness and subsequently at each 50mm increment.
- 3.6.9 All projections, such as lifting lugs, supports, trunnions etc. shall be insulated with the same thickness of insulation as specified for the body of the process equipment. The insulation shall extend a minimum of 4 times the insulation thickness, unless the projection can be fully encapsulated by insulating material.

3.7 Vapour Barriers

- 3.7.1 A vapour barrier shall be applied to all thermal insulation covering pipework and equipment operating below ambient temperature.

If this is not done, ice may form or underlagging corrosion occur as a result of condensation within the insulation due to water vapour drawn towards the cold surface by differences in vapour pressure at ambient and at temperatures below ambient.

- 3.7.2 Vapour sealing materials shall be compatible with the type of insulation applied and shall meet the requirements of [BS 476](#) Part 7, Class 1 (or equivalent, e.g. not more than 4 according to [ASTM E84](#)). The material shall be suitable for the range of temperatures to which it will be exposed. The water vapour permeability of the vapour barrier shall be declared.

If there is a likelihood of the process or other fluid coming into contact with the vapour barrier, at sampling points for example, the vapour barrier shall be chemically resistant to such fluids.

3.7.3 The vapour barrier shall be applied as soon as practical following application of the insulating material to ensure that the insulation material is kept dry.

3.7.4 All vapour barriers shall be applied as a minimum of two coats of contrasting colours. Glass cloth shall be embedded in the first layer whilst still wet. Following the manufacturers recommended drying time, the second coat shall be applied to a wet film thickness of not less than 2.5 mm. No glass mesh shall be visible upon completion of the second layer application. The dry film thickness of the complete vapour barrier shall not be less than 1 mm.

Polyester fabric meshes may also be used in place of glass fibre in the vapour barrier to increase strength. Vapour barrier reinforcement tapes must be selected and applied in accordance with the manufacturer's recommendations.

3.7.5 At all insulation terminations, including those at flanges, the vapour barrier shall extend a minimum of 75 mm beyond the edges of the insulated section on to adjacent uninsulated equipment, see Figure 6.

3.8 Cladding

3.8.1 All thermal insulation exposed to the weather, likely to suffer mechanical abuse or being used for noise control shall be protected with metallic cladding.

Alternative finishes to metallic cladding may be specified where their use is advantageous. They shall be applied in accordance with the manufacturer's instructions, ensuring in particular that the selected finish is compatible with the insulating material.

For example, aluminised glass cloth may be used on complex geometries, and where ingress of moisture cannot occur. Finishes for weatherproofing alone may be reinforced asphaltic mastics or elastomers.

3.8.2 Cladding sheets shall be as large as practical to minimise the number of overlaps. All surfaces and joints in the cladding shall be arranged to shed water, and have sufficient overlap to allow weatherproofing if required.

Typically, joints should overlap a minimum of 50 mm on small diameter piping ($\leq 24''$) and 75 mm on all other piping and vessels, unless complex geometrics such as at bends, tees etc. render this impractical. This may not always be possible, e.g. on lobsterbacks.

3.8.3 On externally exposed plant and equipment where no vapour barrier is present, all cladding joints shall be fully sealed with a flexible, non-hardening elastomeric sealant, which must be applied before closure of the seam or joint. This weather protection shall not preclude the use of a vapour barrier on cold insulation.

Elastomeric sealant in strip form - butyl strip - is to be preferred unless its use is precluded by cladding complex geometry. The elastomeric strip shall be typical 25 mm wide by 3 mm thick and arranged so as to display a continuous external 2 to 3 mm margin of sealant at the completed joint. Cartridge dispensed mastics or cements are a practical alternative to mastic strip, and are also to be applied before closure of the joints or seam.

- 3.8.4 In selecting the type of metal cladding, specific attention shall be given to the environmental conditions prevailing at the site.

In particularly corrosive atmospheres, [ASTM A167](#) Type 316 stainless steel should be used.

- * 3.8.5 Where it is considered advantageous, e.g. for ease of installation on straight runs, properly supported corrugated interlocking spiral wound flexible metal tube cladding of a design approved by BP may be used for foamed in-situ pipework insulation.

- 3.8.6 At complex geometries in external plant and equipment, such as at pipe supports, saddles, etc. where it is often impossible to render the cladding completely watertight once the plant is in service, specific attention should be given to the installation of water shedding devices and weatherhoods above the complex geometry. See Figure 12.

- 3.8.7 Metal cladding should normally be secured using metal banding, self tapping screws and/or blind pop rivets. Metal banding shall be placed over each circumferential joint, and then at a maximum pitch of 450 mm. Screws and rivets shall be used at a maximum pitch of 150 mm. All joints on external pipework cladding shall be sealed with butyl strip. Cladding directly over a vapour barrier shall not be secured using screws. Blind pop rivets shall be used in preference to screws over electrical trace heating, on tanks, on cold insulation, and on insulation sheltered from the weather, but should never be used where cladding is to be removed for maintenance purposes.

To use screws over a vapour barrier, an extra layer of 25 mm mineral wool may be applied over that barrier to ensure it is not broken by the screws.

- 3.8.8 Adjacent sections of cladding on piping and equipment containing flammable fluids shall be made electrically continuous by fitting continuity straps and ensuring the cladding is properly earthed at appropriate intervals.

- 3.8.9 Lines conveying corrosive fluids and lines that require frequent washing or steaming out shall be independently insulated and shall not share common cladding with any adjacent line.

- 3.8.10 When galvanised and aluminised steel cladding is used in conjunction with magnesia or other insulating material having a high alkali content,

a protective coating shall be applied to the internal surfaces of the cladding.

Both aluminium and zinc are attacked by alkaline solutions, typically with pH > 11 for aluminium and pH > 12 for zinc.

4. SPECIFIC REQUIREMENTS FOR PIPING

4.1 General

4.1.1 Thermal insulation shall not normally be applied to:-

- Piping which becomes intermittently hot, e.g. relief valves, non-heat traced flare and blowdown systems, by-passes at control valves;
- Supports to piping;
- Steam traps;
- Pipe union fittings;
- Thermowell bosses and pressure tappings;
- Expansion joints;
- Hinged joints;
- Hose assemblies;
- Sight flow indicators.
- Piping in non-hazardous areas where personnel protection is the only requirement.
- Long bolt (between flanges) fittings.

4.1.2 Thermal insulation designs employed on hot and cold pipework shall be as illustrated in Figures 1 to 16.

4.1.3 Preformed sections of pipe insulation are preferred for ease of installation.

Where it is economically justified, pre-insulated pipework may be used, for example on long straight runs. Such insulation is factory applied and hence requires minimal on-site work. However, care and attention is required during transport, handling and installation to ensure that the cladding and/or the insulation is not damaged.

4.1.4 Where insulated pipes are to be thermally isolated from their supports, this shall be achieved by incorporating 'cold breaks' made from a split cylinder of hardwood, high density plastic, or other non-metallic material of low thermal conductivity and high compressive strength, suitable for the operating temperature range of the pipework. See Figure 11.

Where the pipe hanger is to be clamped around the outside of the metallic cladding and the load is light, the insulating material may have sufficient compressive strength to withstand the compressive forces acting upon it. If it does not have

sufficient compressive strength, a split cylinder of hard wood or other suitably high density insulating material of the same thickness as the insulation should be introduced beneath the support. Any vapour barrier seal must be continuous over the support blocks and adjacent insulation.

- 4.1.5 Where insulated cold pipework is supported directly and no 'cold break' exists within the support or hanger, the thermal insulation shall be extended a minimum distance of 4 times the insulation thickness along the support or hanger to prevent ice formation at the support point. See Figure 12.

A cold break is preferred, since in practice pipe/equipment support details rarely permit an extension of the insulation down the support for the required distance.

- 4.1.6 Insulation at welded or clamped pipe supports shall be shaped to fit round the support and shall be tied securely. Supports designed to allow independent movement of the pipe shall be insulated to allow movement without damaging the insulation. Specially fabricated cladding boxes are to be used to cover changes in OD brought about by the requirement to insulate over clamps and supports. These boxes shall be weatherproofed or vapour sealed where required.

BS 5970 also contains diagrams of many typical insulation installations around pipe clamps and supports.

- 4.1.7 Insulation on pipe work shall be stopped short of flanges and valve joints and, in the case of hot insulation, the flanges and valve joints shall not normally be insulated. The insulation terminations shall be completed in such a way that the flanged joints can be broken and remade without damaging adjacent insulation, see Figures 6 and 16. At such points, adequate provision shall be provided to prevent the ingress of moisture, by weatherproofing and sealing and, in the case of cold insulation, by extending the vapour barrier onto the surface of the piping or equipment at the termination of the insulation as required in clause 3.7.5. Figure 5 shows typical installation details for hot and cold insulation. Cladding terminations for < 150 mm OD (over insulation) sizes shall employ ball swage covers; larger diameters shall employ a lockform construction. Vertical pipe insulation shall be terminated with conical lockform.

Flanges, valve joints, in line fittings etc. on insulated cold piping shall be thermally insulated in an identical manner to the pipe unless otherwise advised by BP.

Flanges and flanged valves on hot insulation are usually left bare so that flange leakage can be readily observed, and joints can be readily maintained. Also, by leaving flanges uninsulated, the bolts operate at a lower temperature than the flanges which results in an increase in gasket load from ambient to operating temperature. Typically, pipe insulation is cut back and sealed to leave bolt length +40 mm either side of flange or joint. See Figures 14 and 16. Where appropriate, personnel protection against contact with hot surfaces should be provided by guards/mesh as described in 3.1.1.

- 4.1.8 The insulation on butt welded, socket welded and screwed valves shall be continuous with that on the associated pipework.
- 4.1.9 If insulation of flanges and joints is required on hot service, box covers as described in 3.1.6 and shown in Figure 16 shall be used. Flanges shall not be thermally insulated until all system pressure and leak tests have been completed and all leakages made good. Covers shall be installed after the adjacent pipework insulation has been completed, but before systems are commissioned. For external pipework, watertight seals shall be employed at the termination of the pipework insulation/cladding, between the cover and the pipework cladding and on the box closure seams. Boxes having a drain hole at the lowest point shall normally be used for insulating such items on oil and chemical lines, and materials selection shall consider any possible interaction between the materials employed and any leakage from an insulated joint.
- 4.1.10 Lines to steam traps shall be insulated. In the case of thermostatic type traps, approximately 600-1000 mm of line before the trap shall be left uninsulated, with expanded metal screens for personnel protection if required.
- * 4.1.11 At the junction of insulated and uninsulated lines, the insulation shall extend to the first block valve or fitting in the uninsulated line. Termination of insulation shall be as described in 4.1.7.
- 4.2 Insulation**
- 4.2.1 Insulation on bends, tees and elbows shall be of the same thickness as the straight pipe. Mitred sections shall be used up to 150 mm OD (over insulation), radial sections above this.
- 4.2.2 For externally steam traced lines, the pipe and tracer should be insulated with oversized pipe sections of insulation large enough to completely encircle both pipes (see Figure 10). When a tracer pipe protrudes through insulation it shall be encased in a box fabricated so as to shed water and sealed with butyl mastic strip to prevent ingress of water.
- Flexible mattresses may be used for large diameter pipes where preformed pipe sections of sufficient size are unavailable. It should be noted that no adequate method has been found to eliminate corrosion in this method of line heating, other than complete exclusion of moisture.*
- 4.2.3 Small bore instrument lines shall be insulated using wrappings of 13 mm insulating ceramic or glass fibre rope. Weatherproofing shall consist of cement or mastic overwrapped with aluminised tape.

- 4.2.4 Pipework which is electrically traced shall be wrapped in aluminium foil prior to installation of the electrical tracing and insulation. Tracer entry points shall be completely sealed using a box attached with stainless steel screws and sealed with butyl mastic to prevent ingress of water. All penetrations of heat tracing cables through cladding shall be made by drilling the cladding and inserting rubber grommets of the correct size for the heat tracing cable. See Figure 9.

Wherever an electric surface heating system is to be insulated, the insulation shall meet the requirements of the relevant trace heating standard, e.g. [BS 6351: Part 2](#).

- 4.2.5 Insulation should be taken up to, but should not include, the isolating valves of pressure indicator connectors and relief valves to atmospheric vents unless otherwise called for.

4.3 Insulation Supports

- 4.3.1 On vertical piping, or piping inclined at > 45 degrees from the horizontal where straight runs are in excess of 3 m, insulation supports shall be provided in the form of a metal ring or part ring either clamped or welded to the pipe, although angled studs may also be used to prevent downward displacement of the insulation. Supports shall be located at the bottom of the run and every 3 m above thereafter. In addition, insulation supports shall be provided above flanged joints or valves, if a straight vertical pipe run exists in excess of 1 m in length above that flange. Supports shall be located and installed to allow removal of bolts at flanged joints. See Figure 14 for the general arrangement of insulation supports on vertical pipe.

- 4.3.2 Any damage to the protective coating caused by the installation of insulation supports shall be repaired in full accordance with the project painting specification.

4.4 Securing Insulation

- 4.4.1 Each and every layer of pipework insulation shall be secured circumferentially. For sizes < 150 mm OD (over insulation), this will be achieved with tie wires at intervals of no greater than 450 mm, with not less than two wires per section of insulating material. For over insulation OD > 150 mm, metal bands should be employed at the same minimum separation. Insulation under a vapour barrier shall be secured according to 3.6.4. See also Table 2.

4.5 Cladding

- 4.5.1 Straight pipework cladding shall be cut from flat metal sheet not more than 1m in length. Longitudinal edges shall be crimped over their full length, to allow placement of sealing mastic. Individual rolled castings shall be ball swaged 75 mm from the leading edge, so as to provide a

circumferential stop to adjacent lengths of cladding. Minimum joint overlap shall be 50 mm up to 24" NPS, and 75 mm above this.

- 4.5.2 Pipe bends exposed to the weather shall be covered by segmental cladding of lobster back form having either swaged joints or a sufficient overlap to exclude moisture. Adjacent segments of this cladding must be secured to each other by adequate metallic tie-backs, and completely sealed and weatherproofed with butyl mastic strip and elastomer joint sealant, as illustrated in Figure 6. Stove-pipe cladding sections are only acceptable on diameters less than 150 mm (including insulation).
- 4.5.3 For vertical or inclined pipework, cladding shall have joints arranged to shed water, and shall normally require the use of "s" clips to support individual sheets of cladding, together with positive attachment to the insulation supports.
- 4.5.4 Insulation at tees and reducers shall be clad using pieces of metal sheet specially fabricated to fit closely around the outer surface of the insulation. See Figure 25.
- 4.5.5 Large tanks and vessels may be clad with corrugated or troughed metal sheeting with all overlaps arranged to shed rain water. The cladding should have side laps of at least 1.5 corrugations and end laps of 150mm (6in). The overlaps should be full sealed with elastomeric sealant and the laps fixed with self tapping screws or blind rivets spaced at 150mm intervals except where expansion joints are located.

5. SPECIFIC REQUIREMENTS FOR OTHER EQUIPMENT

5.1 General

5.1.1 Thermal insulation shall not normally be applied to:-

- Pumps with operating temperatures below 200°C, unless the pumped fluid has a pour point above minimum ambient temperature;
- Fans, compressors, blowers or other rotating or reciprocating equipment;
- Heads of vessels fully enclosed by support skirts with vessel diameter 1200 mm and less; unless the operating temperature of the vessel exceeds 175°C or it is necessary for the operator to enter the skirt during normal duties.
- Internal surfaces of fully enclosing support skirts of insulated vessels with vessel diameter 1200 mm and less; unless the operating temperature of the vessel exceeds 175°C or it is necessary for the operator to enter the skirt during normal duties.
- Surfaces of coolers and condensers;

- Thermowell bosses and pressure tappings.

- 5.1.2 Insulation supports shall be provided, generally consisting of studs or cleats welded, brazed, or adhesively bonded directly onto the surface to be insulated. These shall be used either as direct support for insulation by impalement, or as fittings onto which supports in the form of metallic flat bars, rings or lengths of angle shall be attached. The insulation supports shall be designed to prevent the channelling or entrapment of water, see Figures 14 and 15. All welding and brazing operations shall require adequate repair to protective coatings.
- 5.1.3 Horizontal insulation supports on vessels shall be spaced to suit the standard size of the insulation, but in no case shall exceed 3 m vertical pitch.
- 5.1.4 The welding attachment of insulation supports and fixtures to pressure vessels shall not contravene the requirements for stress relieving as laid down in the relevant vessel design code. Such welding shall normally be carried out at the vessel manufacturers works; prior to release for shipment.
- 5.1.5 For attachment of the insulation by impalement, insulation supports shall be arranged in a diamond pattern. The actual spacing between the pins shall depend upon the weight of the insulation, the extent and orientation of the surface and the service conditions, i.e. degree of temperature cycling, vibration, etc.

The following spacings may be used as a guide:-

<i>Vertical surfaces</i>	<i>450 mm</i>
<i>Upward facing surfaces, e.g. tank roofs</i>	<i>600 mm</i>
<i>Overhanging or downward facing surfaces</i>	<i>300 mm</i>

- 5.1.6 Insulation design shall incorporate measures to accommodate thermal expansion and contraction. In addition, to the requirements of 3.1.16, insulation retaining banding shall incorporate suitably tensioned spring buckles, typically at 15 m intervals around the bands.

On vessels of 6 m diameter and above and on storage tanks, the insulation may alternatively be secured by lacing with galvanised or stainless steel wire fixed to studs or cleats long enough to project through the insulation.

- 5.1.7 Cladding shall be fabricated from the selected type of flat or profiled sheet metal cut and assembled to contour, always being applied so as to shed water. The minimum overlap on all cladding joints shall be 75 mm for vertical seams, and 100 mm for circumferential seams. Metal sheets for cladding shall be as large as practicable to minimise the number of joints, and where weatherproofing is required, all these joints shall be sealed with butyl mastic.

- 5.1.8 Metal cladding on vertical vessels and tanks shall be supported on metal studs, spaced at no more than 14" circumferential centres and no less than three per sheet. S clips shall also be used to support circumferential overlaps.
- 5.1.9 Where diameter permits, standard pipe sections shall be used for insulation.
- 5.1.10 The continuity of cladding at projections shall be ensured by careful design and good workmanship. Insulation around protrusions at ladder and gantry supports shall be clad with metal flashing, nozzles with sealing discs, and manways with removable box covers. The design of cladding components shall take into account the need for continuity of weatherproofing and vapour barriers, as appropriate, and the requirements of clause 3.1.3. See Figure 19.
- 5.1.11 If thermal insulation is to be used for limiting the heat absorption to a vessel in the case of fire, and the pressure relief valve is sized on this assumption, the clad insulation shall be sufficiently robust, secure and water tight to resist the force of fire water from monitors, hoses and deluge systems.
- 5.1.12 Ladders and platforms shall normally be thermally isolated from the tanks and vessels to which they are attached and an allowance for this requirement should be included in the ladder and platform stand off detail.
- 5.1.13 The use of flexible mattresses is recommended for heat exchanger and vessel sections subject to frequent dismantling, since they are less easily damaged by frequent disturbance.

Flexible sections shall have adjacent edges of the covering mesh fastened together. Supports or spacer rings should be provided to maintain the correct insulation thickness and to minimise compression by ladders, etc. It should be noted that slabs are always easier to fit and restrain.

5.2 Vessels and Exchangers

- 5.2.1 The thermal insulation of vessels shall normally be in accordance with the principles illustrated in Figure 7. See Figures 17 to 25.

In Figures 17 and 18, in keeping with general principles previously outlined, for cold vessels self tapping screws should not be used - rather blind pop rivets should be employed to avoid damage to the vapour barrier.

- 5.2.2 Notwithstanding the requirements of 5.1.1, saddles, supports and skirts of vessels shall be insulated to a minimum distance of 600 mm below the point of contact with the shell.

- 5.2.3 External stiffening rings on vessels such as vacuum columns shall be fully and independently insulated. The cladding shall be fully weatherproofed and allowances made for expansion and contraction of each vessel in service. See Figure 24.
- 5.2.4 Only rigid sections of insulation shall be applied to heads of vessels. These shall be held in place with binding wire and secured by radial bands fixed to a floating 10 mm ring at the centre of the head, and a fixed support ring on the shell around the perimeter of the head, as shown in Figures 17 and 18. Spacing of the bands at the support ring shall not exceed 150 mm.
- 5.2.5 Metal cladding on heads of vessels shall be fabricated with an overlapped, 'orange peel' design, with overlaps arranged to shed water. In the case of external locations the cladding shall be sealed to prevent moisture entering under the vertical cladding. Square end covers shall be used on vessels <20" OD.
- 5.2.6 Except in the case referred to below, bonnets and channel flanges on heat exchangers shall be insulated by means of a removable double skin box fabricated in stainless steel, as described in 3.1.6. For heat exchangers on hydrogen duty, tube sheet and channel flanges shall not be insulated, but a simple removable stainless steel sheet protecting shroud shall be placed over the bolts to protect them from the effect of thermal shock from rain storms. A suitable gap shall be left between the bolts and the shroud to allow adequate ventilation.

5.3 Cylindrical Tanks

- 5.3.1 The thermal insulation of tanks shall normally be in accordance with the principles illustrated in Figure 21.

Tank insulation shall generally be in accordance with [BS 2654](#).

- 5.3.2 When banding is used to secure the cladding on tanks, a minimum of three vertical strips of plain sheeting compatible with the cladding and extending the full height of the tank should be introduced at equal spacing around the circumference to facilitate correct tensioning of the banding. Tensioning shall generally allow for thermal expansion of the shell plate, strains caused by filling and emptying the tank and for wind pressure.
- 5.3.3 In order to avoid 'wicking', the insulation on tanks shall terminate at 150 mm above the lowest portion of the tank shell and, on floating roof tanks, 75 to 100 mm above the wind girder. Adequate means of support for the insulation material shall be provided, and these supports shall be free draining. The resultant gap may be filled with cellular glass if insulation is demanded by process or other requirements, as illustrated in Figures 21 and 23.

The cellular glass should be applied as adhesively bonded multi-layers with gaps and external surfaces sealed. The glass should be banded or pinned, and covered by an extension of the cladding.

5.3.4 When the fixed roofs of hot tanks require insulation, a framework shall be erected on the roof to provide a positive means of attachment for the cladding material. The transition from the shell to the roof shall be designed to be weatherproof, for example as illustrated in Figure 22.

5.3.5 Roofs of cold tanks, and other tanks where there is no likelihood of roof access being required in service, shall be insulated by means of polyurethane foam, either spray applied or foamed within a sheet of galvanised steel cladding. All sprayed polyurethane shall be protected by a vapour barrier.

5.4 Spheres

5.4.1 Spheres may be thermally insulated using foamed in situ organic foam or preformed slabs. For the insulation of spheres using slab insulation, the slabs shall be bonded to the surface of the sphere and to each other using a compatible adhesive. Alternatively a cage of banding may be used incorporating both horizontal and vertical banding and floating rings.

CHARACTERISTICS	PIPE SECTION	WIRED MATTRESSES	SLAB	LOOSE FILL
Normal Density Min	115 kg/m ³	90 kg/m ³	95 kg/m ³	-
Thermal conductivity w/mK at 10°C at 300°C	0.036 0.091	0.034 0.084	0.034 0.084	-
Max operating temperature, °C	650	800	750	-
Fire performance (BS 476 Pt 7/ISO 1182)	Non-comb	Non-comb	Non-comb	Non-comb
Linear shrinkage %	2.0 max	2.0 max	2.0 max	-
pH	7-10	7-10	7-10	-
Water absorption: Partial immersion				
20°C kg/m ²	0.2 max	0.2 max	0.2 max	0.2 max
250°C kg/m ²	0.2 max	0.2 max	0.2 max	0.2 max
Total immersion				
20°C kg/m ³	20 max	(1)	20 max	(1)
250°C kg/m ³	20 max	(1)	20 max	(1)

Notes:-

- (1) Water retention figures for wired mattresses and loose fill on total immersion shall be subject to approval by BP.
- (2) Maximum operating temperatures, density and thermal conductivity given are approximate only and vary with grade of material - consult manufacturer for confirmation of details.
- (3) Chemicals in the insulation environment may restrict insulants operational limits.
- (4) Note that water repellency is limited to around 250°C maximum.
- (5) Mineral wool mattresses shall be faced in accordance with BS 3958, Part 3. Where expanded metal is used in one side only, this shall be on the cold side.
- (6) Determination of properties generally described by the various sections of BS 2972, and references within standards quoted in Table 1B and 1C.

TABLE 1A
TYPICAL CHARACTERISTICS OF MINERAL WOOL INSULATION

Material	Relevant Standards	Maximum operating temperature/ °C	Bulk Density kg/m ³	Approximate thermal conductivity W/mK
Ceramic fibres: Bulk fibres Blankets	ASTM C892	650 to 1260	48 to 250 64 to 290	0.072 (300°C), 0.288 (800°C) 0.060 (300°C), 0.260 (800°C)
Mineral Wool: Loose Fill Pipe-Sections Mattresses	ASTM C764 BS 3958 Pt 4 ISO 8142 ASTM C547 BS 3958 Pt 3 ASTM C553/592	850 260 to 850 850	 80 to 144 88 to 128	Varies with application 0.082 at 300°C 0.083 at 300°C
Glass fibre wool	-	230 to 550	15 to 100	-
Calcium Silicate	BS 3958 Pt 2 ASTM C533	800 to 1000	160 to 320	0.083 at 300°C
Magnesia	BS 3958 Pt 1	310	180 to 220	0.062 at 175°C
Perlite - loose fill	ASTM C549	870	40 to 150	0.1 at 230°C
Vermiculite	ASTM C516	1100	50 to 150	0.062 / 0.065 at ambient

Notes:-

- (1) Maximum operating temperatures, density and thermal conductivity are approximate only and vary with grade of material - consult manufacturer for confirmation of details.
- (2) Chemicals in the insulation environment may restrict insulant operational limits (e.g. ceramic fibre may be affected by some alkalis).
- (3) Calcium silicate to be used above 120°C to ensure it remains moisture free.

TABLE 1B
TYPICAL CHARACTERISTICS OF HOT INSULATION MATERIALS

Material	Relevant Standards	Approximate max. operating temperature, °C	Bulk Density kg/m ³	Approximate thermal conductivity W/ mK	
				at 10°C	at 100°C
Cellular glass	ASTM C552	400	120 to 160	0.045	0.032
Phenolic foam - rigid	BS 3927	50	35 to 200	0.022	0.016
Polyisocyanurate foam - rigid	BS 5608	50	30 to 65	0.025	0.022
Polyurethane foam:	BS 5608				
Rigid		50	30 to 160	-	-
Flexible		50	30 to 65		
Perlite	ASTM C549	870	40 to 150	0.055	0.030

Notes:-

- (1) Polyurethane foam insulation should not be considered for use in enclosed spaces because of smoke generation where the risk of fire is a possibility.
- (2) Chemicals in the insulation environment may restrict insulant operational limits.
- (3) Use of plastic foams should not go above 50°C, as there is evidence of generation of acids and chlorides under such circumstances.

TABLE 1C

TYPICAL CHARACTERISTICS OF COLD INSULATION MATERIALS

ITEM	O/D OF INSULATION	JACKET	
		TYPE	THICKNESS
PIPING/FLANGES AND VALVES	150mm and below Over 150mm up to 450mm Over 450mm	Flat Flat Flat	0.6mm 0.8mm 1.0mm
- Foot traffic areas	ALL	Flat	1.2mm
VERTICAL VESSELS			
- Top Heads	All Sizes	Flat	1.0mm
- Shells	450mm and below Over 450mm and flat surfaces	Flat Flat	As piping 1.0mm
- Bottom heads (i) without skirt (ii) with skirt	All sizes All sizes	Flat Not Req'd	1.0mm Not required
HORIZONTAL VESSELS			
- Heads	All sizes	Flat	1.0mm
- Shells	450mm and below Over 4450mm and flat surfaces	Flat Flat	As piping 1.0mm
- Exchanger bonnets and channels and bonnet/channel flanged joints	All sizes	Flat	1.0mm
- Exchanger Ends	All sizes	Flat	1.2mm
VERTICAL AND HORIZONTAL VESSELS			
- Transition pieces	All sizes	Flat	1.0mm
- Stiffening rings	All sizes	Flat	1.0mm
MACHINERY			
- Pump and Turbine casing	All sizes	Flat	1.0mm
PIPING, VERTICAL/HORIZONTAL VESSELS AND MACHINERY ACOUSTICALLY INSULATED			
- Class A and combinations incorporating A	All sizes	Flat	As previously stated in this Table
- Class B and combinations incorporating B	All sizes	Flat	As previously stated in this Table
- Class C and combinations incorporating C	All sizes	Flat	1.3mm

Notes: When troughed, corrugated or reeded cladding is used on vertical sections of tanks, the thickness may be 0.2 mm thinner (0.079 in). For a given thickness, aluminium cladding will be far more susceptible to mechanical damage than other cladding materials and this should be born in mind when selecting the former.

mm (SWG)

0.6 23

0.8 21

1.0 19

TABLE 2
MINIMUM THICKNESSES FOR FLAT SHEET
(Zinc or Alu-Zinc Coated Steel Aluminised or Stainless Steel)

Item	Layers	Size	Insulation		Finish	
			Fastening	Spacing	Fastening	Spacing
Piping	Single	100mm NPS and below	1.0mm to 1.6mm dia tie wire	220mm	20mm x 0.8mm bands	Maximum 500mm centres
“	Single	150mm NPS and above	13mm x 0.6mm bands	220mm centres	20mm x 0.8mm bands	Maximum 500mm centres
“	Multi - 1 st	All sizes	1.00mm to 1.6mm dia tie wires	220 centres	As single layer	As single layer
“	Multi - Inter	All sizes	1.00mm to 1.6mm dia tie wires	220 centres		
“	Multi - Final	All sizes	20mm x 0.8mm bands	As single layer		
Vertical & Horizontal Vessels	Single	550mm O/D and below	As for piping	As for piping	As for piping	As for piping
“	Single	Over 550mm O/D	13mm x 0.6mm bands	300mm centres	No.8 dia x 13mm long screws and 40mm x 1.00mm bands	Screws 150mm centres bands 1000mm centres
Vertical and Horizontal vessels	Multi - 1 st	550mm O/D and below	1.0mm to 1.6mm dia tie wires	220 mm centres	As single layer	As single layer
“	Multi - Inter	550mm O/D and below	1.00mm to 1.6mm dia tie wires	220mm centre		
“	Multi - Final	550mm O/D and below	As single layer	As single layer		
“	Multi - 1 st	Over 550mm O/D	13mm x 0.6mm bands	300mm centre	As single layer	As single layer
“	Multi - Inter	Over 550mm O/D	13mm x 0.6mm bands	300mm centre		
“	Multi- Final	Over 550mm O/D	As single layer	As single layer		

TABLE 3

TYPE AND SIZE OF FASTENINGS FOR INSULATION AND FINISHES

OUTSIDE DIAMETER NOMINAL	PIPE O/Dmm BORE NB	THICKNESS OF INSULATION, MM													
		AT HOT FACE TEMPERATURE, °C													
		Up to 100	101 to 150	151 to 200	201 to 250	251 to 300	301 to 350	351 to 400	401 to 450	451 to 500	501 to 550	551 to 600	601 to 650	651 to 700	Frost Protection If
mm - O/D	Inches N/B														
33	25 - 1"	40	40	50	50	50	80	90	90	100	100	100	100		50
48	40 - 1 1/2"	40	50	50	50	80	80	90	90	100	120	140	140		50
60	50 - 2"	40	50	50	50	80	80	90	100	100	120	140			50
89	80 - 3"	40	50	50	80	80	80	100	100						50
114	100 - 4"	50	50	50	80	80	90	100	100						50
168	150 - 6"	50	50	50	80	80	90								25
219	200 - 8"	50	50	80	80	90									25
273	250 - 10"	50	50	80	100	100									25
324	300 - 12"	50	70	80	100	100									25
355	350 - 14"	50	70	80	100	100									
406	400 - 16"	50	70	80	100										
457	450 - 18"	50	80	80	100										
508	500 - 20"	50	80	80	100										
559	550 - 22"	50	80	80	100										
609	600 - 24"	50	80	80	100										
SINGLE LAYER INSULATION		DOUBLE LAYER INSULATION				CALCULATE ECONOMIC THICKNESS FOR INDIVIDUAL CASES									

The thickness given above are based on the use of performed mineral wool - densities of 90-110 kg/m³ for temperatures up to 400°C and 140 kg/m³ above 400°C. Calculation on method based on [BS 5422](#).

TABLE 4A

THICKNESS OF WATER REPELLANT MINERAL WOOL FOR HOT INSULATION - GALVANISED STEEL FINISH

Nom Pipe Size	Thickness of insulation, mm											
	Hot face temperature, °C											
	Upto 100	150	200	250	300	350	400	450	500	550	600	650
1"	25	25	25	25	25	25	30	40	40	50	60	60
1 1/2"	25	25	25	25	25	25	40	40	50	50	60	70
2"	25	25	25	25	25	30	40	40	50	60	70	70
3"	25	25	25	25	25	30	40	50	50	60	70	80
4"	25	25	25	25	25	40	40	50	60	70	80	90
6"	25	25	25	25	30	40	50	50	60	80	90	100
8"	25	25	25	25	30	40	50	60	70	80	90	100
10"	25	25	25	25	30	40	50	60	70	90	100	120
12"	25	25	25	25	40	50	60	60	80	90	100	120
14"	25	25	25	25	40	50	60	70	80	90	100	120
16"	25	25	25	25	40	50	60	70	80	90	120	140
18"	25	25	25	25	40	50	60	70	80	100	120	140
20"	25	25	25	30	40	50	60	70	90	100	120	140
22"	25	25	25	30	40	50	60	70	90	100	120	140
24"	25	25	25	30	40	50	70	70	90	100	120	140

This table is based upon the same data as Table 4A and will reduce the insulation surface temperature to 60°C or less.

TABLE 4B

**THICKNESS OF WATER REPELLANT MINERAL WOOL FOR PERSONNEL
PROTECTION - GALVANISED STEEL FINISH**



Nom Pipe Size	Thickness of insulation, mm											
	Hot face temperature, °C											
	Upto 100	150	200	250	300	350	400	450	500	550	600	650
1"	25	25	25	25	25	25	25	25	30	40	40	50
1 1/2"	25	25	25	25	25	25	25	30	40	40	50	50
2"	25	25	25	25	25	25	25	30	40	40	50	60
3"	25	25	25	25	25	25	30	40	40	50	60	60
4"	25	25	25	25	25	25	30	40	40	50	60	70
6"	25	25	25	25	25	30	40	40	40	60	60	70
8"	25	25	25	25	25	30	40	40	40	60	70	80
10"	25	25	25	25	25	30	40	40	40	60	70	80
12"	25	25	25	25	25	30	40	50	60	60	70	90
14"	25	25	25	25	25	30	40	50	60	70	80	90
16"	25	25	25	25	25	30	40	50	60	70	80	90
18"	25	25	25	25	25	40	40	50	60	70	80	90
20"	25	25	25	25	25	40	40	50	60	70	80	90
22"	25	25	25	25	25	40	50	50	60	70	80	100
24"	25	25	25	25	25	40	50	50	60	70	80	100

This table is based upon the same data as Table 1A and a reduction in insulation surface temperature to 60°C or lower.

TABLE 4C

**THICKNESS OF WATER REPELLANT MINERAL WOOL FOR PERSONNEL
PROTECTION - NON METALLIC FINISH**



OUTSIDE DIAMETER NOMINAL mm - O/D	PIPE O/Dmm BORE NB> Inches N/B	THICKNESS OF INSULATION mm AT HOT FACE TEMPERATURE °C													
					SINGLE LAYER INSULATION					DOUBLE LAYER INSULATION					
		Up to 100	101 to 150	151 to 200	201 to 250	251 to 300	301 to 350	351 to 400	401 to 450	451 to 500	501 to 550	551 to 600	601 to 650	651 to 700	
33	25 - 1"				25	38	38	50	50	63	63	75	88		
48	40 - 1 1/2"				25	38	38	50	50	63	75	75	88		
60	50 - 2"				25	38	38	50	63	63	75	88	100		
89	80 - 3"				38	38	50	50	63	75	75	88	100		
114	100 - 4"				38	38	50	63	63	75	88	100	100		
168	150 - 6"				38	38	50	63	75	75	88	100			
219	200 - 8"				38	50	50	63	75	88	100				
273	250 - 10"				38	50	50	63	75	88	100				
324	300 - 12"				38	50	63	63	75	88	100				
355	350 - 14"				38	50	63	63	75	88	100				
406	400 - 16"				38	50	63	75	75	88	100				
457	450 - 18"				38	50	63	75	75	100					
508	500 - 20"				38	50	63	75	88	100					
559	550 - 22"				38	50	63	75	88	100					
609	600 - 24"				38	50	63	75	88						
					RADIUSED AND BEVELLED SINGLE LAYER INSULATION			RADIUSED AND BEVELLED DOUBLE LAYER INSULATION							

TABLE 5

THICKNESS OF CALCIUM SILICATE FOR HOT INSULATION

- METALLIC FINISH

Temp °C	Thickness of insulation, mm													
	Nominal pipe size, inches													
	3/4	1	1 1/2	2	3	4	6	8	10	12	14	16	18	24
10	20	20	20	20	20	20	20	20	20	20	20	20	20	20
0	20	20	20	20	20	20	20	20	25	25	25	25	25	25
-10	20	25	25	25	25	40	40	40	40	40	40	40	40	40
-20	25	40	40	40	40	40	40	40	40	40	40	50	50	50
-30	40	40	40	40	40	50	50	50	50	50	50	65	65	65
-40	40	40	40	50	50	50	65	65	65	65	65	65	65	65
-50	40	40	50	50	65	65	65	65	75	75	75	75	75	75
-60	50	50	50	65	65	65	65	75	75	75	75	90	90	90
-70	50	50	65	65	65	65	75	90	90	90	90	90	90	100
-80	65	65	65	65	75	75	90	90	90	90	100	100	100	100
-90	65	65	65	75	75	90	90	100	100	100	100	115	115	115
-100	65	65	75	75	90	90	100	100	115	115	115	115	115	125
-110	65	75	75	90	90	90	100	115	115	115	115	125	125	125
-120	75	75	90	90	90	100	115	115	125	125	125	150	150	150
-130	75	75	90	90	90	100	115	115	125	125	150	150	150	150
-140	75	90	90	100	100	115	125	125	150	150	150	150	150	165
-150	90	90	90	100	115	115	125	150	150	150	150	150	165	165
-160	90	90	100	100	115	125	150	150	150	150	165	165	165	175

The thickness given above is that required to prevent the formation of condensation on the insulation surface in ambient still air at 20°C and a relative humidity of 85% and with an insulation finish of medium emissivity.

TABLE 6

**PIPING INSULATION THICKNESS FOR ANTI-CONDENSATION AND
PERSONNEL PROTECTION USING POLYURETHANE, ISOCYANURATE AND
PHENOLIC FOAM - NON METALLIC FINISH**



Temperature, °C	Thickness, mm
10	20
0	25
-10	40
-20	50
-30	60
-40	70
-50	90
-60	100
-70	110
-80	120
-90	130
-100	140
-110	150
-120	170
-130	180
-140	190
-150	200
-160	210

The thickness given is that required to prevent condensation on insulated surfaces at ambient still air conditions of 20°C and 85% relative humidity over an insulation finish of medium emissivity.

TABLE 7

**COLD VESSEL INSULATION THICKNESS FOR ANTI-CONDENSATION AND
PERSONNEL PROTECTION USING POLYURETHANE, ISOCYANURATE OR
PHENOLIC FOAM - NON METALLIC FINISH**



MINERAL WOOL PIPEWORK SECTION

Total thickness of insulation, mm	Number of layers	Inner layer	Second layer	Third layer
70	1	70	-	-
75	2	25	50	-
80	2	40	40	-
100	2	50	50	-
120	2	60	60	-
140	2	70	70	-
150	3	50	50	50
180	3	60	60	60
200	3	60	70	70

POLYISOCYANURATE FOAM PIPEWORK SECTIONS, SLABS, AND LAGS

Total thickness of insulation, mm	Number of layers	Inner layer	Second layer	Third layer	Fourth layer
50	1	50	-	-	-
75	2	25	50	-	-
90	2	40	50	-	-
100	2	50	50	-	-
125	3	25	50	50	-
150	3	50	50	50	-
175	4	25	50	50	50
190	4	40	50	60	50

TABLE 8

EXAMPLES OF TYPICAL THICKNESSES FOR MULTILAYER INSULATION



Item	Process	Quality Control Activity	Spec. Ref.	Acceptance Criteria	Verifying Document
1.1	Pre-commencement inspection - general	Verifying need for insulation of equipment/pipework. Verify reason, process or personnel protection. Check if heat tracing is required. Confirm steam or electric tracing.		Senior Process Engineer written confirmation.	Release note from BP Site Engineer.
1.2	Insulation Drawings	Verify conformance with specification requirements and equipment to be insulated.		Specification requirements.	Release note from BP site engineer.
1.3 ●	Pre-commencement preparation.	Identify any items of equipment which could incur damage or suffer contamination throughout the insulation process.		Critical surfaces protected, open ended pipework sealed in such a manner as to prevent ingress of contamination, during the full work period.	Daily inspection report.
1.4 ●	Surface preparation.	Confirm surfaces to be insulated are in accordance with paint specification and signed off as complete.		Specified painting system.	Daily inspection report.
1.5 ●	Surface contamination.	All surfaces to be free of any contaminants oil, chemicals, etc.		A clean dry surface.	Daily inspection report.
1.6 ●	Mandatory pre-commencement requirements.	Hazard warning notices displayed and area roped off. Permit to work issued. Control document - BP Safety manual. BP Standard of safe work practices.		Thoroughly check to ensure that whatever direction of approach, access cannot be gained without observing warning signs. Continuously check throughout work period. Signed and dated permit to work in possession of the nominated responsible person. The work period shall not extend beyond the allocated time period indicated on the current work permit.	BP reps daily log.
1.7	Environmental conditions.	Check the following prior to work: Present weather conditions, forecast conditions, work surface conditions.		Current weather conditions are dry and free from mist and fog. General forecast does not predict rain. Local conditions do not indicate possible rainfall. Steel surface is dry and free from ice or snow.	Daily inspection report.
1.8 ●	Storage facilities.	Check storage facilities.		Storage facilities shall be suitable for intended purpose ie. To keep insulating materials dry and undamaged.	Materials release document.
1.9 ●	Insulating cladding and ancillary materials.	Check cladding insulating/cladding materials. Verify certificate of conformity for all materials.		Only insulating/cladding materials listed in the applicable specifications shall be allowed on site. No materials to be accepted if not accompanied by the product data sheets and relative COSHH data statements or other legislation if applicable.	Materials release document.

TABLE 9 (PAGE 1 OF 2)

TYPICAL QUALITY CONTROL PLAN FOR THE INSULATION OF PIPEWORK AND EQUIPMENT

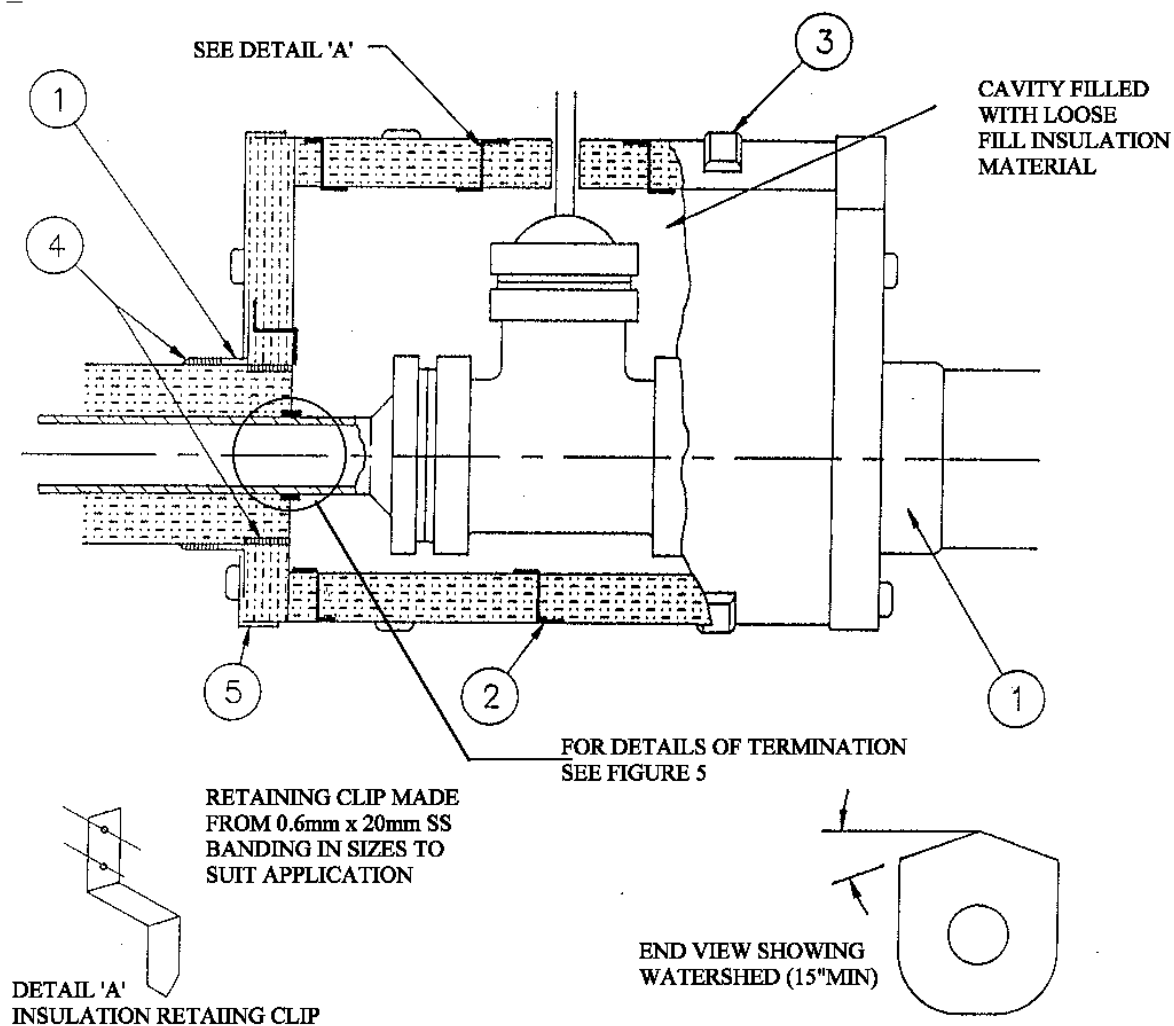


Item	Process	Quality Control Activity	Spec. Ref.	Acceptance Criteria	Verifying Document
2.0 ●	Insulation equipment	Check any compressor equipment used for foam injection is applicable along with associated foam pots.		Moisture to be drained from equipment before use. All equipment to be in good order and a current Independent Inspection report with regard to pressure containing parts/relief devices available for viewing.	Equipment inspection report.
2.1	Insulation application.	Routinely monitor environmental conditions and surfaces to be insulated prior to commencement. Take samples of applied materials.		Surfaces to be insulated to be dry and free from contamination. Insulation not to be carried out during inclement weather conditions. All part finished applications to be sealed at the end of the working day. Materials analyses conform to specification requirements.	Daily inspection reports/Materials analysis reports.
2.2 ●	Acceptance of applied insulation.	Monitor activities and conditions.		Check material has been applied in accordance with the specification. All vapour barriers as required applied.	Daily inspection report, either by item or line number.
2.3	Non conformance rectification.	Check rework activities. (see 2.0 & 2.1)		All surfaces to be covered satisfactorily with no damage noted to the insulating material.	Daily inspection report, either by item or line number.
2.4	Cledding application.	Monitor cledding application. Check all fixings and banding are secure, all overlaps as specified and all seams fully seated.		All cledding should overlap by the required amount and retaining bands be spaced in the specified manner. Check that all areas are sealed correctly and that water shedding arrangements are fitted to prevent moisture ingress. No self tapping screws to be used when vapour barrier is fitted.	Daily inspection reports, either by item or line number.
2.5	Non conformance rectification.	Check rework activities (see 2.4).		Fully in conformance with the specification.	Daily inspection reports, either by item or line number.
2.6 ●	Final acceptance.	Check site overall.		All waste insulation material etc. cleared away and all scaffolding removed. Reinstate any fittings removed during the insulation process.	Daily and final acceptance report by item or line number.

- Hold point

TABLE 9 (PAGE 2 OF 2)

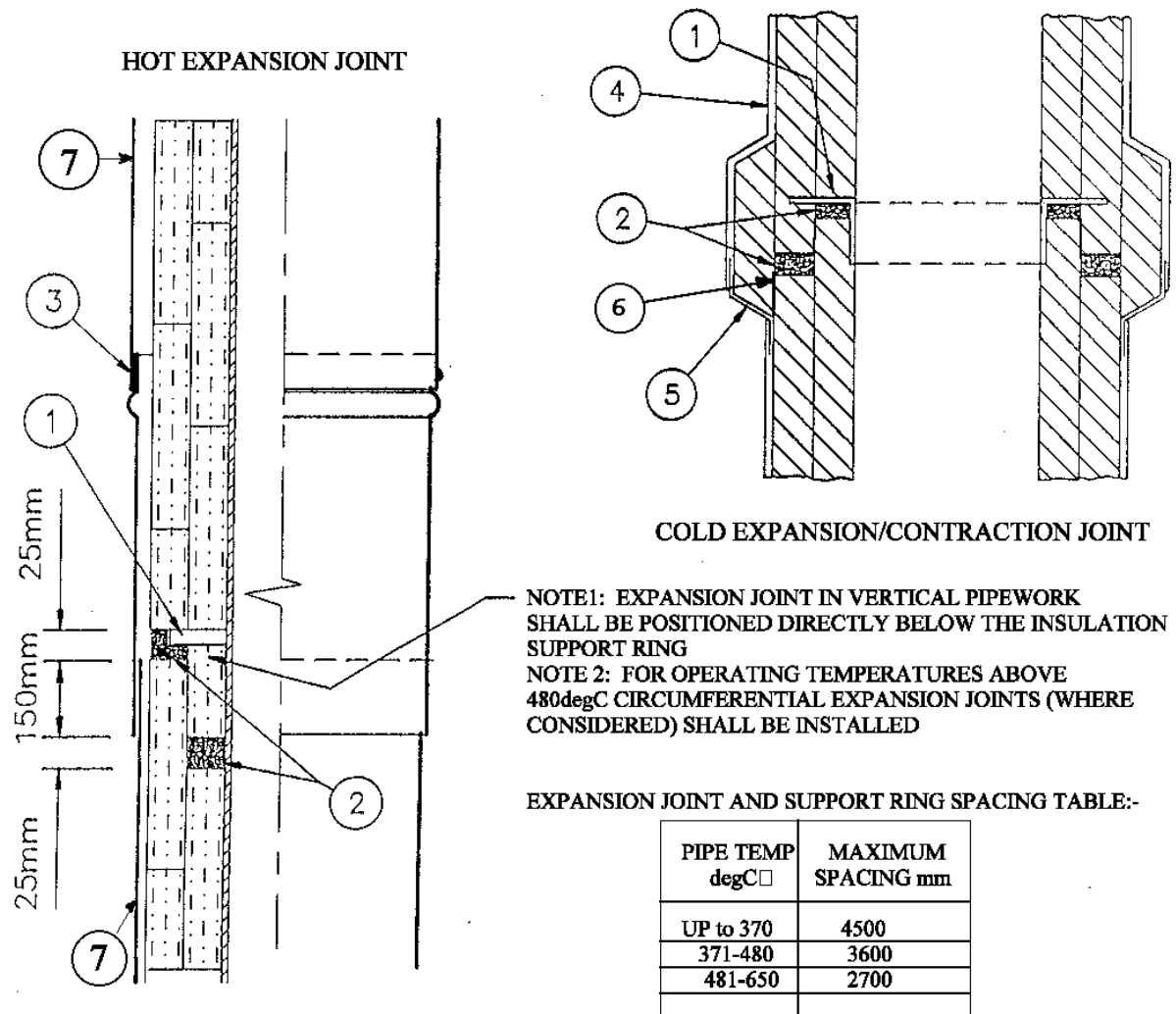
TYPICAL QUALITY CONTROL PLAN FOR THE INSULATION OF PIPEWORK AND EQUIPMENT



ITEM	DESCRIPTION
5	VALVE BOX END COVER LOCKFORMED ALL SIZES
4	BUTYL MASTIC STRIP
3	SS QUICK RELEASE TOGGLES
2	INSULATION RETAINING CLIP (DETAIL 'A')
1	VALVE BOX LANDING COLLAR

FIGURE 1

VALVE BOX COVER CONSTRUCTION



ITEM	DESCRIPTION
7	METAL CLADDING
6	NON SETTING MASTIC
5	BUTYL RUBBER SHEET
4	VAPOUR BARRIER
3	BUTYL MASTIC STRIP
2	LOOSE FILL MINERAL WOOL - TIGHTLY PACKED
1	INSULATION SUPPORT RING

FIGURE 2

EXPANSION/CONTRACTION JOINTS

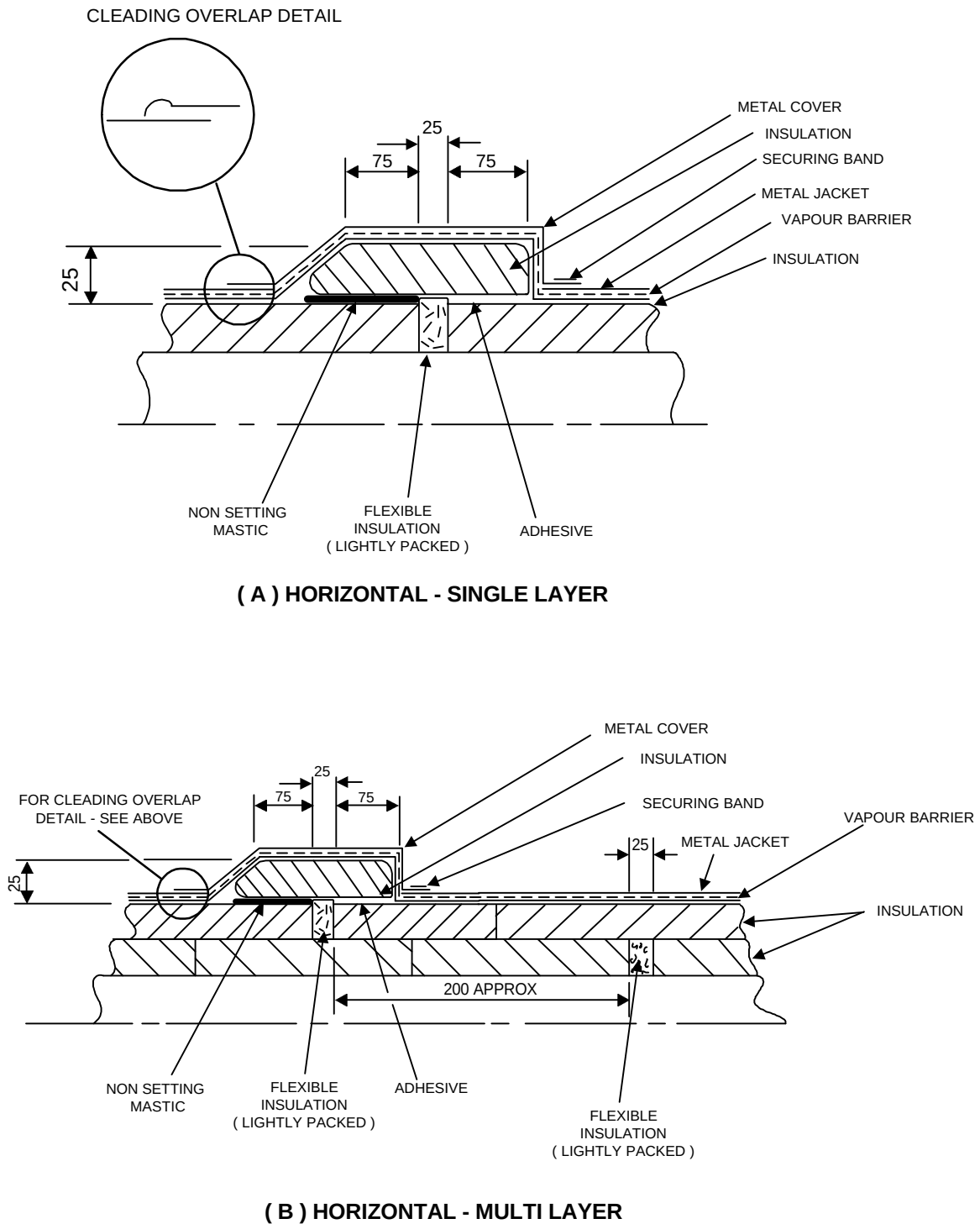
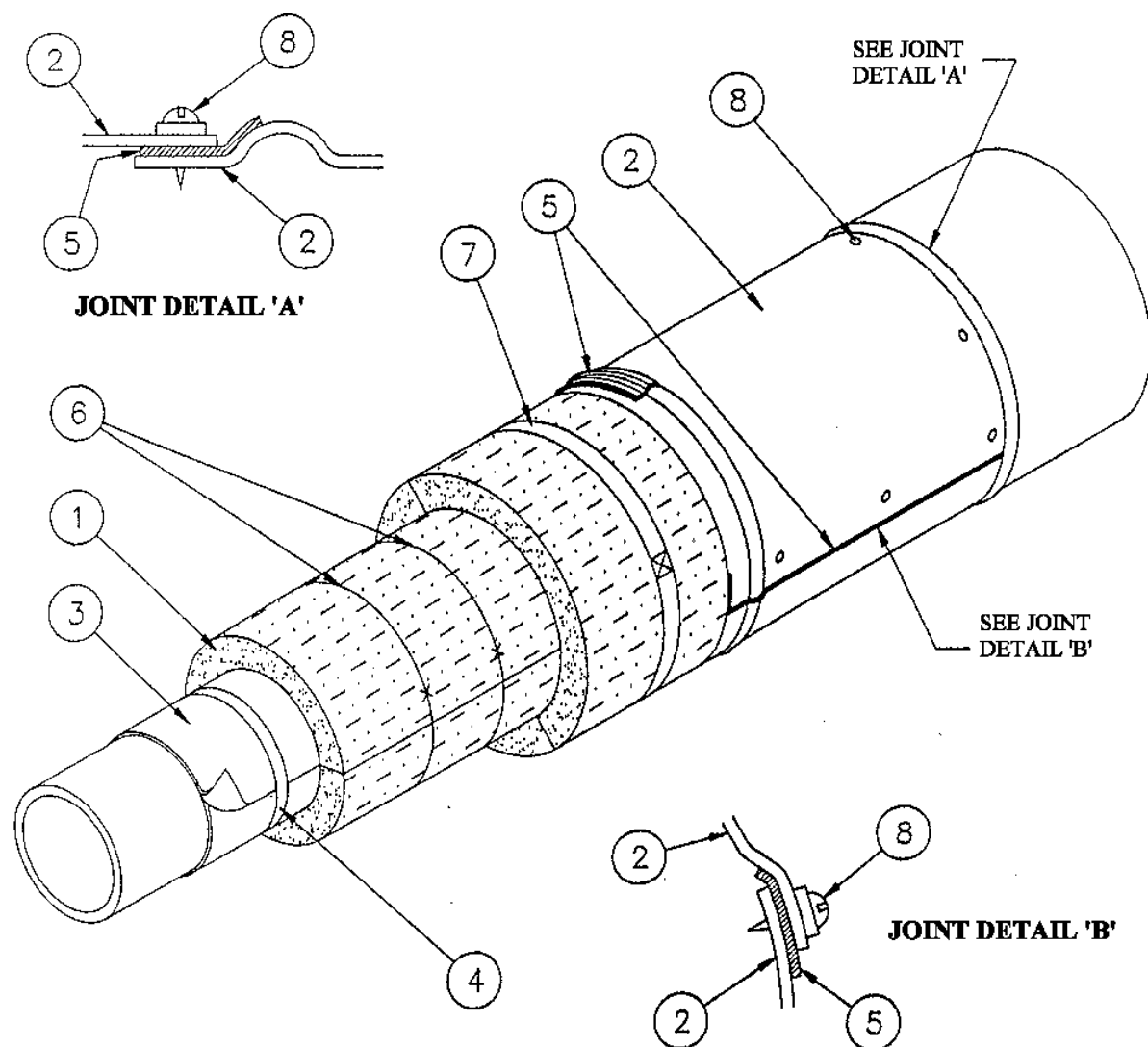


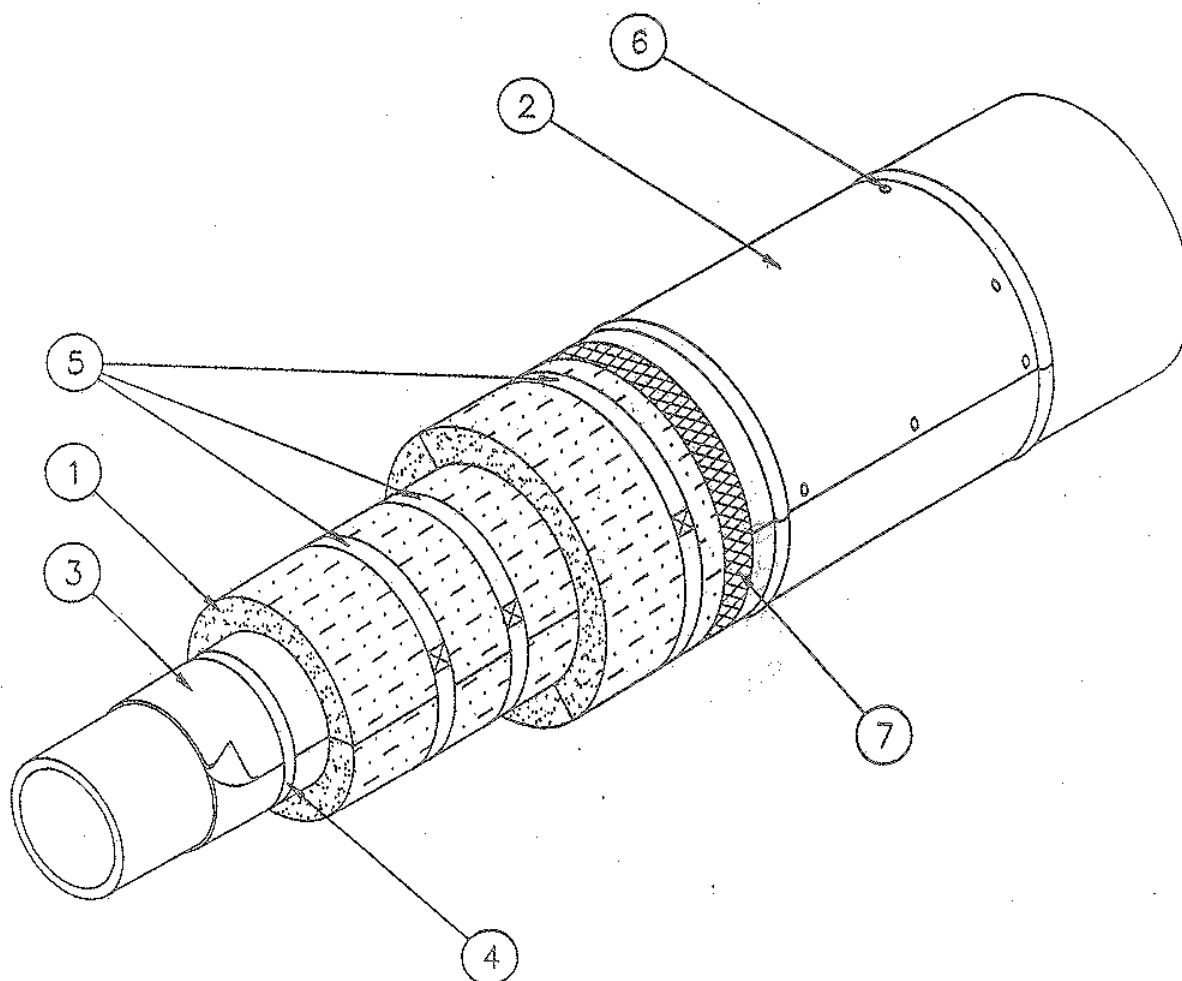
FIGURE 3

TYPICAL CONTRACTION JOINT DETAILS ON HORIZONTAL SURFACES ON COLD SERVICE (ALL DIMENSIONS IN MM)



ITEM	DESCRIPTION
8	STAINLESS STEEL SLOTTED PAN-HEAD SELF TAPPING SCREW C/W REINFORCED NEOPRENE WASHER
7	316 STAINLESS STEEL BANDING
6	316 STAINLESS STEEL TIE WIRE
5	BUTYL MASTIC TAPE
4	ADHESIVE TAPE
3	CHLORIDE BARRIER (WHERE APPLICABLE)
2	SHEET METAL CLADDING
1	WATER REPELLANT MINERAL WOOL SECTIONS OR R&B LAGS

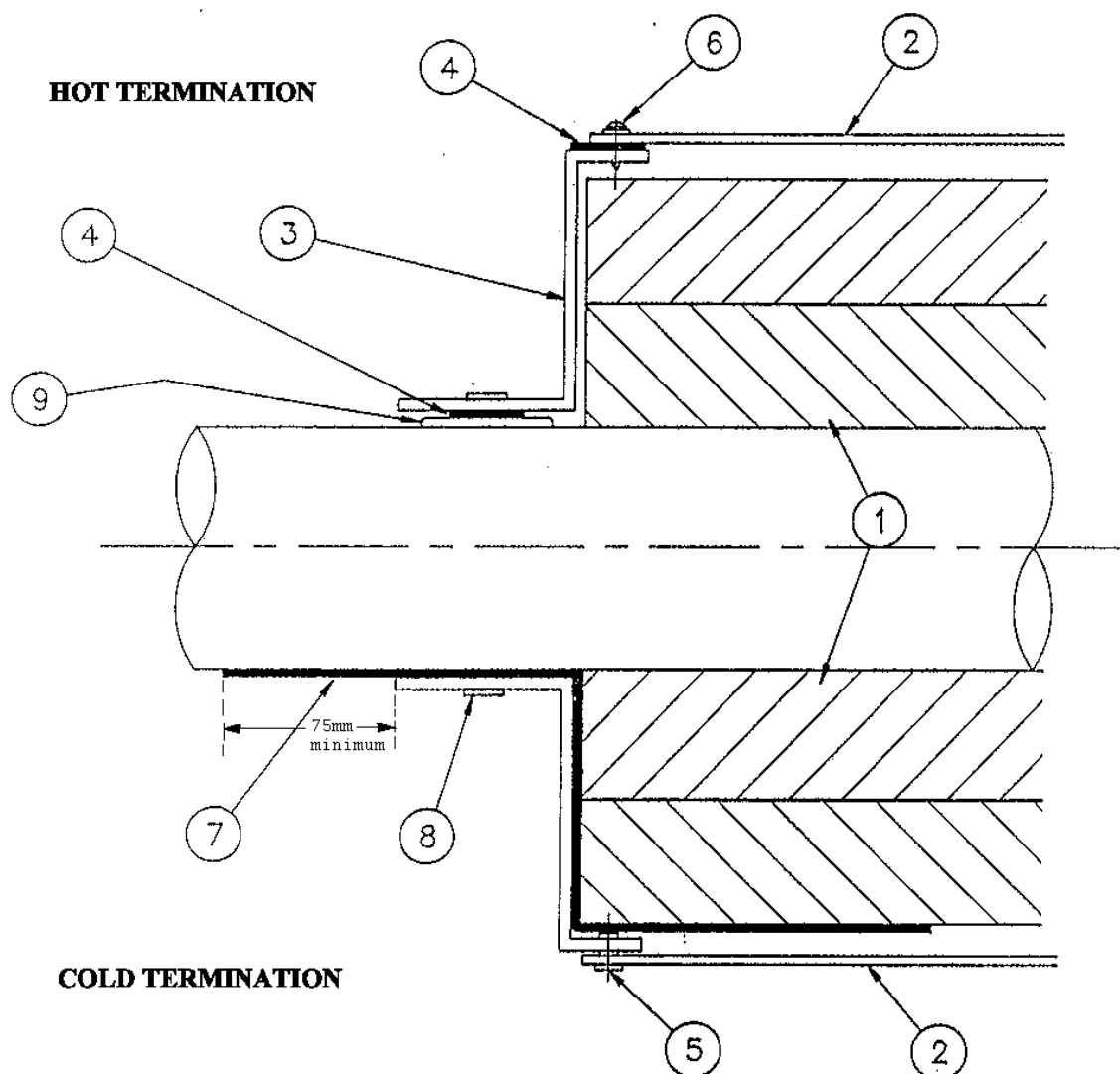
FIGURE 4
THERMAL INSULATION CONSTRUCTION FOR HOT PIPEWORK



ITEM	DESCRIPTION
7	VAPOUR BARRIER
6	STAINLESS STEEL POP RIVETS
5	PLASTIC BANDING
4	ADHESIVE TAPE
3	CHLORIDE BARRIER (WHERE APPLICABLE)
2	SHEET METAL CLADDING
1	PREFORMED PUR/PIR PIPE SECTION INSULATION

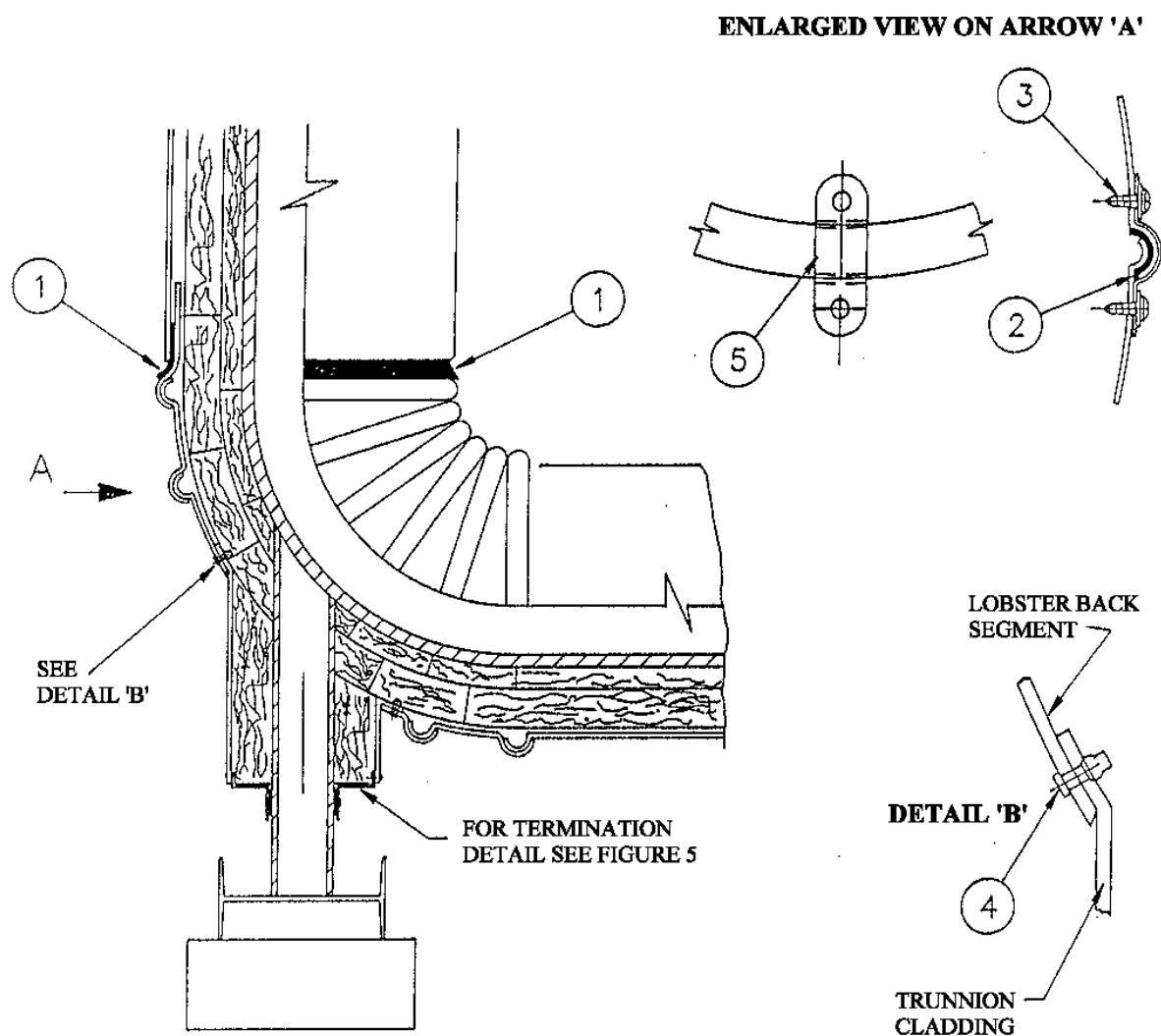
FIGURE 5

THERMAL INSULATION CONSTRUCTION FOR COLD PIPEWORK



ITEM	DESCRIPTION
9	THERMAL BREAK WEBBING TAPE
8	METAL BAND
7	VAPOUR BARRIER
6	SELF TAPPING SCREW W/NEOPRENE WASHERS
5	POP RIVET
4	BUTYL MASTIC STRIP
3	METAL END CAP
2	SHEET METAL CLADDING
1	PREFORMED PIPE SECTION INSULATION

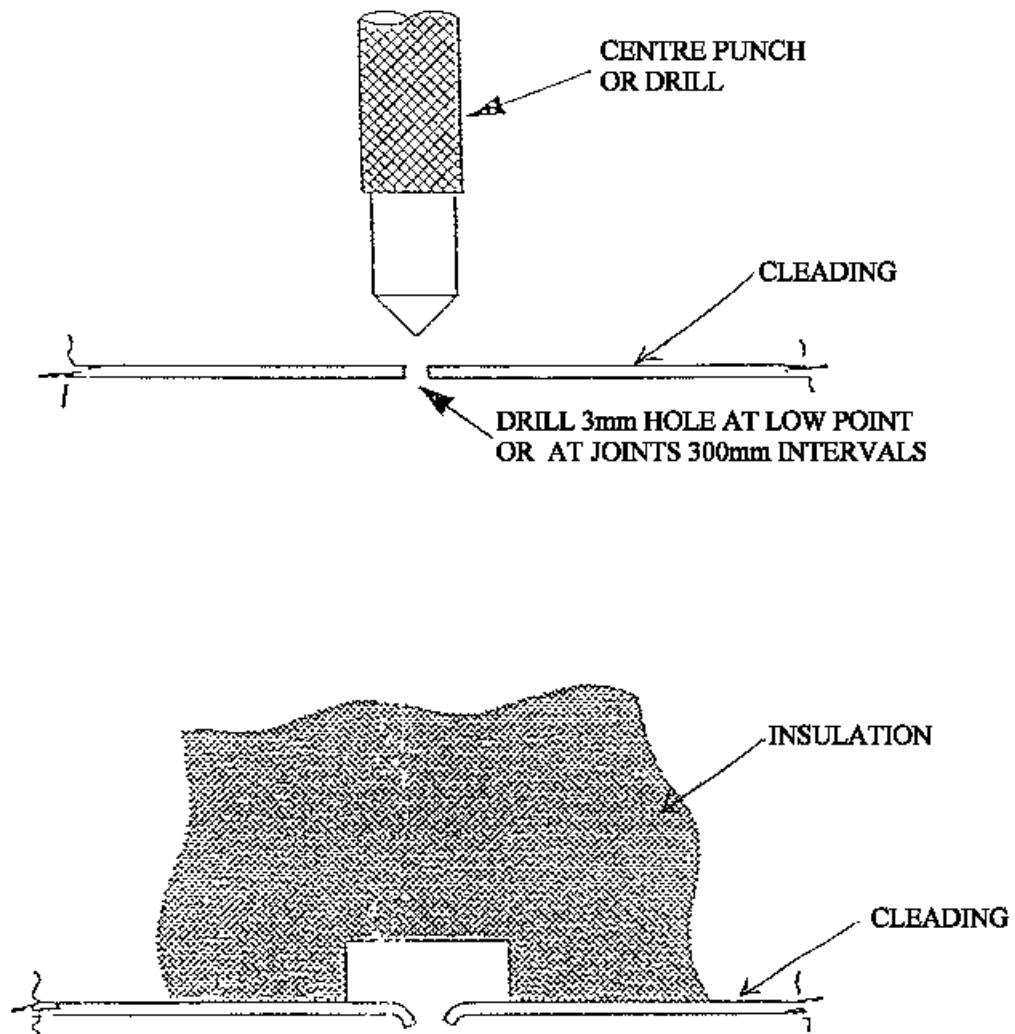
FIGURE 6
TERMINATION OF INSULATION ON PIPEWORK DETAIL



ITEM	DESCRIPTION
5	SHEET METAL CLADDING
4	POP RIVET
3	SELF TAPPING SCREW W/NEOPRENE WASHERS (HOT INSULATION ONLY)
2	ELASTOMERIC JOINT SEALANT
1	BUTYL MASTIC STRIP

FIGURE 7

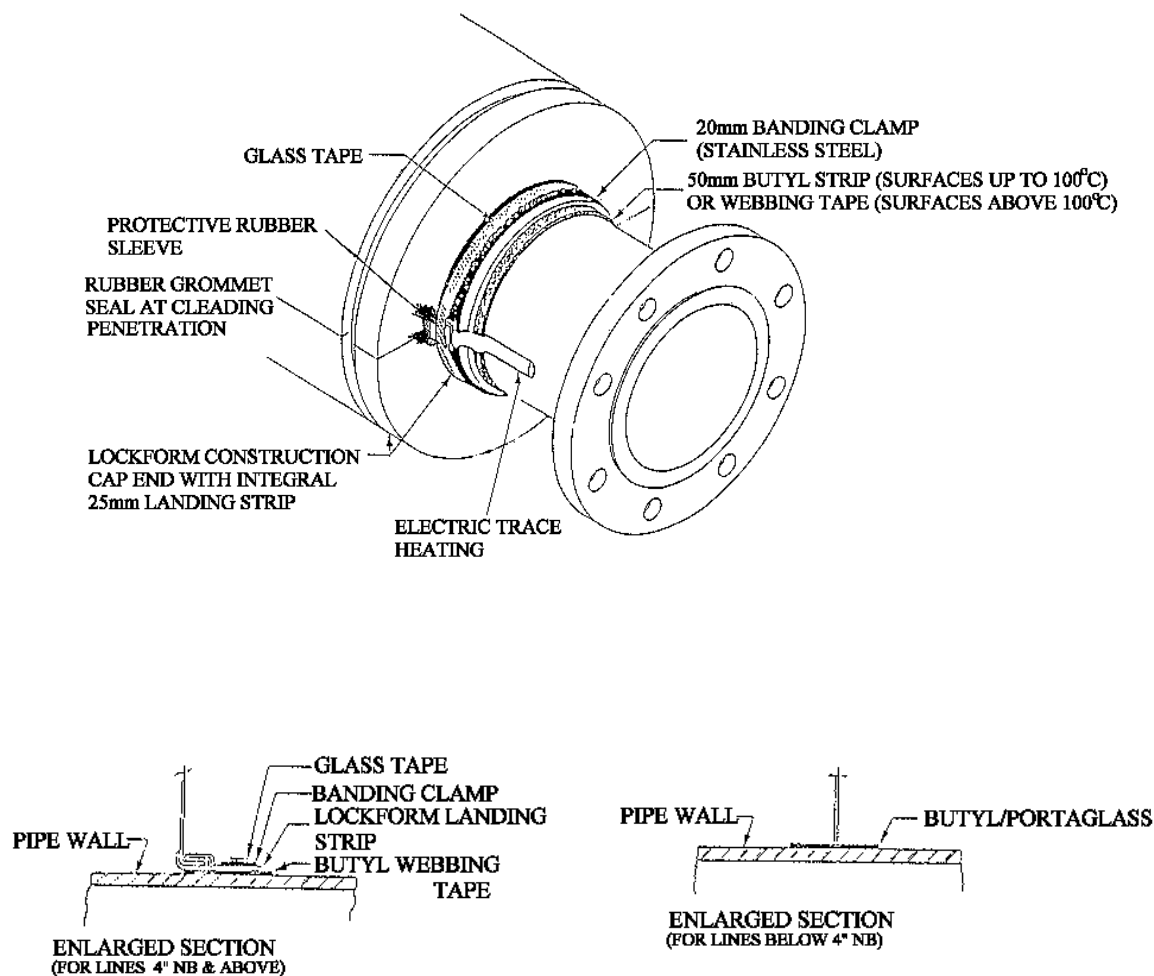
THERMAL INSULATION CONSTRUCTION ON PIPE BENDS



INSULATION REMOVED LOCAL TO FINISHED DRAIN HOLE TO LEAVE 25mm CLEARANCE ALL ROUND.

FIGURE 8

DRAINAGE FACILITY ON HORIZONTAL PIPE - HOT INSULATION ONLY



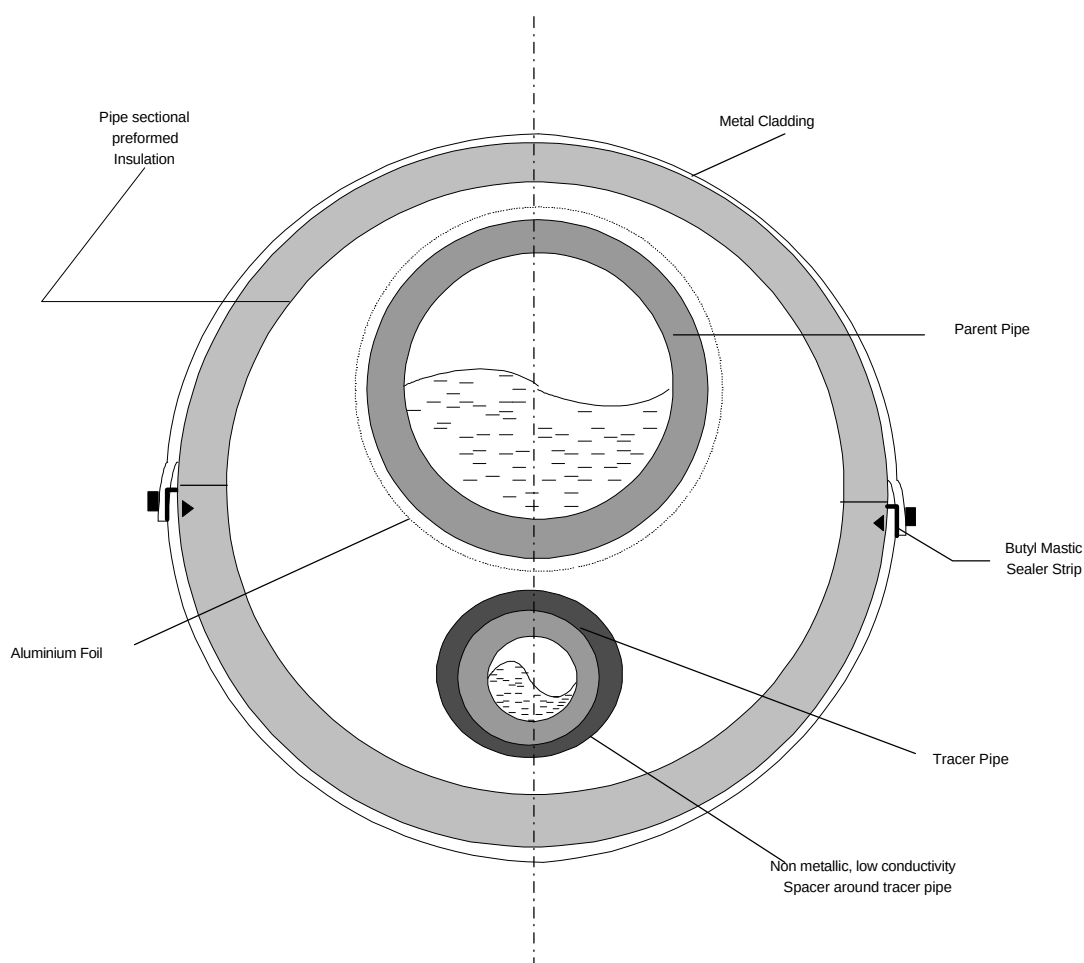
LOCKFORMED END CAP

NOTES:

1. ALL SEAMS TO BE SEALED WITH MASTIC TO PREVENT THE INGRESS OF WATER.
2. CAP END TO BE POSITIONED SO AS NOT TO IMPEDE THE WITHDRAWAL OF FLANGE STUDBOLTS.

FIGURE 9

ELECTRICAL HEAT TRACING - DETAIL AT INSULATION TERMINATION



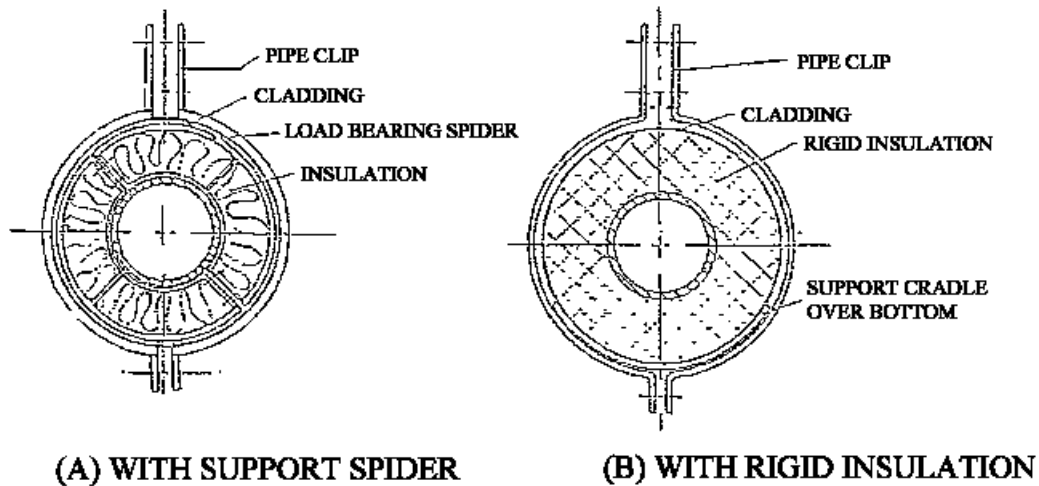
NOTES:

1. Only rigid insulation to be used on steam traced lines to preserve the symmetrical air space.
2. The open ends of the air gap to be sealed with a disc of insulating material at insulation terminations adjacent to flanges etc.

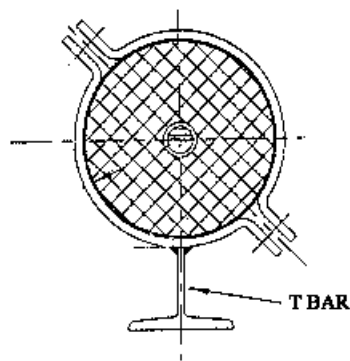
FIGURE 10

THERMAL INSULATION AND WEATHERPROOFING DETAIL ON STEAM TRACED PIPE

SUSPENDED FROM ABOVE



SUPPORTED FROM BELOW

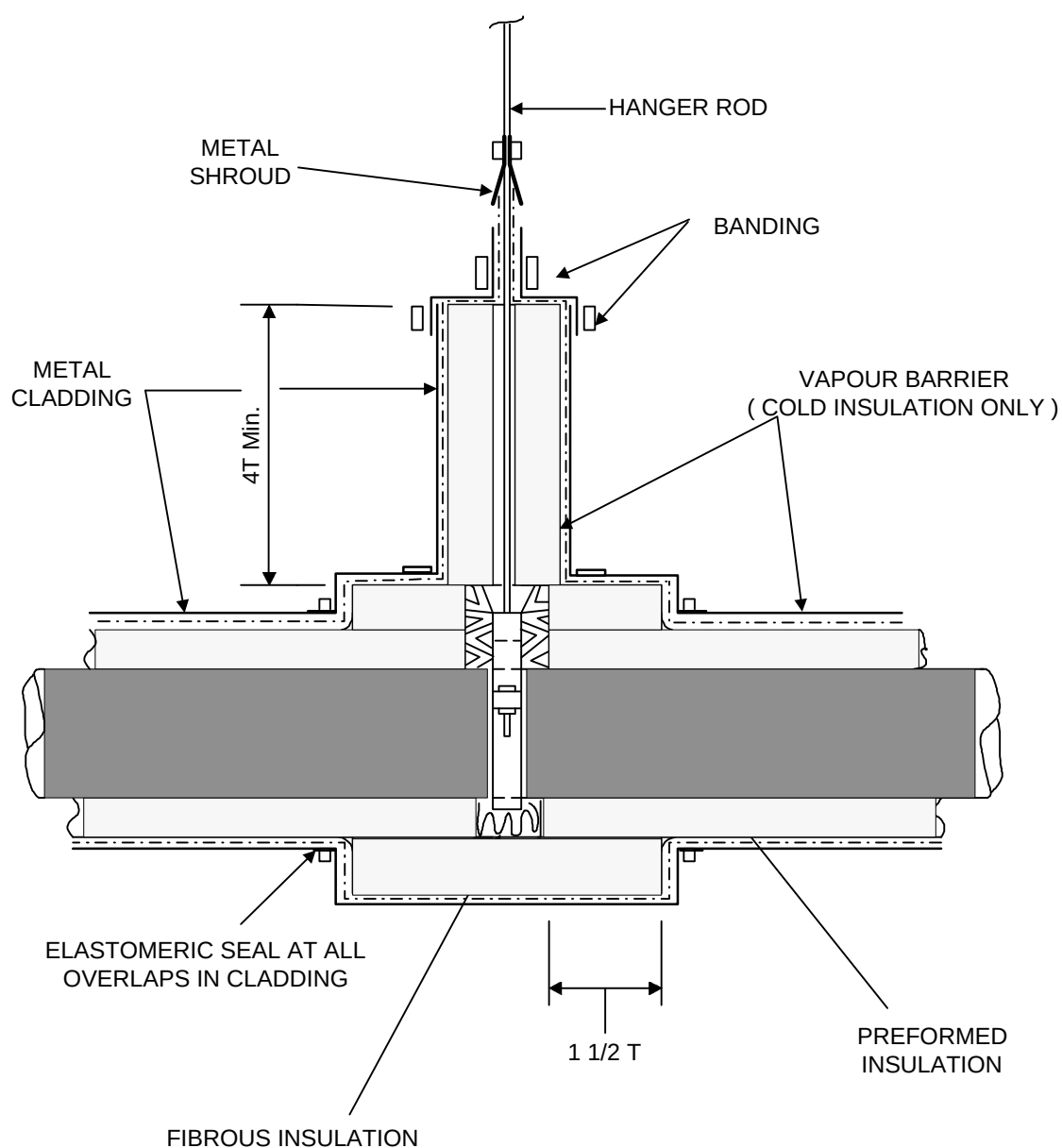


NOTES:

1. FOR THE RIGID INSULATION OPTION THE LENGTH OF RIGID INSULATION TO BE NOT LESS THAN 3 TIMES THE WIDTH OF THE PIPE CLIP.
2. COMPRESSIVE STRENGTH OF RIGID INSULATION TO BE $\geq 0.75\text{N/mm}^2$ (75psi)

FIGURE 11

**THERMAL INSULATION OF PIPE AT PIPE HANGERS OR BOTTOM SUPPORTS
NOT PENETRATING THE INSULATION OR CLADDING - HORIZONTAL PIPE**



T = Insulation Thickness

FIGURE 12

THERMAL INSULATION AT PIPE HANGERS WHERE THE PIPE IS SUPPORTED DIRECTLY

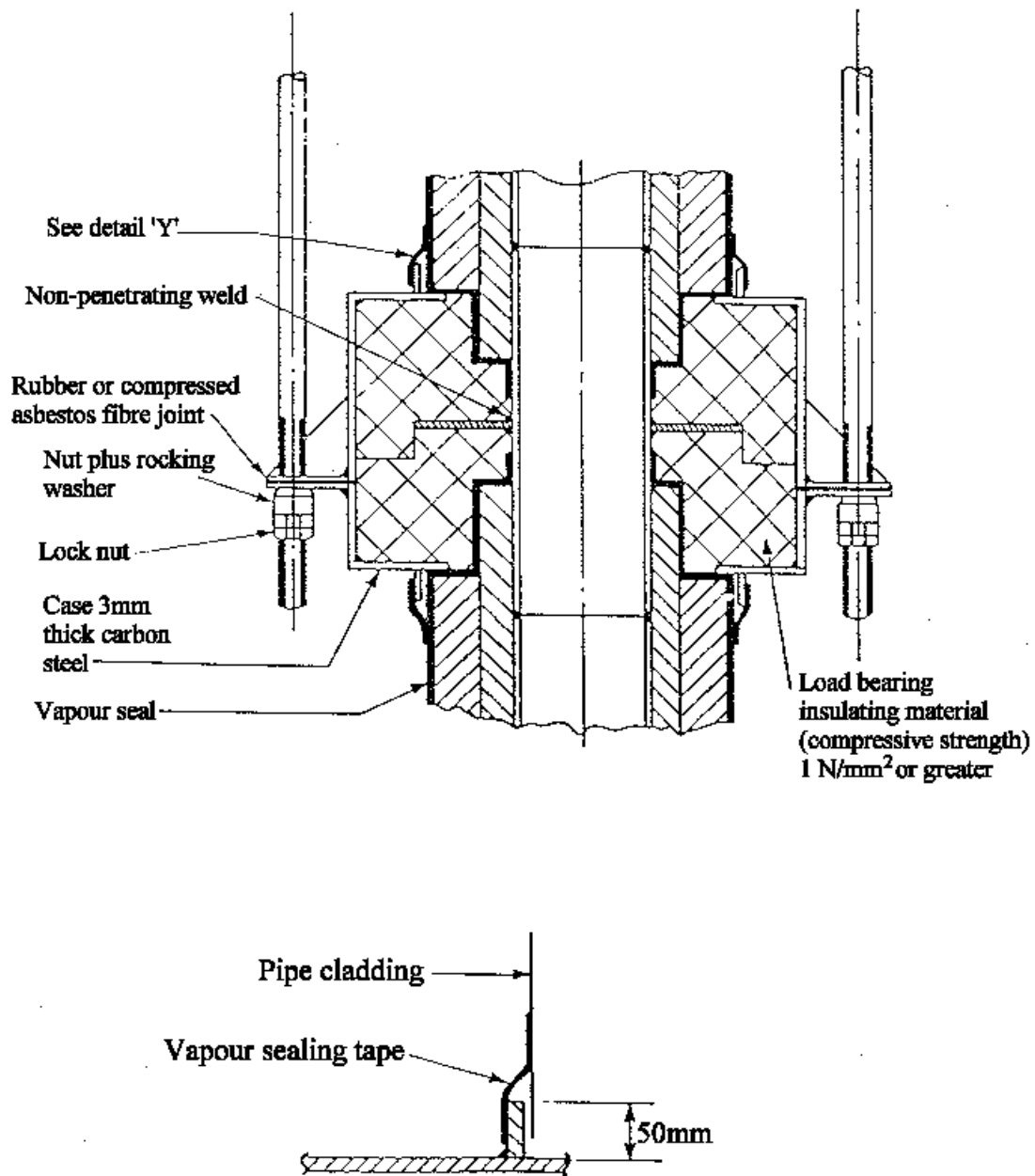


FIGURE 13

THERMAL INSULATION AT PIPE HANGERS - VERTICAL PIPE

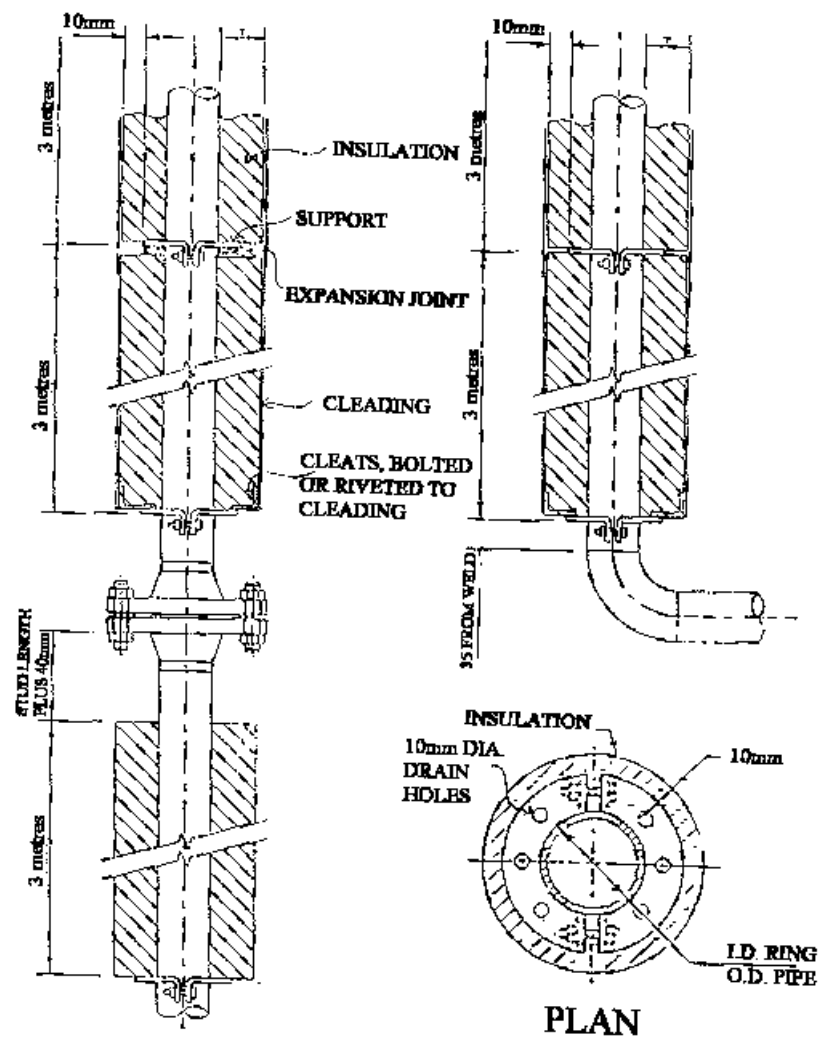
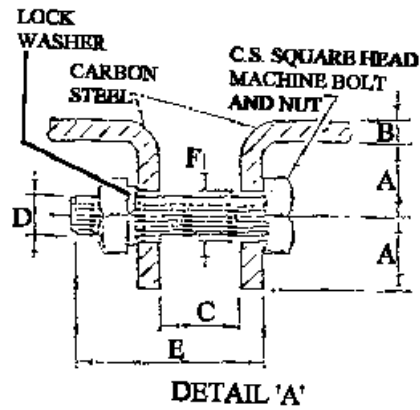


FIGURE 14 (PAGE 1 OF 2)

THERMAL INSULATION SUPPORTS FOR VERTICAL INSULATED PIPE



SUPPORT DIMENSIONS							
PIPE SIZE	LD RING	A	B	C	D	E	F
1/2	7/8	1/2	1/8	1/8	1/4	1	3/8
3/4	1 1/16	1/2	1/8	1/8	1/4	1	3/8
1	1 5/16	1/2	1/8	1/8	1/4	1	3/8
1-1/2	1 15/16	1/2	1/8	1/8	1/4	1	3/8
2	2 3/8	3/4	1/16	1/16	3/8	1 1/4	1/2
3	3 1/2	3/4	3/16	1/16	3/8	1 1/4	1/2
4	4 1/2	3/4	3/16	3/16	3/8	1 1/4	1/2
6	6 5/8	3/4	3/16	3/16	1/8	1 1/4	1/2
8	8 5/8	1	1/4	1/4	1/2	1 1/2	5/8
10	10 3/4	1	1/4	1/4	1/2	1 1/2	5/8
12	12 3/4	1	1/4	1/4	1/2	1 1/2	5/8
14	14	1	1/4	1/4	1/2	1 1/2	5/8
16	15	1	1/4	1/4	1/2	1 1/2	5/8
18	18	1	1/4	1/4	1/2	1 1/2	5/8
20	20	1	1/4	1/4	1/2	1 1/2	5/8
24	24	1	1/4	1/4	1/2	1 1/2	5/8

FIGURE 14 (PAGE 2 OF 2)

THERMAL INSULATION SUPPORTS FOR VERTICAL INSULATED PIPE

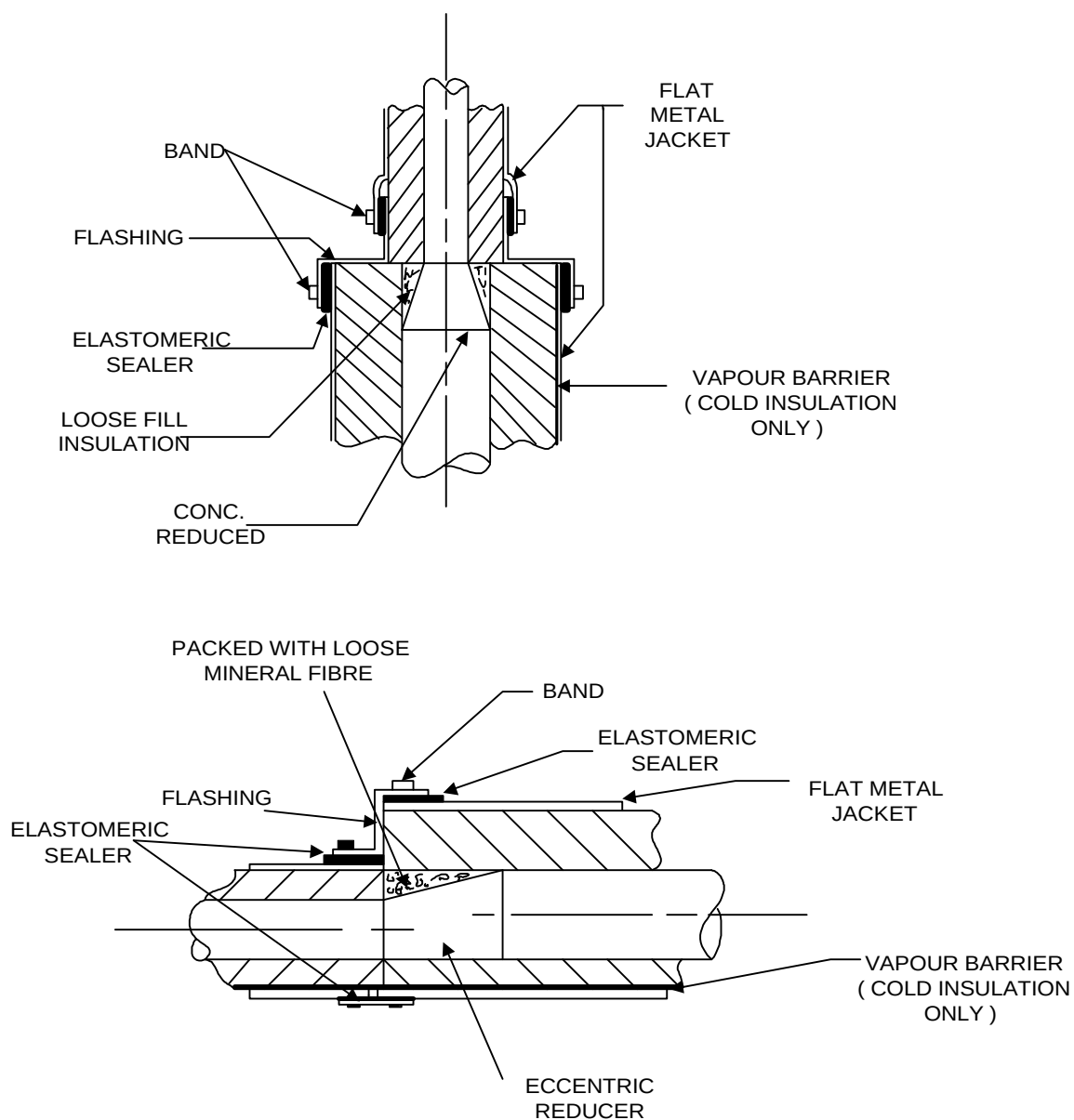
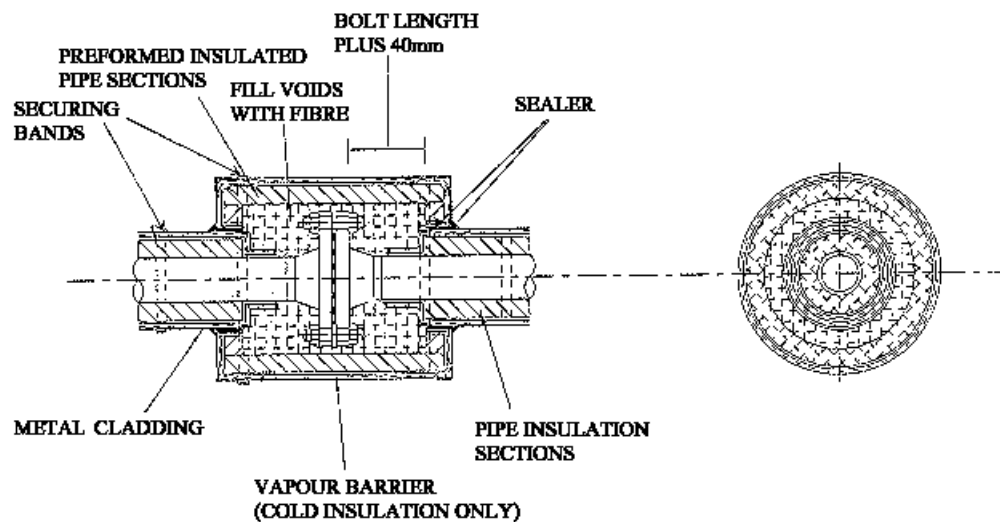
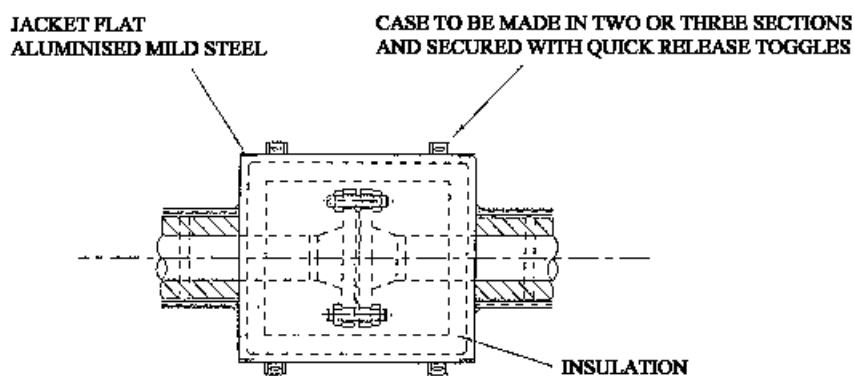
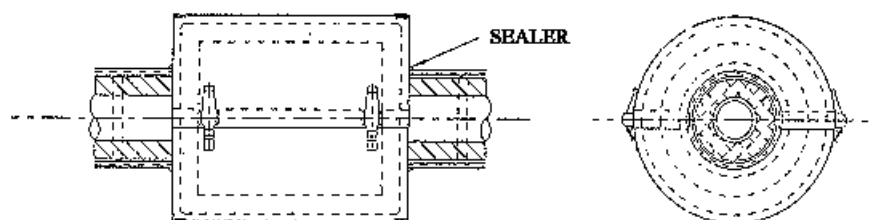


FIGURE 15

THERMAL INSULATION DETAILS FOR REDUCERS



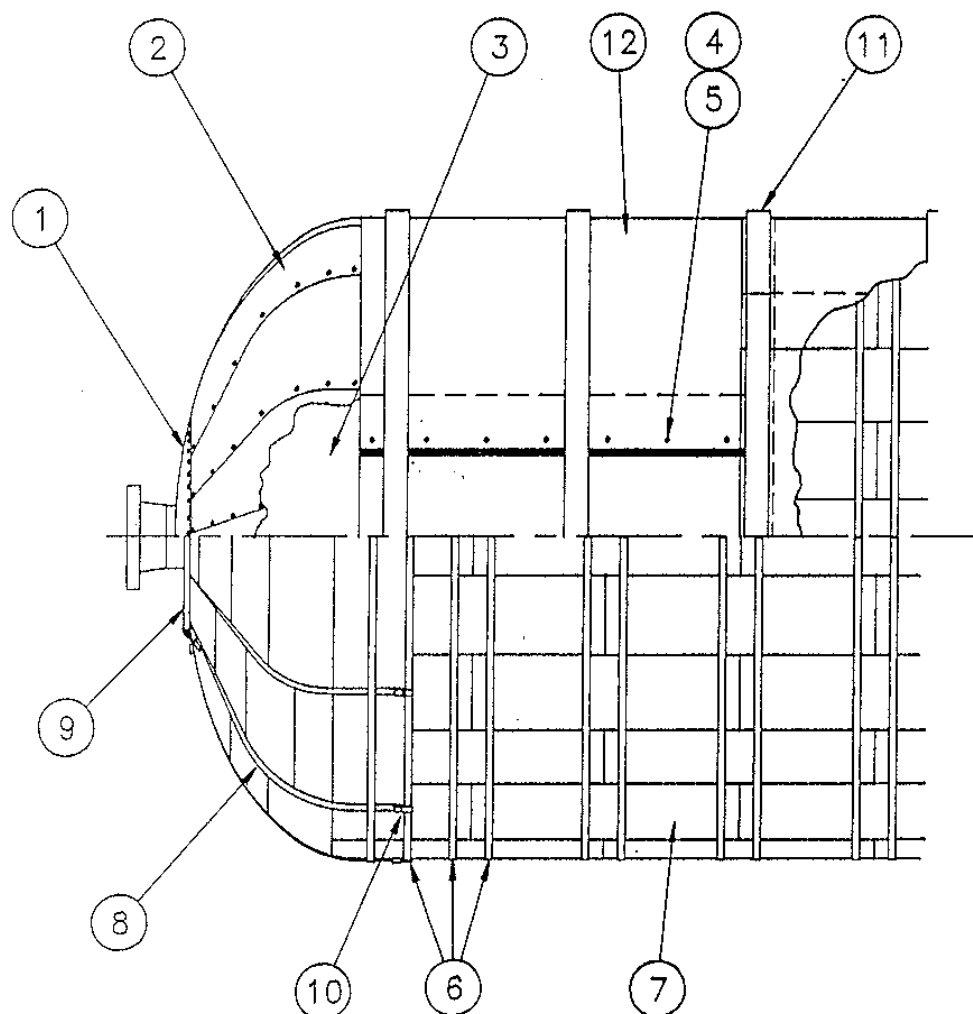
(A) PERMANENT COVERS



(B) REMOVABLE COVERS

FIGURE 16

THERMAL INSULATION DETAILS FOR FLANGES



ITEM	DESCRIPTION
12	CLADDING
11	CLADDING SECURING BANDS
10	HEAD BAND TIES
9	FLOATING RING
8	INSULATION RETAINING HEAD BANDS
7	STAGGERED INSULATION BLOCKS
6	INSULATION RETAINING BANDS
5	SELF TAPPING SCREW W/NEOPRENE WASHERS
4	BUTYL MASTIC STRIP
3	VAPOUR BARRIER (COLD INSULATION ONLY)
2	'ORANGE PEEL' CLADDING
1	SEALING CAP OR DISC

FIGURE 17

**THERMAL INSULATION FOR HORIZONTAL VESSELS - GENERAL
ARRANGEMENT**

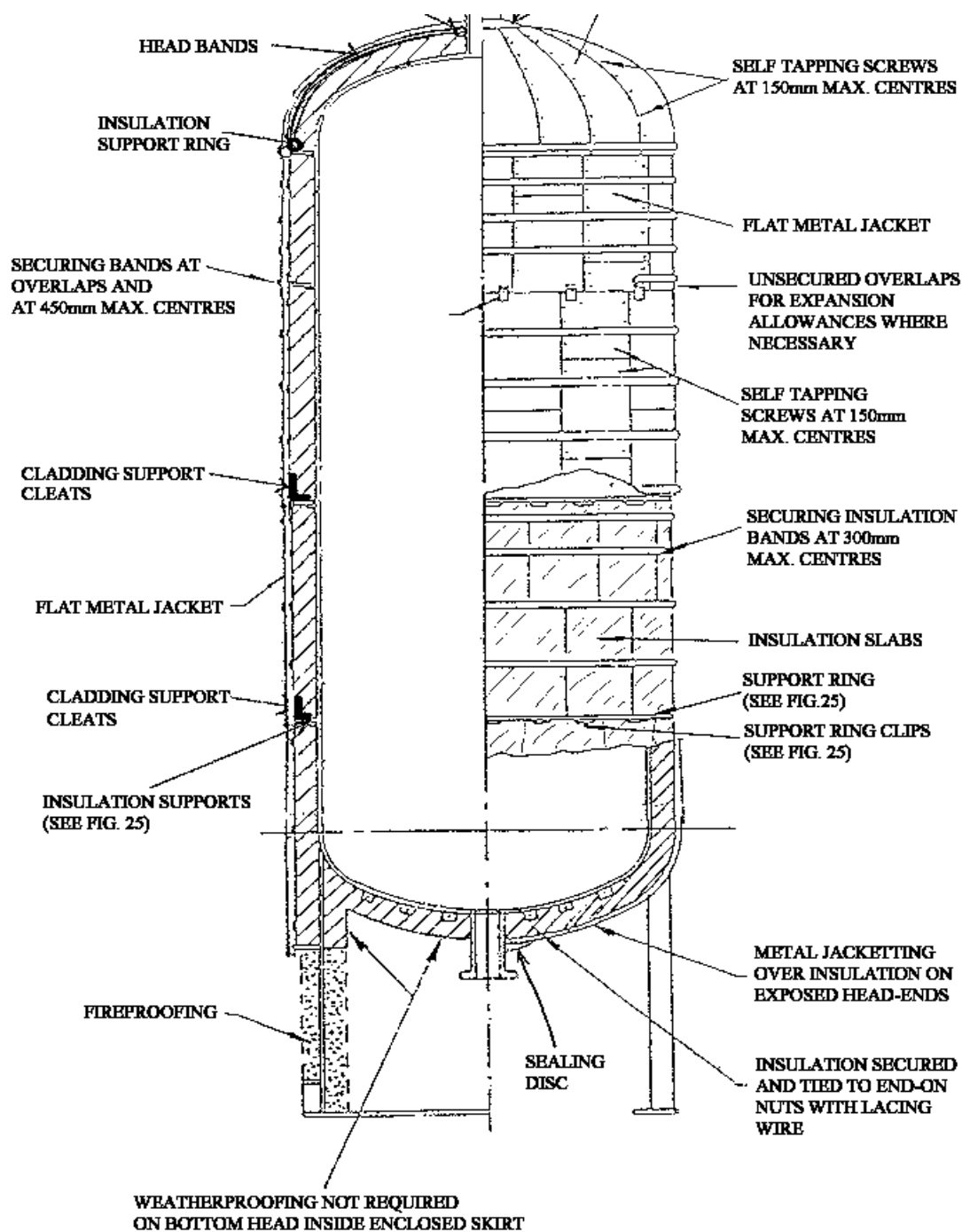
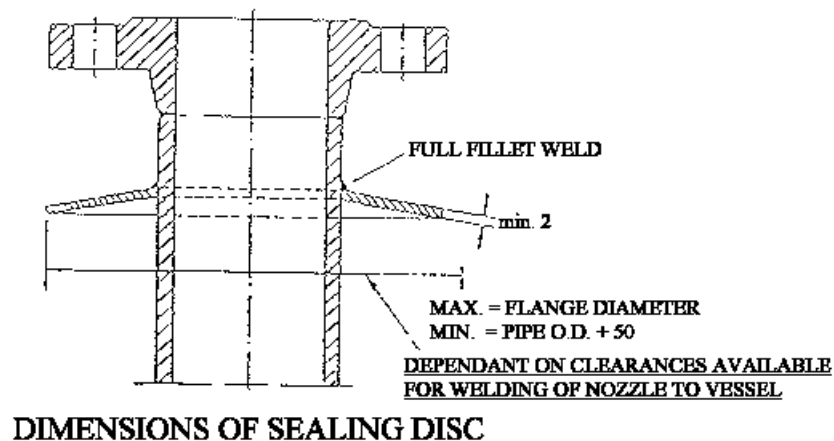
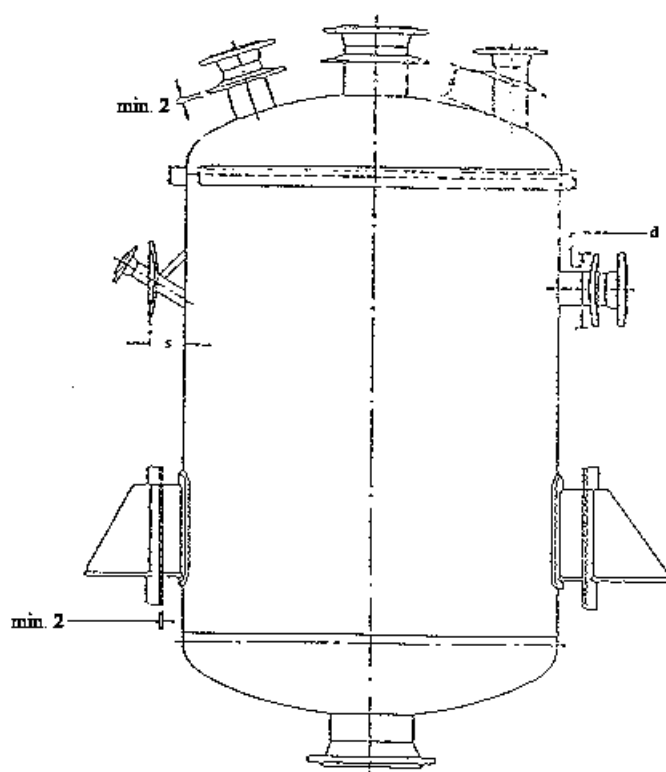


FIGURE 18

THERMAL INSULATION FOR VERTICAL VESSELS - GENERAL ARRANGEMENT



DIMENSIONS OF SEALING DISC

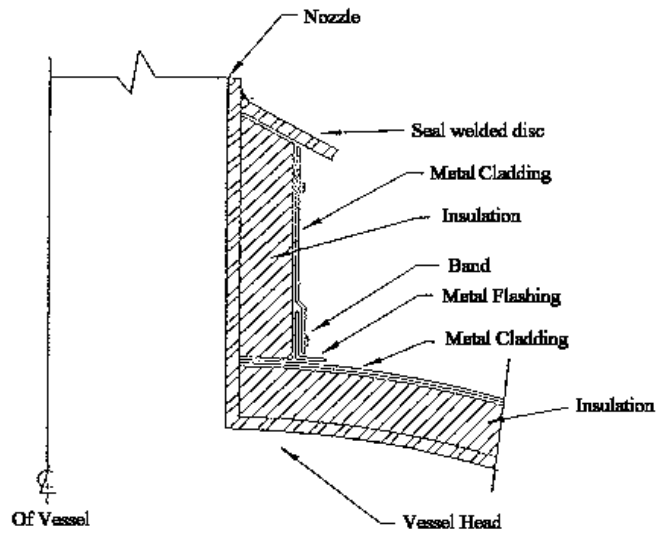


d = AS LARGE AS POSSIBLE BETWEEN
 MAX. = FLANGE DIAMETER
 MIN. = PIPE O.D. + 50

s = INSULATION THICKNESS
 (ALL DIMENSIONS IN MM)

FIGURE 19

TYPICAL ARRANGEMENTS FOR SEALING DISCS AND PLATES ON VERTICAL VESSELS



(A) Insulation Detail for Centre Nozzle at Top Head of Vessel

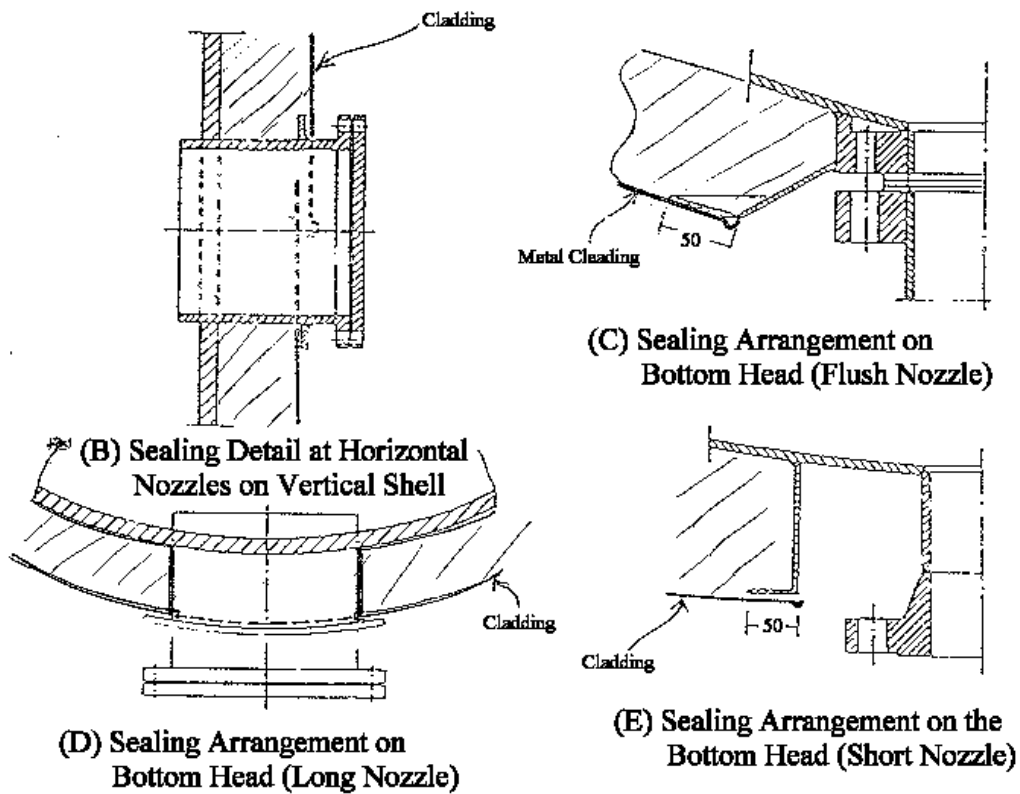
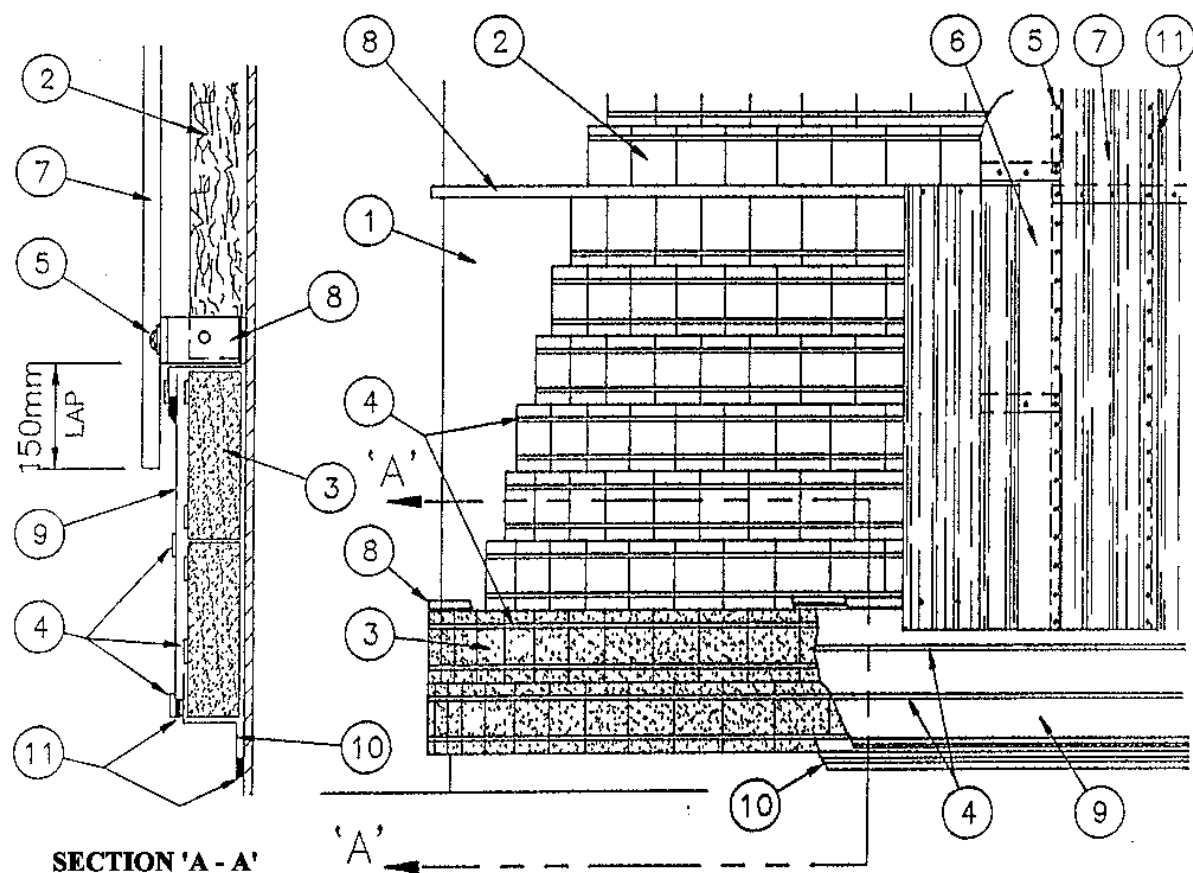


FIGURE 20

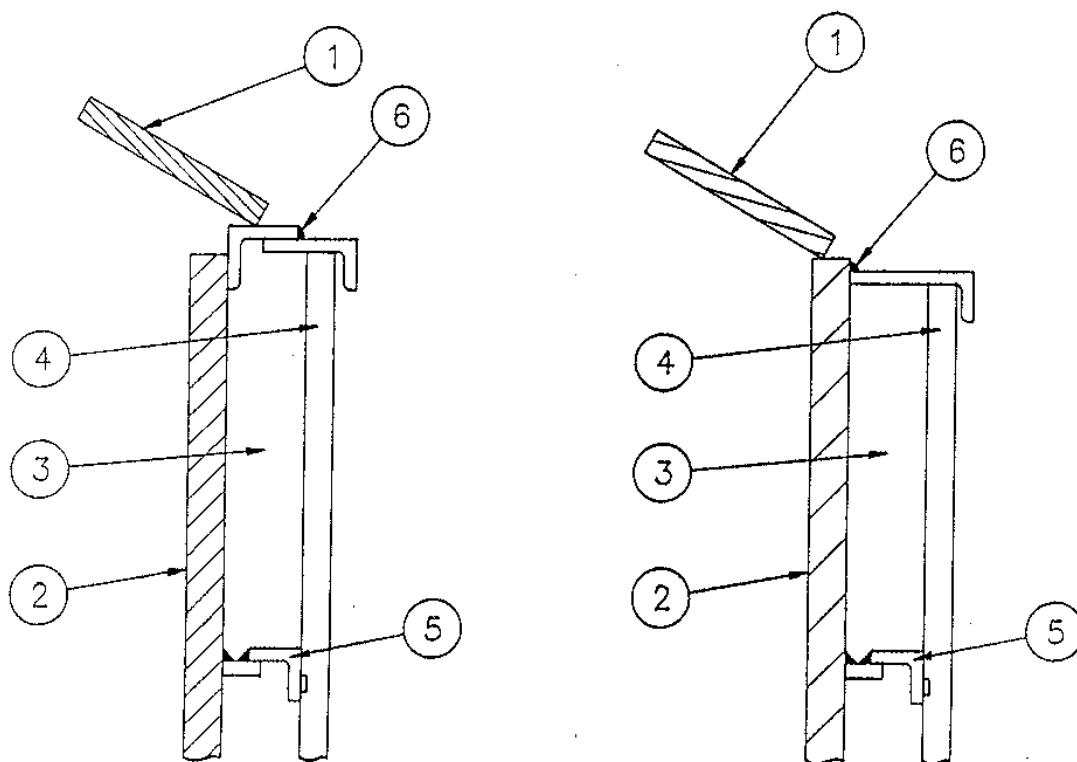
THERMAL INSULATION AND CLADDING DETAILS AT VESSEL SEALING DISCS



ITEM	DESCRIPTION
11	BUTYL MASTIC STRIP (TYP VERTICAL SEAMS)
10	FLAT SHEET METAL FOAM GLASS SUPPORT ANGLE
9	FLAT SHEET METAL FOAM GLASS SHROUD
8	MILD STEEL CLADDING SUPPORT FRAME
7	TROUGHED OR CORRUGATED CLADDING AS SPECIFIED
6	FLAT SHEET METAL EXPANSION PIECE
5	SS SCREWS WITH NEOPRENE WASHERS
4	SS BANDS SECURED WITH EXPANSION STRAPS
3	ANTI-ABRASIVE FOAM GLASS SLAB
2	MINERAL FIBRE SLAB
1	TANK SHELL

FIGURE 21

THERMAL INSULATION FOR STORAGE TANKS

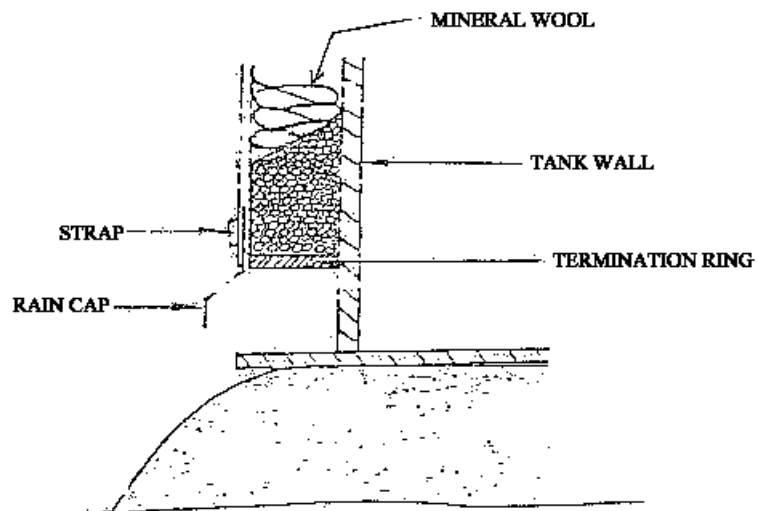


ITEM	DESCRIPTION
6	CONTINUOUS SEAM WELD
5	INSULATION SUPPORT RING
4	CLADDING
3	INSULATION
2	TANK SHELL
1	ROOF PLATE

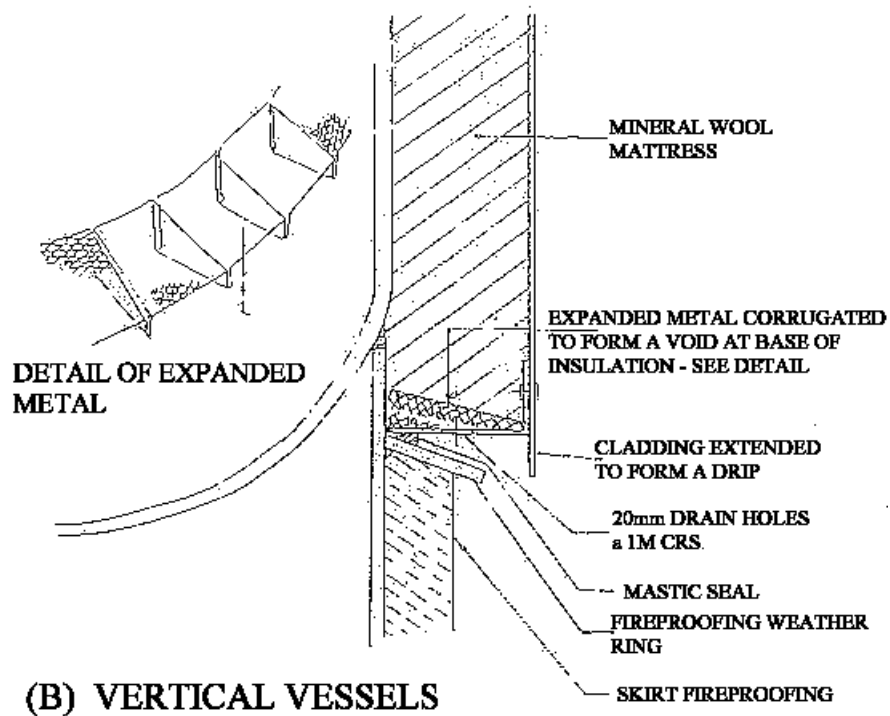
FIGURE 22

WEATHERPROOF TANK, ROOF TO SHELL TRANSITION DETAIL

FOAM GLASS BLOCK TO PREVENT WICKING



(A) TANKS



(B) VERTICAL VESSELS

FIGURE 23

TYPICAL THERMAL INSULATION BOTTOM END DETAILS FOR TANKS AND VERTICAL VESSELS

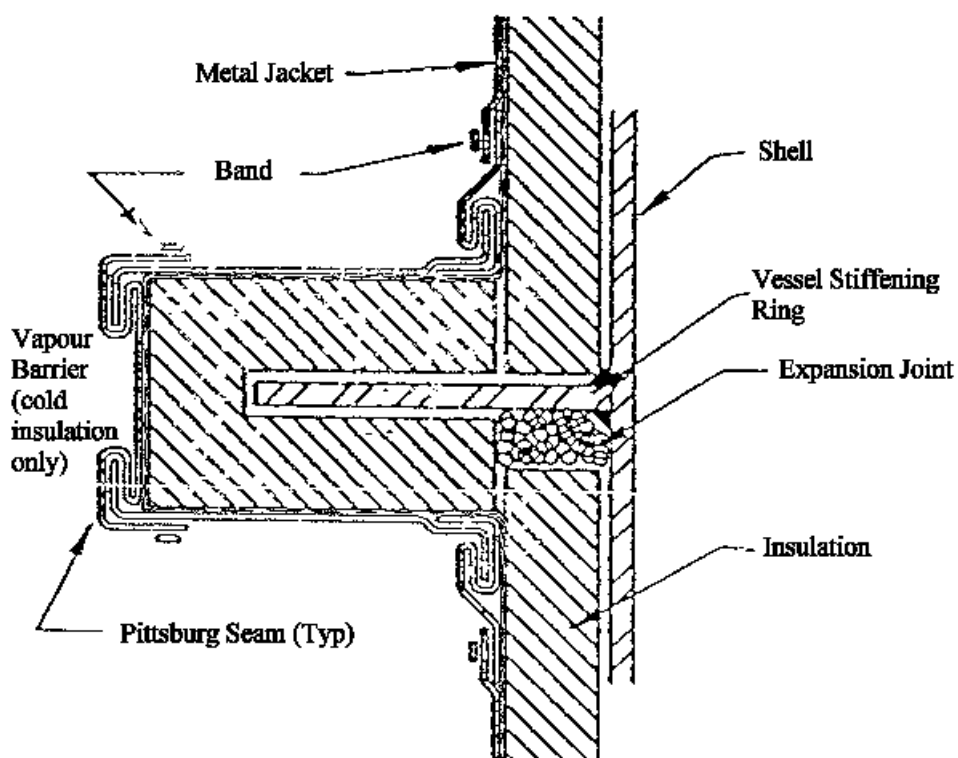


FIGURE 24

TYPICAL INSULATION DETAIL AT STIFFENING RINGS

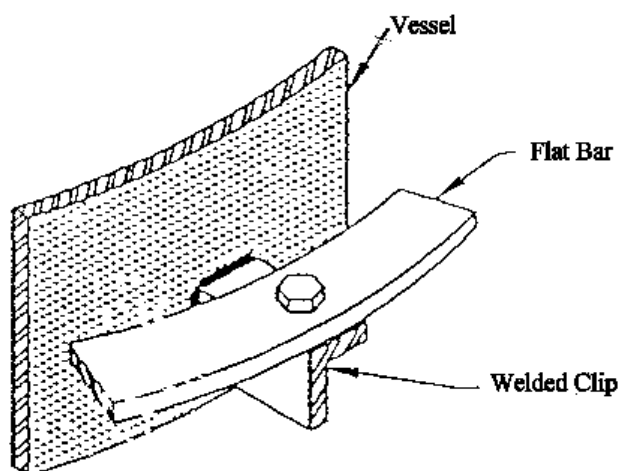


FIGURE 25

TYPICAL THERMAL INSULATION SUPPORT DETAIL FOR VERTICAL VESSELS AND TANKS TO PREVENT MOISTURE ACCUMULATION

DEFINITIONS AND ABBREVIATIONS**Definitions**

Standardised definitions may be found in the BP Group RPSEs Introductory Volume.

Abbreviations

AISI	American Iron and Steel Institute
ASTM	American Society for Testing Materials
BS	British Standard
COSHH	Control of Substances Hazardous to Health
CUI	Corrosion under Insulation
EEMUA	Engineering Equipment and Materials Users Association
ISO	International Organisation for Standardisation
LNG	Liquefied natural gas
NPS	Nominal pipe size
OD	Outside Diameter
SI	Système International d'Unités

LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Referenced standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards.

International

ISO 1182	Fire tests - Building Materials - Non-combustibility test
ISO 3575	Continuous hot dipped zinc coated carbon steel sheet
ISO 5000	Continuous hot dipped aluminium-silicon coated cold reduced carbon steel sheet
ISO 8142	Thermal insulation - Bonded preformed man-made mineral fibre pipe sections
ISO 9364	Continuous hot dipped aluminium-zinc coated steel sheet
ISO 9000	Quality Management and Quality Assurance Standards

British Standards

BS 476	Fire tests on building materials and structures: Part 7 Method of classification of the surface spread of flames of products
BS 1706	Electroplated coatings of cadmium and zinc on iron and steel.
BS 2654	Specification for the manufacture of vertical steel welded non-refrigerated storage tanks with butt welded shells for the petroleum industry.
BS 2989	Specification for continuously hot-dip zinc coated and iron-zinc alloy coated steel
BS 2972	Methods of test for inorganic thermal insulating materials.
BS 3927	Specification for rigid phenolic foam for thermal insulation in the form of slabs and profiled sections.
BS 3958	Specification for thermal insulating materials Part 1: Magnesia preformed insulation Part 2: Calcium silicate preformed insulation Part 3: Metal mesh faced man-made mineral wool mats and mattresses Part 4: Bonded preformed man-made mineral fibre pipe sections Part 5: Bonded man-made mineral wool slabs (For use at temperatures above 50°C) Part 6: Finishing materials; hard setting composition, self-setting cement and gypsum plaster.
BS 5241	Rigid polyurethane (PUR) and polyisocyanurate (PIR) foam when dispensed or sprayed on a construction site.

BS 5422	Method for specifying thermal insulating materials on pipes, ductwork and equipment (in the temperature range 40°C to +700°C)
BS 5608	Specification for preformed rigid polyurethanes (PUR) and polyisocyanurate (PIR) foam for thermal insulation of pipework and equipment
BS 5750	Quality Management and Quality Assurance Standards
BS 5970	Code of Practice for thermal insulation of pipework and equipment (in the temperature range -100°C to +870°C)
BS 6536	Continuous hot dip aluminium-silicon coated cold reduced carbon steel sheet and strip
BS 6351	Electrical surface heating: Part 2 Guide to design of electrical surface heating systems
BS 6830	Continuous hot dip aluminium-zinc coated cold reduced carbon steel flat products

American

ASTM A167	Standard specification for stainless and heat-resisting chromium-nickel steel plate, sheet and strip.
ASTM A463	Specification for steel sheet, cold rolled, aluminium coated, Type 1 and Type 2
ASTM A526	Specification for steel sheet, zinc coated (galvanised) by the hot dip process, commercial quality
ASTM A792	Specification for steel sheet, 55% aluminium-zinc alloy coated by the hot dip process
ASTM B209	Specification for aluminium and aluminium alloy sheet and plate
ASTM C516	Specification for vermiculite loose fill thermal insulation
ASTM C549	Specification for perlite loose fill insulation.
ASTM C552	Specification for cellular glass block and pipe thermal insulation
ASTM C647	Guide for properties and tests of mastics and coatings for thermal insulation
ASTM C1029	Specification for spray applied rigid cellular polyurethane thermal insulation
ASTM E84	Test method for surface burning characteristics of building materials
ASTM C755	Standard Practice for selection of Vapour Retards for Thermal Insulation

BP Group Documents

BP Group RP 24-1	Fire Protection - Onshore
BP Group RP 24-2	Fire Protection - Offshore
BP Group RP 44-7	Plant Layout
BP Group GS 106-2	Painting of Metal Surfaces



Others

COSHH	Control of substances hazardous to health (UK Regulations).
EEMUA Publication 142	Noise-acoustic insulation of pipes, valves and flanges
EN 29000	Quality Management and Quality Assurance Standards