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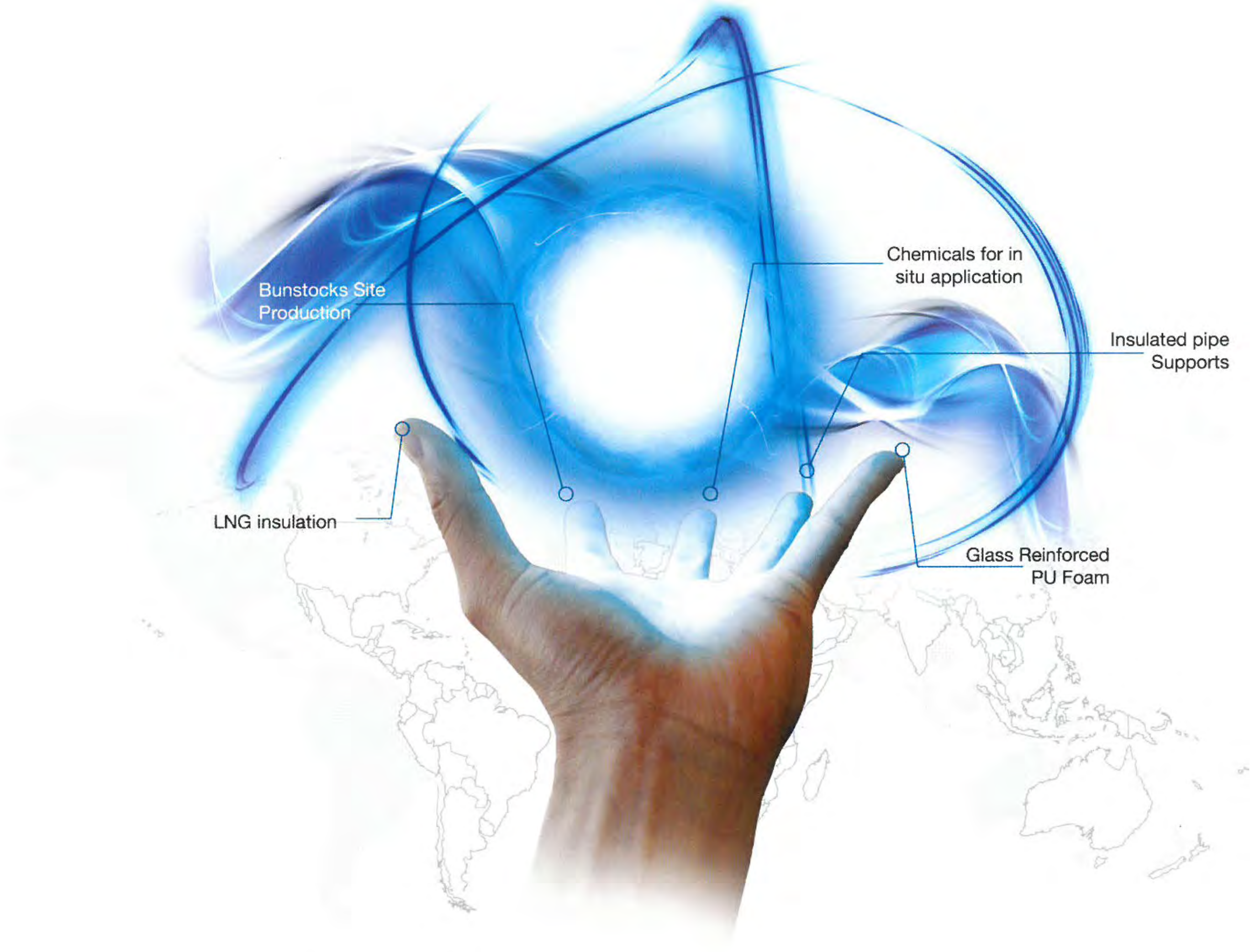


Polyurethane / Polyisocyanurate for

CRYOGENIC INSULATION

DUNA-Corradini
FOAMS & CHEMICALS

THERMAL INSULATION

Thermal insulation is the capacity of a structure to retard the transmission of heat. Every material has its own specific rate of heat transmission commonly indicated as thermal conductivity. Some materials, like metals, transmit heat at a very high rate and they are considered good heat conductors; other materials, like polyurethane foams, transmit heat at a very low rate so they are classified as good insulators.
All solid materials with cellular structure (i.e. consisting of cells/bubbles) entrapping air or other gases, are usually good insulators.

Basic Materials

Thermal insulators may consist of (1) fibrous or cellular mineral matter such as glass, silica, rock or slag; (2) fibrous or cellular organic matter such as cane, cotton, rubber, wood or wood bark, including cork; (3) cellular organic plastics such as polystyrene or polyurethane; or (4) heat reflecting metals (which must face air-filled or gas-filled or vacuum spaces).
The more common physical forms of industrial and building types of insulation are:

- Loose-fill and cement. Loose fill insulation consists of powders, granules or nodules which can be poured or blown into hollow walls or other spaces. Insulating cement is a loose material that, thanks to the plasticity and adhesion obtained by blending it with water, can be trowelled onto a surface and dried in place to serve as insulation.
Some types of cement can be sprayed in place. Both loose-fill and cement are especially suited for uneven, irregular surfaces.
- Flexible and semirigid. Materials with varying degrees of compressibility and flexibility, generally blanket, batt or felt insulation, are available in sheet and rolls of many types and varieties, both organic and inorganic (with or without binders).
- Rigid. These materials are available in rectangular dimensions called block, board or sheet, preformed during manufacture to standard lengths, widths and thicknesses. Insulation for pipes and curved surfaces is supplied in half sections or segments with radius of curvature to suit standard sizes of pipe and tubing.
- Reflective. Reflective material is available in sheets and rolls of single- or multilayer construction, and in preformed shapes with integral air spaces.
- Formed in place. These materials are available as liquid components, which may be poured or sprayed in place to form rigid or semirigid foam insulation.

Accessory materials for thermal insulation include fasteners, both mechanical and adhesive; finishes, such as facings and jackets, which may be protective and/or vapour-barrier; vapour-barrier and weather coating; lagging adhesive, sealants, membranes, and flashing compounds.

Thermal properties. The ability of a material to retard the heat flow is expressed by its thermal conductivity (for unit thickness) or conductance (for a specific thickness). Low values for thermal conductivity or conductance (or high thermal resistivity or resistance value), therefore, characterize thermal insulation.

CRYOGENIC INSULATION

The liquefaction and transportation of natural gas, the development of superconductors, electronic devices, medical techniques, and the increasing use of cryogenic fluids in manufacturing processes require much higher thermal insulation efficiency than usual industrial and building insulations.

Polyurethane

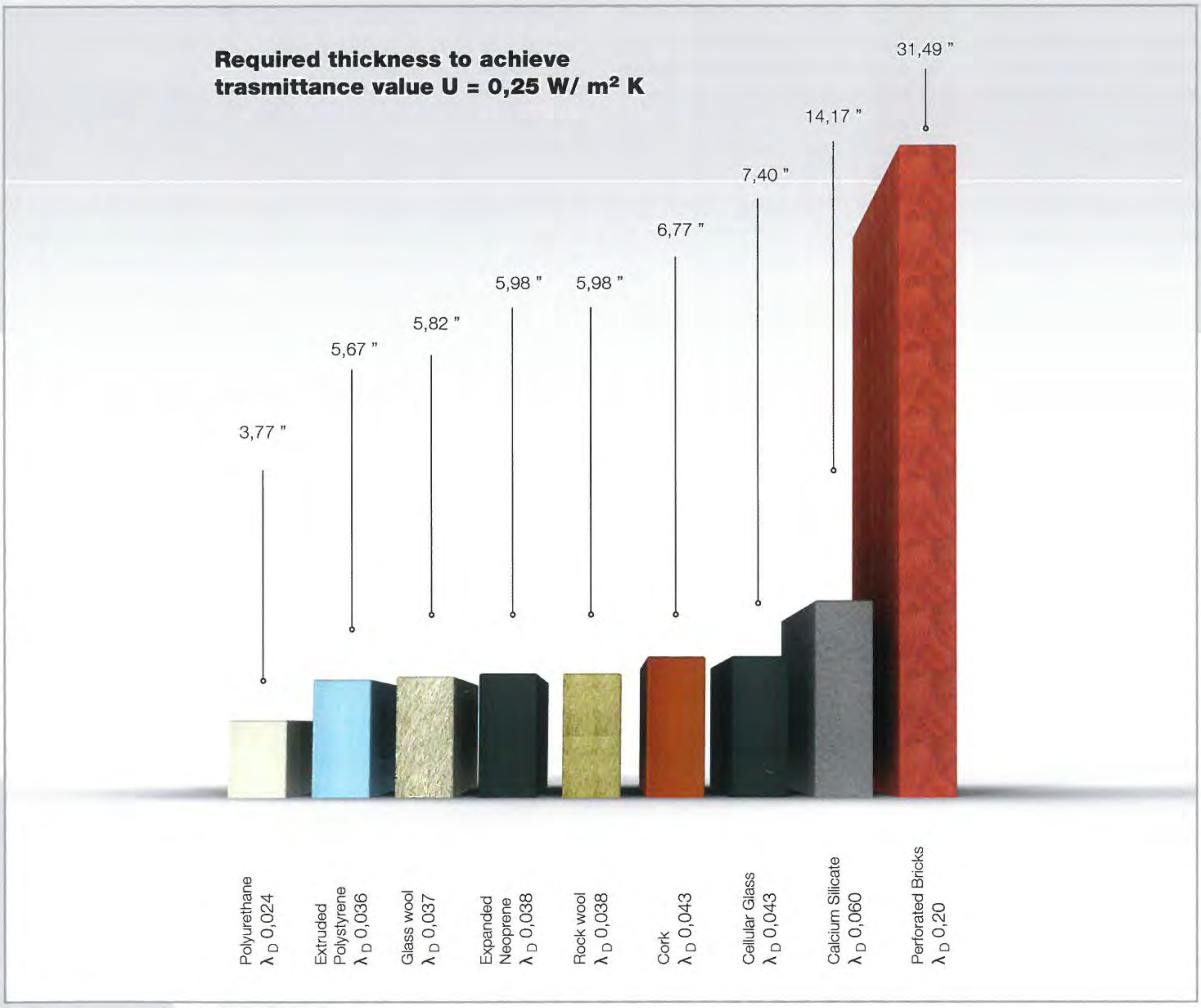
More than 70 years of success.

The synthesis of the first polyurethane resin, carried out by the German chemist Otto Bayer (1902-1982) back in 1937, marked the beginning of a new chapter in the history of plastics. The industrial and commercial success of polyurethane occurred only later, during the post war period (1945-1955), with first relevant applications in the field of elastomer and protective coatings.

Other immediate successes were achieved by both flexible foams, used in the field of padded materials and mattresses, and early rigid foams with their excellent insulating properties, which were essential in the widespread use of domestic refrigerators. The versatility of polyurethane was the driving-force behind increasing research and industrial investments carried out both by big chemical groups for the production of raw materials and by manufacturing industry for the characterization of new products and application sectors.

The chemical reaction of polyurethanes

Polyurethane belongs to the family of thermoset polymers; it is a polymeric chain obtained by polyaddition reaction between a polyisocyanate and a polyol, forming a sequence of urethane bonds (-NH-(CO)-O-). This reaction is exothermic and has no by-products.



Thermal conductivity values of other materials come from the databases and technical data sheets of various manufacturers.

BENEFITS AND ADVANTAGES OF POLYURETHANE INSULATION

Low thermal conductivity

Heat is a form of energy, always moving from a higher to lower temperature. The low thermal conductivity rating of rigid polyurethane foam, one of the lowest values among commonly used insulating materials, allows efficient retention of heat flow.

Insulation improves operating efficiency and reduces energy consumption, playing a vital role in the conservation of non-renewable fossil fuels, reducing emissions of carbon dioxide gas released by the burning of fuels for energy and therefore reducing global warming.

Strength

The good balance between weight, mechanical strength and insulation properties of DUNA-Corradini polyurethane foam CORAFOAM® demonstrates its versatility as an insulating material. These qualities allow it to be used in applications that require a combination of insulation with load-bearing, impact resistance, weight- and space-saving, as well as ease of installation and maintenance.

CORAFOAM® provides a very favourable ratio of physical-mechanical properties versus density; further enhancement of the overall properties is achieved when bonded with facing materials such as metal or plasterboard.

Lightness

Polyurethane rigid foams are cellular materials. The foam is made of little bubbles filled with the blowing agent, that provides the good insulation properties. The polyurethane matrix is in charge of holding all the cells together: the higher the amount of polymer that holds together the structure, the higher the density. In fact, in 1 cubic metre of foam, only 4% of the total volume is occupied by the polymer while the remaining 96% is filled by the blowing agent (this applies to a typical 40-45 Kg/m3 foam)

The lightness of the foam allows easy transportation, handling and installation.

Low water absorption and low water permeability

Water has a thermal conductivity that is 10-20 times higher than commonly used insulating materials, so it is evident how important it is to keep water out of the insulation package.

The presence of water, besides causing the loss of insulation efficiency, leads to an increase in weight, the risk of corrosion for metal surfaces and ice formation whenever it reaches temperatures below freezing point. In this last case the risk of deterioration of the insulation package is possible, thus negatively affecting the insulation properties.

The closed cell structure of rigid polyurethane foams guarantees low water absorption; the incorporation of a moisture vapour barrier is nevertheless provided for, with the aim of enabling the insulation to withstand the most stringent requirements.

Dimensional Stability

A dimensionally stable material is a basic requirement to achieve proper insulation performance.

A size change in the insulating material can be reversible or irreversible: size changes due to simple thermal contraction/ expansion are usually reversible, while size changes due to the combined effects of extreme temperatures, water, moisture and mechanical loads constitute an irreversible component.

All materials, in fact, change size when heated up or cooled down: the amount of size change depends on the chemical composition of the material, thus every material has its own coefficient of thermal expansion: this parameter measures how much materials shrink or expand when they are exposed to a temperature change.

Size variations due to the coefficient of thermal expansion are reversible.

Because of their chemical composition, good mechanical properties, reduced moisture pick-up, closed cell structure and chemical resistance, rigid polyurethane foams show significant performances in size stability.

Chemical resistance

The chemical composition of rigid polyurethane foam provides excellent resistance to a wide range of chemicals, solvents and oils.

Compatibility

Rigid polyurethane foam is compatible with a large number of auxiliary materials, including paper, foil, glass fibre, aluminium and bitumen. The combination of rigid polyurethane foam with these materials enhances the overall properties, enabling it to be used as semi-structural panels and cladding. Furthermore, proper choice of plaster or foil improves the insulating performance of the foam by forming protective moisture barriers, useful when conditions of high humidity are present.

Range of service temperatures

Rigid polyurethane foam can be used in applications which experience exceptional extremes of temperature, from -200°C to +130°C.

Nevertheless, every polyurethane foam has its own temperature range of application so it is important to double check the indications on the technical data sheets before selecting the most convenient solution.

Fire properties

Polyurethane rigid foams are organic compounds. Organics are all combustible materials, although the ignitability and rate of burning of polyurethane rigid foams can be improved to suit a variety of insulating applications and they can be formulated to meet the most stringent fire protection standards.

PU/PIR TYPICAL APPLICATIONS

PIR and PU foams are widely used in the gas liquefaction industry thanks to their excellent behaviour at critical temperatures such as those in cryogenic applications.
Being strongly resistant to thermal shocks, as well as chemically inert, our CORAFOAM® materials can withstand a wide range of operating temperatures from strong cryogenic (liquid nitrogen -196 °C) up to about 130 °C, granting the best compromise in terms of cost/efficiency. For these reasons they are massively used in the most critical cryogenic applications where the saving of frigories is vital for the efficiency of the running plant. The main categories of industrial plants where PIR/PU foams can be used are the following:

Liquefied Natural Gas (LNG)

Definitely the most technically advanced development in the oil & gas business, which has allowed several countries to start up a profitable trade in natural resources that were once impossible to export.
The natural gas is condensed into a liquid by cooling it to approximately –162 °C (–260 °F); during this process it is also separated from other secondary gases to get a pure product.
The reduction in volume makes it much more cost efficient to transport over long distances where pipelines do not exist, optimizing the supply chain from producer to market and increasing the numbers of potential markets.
PIR and PU are main contributors to the good results of these operations in all aspects of the supply chain, from liquefaction, through insulation of the tanks on LNG carriers, to the regasification terminal where ships download it into various kinds of reservoirs.

Ethylene

This is one of the most important hydrocarbons, as it is the first building block for other plastics. Ethylene is the most widely produced organic compound in the world, initially manufactured directly close to the market. Since gas liquefaction technology developed reliable solutions for the transportation of the liquefied gases (in this case, the storage temperature is around -104°C), it has become more convenient to process the natural gas close to the gas fields. PU/PIR, thanks to their versatility, have contributed significantly to the success of the development of local industries in several developing countries.

LPG

LPG is synthesized by refining petroleum or 'wet' natural gas, and is usually derived from fossil fuel sources, being manufactured during the refining of crude oil, or extracted from oil or gas streams as they emerge from the ground. Varieties of LPG include mixtures that are mainly propane based, mixtures mainly butane based and most commonly - mixtures including both propane and butane.
The development of the LNG business, whose production process consists of various purification phases, enables LPG gases to be obtained as secondary product with low production costs. LPG plants are therefore often located near large LNG plants.
LPG is normally considered "soft cryogenic", as the storage temperatures are about -10/-45°C depending on the ratio of the various components.

Ammonia/Fertilizer

Ammonia is a compound of nitrogen and hydrogen with the formula NH3. It is a gas with a characteristic pungent odour. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to food, being a fertilizer. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals.

Underground Oil ducts

Oil pipelines are made from steel or plastic tubes with inner diameter typically from 10 to 120cm (about 4 to 48 inches). Most pipelines are buried at a typical depth of about 1 - 2 metres (about 3 to 6 feet). The oil is kept warm enough (about 80°C) to be fluid, and this allows pumps to move it at about 1 to 6 m/s. Thanks to the great resistance to organic attacks, PU/PIR are often applied for the insulation of these underground ducts.

DUNA-Corradini PRODUCTS

Thanks to its specific experience and know how, DUNA-Corradini has developed the following range of products:

CORAFOAM®

Low density foams

Suitable for pipelines and plant insulation. Main applications are in insulation of critical plants like ethylene units and NGL, GTL and LNG liquefaction/regasification (strong cryogenic) as well as of soft cryogenic systems (ammonia/fertilizer LPG, etc).

- CORAFOAM® PB M1 HC
- CORAFOAM® GP

High density foams:

Suitable for the insulation of cryogenic pipe supports, where strong mechanical characteristics are requested in combination with high insulation properties.

- CORAFOAM® RTS
- CORAFOAM® MD

Special Foams

Continuous Fibre Glass filament reinforced foam, where particularly strong mechanical characteristics and a reduced weight are required.

- CORAFOAM® RV

All CORAFOAM® products are available in different densities.

DUNAPOL™ SYSTEMS

DUNAPOL™ C

Liquid components for casting with specific equipment or without (hand mixing). All products are CFC and HCFC free.

- DUNAPOL™ C 452 – Insulation of storage tanks for fertilizers, ammonia, urea. RINA (Italian Naval Register) homologated, it can be used both on-shore and offshore.
- DUNAPOL™ C 453 – Insulation of tanks, but also of valves and flanges. Fire reaction Class B2 according to DIN 4102, RINA (Italian Naval Register) homologated.
- DUNAPOL™ C 472 – Pipeline insulation. More fluid than the previous ones, it is suitable for the insulation of pipelines directly on site.

DUNAPOL™ S

Liquid components for spraying. Their main application is the spray insulation of tanks containing LPG, ammonia, urea, or for corner protection of LNG tanks. All products are CFC and HCFC free.

- DUNAPOL™ S 236 E - the most common spray system.
- DUNAPOL™ S 235 E - fire reaction Class B2, for special uses.
- DUNAPOL™ S 236 H - blown with CO2 for minimum environmental impact

DUNAPOL™ AD

Two component structural adhesives.

- DUNAPOL™ AD 1566 – Liquid glue. Flexible, it can be sprayed. Self-extinguishing. Slow-to-medium hardening at room temperature. Resistant to water and mechanical stress. Approved by RINA (Italian Naval Register) for cryogenic applications. Suitable to bond polyurethane with polyurethane or polyurethane with metal (e.g. jacketing). Operating temperatures: +80/-165 °C.

- DUNAPOL™ AD 1576 – Thixotropic glue. Self-extinguishing, fire properties: B2 (DIN4102). Intermediate hardening at room temperature. Resistance to water and to mechanical stress. Approved by RINA (Italian Naval Register) for cryogenic applications. Suitable to bond polyurethane with polyurethane or polyurethane with metal. Operating temperatures: +80/-165 °C

- DUNAPOL™ AD 1586 – Thixotropic glue. Medium-slow hardening at room temperature. Available in 400 ml cartridges, particularly convenient for applying and suitable for critical conditions; it can be easily adjusted to successfully perform at very high and very low ambient temperatures.

VAPOUR BARRIER

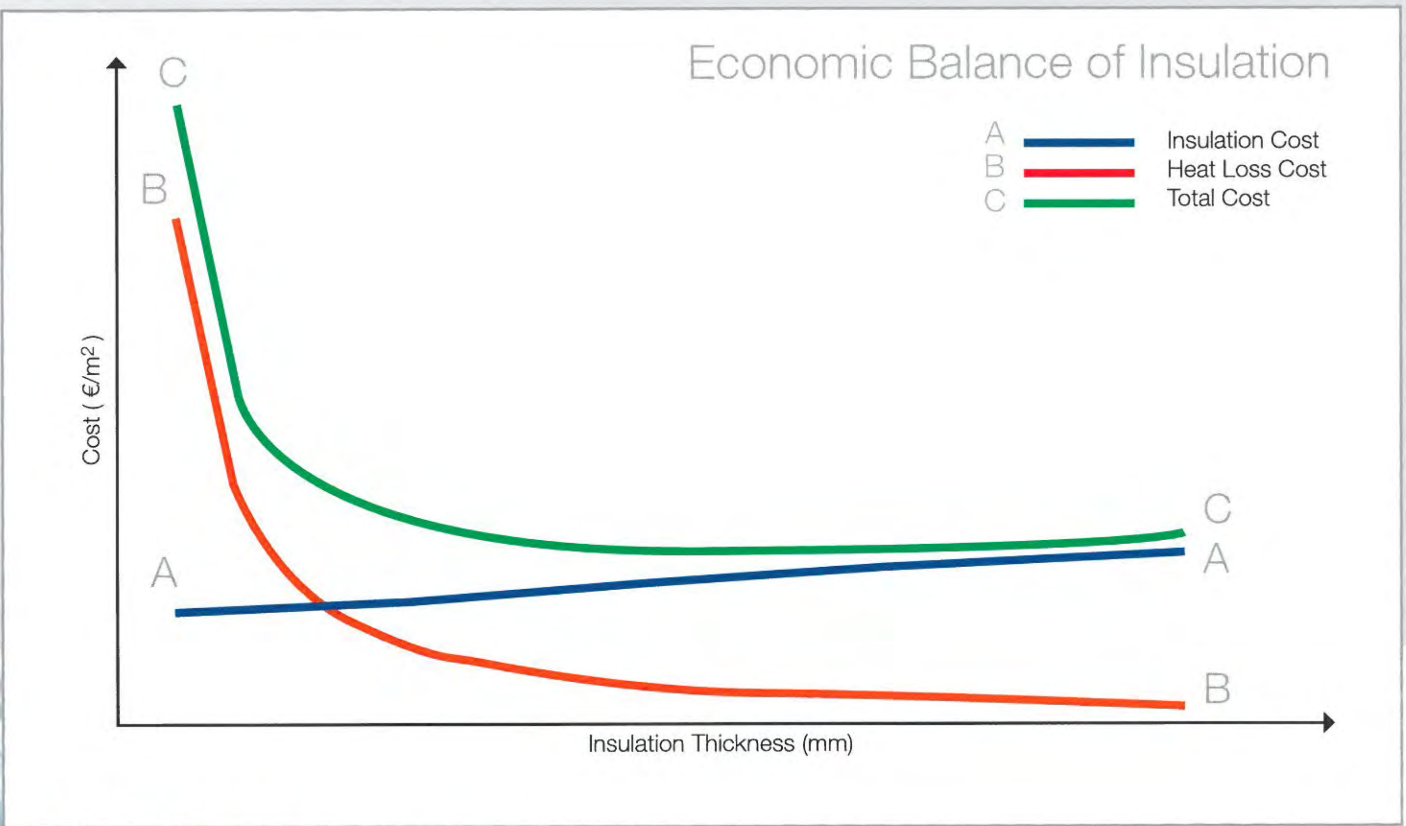
To complete the product range, DUNA-Corradini also supplies a secondary vapour barrier.

DUNAPAP™ – composite film of polyester/aluminium/polyester (12/25/12 micron). The application of DUNAPAP™ is particularly practical as it is pre-glued with a hot melt adhesive on one side. Just heat it to activate the glue.

CHOICE OF THICKNESS

Economic thickness is defined as the thickness of insulating material that minimizes the total-cost curve, this curve being the sum of the cost of installed insulation and the cost of annual heat loss. At low thickness values, the cost of insulation is low, but the annual cost of energy (heat) lost is high. Additional thickness raises the cost of insulation but reduces the loss of energy and, therefore, its cost. At some insulation thickness values, the sum of the cost of insulation and the cost of heat loss will be minimum, as indicated by curve C in the figure below, which is obtained by adding curve A and curve B. Beyond the minimum, curve C rises because the increased cost of insulation is no longer offset by the reduced cost of heat loss. On curve C, the amount of savings in total cost decreases for each ½-in. increase in insulation added.

Even though curve C may begin to turn upward just after an increase in insulation is applied, it is recommended practice not to go on to the next increase to take care of future rises in fuel costs.



COLD SERVICE PIPE INSULATION

Insulation Thickness Table (mm) Boundary conditions	calculated for a 25 W/m^2 maximum heat loss		
External ambient temperature	35 °C	**Relative Humidity**	80%
Wind speed	3,6 km/h	**Dew point**	31,1 °C
Surface emissivity	0,4		
Designed max. heat-loss	**25,0 W/m^2**		

DISCLAIMER:

Thicknesses reported in the following table are shown for demonstrative purposes only and they are strictly related to boundary conditions reported above.
They are calculated using ASTM C 690-95 algorithm, without considering any safety coefficient and assuming the perfect design and installation of an insulation system.
Duna-Corradini SpA assumes no responsibility for any use of data shown in the table below.
We strongly recommend contacting a qualified insulation-design engineer for a proper thickness calculation related to any specific project.

	Pipe Service Temperature (°C)							
Nominal Pipe Size (inch)	**-40**	**-60**	**-80**	**-100**	**-120**	**-140**	**-160**	**-180**
1/2	35	45	45	55	60	65	70	70
1	40	50	50	60	65	75	80	80
1 1/2	45	50	50	65	75	80	85	85
2	45	55	55	70	75	85	90	90
2 1/2	45	55	55	75	80	85	95	95
3	50	60	60	75	85	90	95	95
4	50	60	60	80	85	95	105	105
6	55	65	65	85	95	100	110	110
8	55	70	70	90	100	105	115	115
10	55	70	70	90	100	110	120	120
12	55	70	70	95	105	115	125	125
14	60	70	70	95	105	115	125	125
16	60	75	75	100	110	120	130	130
18	60	75	75	100	110	120	130	130
20	60	75	75	100	110	120	135	135
22	60	75	75	100	115	125	135	135
24	60	75	75	100	115	125	135	135
26	60	75	75	105	115	125	135	135
28	60	75	75	105	115	125	140	140
30	60	75	75	105	115	130	140	140
32	60	75	90	105	115	130	140	150
34	60	80	95	105	120	130	140	150
36	60	80	95	105	120	130	140	155
38	60	80	95	105	120	130	145	155
40	60	80	95	105	120	130	145	155

COLD SERVICE PIPE INSULATION

Insulation Thickness Table (mm) Boundary conditions	calculated for a 15 W/m² maximum heat loss		
External ambient temperature	35 °C	**Relative Humidity**	80%
Wind speed	3,6 km/h	**Dew point**	31,1 °C
Surface emissivity	0,4		
Designed max. heat-loss	**15,0 W/m²**		

DISCLAIMER:

Thicknesses reported in the following table are shown for demonstrative purposes only and they are strictly related to boundary conditions reported above.
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	Pipe Service Temperature (°C)							
Nominal Pipe Size (inch)	**-40**	**-60**	**-80**	**-100**	**-120**	**-140**	**-160**	**-180**
1/2	55	65	75	80	90	95	105	110
1	60	70	80	90	100	110	115	125
1 1/2	65	75	90	100	110	115	125	135
2	65	80	95	105	115	125	130	140
2 1/2	70	85	95	110	120	130	140	145
3	70	85	100	115	125	135	145	155
4	75	90	105	120	130	140	155	165
6	80	100	115	130	140	155	165	175
8	85	105	120	135	150	160	175	185
10	85	105	125	140	155	170	185	195
12	90	110	130	145	160	175	190	200
14	90	110	130	150	165	180	190	205
16	90	115	135	150	165	180	195	210
18	95	115	135	155	170	185	200	215
20	95	115	140	155	175	190	205	220
22	95	120	140	160	175	190	210	225
24	95	120	140	160	180	195	210	225
26	95	120	145	160	180	195	215	230
28	100	120	145	165	180	200	215	230
30	100	125	145	165	185	200	220	235
32	100	125	145	165	185	200	220	235
34	100	125	145	165	185	205	220	240
36	100	125	150	170	185	205	225	240
38	100	125	150	170	190	205	225	240
40	100	125	150	170	190	210	225	245

COLD SERVICE PIPE INSULATION - OUTDOOR LINE

Insulation Thickness Table (mm) Boundary conditions		Calculated to prevent surface condesation	
External ambient temperature	35 °C	**Relative Humidity**	80%
Wind speed	3,6 km/h	**Dew point**	31,1 °C
Surface emissivity	0,9		

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We strongly recommend contacting a qualified insulation-design engineer for a proper thickness calculation related to any specific project.

	Pipe Service Temperature (°C)							
Nominal Pipe Size (inch)	**-40**	**-60**	**-80**	**-100**	**-120**	**-140**	**-160**	**-180**
1/2	30	35	40	45	50	55	60	60
1	35	40	45	50	55	60	65	70
1 1/2	35	40	50	55	60	65	70	75
2	35	45	50	55	65	70	75	80
2 1/2	40	45	55	60	65	70	75	80
3	40	45	55	60	70	75	80	85
4	40	50	60	65	70	75	85	90
6	45	50	60	70	75	85	90	95
8	45	55	65	70	80	85	95	100
10	45	55	65	75	80	90	95	105
12	45	55	65	75	85	90	100	105
14	45	55	70	75	85	95	100	110
16	45	60	70	80	85	95	105	110
18	45	60	70	80	90	95	105	110
20	45	60	70	80	90	95	105	115
22	45	60	70	80	90	100	105	115
24	50	60	70	80	90	100	110	115
26	50	60	70	80	90	100	110	115
28	50	60	70	80	90	100	110	120
30	50	60	70	80	90	100	110	120
32	50	60	75	85	90	100	110	120
34	50	60	75	85	95	100	110	120
36	50	60	75	85	95	105	110	120
38	50	60	75	85	95	105	115	120
40	50	60	75	85	95	105	115	120

COLD SERVICE PIPE INSULATION - INDOOR LINE

Insulation Thickness Table (mm) Boundary conditions	Calculated for a 15 W/m² maximum heat loss		
External ambient temperature	25 °C	**Relative Humidity**	80%
Wind speed	0 km/h	**Dew point**	21,3 °C
Surface emissivity	0,9		

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We strongly recommend contacting a qualified insulation-design engineer for a proper thickness calculation related to any specific project.

	Pipe Service Temperature (°C)							
Nominal Pipe Size (inch)	**-40**	**-60**	**-80**	**-100**	**-120**	**-140**	**-160**	**-180**
1/2	35	40	50	55	60	65	70	75
1	35	45	55	60	65	75	80	85
1 1/2	40	50	60	65	70	80	85	90
2	40	50	60	70	75	85	90	95
2 1/2	45	55	65	70	80	85	95	100
3	45	55	65	75	80	90	95	105
4	45	60	70	80	85	95	100	110
6	50	60	75	85	95	100	110	120
8	50	65	75	85	95	105	115	125
10	50	65	80	90	100	110	120	130
12	55	70	80	90	105	115	125	135
14	55	70	80	95	105	115	125	135
16	55	70	85	95	105	120	130	140
18	55	70	85	95	110	120	130	140
20	55	70	85	100	110	120	130	145
22	55	70	85	100	110	125	135	145
24	55	70	85	100	110	125	135	145
26	55	75	85	100	115	125	135	150
28	55	75	90	100	115	125	140	150
30	55	75	90	100	115	125	140	150
32	55	75	90	100	115	130	140	150
34	55	75	90	105	115	130	140	155
36	55	75	90	105	115	130	140	155
38	55	75	90	105	115	130	145	155
40	60	75	90	105	115	130	145	155

GENERAL GUIDELINES:

The following table shows how variations in boundary conditions influence the insulation thickness required:

Increase in...	Influence on insulation thickness
Surface emissivity	strong reduction
Relative Humidity	strong increase
External Ambient Temperature	moderate increase
Wind speed	moderate reduction

COMMON STANDARDS OF REFERENCE

The following standards have been used to characterize our materials:

ASTM D 1622	Standard Test Method for Apparent Density of Rigid Cellular Plastics
ASTM D 1621	Standard Test Method for Compressive Properties of Rigid Cellular Plastics
ASTM D 1623	Standard Test Method for Tensile and Tensile Adhesion Properties of Rigid Cellular Plastics
ASTM C 203	Standard Test Methods for Breaking Load and Flexural Properties of Block-Type Thermal Insulation
ASTM D 6226	Standard Test Method for Open Cell Content of Rigid Cellular Plastics
ASTM C 518	Standard Test Method for Steady-State Thermal Transmission Properties by means of Heat Flow Meter Apparatus
ASTM C 272	Standard Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions
ASTM E 96	Standard Test Methods for Water Vapour Transmission of Materials
ASTM E 84	Standard Test Method for Surface Burning Characteristics of Building Materials
ISO 845	Cellular plastics and rubbers -- Determination of apparent density
ISO 844	Rigid cellular plastics -- Determination of compression properties
ASTM C 273	Standard Test Method for Shear Properties of Sandwich Core Materials
ASTM D 2842	Standard Test Method for Water Absorption of Rigid Cellular Plastics
ISO 2796	Cellular Plastics, rigid -- Test for Dimensional Stability
DIN 4102	Fire Behaviour of Building Materials and Building Components
ASTM D 3014	Standard Test Method for Flame Height, Time of Burning, and Loss of Mass of Rigid Thermoset Cellular Plastics in a Vertical Position
BS 4735	Laboratory Method of Test for Assessment of the Horizontal Burning Characteristics of Specimens no larger than 150 mm x 50 mm x 13 mm (nominal) of Cellular Plastics and Cellular Rubber Materials when subjected to a Small Flame
ISO 3582	Flexible Cellular Polymeric Materials -- Laboratory Assessment of Horizontal Burning Characteristics of Small Specimens subjected to a Small Flame

SUGGESTIONS AND GUIDELINES FOR ALL APPLICATIONS

Polyurethane rigid foams can be used in a wide range of temperatures; nevertheless, it is important to note that insulation requirements might differ according to working temperature, and therefore the information reported here is only indicative. It is essential to consult a design or specific engineer in order to get the correct application requirements for your own needs.

Before starting installation, all welding work must be completed, and surfaces must be cleaned of dust, oil, grease, loose particles and moisture, and be frost-free. It is advisable to have all sensitive parts primer-painted in order to prevent corrosion.

Properly installing and maintaining insulation is of the utmost importance, so that it functions in the way in which it was originally engineered. It is essential to go back to basics and answer the question, "What is the purpose of the insulation on the pipes and/or equipment?"

- Condensation control (for lines whose operating temperatures are below ambient)
- Energy efficiency
- Freeze protection
- Personnel protection
- Process control and efficiency

In the table below, thermal conductivity at 50°C is given for a number of pipe-insulation materials, along with the relative insulation thickness at an equal heat loss; Polyurethane foam is clearly the most effective material.

Insulating Material	Density (kg/m3)	Thermal conductivity 50°C (mW/mK)	Relative insulation thickness at equal heat loss
Rigid polyurethane foam	70	27-30	1
Mineral wool pipe scales	200	45	1.7
Foamed glass	125	52	1.9
LEBIT (bitumen/cork mixture)	880	105	3.9
Foamed concrete	400	160	5.9

INSTALLATION PRACTICE

Pipes

Small pipes are insulated with cylindrical half sections of insulation fitted with factory-applied jackets that form a hinge and lap. Large pipes may be insulated with curved segments. Fittings and valves are insulated with preformed fitting insulation or individual pieces cut from sectional straight pipe insulation or by casting insulation on site.

- Method of securing

Insulation with certain types of factory applied jacketing may be secured on small pipes by cementing the overlapping jacket. On large pipes, supplementary wiring or banding may be required. Insulation on large pipes requiring separate jacketing is wired or banded in place and the jacket is cemented, wired or banded, depending on type. Insulation with factory-applied metal jacketing is secured by specific design of the jacket and its joint closure.

- Finish

Jacketing may range from asphalt-saturated, or saturated and coated, organic paper, laminates of such papers and plastic films or aluminium foil, or medium-gauge aluminium or stainless steel. Fittings may be finished with asphalt- or resin-base mastics, preformed aluminium covers, or as part of specific factory-designed, combined insulation and jacketing systems.

For pipes at temperatures below ambient, the insulation surface must be sealed to prevent entry of water. The pipes should be protected against corrosion.

There are a variety of systems for carrying out vapour sealing, some designed by manufacturers for their products, and others by applicators and users. Vapour-seal treatment should be as recommended by the insulation manufacturer.

Double layer construction. For best results, pipe insulation should be applied in staggered double layer construction. This construction prevents excessive heat loss and surface temperatures at the joints, when opened by pipe expansion.

- Double-layer

Staggered-joint construction also minimizes thermal stresses in the insulation by reducing the temperature differential across each layer.

Tanks, Vessels and Equipment

Flat, curved and irregular surfaces such as tanks, vessels, boilers and breechings are normally insulated with flat blocks or bevelled lags, curved segments, blanket forms of insulation, or sprayed mineral fibre-inorganic binder insulations. Since no general procedure can apply to all materials and conditions, it is important that the manufacturer's specifications and instructions are followed for specific insulation applications.

- Method of securing.

On small-diameter cylindrical vessels, the insulation may be secured by banding around the circumference. On larger cylindrical vessels, banding may be supplemented by angle-iron brackets to support the insulation against slippage. On large flat and cylindrical surfaces, banding or wiring securing may be supplemented by fastening at frequent intervals to various types of welded studs.

- Finish.

For temperatures above ambient, insulation of suitable type and thickness is finished as required to provide protection against mechanical damage and weather, consistent with acceptable appearance. On smaller equipment indoors, insulation is commonly finished by covering with hexagonal wire mesh tightly stretched and secured, and applying over this a base and hard-finish coat of cement. This may be additionally finished by painting.

For the same equipment outdoors, insulation may be finished with a coat of hard-finish cement, properly secured hexagonal mesh and a coat of weather-resistant mastic (preferably a breathing type). Larger equipment may be finished, both indoors and out, with suitable sheet metal.

For temperatures below ambient, insulation of suitable type and thickness is finished as required to prevent condensation, as well as provide protection against mechanical and weather damage, consistent with an acceptable appearance. The finish is required to provide a degree of vapour sealing in accordance with the operating temperature, to avoid the entry of moisture from the surrounding air. For moderately low temperatures, the insulation may be finished with properly secured hexagonal mesh, a coat of hard-finish cement, and several coats of suitable paint.

For the same equipment outdoors, the insulation may be finished with heavier or additional coats of vapour-seal mastic reinforced with open-mesh glass fabric to provide adequate protection against mechanical and weather damage.

MATERIALS TRANSPORT AND STORAGE

GENERAL

PACKAGING: Insulation materials of any kind shall be delivered to the project-site in the original, unbroken manufacturer's packaging. The packaging shall be such as to prevent the materials being damaged in normal transport conditions and warehouse handling operations. The original labels affixed to the packaging shall quote information regarding the origin (manufacturer), material, type, production date, dimensions and quantity.

- **SHIPPING**: The shipping of materials from the manufacturer to the work-site shall take place in weather-tight transportation. Once delivered to the work-site, the insulation materials shall be stored so as to be protected from moisture and weather during storage and installation. They shall be additionally protected from sunlight in order to avoid exposure to UV rays.
- **STORAGE**: Prolonged storage at the work-site is discouraged. A waterproof layer which prevents the formation of condensation on its inside surface shall completely cover the insulation materials (top and sides). Moreover, insulation materials must be kept raised off the ground, away from floor or walls.

CORAFOAM®

CORAFOAM® in general and CORAFOAM® RV

- Handling: This product is combustible and may constitute a fire hazard if improperly used or installed. When installed this product should be adequately protected. Certain operations such as grinding or cutting may generate dust, which could cause a dust explosion. Provide adequate local ventilation and appropriate dust handling systems. The whole dust collecting system must be protected from electrostatic energy accumulation, and adequate firefighting facilities must be provided.
- Storage: When exposed to intense sunlight over prolonged periods, the surface of the boards degrades into fine dust. Do not expose to flame or other ignition sources.

DUNAPOL™ C, S and AD

Handling: Work in a ventilated place with safety glasses and rubber gloves.

- Storage: In a ventilated place at a temperature lower than 30°C in sealed drums or containers. In high temperatures, the blowing agent may boil off and generate pressure.
- Chemical incompatibility: Keep separate from foods.
- Handling precautions: Avoid contact and inhalation of the vapours. Give adequate ventilation to the premises where the product is stored and/or handled. Do not eat or drink while working. Do not smoke while working.
- Storage conditions: Store in well-sealed packages and at 15-30°C.
- Instructions regarding storage premises: Adequately ventilated premises.

DUNAPOL™ S

- Handling: Work in a ventilated place with safety glasses and rubber gloves.
- Storage: In a ventilated place at a temperature lower than 30 °C in sealed drums or containers. In high temperatures, the blowing agent may boil off and generate pressure.
- Chemical incompatibility: Keep separate from foods.
- Handling precautions: Avoid contact and inhalation of the vapours. Give adequate ventilation to the premises where the product is stored and/or handled. Do not eat or drink while working. Do not smoke while working.
- Storage conditions: Store in well-sealed packages and at 15-30°C.
- Instructions regarding storage premises: Adequately ventilated premises.

DUNAPOL™ AD

- Handling precautions: Avoid contact and inhalation of the vapours. Give adequate ventilation to the premises where the product is stored and/or handled. Do not eat or drink while working. Do not smoke while working.
- Storage conditions: Store in well sealed packages and at 15-30°C
- Instructions regarding storage premises: Adequately ventilated premises.

DUNAPOL™ AD 1576 POL SS

- Handling: Work in a ventilated place with safety glasses and rubber gloves.
- Storage: In a ventilated place at a temperature lower than 30 °C in sealed drums or containers. In high temperatures, the blowing agent may boil off and generate pressure.
- Chemical incompatibility: Keep separate from foods.

EXAMPLES

OF INSULATING SOLUTIONS WITH

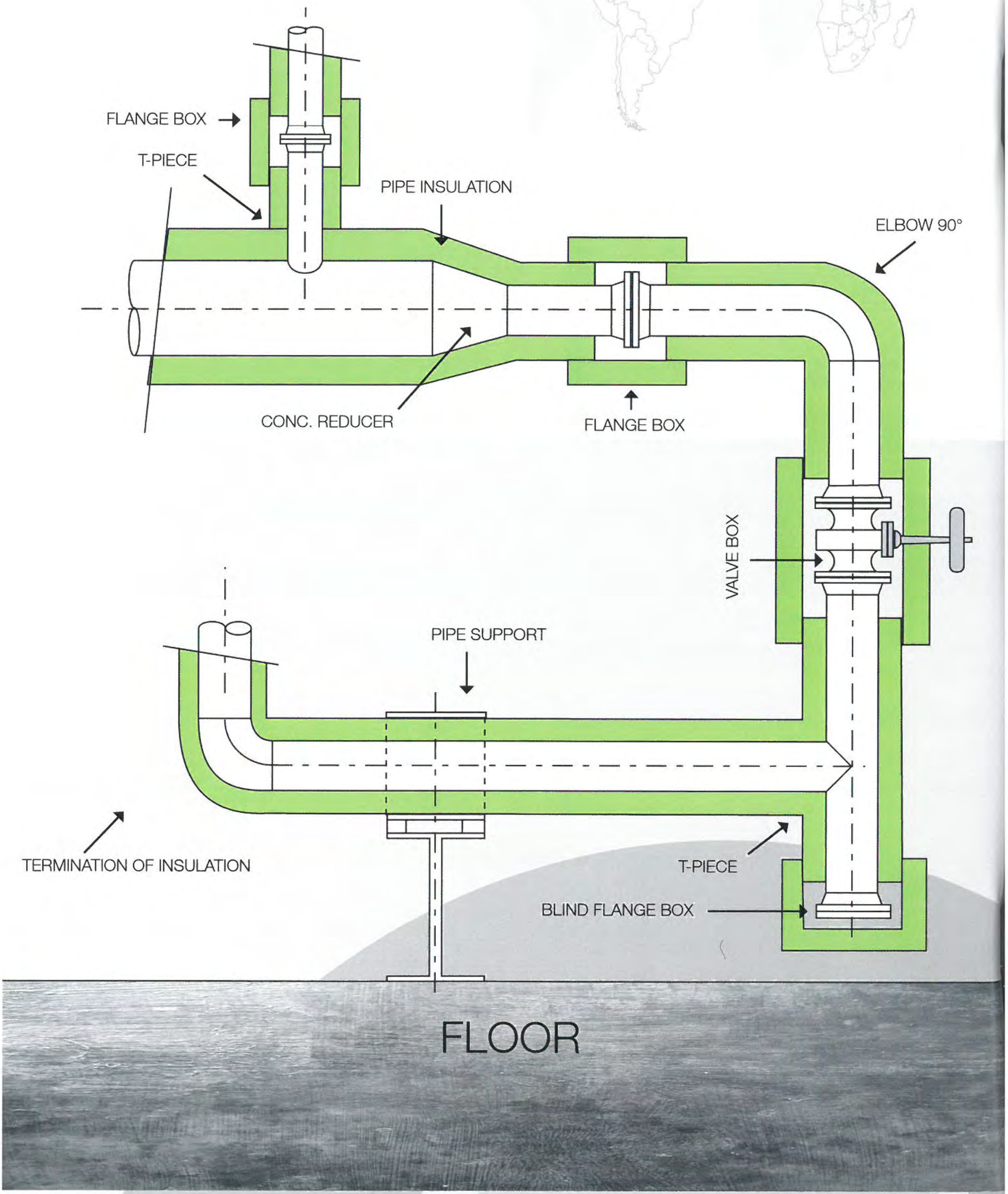
DUNA-Corradini

PRODUCTS

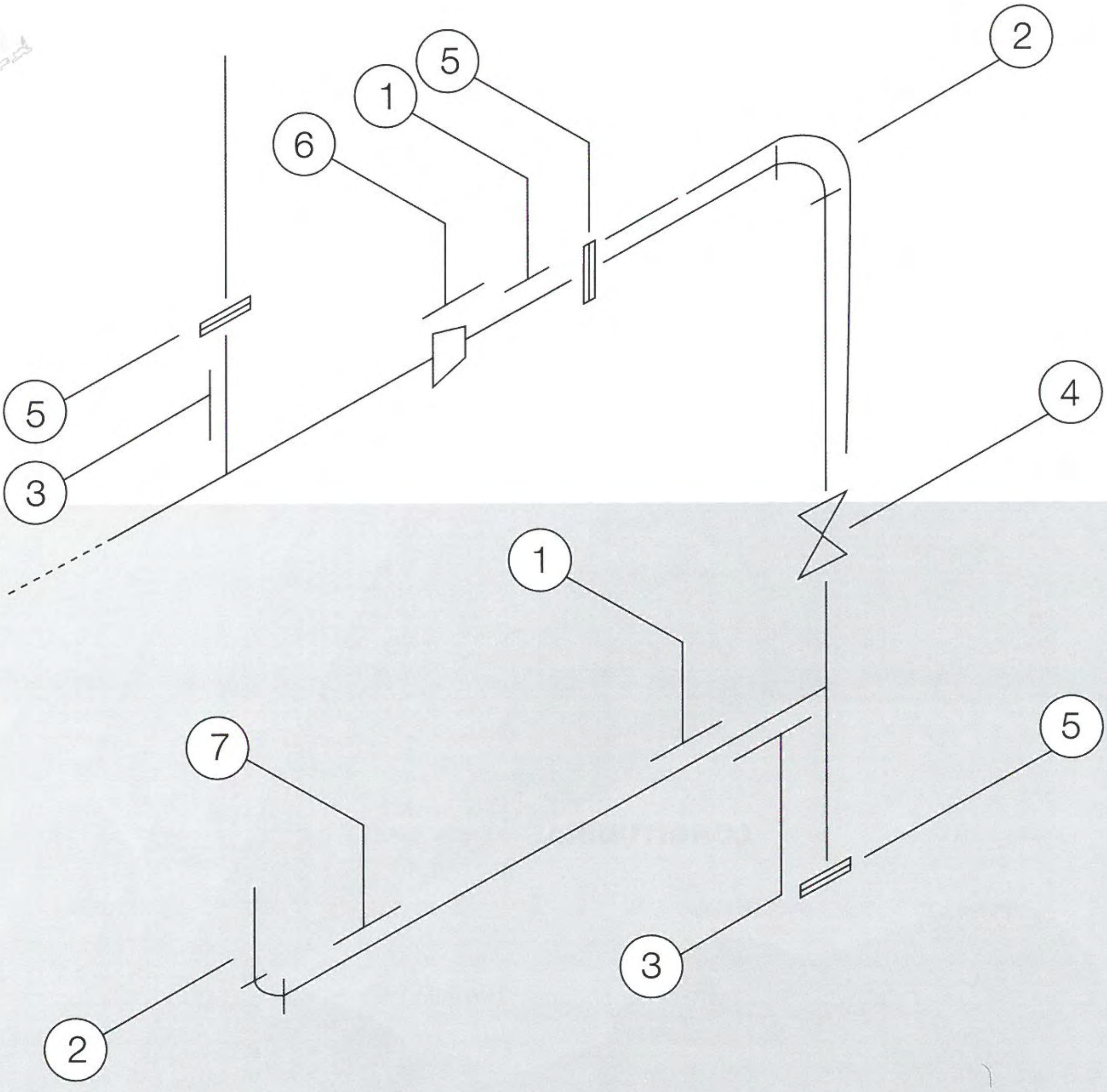
- PIPE INSULATION DETAILS OVERVIEW
- ISOMETRIC DIAGRAM
- STRAIGHT PIPES
- ELBOWS
- VALVES
- FLANGES
- REDUCERS
    - Concentric
    - Eccentric
- SUPPORTS

EXAMPLES OF INSULATING SOLUTIONS WITH DUNA-CORRADINI PRODUCTS

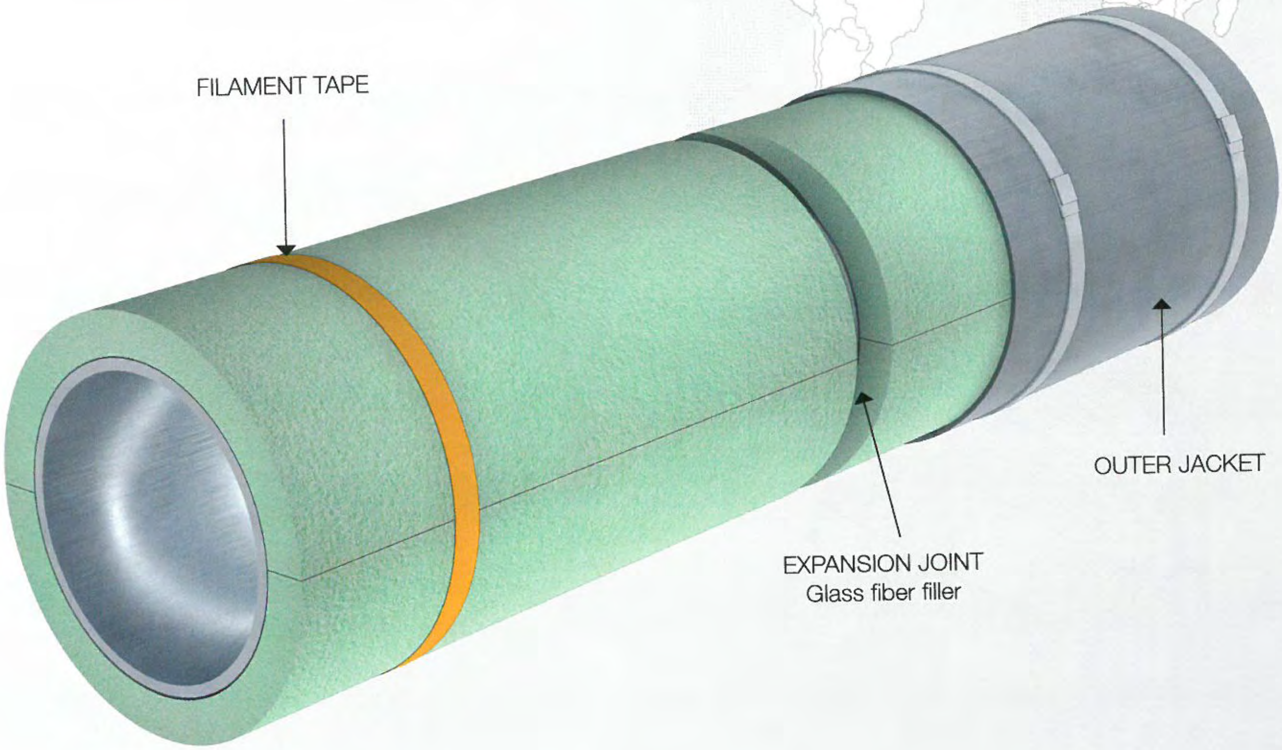
OVERVIEW PIPING INSULATION DETAILS



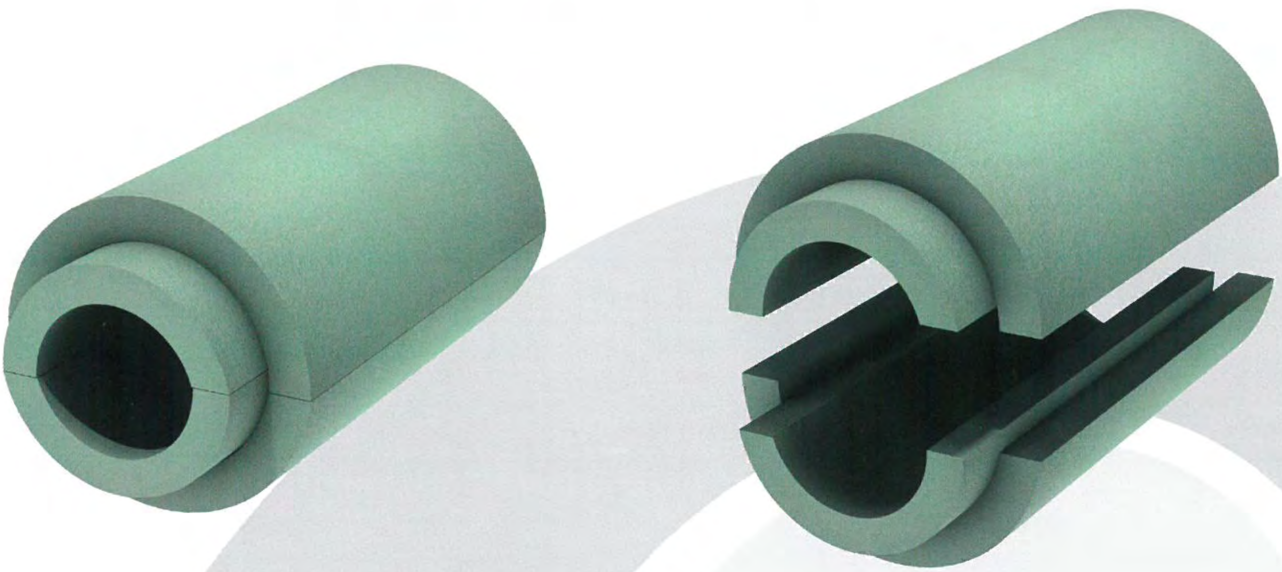
ISOMETRIC DIAGRAM



1 STRAIGHT PIPES

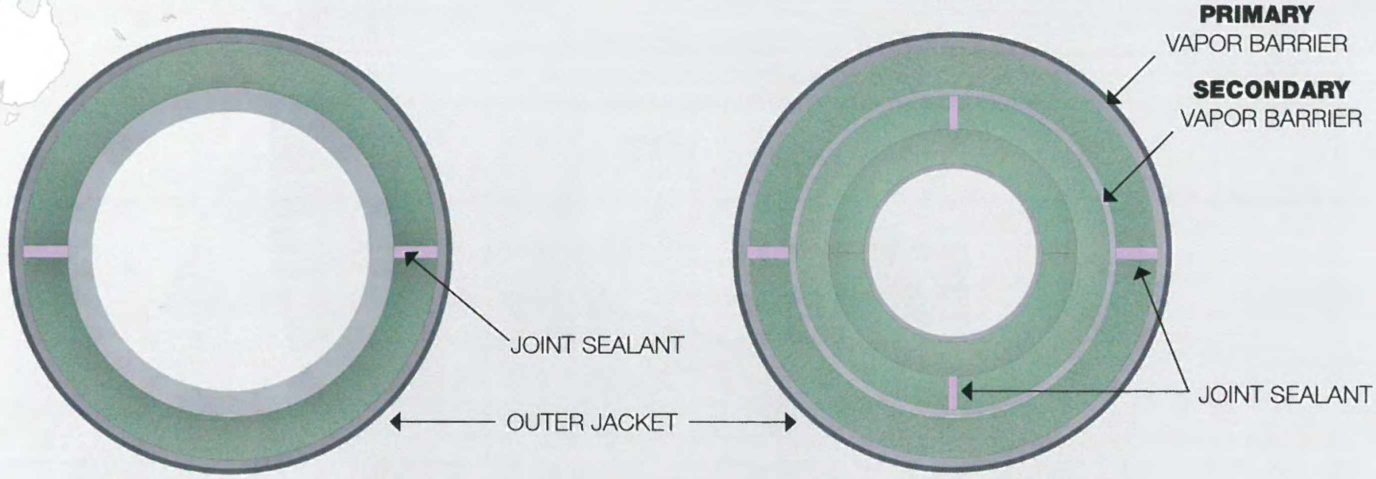


SHIP - LAPPED PIPE
LONGITUDINAL + **CIRCUMFERENTIAL**



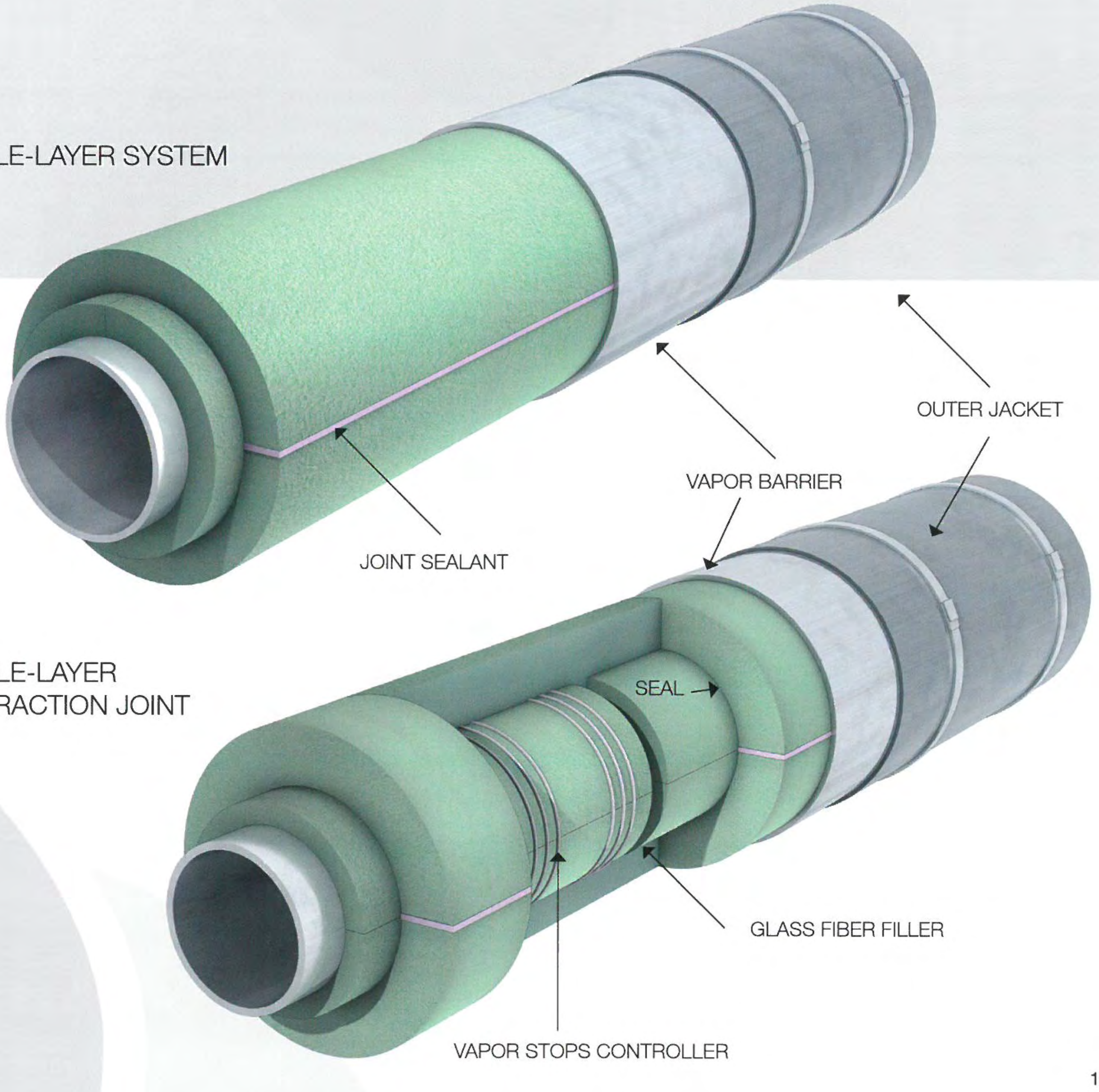
CROSS SECTION
SINGLE LAYER

CROSS SECTION
3-LAYERS



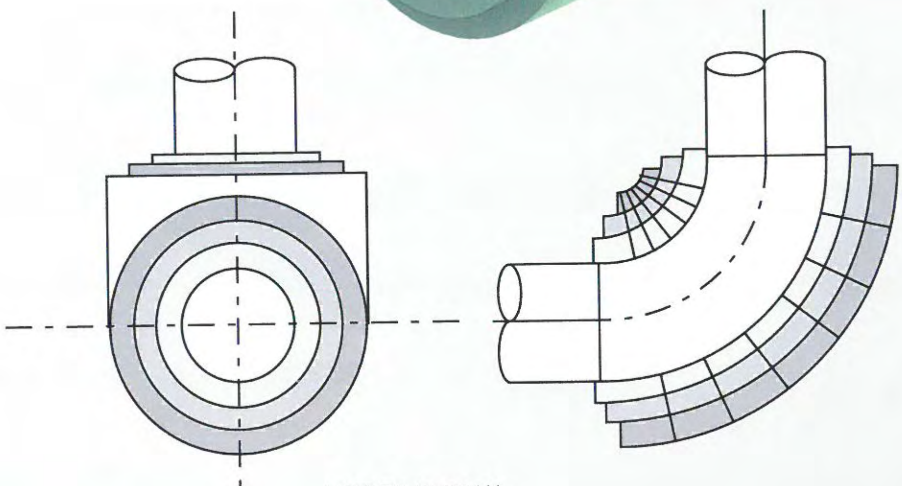
DOUBLE-LAYER SYSTEM

DOUBLE-LAYER
CONTRACTION JOINT

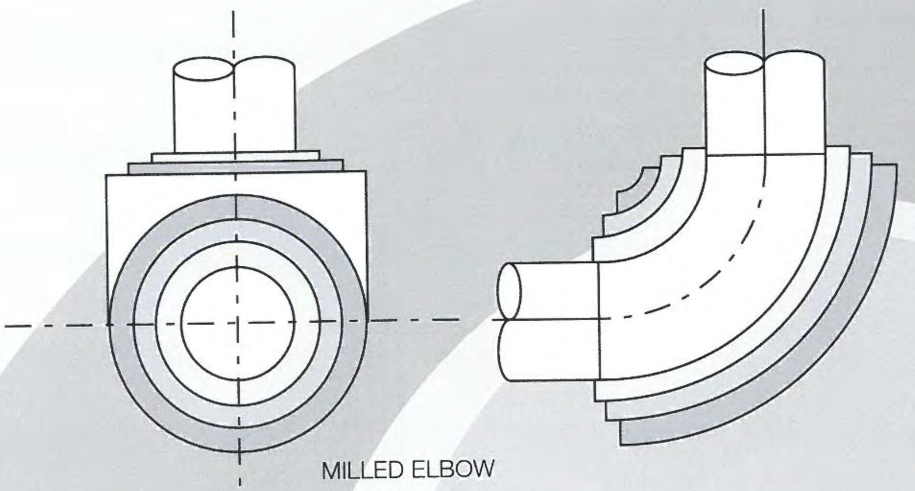


2 ELBOWS

SHIP - LAPPED ELBOW

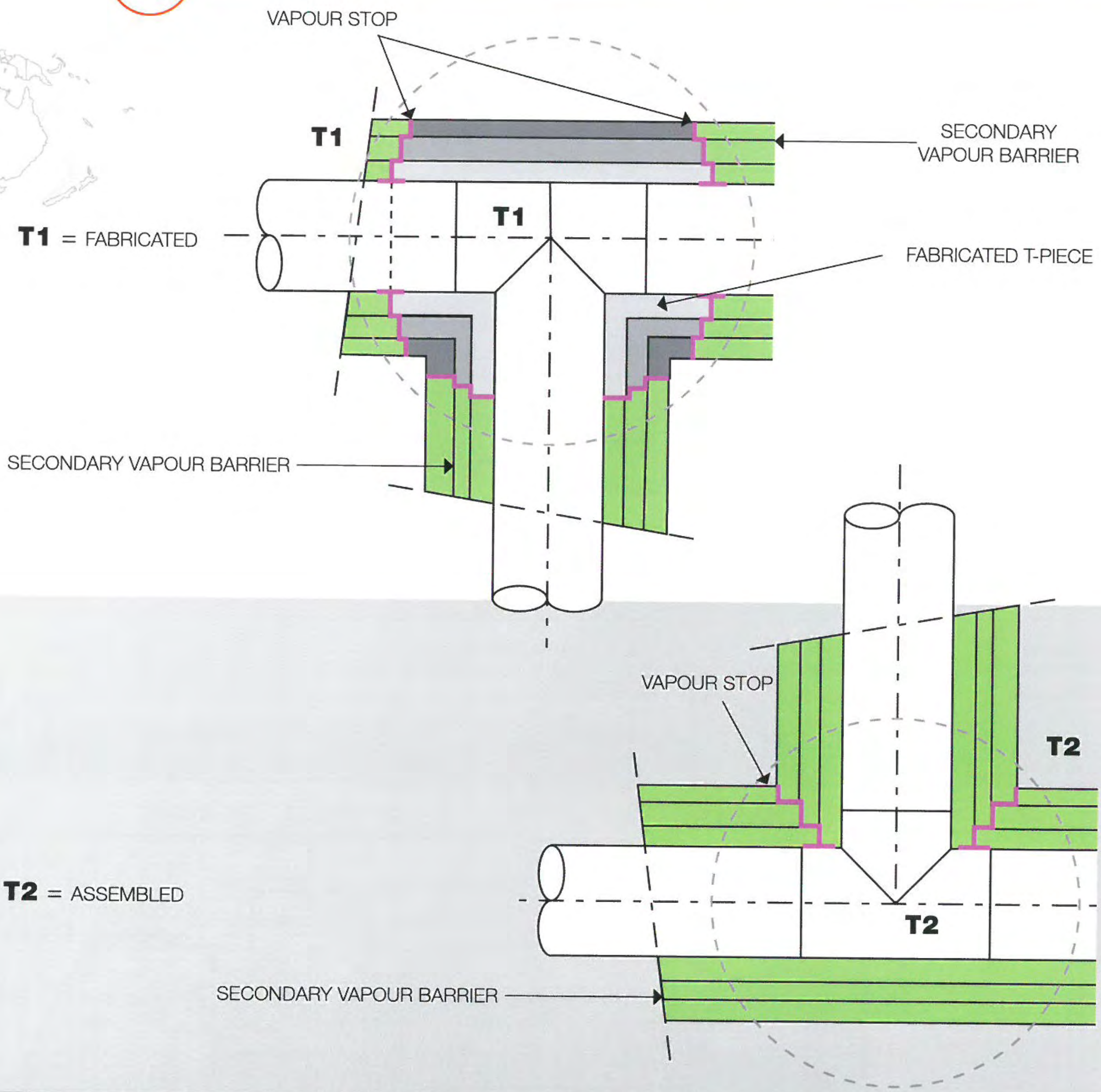


MITRED ELBOW

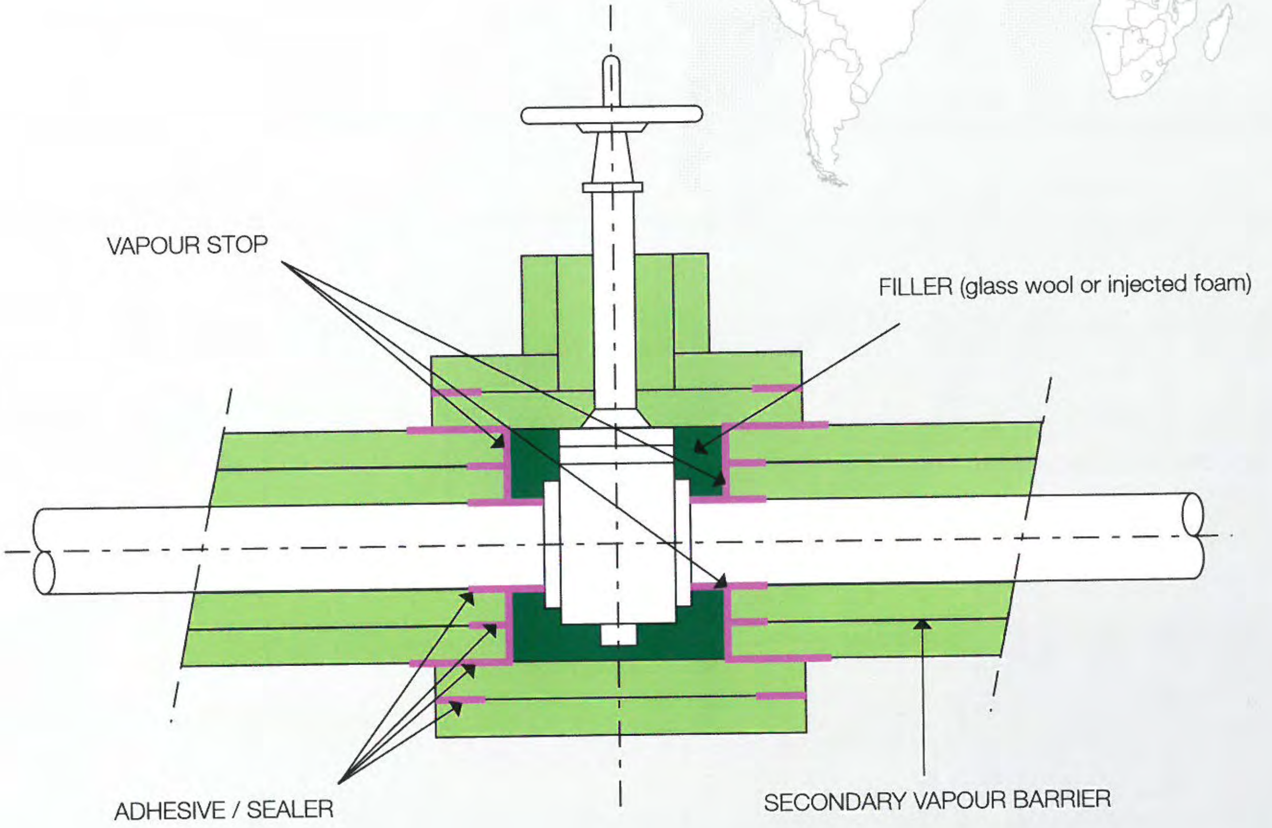


MILLED ELBOW

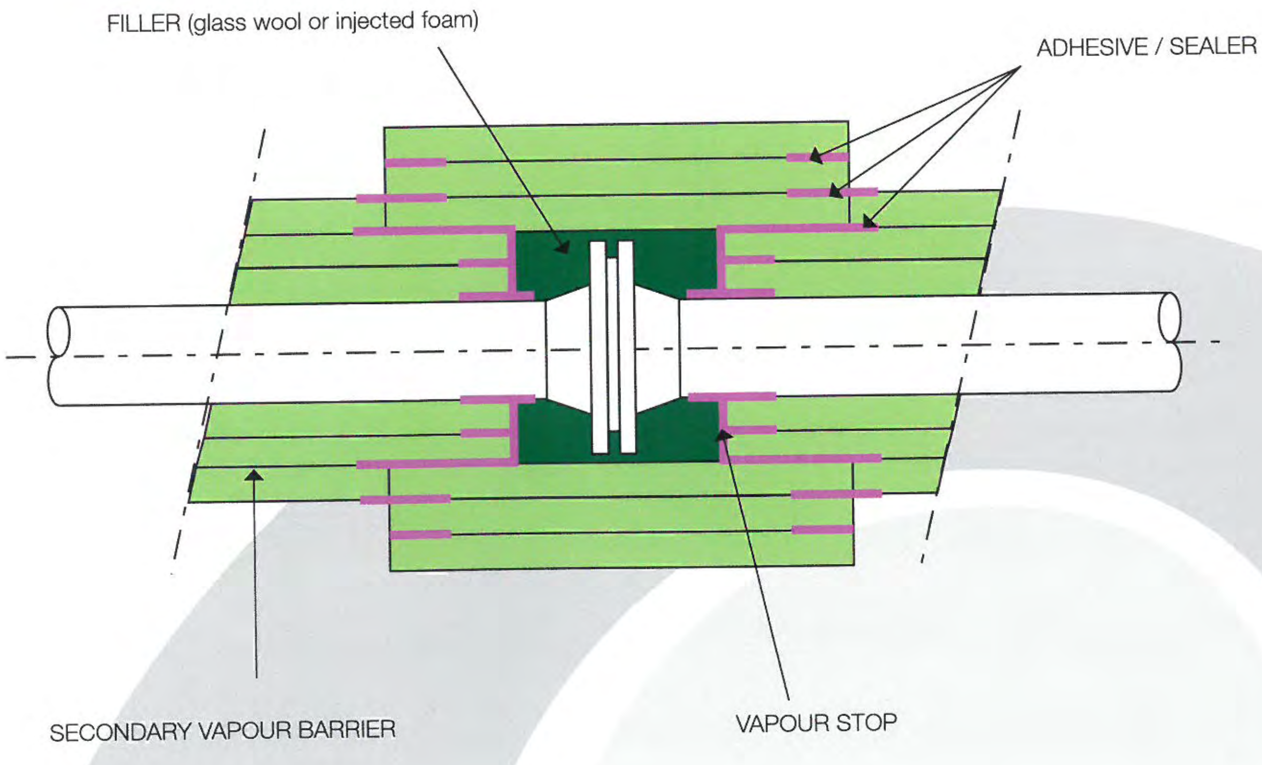
3 TEES


VAPOUR STOP
T1
SECONDARY
VAPOUR BARRIER
T1 = FABRICATED
T1
FABRICATED T-PIECE
SECONDARY VAPOUR BARRIER
VAPOUR STOP
T2
T2 = ASSEMBLED
T2
SECONDARY VAPOUR BARRIER

4 VALVES

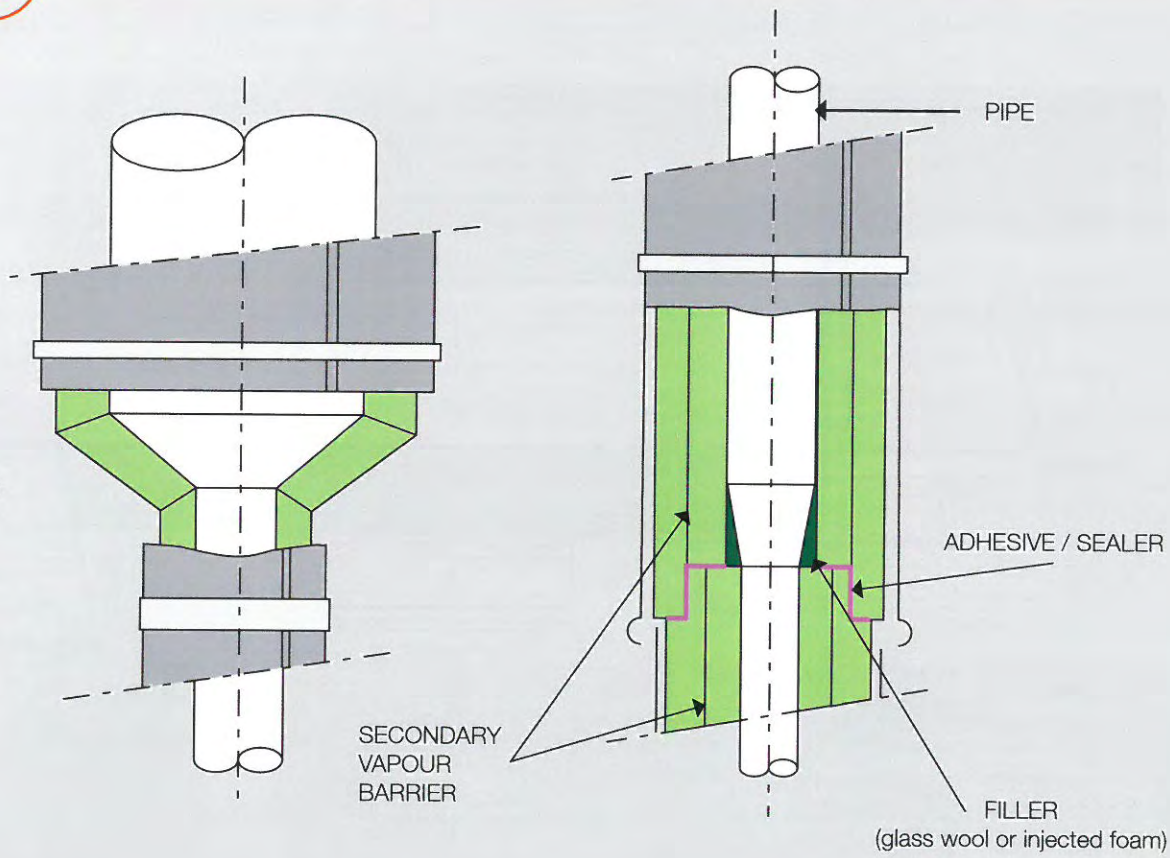


5 FLANGES



6 REDUCERS

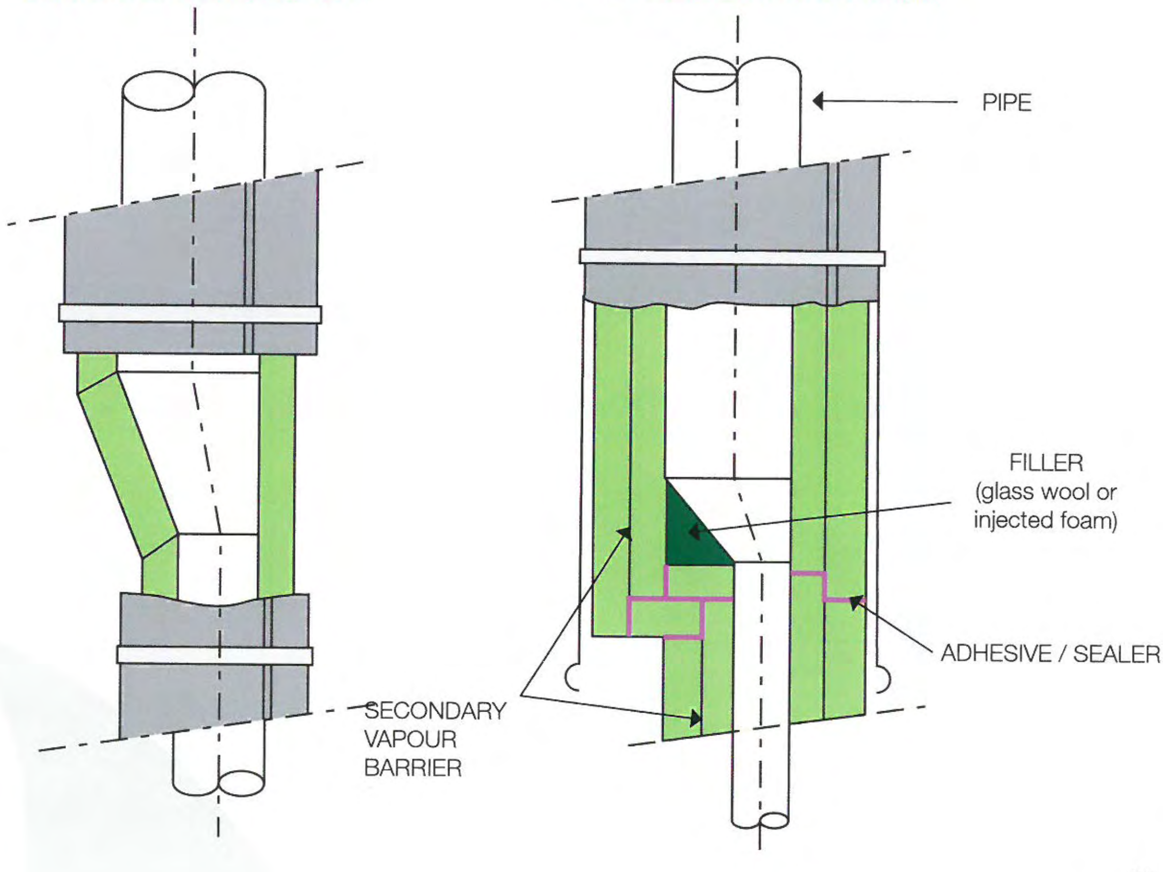
- Concentric



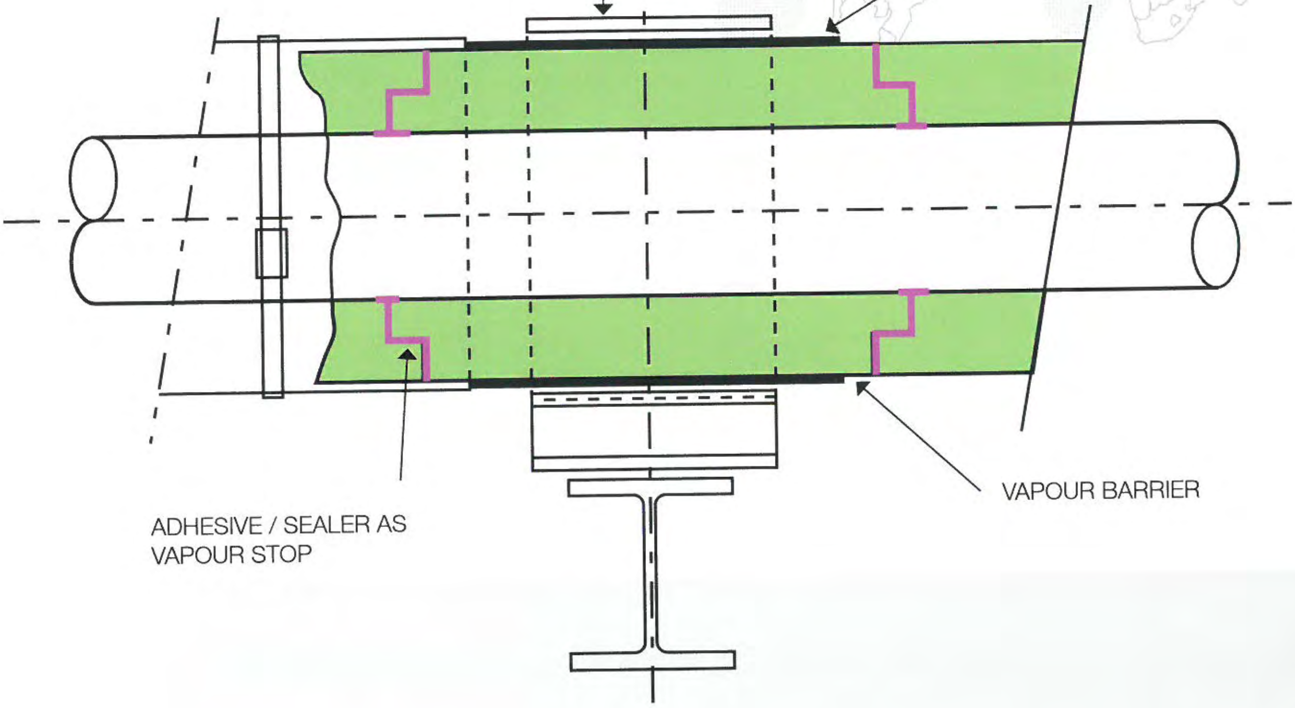
SINGLE LAYER SYSTEM

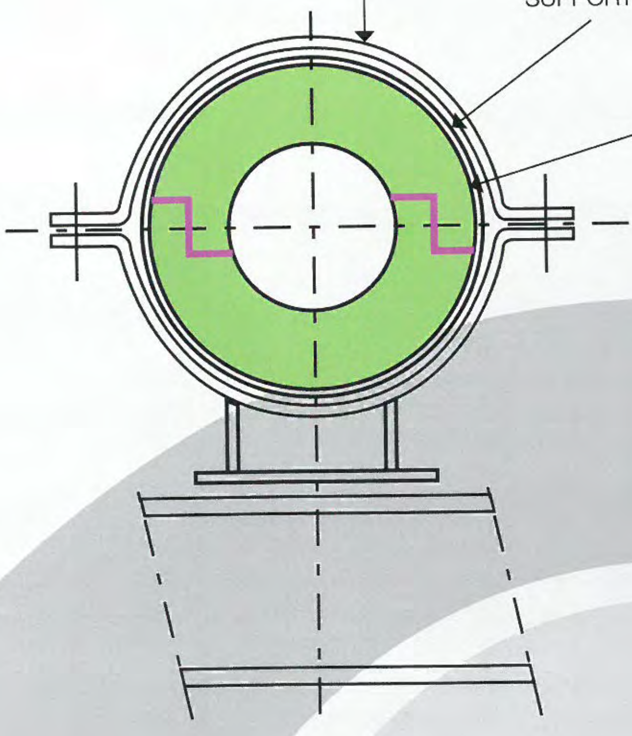
DOUBLE LAYER SYSTEM

- Eccentric



7 INSULATED PIPE SUPPORTS





TECHNICAL CHARACTERISTICS

CORAFOAM®

	Density	Blowing Agent	Compression strength	Initial thermal conductivity at 10 °C	Closed cells content	Fire properties		Operating temperatures
Unit	kg/m3		kPa	mW/mK	%min			°C
Standard	ISO 845		ASTM D 1621	ASTM C 518	ASTM D 6226			
GP 35	35	Pentane	250	22,8	92	BS4735/ ISO3582 DIN 4102	mm/s <60/90 Class B3	-60/+100
GP 40	40	Pentane	340	22,6	92	BS4735/ ISO3582 DIN 4102	mm/s <60/90 Class B3	-165/+100
GP 50	50	Pentane	460	22,6	92	BS4735/ ISO3582 DIN 4102	mm/s<60/90 Class B3	-165/+100
JP 50	50	CO_2	460	24,0	92	BS4735/ ISO3582	mm/s<60/120	-170/+100
RP 50	50	Pentane	400	21,0	92	DIN4102	Class B2	-180/+120
PB 35 M1 HC	35	CFC and HCFC free	260	20,5	92	DIN4102 NF 92 501 ASTM E 84 ASTM D 3014 BS 4735/ ISO3582	Class B2 Class M1 F.S.I. 25 % retention > 90 mm <10	-190/+120
PB 40 M1 HC	42	CFC and HCFC free	320	19,1	92	DIN4102 NF 92 501 ASTM E 84 ASTM D 3014 BS 4735/ ISO3582	Class B2 Class M1 F.S.I. 25 % retention > 90 mm <10	-190/+120
PB 45 M1 HC	>45	CFC and HCFC free	400	19,0	95	DIN4102 NF 92 501 ASTM E 84 ASTM D 3014 BS 4735/ ISO3582	Class B2 Class M1 F.S.I. 25 % retention > 90 mm <10	-190/+120
PB 50 M1 HC	50	CFC and HCFC free	420	19,0	92	DIN4102 NF 92 501 ASTM E 84 ASTM D 3014 BS 4735/ ISO3582	Class B2 Class M1 F.S.I. 25 % retention > 90 mm <10	-190/+120
RTS 60	63	CO_2	670	25,0	92	BS 4735/ ISO3582 DIN 4102	mm/s <30 Class B2	-180/+120
RTS 80	83	CO_2	970	26,0	92	BS 4735/ ISO3582 DIN 4102	mm/s <30 class B2	-180/+120
RTS 120	120	CO_2	1.700	28,0	92	BS 4735/ ISO3582 DIN 4102	mm/s <30 Class B2	-180/+120
RTS 160	163	CO_2	2.600	31,0	92	BS 4735/ ISO3582 DIN 4102	mm/s <30 Class B2	-180/+120
MD 250	250	CO_2	4.200	43,0	92	DIN 4102	Class B2	-180/+80
MD 320	320	CO_2	7.030	54,0	92	DIN 4102	Class B2	-180/+80
MD 490	490	CO_2	16.500	70,0	92	DIN 4102	Class B2	-180/+80
RV 80	80	CO_2	700	26,6	92	DIN 4102	Class B3	-170/+100
RV 130	130	CO_2	1.500	29,2	94	DIN 4102	Class B3	-170/+100

TECHNICAL CHARACTERISTICS

DUNAPOL™ C

	U.M.	STANDARD	DUNAPOL™ C 452	DUNAPOL™ C 453	DUNAPOL™ C 472
Blowing agents			HFC	HFC	CO2
Mixing Ratio by weigth		Pol	100	100	100
		Iso	100	100	100
Mix Time	s		25	15	20
Cream Time	s		35	22	22
Gel Time	s		140	140	135
Free Rise density	kg/m³	ASTM D 1622	50	48	47
Applied density	kg/m³	ASTM D 1622	50	48	58
Compression strength	kg/cm²	ASTM D 1621	4	3,8	4,1
Closed cells content	%	ASTM D 6226	98	98	98
Initial thermal conductivity	W/mK	ASTM C518	0,024	0,026	0,026
Fire reaction			DIN 4102 Class B2	DIN 4102 Class B2	DIN 4102 Class B2
			BS4735/ISO 3582 mm/s 60/120	BS4735/ISO 3582 mm/s 60/120	BS4735/ISO 3582 mm/s 60/120

DUNAPOL™ S

	U.M.	STANDARD	DUNAPOL™ S 236 E	DUNAPOL™ S 235 E	DUNAPOL™ S 236 H
Blowing agents			HFC CO_2	HFC CO_2	CO_2
Mixing Ratio by weigth		Polyol	100	100	100
		Isocyanate	117	107	115
Mix Time	s		6	10	8
Cream Time	s		8	12	11
Gel Time	s		14	23	20
Free Rise density	kg/m3	ASTM D 1622	37	35	36,5
Applied density	kg/m3	ASTM D 1622	54	55	58
Compression strength	kg/cm2	ASTM D 1621	3,5	3,3	3,0
Closed cells content	%	ASTM D 6226	98	96	97
Initial thermal conduc-tivity	W/m°K	ASTM C518	0,0235	0,024	0,0265
Fire reaction		DIN 4102	Class B3	Class B2	Class B3

DUNAPOL™ AD

	Test conditions		Unit of measure	DUNAPOL™ AD 1566	DUNAPOL™ AD 1576	DUNAPOL™ AD 1586
Viscosity	20°C	ASTM D 2393	mPa s	5.500-7.500	thixotropic	thixotropic
Distribution time	20°C	100 ml	h min' sec"	15'-20'	50'-1h10'	50'-1h
Gel time	20°C	thickness 0,2 mm	h min' sec"	1h	3h	1h35'-1h45'
Initial hardening	20°C	---	h min' sec"	6h-8h	8h-10h	8h-10h
Complete hardening	20°C	---	days	10-15	8-10	10-12
Yield	20°C	---	g/m^2	150-350	150-350	150-350
Density	20°C	ASTM D 792	g/cm^3	1,39-1,44	1,35-1,37	1,41-1,42
Hardness	20°C	ASTM D 2240	SHORE A/15	91-93	90-92	---
Glass transition		DSC	°C	5-7	13-15	9-11
Water absorption	1h at 100°C	ASTM D 570	%	+0,4-0,6	+0,4-0,6	+0,4-0,6
	24h at 20°C	ASTM D 570	%	+0,15-0,25	+0,15-0,20	+0,15-0,20
Tensile strength	20°C	ASTM D 638	kg/cm^2	30-40	25-35	---
Elongation	20°C	ASTM D 638	%	65-75	75-85	---
Compression strength	20°C	ASTM D 695	kg/cm^2	600-650	600-650	---
Adhesion	Aluminium-aluminium 20°C	ASTM D 1002	kg/cm^2	95-100	98-105	---
	Steel-steel 20°C	ASTM D 1002	kg/cm^2	80-90	85-95	---
Fire reaction	Adhesive applied to polyurethane foam classed B3 ds.40 kg/m^3	ISO3582 (ASTM D 1692)	mm	10	15	---
	Adhesive applied to polyurethane foam classed B2 ds.40 kg/m^3	DIN 4102	mm	65 (class B2)	45(class B2)	---
Operating temperatures	---	---	°C	+80/-165	+80/-165	---

I N N O V A T I O N P R O V I D E R S

INNOVATION PROVIDERS

Chemicals for Spray insulation, injection and pouring

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DUNA-Corradini
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