DESIGN GUIDE

AIR CONDITIONING

CSR™
Bradford Insulation

AIR CONDITIONING

Contents.

Introduction.

The Bradford Insulation Group forms part of the Building Materials Division of CSR Limited. Bradford manufactures and markets an extensive range of insulation products offering outstanding acoustic, fire protection and thermal properties for use in air conditioning systems.

Two mineral fibre insulation types 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 several 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 rigid duct air conditioning systems, associated mechanical services pipework and equipment.

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

Additional information is available in the Bradford Fire Protection Systems Design Guide, and the Bradford Acoustic Systems Design Guide.

A free and comprehensive technical service, as well as 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**

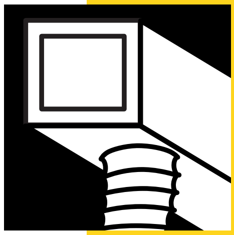
Information included in this Design Guide relates to products as manufactured at the date of publication. As the Bradford Insulation policy is one of continual product improvement, technical details as published are subject to change without notice.

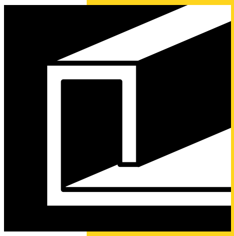
Products & Applications.

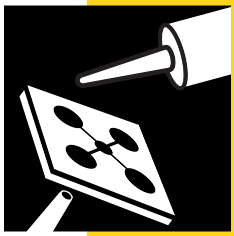
Bradford Product	Density*	Application
Bradford Glasswool SPECITEL™	12 kg/m^3 14 kg/m^3	Flexible lightweight blanket suitable for insulation of flexible ductwork.
Bradford Glasswool MULTITEL™ DUCTWRAP	18 kg/m^3 20 kg/m^3	General purpose insulation suitable for external insulation of rigid ductwork.
Bradford Glasswool FLEXITEL™	24 kg/m^3	Premium quality insulation with superior compression resistance and thermal properties. Suitable for external insulation of rigid ductwork.
Bradford Glasswool SUPERTEL™ DUCTLINER	32 kg/m^3	General purpose high quality insulation suitable for internal insulation of rigid ductwork.
Bradford Glasswool ULTRATEL™	48 kg/m^3	Premium quality insulation with superior acoustic absorption, compression resistance, and thermal properties. Suitable for internal duct insulation .
Bradford Glasswool DUCTEL™ QUIETEL™	80 kg/m^3 130 kg/m^3	Specialty high density board with outstanding thermal, acoustic and compression resistance qualities.
Bradford FIBERTEX™ Rockwool DUCTWRAP/ DUCTLINER	50 kg/m^3 60 kg/m^3	Heavy density premium thermal and acoustic insulation suitable for external and internal duct lining. Non-combustible for insulating fire rated ducts.
Bradford FIBERTEX™ 450 Rockwool	80 kg/m^3	High density insulation for elevated temperatures and superior acoustic performance.
Bradford Glasswool Pipe Insulation	60 kg/m^3	Insulation for hot and cold pipework associated with air handling systems and mechanical services.
Bradford FIBERTEX™ Rockwool Pipe Insulation	120 kg/m^3	Insulation for hot and cold pipework associated with air handling systems and mechanical services. Suitable for use in fire rated penetrations.

*Special density products available on request (subject to minimum order quantities).

Facing Type	Application
Bradford THERMOFOIL™ Medium/Heavy Duty Foil	External vapour barrier for condensation control and durability.
Bradford THERMOFOIL™ Heavy Duty Perforated Foil	Internal insulation facing for excellent acoustic absorption and resistance to air erosion.
Black Matt Face (BMF) Glass Tissue	Internal facing for acoustic absorption and resistance to air erosion.
Microfilm (Melinex™) & Bradford THERMOFOIL™ Heavy Duty Perforated Foil	Acoustic microfilm (Dupont Melinex™ or equivalent) as vapour barrier and surface sealing facing under HD Perf. Foil acoustic facing (outer) layer.
Bradford THERMOTUFF™ Light Duty Facing	Combined acoustic/vapour barrier facing, alternative to Microfilm and Perforated Thermofoil™.
Applied Mastic Coatings	External vapour barrier applied in-situ to pipe insulation for condensation control on pipes operating below ambient temperatures.





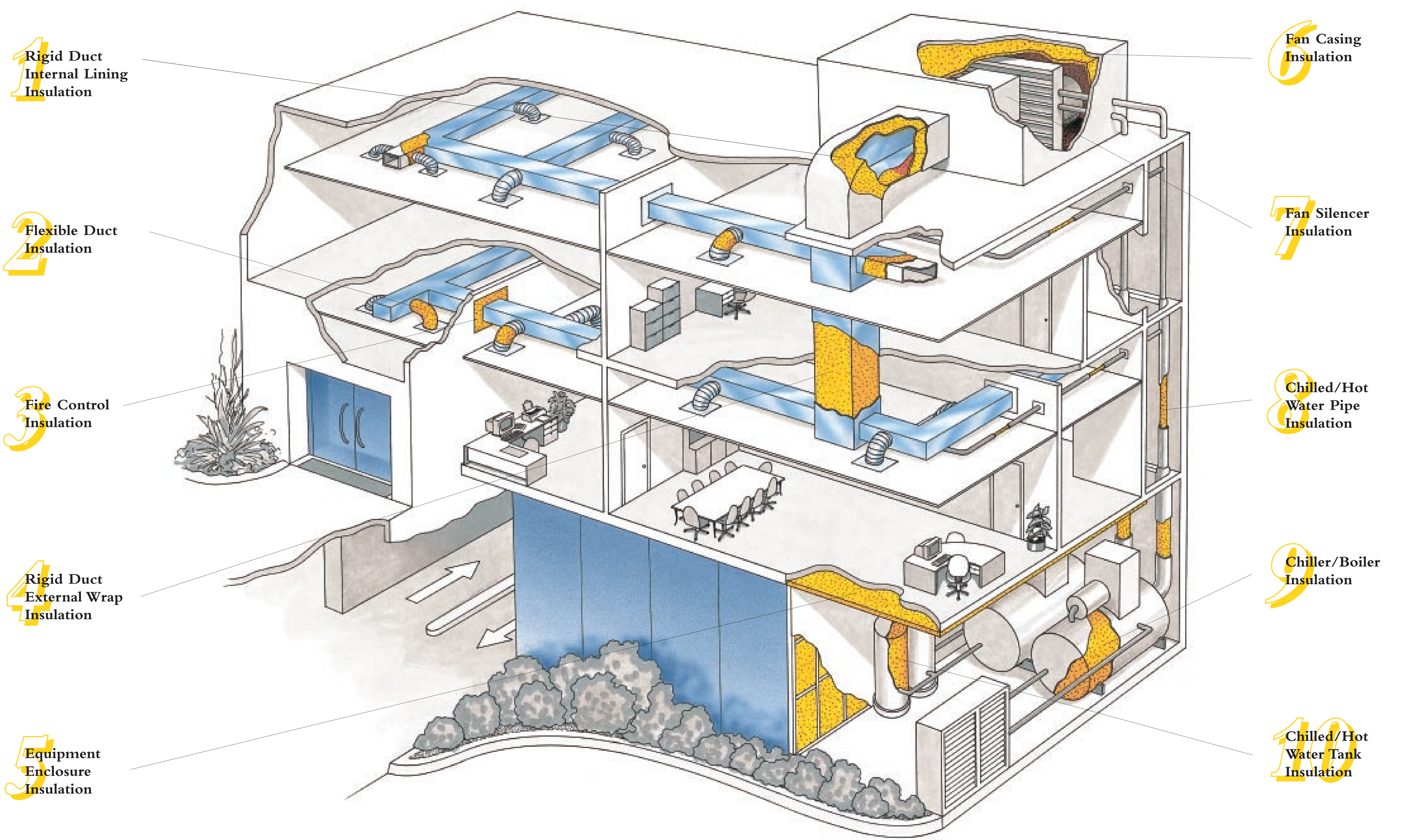


AIR CONDITIONING DESIGN GUIDE

CSR
Bradford
Insulation

Application Guide for Air Conditioning Systems.

Refer to Page 6 for Bradford Insulation Product Selection Recommendations.



Bradford Insulation Application & Selection Guide for Air Conditioning Systems.

Insulation Application	Product Type
1 Rigid Ducting Internal Lining	Bradford Glasswool SUPERTEL™
	Bradford Glasswool DUCTLINER
	Bradford Glasswool ULTRATEL™
	Bradford Glasswool DUCTEL™
	Bradford FIBERTEX™ Rockwool DUCTLINER
2 Flexible Duct	Bradford Glasswool R1.0 SPECITEL™
	Bradford Glasswool R1.5 SPECITEL™
	Bradford FABRIFLEX™ Flexible Ducting
	Bradford ACOUSTOFLEX™ Flexible Ducting
3 Fire Control	Bradford FIRESEAL™ Loose Rockwool
	Bradford FIRESEAL™ Fire Damper Strips
	Bradford FIBERTEX™ Rockwool DUCTWRAP
	Bradford FIBERTEX™ Rockwool Pipe Insulation
4 Rigid Ducting External Wrap	Bradford Glasswool MULTITEL™
	Bradford Glasswool DUCTWRAP
	Bradford Glasswool FLEXITEL™
	Bradford FIBERTEX™ Rockwool DUCTWRAP
5 Equipment Enclosures	Bradford Glasswool SUPERTEL™
	Bradford Glasswool ULTRATEL™
	Bradford FIBERTEX™ Rockwool DUCTLINER
	Bradford FIBERTEX™ 450 Rockwool
6 Fan Casings	Bradford Glasswool FLEXITEL™
	Bradford Glasswool SUPERTEL™
	Bradford Glasswool QUIETEL™
	Bradford FIBERTEX™ Rockwool DUCTLINER
7 Fan Silencers	Bradford Glasswool SUPERTEL™
	Bradford Glasswool ULTRATEL™
	Bradford Glasswool QUIETEL™
	Bradford FIBERTEX™ Rockwool DUCTLINER
	Bradford FIBERTEX™ 450 Rockwool
8 Chilled/Hot Water Pipe	Bradford Glasswool Sectional Pipe Insulation
	Bradford FIBERTEX™ Rockwool Sectional Pipe Insulation
9 Chillers/Boilers	Bradford Glasswool FLEXITEL™
	Bradford Glasswool SUPERTEL™
	Bradford FIBERTEX™ Rockwool DUCTWRAP
	Bradford FIBERTEX™ 450 Rockwool
10 Chilled/Hot Water Tanks	Bradford Glasswool FLEXITEL™
	Bradford FIBERTEX™ Rockwool DUCTWRAP
	Bradford BRADFLEX™ FLEXIBLE DUCTING

Performance Characteristics of Bradford Insulation.

Bradford Insulation products suitable for use in air conditioning systems and other mechanical service applications are manufactured to meet the following performance characteristics. These characteristics are critical design considerations in all mechanical services application.

Performance Characteristic	Bradford Insulation for Ductwork (External Wrap)	Bradford Insulation for Ductwork (Internal Lining)	Bradford Pipe Insulation
Low thermal conductivity to ensure adequate thermal performance at specified thickness	✓	✓	✓
Sufficient compression resistance to prevent loss of thickness and thermal performance when flexed around intersections	✓	✓	n/a
Adequate flexibility to allow wrapping around ductwork	✓	n/a	n/a
Fire resistance to meet regulatory standards and ability to maintain integrity under fire attack	✓	✓	✓
Ability to withstand operating temperature extremes	✓	✓	✓
Ability to accept vapour barriers and acoustic facings	✓	✓	✓
Non corrosive to steel	✓	✓	✓
Sufficient compression resistance to minimise air friction & turbulence caused by unacceptable quilting of the surface	n/a	✓	n/a
Excellent sound absorption properties to reduce fan noise	✓	✓	n/a
Rigidity to provide stability during sheet metal duct fabrication	n/a	✓	n/a
Sufficient compression resistance to minimise loss of thickness and thermal performance under dead / live loads	✓	✓	✓
Excellent sound absorption properties to reduce radiated fluid transfer noise	n/a	n/a	✓
Insulation available in required size and thickness to ensure performance, ease of installation and proper fit	✓	✓	✓
Ease of cutting and handling	✓	✓	n/a
Easily pinned onto rigid duct	✓	✓	✓
Long-term durability at specified operating temperatures	✓	✓	✓
Meets Indoor Air Quality (IAQ) requirements	✓	✓	✓

Design Considerations.

In the design of insulation for Air Conditioning Systems there are several parameters which need to be considered. The relative importance of each of these parameters will vary in individual cases and will be influenced by local climate, building aspect and design, building purpose, and the desired internal thermal and acoustic environment.

CONSIDERATION	ACTION
Thermal Control and Energy Conservation	Specify pipe or ductwork insulation thickness or R-Value to limit heat gain or loss in system
Condensation Control	Design insulation thickness and vapour barrier type for expected atmospheric conditions
Noise Control	Choose insulation of density and thickness with correct facing type for control of equipment and air flow noise throughout system
Ducted Air Velocity	Select insulation and facing to resist air erosion and minimise frictional resistance
Air Friction Correction Factor	Allow for air frictional losses in the air ducting system
Fire Protection	Ensure the fire performance requirements of insulation materials are met
Moisture Resistance and Water Repellency	Select material with high water repellency and low moisture absorption
Mechanical Properties	Ensure the dimensional stability, compressive strength, rigidity or flexibility requirements for the application are satisfied by the selected insulation
Durability	Select insulation capable of enduring long term effects of the application and operating conditions
Environmental and Biological Aspects	Choose environmentally friendly insulation products for ecological sustainable design
Installed Cost	Select insulation products and systems for ease and speed of installation
Health & Safety	Observe CSR Bradford Insulation MSDS recommendations

Thermal Control & Energy Conservation.

Proper design of the building envelope, and the components of the systems used to achieve comfort within it, requires an understanding of thermal insulation and the thermal behaviour of insulated assemblies.

The Bradford Insulation Building Design Guide provides data and examples to equip the designer with basic information necessary to provide for good building envelope thermal performance.

It is also necessary to insulate ducting, piping, fittings and equipment components of air conditioning systems. Insulation design gives consideration to requirements for control of delivery temperatures, energy conservation and personnel protection.

The cost of energy, and particularly the energy cost of refrigeration, justify assessment of the performance, and therefore of the thickness, of insulation which represents an economic investment over the life of an air conditioning system. This is one component of energy efficient design which can economically (in relation to capital investment) minimise operating costs.

In summer the temperature of air in the supply ducting will be lower than the air surrounding the duct. The converse is true in winter. Insulation applied to the duct surface can reduce heat transfer to pre-determined acceptable levels.

Return air ducts convey air at the same temperature and humidity as that of the conditioned space. It may be necessary to insulate return air ducts installed in non-conditioned spaces, such as risers or plant rooms, to minimise heat transfer and energy required to recondition the return air.

Insulation requirements for ductwork may be designed on the basis of the heat gain or loss through the duct, calculated as a function of temperature differentials, surface coefficients and the thermal resistance value of the bulk insulation.

Table 3 in the Design Calculations section of this guide entitled 'Heat Gain by Ducted Air in Summer Conditions', provides a set of calculated typical heat gains for selected thicknesses of Bradford Glasswool or Fibertex Rockwool Ductliner bulk insulation products.

Findings from the economic evaluation of insulation options from modelling building performance in various climates are shown in Table 1.

These recommended insulation standards for energy conservation in rigid and flexible air conditioning ducting for commercial and residential applications, were derived from comprehensive modelling work conducted by Standards Australia across the various climatic zones in Australia.

AS4508 'Thermal Resistance of Insulation for Ductwork used in Building Air Conditioning' was published in 1999 and follows similar standards in the USA and Europe.

These standards would represent the minimum for air conditioning duct work insulation in Asia where higher temperature and humidity combined with high energy costs would justify even greater R-values.

These recommended minimum R-values are a guide only and mechanical services engineers should calculate the correct levels of insulation to be used to optimise energy conservation, acoustics and condensation control. Your nearest Bradford Insulation office would be able to assist with these calculations.

TABLE 1. MINIMUM BULK THERMAL RESISTANCE R-VALUES.

Minimum R Value (m^2K/W)	System Application
1.5	Ductwork -combined heating and refrigerative cooling
0.9	Ductwork - Heating or refrigerative cooling only
0.6	Ductwork - Evaporative Cooling

Source: AS4508 : 1999 'Thermal Resistance of insulation for ductwork used in building air conditioning'.

The correct insulation thickness should be selected based on the thermal resistance performance of the bulk insulation at the design operating temperatures. The Thermal Resistance R-Value is calculated as R = L/k, where k = thermal conductivity (W/mK) at mean temperatures, as per Table 2, L = Insulation Thickness (m).

TABLE 2. THERMAL CONDUCTIVITY (W/mK).

Bradford Insulation Type	Mean Temperature 20°C	40°C	60°C
Bradford Glasswool			
MULTITEL™	0.035	0.042	0.045
DUCTWRAP	0.034	0.042	0.045
Bradford Glasswool FLEXITEL™	0.033	0.037	0.042
Bradford Glasswool SUPERTEL™ DUCTLINER	0.032	0.036	0.039
Bradford Glasswool ULTRATEL™	0.031	0.035	0.037
Bradford FIBERTEX™ Rockwool DUCTWRAP/ DUCTLINER	0.034	0.038	0.042

In air conditioning system pipework, modulation of the flow rate of heating or cooling water may be the means by which energy flows to the air conditioning system are controlled. If this is the case, the insulation system should be designed to control heat loss or gain through the pipe wall. This will ensure predictable fluid temperatures at each discharge point in the system.

Piping or equipment may be required to be insulated for personnel protection, to ensure that accessible exposed surfaces do not operate at temperature above 55° - 65°C.The thickness of insulation determined to meet energy conservation or temperature control criteria will normally be adequate.

In the case of exhaust flues or stacks from boilers or stand-by generator (diesel) motors, the governing requirement will usually be sufficient insulation thickness to provide safe touch temperature for service personnel. Insulation design information for high temperature applications such as this is included in the Bradford Insulation Industrial Design Guide.

Detailed data, formulae and worked examples are given in the Design Calculation section of this guide.

Condensation Control.

Condensation of atmospheric moisture will occur on any surface which is at or below the dew point temperature of the air in contact with that surface. In the case of ductwork prevention of such condensation requires the installation of thermal insulation on the inside of the duct, or insulation plus a Thermofoil vapour barrier on the outside of the duct. In this case the Thermofoil should be factory adhered to the outside of the insulation. Insulation thickness required to control condensation may be calculated taking into account;

- Ducted air velocity
- Ducted air temperature (minimum)
- Temperature of the surrounding air (maximum)

See the Design Calculation section of this guide for design examples of condensation control.

Under operating conditions, condensation may be possible on refrigerant or chilled water piping.

Insulation of sufficient thickness installed with a vapour barrier will prevent condensation. Pipe supports should, where possible, be external to the insulation and vapour barrier. Alternatively, the vapour barrier system should be continuous through the pipe support.

Noise Control.

Noise arises in air conditioning systems principally from fans and from air flow generated noise in both ducts and through registers. In addition, it is sometimes necessary to deal with sound transmitted along a duct from one room to another. Insulation systems with applied facings must provide adequate sound absorption to ensure that effective Noise Insertion Loss performance is achieved.

To control the noise generated by the fan to which the duct is attached, the insulation ductliner should be installed inside the duct, immediately ‘downstream’ from the fan. Similarly, to reduce room to room noise transmission along the duct, the insulation system should be installed in the duct from immediately inside the supply register of the noisy room. To ensure maximum noise controlling properties the internal duct insulation should be faced with an acoustically transparent facing such as perforated Thermofoil or black matt tissue.

If internal insulation alone is not deemed to reduce noise transmission through the duct walls sufficiently, then the addition of external insulation together with an appropriate heavy outer finish, will achieve the desired result.

Bradford Glasswool and Fibertex Ductliner products have excellent sound absorption qualities, refer to the Noise Control section under Design Calculations for further details.

Bradford Acoustilag for noise insulation of pipes, and Bradford Acousticlad for industrial noise absorption are also available. Please refer to the Bradford Insulation Acoustic Design Guide for more details.

Ducted Air Velocity.

When installed inside the duct, the insulation material and its surface facing must be able to resist erosion by the high velocity ducted air and also offer the least possible frictional resistance.

Bradford Glasswool and Fibertex Rockwool Ductliners with factory applied surface facings have been tested for surface erosion at extreme velocities by the quantitative method developed by the CSR Building Research Material Laboratories and based on Underwriters Laboratory Standard UL181. On the basis of these results and air friction correction factors, maximum design velocities are recommended for Bradford Glasswool or Fibertex Ductliners. Refer to Page 27 in the Design Calculations section for Air Friction for maximum design velocities.

Air Friction Correction Factor.

The energy absorbed in frictional losses in the air conditioning system may be significant, particularly for high velocity systems. The usual procedure for determining friction losses in air ducts is by use of the Air Friction Charts published in the ASHRAE Handbook of Fundamentals and the IHVE Guide.

Refer to FIG 7, page 27 in the Design Calculations section of this guide for Air Friction Correction Factors.

Fire Protection.

Air conditioning systems in buildings are designed to ensure fire does not propagate along ductwork and that all duct and pipe penetrations through walls and floors are adequately sealed against fire ingress with fire dampers, collars and fire resistant perimeter details.

Bradford Insulation products for air conditioning systems do not burn and provide excellent protection against fire. Fibertex™ Rockwool offers superior fire resistance due to its very high fusion temperature of greater than 1150°C.

NON - COMBUSTIBILITY.

Bradford Glasswool HT Thermatel and all Bradford Fibertex Rockwool have a low content of organic binder and are deemed to be non-combustible insulation materials when tested to AS1530.1, BS476.4, ASTM or equivalent.

Australian Standard AS1668.1 Part 1 'Fire and smoke control in multi-compartment buildings' prescribes that materials used in ductwork for fire dampers, smoke spill and exhaust systems shall be deemed to be non-combustible in accordance with AS1530.1 – 1989.

EARLY FIRE HAZARD.

Early fire hazard performance is determined in accordance with Australian Standard AS1530 : Part 3 – 1989. The test indices provide a measurement for ignitability, heat evolved, spread of flame and smoke developed. The lower the index, the less hazardous the material is considered to be.

Australian Standards AS4254 'Ductwork for Air Handling Systems in Buildings' prescribes

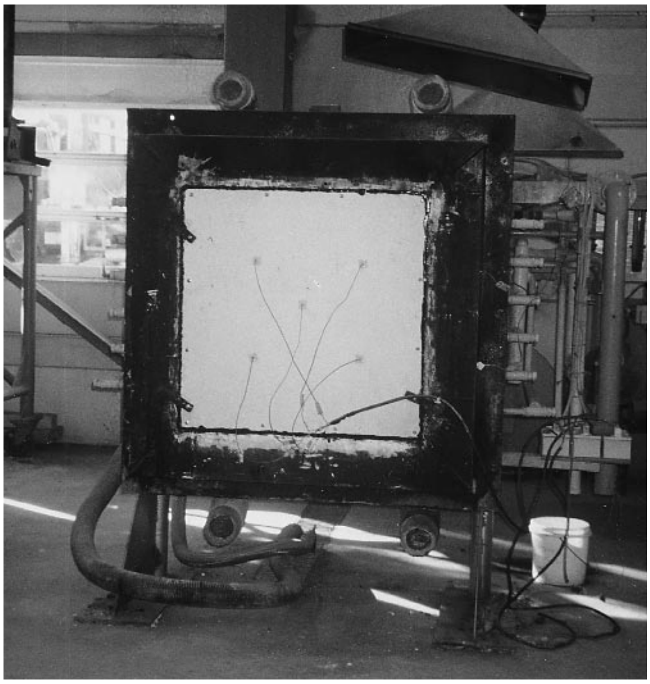
i) A spread of flame index number not greater than 0, and

ii) A smoke developed index number not greater than 3

as determined in accordance with AS1530 : Part 3 – 1989, when tested on the exposed face of the internal and/or external insulation.

All Bradford Glasswool and Fibertex Rockwool products comply with these requirements and have excellent early fire hazard performance when tested to AS1530.3, ASTM E84, BS476 or equivalent.

For compliance with other international standards such as UL181, please refer to the Bradford Insulation office in your region.



FIRE RESISTANCE.

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

Bradford Rockwool and Glasswool insulation produces no toxic fumes when subject to fire conditions and are used successfully in one & two hour rated fire protection systems which allow building occupants to escape safely.

Bradford Fibertex Rockwool provide high levels of fire resistance due to their low thermal diffusivity and are able to withstand fire with only slow breakdown in physical properties when tested to AS1530.4, BS476, ASTM 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 party walls, fire dampers and pipe/cable penetrations.

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

Moisture Resistance & Water Repellency.

MOISTURE ABSORPTION.

Excessive moisture will reduce the thermal insulation performance of an insulation material.

Exposure of Bradford Glasswool or Fibertex Rockwool 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.

WATER REPELLENCY.

Should rockwool or glasswool insulation become wet full thermal efficiency will be restored on drying out.

Bradford Fibertex WR is a specialty water-repellent rockwool developed by Bradford Research Laboratories for applications subject to water ingress. The water repelling agents contained in Fibertex WR have been engineered to ensure maximum resistance to water penetration.

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

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

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.

COMPRESSIVE STRENGTH.

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

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 Glasswool and Fibertex Rockwool insulation in rigid and semi-rigid board offer excellent deflection resistance for insulating areas where excessive sag can occur, such as the underside of wide duct and soffits. Flexible blankets are easy to apply and are particularly suitable for insulating around small radius bends and curved surfaces.

Durability & Mechanical Damage.

Durability under operating conditions can generally only be determined from experience. Bradford Glasswool and Fibertex Rockwool insulation products enjoy a proven record of efficient, durable service in a wide range of air conditioning duct and pipework applications. The insulation system must;

- Accommodate thermal movement and resist settling, breakdown or sagging from vibration of the insulated surface.
- Continue to provide efficient thermal resistance throughout the economic life of the insulated equipment.
- Be thermally stable across variable operating temperatures.

Bradford Glasswool and Fibertex Rockwool insulation meet these durability criteria.

Externally applied insulation and vapour barrier systems are vulnerable to mechanical damage from equipment or personnel, particularly where the ducting is operating in exposed locations such as service corridors and plant rooms. Where the ducting is installed above suspended ceilings, the risk of damage is minimal.

Damage to the vapour barrier where it is penetrated may result in condensation of atmospheric water vapour within the insulation or on the metal ducting. This can reduce the performance of the insulation system and cause water dripping into the space below the duct. External insulation systems can be protected using metal screens or completely cladding the insulation with sheet metal.

For outdoor applications adequate reinforcement and cladding systems shall be employed for weather protection.

Environmental and Biological Aspects.

ENVIRONMENTAL.

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

Bradford Insulation plants utilise the latest technology in manufacturing processes, coupled with best energy efficiency practice to ensure the embodied energy of the final glasswool and rockwool material is kept to a minimum. Bradford is committed to producing ecologically sustainable materials for the long term benefit of the environment.

BIOLOGICAL.

Environments with warm, moist conditions can be susceptible to biological growth if not correctly guarded against. Preventing condensation through adequate thermal control using Bradford Glasswool and Fibertex Rockwool bulk insulation with appropriate facings will inhibit mould growth.

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

The Bradford Insulation office in your region can also assist with information about specialist anti-fungal products.

Installed Cost.

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

Bradford Fibertex™ Rockwool and Glasswool products are resilient and lightweight, resulting in ease of handling and minimum accidental damage during installation. Their ease of cutting, detailing and securing around ducting and pipework ensure minimal installation time.

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. A range of factory applied facings are available to meet the acoustic and/or vapour sealing needs of the air conditioning system.

Easy handling on 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.

Health & Safety.

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

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

Design Calculations.

Thermal Control.

Heat Flow Rate through a uniformly insulated duct wall for a duct of rectangular section is given by the equation:

$$Q = \frac{t_{da} - t_a}{\left(\frac{1}{f_i} + \frac{L}{k} + \frac{1}{f_o}\right)}$$

Where:

Q = heat loss rate (W/m²)

t_{da} = temperature of ducted air (°C)

t_a = ambient air temperature (°C)

L = thickness of insulation (m)

k = thermal conductivity of insulation (W/m.K)

f_i = internal surface coefficient (W/m².K)

f_o = external surface coefficient (W/m².K)

$\frac{L}{k}$ = thermal resistance of insulation

$\frac{1}{f_i}$ = internal air surface resistance

$\frac{1}{f_o}$ = external air surface resistance

In using this formula, the insulation thicknesses must be expressed in metres, not millimetres.

Note that for hot air ducts, t_{da} will be greater than t_a and Q will be positive.

For cold air ducts, t_{da} will be less than t_a and Q will be negative, indicating a reversal in the direction of heat flow.

Heat transfer and outside surface temperatures are listed in Table 3 for a range of ambient and ducted air temperatures.

The internal surface film conductance, f_i, was taken as 12.4W/m².K based on air velocity 10m/s (1,968fpm) in a galvanised steel duct.

WINTER CONDITIONS.

Table 3 may also be used to estimate the heat loss from hot air ducts by assuming the ducted air temperature to be the ambient temperature as shown and vice versa. Surface temperatures of insulated hot air ducts have no significance in winter conditions as no condensation problems are involved.

TABLE 3. HEAT GAIN BY DUCTED AIR IN SUMMER CONDITIONS.

Q = Heat Gain by Ducted Air. t_s = External Surface Temperature.

	Temp of Ducted Air	Insulation Thickness	Ambient Temperature							
			20°C		25°C		30°C		35°C	
	°C	mm	Q (W/m²)	t_s°C	Q (W/m²)	t_s°C	Q (W/m²)	t_s°C	Q (W/m²)	t_s°C
Non-reflective Outside Surface	5	25	15.9	18.4	21.4	22.9	27.1	27.3	32.9	31.8
		50	8.8	19.1	11.9	23.8	15.1	28.5	18.3	33.2
	10	25	10.7	18.9	16.3	23.4	22.0	27.8	27.8	32.3
		50	6.0	19.4	9.1	24.1	12.2	28.8	15.5	33.5
	15	25	5.5	19.5	11.0	23.9	16.7	28.4	22.6	32.8
		50	3.0	19.7	6.1	24.4	9.3	29.1	12.6	33.8
	20	25	–	–	5.6	24.5	11.3	28.9	17.2	33.3
		50	–	–	3.1	24.7	6.3	29.4	9.6	34.1
Reflective Outside Surface	5	25	14.6	17.4	19.7	21.5	24.9	25.6	30.1	29.7
		50	8.4	18.5	11.3	23.0	14.3	27.5	17.4	31.9
	10	25	9.9	18.3	15.0	22.4	20.2	26.4	25.5	30.5
		50	5.7	19.0	8.6	23.5	11.6	27.9	14.7	32.4
	15	25	5.0	19.1	10.1	23.2	15.4	27.3	20.7	31.4
		50	2.9	19.5	5.8	24.0	8.9	28.4	12.0	32.9
	20	25	–	–	5.1	24.1	10.4	28.2	15.7	32.2
		50	–	–	3.0	24.5	6.0	28.9	9.1	33.4

SURFACE HEAT TRANSFER COEFFICIENTS.

The External Surface Coefficient or Surface Film Conductance, f_o, 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 facing lowers the external surface coefficient. This has little effect on the overall heat flow, but results in surface temperatures considerably higher in the case of hot air ducts and considerably lower for cold air ducts.

Recommended values for the external surface coefficient for still air conditions are shows in Table 4.

TABLE 4. SURFACE COEFFICIENTS.

Surface	f_o (W/m².K)
Aluminium sheet, foil and foil laminates	5.7
Zincalume	6.3
Galvanised steel	6.3
Zincanneal	8.0
Bare insulation, mastics and darker paints	10.0

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.

FIG 1. EXTERNAL SURFACE HEAT TRANSFER COEFFICIENT vs AIR VELOCITY.

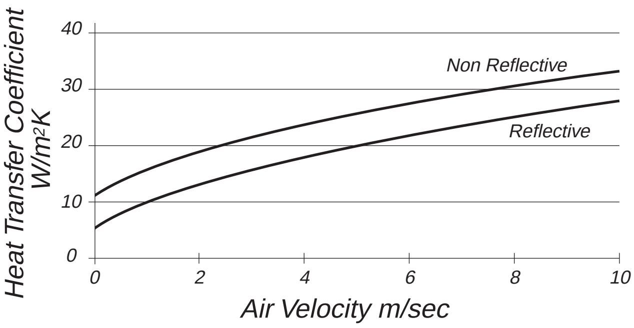


Figure 1 indicates the effect of air velocity on the external surface coefficient for a reflective cladding, e.g. aluminium and a typical non-reflective surface finish. The curves shown are for a surface temperature of 50°C and an ambient air temperature of 20°C.

The Internal Surface Coefficient or Surface Film Conductance, f_i, is the time rate of heat transfer between the internal surface of the duct and the transported air.

Heat transfer from and to the internal duct wall surface is almost entirely by convection. Therefore the value of f_i, will depend mainly on the physical state of the surface, the velocity of the ducted air and the difference between its temperature and that of the surface.

Recommended values for the internal surface coefficient for a galvanised steel duct operating within the range of temperatures normally used in air conditioning are given in Table 5.

TABLE 5. INTERNAL SURFACE COEFFICIENTS.

Ducted Air Velocity m/s	f_i (W/m².K)
5	9.4
10	12.4
15	14.5

OUTSIDE SURFACE TEMPERATURE.

The Outside Surface Temperature, t_s, may be calculated from the following formula (note Q is negative for cold ducts – heat gain):

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

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

Values for bare surface heat loss or gain are listed in Table 6. They are based on the heat transfer between a flat surface of high emissivity and still air at 20°C.

TABLE 6.
BARE SURFACE HEAT TRANSFER.

Surface Temperature °C	Heat Loss or Gain W/m²
40	198
35	142
30	90
25	41
15	–40
10	–84
5	–130

TABLE 7. THERMAL CONDUCTIVITY.

The thermal conductivity of Bradford Glasswool and Fibertex Rockwool varies with the mean temperature of the insulation, as shown in Table 7. Test measurements are made in accordance with AS2526 Part 5 and 6, BS874, ASTM C518 and ASTM C177. Pipe Insulation testing 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.

Thermal Conductivity (W/mK)					
Bradford Insulation	Mean Temperature °C				
Product	20°C	40°C	60°C	100°C	200°C
Bradford Glasswool MULTITEL™	0.035	0.042	0.045	–	–
Bradford Glasswool DUCTWRAP	0.034	0.042	0.045	–	–
Bradford Glasswool FLEXITEL™	0.033	0.037	0.042	0.052	–
Bradford Glasswool SUPERTEL™/DUCTLINER	0.032	0.036	0.039	0.049	0.080
Bradford Glasswool ULTRATEL™	0.031	0.035	0.037	0.045	0.068
Bradford Glasswool DUCTEL™	0.031	0.034	0.037	0.042	0.063
Bradford Glasswool QUIETEL™	0.031	0.034	0.036	0.041	0.059
Bradford Glasswool Pipe Insulation	0.032	0.035	0.037	0.041	0.057
Bradford FIBERTEX™ Rockwool DUCTLINER/DUCTWRAP	0.034	0.038	0.042	0.046	0.071

Thermal Conductivity (W/mK)								
Bradford Insulation	Mean Temperature °C							
Product	20	50	100	200	300	400	500	600
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

For conversion 1W/mK = 6.9335 Btu.in/ft²h°F

HEAT TRANSFER CALCULATIONS.

Examples for Flat and Curved Surfaces

Example 1: Determining heat loss and surface temperature.

A supply air riser operates in a masonry shaft in a multi-storey building.

The supply air temperature is controlled at 24°C in winter and the air temperature in the unconditioned riser, in the worst case, will be 10°C.

Determine the heat loss and surface temperature, assuming still air conditions, and that the insulation is 25mm thick Glasswool, faced with reinforced aluminium foil.

Ducted air velocity 5m/s

$f_i = 9.4\,W/m^2K$

Assume surface temp 14°C

$$\text{Mean Temperature} = \frac{24 + 14}{2} = 19°C$$

Thermal conductivity k = 0.033 W/m²K for Bradford Glasswool Flexitel.

The recommended outside surface heat transfer coefficient for aluminium for still air conditions is 5.7W/m²K.

The first trial calculation for heat loss will be

$$Q = \frac{(t_{da} - t_a)}{\left(\frac{1}{f_i} + \frac{L}{k} + \frac{1}{f_o}\right)}$$

$$= \frac{(24 - 10)}{\left(\frac{1}{9.4} + \frac{.025}{.033} + \frac{1)}{5.7}\right)}$$

$$= \frac{14}{0.106 + 0.758 + 0.175}$$

$$= \frac{14}{1.039}$$

$$= 13.47\ W/m^2$$

Using this value for Q, the outside surface temperature can be calculated

$$= \frac{Q}{f_o} + t_a$$

$$= \frac{13.47}{5.7} + 10$$

$$= 12.36°C$$

A recalculation is now made using 12°C as the surface temperature.

$$\text{Mean Temperature} = \frac{24 + 12}{2} = 18°C$$

Thermal conductivity k = 0.033W/m²K

$$Q = \frac{14}{0.106 + \frac{0.025}{0.0335} + 0.175}$$

$$= \frac{14}{1.027}$$

$$= 13.63\ W/m^2$$

Using this value for Q, the outside surface temperature will be

$$t_s = \frac{13.63}{5.7} + 10 = 12.4°C$$

This is close enough to the surface temperature assumed for this recalculation. The heat loss of 13.63W/m² may therefore be used for heating load design purposes.

Example 2: 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°C. It is to be insulated for personnel protection, designing for a cladding temperature not exceeding 62°C when the ambient temperature is at the anticipated maximum of 32°C.

Calculations are to 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°C hot face temperature, it will be necessary to use kerfed Fibertex 650 batts 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 10.0W/m².K for the surface heat transfer coefficient (refer to Table 4).

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:

$$t = \frac{Q}{f_o} + t_a$$

Using the stated maximum values for ts and ta, 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 300W/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°C, the top service temperature for Fibertex 450.

This is done by trial and error. As a first estimate it can be assumed that 38mm of Fibertex 650 and 85mm 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°C for the junction temperature is suggested.

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

Inner layer: $\frac{520 + 425}{2} = 472°C$

Outer layer: $\frac{425 + 62}{2} = 244°C$

The thermal conductivities for the two materials are then established by reference to the product data sheets or the tables in Table 7. Thus:

Inner layer Fibertex 650 = 0.141W/m.K

Outer layer Fibertex 450 = 0.077W/m.K

$$Q = \frac{t_v - t_a}{\frac{L_1}{k_1} + \frac{L_2}{K_1} + \frac{1}{f}}$$

$$= \frac{515 - 32}{\frac{0.038}{0.141} + \frac{0.088}{0.077} + \frac{1}{10}}$$

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

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.

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

$$= 520 - \left(323 \text{ x } \frac{0.038}{0.141}\right)$$

$$= 433°C$$

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:

Inner layer: $\frac{520 + 440}{2} = 480°C$

Outer layer: $\frac{440 + 62}{2} = 251°C$

At these new values:

Inner layer Fibertex 650 = 0.144W/m.K

Outer layer Fibertex 450 = 0.079W/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:

$$t_j = 520 - 299 \text{ x } \frac{0.038}{0.144} = 441°C$$

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:

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

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

$$= 61.9°C$$

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).

Example 3: Determining heat loss and surface temperature of an existing insulation system.

A 76.1mm O.D. steam pipe operating at 180°C is insulated with 38mm thickness of Glasswool 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 approximately thermal conductivity to be determined.

A suggested starting temperature is 40°C. The assumed mean temperature will then be:

$$\frac{180 + 40}{2} = 110°C$$

From Table 7 for Glasswool Pipe Insulation, the thermal conductivity at 110°C mean temperature is 0.043W/m.K.

The recommended surface film conductance for aluminium cladding and still air conditions is 5.7W/m^2.K. (Table 4).

Then, for the first trial calculation,

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

$$= \frac{\pi (180 - 30)}{\left(\frac{1}{2 \times 0.043} \times \log_e \frac{0.1521}{0.076}\right) + \frac{1}{5.7 \times 0.152}}$$

$$= 50.7 \text{ W/m}$$

Checking the surface temperature using this figure for Q',

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

$$t_s = \frac{50.7}{\pi \times 0.152 \times 5.7} + 30$$

$$= 48.6°C$$

The calculation must now be repeated for an assumed surface temperature of 48.6°C. The new mean temperature will be approximately:

$$\frac{180 + 48.6}{2} = 114.3°C$$

The thermal conductivity corresponding to this mean temperature from Table 7 on page 16 will now be 0.043 W/m.K.

Now,

$$Q' = \frac{\pi (180 - 30)}{\frac{1}{2 \times 0.043} \times 0.692 + \frac{1}{5.7 \times 0.152}}$$

$$= 51.4 \text{W/m}$$

Checking the surface temperature using this new value for Q',

$$t_s = \frac{51.4}{\pi \times 0.152 \times 5.7} + 30$$

$$= 48.9°C$$

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: 51.4 W/m

Surface Temperature: 48.9°C

Example 4: 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 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:

$$\frac{500 + 65}{2} = 283°C$$

From Table 7, the thermal conductivity for Fibertex 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 10W/m.K (refer Table 4).

As a first approximation, assume that 88mm may be sufficient insulation. A first trial calculation then gives:

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

$$Q' = \frac{\pi (500 - 30)}{\frac{0.360}{2 \times 0.074} + \frac{1}{10.0 \times 0.582}}$$

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

The surface temperature is checked as follows:

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

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

$$= 61°C$$

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

$Q' = 642$ W/m

and

$t_s = 67°C$

Thus, 75mm thickness would not meet the requirements and the minimum thickness to be used is 88mm.

Therefore the specification should be:

Lagging : 88mm Fibertex Pipe Insulation

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

Condensation Control.

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 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 8 which lists the dew point temperatures for a wide range of dry bulb temperatures and relative humidities.

TABLE 8.
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

By using the dew point temperature determined from Table 8 as the surface temperature, t_s, in the conventional heat transfer formulae, the theoretical thickness of insulation, L_c, 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.

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

Where:

t_s = outside surface temperature

t_v = temperature of vessel

t_a = ambient temperature

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:

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

For ducts or vessels with flows of the process fluid or gas, the following formula applies.

$$L_c = \frac{k(t_s - t_{da})}{f(t_a - t_s)} - \frac{1}{f_i}$$

Where:

t_{da} = fluid temperature (°C)

f_i = internal fluid surface conductance (W/m^2.K.)

Example 1:

Calculate the thickness of foil faced external duct insulation required for a duct transporting air of temperature 10°C at a velocity of 5m/s through a 30°C environment at 80% maximum relative humidity.

From Table 8, t_s at the dew point will be 26.3°C. For reflective facing (from Table 4) f_o = 5.7W/m^2.K. At a velocity of 5m/s (from Table 5) f_i = 9.4W/m^2.K.

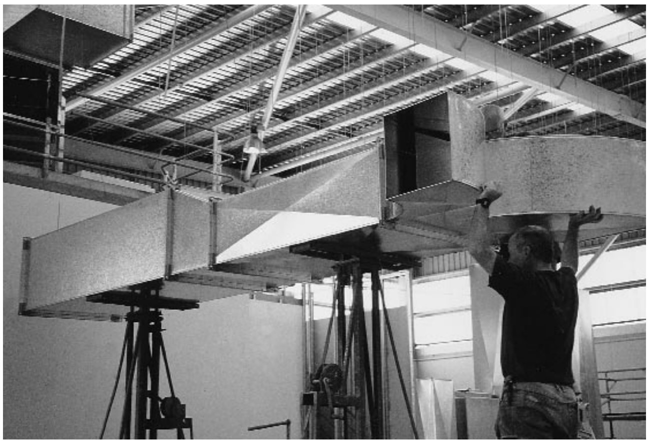
At a mean temperature close to 20°C, Flexitel has a thermal resistance 0.033W/m.K (refer Table 7).

Then:

$$L_c = 0.033 \times \frac{(26.3 - 10)}{5.7(30 - 26.3)} - \frac{1}{9.4}$$

$$= 0.022\text{m}$$

Therefore, the thickness of insulation required will be a standard thickness greater than 22mm. As the next higher standard thickness, 25mm, allows very little safety margin, the correct choice would be 38mm.



Example 2:

Calculate the thickness of Fibertex 350 required to prevent condensation on a tank at -5°C in an environment of 25°C and 80% maximum relative humidity. The vapour barrier is to be a dark coloured reinforced mastic.

From Table 8 the dew point temperature for the condition specified is 21.4°C and this becomes the value for t_s in the equation. For the dark coloured vapour barrier, f = 10.0W/m².K The thermal conductivity of Fibertex 350 at the approximate mean temperature of 8°C is close to 0.033W/m.K. Then, from:

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

$$L_c = \frac{0.033\,[21.4 - (-5)]}{10\,(25 - 21.4)}$$

$$= 0.024$$

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 3 Pipes:

A pipe of 101.6mm O.D. at 5°C is insulated with 25mm thickness of Fibertex Pipe Insulation faced with foil laminate.

The most severe environment anticipated is 30°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.

i) From Table 8 the dew point for conditions specified is 26.3°C. For the foil laminate surface finish, f = 5.7 W/m².K. The thermal conductivity of Fibertex Pipe Insulation at the approximate mean temperature of 16°C is 0.0335 W/m.K.

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

$$= 0.152\text{m approximately}$$

$$d_p = 0.102\text{m approximately}$$

Then,

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

$$0.152 \times 0.4 = \frac{2 \times 0.0335}{5.7} \times \frac{(t_s - 5)}{(30 - t_s)}$$

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

$$t_s = 25.9°C$$

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

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

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

$$= 0.178\text{m approximately}$$

$$0.178 \log_e \times \frac{0.178}{0.102} = \frac{2 \times 0.0335}{5.7} \times \frac{(t_s - 5)}{(30 - t_s)}$$

from which t_s = 27.35°C

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

Noise Control.

Noise arises in Air Conditioning Systems principally from fans and from air flow generated noise in both ducts and through registers. In addition, it is sometimes necessary to deal with sound transmitted along a duct from one room to another. This section provides methods and data to assist in the design of internal duct lining to control noise.

NOISE CRITERIA.

Noise Criteria curves (NC) and Noise Rating numbers (NR) have been developed to approximate loudness contours and speech interference levels at particular frequencies. These criteria graphs indicate a sound pressure level at each frequency that will be appropriate in a particular environment. Noise Rating numbers are covered by Australian Standard AS1469.

Sound levels are often expressed in A-weighted decibels, dB(A), having the advantage of being easy to measure by a sound level meter. Australian Standard AS2017 covering the recommended background sound levels for occupied spaces makes use of this form of expression. It is recommended that design calculations of noise reduction use Noise Rating numbers and convert to dB(A) at the end of the calculation.

GENERAL PROCEDURE.

The fan sound power level is first established, then each duct path is examined separately. Noise generated by 90° elbows and branches is estimated using data from the Sound and Vibration section of the ASHRAE Guide and Data Book and added to the fan noise. From this is deducted any branch take-off losses and the natural attenuation due to straight runs of ductwork, elbows and end reflections losses, again using the data tabulated in the ASHRAE Guide. The resultant sound power level represents the noise reaching the conditioned space. This is compared to the design requirements for the space based on the selected Noise Rating number plus corrections for the characteristics of the room and the distance to the nearest occupant. If the design goals have not been achieved, the additional attenuation needed at each frequency band must be designed into the system. The most economical approach where space permits is by the use of internal duct liners.

FAN NOISE.

Generally the fan manufacturer will provide data on fan noise characteristics. However if no data is available, the following empirical formulae developed by Beranak may prove useful:

$$SWL = 77 + 10 \log kW + 10 \log P$$

$$SWL = 25 + 10 \log Q + 20 \log P$$

$$SWL = 130 + 20 \log kW - 10 \log Q$$

Where:

SWL = overall fan sound power level, dB

kW = rated motor power, kW

P = static pressure developed by fan, mm w.g.

Q = volume flow delivered, m^3/h

Octave band sound power levels are then found by subtracting correction factors from the overall sound power level calculated by any one of the above formulae.

Maximum noise usually occurs from the blade tip frequency of the fan. This is determined from the number of blades on the fan rotor multiplied by the number of revolutions per second. The octave band in which the blade tip frequency falls will have the highest sound power level and therefore the smallest correction factor to be subtracted from the overall sound power level.

The recommended correction factors are indicated in Table 9.

TABLE 9.
CORRECTIONS FACTORS FOR FAN SOUND POWER LEVELS.

Fan Type	Blade Tip Freq. Band	Octave 1st	2nd	3rd	4th	5th	6th
Centrifugal							
Backward Curved Blades	4	6	9	11	13	16	19
Forward Curved Blades	2	6	13	18	19	22	25
Radial Blades	3	5	11	12	15	20	23
Axial	7	9	7	7	8	11	16
Mixed Flow	0	3	6	6	10	15	21

NOTE: Correction factors are to be subtracted from Overall Calculated Fan Sound Power Levels.

DUCT ATTENUATION.

The most important octave bands where fan noise is concerned are the 125Hz and 250Hz bands.

Duct internally lined with a suitable length and at least 50mm thickness of Bradford Glasswool or Fibertex Ductliner can effectively reduce the low frequency component of fan noise.

Table 10 is a guide to the attenuation achieved by lining two opposite sides of a duct with Bradford Glasswool Ultratel at 50mm and 100m thickness. The distance D is the depth in mm between the linings. It is assumed that any facing material used is deemed acoustically transparent. If the duct is to be lined on all four sides, the total attenuation may be obtained by adding, arithmetically, the attenuation achieved by lining the other two opposite sides.

TABLE 10.
CALCULATED LINED DUCT ATTENUATION (dB/m).

Thickness of Lining (mm)	Depth Between Linings D(mm)	Frequency (Hz) 125	250	500	1000	2000	4000
50	200	1.3	4.5	10.8	15.8	15.4	7.7
	300	1.2	3.3	7.7	9.2	6.8	3.4
	400	1.2	2.6	5.8	8.0	3.8	1.9
	600	1.0	1.5	3.5	3.4	1.6	0.9
	800	0.6	1.2	2.4	2.0	1.0	0.4
	1000	0.5	1.1	2.0	1.1	0.6	0.3
100	200	4.3	8.8	14.5	15.8	15.4	7.7
	300	3.2	6.5	10.2	9	6.8	3.4
	400	2.1	5.4	7.9	8.0	3.8	1.9
	600	1.7	3.8	5.2	3.4	1.6	0.9
	800	1.3	2.9	4.0	2.0	1.0	0.4
	1000	0.8	2.0	3.1	1.1	0.6	0.3
Limit of Attenuation		26	31	38	42	50	60

It should be noted, that a limit to the attenuation of sound in duct work may be imposed by flanking transmission or noise breakout. This particularly occurs when the aim is to achieve high attenuation in a short length of straight duct.

There are positive steps that can be taken to counter the effect of flanking transmission but for the purpose of this guide it is recommended that, in using Table 10, reliance should not be placed on achieving attenuation in excess of the limiting values shown. If attenuation beyond these limits is required, it should be achieved by other acoustic treatment or lining at a location remote from the length of duct under consideration.

MEASURED SOUND ATTENUATION IN DUCTS.

Bradford Insulation has carried out extensive research to establish the real performance of ductliners in reducing noise levels. Tests have been carried out on Bradford Insulation 25mm and 50mm ductliners using different duct sizes and lengths of lined duct.

Figures 2, 3 and 4 have been plotted from measurements of sound levels taken in standard sheetmetal ducts using 25mm ductliners. The graphs present a conservative guide to the performance of all Bradford Glasswool and Fibertex™ Rockwool ductliners at 25mm thickness. Four different lengths of lining are shown for each of three duct sizes.

FIG 2.
SOUND ATTENUATION IN DUCT SIZE 254 x 305mm.

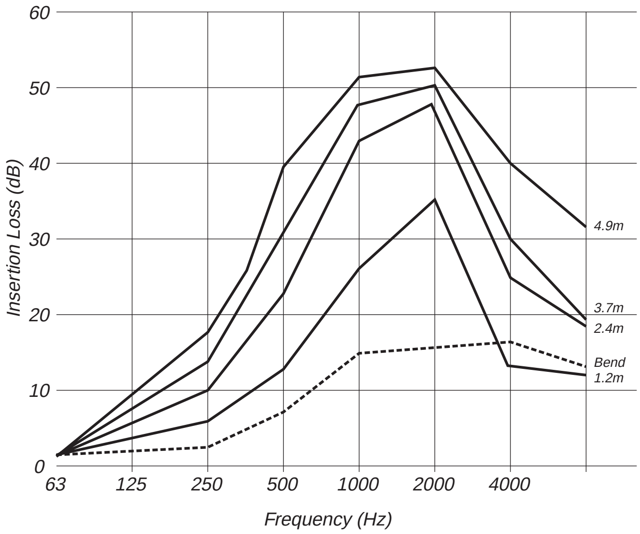


FIG 3.
SOUND ATTENUATION IN DUCT SIZE 406 x 813mm.

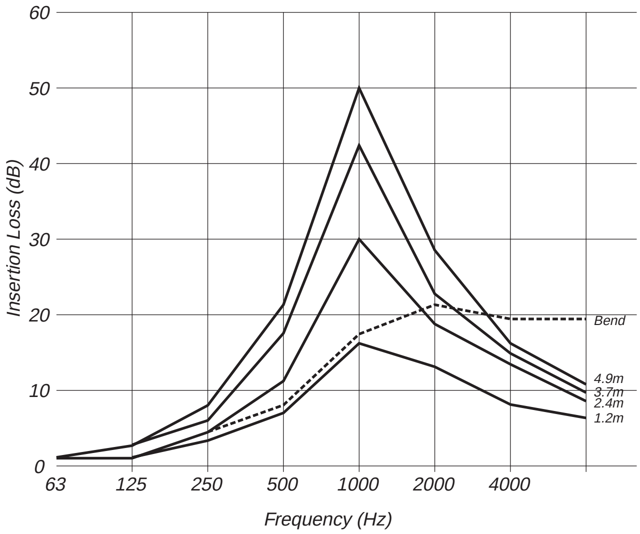
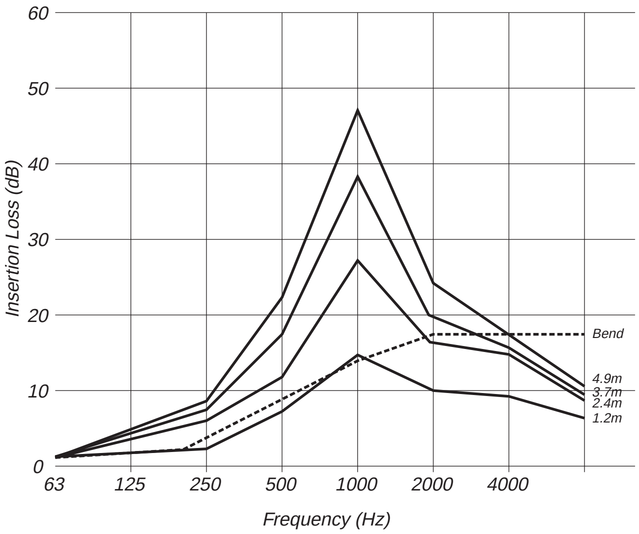


FIG 4.
SOUND ATTENUATION IN DUCT SIZE 508 x 610mm.



Research has also been carried out on sound attenuation characteristics of different facing materials used on ductliners. Insertion Loss measurements carried out in accordance with Australian Standard AS1277 demonstrate the effect of typical facing materials on the acoustic performance of Bradford Glasswool and Fibertex ductliners, as shown in Table 11.

Note: For correct materials handling procedure refer to Bradford MSDS for the appropriate product.

An alternative rough indication of attenuation achieved by the lining of ductwork can be found by use of the 'Sabine' formula.

This gives reasonable results for straight ducts at low frequencies provided the smallest duct dimension is within the range 150mm to 450mm and the width is no greater than three times the depth.

$$\text{Attenuation (dB/m)} = 1.05 \frac{P}{A} \alpha^{1.4}$$

Where:

P = inside perimeter of lined duct, m.

A = internal cross-sectional area, m^2.

α = absorption coefficient of the ductliner at the frequency concerned (from Table 12).

The location of duct lining can be a critical factor. It is normally placed at the start of a duct system to attenuate fan noise and near the outlets to correct air flow generated noise from dampers and fittings and to restrict noise transmission from adjacent areas through the air conditioning duct.

TABLE 11.
INSERTION LOSS CHARACTERISTICS OF FACED DUCTLINERS.

Product	Facing	Thickness	Insertion Loss (dB loss 600x600x4000 test duct)						
			Octave Band Centre Frequency (Hz)						
		mm	63	125	250	500	1000	2000	4000
Bradford Glasswool SUPERTEL™ 32 kg/m³	BMF	50	1.4	4.6	16.8	53.2	51.6	32.4	24.4
	THERMOFOIL™ HD Perf.	50	1.6	5.3	18.9	53.4	48.3	31.8	24.6
	23µm Melinex + THERMOFOIL™ HD Perf.	50	1.9	5.7	21.1	26.6	16.7	12.9	12.8
	THERMOTUFF™ LD Facing	50	2.7	7.1	31.6	37.6	20.1	11.1	7.2
Bradford FIBERTEX™ DUCTLINER 60 kg/m³	THERMOFOIL™ HD Perf.	50	2.8	5.8	19.9	56.6	49.1	32.4	24.6

TABLE 12.
SOUND ABSORPTION OF BULK INSULATION DUCTLINERS .

Product	Facings	Thickness (mm)	Frequency (Hz) 125	250	500	1000	2000	4000	5000	NRC*
Bradford Glasswool	THERMOFOIL™	25	0.10	0.33	0.66	0.90	1.03	0.79	0.76	0.75
FLEXITEL™	HD Perf.	50	0.39	0.84	1.08	1.20	1.06	1.01	0.95	1.05
24kg/m³										
Bradford Glasswool	THERMOFOIL™	25	0.12	0.28	0.68	0.94	1.09	0.85	0.75	0.75
SUPERTEL™	HD Perf.	50	0.39	0.72	1.14	1.19	1.05	0.98	0.90	1.02
32kg/m³	BMF	25	0.07	0.26	0.65	0.93	1.04	1.03	1.00	0.72
		50	0.24	0.62	1.00	1.07	1.12	1.15	1.17	0.95
Bradford Glasswool	THERMOFOIL™	25	0.12	0.31	0.81	1.09	1.09	0.91	0.89	0.80
ULTRATEL™	HD Perf.	75	0.69	1.19	1.15	1.09	1.03	0.92	0.90	1.11
48kg/m³										
Bradford	THERMOFOIL™	25	0.14	0.38	0.87	1.07	1.06	0.90	0.79	0.85
FIBERTEX™	HD Perf.	50	0.31	0.83	1.16	0.99	0.90	0.78	0.73	0.97
DUCTLINER	BMF	25	0.15	0.33	0.74	0.94	1.03	1.04	0.98	0.76
60kg/m³		50	0.36	0.76	1.19	1.09	1.03	1.04	0.90	1.01

* NRC: Arithmetic average of absorption coefficients of frequency 250, 500, 1000 and 2000 Hz.
Refer to the Bradford Insulation Acoustic Design Guide for additional sound absorption data.

ATTENUATION BY LINED BENDS.

The application of acoustic lining to bends can be very effective in attenuating duct-borne sound.

Square elbows are preferred to radius bends.

The lining should have a thickness at least 10% of D, the clear width between the two linings (refer FIG 5), and the length of lining should extend a distance not less than 2D before and after the bend.

Table 13 gives attenuation in dB achieved by square elbows without turning vanes when lined as recommended.

FIG 5.
SOUND ATTENUATION BY LINED SQUARE BEND.

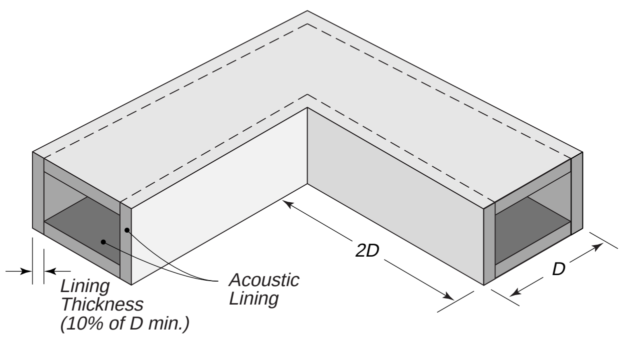


TABLE 13.
SOUND ATTENUATION BY LINED SQUARE BEND (dB).

D mm	Frequency (Hz) 63	125	250	500	1000	2000	4000	8000
125				1	6	12	14	16
250			1	6	12	14	16	18
500		1	6	12	14	16	18	18
1000	1	6	12	14	16	18	18	18

SOUND ATTENUATION BY LINED PLENUM.

The acoustical lining of fan discharge and suction plenums is often the most economical and convenient approach to achieving a major part of the sound attenuation required in a system. The following formula gives an approximate value of the attenuation in dB achieved by this means (refer diagram).

$$10 \log_{10} \left[S_o \left(\frac{\cos\theta}{2\pi d^2} + \frac{1-\alpha}{\alpha S_w} \right) \right]$$

Where:

α = absorption coefficient of the lining.

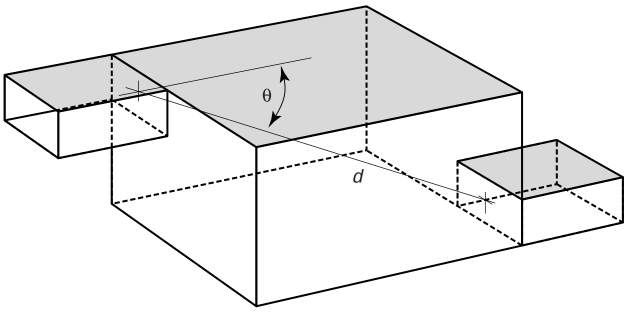
S_o = area of outlet opening, m^2.

S_w = total plenum wall area, m^2.

d = slant distance, centre inlet to centre outlet, m.

θ = angle of incidence at the outlet, degrees.

FIG 6.
SOUND ATTENUATION IN LINED PLENUM.



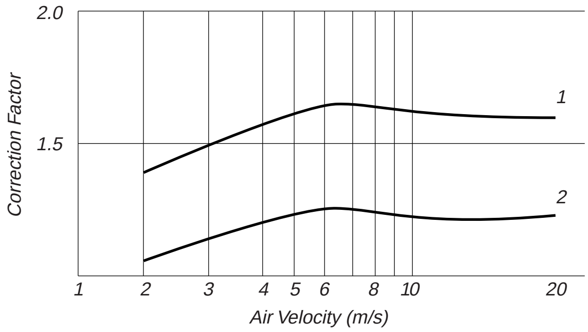
AIR FRICTION.

The energy absorbed by frictional losses in the air conditioning system may be significant, particularly for high velocity systems. The following information will assist the designer in assessing the effect of ductliners upon frictional losses.

The usual procedure for determining friction losses in air ducts is by use of the Air Friction Charts published by the ASHRAE Handbook of Fundamentals and the IHVE Guide. These charts provide friction losses for sheet metal ducts of standard construction. These losses must be multiplied by a factor to correct for the influence of ductliners.

The following graph shows correction factors for the Bradford range of Glasswool and Fibertex Rockwool ductliners. It is based on actual tests on a lined duct of 460 x 200mm internal dimensions, equivalent to a 280mm diameter circular duct. To adjust the correction factor selected for ducts of other dimensions, increase by up to 10% for circular equivalent sizes down to 150mm and decrease by up to 10% for circular equivalent sizes up to 1000mm.

FIG 7. AIR FRICTION CORRECTION FACTOR.



1 = Black Matt tissue (BMF) Faced Ductliners.

2 = Thermofoil™ Perforated Foil Laminate Faced Ductliners.

RESISTANCE TO AIR EROSION AND RECOMMENDED VELOCITIES.

Bradford Glasswool and Bradford Fibertex™ Rockwool ductliners have been tested for surface erosion at extreme velocities by the quantitative method developed by the CSR Building Materials Research Laboratories, based on Underwriters Laboratory Standard UL181-1990.

The products were subject to velocities up to 36 m/s and then a safety factor of 0.4 applied in accordance with the Underwriters Laboratory test.

On the basis of these results and the air friction correction factors, the following maximum design velocities are recommended.

TABLE 14.
MAXIMUM DESIGN VELOCITY.

Product	Maximum Design Velocity (m/s)
Bradford Glasswool covered with Perforated Metal	23
Bradford Glasswool faced with Perforated Foil	18
Bradford Glasswool faced with Black Matt Tissue (BMF)	22
Bradford FIBERTEX™ DUCTLINER CF covered with Perforated Metal	23
Bradford FIBERTEX™ DUCTLINER faced with Perforated Foil	18
Bradford FIBERTEX™ DUCTLINER faced with Black Matt Tissue (BMF)	22

System Specifications.

The following sample specifications are intended as general purpose fixing specifications for Bradford Insulation products. They are specified on the basis of ensuring proper insulation selection, installation and in-situ performance. More detailed information on insulation systems for ductwork is available in AS4254 and NATSPEC Services Reference.

External Insulation of Sheet Metal Ducts.

1. The duct surface shall be clean and dry.
2. The insulation shall be dry and free from off-cuts, dust, etc.
3. The insulation shall be CSR Bradford:
   Glasswool Ductwrap R0.9.
   Glasswool Ductwrap R1.5.
   Glasswool Flexitel.
   Fibertex Rockwool Ductwrap.

   The insulation shall be faced with *Thermofoil (730-Medium Duty or 750-Heavy Duty) Plain Foil* as manufactured by CSR Bradford Insulation.
   (Select insulation density and facing based on thermal performance criteria, refer to the Design Considerations and Calculations section of this guide, the Bradford Insulation Air Conditioning Product Guide, or as per AS4508).
4. The insulation thickness shall be ......*mm*. *(*To calculate the appropriate thickness refer to the Design Considerations and Calculations sections of this guide or as per AS4508 R-values).
5. The insulation should be dry when installed and shall be kept dry.
6. The insulation shall be factory faced with fire retardant *Thermofoil......(specify grade - medium or heavy).*

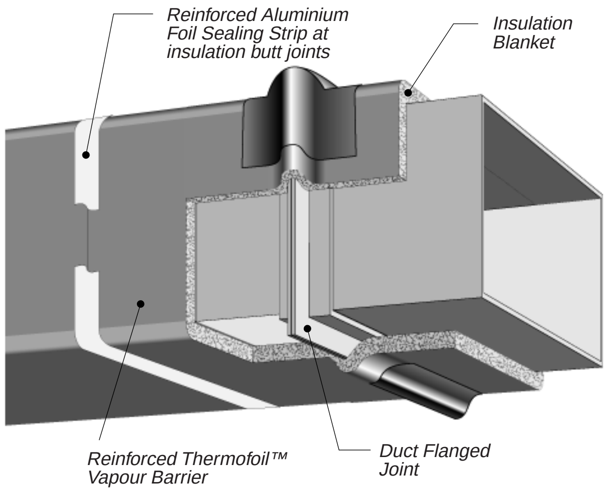
   Note: For certain applications the faced blanket must meet the requirements of regulatory bodies in respect of Early Fire Hazard. This specification satisfies these requirements.
7. The insulation shall be handled and stored so as to ensure that there is no damage to the insulation or facing.
8. The insulation and facing shall be cut and fitted to the duct so that all junctions shall be tightly butted together to prevent heat leakage.
9. The insulation shall be held to the underside of horizontal sheet metal ducting by means of pins (and clips) which are fixed to the duct surface by welding or by an approved adhesive.

TABLE 15 SPACING OF PINS - EXTERNAL DUCTWORK INSULATION.

Duct Widths	Pins Required
Up to 300mm	None
300mm to 600mm	One row pins along centreline at 300mm spacing
Over 600mm	Staggered formation of pins at maximum 300mm spacing

10. All insulation butt joins shall be sealed by means of a pressure sensitive vapour impervious tape such as reinforced foil tape - maintaining the laps as stated below. Alternatively, butt joins can be covered by strips of the facing material applied centrally over the butt join by means of an approved adhesive. The minimum lap of the sealing strip shall be 50mm except that at flanged joints in ductwork the minimum lap shall be 75mm.

FIG 8. EXTERNAL INSULATION OF SHEET METAL DUCTING.



Where the facing is wire netting, the previous clause shall not apply but the adjacent edges of wire netting shall be pulled together by means of galvanised soft wire laced through the wire netting.

11. When specified, galvanised steel corner angles 38 x 38mm for 25mm insulation thickness or 63 x 63mm for 50mm insulation thickness, shall be installed on all corners of the duct, retained by 12mm wide galvanised steel strapping at no greater than 750mm centres.

12. Where the Thermofoil facing is impaled over pins it shall be covered with a 100mm square piece of pressure sensitive foil tape to complete the vapour barrier.
13. It shall be ensured that the insulation system integrity is maintained where damper assemblies and the like are installed.
14. For further specification details refer to Australian Standard AS4254 'Ductwork for air-handling systems in buildings'.

    Note: For correct materials handling procedure refer to Bradford MSDS for the appropriate product.

Internal Insulation of Sheet Metal Ducts.

1. The selected ductliner must be dry and free from off-cuts, dust, grease, solvents, etc.

   In fitting ductliner insulation, ensure that all junctions are tightly butted together to prevent heat leakage.
2. The insulation shall be:
   Glasswool Ductliner R0.9.
   Glasswool Ductliner R1.5.
   Glasswool Supertel 32kg/m³.
   Glasswool Ultratel 48kg/m³.
   Fibertex Rockwool Ductliner.

   Where an acoustic facing only is required add:

   The facing shall be *Thermofoil 750 (Heavy Duty) Perforated Foil or Black Matt Tissue (BMF).*

   Where a dual layer acoustic and vapour barrier facing is required replace with:

   The facing shall be:

   1st Layer: Melinex 23mm film adhered to bulk insulation.

   2nd Layer: Thermofoil 750 Heavy duty Perforated Foil.

   Where a single layer acoustic and vapour barrier facing is required replace with:

   The facing shall be Thermotuff Light Duty Plain Foil as manufactured by CSR Bradford Insulation.

   (Select insulation density and facing based on thermal and acoustic performance criteria. Refer to the Design Considerations and Calculations section of this guide, the Bradford Insulation Air Conditioning Product Guide, or as per AS4508)
3. The insulation thickness shall be *......mm.* (To calculate the appropriate thickness refer to the Design Considerations and Calculations sections of this guide or as per AS4508 R-values).
4. The insulation should be dry when installed and shall be kept dry.
5. Where the insulation changes from internal to external, there shall be a minimum overlap of 300mm.
6. The insulation facing shall be factory applied except when sheetmetal facing is specified.
7. Adhesives shall be restricted to those having the approval to the appropriate authority in relation to fire hazard. Adhesives shall be used in accordance with the manufacturer's recommendations.
8. The internal ductliner insulation shall be supported against the duct surface by means of stud welded pins and speed clips. At corners sheetmetal angles shall be used. These will cover either
   i) Butted edge - overlap insulation joints or
   ii) Ductliner insulation folded and compressed into the corners

   Refer to Table 16 for pin spacings.

FIG 9.
INTERNAL INSULATION OF SHEETMETAL DUCTING.

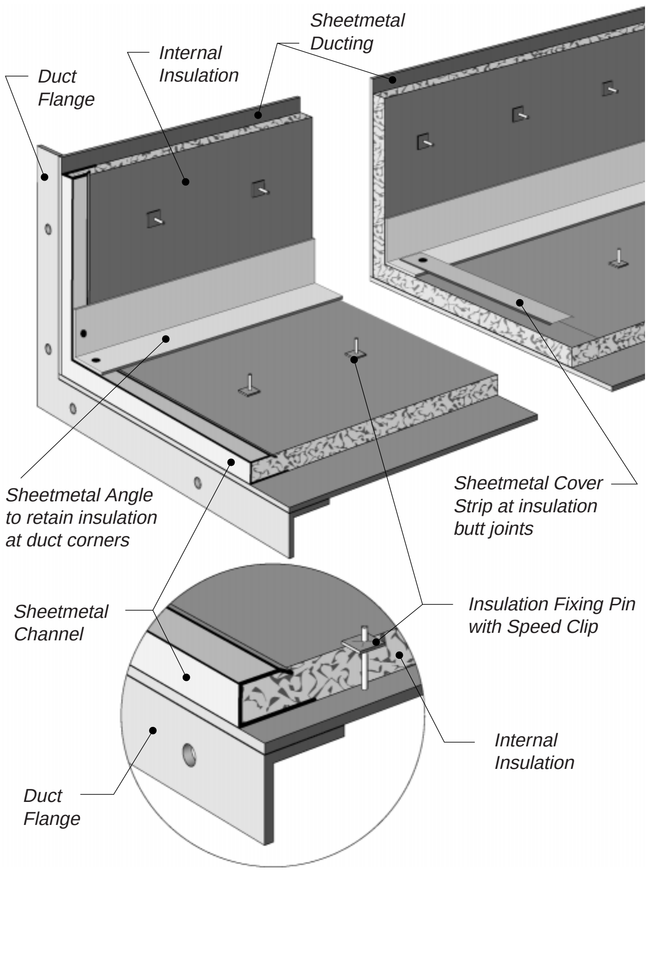


TABLE 16 SPACING OF FIXING PINS – EXTERNAL DUCTWORK INSULATION.

Duct Widths	Pins Required
Up to 300mm	None
300mm to 600mm	One row pins along centreline at 300mm spacing
Over 600mm	Staggered formation of pins at maximum 300mm spacing

In accordance with Australian Standard AS4254.

9. The insulation and facing shall be installed in one piece along the length of the duct. Where this is not possible, the edges of adjacent pieces of insulation and facing shall be cut straight and butted tightly together. The join shall be covered with a sheet metal cover strip, with edges turned down, and pinned to corner angles.
10. The insulation and facing shall be retained in position, at the ends of each duct section, by means of a sheet metal channel, with exposed edges turned down, fixed to the duct surface by means of pins or rivets. For joining flanges in the metal use Fosters 32-14 or 32-50 high velocity sealant or equivalent.
11. Each completed length or section of duct shall be carefully cleaned of all off-cuts, drill swarf, or other loose material, and shall be stored, before erection, under cover.
12. For further specification details refer to Australian Standard AS4254 'Ductwork for air-handling systems in buildings'.

    Note: For correct materials handling procedure refer to Bradford MSDS for the appropriate product.

Pipe Insulation (Air Conditioning and Mechanical Services).

1. Before application of pipe insulation, ensure that the metal surface of the pipe is clean and dry and that the insulation is dry.
2. The insulation shall be:

    Glasswool Sectional Pipe Insulation.
    Fibertex Rockwool Sectional pipe Insulation.

    Where a vapour barrier facing is required add:

    The insulation shall be faced with Thermofoil 750 Heavy duty Plain Foil as manufactured by CSR Bradford Insulation.

    (The appropriate thickness of insulation can be referenced in Appendix A or calculated using the information in this guide. Alternatively, consult the Bradford Insulation office in your region for expert advice).
3. Open a length of Bradford *Glasswool SPI or Fibertex Rockwool SPI (Sectional Pipe Insulation)* and snap into position over the pipe, tightly butting it against the adjacent section.

    The insulation may be held tight to the pipe with a variety of methods. In small sizes, the metal cladding will fulfil this function. Loops of soft galvanised or stainless steel wire are used up to 300mm O.D. of insulation, using three loops for each section beyond 200mm O.D. Above 300mm, 19mm metal bands should be used instead of wire loops.
4. Where multiple layers of insulation are used, apply the outside sections over the first layer in similar fashion ensuring that all joints are staggered to avoid direct heat transfer paths.
5. Bends can be insulated by cutting segments from a straight section of pipe insulation with a sharp knife i.e. mitred. The insulation segments are drawn tightly into position with 25mm galvanised hexagonal mesh and soft lacing wire. A surface finish can then be applied to correspond with that on the adjacent straight sections.
6. Valves, flanges and fittings may be insulated in much the same way as bends, using a sharp knife to cut board or pipe insulation to give a neat close fit. The pieces can be secured by wrapping with wire mesh and the relevant surface finish can then be applied.

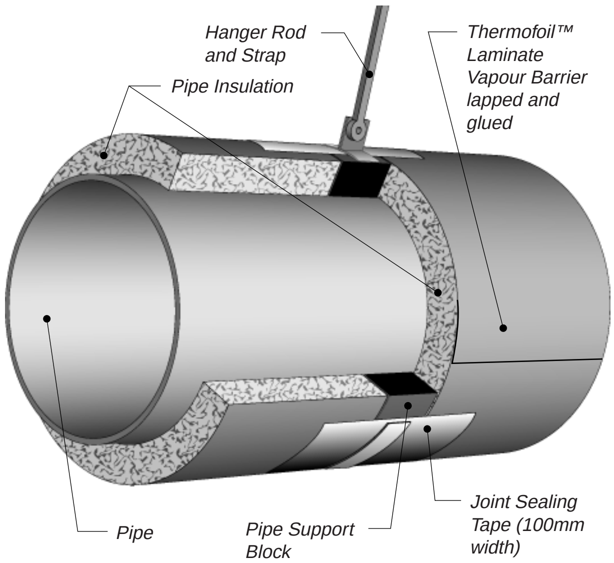
    Alternatively, a sheet metal box may be constructed and lined with Fibertex 450 secured with pins or adhesive. This approach allows speedy access for maintenance or inspection.

Pipes at Low Temperatures.

Pipes at low temperatures (chilled water and refrigeration) require a complete vapour barrier on the outside of the insulation. This is best provided by use of a factory-applied Thermofoil 750 foil laminate facing with 50mm laps that can be glued down. The vapour barrier is then completed by applying to all radial joints a 100mm wide strip of fire resistant vapour impermeable pressure sensitive tape, such as reinforced foil tape. Use of impermeable pipe supports are recommended to restrict transmission of vapour if damage occurs to a particular section of the vapour barrier.

At insulated bends, valves, flanges and fittings, the vapour barrier can be a foil laminate applied in strips by means of an adhesive reinforced foil tape. In view of the greater risk of puncture in these locations a wise precaution is to apply by glove-coat or brush a layer of a suitable reinforced vapour seal mastic, such as Fosters 30-80 to a dry finish thickness of 0.9mm.

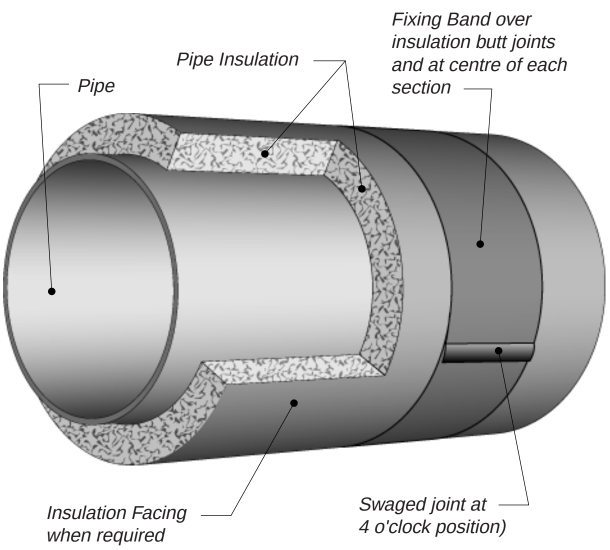
FIG 10.
INSULATION OF PIPES AT LOW TEMPERATURE.



Pipes at Moderate Temperatures.

Pipes at moderate temperatures (up to 350°C), if hidden from view, may not need a surface finish. The plain or unbound pipe sections are then secured with soft galvanised wire as described previously.

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



Low cost surface finishes include calico, scrim and Thermofoil may be applied where surface temperature is below 70°C. The longitudinal lap of the facing is glued down with a suitable adhesive. Aluminium fixing bands are then applied over the radial joints and at the centre of each section.

Metal Cladding.

Metal cladding is the recommended surface finish in locations where the insulation is exposed to the weather or the risk of mechanical damage. The preferred sheet metals for this purpose are galvanised steel, zincanneal and aluminium. The metal is cut and rolled to size, allowing for side laps in accordance with the outside diameter of the insulation as follows:

TABLE 17.

Insulation O.D. mm	Side Lap mm
Up to 168.3	38
168.3 to 355.6	50
Over 355.6	75

The outer edges to be lapped are swaged and, when fixing in position, the laps are located to shed water.

For service above ambient temperature, the metal can be secured by self-tapping screws or pop rivets; alternatively, and particularly for low temperature work, metal fixing bands can be used at the ends of the joints and the middle of each section of cladding. Care must be taken not to puncture the enclosed vapour barrier in low temperature applications.

As an alternative to sheet metal cladding, protection may be provided by applying two coats of a finishing cement. This may be considered where mechanical damage is a particular concern or acoustic considerations are important. Wire mesh is used over the insulation to provide a key for the first layer of cement. The first layer of 6mm is applied with a rough finishing to provide a key for the second 6mm layer, which is applied only after the first layer is fully dry.

The insulation must be dry when installed and kept dry. If necessary, waterproof covers should be used to protect pipe insulation which has been fixed in position but cannot immediately be protected by metal sheathing or other specified surface finish.

APPENDIX A.

Design Tables.

INTRODUCTION.

The following tables present the minimum required thicknesses of insulation to prevent condensation on cold surfaces together with the theoretical heat gains and surface temperatures for insulated flat and curved surfaces and pipes with hot face temperatures up to 200°C. Separate tables are shown for different microclimatic conditions with 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 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 Insulation office in your region.

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. Please contact the CSR Bradford Insulation 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.

In ordering Fibertex Rockwool Pipe Insulation for dual layer applications, it is important to indicate the pairs of sizes to be mated. 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.

MINIMUM THICKNESS OF INSULATION TO PREVENT CONDENSATION.

Flat and Curved Surfaces: -20°C to +10°C.
(Fibertex Rockwool/Glasswool Ductwrap)

Pipes: -20°C to +10°C.
(Glasswool and Fibertex Rockwool Pipe Insulation)

HEAT LOSS TO STILL AIR AT 20°C.

Flat and Curved Surfaces: +75°C to +200°C.
(Fibertex Rockwool/Glasswool Ductwrap)

Pipes: +75°C to +200°C.
(Glasswool and Fibertex Rockwool Pipe Insulation)

FLAT AND CURVED CLADDING SURFACES.
INSULATION: FIBERTEX™ ROCKWOOL OR GLASSWOOL DUCTWRAP.

MINIMUM THICKNESS OF INSULATION TO PREVENT CONDENSATION.

Table A1

	Minimum Insulation Thickness for Non-Reflective Cladding (mm)					
	Vessel Temperature °C					
Atmosphere at:	10	5	0	–5	–10	–20
30°C + 80% R.H.	25	25	25	38	38	50
30°C + 90% R.H.	50	50	63	75	88	100

Table A2

	Minimum Insulation Thickness for Reflective Cladding (mm)					
	Vessel Temperature °C					
Atmosphere at:	10	5	0	–5	–10	–20
30°C + 80% R.H.	38	38	50	63	63	75
30°C + 90% R.H.	75	88	113	125	150	175

PIPES: -20°C TO +10°C. AMBIENT: 30°C AND 80%R.H.
INSULATION: GLASSWOOL OR FIBERTEX™ ROCKWOOL PIPE INSULATION (WITH NON-REFLECTIVE SURFACE FINISH)

MINIMUM THICKNESS TO PREVENT CONDENSATION AT 30°C AND 80%R.H.

Table A3

	Minimum Insulation Thicknesses to Prevent Condensation (mm) (Non-Reflective Insulation – Surface Coefficient: 10 W/m²K)					
Pipe Temperature °C	10	5	0	–5	–10	–20
Pipe OD (mm)						
21.3	25	25	25	25	25	25
26.9	25	25	25	25	25	38
33.7	25	25	25	25	25	38
42.4	25	25	25	25	25	38
48.3	25	25	25	25	25	38
60.3	25	25	25	25	25	38
76.1	25	25	25	25	38	38
88.9	25	25	25	25	38	38
101.6	25	25	25	25	38	38
114.3	25	25	25	25	38	38
139.7	25	25	25	25	38	38
165.1	25	25	25	25	38	38
215.9	25	25	25	38	38	38
266.7	25	25	25	38	38	38
317.5	25	25	25	38	38	38

PIPES: -20°C TO +10°C. AMBIENT: 30°C AND 90% R.H.
INSULATION: GLASSWOOL OR FIBERTEX™ ROCKWOOL PIPE INSULATION (WITH A NON-REFLECTIVE SURFACE FINISH).

MINIMUM THICKNESS TO PREVENT CONDENSATION AT 30°C AND 90% R.H.

Table A4

	Minimum Insulation Thicknesses to Prevent Condensation (mm) (Non-Reflective Insulation – Surface Coefficient: 10 W/m²K)					
Pipe Temperature °C	10	5	0	-5	-10	-20
Pipe OD (mm)						
21.3	25	38	38	38	38	50
26.9	25	38	38	38	50	50
33.7	25	38	38	50	50	63
42.4	38	38	38	50	50	63
48.3	38	38	38	50	50	63
60.3	38	38	38	50	50	63
76.1	38	38	50	50	50	63
88.9	38	38	50	50	63	63
101.6	38	38	50	50	63	63
114.3	38	38	50	50	63	75
139.7	38	38	50	50	63	75
165.1	38	38	50	63	63	75
215.9	38	50	50	63	63	75
266.7	38	50	50	63	63	75
317.5	38	50	50	63	63	75

PIPES: -20°C TO +10°C. AMBIENT: 30°C AND 80% R.H.
INSULATION: GLASSWOOL OR FIBERTEX™ ROCKWOOL PIPE INSULATION (WITH A REFLECTIVE SURFACE FINISH).

MINIMUM THICKNESS TO PREVENT CONDENSATION AT 30°C AND 80% R.H.

Table A5

	Minimum Insulation Thicknesses to Prevent Condensation (mm) (Reflective Insulation – Surface Coefficient: 5.7 W/m²K)					
Pipe Temperature °C	10	5	0	-5	-10	-20
Pipe OD (mm)						
1.3	25	25	25	38	38	38
26.9	25	25	38	38	38	50
33.7	25	25	38	38	38	50
42.4	25	25	38	38	38	50
48.3	25	25	38	38	38	50
60.3	25	38	38	38	50	50
76.1	25	38	38	38	50	50
88.9	25	38	38	38	50	63
101.6	25	38	38	50	50	63
114.3	25	38	38	50	50	63
139.7	25	38	38	50	50	63
165.1	25	38	38	50	50	63
215.9	25	38	38	50	50	63
266.7	25	38	38	50	50	63
317.5	25	38	38	50	50	63

PIPES: -20°C TO +10°C. AMBIENT: 30°C AND 90% R.H.
INSULATION: GLASSWOOL OR FIBERTEX™ ROCKWOOL PIPE INSULATION (WITH A REFLECTIVE SURFACE FINISH).

MINIMUM THICKNESS TO PREVENT CONDENSATION AT 30°C AND 90% R.H.

Table A6

	Minimum Insulation Thicknesses to Prevent Condensation (mm) (Reflective Insulation – Surface Coefficient: 5.7 W/m²K)					
Pipe Temperature °C	10	5	0	-5	-10	-20
Pipe OD (mm)						
21.3	38	50	50	63	63	75
26.9	38	50	50	63	63	75
33.7	38	50	63	63	75	75
42.4	50	50	63	63	75	88
48.3	50	50	63	63	75	88
60.3	50	63	63	75	75	88
76.1	50	63	63	75	88	100
88.9	50	63	75	75	88	100
101.6	50	63	75	75	88	100
114.3	50	63	75	75	88	100
139.7	50	63	75	88	88	113
165.1	50	63	75	88	100	113
215.9	63	75	75	88	100	113
266.7	63	75	88	88	100	125
317.5	63	75	88	100	100	125

FLAT AND CURVED SURFACES: 75°C TO 200°C.
INSULATION: FIBERTEX™ ROCKWOOL OR GLASSWOOL DUCTWRAP.
HEAT LOSS TO STILL AIR AT 20°C.

Q = Heat loss per square metre.

t_s = Surface Temperature.

Minimum general purpose thicknesses are highlighted.

Table A7 / *Table A8*

	Non-Reflective Cladding Surface coefficient: 10 W/m²K			Reflective Cladding Surface coefficient: 5.7 W/m²K		
Hot Face Temperature t_v	Insulation Thickness L	Heat Loss Q	Surface Temperature t_s	Insulation Thickness L	Heat Loss Q	Surface Temperature t_s
°C	mm	W/m²	°C	mm	W/m²	°C
75	25	75	27	25	69	32
	38	51	25	38	48	28
100	25	116	32	25	106	39
	38	80	28	38	75	33
	50	62	26	50	59	30
150	25	213	41	25	194	54
	38	147	35	38	138	44
	50	114	31	50	108	39
	63	91	29	63	88	35
200	38	231	43	38	217	58
	50	179	38	50	170	50
	63	144	34	63	138	44
	75	122	32	75	118	41

PIPES: 75°C TO 200°C.
INSULATION: GLASSWOOL AND ROCKWOOL SECTIONAL PIPE INSULATION.
HEAT LOSS TO STILL AIR AT 20°C.

Q' = Heat loss per lineal metre.

t_s = Surface Temperature.

Minimum general purpose thicknesses are highlighted.

Table A9

		Non-Reflective Cladding Surface coefficient: 10 W/m²K							
Pipe Temperature °C		75		100		150		200	
Pipe OD	Insulation thickness	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
21.3	25	9	24	14	26	25	31	38	37
	38	7	22	11	24	20	27	31	30
	50	7	22	10	23	18	25	28	27
	63	6	21	9	22	16	24	25	25
26.9	25	10	24	16	27	28	32	44	38
	38	8	23	13	24	23	27	35	31
	50	7	22	11	23	20	25	31	28
	63	7	21	10	22	18	24	28	26
33.7	25	12	25	18	27	33	32	50	39
	38	10	23	15	24	26	28	40	32
	50	8	22	13	23	23	25	35	28
	63	7	21	11	22	20	24	31	26
42.4	25	14	25	21	27	38	33	58	40
	38	11	23	17	24	30	28	46	32
	50	9	22	14	23	26	26	39	29
	63	8	22	13	22	23	24	35	27
48.3	25	15	25	23	28	42	33	64	41
	38	12	23	18	25	32	28	50	33
	50	10	22	15	23	28	26	42	29
	63	9	22	14	22	24	24	37	27
60.3	25	18	25	27	28	49	34	75	42
	38	14	23	21	25	37	29	57	33
	50	12	22	18	24	32	26	49	30
	63	10	22	15	23	28	25	43	27
76.1	25	21	25	32	28	58	35	89	42
	38	16	23	25	25	44	29	67	34
	50	14	22	21	24	37	27	56	30
	63	12	22	18	23	32	25	49	28
88.9	25	24	26	37	28	65	35	100	43
	38	18	23	27	25	49	29	75	35
	50	15	23	23	24	41	27	63	31
	63	13	22	20	23	35	25	54	28
101.6	25	27	26	41	29	73	35	111	43
	38	20	24	30	25	54	30	83	35
	50	17	23	25`	24	45	27	69	31
	63	14	22	22	23	39	25	59	28
114.3	25	29	26	45	29	80	36	123	44
	38	22	24	33	26	59	30	91	35
	50	18	23	27	24	49	27	75	31
	63	15	22	23	23	42	26	64	29
139.7	25	35	26	53	29	95	36	145	44
	38	26	24	39	26	69	30	106	36
	50	21	23	32	24	57	28	87	32
	63	18	22	27	23	48	26	74	29

continued over page

***Table A9** continued*

		Non-Reflective Cladding Surface coefficient: 10 W/m²K							
Pipe Temperature °C		75		100		150		200	
Pipe OD	Insulation thickness	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
165.1	25	40	26	61	29	109	36	168	45
	38	29	24	44	26	79	30	122	36
	50	24	23	36	24	65	28	99	32
	63	20	22	31	23	55	26	84	29
	75	18	22	27	23	48	25	74	27
190.5	25	46	26	69	29	124	36	190	45
	38	33	24	50	26	90	31	137	36
	50	27	23	41	24	73	28	111	32
	63	22	22	34	23	61	26	94	29
	75	20	22	30	23	54	25	82	28
215.9	25	51	26	77	29	139	37	212	45
	38	37	24	56	26	100	31	153	37
	50	30	23	45	25	80	28	123	32
	63	25	22	38	24	67	26	103	30
	75	22	22	33	23	59	25	91	28
241.3	25	56	26	86	29	153	37	234	46
	38	40	24	61	26	110	31	168	37
	50	32	23	49	25	88	28	135	33
	63	27	22	41	24	74	26	113	30
	75	24	22	36	23	64	25	99	28
	88	21	22	32	22	57	24	88	27
266.7	25	62	26	94	29	168	37	257	46
	38	44	24	67	26	120	31	183	37
	50	35	23	54	25	96	28	147	33
	63	29	22	45	24	80	26	123	30
	75	26	22	39	23	70	25	107	28
	88	23	22	35	22	62	24	95	27
317.5	25	72	26	110	30	197	37	301	46
	38	51	24	78	26	140	31	214	37
	50	41	23	62	25	111	28	171	33
	63	34	22	52	24	92	27	142	30
	75	30	22	45	23	80	25	123	28
	88	26	22	40	23	71	25	109	27
355.6	25	80	26	122	30	218	37	335	46
	38	57	24	86	26	154	31	237	37
	50	45	23	69	25	123	29	189	33
	63	37	22	57	24	102	27	156	30
	75	32	22	49	23	88	26	136	29
	88	29	22	43	23	78	25	119	27

PIPES: 75°C TO 200°C.
INSULATION: GLASSWOOL AND ROCKWOOL SECTIONAL PIPE INSULATION.
HEAT LOSS TO STILL AIR AT 20°C.

Q' = Heat loss per lineal metre.

t_s = Surface Temperature.

Minimum general purpose thicknesses are highlighted.

Table A10

		Reflective Cladding Surface coefficient: 5.7W/m²K							
Pipe Temperature °C		75		100		150		200	
Pipe OD	Insulation thickness	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
21.3	25	9	27	13	30	24	38	36	48
	38	7	24	11	26	20	31	30	37
	50	6	23	10	25	18	28	27	32
	63	6	22	9	23	16	26	25	29
26.9	25	10	27	15	31	27	40	41	50
	38	8	24	12	26	22	32	34	38
	50	7	23	11	25	20	29	30	33
	63	7	22	10	24	18	26	27	30
33.7	25	11	28	17	32	31	41	47	51
	38	9	25	14	27	25	33	38	40
	50	8	23	12	25	22	29	34	34
	63	7	23	11	24	20	27	30	31
42.4	25	13	28	22	32	36	42	55	53
	38	11	25	16	28	29	34	44	41
	50	9	24	14	25	25	30	38	35
	63	8	23	12	24	22	27	34	31
48.3	25	14	28	22	32	39	42	60	54
	38	11	25	17	28	31	34	48	41
	50	10	24	15	26	27	30	41	36
	63	9	23	13	24	24	28	37	32
60.3	25	17	28	26	33	46	43	70	55
	38	13	25	20	28	36	35	55	43
	50	11	24	17	26	31	31	47	36
	63	10	23	15	25	27	28	42	32
76.1	25	20	29	30	33	54	44	83	57
	38	15	26	24	29	42	35	64	44
	50	13	24	20	26	36	31	55	37
	63	11	23	17	25	31	29	48	33
88.9	25	22	29	34	34	61	44	93	57
	38	17	26	26	29	47	36	72	44
	50	15	24	22	27	40	32	61	38
	63	13	23	19	25	34	29	53	34
101.6	25	25	29	38	34	68	45	104	58
	38	19	26	29	29	52	36	79	45
	50	16	24	25	27	43	32	67	38
	63	14	23	21	25	38	29	58	34
114.3	25	27	29	42	34	74	45	114	59
	38	21	26	32	29	57	37	87	45
	50	17	25	26	27	47	32	72	39
	63	15	23	23	25	41	29	63	35
139	25	32	30	49	35	88	46	134	60
	38	24	26	37	30	66	37	101	46
	50	20	25	31	27	55	33	84	40
	63	17	24	26	26	47	30	72	35

continued over page

Table A10 *continued*

		Reflective Cladding Surface coefficient: 5.7W/m²K							
Pipe Temperature °C		75		100		150		200	
Pipe OD	Insulation thickness	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
165.1	25	37	30	57	35	101	46	155	60
	38	28	26	42	30	76	38	116	47
	50	23	25	35	27	62	33	96	40
	63	20	24	30	26	53	30	82	36
	75	17	23	26	25	47	28	72	33
190.5	25	42	30	64	35	115	47	175	61
	38	31	27	48	30	85	38	130	47
	50	26	25	39	28	70	33	107	41
	63	22	24	33	26	59	30	91	36
	75	19	23	29	25	52	29	80	33
215.9	25	47	30	72	35	128	47	196	61
	38	35	27	53	30	95	38	145	48
	50	28	25	43	28	77	34	119	41
	63	24	24	37	26	65	31	100	36
	75	21	23	32	25	58	29	88	34
241.3	25	52	30	79	35	141	47	216	61
	38	38	27	58	30	104	38	159	48
	50	31	25	47	28	85	34	130	41
	63	26	24	40	26	71	31	110	37
	75	23	23	35	25	63	29	96	34
	88	21	23	31	24	56	28	86	32
266.7	25	57	30	87	35	155	47	236	62
	38	42	27	64	30	113	38	174	48
	50	34	25	52	28	92	34	141	42
	63	29	24	43	26	78	31	119	37
	75	25	23	38	25	68	29	104	34
	88	22	23	34	24	61	28	93	32
317.5	25	67	30	102	35	181	48	277	62
	38	49	27	74	31	132	39	203	49
	50	39	25	60	28	107	34	164	42
	63	33	24	50	26	90	31	137	37
	75	29	23	44	25	78	29	120	34
	88	26	23	39	24	69	28	107	32
355.6	25	74	30	113	36	201	48	308	62
	38	54	27	82	31	146	39	224	49
	50	43	25	66	28	118	34	181	42
	63	36	24	55	26	99	31	151	38
	75	32	23	48	25	86	30	132	35
	88	28	23	43	24	76	28	117	32

APPENDIX B.

Frequently Asked Questions and Answers.

Q. ***Insulation specifications are often presented in terms of density. What are the densities of Bradford products?***

A. Bradford makes a range of Glasswool and Fibertex Rockwool products to suit any air conditioning application. Densities have importance sometimes for application and mechanical reasons but of equal or often greater importance is the performance properties of the materials. Where possible the performance specifications of the Insulation (e.g. thermal conductivity, sound absorption coefficients, compression resistance) should be specified or sought so that the most cost-effective product is used.

Product	Density (kg/m^3)
Bradford Glasswool MULTITEL™	18
Bradford Glasswool DUCTWRAP	20
Bradford Glasswool FLEXITEL™	24
Bradford Glasswool SUPERTEL™/DUCTLINER	32
Bradford Glasswool ULTRATEL™	48
Bradford FIBERTEX™ DUCTLINER	60
Bradford FIBERTEX™ 450	80

Q. ***There is quite a range of Ductliner type insulation, which one should I use?***

A. All Bradford Ductliners will provide good insulation for thermal efficiency and condensation control. The question of which one is related to:

a) Sound absorption characteristics, Generally speaking all Ductliners perform excellently in the mid to high frequency range. In the low frequency range absorption increases with thickness and/or density. The final choice will be influenced by the amount of absorption required.

b) Compression resistance/smoothness of internal surface. As density of insulation increases so does resistance to "quilting" due to pinning. This has significance in high velocity ducts, where a smooth flat surface is desirable to minimise friction losses, turbulence and air noise.

Most commonly Bradford Glasswool Supertel is used although for higher compression resistance Glasswool Ultratel or Rockwool Ductliner are recommended.

Q. ***What is the fixing detail and pin spacings for Bradford Air Conditioning Duct Insulation?***

A. There are two recommended systems here:

1) AS4254
This provides recommendations for a range of internal duct velocities and insulation techniques.

2) Natspec services specification
This provides alternative and complementary recommendations to AS4254.

Q. ***Why is there a need for facing materials for Bradford Air Conditioning Insulation? Which facing do I specify?***

A. For **External Duct Insulation** and for **Cold Pipe Insulation** a facing is needed predominantly to act as a vapour barrier. This is necessary since the duct in summer or the cold pipe will carry air or fluid at a temperature **below** that of the surrounding atmosphere. Under these conditions water condensation from the vapour in the atmosphere will readily occur at the duct or pipe casing since Glasswool Insulation is very permeable. This is highly undesirable, causing possible corrosion, mould, etc. A vapour barrier such as **Thermofoil Heavy Duty Plain** pre-laminated to the external face of the Ductwrap, Flexitel or pipe insulation is recommended, all joints and penetrations need to be carefully sealed, sample specifications are offered in this guide.

For **Internal Duct Insulation** a facing is needed to provide a relatively smooth surface for air transport and to safeguard against air erosion of the insulation at high ducted velocities. At the same time the facing must be acoustically transparent so that the insulation can perform its sound absorbent function. **Bradford Thermofoil Heavy Duty Perforated** is a premium facing. For linings in the vicinity of grilles and diffusers the aesthetically less intrusive **Black Matt Facing** (BMF) is recommended.

Q. What thickness air conditioning duct insulation should I use?

A. There are three considerations here:

1) Thermal Control.

2) Condensation Control.

3) Acoustic Control.

Thermal Control

The factors influencing the desired level of thermal control are many, including:
Local climate
Building Design and aspect
Building purpose / comfort level
Cost/Effective building energy efficiency
Design of heating/cooling plant

The building designer will usually optimise insulation thickness based on heat transfer calculations using the thermal conductivities of Bradford products. In Australia, AS4508 now sets minimum duct insulation R-values (refer to page 9). CSR Bradford Insulation recommends the specification of AS4508 for all rigid and flexible duct air conditioning systems in Australia, New Zealand and Asia.

Condensation Control

This will depend very much on local climate. In temperature climates such as Sydney, 25mm thickness is usual. Vapour barrier temperatures calculations need to be done for expected operating and ambient dry bulb temperatures and compared with expected worst case dewpoints. Sample calculation is provided in this guide.

Acoustic Control

Generally speaking 25mm thickness of Ductliner is commonly used. However, depending on the sound level generated by fan noise and/or air content the acoustic designer may opt for 50mm thickness.

Q. How are pipe bends and values insulated?

A. Pipe bends are insulated by cutting wedge-shaped sections from Bradford Glasswool sectional pipe insulation to form the bend. When the wedge series is assembled ("Lobster Backing") vapour barriers (where required) or cladding similarly needs to be cut into sectional shapes which, when assembled, neatly and without "leaks" form a cover to the lobster back sections. This is a skilled procedure best left to a skilled insulation contractor.

Small radius right angle bends are usually formed by simply mitring a length of pipe insulation.

Valves are often insulated by fabricating a sheet metal box to surround the valve and lining fully with Bradford Glasswool Supertel or Fibertex Rockwool Ductliner. The box needs to be well sealed on all joints for vapour barrier purposes.

Q. How can noisy pipes be quietened?

A. Pipe noise usually results from turbulence within the fluid being transported. The noise manifests itself as a combination of pipe vibration and air-borne radiated noise from the pipe casing. Pipe vibration is structurally borne and therefore needs to be reduced by incorporating resilience in either the pipe support collars or hangers.

Radiated noise must be reduced by introducing a noise barrier into the system. A suitable form of acoustic barrier membrane is Soundlagg loaded vinyl. Soundlagg is either laminated to glasswool blanket (Bradford Acoustilag) or wrapped over Bradford Glasswool sectional pipe insulation. Soundlagg may also be applied directly onto pipes where insulation is not required. For compliance with Building Code of Australia requirements, there is a need to provide an extra barrier in the form of a CSR Gyprock® lined bulkhead. Details of professionally designed systems are given in the CSR Gyprock® Fire & Acoustic Design Guide and the Bradford Insulation Acoustic Design Guide.

APPENDIX C.

Terminology.

ACOUSTIC.

absorption coefficient (α):	The ratio of the sound absorbed by a surface to the total incident sound energy.
attenuation:	The reduction in intensity of a sound signal between two points in a transmission system.
decibel (dB):	An acoustic unit of sound level based on 10 times the logarithm to the base 10 of the ratio of two comparable sound intensities.
flanking transmission:	The transmission of sound between two points by any indirect path.
frequency:	The number of vibrations per second. The unit is the Hertz (Hz), equivalent to one complete oscillation per second.
reverberation:	The persistence of sound within a space due to repeated reflections at the boundaries.

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 in the appropriate units (metric or imperial)
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.
surface heat transfer coefficient (f):	Time rate of heat flow per unit area under steady conditions between a surface and air when there is unit temperature difference between them.
conduction	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 ratio 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 electromagnetic wave motion.
resistance, thermal:	Reciprocal of thermal conductance, or ratio of material thickness to thermal conductivity
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 D.

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^2	=	645.2 mm^2	1 m^2	=	10.764 ft^2
	1 ft^2	=	0.0929 m^2		=	1.196 yd^2
	1 yd^2	=	0.836 m^2	1 ha	=	2.471 acre
	1 acre	=	0.4047 ha			
Volume	1 in^3	=	16387 mm^3	1 m^3	=	35.315 ft^3
	1 ft^3	=	0.0283 m^3	1 *l*	=	0.0353 ft^3
	1 ft^3	=	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^3	=	16.018 kg/m^3	1 kg/m^3	=	0.06243 lb/ft^3
Pressure	1 lb/in^2	=	6.895 kPa	1 kPa	=	0.1450 lb/in^2
	1 lb/ft^2	=	47.88 Pa	1 Pa	=	0.0209 lb/ft^2
	1 atm	=	101.3kPa		=	
Gauge Pressure	1 mm Hg	=	0.133 kPa	1 kPa	=	7.501 mm Hg
	1 in H_2O	=	0.2486 kPa		=	4.022 in H_2O
	1 in Hg	=	3.386 kPa		=	0.2953 in Hg
	1 millibar	=	0.1000 kPa		=	10 mb
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^2h	=	3.155 W/m^2	1 W/m^2	=	0.3170 Btu/ft^2h
Flat Surfaces	1 kcal/m^2h	=	1.163 W/m^2		=	0.860 kcal/m^2h
Pipes	1 Btu/ft.h	=	0.9615 W/m	1 W/m	=	1.04 Btu/ft.h
Specific Heat Capacity	1 Btu/lb°F 1 kcal/kg.°C	=	4.1868 kJ/kg.K	1 kJ/kgK	=	0.2388 Btu/lb°F kcal/kg.°C
Thermal Conductance (Surface Coeff.f)	1 Btu/ft^2h°F	=	5.678 W/m^2K	1 W/m^2K	=	0.1761 Btu/ft^2h°F
	1 kcal/m^2h°C	=	1.163 W/m^2K		=	0.860 kcal/m^2h°C
Thermal Conductivity	1 Btu.in/ft^2h°F	=	0.1442 W/mK	1 W/mK	=	6.933 Btu.in/ft^2h°F
Thermal Resistance	1 ft^2h°F/Btu	=	0.1761 m^2K/W	1 m^2K/W	=	5.678 ft^2h°F/Btu
Thermal Resistivity	1 ft^2h°F/Btu.in	=	6.933mK/W	1 mK/W	=	0.1442 ft^2h°F/Btu
Permeance	1 perm	=	57.2 ng/N.s	1 ng/N.s	=	0.0175 perm

CSR™

Bradford Insulation

CSR Building Solutions Website.

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 CSR 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.

BI102.BMS.0800