

DESIGN GUIDE

INDUSTRIAL

**CSR**<sup>™</sup>  
**Bradford**  
**Insulation**

**INDUSTRIAL**

Insulation Design Guide

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## Introduction.

The Bradford Insulation Group forms part of the Building Materials Division of CSR Limited.

Bradford Insulation manufactures and markets a wide range of insulation products which offer excellent thermal resistance properties for temperature control and energy conservation as well as outstanding acoustic and fire performance.

Two bulk insulation materials are available; 'Bradford Glasswool', which is manufactured by controlled felting of glass wool bonded with a thermosetting resin; and 'Bradford Fibertex™ Rockwool' which is spun from natural rock and bonded with a thermosetting resin. Both are available in sheet or roll form and as moulded pipe insulation.

Bradford Thermofoil™ comprises a range of aluminium foil laminates available in various grades.

All Bradford Insulation products are tested to meet stringent quality control standards incorporating quality management systems such as AS3902/ISO9002.

### TECHNICAL ASSISTANCE.

The purpose of this 'Guide' is to provide an insight into the design and application considerations for insulation systems as applied to industrial vessels, pipework and equipment.

The range of Bradford products and their applications is presented along with data and worked examples to illustrate design considerations. System specifications for typical applications are also included.

This guide deals primarily with thermal performance of Bradford insulation products and systems. Additional specific information is available in the Bradford Insulation Acoustic Design Guide, and the Bradford Insulation Fire Protection Design Guide.

To assist designers, a free and comprehensive technical service offering advice and assistance in specifying and using Bradford products is available from Bradford Insulation offices in your region. Further technical data and product updates are also available on the CSR Building Solutions Website: [www.csr.com.au/bradford](http://www.csr.com.au/bradford)

Information included in this Design Guide relates to products as manufactured at the date of publication. As the Bradford Insulation policy is one of continual product improvement, technical details as published are subject to change without notice.

# Industrial Insulation Product Range.

Bradford Fibertex Rockwool is the most widely used industrial insulation with grades suitable for a range of applications with maximum service temperatures up to 820°C.

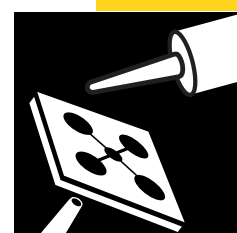
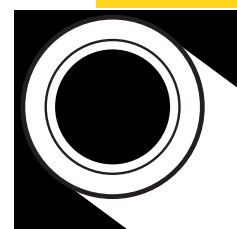
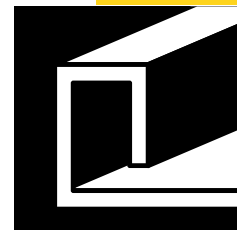
The Bradford Glasswool industrial range includes products suitable for applications up to 450°C with the advantage of relatively lower density.

Bradford Industrial Insulation Product	Density* kg/m <sup>3</sup>	Max. Service Temp °C
FIBERTEX™ 350 Rockwool	60	350
FIBERTEX™ 450 Rockwool	80	450
FIBERTEX™ 650 Rockwool	100	650
FIBERTEX™ 820 Rockwool (Marine Grade)	110	820
FIBERTEX™ HD Rockwool	120	650
FIBERTEX™ Rockwool Pipe Insulation (SPI)	>120	750 <sup>①</sup>
FIBERTEX™ V-LOCK Rockwool Pipe Wrap	128	650
FIBERMESH™ 350 Rockwool	60	350
FIBERMESH™ 450 Rockwool	80	450
FIBERMESH™ 650 Rockwool	100	650
FIBERMESH™ 820 Rockwool	110	820
FIBERTEX™ Loose CR Rockwool (Cryogenic)	†	-250 (min)
FIBERTEX™ Loose Rockwool	†	450
FIBERTEX™ Loose HT Rockwool	†	650
FIRESEAL™ Loose Rockwool	†	820
Glasswool SUPERTEL™	32	350
Glasswool ULTRATEL™	48	350
Glasswool HT THERMATEL™	44	450
Glasswool QUIETEL™	130	350
Glasswool Pipe Insulation (SPI)	60	450

\* Specialty density board, blanket and pipe insulation and factory applied facings are available subject to minimum order quantities.

† FIBERTEX™ Loose/Granulated Rockwool products are installed to specified packed densities.

① FIBERTEX™ SPI 750 not available in all regions. Please refer to the Product Guides or contact the CSR Bradford Insulation office in your region.



# Application Guide for

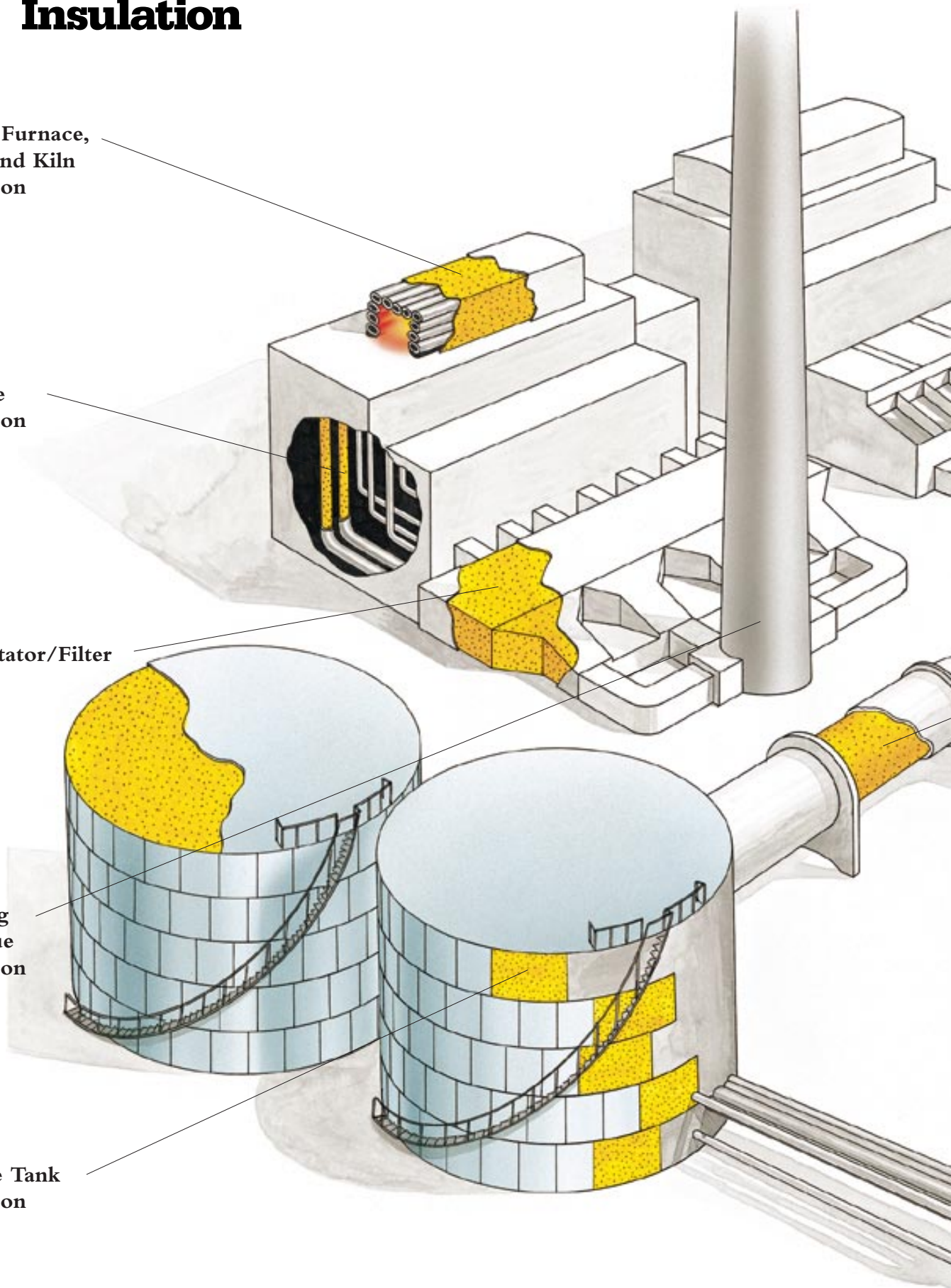
**1** Boiler, Furnace,  
Drier and Kiln  
Insulation

**2** Turbine  
Insulation

**3** Precipitator/Filter  
Lining

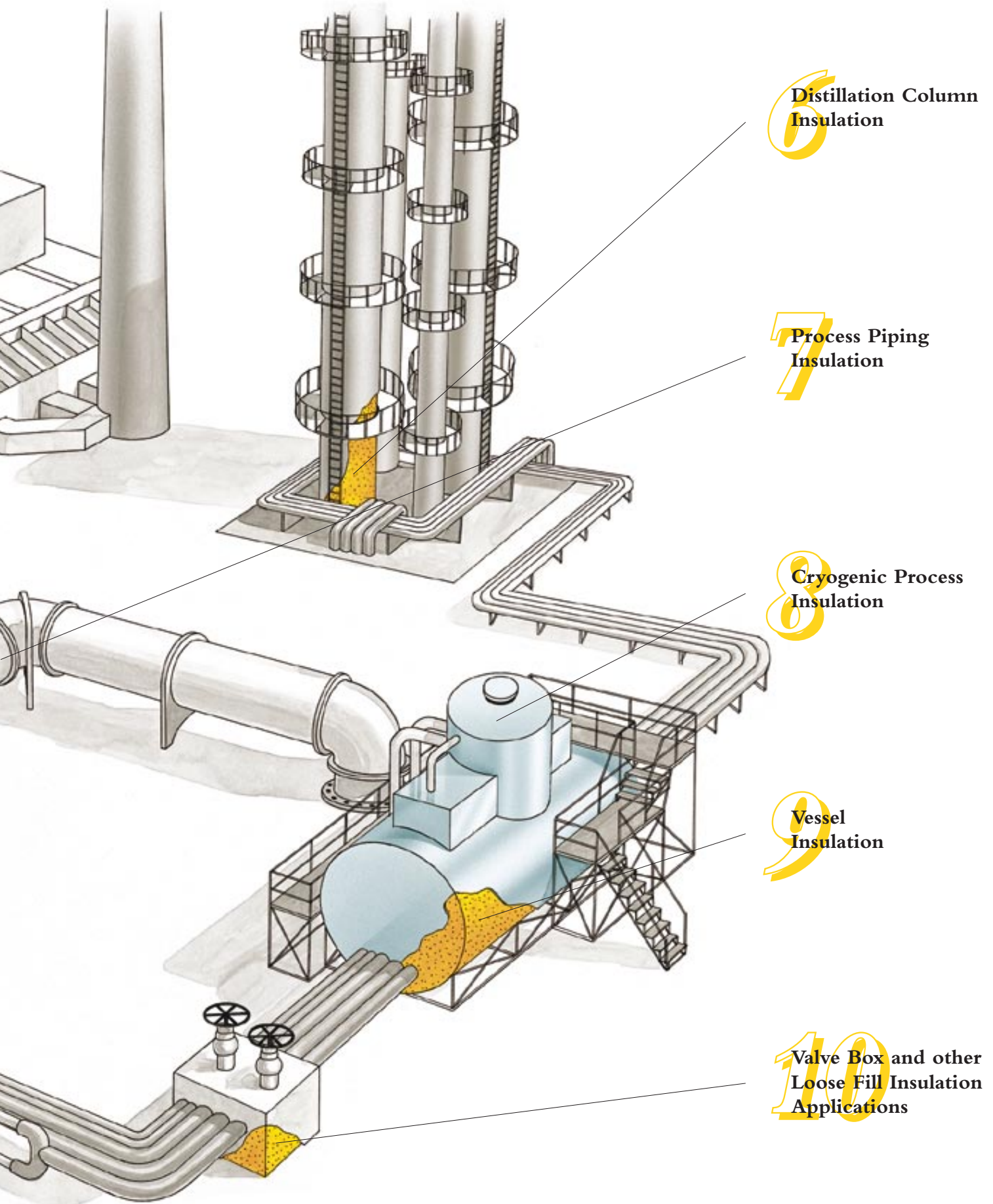
**4** Ducting and Flue  
Insulation

**5** Storage Tank  
Insulation





# Industrial Insulation.



Refer to Page 6 for Bradford Insulation Product Selection Recommendations

## Applications & Selection Guide for Industrial Insulation.

Insulation Application (Refer to Pages 4 – 5)		Max. Operating Temperature °C	Product Type
<b>1</b>	Boiler, Furnace, Drier and Kiln Insulation	450	Bradford FIBERTEX™ 450/FIBERMESH™ 450 Rockwool
		650	Bradford FIBERTEX™ 650/FIBERMESH™ 650 Rockwool
		820	Bradford FIBERTEX™ 820/FIBERMESH™ 820 Rockwool
<b>2</b>	Turbine	450	Bradford FIBERTEX™ 450/FIBERMESH™ 450 Rockwool
		650	Bradford FIBERTEX™ 650/FIBERMESH™ 650 Rockwool
		820	Bradford FIBERTEX™ 820/FIBERMESH™ 820 Rockwool
<b>3</b>	Precipitator /Filter Lining	350	Bradford FIBERMESH™ 350 Rockwool
		450	Bradford FIBERMESH™ 450 Rockwool
<b>4</b>	Ducting/Flues	350	Bradford FIBERTEX™ 350/FIBERMESH™ 350 Rockwool
		450	Bradford FIBERTEX™ 450/FIBERMESH™ 450 Rockwool
		650	Bradford FIBERTEX™ 650/FIBERMESH™ 650 Rockwool
		820	Bradford FIBERTEX™ 820/FIBERMESH™ 820 Rockwool
<b>5</b>	Storage Tanks	250	Bradford THERMACLAD™ Panel System
		350	Bradford FIBERTEX™ 350/FIBERMESH™ 350 Rockwool
		350	Bradford Glasswool SUPERTEL™
		450	Bradford FIBERTEX™ 450/FIBERMESH™ 450 Rockwool
		650	Bradford FIBERTEX™ HD Rockwool
		450	Bradford Glasswool HT THERMATEL™
<b>6</b>	Distillation Columns	650	Bradford FIBERTEX™ 650/FIBERMESH™ 650 Rockwool
		820	Bradford FIBERTEX™ 820/FIBERMESH™ 820 Rockwool
<b>7</b>	Process Piping	450	Bradford Glasswool Pipe Insulation
		750	Bradford FIBERTEX™ Rockwool Pipe Insulation
		650	Bradford FIBERMESH™ 650 Pipe Wrap
		650	Bradford FIBERTEX™ V-LOCK Pipe Wrap
<b>8</b>	Cryogenic Process	Min -250	Bradford FIBERTEX™ Loose Industrial CR
<b>9</b>	Process Vessels	350	Bradford FIBERTEX™ 350/FIBERMESH™ 350 Rockwool
		350	Bradford Glasswool SUPERTEL™
		450	Bradford FIBERTEX™ 450/FIBERMESH™ 450 Rockwool
		450	Bradford Glasswool HT THERMATEL™
		650	Bradford FIBERTEX™ 650/FIBERMESH™ 650 Rockwool
		820	Bradford FIBERTEX™ 820/FIBERMESH™ 820 Rockwool
<b>10</b>	Valve Boxes and Loose Fill Applications	350	Bradford FIBERTEX™ 350/FIBERMESH™ 350 Rockwool
		450	Bradford FIBERTEX™ 450/FIBERMESH™ 450 Rockwool
		450	Bradford FIBERTEX™ Loose Rockwool
		650	Bradford FIBERTEX™ Loose HT Rockwool
		820	Bradford FIRESEAL™ Loose Rockwool

# Design Considerations.

In the selection and design of the optimum type of insulation for industrial systems, there are several factors which should be considered to ensure satisfactory performance of the overall system.

CONSIDERATION.	ACTION.
Surface Operating Temperature	Choose insulation grade capable of operating continuously at maximum expected design temperature.
Surface Size and Shape	Choose insulation in appropriate form; semi-rigid board, flexible blanket, pipe insulation.
Heat Transfer and Thermal Conductivity	Select material with low thermal conductivity at design operating temperatures.
Process Control Requirements	Understand the type of process and the control requirements
Economic Thickness of Insulation	Design insulation thickness based on operating temperature, ambient conditions, thermal conductivity of insulation, external surface cladding type.
Personnel Protection	Design for maximum safe temperature of cladding surfaces.
Condensation Control	Design with respect to dew point at expected atmospheric conditions.
Noise Control	Choose insulation of sufficient density and thickness for required noise attenuation to be achieved.
Minimisation of Stress Corrosion Cracking Risk	Use insulation deemed suitable for use with Austenitic Stainless Steel
Punking of Thermal Insulation	Select insulation with low binder content and specify controlled gradual heating during plant start-up.
Fire Protection	Select material with suitable fire resistance for protection of people and equipment.
Moisture Resistance & Water Repellency	Select material with low water absorption.
Mechanical Properties	Ensure dimensional stability, compressive strength, vibration resistance, rigidity or flexibility are satisfactory for purpose.
Durability	Select suitable product for the application and operating conditions.
Environmental and Biological Aspects	Choose environmentally friendly insulation products for ecologically sustainable development.
Installed Cost	Select insulation products and systems for ease of installation and low maintenance.
Cladding Selection	Selection of cladding material for service requirements and durability.
Original Equipment Manufacturing	Determine dimensional tolerances to provide for ease of installation.
Health & Safety	Observe MSDS recommendations.

## Surface Operating Temperature.

Thermal insulation products must be suitable for the maximum operating temperature of the metal surface which is to be insulated.

The maximum service temperatures for mineral fibre insulation is specified to ensure minimal dimension change and low thermal conductivity at the design temperature. Higher density products are required at elevated temperatures for dimensional stability and the low conductivity of radiant heat. Selecting the optimum density will ensure the most economic thickness of insulation is used.

The range of Bradford mineral fibre products are suitable for a maximum service temperature of 350°C up to 820°C, and all are suitable for sub-zero operating temperatures. For faced products the temperature at the facing should not exceed the melt temperature of the adhesive or facing material.

Glasswool and Fibertex Rockwool products suitable for maximum temperatures of 450°C or 820°C respectively, and are available to meet the insulation requirements for the vast majority of industrial operating temperatures.

Particular attention is required for vessels or pipes which may operate at below ambient temperatures but which may be heated for maintenance cleaning.

Maximum service temperatures for the full range of Bradford Insulation industrial products are shown in the Product Selection Guide.

## Surface Shape and Size.

To minimise heat loss or gain from a surface, the insulation product must be installed firmly against the surface. The size and shape of the surface to be insulated shall be considered when selecting a suitable insulation material and installation method. Bradford Insulation offers a range of product to suit surfaces of all shapes and sizes.

Flat or curved surfaces are ideally insulated with Bradford Fibertex Rockwool products. The Fibertex range includes semi-rigid boards or Flex-skin flexible rolls.

Bradford Glasswool Supertel, Ultratel, HT Thermatel and Quietel are available as boards or rolls which are both easy to handle and suitable for applications such as roofs of process vessels or storage tanks. Bradford Fibertex 820, Fibertex HD, Bradford Glasswool Quietel and some other specialty high density products are available in board form only.

Irregular surfaces are best suited to the Fibermesh Rockwool range of products. Varieties include Fibermesh 350, 450 and 650, and as the name suggests, each product consists of Rockwool fibres stitched with wire to a facing of galvanised or stainless steel hexagonal mesh. Apart from the addition of this wire mesh, the only other physical difference to conventional Fibertex products is the reduced binder content to allow even greater flexibility.

Bradford Fibertex Rockwool Loose Industrial CR and HT are used commonly for insulating around tight and irregular spaces, often where access is difficult.

Pipes may be insulated with Fibertex Rockwool Pipe Insulation and Glasswool Pipe Insulation to maximum service temperatures of 650°C and 450°C respectively. For large diameter pipes, Fibertex V-Lock or Fibermesh 650 Pipe Wrap are suitable to 650°C.

## Heat Transfer and Thermal Conductivity.

The thermal conductivity, or k-value (W/mK) is a measure of heat transfer through a material and therefore is the principle property of an insulation material. If a temperature difference exists between two parts of a system heat transfer will take place. There are three modes of heat transfer in a mineral wool insulation:—

### CONDUCTION.

The flow of heat by conduction results from a transfer of vibrational energy from one molecule to another. This energy transfer occurs as Fibre Conduction; within fibres and between fibres in contact with one another, and as Air Conduction; conduction between molecules of air trapped in tiny cavities.

### CONVECTION.

Heat transfer by convection occurs from the movement of heated air rising and the subsequent replacement by gravity of colder, denser air. If the air movement arises from the heat transfer process itself natural convection occurs. Convection heat flow adds very little contribution to the total k-value of Glasswool and Fibertex Rockwool industrial insulation products.

### RADIATION.

Heat flow from radiation is caused by electromagnetic waves which are reflected, transmitted or absorbed by a material. The effect of radiation heat transfer rises significantly at higher temperatures, however high density mineral fibre will effectively reduce heat flow from radiation.



In many applications of heat transfer, each of the mechanisms of conduction, convection and radiation are involved.

The total heat flow is a sum total of the individual modes of heat transfer.

$$Q_{\text{total}} = Q_{\text{conduction}} + Q_{\text{convection}} + Q_{\text{radiation}}$$

## THERMAL CONDUCTIVITY.

The thermal conductivity of an insulating material will vary with the mean temperature under operating conditions. In heat transfer calculations, the thermal conductivities are derived for the design operating temperature and calculated mean temperature, dependant on the thickness and type of insulation. Selection of insulation with the lowest thermal conductivity under operating conditions will result in minimum insulation thickness required for a given maximum heat loss or surface temperature.

Bradford Insulation offers a free and comprehensive technical service to undertake heat transfer calculations and economic thickness analysis for your specific design conditions. For assistance, contact the Bradford Insulation office in your region.

Typical thermal conductivity (k) values of insulation boards and blankets are derived from measurements taken in accordance with laboratory test methods detailed in AS2464.6, ASTM C177 or BS874. Pipe insulation is tested to ASTM C335.

Detailed thermal conductivity data is shown in Appendix B of this guide. The derived values are given as design performance data of the insulating material at stated mean temperatures without factors of safety or other allowances for overall installed system performance.

In specifying or guaranteeing thermal performance levels of an installed insulation system, the designer or contractor should give due consideration to making appropriate allowance for;

- Varying temperature differentials.
- Effects of joints in multi-layer lagging.
- Moisture absorption.
- Density variations.
- Thermal bridging by support structures.
- Air gaps.
- Cladding type.

## Process Control Requirements.

For correct design of an insulation system for

process control requirements it is necessary to understand the nature of the process.

For example, a process may require control of the temperature of the process fluids in storage vessels and in piping systems within a specified range, with periodic mechanical heating. This may require consideration of the heat loss over time or length of pipe.

Calculation of the insulation thickness needed to achieve process temperature control will require the following additional data:

- The residence time or flow rates of the process fluids.
- Vessel dimensions or pipe length
- The probable range of ambient air temperatures.
- The capacity of any heating devices used.
- Heat capacity of the fluid.

The method and quality of installation of the insulation system is critical to ensure no thermal leakage occurs, creating inefficient and adverse process control.

## Economic Thickness of Insulation.

### TRADITIONAL INSULATION THICKNESS DESIGN METHOD.

The objectives of the traditional methods used for the calculation of insulation thickness and for the selection of insulation materials and systems, include –

- Limitation of the outside surface temperatures of hot piping or equipment, to approximately 60°C. The objective is to minimise injury to personnel,
- Control of process temperatures. Large uninsulated tank surfaces, for example, cause convective movement of liquid contents which may interfere with the process. On the other hand, long runs of uninsulated piping may result in difficulty in achieving the desired discharge temperature remote from the heat source,
- Control of outside surface temperature of cold surfaces so as to avoid condensation of atmospheric moisture on the outside surface of the cladding.

The design method used to determine the insulation thickness to meet all objectives, based on the ‘steady state’ theory of heat transfer requires the following data –

- Pipe, or equipment, design temperatures (under operating conditions) and ambient air temperature.
- Desired outside surface temperature (or sometimes the maximum allowable heat loss, or gain).

- Thermal conductivity of the insulation.
- Surface resistance of the outer finish to be used over the insulation.

Specifications for the thickness of thermal insulation, based on this design method, were written and imposed on energy dissipating plant and equipment, without evident concern for present and escalating energy costs.

The obvious omission is the effect, over the lifetime of the insulation system, of the relationship between the cost of incremental increases in insulation thickness and the consequent incremental decreases in the cost of heat lost (or gained in below ambient cases).

## ECONOMIC THICKNESS OF INSULATION DESIGN (ETI).

This computerised analysis method enables the complex calculations to be made speedily and reliably, the 'Thermecon' ETI package offered by Bradford Insulation is extremely flexible and easy to operate.

Although the scope of data required for 'Thermecon' ETI design is wider than for the traditional method, the assembly of that data usually succeeds in increased awareness of the importance of energy costs, to the enterprise.

In addition to the operating details required for the traditional design, the actual lengths and areas of heated piping, tankage, etc., are required.

The financial information required for ETI design will have been considered in the overall project feasibility, or is simply extracted from accounting records for an existing facility. This information includes actual energy costs (including efficiency of conversion), interest rates, depreciation, etc.



## WHY ETI?

Increasingly, sophisticated procedures for the determination of the economic efficiency of an existing plant, the feasibility of a particular investment, or of comparing alternative investments, in financial

terms, demand parallel sophistication in assessing and meeting energy criteria. The ETI concept will invariably lead to revised insulation specifications –

- to optimise on both financial and energy use criteria,
- to update insulation during maintenance,
- to update insulation in new work.

## ETI CALCULATIONS.

Economic thickness may be defined as the thickness of insulation which produces the **minimum** total cost for the period of evaluation (for example, the estimated service life of the insulation system).

The total cost is the sum of the installed cost of the insulation system plus the cost of the energy lost through that insulation system.

The trends of these two costs and their sum is shown graphically in Figure 1. The graphs indicate what Economic Thickness of Insulation or ETI is economically justified. Put simply, to use less than ETI wastes energy dollars; to use more than ETI wastes insulation dollars.

The calculation of the Economic Thickness of Insulation or ETI for any industrial application can be done by Bradford Insulation's Thermecon computer program. This program performs the complex financial and transfer calculations quickly and reliably.

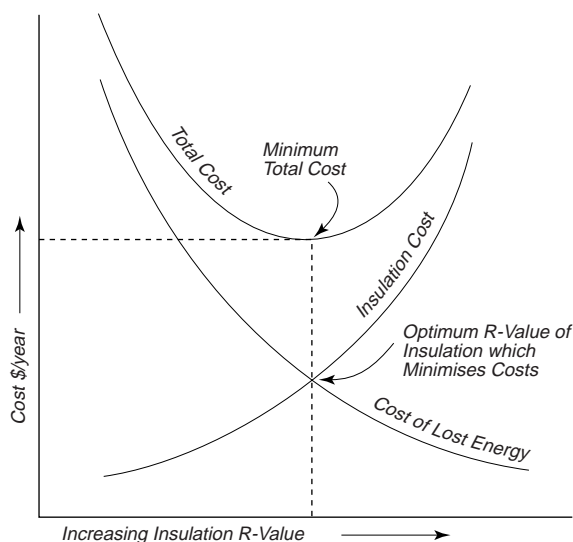
Calculation of the rate of heat transfer through a specified thickness and type of insulation requires the following data;

- Hot face surface or process temperature.
- Average ambient air temperature,
- Thermal conductivity of the insulation at the appropriate mean temperature.
- Surface heat transfer coefficient (reflective or non-reflective cladding, ambient air velocity).
- Surface area of vessels or outside diameter and length of piping.

Financial calculations require the following additional data;

- Fuel type and cost.
- Estimated fuel price inflation rate.
- Operating hours per year.
- Cost of money for insulation or return on investment required (specify if before or after tax).
- Degree of difficulty in installing the insulation (eg. height above ground, number of bends in piping).
- Planned lifetime of the project or the period over which costs are evaluated.

FIG 1. ECONOMIC THICKNESS OF INSULATION.



## Optimum Thermal Resistance of Insulation.

The optimum thermal insulation is calculated by balancing the initial installed cost of the insulation with the ongoing energy savings over the life of the project. At this point, total costs are minimised.

Worked examples are provided in the Sample Design Calculation section of this guide. For a given insulation thickness, these calculations determine the rate of insulated system heat loss and cladding surface temperature under the assumed operating steady state conditions.

## Personnel Protection.

To minimise the risk of injury to personnel, the temperature of the exposed surface of an insulated vessel or pipe should be no greater than 55°C in locations where the surface is accessible.

Surface temperature has traditionally been used as a 'rule of thumb' test for the effectiveness of insulation. While such a 'test' may locate 'hot spots', it is not a reliable indication of the effectiveness of the insulation system as a whole.

For a given insulation thickness, the surface temperature of polished aluminium cladding will always be higher than that of weathered zincanneal cladding, yet the heat loss through the aluminium will be the lower of the two, particularly at high operating temperatures.

Cladding surface temperature is also heavily influenced by the ambient air temperature and wind speed under operating conditions, which can be quite different from the air temperature specified and used for design calculations. The designer therefore should take into account the 'worst case' ambient conditions for calculation purposes.

## Condensation Control.

### i) Below ambient process temperatures

It is necessary to provide an insulation thickness which will produce an outside surface temperature (on the vapour barrier) which will always be above the dew point temperature of the surrounding air.

The worst case atmospheric relative humidity and temperature should be assumed.

Bradford Fibertex Rockwool and Glasswool provide efficient insulation with adequate flexibility to protect the vapour barrier system from fracture due to thermal contraction or expansion of the vessel.

### ii) Above ambient process gases of high water content or relative humidity.

The insulation thickness must be adequate to ensure that the vessel wall temperature is kept higher than the dew point temperature of the process gas, thus preventing condensation of the process gas onto the internal surfaces of the vessel. Electrostatic precipitators and bag filters are insulated to prevent this type of internal condensation.

Calculation of the necessary insulation thickness requires the following data – the dew point temperature of the process gas; gas flow; heat capacity of the process gas; vessel dimensions; and the minimum outside ambient air temperature.

## Noise Control.

All Bradford Fibertex Rockwool and Glasswool products offer excellent sound absorption properties. Alone, or in combination with other selected materials, they offer solutions to problems involving both sound transmission and reverberation.

Guidance in handling industrial noise problems is not included in the scope of this Design Guide. Please refer to the Bradford Insulation Acoustic Design Guide.

## Minimisation of Stress Corrosion Cracking Risk.

With austenitic stainless steel pipes and vessels, there is a risk of stress corrosion cracking if the metal surface comes into contact with soluble chloride salts. The risk is greatest in the operating temperature range of 70°C to 105°C, and requires the presence of moisture.

Bradford Fibertex Rockwool products are acceptable as safe to use in austenitic stainless steel applications in accordance with ASTM C795

Consideration should also be given to the possible ingress of soluble chlorides from external sources.

## Punking.

Punking is a phenomenon that can occur from an excessive rise in temperature inside a thermal insulation material during the start-up period of equipment which operates at elevated temperatures.

Punking is caused by a temperature peak inside the insulation higher than the temperature increase expected from the calculated hot to cold face temperature gradient across the insulation. The temperature peak and resultant exothermic reactions may result in excessive loss of binder from the insulation.

Potential problems associated with temperature peaks and punking include;

- Temperature limits for personnel protection may be exceeded.
- Cladding damage.
- Excessive smoke development.
- Heat effects on adjacent equipment.

Punking is influenced by the combination of three main factors;

- The rate of temperature increase of the hot face.
- Insulation thickness and density.
- Organic binder content of insulation.

Use of insulation with minimal binder content is usually the most practical solution for the prevention of excessive punking. However, controlled gradual heating during plant start-up is recommended.

Bradford Fibertex Rockwool and Bradford Glasswool HT Thermatel products minimise the potential for these exothermic reactions to occur.

## Fire Protection.

Industrial insulation systems in plants should be designed to ensure the insulation and cladding protect the equipment and its contents in the event of fire.

Where process vessels, piping or storage tanks contain volatile products, the importance of fire protection may be a critical consideration.

Bradford Glasswool and Bradford Fibertex Rockwool industrial insulation products provide excellent protection against fire with low thermal conductivities delaying heat rise on the exposed side. Fibertex Rockwool offers superior fire resistance with a very high fusion temperature of greater than 1150°C.

### NON-COMBUSTIBILITY AND FIRE INDICES.

Bradford Fibertex Rockwool and Bradford Glasswool HT Thermatel products have a low content

of organic binder and are deemed to be non-combustible insulation materials when tested to AS1530.1, BS476.4 or equivalent.

All Bradford Glasswool and Fibertex Rockwool products have excellent early fire hazard indices including resistance to spread of flame and development of smoke when tested to AS1530.3, ASTM E84, BS476 or equivalent.



### FIRE RESISTANCE.

A high level of fire resistance in insulation and other materials used in industrial systems is essential to protect plant occupants and operators and to limit the extent of damage to plant building and equipment.

Mineral fibre insulation will not burn when subject to fire conditions, and are used successfully in one and two hour rated fire protection systems which can allow building occupants to escape safely.

Bradford Fibertex Rockwool provides superior levels of fire resistance due to its low thermal diffusivity and is able to withstand fire with only slow breakdown in physical properties when tested to AS1530.4, BS476, or equivalent.

Bradford Fireseal products are specialty fire grade rockwool offering outstanding fire resistance for long periods, making them suitable for fire sealing applications in curtain walls, party walls, fire dampers and pipe/cable penetrations.

For fire protection of plant and equipment Bradford Fibertex 820 is robust, high density mineral wool has been specially formulated to achieve remarkable resistance to shrinkage at elevated temperature levels.



For pipe penetrations through concrete slabs, block wall or lightweight partitions, steel or copper pipe should be lagged with non-combustible Bradford Fibertex Rockwool Pipe Insulation, and all gaps sealed with an intumescent mastic. For chilled water pipes the external vapour barrier must be continuous for condensation control.

## MARINE APPLICATIONS.

Bradford has a range of maritime grade products with superior fire resistance properties to meet the most stringent fire performance standards required for marine applications. They are commonly used in marine vessels as the insulation component of fire rated bulkheads and deckheads as well as for acoustic treatment of walls in engine room areas.

For further information on fire protection, please refer to the Bradford Insulation Fire Design Guide.



## Moisture Resistance & Water Repellency.

Waterproof cladding systems are integral in protecting bulk insulation material from the weather and any other potential sources of water ingress.

Failure of the cladding system can result in water penetrating the insulation layers, causing a reduction in thermal performance of the insulation. This can lead to loss of thermal control, increased heat loss and high cladding temperatures causing danger to personnel and surrounding equipment.

Should Bradford Fibertex Rockwool or Glasswool insulation become wet, full thermal efficiency will be restored on drying out.

Water ingress may also cause corrosion to the surface of process piping or equipment under the insulation. Stainless steel fabrications can be seriously damaged from stress corrosion cracking initiated by chloride ions which migrate through the insulation in the presence of water.



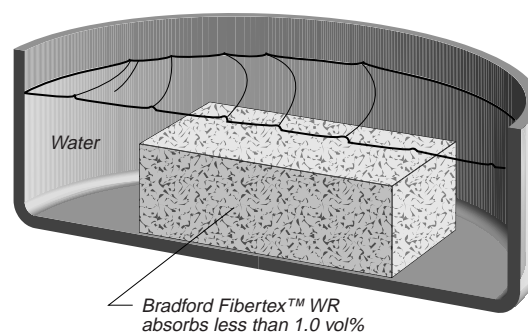
## WATER REPELLENCY.

Bradford Fibertex WR has been developed as a specialty water-repellent rockwool by the Bradford Insulation Research Laboratories making it suitable for applications subject to possible water ingress. The water repelling agents contained in Fibertex WR have been engineered to ensure maximum resistance to water penetration.

Fibertex Rockwool is non-hygroscopic and will absorb water only when forced in under pressure. Once the pressure is relieved the water will evaporate, leaving the material dry with maximum insulating value. If Fibertex is exposed to a spray or rain then water will usually only penetrate a few millimetres from the surface, with only minimal effect on the insulating properties.

When tested in accordance with BS2972 Total Immersion in water, Bradford Fibertex absorbs less than 1% moisture by volume.

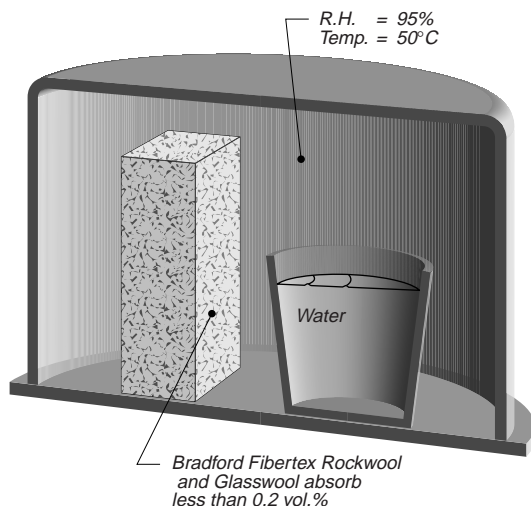
FIG 2.  
WATER IMMERSION TESTING TO BS2972.



## MOISTURE ABSORPTION.

Bradford Fibertex Rockwool and Glasswool absorb negligible moisture from surrounding air. Exposure of Bradford Glasswool or Fibertex Rockwool bonded products to a controlled atmosphere of 50°C and 95% relative humidity for 96 hours results in water vapour absorption of less than 0.2% by volume, in accordance with ASTM C1104.

**FIG 3.**  
**MOISTURE ABSORPTION TESTING.**



## **CAPILLARITY.**

Bradford Fibertex Rockwool will not draw water into the bulk of the material by capillary action. The water-repellent additive prevents any wick effect occurring in the capillaries.

## **VAPOUR DIFFUSION.**

Bradford Glasswool and Fibertex Rockwool consist of an open, inert air cell structure which provides negligible resistance to water vapour diffusion, allowing water vapour to pass through without condensing or absorbing.

However, should the outer cladding or fibres be allowed to fall below dew point temperature at prevailing relative humidity and temperature then condensation may occur.

# Mechanical Properties

## **DIMENSIONAL STABILITY.**

Bradford Glasswool and Fibertex Rockwool products exhibit low shrinkage characteristics when tested at their maximum service temperature in accordance with ASTM C356 and ASTM C411.

## **COMPRESSIVE STRENGTH.**

Bradford Fibertex Rockwool and Glasswool are resilient insulation materials which readily recover to the nominal thickness after the removal of a normal compressive load. Higher density insulation materials offer greater compression resistance and should be specified for use in areas subject to live or dead loads.

## **VIBRATION RESISTANCE.**

Because Bradford Fibermesh Rockwool is stitched to wire mesh, the blankets are especially resistant to fallout under conditions where vibration is present.

Fibermesh is particularly suitable for applications involving both vibration and high temperature where standard bonded insulation materials are less resistant to the effects of vibration.

Fibermesh with hexagonal wire mesh stitched to the rockwool blanket has superior flexibility and high resistance to vibration. Suitable for the insulation of irregular surface profiles, Fibermesh can also be used to cost effectively insulate large diameter pipes (200mm O.D. and larger) as an alternative to Rockwool (SPI) Pipe Insulation. Typically, an extra 12mm thickness is required to achieve comparable thermal resistance.

## **RIGIDITY AND FLEXIBILITY.**

To ensure thermal insulation performs as intended it is essential that the insulating material is installed and held firmly against the surface being insulated.

Bradford Fibertex Rockwool and Glasswool rigid and semi-rigid board insulation products offer excellent deflection resistance for insulating areas where excessive sag can occur, such as the underside of soffits or vessels.

Bradford Fibertex Flex-skin, Fibermesh Rockwool and Glasswool Blanket are flexible insulation blankets that readily conform to the desired profile along curved vessels or around small radius objects and corners, ensuring speedy installation.

Bradford Fibermesh products form the most versatile range of insulation materials available. They exhibit advantages over traditional insulation products in terms of:

- Reduced labour costs – especially where wire mesh is specified as the support mechanism.
- Maximum flexibility – without cracking or breaking. This permits the full insulation thickness to be maintained around stiffeners and other irregular shaped surfaces.
- High Temperature Vibration Resistance – due to the integrated stitching of the wire mesh, the fibres are more readily retained in position where high temperatures and vibration exist.
- Convenience in retro-fit situations – especially where the fitting of additional insulation to existing pipe insulation is economically justified.
- Excellent Tensile Strength.

## Durability.

Durability under operating conditions can only be determined from experience. Bradford industrial insulation products enjoy a proven record of efficient, durable service in a wide range of applications including power stations, oil refineries and chemical plants.

The insulation and cladding system must;

- Accommodate thermal movement and any vibration of the insulated surface.
- Continue to provide efficient thermal resistance throughout the economic life of the insulated equipment.
- Be thermally stable to minimise shrinkage at elevated temperatures.
- Provide weatherproofing in external applications and protection against damage from maintenance personnel or machinery.

## Environmental and Biological Aspects.

### ENVIRONMENTAL.

Bradford is committed to producing ecologically sustainable materials for the long term benefit of the environment.

Bradford Glasswool and Fibertex Rockwool products are manufactured using highly abundant, naturally occurring raw material including a significant proportion of recycled matter. The molten mixtures are spun into fibres and bonded together with organic resin.

Bradford's world leading plant technologists have developed the latest advancements in manufacturing processes to meet the most stringent government environmental regulations.

Utilising world's best energy efficiency practice ensures the embodied energy in all Bradford Glasswool and Fibertex Rockwool products is minimal. This energy conservation also contains plant emission levels and helps achieving greenhouse gas commitments.

### BIOLOGICAL.

Environments with warm, moist conditions can be susceptible to biological growth if not correctly guarded against. Preventing condensation through adequate thermal control using rockwool and glasswool insulation materials will inhibit mould growth.

Should mould initiate and propagate from another source glasswool and rockwool will not sustain any growth of biological matter.

## Installed Cost.

Insulation materials should be selected by considering the total installed cost. Influencing factors include material purchase costs, installation labour costs and cost of materials damaged during handling and installation.

Bradford Fibertex Rockwool and Glasswool are resilient and lightweight, resulting in ease of handling and minimum accidental damage during installation.

Convenient standard and custom roll or sheet sizes in a wide range of thicknesses ensure that the required total thickness of insulation may be quickly and economically installed.

Easy handling in site, particularly on scaffolding and in confined spaces around process vessels and piping, not only reduces labour costs but also contributes to meeting completion dates.

## Cladding Selection.

Insulation cladding systems are typically required to act as a vapour barrier and/or protect the insulation from weather and damage. Common types include;

- Metal cladding.
- Mastic sealant.
- PVC jacketing.

Bradford products are available with the following factory applied facings;

- Reinforced aluminium foil laminates (vapour barrier).
- Glass cloth.
- Paper.
- Calico.
- Aluminium foil.

Design of the cladding system should consider the following;

- Operating and surface temperatures.
- Design live or dead loads.
- Surface impact.
- Chemical attack.
- Waterproofing.
- Vapour pressures.
- Wind conditions.
- Long term durability.

Full metal cladding is generally accepted as a high performance method of cladding internal and external insulation to meet the above requirements.

For metal cladding it is critical to avoid any contact between metals that may cause galvanic corrosion. This includes screws or rivets used to fasten the cladding. Refer to Table 1 for compatible metal combinations.



**TABLE 1. COMPATIBLE METALS.**

Compatible Metal Combinations	Ferritic Steel	Galvanised Steel	Cadmium Plated Steel	Austenitic Stainless Steel	Aluminium	Nickel Alloys
Ferritic Steel	✓	✓	✓	✗	✗	✗
Galvanised Steel	✓	✓	✓	✓	✗	✗
Cadmium plated steel	✓	✓	✓	✓	✗	✗
Austenitic S/steel	✗	✓	✓	✓	✓	✓
Aluminium	✗	✗	✗	✓	✓	✗
Nickel Alloys	✗	✗	✗	✓	✗	✓



## Original Equipment Manufacturing.

Mineral fibre products are extremely versatile and provide economical and functional solutions for a variety of applications. Their unique chemical and physical compositions ensure excellent durability and high end-product performance.

Bradford can engineer and manufacture quality Glasswool and Fibertex Rockwool products to meet required specifications for use in many types of domestic and commercial equipment, including;

- Ovens.
- Air conditioning systems.
- Automotive.
- Hot water heaters.
- Brake pads.
- Exhaust systems.
- Appliances.
- Specialty equipment.



## Health & Safety.

Bradford Fibertex Rockwool and Glasswool products have been widely used in industry for several generations. There is no evidence to demonstrate any long term health effects from these products when used in accordance with the simple procedures of the Australian National WorkSafe Standard and Code of Practice for the Safe Use of Synthetic Mineral Fibres (1990, Reprinted with Amendments 1994).

Full health and safety information is provided in the Bradford Insulation Material Safety Data Sheets.



# Design Calculations.

## Thermal Control at High Temperatures.

In calculating heat transfer through thermal insulation materials, it is customary to assume that the surface of the vessel or pipe is at the same temperature as the contained fluid. This is not strictly true, and the calculated heat flow rates are therefore slightly exaggerated. The errors involved are very small.

### FLAT SURFACES AND LARGE DIAMETER VESSELS.

The heat transfer rate per unit area through a uniformly insulated flat or curved surface is given by:

#### Heat Flow Rate.

a. One type of insulation:

$$Q = \frac{t_v - t_a}{\frac{L}{k_1} + \frac{1}{f}}$$

b. Two layers of different types of insulation:

$$Q = \frac{t_v - t_a}{\frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{1}{f}}$$

#### Junction Temperature.

$$t_j = t_v - \frac{QL_1}{k_1}$$

#### Outside Surface Temperature.

$$t_s = \frac{Q}{f} + t_a$$

#### Where:

- $Q$  = heat loss rate ( $W/m^2$ )
- $t_v$  = surface temperature of vessel ( $^{\circ}C$ )
- $t_a$  = ambient air temperature ( $^{\circ}C$ )
- $t_s$  = external surface temperature of insulation or cladding ( $^{\circ}C$ )
- $t_j$  = junction temperature between inner and outer layers ( $^{\circ}C$ )
- $L$  = thickness of insulation (m)
- $L_1$  = thickness of inner layer (m)
- $L_2$  = thickness of outer layer (m)
- $k_1$  = thermal conductivity of inner layer ( $W/m.K$ )
- $k_2$  = thermal conductivity of outer layer ( $W/m.K$ )

$\frac{L}{k}$  = insulation resistance ( $m^2K/W$ )

$\frac{1}{f}$  = external surface resistance ( $m^2K/W$ )

$f$  = surface heat transfer coefficient ( $W/m^2.K$ )

### PIPES AND CYLINDERS.

The heat loss per unit length from a uniformly insulated pipe or cylinder is given by:

#### Heat Flow Rate.

a. One type of insulation:

$$Q' = \frac{\pi (t_p - t_a)}{\frac{1}{2k} \log_e \frac{d_s}{d_p} + \frac{1}{fd_s}}$$

b. Two layers of different types of insulation

$$Q' = \frac{\pi (t_p - t_a)}{\frac{1}{2k_1} \log_e \frac{d_j}{d_p} + \frac{1}{2k_2} \log_e \frac{d_s}{d_j} + \frac{1}{fd_s}}$$

#### Junction Temperature.

$$t_s = t_p - \frac{Q' \log_e \frac{d_s}{d_p}}{2\pi k_1}$$

#### Outside Surface Temperature.

$$t_s = \frac{Q}{\pi d_s f} + t_a$$

#### Where:

- $Q'$  = heat loss per lineal metre of pipe per second ( $W/m$ )
- $t_p$  = surface temperature of pipe ( $^{\circ}C$ )
- $t_s$  = external surface temperature of insulation or cladding ( $^{\circ}C$ )
- $t_a$  = ambient air temperature ( $^{\circ}C$ )
- $t_j$  = junction temperature between inner and outer layers ( $^{\circ}C$ )
- $k$  = thermal conductivity of insulation ( $W/m.K$ )
- $k_1$  = thermal conductivity of inner layer ( $W/m.K$ )
- $k_2$  = thermal conductivity of outer layer ( $W/m.K$ )
- $d_s$  = diameter of outside surface of insulation (m)
- $d_p$  = outer diameter of pipe (m)
- $d_j$  = diameter of junction between inner and outer layers (m)
- $f$  = surface heat transfer coefficient ( $W/m^2.K$ )
- $\pi$  = 3.1416
- $\log_e$  = Natural log, where  $e = 2.7183$

## Surface Heat Transfer Coefficients.

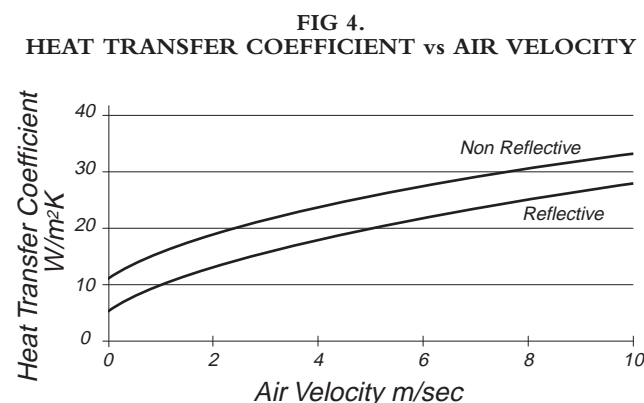
The Surface Heat Transfer Coefficient or Surface Film Conductance,  $f$ , is the time rate of heat transfer between the outside surface of the insulation or cladding and the surrounding air. Heat is transmitted at the surface by both convection and radiation, but for convenience the two are combined and expressed as a conductance.

The value of the coefficient varies widely and is influenced by the physical state of the surface, its temperature and emissivity, the temperature difference between the surface and the surrounding atmosphere, the dimensions, shape and orientation of the surface and the velocity of air in contact with it.

The use of a reflective cladding or surface finish lowers the surface coefficient and reduces slightly the overall heat transfer. It has a severe influence, however, on surface temperatures, bringing about a marked increase in the case of hot vessels, which can create problems in personnel protection. Similarly, in the insulation of cold vessels, a reflective surface finish reduces the surface temperature which may not be desirable for condensation reasons.

Air velocity can also have a considerable effect on the surface temperature and the overall heat transmission. The effect of increasing air velocity will be to decrease the cladding temperature of a hot vessel and increase that of a cold vessel. This may be important in condensation prevention.

Figure 4 indicates the effect of air velocity on the surface coefficient for a reflective cladding, e.g. aluminium and a typical non-reflective surface finish. The curves shown are for a surface temperature of 50°C and an ambient air temperature of 20°C.



The graph shows that an increase in wind velocity across the surface results in an increased rate of heat transfer from the surface.

Recommended values for surface coefficients for still air conditions and ambient temperatures not exceeding 45°C are given in Table 2.

**TABLE 2. SURFACE COEFFICIENTS.**

Cladding	W/m².K
Aluminium	5.7
Galvanised steel and Zinalume	6.3
Zincanneal	8.0
Bare insulation, dark paints and mastics	10.0

## Heat Transfer Calculations.

### EXAMPLES FOR FLAT AND CURVED SURFACES.

Use of the basic heat transfer formulae in typical problems is demonstrated in the following examples.

#### Example 1: Determining heat loss and surface temperature for an existing insulation system.

Gas ducting in a power station operates at a maximum temperature of 420°C. The insulation system consists of an inner layer of 75mm Fibertex 450 plus an outer layer of 100mm Fibertex 350 with aluminium cladding.

Determine the heat loss and surface temperature for an ambient temperature of 30°C, basing calculations on still air conditions.

The first step is to assume values for the junction temperature between the two materials and for the outside surface temperature. Suggested figures in this example are 320°C for the junction temperature and 60°C for the outside surface temperature.

The assumed mean temperatures for the two materials will then be:

$$\text{Inner layer: } \frac{420 + 320}{2} = 370^{\circ}\text{C}$$

$$\text{Outer layer: } \frac{320 + 60}{2} = 190^{\circ}\text{C}$$

The thermal conductivities for the two materials are then determined by interpolation from the tables in Appendix B, thus:

Inner Layer (Fibertex 450): 0.116 W/m.K.

Outer Layer (Fibertex 350): 0.070 W/m.K.

The recommended surface heat transfer coefficient for aluminium for still air conditions is 5.7 W/m².K (refer Table 2).

Then the first trial calculation of the heat loss will be:

$$Q = \frac{t_v - t_a}{\frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{1}{f}}$$

$$Q = \frac{420 - 30}{\frac{0.075}{0.116} + \frac{0.100}{0.070} + \frac{1}{5.7}}$$

$$Q = 173 \text{ W/m}^2$$

Using this value for Q, the junction and outside surface temperatures are then checked:

$$\begin{aligned} t_j &= t_v - \left[ \frac{QL_1}{k_1} \right] \\ &= 420 - \left[ \frac{173 \times 0.075}{0.116} \right] \\ &= 308^\circ\text{C} \end{aligned}$$

$$t_s = \frac{Q}{f} + t_a$$

$$\begin{aligned} t_s &= \frac{173}{5.7} + 30 \\ &= 60^\circ\text{C} \end{aligned}$$

A recalculation is now made using 308°C and 60°C as the junction and surface temperatures. Mean temperatures will be:

$$\text{Inner layer: } \frac{420 + 308}{2} = 364^\circ\text{C}$$

$$\text{Outer layer: } \frac{308 + 60}{2} = 184^\circ\text{C}$$

Thermal conductivities as determined by interpolation from the tables in Appendix B are:

Inner Layer (Fibertex 450): 0.114 W/m.K

Outer Layer (Fibertex 350): 0.068 W/m.K

Repeating the calculation using these new thermal conductivity figures:

$$Q = \frac{420 - 30}{\frac{0.075}{0.114} + \frac{0.100}{0.068} + \frac{1}{5.7}}$$

$$Q = 169 \text{ W/m}^2$$

Again checking junction and surface temperatures as before:

$$t_j = 420 - \left[ \frac{169 \times 0.075}{0.114} \right]$$

$$= 309^\circ\text{C}$$

$$t_s = \frac{169}{5.7} + 30$$

$$= 60^\circ\text{C}$$

As these temperatures are the same as or very close to those used to determine the thermal conductivities for the second calculation, the results of this calculation are reasonably accurate; i.e. for the conditions specified, the answers are:

Heat Loss: 169 W/m<sup>2</sup>.

Surface Temperature: 60°C

**Note:** By reference to the Heat Loss Tables in Appendix B it is possible to be fairly close with the first estimates of junction and surface temperatures. This means that two sets of calculations are often sufficient. At times, however, with more extreme conditions, or with problems involving less familiar materials, it may be necessary to calculate a third or even fourth time to ensure reasonable accuracy.

## Example 2: Determining thickness of insulation to achieve a specified maximum heat loss.

A horizontal steel tank of 2.5m diameter and length of side 6.5m has two dished ends of radius equal to the diameter of the tank.

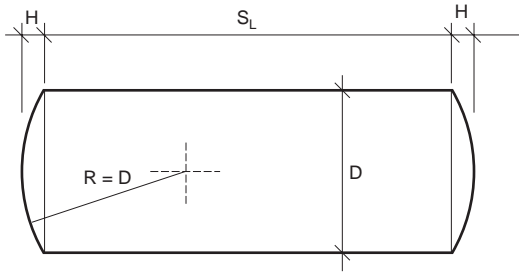
It is to be used as a holding tank for asphalt which will be pumped in at a temperature not less than 180°C.

Insulation is required to ensure that the drop in temperature is no greater than 1.5°C per hour.

The density of the particular grade of asphalt over the temperature range in question will average 930 kg/m<sup>3</sup> and the specific heat capacity will average 2.28 kJ/kg.K.

The worst expected climatic conditions are 0°C and a wind velocity of 25 km/h.

On the basis that the lowest level at which the contents of the tank will be held for prolonged periods of time is 30% of its capacity, what thicknesses of the recommended insulation will be required. Aluminium cladding is to be used.



**Tank Volume:** The volume of the cylindrical section

$$= \frac{\pi D^2}{4} \times S_L$$

$$= \frac{\pi \times (2.5)^2 \times 6.5}{4}$$

$$= 31.9\text{m}^3$$

H, the 'depth' of a dished end is given by;

$$D \left(1 - \sqrt{\frac{3}{4}}\right) = 0.134D = 0.0335\text{m}$$

The volume of a dished end is given by

$$= \frac{1}{6} \pi H \left(3 \frac{D^2}{4} + H^2\right)$$

$$= \frac{0.335\pi}{6} \left[3 \frac{(2.5)^2}{4} + (0.335)^2\right]$$

$$= 0.84\text{m}^3$$

Therefore:

$$\text{Total Volume of tank} = 31.9 + 2(0.84)$$

$$= 33.58\text{m}^3$$

## Surface Area of Tank.

The surface area of the cylindrical section

$$= \pi \times D \times S_L$$

$$= \pi \times 2.5 \times 6.5$$

$$= 51.05\text{m}^2$$

The surface area of a dished end

$$= \pi DH$$

$$= \pi \times 2.5 \times 0.335$$

$$= 2.63\text{m}^2$$

Therefore:

$$\text{Total surface area of tank}$$

$$= 51.05 + 2(2.63)$$

$$= 56.3\text{m}^2$$

The most critical state as far as heat loss is concerned is when the tank is held at the 30% level, and the maximum allowable rate of heat loss should be determined on this basis. This is given by mass x specific heat x fall in temperature

$$= (0.3 \times 33.58 \times 930) \times 2.28 \times 1.5\text{kJ/h}$$

$$= \frac{32041 \text{ kW}}{3600}$$

$$= 8.9\text{kW}$$

As the rate of heat transfer around the steel shell will be high, a wise precaution is to assume that the heat loss is taking place from the whole surface area; therefore, the maximum rate of heat loss through the insulation will be:

$$Q_{\text{max}} = \frac{8.9}{56.3} \times 1000$$

$$= 158\text{W/m}^2$$

In calculating the thermal performance of the insulation system, it is satisfactory to ignore the resistance of the surface film on the inside of the tank. In other words, assume that the steel is at the same temperature as the contents.

An appropriate value for the air surface film conductance, f, may be determined from FIG 4. For a wind velocity of 6.94m/s using reflective cladding, a reasonable value is 22W/m<sup>2</sup>.K.

A close approximation of the outside surface temperature of the insulation system can be determined from the formula:

$$t_s = \frac{Q_{\text{max}}}{f} + t_a$$

$$= \frac{158}{22} + 0$$

$$= 7^\circ\text{C}$$

Fibertex 350 flexible blanket is the most suitable insulation for this application. The mean temperature of the insulation will be approximately:

$$\frac{180 + 7}{2} = 94^\circ\text{C}$$

Interpolating from Appendix B, the thermal conductivity will be approximately 0.045 W/m.K.

The heat transfer through the insulation is given by:

$$Q = \frac{t_v - t_a}{\frac{L}{k} + \frac{1}{f}}$$

$$Q = \frac{180 - 0}{\frac{L}{0.045} + \frac{1}{22}}$$



By making  $Q$  equal to  $Q_{\max}$  ( $158 \text{ W/m}^2$ ), the minimum thickness of the selected insulation material can be calculated thus:

$$L = 0.045 \left[ \frac{180}{158} - \frac{1}{22} \right]$$

$$= 0.049\text{m}$$

The thickness of Fibertex 350 blanket required will be the next standard thickness above the calculated minimum; i.e., 50 mm.

### Example 3: Determining thickness of insulation to achieve a required surface temperature.

A 1200mm duct from a tunnel kiln is expected to reach a temperature as high as  $520^\circ\text{C}$ . It is to be insulated for personnel protection, designing for a cladding temperature not exceeding  $62^\circ\text{C}$  when the ambient temperature is at the anticipated maximum of  $32^\circ\text{C}$ . Calculations are to be based on still air conditions.

What insulation and cladding system should be specified and what thicknesses will be required?

As the duct diameter is greater than the largest pre-formed pipe insulation produced, Fibertex batts and blankets are the obvious choice of insulation material. At  $520^\circ\text{C}$  hot face temperature, it will be necessary to use Fibertex 650 for the inner layer; the outer layer should be Fibertex 450 blankets.

To assist in achieving low surface temperature, the cladding should be zincanneal or galvanised steel painted a dark colour. This permits the use of a value of  $10.0 \text{ W/m}^2 \cdot \text{K}$  for the surface heat transfer coefficient.

The use of flat surface formulae in the calculations will be accurate enough for such a large diameter duct.

The outside surface temperature of the insulation system is given by the formula:

$$t_s = \frac{Q}{f} + t_a$$

Using the stated maximum values for  $t_s$  and  $t_a$ , a maximum allowable value for the heat transfer,  $Q$ , can be found:

$$62 = \frac{Q}{10} + 32$$

from which, the maximum value for  $Q$  is  $300 \text{ W/m}^2$ .

The correct combination of standard thicknesses of the two insulation materials must now be determined to ensure that this value of  $Q$  is not exceeded and also that the junction temperature,  $t_j$ , between the two materials is not greater than  $450^\circ\text{C}$ , the top service temperature for the Fibertex 450.

This is done by trial and error. Reference to the Appendix A, Table A5 indicates that 38mm of Fibertex 650 and 88mm of Fibertex 450 may be close to the solution required.

In dual layer calculations, it is wise to aim at a junction temperature a little below the top service limit of the outer layer as a safety precaution. In this case, an initial figure of  $425^\circ\text{C}$  for the junction temperature is suggested.

Then the mean temperatures of the two layers will be approximately:

$$\text{Inner layer: } \frac{520 + 425}{2} = 472^\circ\text{C}$$

$$\text{Outer layer: } \frac{425 + 62}{2} = 244^\circ\text{C}$$

The thermal conductivities for the two materials are then established by interpolating from Appendix B thus:

Inner layer (Fibertex 650):  $0.141 \text{ W/m.K}$

Outer layer (Fibertex 450):  $0.077 \text{ W/m.K}$

The heat transfer will be given by:

$$Q = \frac{t_v - t_a}{\frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{1}{f}}$$

$$Q = \frac{520 - 32}{\frac{0.038}{0.141} + \frac{0.088}{0.077} + \frac{1}{10}}$$

$$= 323 \text{ W/m}^2$$

This is greater than the maximum allowable value for  $Q$  and therefore an additional 12mm thickness of insulation will be required.

Before deciding which material to increase in thickness, the junction temperature should be checked by the formula:

$$t_j = t_v - \frac{QL_1}{k_1}$$

$$= 520 - \frac{323 \times 0.038}{0.141}$$

$$= 433^\circ\text{C}$$

This is reasonably close to the assumed junction temperature and sufficiently below the top service limit for Fibertex 450 to permit the increase in thickness to be in the outer layer.

Therefore it appears that 38mm of Fibertex 650 and 100mm of Fibertex 450 will be satisfactory.

The increase in thickness of the outer layer will increase the junction temperature. For the second trial calculation, an assumed junction temperature of 440°C is suggested.

The mean temperatures of the two layers will then be:

$$\text{Inner layer: } \frac{520 + 440}{2} = 480^{\circ}\text{C}$$

$$\text{Outer layer: } \frac{440 + 62}{2} = 251^{\circ}\text{C}$$

The thermal conductivities interpolated from the tables in Appendix B then become

Inner layer (Fibertex 650): 0.144 W/m.K

Outer layer (Fibertex 450): 0.079 W/m.K

Proceeding with the calculation,

$$Q = \frac{520 - 32}{\frac{0.038}{0.144} + \frac{0.100}{0.079} + \frac{1}{10}}$$

$$= 299 \text{ W/m}^2$$

The junction temperature is then checked:

$$t_j = 520 - \frac{299 \times 0.038}{0.144}$$

$$= 441^{\circ}\text{C}.$$

This is sufficiently close to the assumed junction temperature to indicate that the thermal conductivities used in the calculations are reasonably accurate. As a final check that the solution is correct, the actual surface temperature achieved should be determined by the formula:

$$t_s = \frac{Q}{f} + t_a$$

$$= \frac{299}{10} + 32$$

$$= 61.9^{\circ}\text{C}$$

This meets the requirement of being less than 62°C; therefore the problem has been solved and the insulation system should be specified as:

Inner layer: 38mm Fibertex 650.

Outer layer: Two 50mm thicknesses of Fibertex 450.

Cladding: Painted galvanised steel or zincanneal (dark colour).

## EXAMPLES FOR PIPE INSULATION.

### Example 4: Determining heat loss and surface temperature of an existing insulation system.

A 76.1 mm OD steam main operating at 180°C is insulated with 38mm thickness of Glasswool Sectional Pipe Insulation with aluminium cladding. Determine the heat loss and cladding temperature for an ambient temperature of 30°C, basing calculations on still air conditions.

The first step is to assume an outside surface temperature to enable an approximate thermal conductivity to be determined. A suggested starting temperature is 40°C. The assumed mean temperature will then be:

$$\frac{180 + 40}{2} = 110^{\circ}\text{C}$$

For Glasswool Pipe Insulation, the thermal conductivity at 110°C mean temperature is approximately 0.042 W/m.K. The recommended surface film conductance for aluminium cladding and still air conditions is 5.7 W/m<sup>2</sup>.K (refer to Table A2). Then, for the first trial calculation,

$$Q' = \frac{\pi (t_p - t_a)}{\frac{1}{2k} \log_e \frac{d_s}{d_p} + \frac{1}{fd_s}}$$

$$Q' = \frac{\pi (180 - 30)}{\left[ \frac{1}{2 \times 0.042} \times \log_e \frac{0.1521}{0.0761} \right] + \frac{1}{5.7 \times 0.0152}}$$

$$= 49.8 \text{ W/m}.$$

Checking the surface temperature using this figure for Q',

$$t_s = \frac{Q'}{\pi d_s f} + t_a$$

$$t_s = \frac{49.8}{\pi \times 0.152 \times 5.7} + 30$$

$$= 48^{\circ}\text{C}$$

The calculation must now be repeated for an assumed surface temperature of 48.3°C. The new mean temperature will be:

$$\frac{180 + 48.3}{2}$$

$$= 114^{\circ}\text{C approximately.}$$

The thermal conductivity corresponding to this mean temperature from Table B2 will now be 0.043W/m.K.

Now:

$$Q' = \frac{\pi (180 - 30)}{\left[ \frac{1}{2 \times 0.043} \times 0.692 \right] + \frac{1}{5.7 \times 0.0152}}$$

$$= 51.2 \text{ W/m}$$

Checking the surface using this new value for  $Q'$

$$t_s = \frac{51.2}{\pi \times 0.152 \times 5.7} + 30$$

$$= 48.8^\circ\text{C}$$

As this checks with the assumed surface temperature for the second calculation, the problem has been solved with reasonable accuracy; therefore the answers required are:

Heat Loss: 51.2 W/m

Surface Temperature: 48.8°C

### Example 5. Determining thickness of insulation to achieve a required surface temperature.

A 406.4mm diameter exhaust flue within a plant room requires insulation for personnel protection. The maximum anticipated pipe temperature is 500°C and the aim is to achieve an outside surface temperature not greater than 65°C.

What insulation and cladding system should be used and what insulation thickness is required?

The calculation is to be based on an ambient still air temperature of 30°C.

The most suitable insulation materials for this application is Fibertex Pipe Insulation. The cladding system should be zincanneal or galvanised steel painted a dark colour to assist in achieving the surface temperature required.

The approximate mean temperature of the insulation will be

$$\text{Outer layer: } \frac{500 + 65}{2} = 283^\circ\text{C}$$

From Appendix B, the thermal conductivity for Fibertex Rockwool Pipe Insulation at this mean temperature is 0.074 W/m.K.

For a dark coloured painted metal finish, the surface heat transfer coefficient to use is 10.0 W/m<sup>2</sup>.K.

Using the Table A9 as a guide, it appears that 88mm may be sufficient insulation. A first trial calculation then gives:

$$Q' = \frac{\pi (t_p - t_a)}{\frac{1}{2k} \log_e \frac{d_s}{d_p} + \frac{1}{fd_s}}$$

$$Q' = \frac{\pi (500 - 30)}{\left[ \frac{1}{0.148} \times \log_e \frac{0.5824}{0.4064} \right] + \frac{1}{10.0 \times 0.582}}$$

$$= 567 \text{ W/m.}$$

The surface temperature is checked as follows:

$$t_s = \frac{Q}{\pi d_s f} + t_a$$

$$t_s = \frac{567}{\pi \times 0.582 \times 10} + 30$$

$$= 61^\circ\text{C}$$

This is well within the surface temperature limit and it appears that 75mm thickness could be satisfactory. A second trial calculation using 75mm SPI gives:

$$Q' = 642 \text{ W/m and}$$

$$t_s = 67^\circ\text{C}$$

Thus, 75mm thickness would not meet requirements and the minimum thickness to be used is 88mm. The thickness of the layer will be the next standard size above half this figure. Therefore the specification should be:

Inner Layer: 50mm Fibertex Pipe Insulation.

Outer Layer: 38mm Fibertex Pipe Insulation.

Cladding: Painted galvanised steel or zincanneal (dark colour).

A single layer pipe section of 88mm thickness may be considered, however single layers are not recommended above 75mm thickness.

## Thermal Control at Low Temperatures.

In designing insulation systems for low temperature applications the same formulae specified for high temperature applications can be used. Note, however, that in this case  $Q$  and  $Q'$  will be negative because the vessel or pipe temperature will be less than ambient. This negative sign indicates the reversal in direction of heat flow; i.e., a heat gain is occurring.

In the insulation of vessels and pipe lines below 10°C it is essential to use a vapour barrier on the warm side of the insulation to prevent penetration of water vapour into the insulation. If such penetration does occur, condensation within the insulation layer increases the thermal conductance and can cause serious corrosion and water accumulation problems. In the worst cases, it can expand on freezing and cause serious physical damage.

Typical vapour barriers are foils and foil laminates, plastic films of adequate thickness, and mastic compositions usually applied as two coats with glass fibre cloth as reinforcement. Sheet metal cladding can also be used to function as a vapour barrier provided full care is directed to sealing all joints. Whatever the vapour barrier selected, a check should be made to ensure that it has a satisfactory permeance for the particular application.

## CONDENSATION CONTROL.

Condensation must also be avoided on the outside of the vapour barrier to prevent problems arising from water drips. Condensation will occur if the surface temperature falls below the dew point temperature, this being the temperature at which the ambient air of a certain relative humidity will become saturated if cooled. Hence the insulation thickness used must be sufficient to ensure that the surface temperature of the vapour barrier is above the dew point temperature for the worst anticipated conditions of temperature and humidity.

The dew point temperature for any set of conditions can be established by reference to Table B3 which lists the dew point temperatures for a wide range of dry bulb temperatures and relative humidities.

By using the dew point temperature determined from the table as the surface temperature, 't' in the conventional heat transfer formulae, the theoretical thickness of insulation 'L', required to prevent condensation can be calculated. This theoretical thickness, so calculated, must be regarded as a minimum, and the next higher standard thickness should be used.

**For Flat Surfaces and Vessels**, the formula becomes:

$$L_c = \frac{k(t_s - t_v)}{f(t_a - t_s)}$$

**For Pipes**, the most convenient formula is:

$$d_s \log_e \frac{d_s}{d_p} = \frac{2k(t_s - t_p)}{f(t_a - t_s)}$$

The value of  $d_s$  is found by solving this equation and then the value of  $L_c$  found from:

$$L_c = \frac{1}{2} (d_s - d_p)$$

### Example Flat and Curved Surfaces:

Calculate the thickness of Fibertex 350 required to prevent condensation on a tank at  $-5^\circ\text{C}$  in an environment of  $25^\circ\text{C}$  and 80% maximum relative

humidity. The vapour barrier is to be a dark coloured reinforced mastic.

From Table B3, the dew point temperature for the condition is  $21.4^\circ\text{C}$  and this becomes the value for  $t_s$  in the equation. For the dark coloured vapour barrier,  $h = 10.0 \text{ W/m}^2\text{K}$  (refer Table 2). The thermal conductivity of Fibertex 350 at the approximate mean temperature of  $8^\circ\text{C}$  is close to  $0.033 \text{ W/m.K}$  (refer to Table B1). Then, from:

$$L_c = \frac{k(t_s - t_v)}{f(t_a - t_s)}$$

$$L_c = \frac{0.033}{10} \times \frac{21.4 - (-5)}{(25 - 21.4)}$$

$$= 0.024$$

Thus, 25mm thickness of Fibertex 350 would theoretically be just sufficient to prevent condensation.

Obviously, a margin of safety is required and the correct decision would be to specify the next higher standard thickness which is 38mm.

### Example Pipes:

A pipe of 101.6mm OD at  $5^\circ\text{C}$  is insulated with 25mm thickness of Fibertex Pipe Insulation faced with foil laminate. The most severe environment anticipated is  $30^\circ\text{C}$  and 80% maximum relative humidity. It is required to calculate:

1. will condensation occur, and
2. if there is a condensation risk, what greater thickness of insulation is needed to avoid it.

a) From Table B3 the dew point for the conditions specified is  $26.3^\circ\text{C}$ . For the foil laminate surface finish,  $h = 5.7 \text{ W/m}^2 \text{ K}$  (refer Table 2). The thermal conductivity of Fibertex 450 Rockwool Pipe Insulation at the approximate mean temperature of  $16^\circ\text{C}$  is approximately  $0.0335 \text{ W/m.K}$  (refer to Table B1)

$$d_s = 0.1016 + (2 \times 0.025)\text{m} \\ = 0.152\text{m approximately.}$$

$$d_s \times \log_e \frac{d_s}{d_p} = \frac{2k(t_s - t_p)}{f(t_a - t_s)}$$

$$0.152 \times \log_e \frac{0.152}{0.101} = \frac{2 \times 0.0335}{5.7} \times \frac{(t_s - 5)}{(30 - t_s)}$$

$$0.0621 = 0.0118 \frac{(t_s - 5)}{(30 - t_s)}$$

$$t_s = 26^\circ\text{C}$$

This is below the dew point temperature for the specified environment and condensation will occur.



b) The thickness required is found by repeating the calculation for greater insulation thicknesses. The next standard thickness in Pipe Insulation is 38mm; for this thickness:

$$d_s = 0.1016 + (2 \times 0.038) \\ = 0.178 \text{m approximately.}$$

$$\text{and } \log_e \frac{d_s}{d_p} = 0.558$$

Then:

$$0.178 \times 0.558 = \frac{2 \times 0.0335}{5.7} \times \frac{(t_s - 5)}{(30 - t_s)}$$

from which  $t_s = 27.4^\circ\text{C}$ .

This is safely above the dew point and therefore 38mm thickness of insulation is sufficient to prevent condensation.

**TABLE 3.**  
**DEW POINT TEMPERATURE, °C.**

Temp °C (Dry Bulb)	Ambient Air Relative Humidity, %							
	20	30	40	50	60	70	80	90
5	-14.4	-9.9	-6.6	-4.0	-1.8	0	1.9	3.5
10	-10.5	-5.9	-2.5	-0.1	2.7	4.8	6.7	8.4
15	-6.7	-2.0	1.7	4.8	7.4	9.7	11.6	13.4
20	-3.0	2.1	6.2	9.4	12.1	14.5	16.5	18.3
25	0.9	6.6	10.8	14.1	16.9	19.3	21.4	23.3
30	5.1	11.0	15.3	18.8	21.7	24.1	26.3	28.3
35	9.4	15.5	19.9	23.5	26.5	29.0	31.2	33.2
40	13.7	20.0	24.6	28.2	31.3	33.9	36.1	38.2

## INSULATION THICKNESS FOR CONDENSATION CONTROL.

The thickness of insulation needed to prevent condensation on the vapour barrier will usually be sufficient to keep heat gain within acceptable limits. However, the continual increase in both capital and operational costs of refrigeration equipment may force consideration of increased thickness on economic grounds.

Bradford Sales and Technical Service personnel are available to assist with any enquires of this nature.

## Thermal Efficiency.

Tender documents sometimes require a statement of insulation efficiency. Expressed as a percentage it may be calculated by the following formula:

$$\frac{Q_b - Q_i}{Q_b} \times 100$$

where  $Q_b$  = Heat loss from bare surface

$Q_i$  = Heat loss from insulated surface

### BARE SURFACE HEAT LOSSES.

Theoretical heat losses from bare surfaces to still air at  $20^\circ\text{C}$  are presented in Tables 4 and 5. These values may be used in estimating thermal efficiency.

The calculations to prepare these tables were based on a surface emissivity of 0.9.

**TABLE 4. BARE SURFACE HEAT LOSS  
FOR FLAT SURFACES.**

Flat Surface °C	Heat Loss (W/m <sup>2</sup> )
100	1090
150	2140
200	3500
250	5250
300	7450
350	10180
400	13540
450	17630
500	22540
550	28400
600	35330
650	43450

**TABLE 5. BARE SURFACE HEAT LOSS FOR PIPES.**

Nominal Pipe OD	Bare Surface Heat Loss (W/m)											
	Surface Temperature °C											
	100	150	200	250	300	350	400	450	500	550	600	650
21.3	88	171	276	408	571	770	1012	1303	1651	2062	2545	3110
26.9	108	209	340	503	705	954	1255	1619	2054	2569	3174	3882
33.7	131	255	415	616	865	1172	1546	1997	2537	3178	3932	4814
42.4	161	313	509	758	1067	1448	1913	2476	3149	3949	4892	5996
48.3	180	351	572	852	1202	1633	2160	2797	3561	4469	5539	6793
60.3	219	428	699	1043	1473	2005	2656	3445	4391	5518	6847	8405
76.1	269	527	862	1289	1824	2488	3301	4288	5474	6887	8556	10512
88.9	309	606	992	1485	2105	2875	3819	4966	6345	7989	9931	12209

# System Specifications.

## Industrial Insulation Up To 350°C.

1. Surfaces to be insulated must be clean and dry. In some circumstances a special surface coating may be specified for corrosion protection. Where this is the case, the coating must be applied and allowed time to cure before insulation work commences.
2. The insulation material must be dry before application. The use of temporary weatherproof covers is recommended to protect insulation which has been fixed, but not yet covered with the final cladding. In the event of insulation becoming wet during application, it must be allowed to dry thoroughly before applying metal cladding or other surface finish.  
  
Failure to do this can promote corrosion; at higher temperatures, it can even destroy the insulation when the plant is brought on stream by the sudden generation of steam within the insulation system.
3. Batts, blankets or boards should be butted closely at all joints to minimise heat losses. Where multiple layers are used, joints should be staggered to avoid direct heat loss paths.
4. Metals pins used for fixing insulation should be at least 3.25mm diameter and 25mm longer than the total insulation thickness. They are welded to the surface at 600mm maximum centres. After cutting to size and impaling over the pins, the batt or blanket is secured with 25mm speed clips over 75 or 100mm metal washers. Alternative means of fixing, particularly with cylindrical vessels, are metal bands (19mm x 0.5mm) or 0.8mm galvanised wire mesh. The overlapping ends of the wire mesh may be tightened by twitching.

5. If the vessel or equipment to be insulated is to be operated outdoors or is otherwise subject to mechanical damage, metal cladding is the preferred finish. Particularly in outdoor applications and corrosive atmospheres, all lap joints in metal cladding should be weatherproofed. This is achieved by either prefabricating and installing the laps to shed water or by the use of appropriate non-hardening sealants.

As an alternative to metal cladding and of particular interest in corrosive situations, reinforced finishing cements or mastic surface coatings may be used.

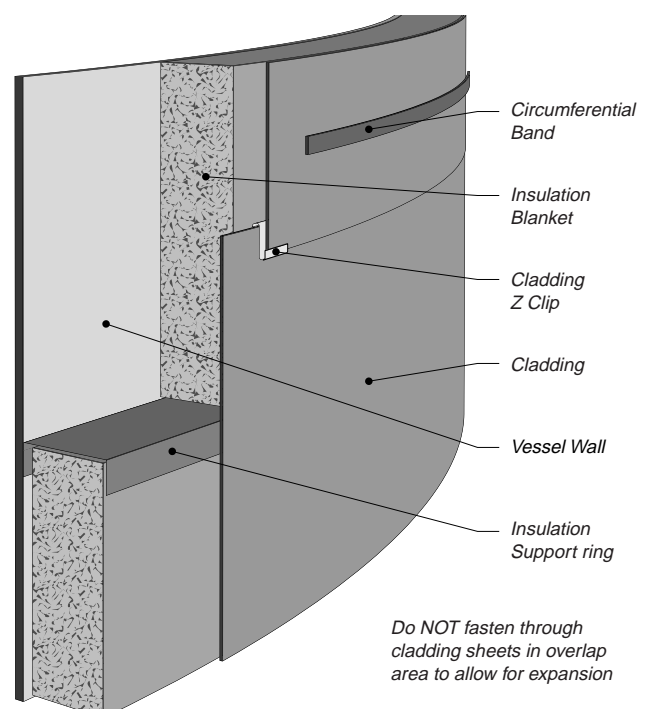
6. Insulation applied to surfaces operating at temperatures below the dew point of the ambient air will also require a vapour barrier. This will be installed on the outer or 'warm' surface of the insulation and should be adequately protected against mechanical damage. This can be achieved by covering the vapour barrier with the metal cladding or an alternative surface finish and ensuring that there is no damage to the vapour barrier when the cladding is applied.

Suitable vapour barrier membranes are the fire-resistant Thermofoil range of reinforced foil laminates. Joints should be lapped 75mm and sealed, preferably with a contact-type adhesive or with 75mm wide impermeable pressure sensitive tape such as reinforced foil tape. Alternative vapour barrier materials are reinforced mastics applied to the thickness required to achieve low permeance. Only fire resistant grades are recommended.

### RECOMMENDED PRODUCTS

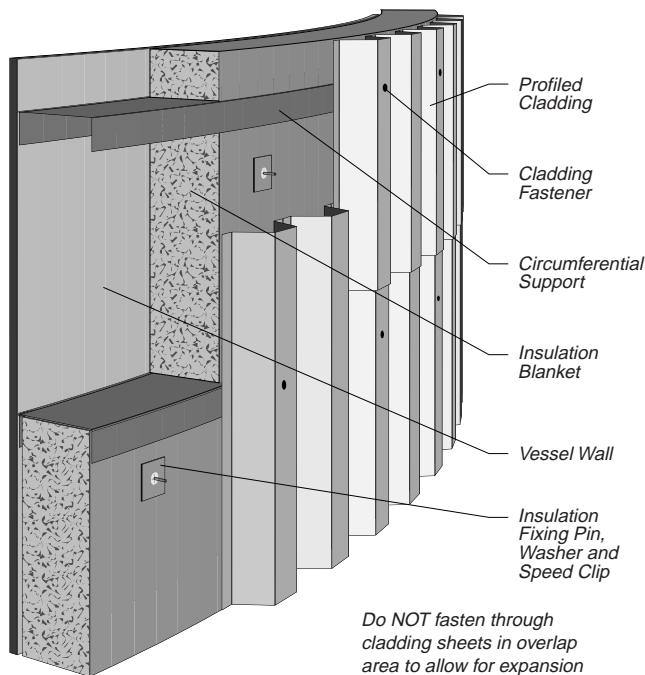
- Fibertex 350 Rockwool, Glasswool Supertel or Ultratel in blanket or board form provide effective thermal and acoustic insulation and are suitable for maximum service temperatures up to 350°C.
- Fibermesh 350 offers comparative performance to the above products with superior vibration resistance.

**FIG 5. INSULATION OF VERTICAL TANKS/VESSELS UP TO 350°C (FLAT CLADDING).**

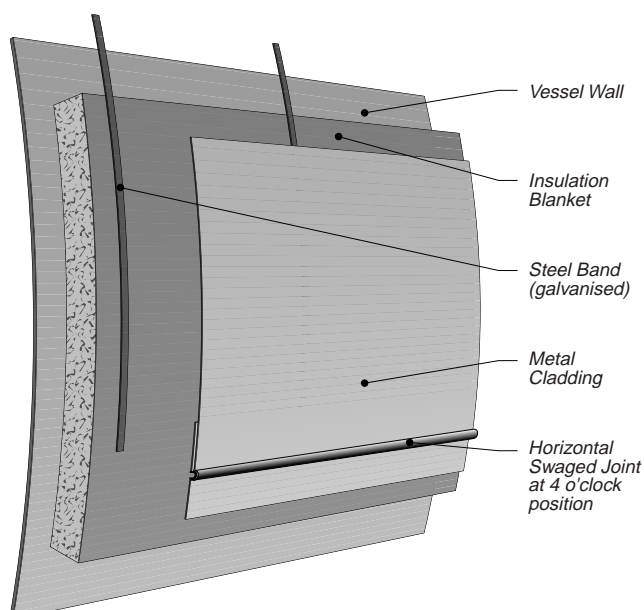


- Fibertex 450 and Fibermesh 450 are premium products in terms of thermal and acoustic performance, and vibration resistance due to higher densities. These are the preferred products for use in power stations.
- The appropriate thickness of insulation can be calculated using the information contained in this Industrial Design Guide. Alternatively, contact the Bradford Insulation office in your region to make use of the Thermecon computer programme.

**FIG 6. INSULATION OF VERTICAL TANKS/VESSELS UP TO 350°C (PROFILED CLADDING).**



**FIG 7. INSULATION OF HORIZONTAL TANKS/VESSELS UP TO 350°C (FLAT CLADDING).**



## Industrial Insulation Above 350°C.

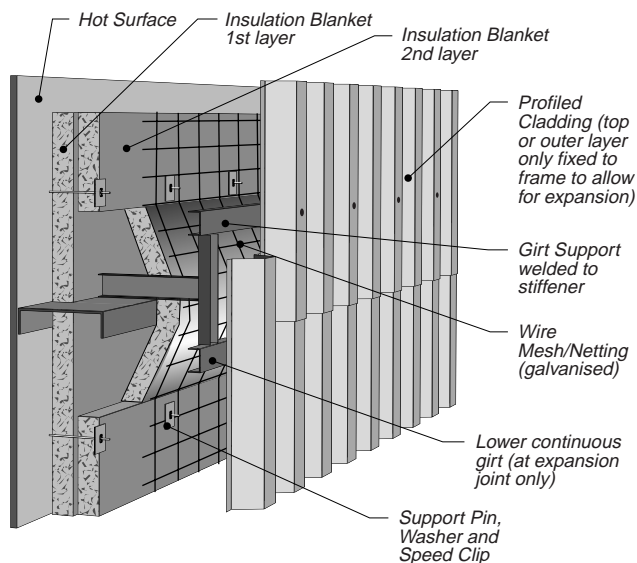
1. *Bradford Glasswool and Fibertex Rockwool* is installed by the same procedures as for applications up to 350°C detailed previously, however particular attention should be given to some details to ensure trouble free services at such high temperatures.
2. In insulating curved surfaces it is essential to ensure a closely fitting insulation system; this will often involve slitting or kerfing the Fibertex 650 board to achieve a degree of flexibility.
3. Invariably multiple layers of insulation are involved and in most cases Fibertex 450 is specified as the outer back-up insulation. In all multi-layer applications, the joints in the preceding layer should be overlapped to eliminate direct heat loss paths. Consideration should also be given to installing a mesh over the inner layer(s) of insulation. This mesh should be stainless steel to avoid corrosion/contamination problems.
4. It is essential to tightly constrain the insulation against expansion at operating temperatures. This is normally achieved by the metal cladding, but with some installations, due to the location of structural members, the metal cladding stands well clear of the insulation. In this case, 25mm wire mesh or expanded metal is used to constrain the insulation system. Expanded metal is also used for insulation constraint and for the additional function of providing a reinforcement and key for the application of a finishing cement where this type of finish is specified.
5. The insulation of tall units may require additional support for the insulation system. The recommended approach is to attach around the vessel steel support rings with a dimension 25mm less than the total insulation thickness at a vertical spacing of 3 to 5m.
6. At temperatures within this range, it is of vital importance to ensure that the insulation system is dry when the plant goes on stream. This can be ensured by good workmanship and the use of waterproof covers during construction.
7. In some furnace wall applications, particularly those of boilers incorporating the use of refractory tiles, there is risk of furnace gas leakage into the insulation space as a result of tube movement. It is important in such cases, that the Fibertex 650 should be protected from direct furnace gas impingement. This can be achieved by use of a thickness of lightweight castable refractory.

## RECOMMENDED PRODUCTS

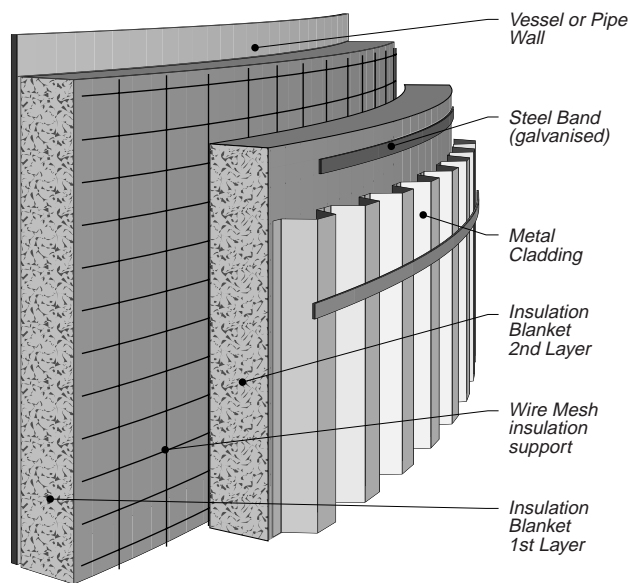
- HT Thermatel – Non combustible medium density glasswool with maximum service temperature of 450°C.
- Fibertex 450 and Fibermesh 450 – high density rockwool products with a maximum service temperature of 450°C.
- Fibertex HD – highest density product manufactured by Bradford Insulation, a rigid material with superior resistance to compression. Maximum temperature 650°C.
- Fibertex 650 and Fibermesh 650 – premium rockwool products with maximum service temperature of 650°C.
- Fibertex 820 is a robust high density product with exceptional resistance to shrinkage at elevated temperatures. Maximum service temperature is 820°C.
- For further information regarding these products please refer to the Industrial product technical data bulletins.

Note: the appropriate thickness of insulation can be calculated using the information contained in this guide. Alternatively, contact the Bradford Insulation office in your region to make use of the Thermecon computer programme.

**FIG 8. INSULATION OF FLAT SURFACE ABOVE 350°C (PROFILED CLADDING).**



**FIG 9. INSULATION OF VERTICAL TANKS/VESSLS ABOVE 350°C (PROFILED CLADDING).**





## Insulation of pipes Up To 350°C.

### EXPOSED LOCATION.

1. The pipe to be insulated shall be clean, dry and free from grease, loose rust, etc.
2. The insulation material shall be *Glasswool SPI* or *Fibertex SPI Sectional Pipe Insulation* manufactured by CSR Bradford Insulation.
3. The wall thickness of the pipe insulation shall be .....mm.

The appropriate thickness of insulation can be calculated using the information contained in this guide. Alternatively contact the Bradford Insulation office in your region to make use of the Thermecon computer programme.

4. The insulation should be dry when installed and shall be kept dry.
5. The sections of pipe insulation shall be placed in position on the pipe ensuring that each section is tightly butted against the adjacent one.
6. The pipe insulation shall be secured in position by *two/three* loops per section of *0.9mm soft galvanised/stainless steel wire*, tightened by twitching; excess wire shall be cut off and the cut end twisted to embed in the insulation surface.

Alternatively secure insulation by *two/three* metal bands per section *19mm x 0.5mm galvanised steel or aluminium (delete as required)*.

7. Cladding shall be *galvanised steel galvabond/zincanneal/zincalume/aluminium (plain/stucco embossed)* .....(other) (select as required) of .....mm thickness.
8. The metal cladding shall be cut and rolled to provide minimum end laps of 75mm and 38/50/75mm longitudinal laps. The edges to be exposed to all lap joints, shall be swaged to exclude water.
9. The cladding shall be fitted to the insulation pipe, lapping the swaged edges to shed water. On horizontal pipes the longitudinal laps shall be located at 4 o'clock or 8 o'clock. On vertical pipes, they shall be located in the most sheltered position.
10. Where exposure to extreme conditions is unavoidable, the laps behind the swaged edges shall be sealed with a liberal application of .....sealer as manufactured by .....
11. All laps in the cladding shall be secured/rivetted at maximum centres of 150mm for longitudinal laps and 100mm for circumferential laps.

12. Adjacent to bends and at sufficient points in straight runs, provision shall be made for thermal expansion of the pipe by increasing the width of the end laps in the metal cladding and by omitting the circumferential screws/rivets at these points.

Note: Areas where austenitic stainless steel is used the preferred product is Fibertex Rockwool with a low chloride content. Contact the Bradford Insulation office in your region for details.

FIG 10.  
INSULATION OF PIPES AT  
TEMPERATURES BELOW AMBIENT.

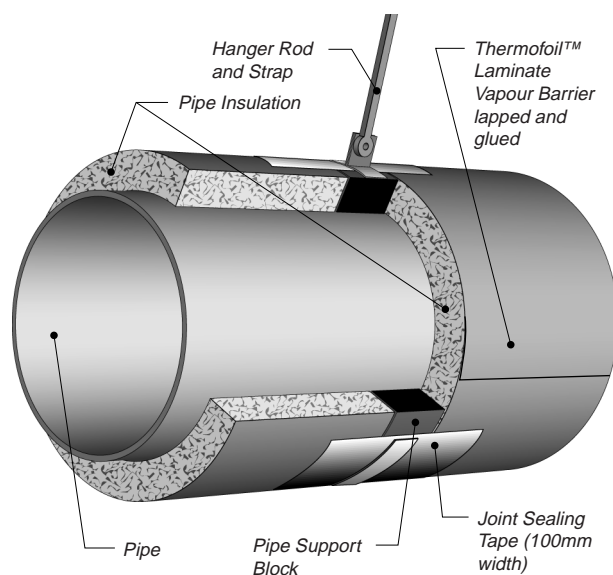
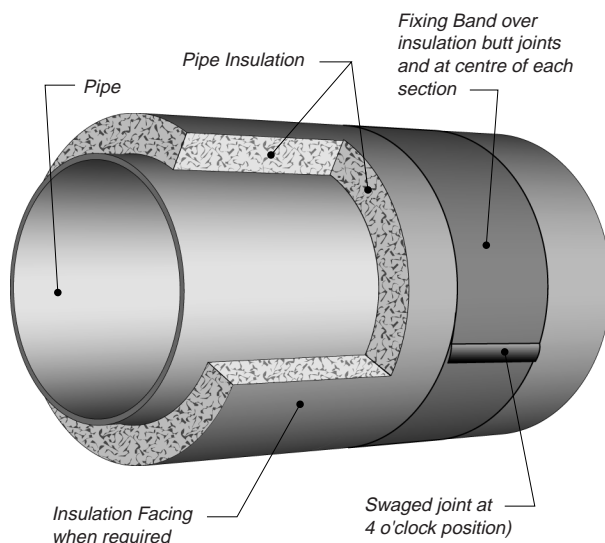


FIG 11.  
INSULATION OF PIPES UP TO 350°C.

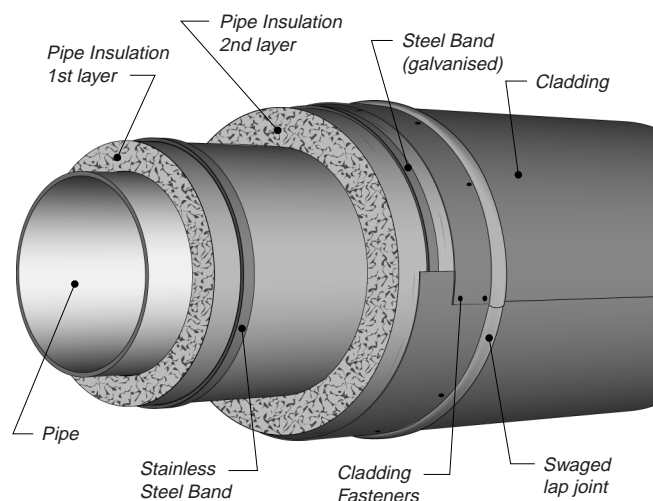


## Insulation of Pipes Above 350°C

1. The pipe to be insulated shall be clean, dry and free from grease, loose rust, etc.
2. The insulation materials shall be manufactured by Bradford Insulation and shall consist of:  
1st Layer: *Fibertex 450 SPI or Fibertex 650 SPI, thickness .....mm* (use Fibertex 650 SPI for temperatures above 450°C).  
2nd Layer: *Fibertex 450, thickness .....mm.*  
(The appropriate thickness of insulation can be calculated using the information contained in this guide. Alternatively contact the Bradford Insulation office in your region to make use of the Thermecon computer programme).
3. The insulation should be dry when installed and shall be kept dry.
4. The first layer of insulation shall be placed on the pipe, butting tightly all end joints. The sections shall be secured in position by means of 19mm x 0.5mm stainless steel bands using *two/three* bands per section.
5. The second layer of insulation shall be placed in position with all joints well staggered from those in the first layer. All joints between sections shall be butted tightly and each section shall be secured in position by means of *two/three* galvanised steel bands 19mm x 0.5mm.
6. Cladding shall be *galvanised steel/galvabond/zincanneal/zincalume/aluminium (plain/stucco embossed)* or .....(other) (select as required) of .....mm thickness.
7. The metal cladding shall be cut and rolled to provide minimum end laps of 75mm and 38/50/75mm longitudinal laps. The edges to be exposed at all lap joints shall be swaged.
8. The cladding shall be fitted tightly to the insulation so as to provide adequate support. Lap the edges of the cladding so as to shed water. On horizontal pipes the longitudinal laps shall be located at 4 o'clock or 8 o'clock. On vertical pipes, they shall be located in the most sheltered position.

9. Where exposure to extreme conditions is unavoidable, the laps behind the swaged edges shall be sealed with a liberal application of .....sealer as manufactured by .....
10. All laps in the cladding shall be secured/rivetted at maximum centres of 150mm for longitudinal laps and 100mm for circumferential laps.
11. Adjacent to bends and at sufficient points in straight runs, provision shall be made for thermal expansion of the pipe by increasing the width of the end laps in the metal cladding and by omitting the circumferential screws/rivets at these points.

FIG 12.  
INSULATION OF PIPES ABOVE 350°C.



## APPENDIX A.

# Heat Loss Tables.

### INTRODUCTION.

The following tables present theoretical heat losses and surface temperatures for insulated flat and curved surfaces and pipes for a range of hot face temperatures up to 650°C. Separate tables are shown for non-reflective and reflective cladding.

Insulation thicknesses are highlighted in the tables to provide a guide to the minimum thickness which will give a satisfactory degree of insulation for most purposes.

The following heat loss tables are indicative only. For other specific conditions of operating temperature, ambient temperature, surface coefficient, etc., it will be necessary to either carry out calculations using the method described in this guide or contact the CSR Bradford office in your region.

The correct thickness for a particular application should be determined by an economic thickness analysis. In the absence of an economic thickness analysis, it is suggested that the insulation thickness should be selected so that the insulation or cladding surface temperature will be between 30°C and 45°C.

Bradford Insulation has available competent and experienced engineers and computer facilities to undertake heat transfer calculations and economic thickness analysis. This service is available free of charge, by contacting CSR Bradford office in your region.

### DUAL LAYER PIPE INSULATION.

For elevated temperatures (350°C and above) dual layers of insulation will often be necessary to achieve the total insulation thickness required.

For small pipes (up to 50.8mm O.D.) a single insulation thickness is usually satisfactory. For larger pipes the insulation should be applied in at least two layers with all joints staggered.

Bradford can readily provide calculations for cost effective systems on request.

When ordering Fibertex Rockwool Pipe Insulation for dual layer applications, it is important to indicate the inside diameters of the underlag and overlay, and wall thickness of each layer. This enables the fit to be checked in the factory prior to packaging, and keeps problems in the field to a minimum.

### INDEX OF TABLES.

#### HEAT LOSS TO STILL AIR AT 20°C.

##### Flat and Curved Surfaces (Fibertex 350/450/650 Insulation)

Non-Reflective Cladding and Reflective Cladding		
Temperature Range	Table N°	Page
75°C to 350°C	A1 & A2	32
375°C to 450°C	A3 & A4	33
475°C to 650°C	A5 & A6	34 - 35

##### Pipes (Glasswool and Rockwool Pipe Insulation)

Temperature Range	Table N°	Page
75°C to 300°C		
Non-Reflective Cladding	A7	36 -37
Reflective Cladding	A8	38 - 39

##### Pipes (Fibertex Pipe Insulation)

Temperature Range	Table N°	Page
350°C to 600°C		
Non-Reflective Cladding	A9	40 - 44
Reflective Cladding	A10	45 - 49



# INDUSTRIAL DESIGN GUIDE

**FLAT AND CURVED SURFACES: 75°C TO 300°C.**

**INSULATION: FIBERTEX 350 ROCKWOOL.**

**HEAT LOSS TO STILL AIR AT 20°C.**

Q = Heat loss per square metre.

t<sub>s</sub> = Surface Temperature.

Minimum general purpose thicknesses are highlighted.

**Table A1**

Non-Reflective Cladding Surface coefficient: 10 W/m²K			
Hot Face Temperature t <sub>v</sub>	Insulation Thickness L	Heat Loss Q	Surface Temperature t <sub>s</sub>
°C	mm	W/m²	°C
75	25	75	27
	38	51	25
100	25	116	32
	38	80	28
	50	62	26
150	25	213	41
	38	147	35
	50	114	31
	63	91	29
200	38	231	43
	50	179	38
	63	144	34
	75	122	32
250	38	329	53
	50	260	46
	63	209	41
	75	177	38
	88	151	35
	100	134	33
300	50	352	55
	63	289	49
	75	244	44
	88	209	41
	100	185	38
	113	164	36
	125	149	35
350	63	378	58
	75	327	53
	88	280	48
	100	247	45
	113	219	42
	125	199	40
	138	180	38

**Table A2**

Reflective Cladding Surface coefficient: 5.7 W/m²K		
Insulation Thickness L	Heat Loss Q	Surface Temperature t <sub>s</sub>
mm	W/m²	°C
25	69	32
38	48	28
25	106	39
38	75	33
50	59	30
25	194	54
38	138	44
50	108	39
63	88	35
38	217	58
50	170	50
63	138	44
75	118	41
38	306	74
50	248	63
63	201	55
75	171	50
88	148	46
100	131	43
50	332	78
63	279	69
75	238	62
88	205	56
100	181	52
113	161	58
125	146	46
63	360	83
75	319	76
88	275	68
100	243	63
113	216	58
125	196	54
138	178	51



## FLAT AND CURVED SURFACES: 375°C TO 450°C.

### INSULATION: FIBERTEX 450 ROCKWOOL.

#### HEAT LOSS TO STILL AIR AT 20°C.

Q = Heat loss per square metre.

t<sub>s</sub> = Surface Temperature.

Minimum general purpose thicknesses are highlighted.

**Table A3**

**Table A4**

Hot Face Temperature t <sub>v</sub> °C	Non-Reflective Cladding Surface coefficient: 10 W/m²K			Reflective Cladding Surface coefficient: 5.7 W/m²K		
	Insulation Thickness L mm	Heat Loss Q W/m²	Surface Temperature t <sub>s</sub> °C	Insulation Thickness L mm	Heat Loss Q W/m²	Surface Temperature t <sub>s</sub> °C
	mm	W/m²	°C	mm	W/m²	°C
375	75	315	52	75	306	74
	88	270	47	88	264	66
	100	239	44	100	234	61
	113	212	41	113	208	57
	125	192	39	125	189	53
	138	174	37	138	172	50
400	88	303	50	88	296	72
	100	268	47	100	262	66
	113	238	44	113	233	61
	125	216	42	125	212	57
	138	196	40	138	193	54
	150	180	38	150	178	51
425	100	299	50	100	292	71
	113	265	47	113	260	66
	125	240	44	125	236	61
	138	218	42	138	215	58
	150	201	40	150	198	55
	163	185	39	163	183	52
450	113	294	49	113	288	71
	125	267	47	125	262	66
	138	242	44	138	238	62
	150	223	42	150	220	59
	163	205	41	163	203	56
	175	192	39	175	189	53

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**FLAT AND CURVED SURFACES: 475°C TO 650°C.**

**INSULATION: 1<sup>ST</sup> LAYER FIBERTEX 650 – 2<sup>ND</sup> LAYER FIBERTEX 450 ROCKWOOL.  
HEAT LOSS TO STILL AIR AT 20°C.**

Q = Heat loss per square metre.

t<sub>s</sub> = Surface Temperature.

Minimum general purpose thicknesses are highlighted.

**Table A5**

Hot Face Temperature t <sub>v</sub>  °C	Non-Reflective Cladding Surface coefficient: 10 W/m²K			
	1 <sup>st</sup> Layer L <sub>1</sub>	2 <sup>nd</sup> Layer L <sub>2</sub>	Heat Loss  Q	Surface Temperature t <sub>s</sub>
	mm	mm	W/m²	°C
475	25	75	362	56
	25	88	322	52
	25	100	292	49
	38	100	264	46
	38	113	242	44
	38	125	225	42
	38	138	209	41
	38	150	196	40
500	38	75	353	55
	38	88	318	52
	38	100	202	49
	50	100	267	47
	50	113	247	45
	50	125	231	43
	63	125	214	41
	63	138	201	40
525	50	75	351	55
	50	88	319	52
	63	88	291	49
	63	100	271	47
	63	113	252	45
	75	113	235	43
	75	125	221	42
	75	138	209	41
550	63	75	349	55
	63	88	320	52
	75	88	296	50
	75	100	277	48
	75	113	258	46
	88	113	241	44
	88	125	228	43
	100	125	216	42
	100	138	204	40

**Table A6**

Hot Face Temperature t <sub>v</sub>  °C	Reflective Cladding Surface coefficient: 5.7 W/m²K			
	1 <sup>st</sup> Layer L <sub>1</sub>	2 <sup>nd</sup> Layer L <sub>2</sub>	Heat Loss  Q	Surface Temperature t <sub>s</sub>
	mm	mm	W/m²	°C
475	25	75	354	82
	25	88	317	76
	38	88	283	70
	38	100	260	66
	38	113	239	62
	38	125	222	59
	38	138	206	56
	38	150	194	54
500	38	75	346	81
	38	88	313	75
	50	88	285	70
	50	100	264	66
	50	113	244	63
	50	125	228	60
	63	125	212	57
	63	138	199	55
525	50	75	345	80
	50	88	315	75
	63	88	287	70
	63	100	267	67
	63	113	249	64
	75	113	232	61
	75	125	219	58
	75	138	207	56
550	63	75	343	80
	63	88	316	75
	75	88	292	71
	75	100	274	68
	88	100	254	65
	88	113	239	62
	88	125	226	60
	100	125	214	57
	100	138	203	56

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# INDUSTRIAL DESIGN GUIDE

**Table A5** continued

**Table A6** continued

Hot Face Temperature $t_v$	Non-Reflective Cladding Surface coefficient: 10 W/m <sup>2</sup> K				Reflective Cladding Surface coefficient: 5.7 W/m <sup>2</sup> K			
	1 <sup>st</sup> Layer L <sub>1</sub>	2 <sup>nd</sup> Layer L <sub>2</sub>	Heat Loss Q	Surface Temperature $t_s$	1 <sup>st</sup> Layer L <sub>1</sub>	2 <sup>nd</sup> Layer L <sub>2</sub>	Heat Loss Q	Surface Temperature $t_s$
	mm	mm	W/m <sup>2</sup>	°C	mm	mm	W/m <sup>2</sup>	°C
575	75	75	351	55	75	75	346	80
	75	88	325	52	75	88	321	76
	88	88	300	50	88	88	297	72
	88	100	282	48	88	100	279	69
	100	100	265	46	100	100	262	66
	100	113	249	45	100	113	247	63
	113	113	234	43	113	113	232	61
	113	125	223	42	113	125	221	59
	113	138	212	41	125	125	211	57
600	88	88	329	53	100	75	324	77
	100	88	307	51	100	88	304	73
	100	100	290	49	113	88	284	70
	113	100	271	47	113	100	269	67
	113	113	257	46	113	113	255	65
	125	113	243	44	125	113	241	62
	125	125	232	43	125	125	231	60
	138	125	220	42	138	125	219	58
	138	138	211	41	138	138	209	57
625	113	75	333	53	113	75	330	78
	113	88	313	51	113	88	310	74
	125	88	295	50	125	88	292	71
	125	100	280	48	125	100	278	69
	138	100	265	46	138	100	262	66
	138	113	252	45	138	113	250	64
	150	113	240	44	150	113	238	62
	150	125	230	43	150	125	228	60
	163	125	219	42	163	125	218	58
	163	138	210	41	163	138	209	57
650	125	75	341	54	125	75	338	79
	125	88	322	52	125	88	319	76
	138	88	303	50	138	88	300	73
	138	100	288	49	138	100	286	70
	150	100	274	47	150	100	272	68
	163	100	260	46	163	100	258	65
	163	113	249	45	163	113	247	63
	175	113	238	44	175	113	237	62
	175	125	229	43	175	125	228	60
	188	125	220	42	188	125	218	58
	188	138	211	41	188	138	210	57

## PIPES: 75°C TO 300°C.

### INSULATION: GLASSWOOL & FIBERTEX ROCKWOOL SECTIONAL PIPE INSULATION. HEAT LOSS TO STILL AIR AT 20°C.

$Q'$  = Heat loss per metre.

$t_s$  = Surface Temperature.

Minimum general purpose thicknesses are highlighted.

**Table A7**

Non-Reflective Cladding Surface coefficient: 10 W/m <sup>2</sup> K													
Pipe Temperature °C		75		100		150		200		250		300	
Pipe OD	Insulation thickness	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
21.3	25	9	24	14	26	25	31	38	37	54	44	73	53
	38	7	22	11	24	20	27	31	30	44	34	60	40
	50	7	22	10	23	18	25	28	27	39	30	53	34
	63	6	21	9	22	16	24	25	25	36	28	48	30
26.9	25	10	24	16	27	28	32	44	38	62	46	84	55
	38	8	23	13	24	23	27	35	31	50	35	68	41
	50	7	22	11	23	20	25	31	28	44	31	59	35
	63	7	21	10	22	18	24	28	26	39	28	54	31
33.7	25	12	25	18	27	33	32	50	39	71	47	96	57
	38	10	23	15	24	26	28	40	32	57	36	77	42
	50	8	22	13	23	23	25	35	28	49	32	67	36
	63	7	21	11	22	20	24	31	26	44	29	60	32
42.4	25	14	25	21	27	38	33	58	40	83	48	112	59
	38	11	23	17	24	30	28	46	32	65	37	88	44
	50	9	22	14	23	26	26	39	29	56	32	76	37
	63	8	22	13	22	23	24	35	27	50	29	67	33
48.3	25	15	25	23	28	42	33	64	41	90	49	122	60
	38	12	23	18	25	32	28	50	33	70	38	95	44
	50	10	22	15	23	28	26	42	29	60	33	82	38
	63	9	22	14	22	24	24	37	27	53	30	72	33
60.3	25	18	25	27	28	49	34	75	42	106	51	143	61
	38	14	23	21	25	37	29	57	33	81	39	110	46
	50	12	22	18	24	32	26	49	30	69	34	94	39
	63	10	22	15	23	28	25	43	27	60	30	82	34
76.1	25	21	25	32	28	58	35	89	42	126	52	171	63
	38	16	23	25	25	44	29	67	34	96	40	129	47
	50	14	22	21	24	37	27	56	30	80	34	109	40
	63	12	22	18	23	32	25	49	28	70	31	94	35
88.9	25	24	26	37	28	65	35	100	43	142	53	192	64
	38	18	23	27	25	49	29	75	35	107	41	145	48
	50	15	23	23	24	41	27	63	31	89	35	121	40
	63	13	22	20	23	35	25	54	28	77	31	104	35
101.6	25	27	26	41	29	73	35	111	43	158	53	214	65
	38	20	24	30	25	54	30	83	35	118	41	160	49
	50	17	23	25	24	45	27	69	31	98	35	133	41
	63	14	22	22	23	39	25	59	28	84	32	114	36
114.3	25	29	26	45	29	80	36	123	44	174	54	236	66
	38	22	24	33	26	59	30	91	35	129	42	175	49
	50	18	23	27	24	49	27	75	31	107	36	145	41
	63	15	22	23	23	42	26	64	29	91	32	124	36
139.7	25	35	26	53	29	95	36	145	44	206	55	279	67
	38	26	24	39	26	69	30	106	36	151	42	205	50
	50	21	23	32	24	57	28	87	32	124	36	168	42
	63	18	22	27	23	48	26	74	29	105	33	143	37

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**Table A7 continued**

Non-Reflective Cladding Surface coefficient: 10 W/m <sup>2</sup> K													
Pipe Temperature °C		75		100		150		200		250		300	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
165.1	25	40	26	61	29	109	36	168	45	238	55	322	68
	38	29	24	44	26	79	30	122	36	173	43	235	51
	50	24	23	36	24	65	28	99	32	141	37	191	43
	63	20	22	31	23	55	26	84	29	119	33	162	38
	75	18	22	27	23	48	25	74	27	105	31	143	34
190.5	25	46	26	69	29	124	36	190	45	269	56	364	68
	38	33	24	50	26	90	31	137	36	195	43	264	52
	50	27	23	41	24	73	28	111	32	158	37	214	43
	63	22	22	34	23	61	26	94	29	133	33	180	38
	75	20	22	30	23	54	25	82	28	117	31	159	35
215.9	25	51	26	77	29	139	37	212	45	301	56	407	69
	38	37	24	56	26	100	31	153	37	217	44	294	52
	50	30	23	45	25	80	28	123	32	175	38	237	44
	63	25	22	38	24	67	26	103	30	147	34	199	39
	75	22	22	33	23	59	25	91	28	129	31	175	35
241.3	25	56	26	86	29	153	37	234	46	333	56	450	69
	38	40	24	61	26	110	31	168	37	239	44	323	52
	50	32	23	49	25	88	28	135	33	192	38	260	44
	63	27	22	41	24	74	26	113	30	160	34	217	39
	75	24	22	36	23	64	25	99	28	140	31	190	35
	88	21	22	32	22	57	24	88	27	125	30	169	33
266.7	25	62	26	94	29	168	37	257	46	364	57	493	70
	38	44	24	67	26	120	31	183	37	260	44	353	53
	50	35	23	54	25	96	28	147	33	209	38	283	45
	63	29	22	45	24	80	26	123	30	174	34	236	39
	75	26	22	39	23	70	25	107	28	152	32	206	36
	88	23	22	35	22	62	24	95	27	135	30	183	33
317.5	25	72	26	110	30	197	37	301	46	427	57	578	70
	38	51	24	78	26	140	31	214	37	304	45	411	53
	50	41	23	62	25	111	28	171	33	243	39	329	45
	63	34	22	52	24	92	27	142	30	201	34	273	40
	75	30	22	45	23	80	25	123	28	175	32	238	36
	88	26	22	40	23	71	25	109	27	155	30	210	34
355.6	25	80	26	122	30	218	37	335	46	475	57	642	70
	38	57	24	86	26	154	31	237	37	336	45	456	54
	50	45	23	69	25	123	29	189	33	268	39	363	45
	63	37	22	57	24	102	27	156	30	222	35	301	40
	75	32	22	49	23	88	26	136	29	193	32	261	36
	88	29	22	43	23	78	25	119	27	170	30	230	34

## PIPES: 75°C TO 300°C.

### INSULATION: GLASSWOOL & FIBERTEX ROCKWOOL SECTIONAL PIPE INSULATION. HEAT LOSS TO STILL AIR AT 20°C.

$Q'$  = Heat loss per metre.

$t_s$  = Surface Temperature.

Minimum general purpose thicknesses are highlighted.

**Table A8**

Reflective Cladding Surface coefficient: 5.7 W/m <sup>2</sup> K													
Pipe Temperature °C		75		100		150		200		250		300	
Pipe OD	Insulation thickness	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
21.3	25	9	27	13	30	24	38	36	48	51	60	69	74
	38	7	24	11	26	20	31	30	37	43	45	58	53
	50	6	23	10	25	18	28	27	32	38	38	52	44
	63	6	22	9	23	16	26	25	29	35	33	47	38
26.9	25	10	27	15	31	27	40	41	50	58	62	79	77
	38	8	24	12	26	22	32	34	38	48	46	65	56
	50	7	23	11	25	20	29	30	33	43	39	58	47
	63	7	22	10	24	18	26	27	30	39	34	53	39
33.7	25	11	28	17	32	31	41	47	51	67	65	90	80
	38	9	25	14	27	25	33	38	40	55	48	74	58
	50	8	23	12	25	22	29	34	34	48	40	65	47
	63	7	23	11	24	20	27	30	31	43	35	59	40
42.4	25	13	28	22	32	36	42	55	53	77	67	105	83
	38	11	25	16	28	29	34	44	41	62	49	85	60
	50	9	24	14	25	25	30	38	35	54	41	74	49
	63	8	23	12	24	22	27	34	31	49	36	66	42
48.3	25	14	28	22	32	39	42	60	54	84	68	114	85
	38	11	25	17	28	31	34	48	41	68	50	92	61
	50	10	24	15	26	27	30	41	36	59	42	79	50
	63	9	23	13	24	24	28	37	32	52	37	71	43
60.3	25	17	28	26	33	46	43	70	55	99	70	133	87
	38	13	25	20	28	36	35	55	43	78	52	106	63
	50	11	24	17	26	31	31	47	36	67	43	91	52
	63	10	23	15	25	27	28	42	32	59	38	80	44
76.1	25	20	29	30	33	54	44	83	57	117	72	158	90
	38	15	26	24	29	42	35	64	44	91	54	124	65
	50	13	24	20	26	36	31	55	37	78	45	105	53
	63	11	23	17	25	31	29	48	33	68	39	92	45
88.9	25	22	29	34	34	61	44	93	57	132	73	178	91
	38	17	26	26	29	47	36	72	44	102	55	138	67
	50	15	24	22	27	40	32	61	38	86	45	117	55
	63	13	23	19	25	34	29	53	34	75	40	102	46
101.6	25	25	29	38	34	68	45	104	58	146	74	197	93
	38	19	26	29	29	52	36	79	45	113	55	152	68
	50	16	24	25	27	43	32	67	38	95	46	128	55
	63	14	23	21	25	38	29	58	34	82	40	111	47
114.3	25	27	29	42	34	74	45	114	59	161	75	217	94
	38	21	26	32	29	57	37	87	45	123	56	166	69
	50	17	25	26	27	47	32	72	39	103	47	139	56
	63	15	23	23	25	41	29	63	35	89	41	120	48

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**Table A8** *continued*

Reflective Cladding Surface coefficient: 5.7 W/m <sup>2</sup> K													
Pipe Temperature °C		75		100		150		200		250		300	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
139	25	32	30	49	35	88	46	134	60	190	76	256	95
	38	24	26	37	30	66	37	101	46	144	57	194	70
	50	20	25	31	27	55	33	84	40	119	48	162	58
	63	17	24	26	26	47	30	72	35	102	42	139	49
165.1	25	37	30	57	35	101	46	155	60	219	77	295	97
	38	28	26	42	30	76	38	116	47	164	58	222	71
	50	23	25	35	27	62	33	96	40	136	49	184	59
	63	20	24	30	26	53	30	82	36	116	42	157	50
190.5	75	17	23	26	25	47	28	72	33	103	38	139	45
	25	42	30	64	35	115	47	175	61	248	78	334	98
	38	31	27	48	30	85	38	130	47	185	59	250	72
	50	26	25	39	28	70	33	107	41	152	49	206	60
215.9	63	22	24	33	26	59	30	91	36	129	43	175	51
	75	19	23	29	25	52	29	80	33	114	39	155	45
	25	47	30	72	35	128	47	196	61	277	78	373	98
	38	35	27	53	30	95	38	145	48	205	59	278	73
241.3	50	28	25	43	28	77	34	119	41	168	50	228	60
	63	24	24	37	26	65	31	100	36	142	43	193	52
	75	21	23	32	25	58	29	88	34	126	39	170	46
	25	52	30	79	35	141	47	216	61	305	79	411	99
266.7	38	38	27	58	30	104	38	159	48	226	60	306	74
	50	31	25	47	28	85	34	130	41	184	50	250	61
	63	26	24	40	26	71	31	110	37	156	44	211	52
	75	23	23	35	25	63	29	96	34	137	40	186	46
317.5	88	21	23	31	24	56	28	86	32	122	36	166	42
	25	57	30	87	35	155	47	236	62	334	79	450	99
	38	42	27	64	30	113	38	174	48	246	60	333	74
	50	34	25	52	28	92	34	141	42	201	51	272	61
355.6	63	29	24	43	26	78	31	119	37	169	44	229	53
	75	25	23	38	25	68	29	104	34	148	40	201	47
	88	22	23	34	24	61	28	93	32	132	37	179	43
	25	67	30	102	35	181	48	277	62	392	80	528	100
355.6	38	49	27	74	31	132	39	203	49	287	61	388	75
	50	39	25	60	28	107	34	164	42	233	51	315	62
	63	33	24	50	26	90	31	137	37	195	45	264	53
	75	29	23	44	25	78	29	120	34	171	40	231	48
355.6	88	26	23	39	24	69	28	107	32	151	37	205	43
	25	74	30	113	36	201	48	308	62	435	80	586	101
	38	54	27	82	31	146	39	224	49	318	61	430	76
	50	43	25	66	28	118	34	181	42	257	52	348	63
355.6	63	36	24	55	26	99	31	151	38	215	45	291	54
	75	32	23	48	25	86	30	132	35	187	41	254	48
	88	28	23	43	24	76	28	117	32	166	37	225	44

## PIPES: 350°C TO 600°C.

### INSULATION: FIBERTEX ROCKWOOL SECTIONAL PIPE INSULATION.

#### HEAT LOSS TO STILL AIR AT 20°C.

$Q'$  = Heat loss per metre.

$t_s$  = Surface Temperature.

Minimum general purpose thicknesses are highlighted, dual layers recommended over 75mm.

**Table A9**

Non-Reflective Cladding Surface coefficient: 10 W/m <sup>2</sup> K													
Pipe Temperature °C		350		400		450		500		550		600	
Pipe OD	Insulation thickness	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$	$Q'$	$t_s$
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
21.3	38	76	45	96	52	120	59						
	50	68	38	85	42	106	48	130	54	157	61	188	69
	63	61	33	77	37	96	41	118	45	143	51	171	57
	75							110	40	133	45	159	50
	88							103	37	125	40	150	44
	100							98	34	119	37	143	41
26.9	38	86	47	109	54	135	62						
	50	76	39	96	44	119	50	145	56	176	64	210	73
	63	68	34	86	38	107	42	131	47	158	53	190	60
	75							121	42	147	46	176	52
	88							114	38	138	42	165	46
	100							108	35	131	38	157	42
33.7	38	97	48	123	56	153	64						
	50	85	40	107	46	133	52	163	59	197	67	236	76
	63	76	35	96	39	119	44	146	49	177	55	211	62
	75							135	43	163	48	195	54
	88							126	39	152	43	182	48
	100							119	36	144	40	172	43
44.2	38	112	50	141	58	175	67						
	50	96	42	122	47	151	54	185	61	224	70	268	80
	63	85	36	108	40	134	45	164	51	199	58	238	65
	75							151	45	182	50	219	56
	88							140	40	169	45	203	50
	100							132	37	160	41	191	45
48.3	38	121	51	153	59	190	69						
	50	104	42	131	48	163	55	200	63	241	72	289	82
	63	92	37	116	41	144	46	176	52	213	59	256	67
	75							161	46	195	51	234	58
	88							149	41	180	46	216	51
	100							140	38	170	42	203	46

*continued over page*

**Table A9** *continued*

Non-Reflective Cladding Surface coefficient: 10 W/m <sup>2</sup> K													
Pipe Temperature °C		350		400		450		500		550		600	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
60.3	38	121	51	153	59	190	69						
	50	104	42	131	48	163	55						
	63	92	37	116	41	144	46	200	63	213	59	256	67
	75							161	46	195	51	234	58
	88							149	41	180	46	216	51
	100							140	38	170	42	203	46
	113							133	35	160	39	192	42
	125							127	34	153	36	184	40
76.1	38	164	54	207	63	257	74						
	50	138	45	174	52	217	59						
	63	120	39	152	44	188	50	231	56	279	64	334	73
	75							209	49	252	56	302	63
	88							191	44	231	49	276	55
	100							178	41	215	45	258	50
	113							167	38	202	41	242	45
	125							158	35	191	39	229	42
88.9	38	184	55	168	45	288	76						
	50	153	46	194	53	241	61						
	63	133	40	168	45	208	51	255	58	308	66	369	75
	75							229	51	278	57	332	64
	88							209	45	253	50	303	56
	100							194	41	235	46	281	51
	113							182	38	220	42	263	47
	125							172	36	208	40	249	43



**Table A9** *continued*

Non-Reflective Cladding Surface coefficient: 10 W/m <sup>2</sup> K													
Pipe Temperature °C		350		400		450		500		550		600	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
101.6	38	203	56	256	66	318	77						
	50	168	47	213	54	264	62						
	63	145	40	183	46	228	52	279	59	337	67	404	76
	75							250	52	302	58	362	66
	88							227	46	274	51	328	58
	100							210	42	254	47	305	52
	113							196	39	237	43	284	48
	125							185	37	224	40	268	44
114.3	38	222	57	199	46	247	53						
	50	183	47	232	54	288	63						
	63	157	41	199	46	247	53	302	60	366	68	438	78
	75							270	53	327	59	391	67
	88							244	47	296	52	354	59
	100							226	43	273	48	327	53
	113							210	40	254	44	305	48
	125							198	37	240	41	287	45
139.7	38	259	58	328	68	407	80						
	50	213	48	269	56	334	64						
	63	181	42	229	47	285	54						
	75							310	54	375	61	449	69
	88							279	48	337	54	404	61
	100							257	44	311	49	372	55
	113							238	41	288	45	345	50
	125							224	38	271	42	324	46
165.1	138							211	36	255	40	306	43
	38	297	59	375	70	446	81						
	50	243	49	306	57	381	66						
	63	205	42	259	48	322	55						
	75	182	38	230	43	285	49	349	55	422	63	506	71
	88							313	49	379	55	453	62
	100							287	45	348	50	416	56
	113							265	42	321	46	385	51
190.5	125							249	39	301	43	361	48
	138							234	37	283	40	339	44
	38	334	60	422	70	524	83						
	50	272	50	343	58	427	68						
	63	229	43	289	49	360	56						
	75	202	39	255	44	317	50	388	56	470	64	562	73
	88							347	50	420	56	502	64
	100							317	46	384	51	460	57
190.5	113							292	42	354	47	424	52
	125							274	40	331	44	396	49
	138							257	38	310	41	372	45

*continued over page*

Table A9 continued

Non-Reflective Cladding Surface coefficient: 10 W/m²K													
Pipe Temperature °C		350		400		450		500		550		600	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
215.9	38	372	61	470	71	583	86						
	50	301	50	380	58	472	68						
	63	253	44	319	50	397	57						
	75	222	39	281	44	349	50	427	57	516	65	618	74
	88							380	51	460	57	551	65
	100							347	47	420	52	503	59
	113							319	43	386	48	462	53
	125							298	40	361	45	432	49
	138							279	38	338	42	404	46
	150												
241.3	38	409	61	306	45	380	51						
	50	330	51	417	59	518	68						
	63	277	44	349	50	434	58						
	75	242	40	306	45	380	51						
	88							414	52	500	58	599	66
	100							377	47	456	53	546	59
	113							346	44	418	48	501	54
	125							322	41	390	45	467	50
	138							301	39	364	42	436	47
	150							285	37	344	40	412	44
266.7	38	446	61	564	72	700	85						
	50	359	51	454	59	563	69						
	63	300	44	379	51	470	58						
	75	262	40	331	45	412	51						
	88	232	37	294	41	365	46	447	52	541	59	647	67
	100							406	48	492	54	589	60
	113							372	44	450	49	539	55
	125							346	41	419	46	501	51
	138							323	39	391	43	468	47
	150							305	37	369	41	442	45
317.5	38	521	62	658	73	816	86						
	50	417	52	527	60	654	70						
	63	347	45	438	51	544	59						
	75	302	41	382	46	474	52						
	88	267	37	337	42	419	47	513	53	620	60	743	68
	100							465	49	563	55	674	61
	113							424	45	513	50	615	56
	125							394	42	477	47	571	52
	138							367	40	444	44	531	48
	150							345	38	418	42	500	46
355.6	38	577	63	728	74	903	87						
	50	461	52	582	61	722	70						
	63	382	45	482	52	599	60						
	75	332	41	419	46	521	53						
	88	292	38	370	42	459	47	562	54	680	61	814	69
	100							509	49	616	55	737	62
	113							463	45	561	51	671	57
	125							429	43	520	47	622	53
	138							399	40	483	44	578	49
	150							375	38	454	42	544	46

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**Table A9** *continued*

Non-Reflective Cladding Surface coefficient: 10 W/m <sup>2</sup> K													
Pipe Temperature °C		350		400		450		500		550		600	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
406.4	38	651	63	822	74	1020	87						
	50	518	53	655	61	813	71						
	63	428	46	541	52	672	60						
	75	371	41	469	47	583	53						
	88	326	38	413	43	513	48						
	100							567	50	686	56	822	63
	113							515	46	624	51	747	58
	125							477	43	577	48	691	53
	138							442	41	535	45	640	50
	150							415	39	502	43	602	47
	163							390	37	472	41	566	45
457.0	38	725	63	915	75	1135	88						
	50	576	53	727	62	903	72						
	63	475	46	600	53	745	61						
	75	411	42	519	47	645	54						
	88	360	38	456	43	566	48						
	100							625	50	756	57	905	64
	113							567	46	686	52	821	58
	125							523	44	633	49	758	54
	138							485	41	586	45	702	51
	150							455	39	550	43	659	48
	163							427	37	517	41	619	45
508.0	38	799	64	1009	75	1252	88						
	50	634	53	801	62	994	72						
	63	522	46	659	53	818	61						
	75	451	42	569	48	707	54						
	88	395	38	499	43	619	49						
	100							683	51	826	57	989	64
	113							619	47	748	52	896	59
	125							570	44	690	49	827	55
	138							527	41	638	46	764	51
	150							494	39	598	44	716	48
	163							463	38	561	41	672	46
610.0	38	948	64	1197	76	726	49						
	50	750	54	947	62	1176	73						
	63	615	47	777	54	965	62						
	75	530	42	670	48	832	55						
	88	463	38	585	44	726	49						
	100							799	51	967	58	1157	65
	113							722	47	873	53	1046	60
	125							664	45	804	50	963	56
	138							613	42	742	47	888	52
	150							573	40	693	44	830	49
	163							536	38	649	43	777	46

## PIPES: 350°C TO 600°C.

### INSULATION: FIBERTEX ROCKWOOL SECTIONAL PIPE INSULATION.

#### HEAT LOSS TO STILL AIR AT 20°C.

Q' = Heat loss per metre.

t<sub>s</sub> = Surface Temperature.

Minimum general purpose thicknesses are highlighted, dual layers recommended over 75mm.

**Table A10**

Reflective Cladding Surface coefficient: 5.7 W/m <sup>2</sup> K													
Pipe Temperature °C		350		400		450		500		550		600	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
21.3	38	74	62	93	73	115	86						
	50	66	50	83	58	103	66						
	63	60	43	76	49	94	56	116	64	140	73	167	83
	75	56	38	71	43	88	49	108	55	131	63	157	71
	88							102	49	123	55	148	62
	100							98	45	118	50	141	56
	113							93	41	113	46	135	51
26.9	38	83	65	105	77	130	90						
	50	74	52	93	61	116	71						
	63	67	44	84	51	105	58	128	67	155	77	186	88
	75	62	40	79	45	98	51	119	58	145	66	173	75
	88							112	51	136	57	163	65
	100							107	46	129	52	155	58
	113							102	43	123	47	148	53
33.7	38	94	68	118	80	146	95						
	50	82	54	104	64	129	74						
	63	74	46	94	53	117	61	143	70	173	80	207	92
	75	69	41	87	46	108	53	132	60	160	69	192	78
	88							124	53	150	60	179	68
	100							117	48	142	54	170	61
	113							112	44	135	49	162	55
42.4	38	107	70	135	84	167	99						
	50	93	57	118	66	146	77						
	63	84	48	106	55	131	63	160	73	194	84	232	97
	75	77	42	97	48	121	55	148	63	179	72	214	82
	88							138	55	167	63	199	71
	100							130	50	157	56	189	63
	113							124	46	149	51	179	57
48.3	125							118	43	143	47	172	53
	38	116	72	146	86	181	101						
	50	101	58	127	68	157	79						
	63	90	49	113	56	141	65	172	75	208	87	249	100
	75	82	43	104	49	129	56	158	65	191	74	229	84
	88							147	57	178	64	213	73
	100							138	51	167	58	201	65
60.3	113							131	47	159	52	190	59
	125							125	43	152	48	182	54
	38	133	75	168	89	208	105						
	50	115	60	145	71	180	83						
	63	102	50	128	58	159	68						
	75	93	45	117	51	146	59	178	67	216	77	258	89
	88	86	40	108	46	134	52	165	59	199	67	238	76
	100							155	53	187	60	224	68
	113							146	48	177	54	211	61
	125							139	45	168	50	202	56
	138							133	42	161	47	193	52

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Table A10 continued

Reflective Cladding Surface coefficient: 5.7 W/m <sup>2</sup> K													
Pipe Temperature °C		350		400		450		500		550		600	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
76.1	38	156	77	197	92	244	110						
	50	133	62	168	73	209	86						
	63	117	52	148	61	183	71						
	75	106	46	134	53	167	61	204	70	247	81	295	93
	88	97	42	123	47	153	54	187	61	226	70	271	80
	100							175	55	212	63	254	71
	113							165	50	199	57	238	64
	125							156	48	189	52	227	59
	138							149	44	180	49	216	54
88.9	38	174	79	220	94	272	112						
	50	148	64	187	75	232	88						
	63	129	54	163	62	202	73						
	75	117	47	147	54	183	63	224	72	271	83	324	96
	88	107	42	135	48	167	55	205	63	248	72	297	83
	100							191	57	231	65	277	74
	113							179	52	217	58	259	66
	125							170	48	206	54	246	61
	138							162	45	195	50	234	56
101.6	38	192	80	242	96	300	114						
	50	162	65	205	77	254	90						
	63	141	55	178	64	221	74						
	75	127	49	160	56	199	64	244	74	295	85	353	98
	88	116	43	146	49	182	57	222	65	269	74	322	85
	100							207	58	250	66	299	75
	113							193	53	234	60	280	68
	125							183	49	221	55	265	62
	138							174	46	210	51	252	57
114.3	38	210	82	265	98	327	116						
	50	176	66	223	78	276	92						
	63	153	55	193	65	239	76						
	75	137	49	173	57	215	65						
	88	125	44	157	50	195	58	239	66	289	76	346	87
	100							222	59	269	68	322	77
	113							208	54	251	61	300	69
	125							196	50	237	56	284	63
	138							185	47	224	52	269	58
	150							177	44	215	49	257	55
139.7	38	245	83	309	100	383	119						
	50	205	68	258	80	320	95						
	63	176	57	222	67	276	78						
	75	157	50	199	58	246	68						
	88	142	45	179	52	223	59	273	68	330	78	385	90
	100	131	42	166	47	206	54	252	61	305	70	365	80
	113							234	56	284	63	339	72
	125							221	52	267	58	320	66
	138							209	48	252	54	302	61
	150							199	45	241	51	288	57

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**Table A10** *continued*

Reflective Cladding Surface coefficient: 5.7 W/m <sup>2</sup> K													
Pipe Temperature °C		350		400		450		500		550		600	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
165.1	38	280	85	353	102	437	121						
	50	232	69	293	82	364	97						
	63	199	58	251	68	312	80						
	75	177	51	223	60	278	69						
	88	159	46	201	53	250	61						
	100	147	42	185	48	230	55	282	63	341	72	319	58
	113							261	57	316	65	378	74
	125							245	53	297	60	355	68
	138							231	49	280	55	335	62
	150							212	46	266	52	319	58
	163							209	44	253	49	304	55
190.5	38	315	86	397	103	492	123						
	50	260	70	329	83	407	98						
	63	222	59	280	69	347	81						
	75	197	52	248	61	308	71						
	88	176	47	223	54	277	62						
	100	162	43	205	49	254	56	311	65	367	74	451	84
	113	150	40	189	45	235	51	287	59	348	67	416	76
	125	140	38	177	42	220	48	269	54	326	61	390	69
	138							253	50	306	57	367	64
	150							241	47	291	53	349	60
	163							229	45	277	50	331	56
215.9	38	350	87	441	104	546	124						
	50	288	71	363	84	451	100						
	63	244	60	309	70	383	83						
	75	216	53	273	62	339	72						
	88	193	48	244	55	303	63						
	100	177	44	224	50	278	57	340	66	412	75	493	86
	113	163	41	206	46	256	52	314	60	379	68	454	77
	125	153	38	193	43	240	49	293	55	355	63	425	71
	138							275	51	333	59	399	65
	150							261	48	316	54	378	61
	163							248	46	300	51	359	57
241.3	38	385	88	485	105	600	126						
	50	316	72	398	85	494	101						
	63	267	61	337	71	418	84						
	75	235	54	297	62	369	73						
	88	210	48	266	56	330	64						
	100	192	44	243	51	302	58						
	113	177	41	223	57	277	53	339	61	411	69	492	79
	125	165	39	208	44	259	49	317	56	384	64	459	72
	138							297	52	359	59	430	66
	150							281	49	340	55	407	62
	163							266	46	322	52	386	58
	175							255	44	308	49	369	55

*continued over page*

**Table A10** *continued*

Reflective Cladding Surface coefficient: 5.7 W/m <sup>2</sup> K													
Pipe Temperature °C		350		400		450		500		550		600	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
266.7	38	420	88	527	106	654	127						
	50	343	72	433	86	537	102						
	63	289	61	366	72	454	85						
	75	255	54	322	63	400	74						
	88	227	49	287	56	356	65						
	100	207	45	262	51	325	59						
	113	190	42	240	47	298	54	365	61	442	70	529	80
	125	177	39	224	44	278	50	341	57	412	65	493	73
	138							318	53	385	60	461	67
	150							301	50	364	56	436	63
	163							285	47	345	53	413	59
	175							272	45	329	50	394	56
317.5	38	489	89	616	107	762	128						
	50	398	73	502	87	623	103						
	63	334	62	422	73	524	86						
	75	293	55	370	64	460	75						
	88	260	49	329	57	408	66						
	100	237	46	299	52	372	60						
	113	217	42	274	48	340	55	416	63	504	72	603	82
	125	202	40	255	45	316	51	387	58	469	66	561	75
	138							361	54	437	61	523	69
	150							341	51	412	57	494	65
	163							322	48	389	54	466	60
	175							307	46	371	51	444	57
355.6	38	541	90	681	108	843	129						
	50	439	74	554	88	687	104						
	63	368	63	465	74	577	87						
	75	322	56	407	65	505	76						
	88	285	50	360	58	447	67						
	100	259	46	327	53	406	61						
	113	237	43	299	49	371	56	455	64	550	73	658	83
	125	220	40	278	46	345	52	422	59	511	67	611	76
	138							393	55	476	62	569	70
	150							370	52	448	58	536	66
	163							349	49	423	55	506	61
	175							332	46	402	52	482	58

*continued over page*

**Table A10** *continued*

Reflective Cladding Surface coefficient: 5.7 W/m <sup>2</sup> K													
Pipe Temperature °C		350		400		450		500		550		600	
Pipe OD	Insulation thickness	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>	Q'	t <sub>s</sub>
mm	mm	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C	W/m	°C
406.4	38	610	91	769	109	951	130						
	50	494	75	624	89	773	105						
	63	413	63	521	75	647	88						
	75	360	56	455	66	565	77						
	88	318	51	402	59	499	68						
	100	289	47	365	54	453	62						
	113	263	43	332	49	413	56	505	65	611	74	731	85
	125	244	41	308	46	382	53	468	50	567	68	678	78
	138							435	56	527	63	630	72
	150							409	52	495	59	593	67
	163							385	49	466	56	558	63
	175							366	47	443	53	531	59
457.0	38	679	91	855	110	1058	131						
	50	549	75	692	89	858	106						
	63	457	64	577	75	716	89						
	75	398	57	503	66	625	77						
	88	351	51	444	59	551	69						
	100	318	47	402	54	499	62						
	113	289	44	365	50	454	57	555	65	672	75	804	86
	125	268	41	338	47	390	50	514	61	620	69	745	79
	138							477	56	577	64	691	73
	150							448	53	542	60	649	68
	163							421	50	510	56	610	64
	175							400	48	484	53	579	60
508.0	38	749	92	943	110	1166	132						
	50	604	75	762	90	944	107						
	63	502	64	634	76	787	89						
	75	437	57	552	67	685	78						
	88	384	51	486	60	603	69						
	100	347	47	439	55	545	63						
	113	315	44	399	50	495	58	606	66	733	76	877	87
	125	291	41	368	47	458	54	560	61	678	70	817	88
	138							519	57	628	65	752	74
	150							487	54	589	61	706	69
	163							457	51	553	57	663	64
	175							434	48	525	54	628	61
610.0	38	887	92	1118	111	1382	133						
	50	714	76	900	91	1115	108						
	63	592	65	747	77	972	90						
	75	513	58	648	68	805	79						
	88	450	52	569	60	707	70						
	100	406	48	513	55	637	64						
	113	368	45	465	51	577	59	707	67	854	77	1023	88
	125	339	42	429	48	532	55	652	62	789	71	944	81
	138							603	58	729	66	873	75
	150							565	55	683	62	813	70
	163							529	52	640	58	766	66
	175							501	49	606	55	726	62

Bradford Fibertex Sectional Pipe Insulation is available to suit up to 711mm pipe O.D. Larger diameter pipes are insulated with Fibertex V-Lock or Fibermesh Blanket Pipe Wrap. Consult the Bradford Insulation office in your region for further design assistance or information.

## APPENDIX B.

## Design Data.

## THERMAL CONDUCTIVITY.

The thermal conductivity of Bradford Fibertex Rockwool and Glasswool varies with the mean temperature of the insulation, as shown in the table. Test measurements made in accordance with ASTM C518, ASTM C177, BS874 and AS 2464.6. Pipe Insulation is tested in accordance with ASTM C335.

NOTE: Tables provide typical values only. Products may vary slightly from plant to plant. Please refer to the Product Data Sheets, or contact the CSR Bradford Insulation office in your region for product recommendations for your project and assistance with heat loss calculations.

IMPORTANT: CSR Bradford Insulation recommends designers include a safety margin into heat loss calculations by always rounding up the thickness of insulation determined to the next standard thickness instead of rounding down.

**TABLE B1. BRADFORD FIBERTEX/FIBERMESH ROCKWOOL PRODUCTS.**  
**THERMAL CONDUCTIVITY OF INSULATION vs INSULATION MEAN TEMPERATURE.**

METRIC	Thermal Conductivity (W/mK)							
	Mean Temperature °C							
	20	50	100	200	300	400	500	600
Bradford Product								
FIBERTEX™ Rockwool 350	0.034	0.038	0.047	0.072	0.108	-	-	-
FIBERTEX™ Rockwool 450	0.034	0.038	0.045	0.065	0.092	0.126	-	-
FIBERTEX™ Rockwool 650	0.034	0.037	0.044	0.064	0.089	0.118	0.150	0.189
FIBERTEX™ Rockwool 820	0.034	0.037	0.044	0.059	0.090	0.118	0.145	0.180
FIBERTEX™ Rockwool HD	0.033	0.037	0.043	0.060	0.081	0.111	-	-
FIBERMESH™ Rockwool 350	0.034	0.038	0.047	0.072	0.108	-	-	-
FIBERMESH™ Rockwool 450	0.034	0.038	0.045	0.065	0.092	0.126	-	-
FIBERMESH™ Rockwool 650	0.034	0.037	0.044	0.064	0.090	0.118	0.150	0.189
FIBERTEX™ Rockwool Pipe Insulation	0.034	0.037	0.042	0.058	0.078	0.106	0.140	0.180

IMPERIAL	Thermal Conductivity (BTU in/ft²h°F)							
	Mean Temperature °F							
	100	200	300	400	500	600	700	800
Bradford Product								
FIBERTEX™ Rockwool 350	0.252	0.325	0.409	0.520	0.650	0.817	-	-
FIBERTEX™ Rockwool 450	0.251	0.304	0.366	0.455	0.561	0.670	0.813	-
FIBERTEX™ Rockwool 650	0.251	0.300	0.360	0.447	0.550	0.648	0.762	0.882
FIBERTEX™ Rockwool 820	0.250	0.296	0.355	0.434	0.529	0.627	0.753	0.869
FIBERTEX™ Rockwool HD	0.244	0.296	0.348	0.426	0.519	0.620	0.739	-
FIBERMESH™ Rockwool 350	0.252	0.325	0.409	0.520	0.650	0.817	-	-
FIBERMESH™ Rockwool 450	0.251	0.304	0.366	0.455	0.561	0.679	0.813	-
FIBERMESH™ Rockwool 650	0.251	0.300	0.360	0.447	0.550	0.648	0.762	0.882
FIBERTEX™ Rockwool Pipe Insulation	0.250	0.291	0.346	0.415	0.498	0.595	0.706	0.831

**TABLE B2. BRADFORD GLASSWOOL PRODUCTS.  
THERMAL CONDUCTIVITY OF INSULATION vs INSULATION MEAN TEMPERATURE.**

METRIC	Thermal Conductivity (W/mK)					
	Mean Temperature °C					
	<20	60	100	200	300	400
Bradford Product						
Bradford Glasswool FLEXITEL™	0.033	0.042	0.052	-	-	-
Bradford Glasswool SUPERTEL™	0.032	0.039	0.049	0.080	-	-
Bradford Glasswool ULTRATEL™	0.031	0.037	0.045	0.068	0.089	-
Bradford Glasswool HT THERMATEL™	0.032	0.038	0.046	0.064	0.090	0.129
Bradford Glasswool DUCTEL™	0.031	0.037	0.042	0.063	0.088	-
Bradford Glasswool QUIETEL™	0.031	0.036	0.041	0.059	-	-
Bradford Glasswool Pipe Insulation	0.032	0.037	0.041	0.057	0.082	0.114

IMPERIAL	Thermal Conductivity (BTU in/ft²h°F)					
	Mean Temperature °F					
	<100	200	300	400	500	600
Bradford Product						
Bradford Glasswool FLEXITEL™	0.253	0.344	0.449	-	-	-
Bradford Glasswool SUPERTEL™	0.237	0.314	0.415	0.522	-	-
Bradford Glasswool ULTRATEL™	0.232	0.297	0.405	0.501	0.589	-
Bradford Glasswool HT THERMATEL™	0.242	0.308	0.377	0.455	0.550	0.668
Bradford Glasswool DUCTEL™	0.232	0.289	0.361	0.446	0.542	-
Bradford Glasswool QUIETEL™	0.228	0.276	0.336	0.428	-	-
Bradford Glasswool Pipe Insulation	0.240	0.284	0.344	0.420	0.512	0.620



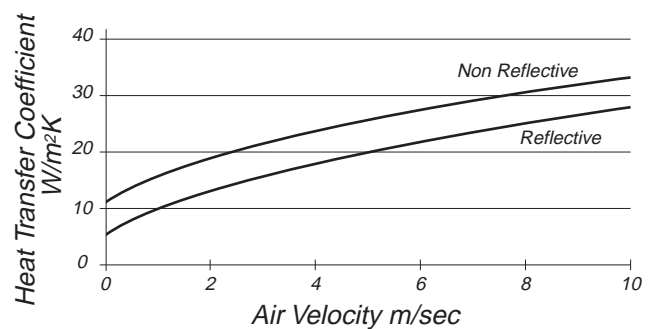
**TABLE B3.**  
**DEW POINT TEMPERATURE, °C.**

Ambient Air Temp. (dry bulb) °C	Relative Humidity Percent (%)							
	20	30	40	50	60	70	80	90
5	-14.4	-9.9	-6.6	-4.0	-1.8	0	1.9	3.5
10	-10.5	-5.9	-2.5	-0.1	2.7	4.8	6.7	8.4
15	-6.7	-2.0	1.7	4.8	7.4	9.7	11.6	13.4
20	-3.0	2.1	6.2	9.4	12.1	14.5	16.5	18.3
25	0.9	6.6	10.8	14.1	16.9	19.3	21.4	23.3
30	5.1	11.0	15.3	18.8	21.7	24.1	26.3	28.3
35	9.4	15.5	19.9	23.5	26.5	29.0	31.2	33.2
40	13.7	20.0	24.6	28.2	31.3	33.9	36.1	38.2

**TABLE B4. SURFACE COEFFICIENTS.**

Cladding	W/m <sup>2</sup> .K
Aluminium	5.7
Galvanised steel and Zinalume	6.3
Zincanneal	8.0
Bare insulation, dark paints and mastics	10.0

**FIG B1.**  
**HEAT TRANSFER COEFFICIENT vs AIR VELOCITY**



**TABLE B5. SOUND ABSORPTION.**

Bradford Fibertex Rockwool and Glasswool products achieve the following sound absorption coefficients when tested in accordance with AS1045 : 1988, Reverberation Room Method.

Product	Facings	Thickness (mm)	Frequency (Hz)							NRC★
			125	250	500	1000	2000	4000	5000	
Bradford Glasswool SUPERTEL™	THERMOFOIL™	25	0.12	0.28	0.68	0.94	1.09	0.85	0.75	0.75
	HD Perf.	50	0.39	0.72	1.14	1.19	1.05	0.98	0.90	1.02
Bradford Glasswool ULTRATEL™	THERMOFOIL™	25	0.12	0.31	0.81	1.09	1.09	0.91	0.89	0.80
	HD Perf.	75	0.69	1.19	1.15	1.09	1.03	0.92	0.90	1.11
Bradford FIBERTEX™ 350	THERMOFOIL™	25	0.06	0.26	0.73	0.96	1.10	0.93	0.84	0.75
	HD Perf.	50	0.20	0.66	1.13	1.13	1.12	1.04	0.91	1.00
	ACOUSTICLAD™ 15% Perf Metal + BMF	50	0.30	0.85	1.05	1.00	1.00	1.00	0.90	1.00
	ACOUSTICLAD™ 15% Perf Metal + 23µm Mylar	50	0.35	0.90	1.00	0.90	0.80	0.65	0.60	0.90

★ NRC: Arithmetic average of absorption coefficients of frequency 250, 500, 1000 and 2000 Hz.

## APPENDIX C.

# Frequently Asked Questions & Answers.

**Q. What type of pipe insulation is best?**

A. Bradford Glasswool and Rockwool pipe insulation are each best suited to meet the following design criteria for particular applications.

**Operating Temperature.**

- For low temperatures down to  $-40^{\circ}\text{C}$  Bradford Glasswool or Rockwool SPI is suitable when installed with a suitable vapour barrier.
- For operating temperatures up to  $450^{\circ}\text{C}$ , Glasswool Pipe Insulation or Rockwool Pipe Insulation may be used. Rockwool is recommended in the upper temperature range because of its greater thermal resistance and compression resistance under operating conditions.
- For high temperatures up to  $650^{\circ}\text{C}$  Rockwool Pipe Insulation is used.

**Handling Characteristics.**

- At the lower end of the industrial temperature range, the lightness and resilience of Glasswool Pipe Insulation are distinct advantages for the installation process.

**Cost Control.**

- For 'large' pipes (200mm diameter or greater) Fibermesh 650 may be cost effectively substituted for Rockwool Pipe Insulation, particularly on large projects and where damage via mechanical compression (e.g. personnel climbing over pipework) is a minimal risk. Generally an extra 13mm insulation thickness is required for performance comparable with pipe insulation.

**Q. What thickness insulation is needed?**

A. This depends very much on the operating temperature of the system, the desired level of control of heat loss (or gain), maximum surface temperature for personnel protection, and condensation control.

In addition, the reflective properties (surface coefficient) of the insulation cladding affects heat loss and surface temperature at a given insulation thickness.

Sample calculations and heat loss tables in Appendix A of this guide will assist the designer. Additionally, Bradford can readily provide calculations based on the designer's requirements.

**Q. Will I get better insulation performance by using a higher grade of Rockwool?**

A. It depends on the hot face temperature.

At lower temperatures (up to  $350^{\circ}\text{C}$ ) there is little or no advantage in using Fibertex 450 or Fibertex 650, since in the lower range the thermal conductivities at mean temperature will be similar (see thermal conductivity data, on page 50).

As the temperature of a process increases, the thermal conductivities at mean temperature diverge substantially so that it is important to use at least the nominal grade for the process operating temperature. In some cases, a saving in insulation thickness may be afforded by the use of a higher grade, but the extra cost must be weighed against any thickness advantage. Calculations for the individual case will verify any advantage. Bradford can provide this service readily and without charge.

**Q. Why is stainless steel mesh available as a specialty option for Fibermesh.**

A. The standard mesh on Fibermesh is zinc coated hexagonal wire (25mm openings). At high operating temperatures (typically 500°C and above) where multilayer insulation systems are used the interface junction temperature between two layers of Fibermesh may also be high. At temperatures above 350°C the zinc coating will soften (zinc melts at approximately 400°C) and in the worst case, melt and run. This leaves the steel wire unprotected. The molten zinc may also damage the assembly. In these cases, stainless steel mesh is a viable alternative.

Bradford can calculate junction temperature data for any multilayer system. Contact the Bradford Insulation office in your region for design assistance.

**Q. Why cannot insulation of sufficient thickness be supplied in one layer for all cases? Why do we have the inconvenience of multilayer systems?**

A. For high temperature industrial vessels and pipes, the thickness of insulation required is often quite large (e.g. greater than 100mm) there are limitations both in terms of product and application that necessitate multilayer systems:

Maximum manufactured thicknesses of Bradford products are limited.

It is often cost effective to assemble a multilayer system with the highest temperature grade insulation against the hot surface, backed up by lower temperature grade(s). Thickness requirements can be calculated to ensure that interface temperatures are not excessive to the capability of the succeeding layer(s), e.g. hot face/Fibertex 650 – Layer 1/Fibertex 450 – Layer 2/Cladding/Air.

For small radius vessels there are minimum bending characteristics of the various flexible products at various thicknesses (see Bradford Industrial Glasswool and Rockwool Product Guides).

In high temperature work the temperature gradient to atmosphere is high. This means that any imperfections in joints between adjacent batts, blankets, pipe insulation sections will ‘amplify’ heat losses. The use of multilayer systems with all joints staggered is recommended to minimise this risk.

In a larger thickness system the inclusion of wire mesh at an intermediate layer (e.g. Fibermesh blanket or steel square mesh) will assist in mechanical stability.

**Q. Why is Fibermesh 650 recommended generally when blanket insulation is to be used on pipework?**

A. Flexible blanket insulation can be a cost effective solution on larger pipes, however blanket has much less compression resistance than Rockwool Pipe Insulation. This is partly due to lower density and partly to the flexibility itself. It is important that insulation compresses minimally in service, since compression means insulation reduction. Therefore the high density Fibermesh 650 is recommended for pipe insulation where a blanket is preferred in lieu of sectional pipe lengths. The superb flexibility of the product ensures close contact around pipe circumference and the mesh reinforcement assists stability.

**Q. What is ‘Flex-skin’ backing on Rockwool blankets for? Is it OK to put it against hot surfaces?**

A. Flex-skin is applied to Rockwool blankets to assist in roll-up in production, unwind on the job and handling generally. It is a thin polyester fabric, and thus has limited temperature resistance.

Flex-skin should always be applied to the ‘cool’ side of the system. In high temperature work (including multilayer blanket systems) it is best to simply peel off the Flex-skin on the job to avoid any problems.

## APPENDIX D.

## Terminology.

**THERMAL.**

British thermal unit (Btu):	Heat required to raise the temperature of 1 lb of water 1°F.
calorie (cal):	Heat required to raise the temperature of 1 gram of water 1°C.
capacity, thermal or heat:	Heat required to raise the temperature of a given mass of a substance by one degree. This equals the mass times the specific heat.
conductance, thermal:	Time rate of heat flow per unit area between two parallel surfaces of a body under steady conditions when there is unit temperature difference between the two surfaces.
conductance, surface film or surface heat transfer coefficient (f):	Time rate of heat flow per unit area under steady conditions between a surface and a fluid when there is unit temperature difference between them. Heat transfer from one point to another within a body without appreciable displacement of particles of the body.
conductivity, thermal (k):	Time rate of heat flow per unit area and unit thickness of an homogeneous material under steady conditions when unit temperature gradient is maintained in the direction perpendicular to the area.
convection:	Heat transfer from a point in a fluid by movement and dispersion of portions of the fluid.
dewpoint	Temperature at which a sample of air with given water vapour content becomes saturated when cooled at constant pressure.
emissivity	Capacity of a surface to emit radiant energy; defined as the ration of the energy emitted by the surface to that emitted by an ideal black body at the same temperature.
humidity, absolute:	Mass of water vapour per unit volume of air.
humidity, relative:	Ratio of the partial pressure of water vapour in a given sample of air to the saturation pressure of water vapour at the same temperature.
Kelvin K:	The unit of thermodynamic temperature. For the purpose of heat transfer, it is an interval of temperature equal to 1°C.
permeance:	Time rate of transfer of water vapour per unit area through a material when the vapour pressure difference along the transfer path is unity.
permeability:	Permeance for unit thickness of a material.
radiation:	Heat transfer through space from one body to another by wave motion.
resistance, thermal:	Reciprocal of thermal conductance.
resistivity, thermal:	Reciprocal of thermal conductivity.
specific heat:	Ratio of the thermal capacity of a given mass of a substance to that of the same mass of water at 15°C.
transmittance, thermal or overall heat transfer coefficient	Time rate of heat flow per unit area under steady conditions from the fluid on one side of a barrier to the fluid on the other side when there is unit temperature difference between the two fluids.

## APPENDIX E.

# Conversion Factors.

	IMPERIAL		METRIC		METRIC		IMPERIAL
Length	1 in	=	25.40 mm	1 mm	=	0.0394 in	
	1 ft	=	304.8 mm	1 m	=	1.094 yd	
	1 yd	=	0.9144 m	1 km	=	0.621 mile	
	1 mile	=	1.609 km				
Area	1 in <sup>2</sup>	=	645.2 mm <sup>2</sup>	1 m <sup>2</sup>	=	10.764 ft <sup>2</sup>	
	1 ft <sup>2</sup>	=	0.0929 m <sup>2</sup>		=	1.196 yd <sup>2</sup>	
	1 yd <sup>2</sup>	=	0.836 m <sup>2</sup>	1 ha	=	2.471 acre	
	1 acre	=	0.4047 ha				
Volume	1 in <sup>3</sup>	=	16387 mm <sup>3</sup>	1 m <sup>3</sup>	=	35.315 ft <sup>3</sup>	
	1 ft <sup>3</sup>	=	0.0283 m <sup>3</sup>	1 l	=	0.0353 ft <sup>3</sup>	
	1 ft <sup>3</sup>	=	28.317 l	1 l	=	0.220 imp gal	
	1 imp gal	=	4.546 l				
Weight	1 lb	=	453.59 g	1 kg	=	2.2046 lb	
		=	0.45359 kg	1 tonne	=	0.984 ton	
	1 ton	=	1.016 tonne				
		=	1016 kg				
Density	1 lb/ft <sup>3</sup>	=	16.018 kg/m <sup>3</sup>	1 kg/m <sup>3</sup>	=	0.06243 lb/ft <sup>3</sup>	
Pressure	1 lb/in <sup>2</sup>	=	6.895 kPa	1 kPa	=	0.1450 lb/in <sup>2</sup>	
	1 lb/ft <sup>2</sup>	=	47.88 Pa	1 Pa	=	0.0209 lb/ft <sup>2</sup>	
	1 atm	=	101.3kPa		=		
Gauge Pressure	1 mm Hg	=	0.133 kPa	1 kPa	=	7.501 mm Hg	
	1 in H <sub>2</sub> O	=	0.2486 kPa		=	4.022 in H <sub>2</sub> O	
	1 in Hg	=	3.386 kPa		=	0.2953 in Hg	
	1 millibar	=	0.1000 kPa		=	10 mb	



## CONVERSION FACTORS. (continued)

	IMPERIAL		METRIC	METRIC		IMPERIAL
Force	1 lb.f	=	4.448 N	1 N	=	0.2248 lb.f
Energy (Heat, Work)	1 Btu	=	1.055 kJ	1 kJ	=	0.9478 Btu
Power	1 Btu/h	=	0.2931 W	1 W	=	3.412 Btu/h
	1 ton refrigeration	=	3.5169 kW	1 kW	=	0.2843 ton refrigtn.
	1 hp	=	0.7457 kW		=	1.341 hp
Heat Transmission	1 Btu/ft <sup>2</sup> h	=	3.155 W/m <sup>2</sup>	1 W/m <sup>2</sup>	=	0.3170 Btu/ft <sup>2</sup> h
Flat Surfaces	1 kcal/m <sup>2</sup> h	=	1.163 W/m <sup>2</sup>		=	0.860 kcal/m <sup>2</sup> h
Pipes	1 Btu/ft.h	=	0.9615 W/m	1 W/m	=	1.04 Btu/ft.h
Specific Heat Capacity	1 Btu/lb°F	=	4.1868 kJ/kg.K	1 kJ/kgK	=	0.2388 Btu/lb°F
	1 kcal/kg.°C					kcal/kg.°C
Thermal Conductance (Surface Coeff.f)	1 Btu/ft <sup>2</sup> h°F	=	5.678 W/m <sup>2</sup> K	1 W/m <sup>2</sup> K	=	0.1761 Btu/ft <sup>2</sup> h°F
	1 kcal/m <sup>2</sup> h°C	=	1.163 W/m <sup>2</sup> K		=	0.860 kcal/m <sup>2</sup> h°C
Thermal Conductivity	1 Btu.in/ft <sup>2</sup> h°F	=	0.1442 W/mK	1 W/mK	=	6.933 Btu.in/ft <sup>2</sup> h°F
Thermal Resistance	1 ft <sup>2</sup> h°F/Btu	=	0.1761 m <sup>2</sup> K/W	1 m <sup>2</sup> K/W	=	5.678 ft <sup>2</sup> h°F/Btu
Thermal Resistivity	1 ft <sup>2</sup> h°F/Btu.in	=	6.933mK/W	1 mK/W	=	0.1442 ft <sup>2</sup> h°F/Btu
Permeance	1 perm	=	57.2 ng/N.s	1 ng/N.s	=	0.0175 perm

## METRIC UNITS.

Area	hectare	1 ha	=	10000m <sup>2</sup>
Volume	litre	1 l	=	10 <sup>-3</sup> m <sup>3</sup>
Force	newton	1 N	=	1 kg.m/s <sup>2</sup>
Pressure	pascal	1 Pa	=	1 N/m <sup>2</sup>
Energy	joule	1 J	=	1 N.m
	kilocalorie	1 kcal	=	4.1868 kJ
	kilowatt hour	1 kW.h	=	3.6 MJ
Power	watt	1 W	=	1 J/s
Frequency	hertz	1 Hz	=	1 c/s

# Notes.

# Notes.

**CSR**

# Bradford Insulation

CSR Building Solutions Web Site.  
[www.csr.com.au/bradford](http://www.csr.com.au/bradford)

## Manufacturing Facilities.

CSR Bradford Insulation is a leading insulation manufacturer in Australia and Asia with manufacturing facilities located throughout the region.

### AUSTRALIA.

Glasswool factory, Ingleburn NSW.

Rockwool factory, Clayton VIC.

Thermofoil factory, Dandenong VIC.

### ASIA.

Glasswool factory, Zhuhai, China.

Rockwool factory, Dongguan, China.

Rockwool factory, Rayong, Thailand.

Rockwool factory, Kuala Lumpur, Malaysia.

Flexible Duct Factory, Singapore.

## Sales Offices.

### AUSTRALIA.

State	Phone	Fax
Head Office	61 2 9765 7100	61 2 9765 7029
NSW	(02) 9765 7100	(02) 9765 7052
ACT	(02) 6239 2611	(02) 6239 3305
VIC	(03) 9265 4000	(03) 9265 4011
TAS	(03) 6272 5677	(03) 6272 2387
QLD	(07) 3875 9600	(07) 3875 9699
SA	(08) 8344 0640	(08) 8344 0644
NT	(08) 8984 4070	(08) 8947 0034
WA	(08) 9365 1666	(08) 9365 1656

### INTERNATIONAL.

Country	Phone	Fax
New Zealand	64 9579 9059	64 9571 1017
Hong Kong	852 2754 0877	852 2758 2005
China (Glasswool)	86 756 551 1448	86 756 551 1447
China (Rockwool)	86 769 611 1401	86 769 611 2900
Thailand	66 2736 0924	66 2736 0934
Malaysia	60 3 3341 3444	60 3 3341 5779
Singapore	65 861 4722	65 862 3533

## Health and Safety Information.

Information on any known health risks of our products and how to handle them safely is displayed on the packaging and/or the documentation accompanying them. Additional information is listed in product Material Safety Data Sheets available from your regional Bradford Insulation office or visit our website.

## Warranty.

CSR Limited warrants its Bradford Insulation products to be free of defects in materials and manufacture. If a CSR Bradford Insulation product does not meet our standard, we will, at our option, replace or repair it, supply an equivalent product, or pay for doing one of these. This warranty excludes all other warranties and liability for damage in connection with defects in our products, other than those compulsorily imposed by legislation.

CSR Bradford Insulation is a business of CSR Limited A.B.N. 90 000 001 276.

CSR Limited is the owner of the following trade marks. Acoustical™, Acousticon™, Acoustilag™, Anticon™, Bradfix™, Bradford™, Comfort Plus™, Ductel™, Fibermesh™, Fibertex™, Fireseal™, Flexitel™, Flex-skin™, Gold Batts™, Multitel™, Quietel™, SoundScreen™, Spanseal™, Specitel™, Supertel™, Thermofoil™, Thermatrel™, Thermodeck™, Thermofoil™, Thermokraft™, Thermoplast™, Thermotuff™, Ultratel™.