Polyurethanes & Polyisocyanurates for cryogenic applications

Installation Guidelines

DUNA-USA
FOAM & CHEMICALS

DUNA-USA's rigid foams CORAFOAM® can be applied in a wide range of temperatures (-300°F/+200°F), however, it is important to remark that insulation requirements might differ according to working temperature, and hence the information here reported is only indicative to an unspecific installation help guide.

AIM

This installation guide is intended to suggest materials and installation practices for PIR manufactured by DUNA USA in the following applications:

- Tank Insulation
- Piping Insulation
- Mechanical Insulation
- Duct Insulation

Suggestions and guidelines for PIR applications

Properly set up insulation and its maintenance is of extreme importance, so that the insulated system works with the efficiency for which it was designed at the beginning. It is crucial to identify which is the aim of the insulation requested by the system. We indicate here below some of the main purposes:

- Condensation control
- Energy efficiency
- Freeze protection
- Personnel protection
- Process control

This guideline handles the placement of the DUNA-Group insulation primarily on Liquefied Natural Gas (LNG) piping, tanks, vessels and equipment. In fact LNG plants, by working at very critical temperatures (-265°F) represent what is normally considered the reference for Cryogenic plants. For this reason some of the indications reported on this guideline may not be relevant for every application.
Typically, insulation works for an industrial plant project are supported by a dedicated technical specification, issued by qualified Engineering companies, to match project demands. Such document considers local conditions, work out, environment and desired function life, so it prevails on any other technical document, including this guideline.
While auxiliary products may be mentioned in this guideline, DUNA-Group suggests consulting those materials manufacturers for their proper installation and handling.

References

Product data sheets and literature are referenced throughout this guide. Guidelines and technical information are subject to revision without notice.
Visit **www.dunagroup.com/usa** for the latest version of these documents or ask our offices.

Disclaimer

This guideline is offered as a handbook for the purpose described herein. No warranty of procedures, either verbalized or involved is intended. All other express or implied warranties of merchantability or fitness for a particular purpose are denied.

GENERAL INFORMATION

Delivery / Shipping

All insulation material shall be delivered to the project site in original, unbroken factory package distinguished with product designation and thickness. The shipping package should not hold moisture in the event of accidental wet weather. Shipment of materials from the manufacturer to final user shall be shipped in a closed weather controlled cargo container. Materials on job-site shall be warehoused so as to protect the materials from moisture and weather during storage and installation. Insulation material shall be protected from sunlight to prevent UV exposure.

Surface cleaning

Before starting installation, all welding work must be terminated and dust, oil, grease, loose particles, frost and moisture must be removed from surfaces. It is better to have all critical parts primer-painted in order to avoid corrosion.

Insulation thickness

The data reported in the tables included in this guideline are for reference only, we suggest to use the 3E plus program available (at http://www.pipeinsulation.org), having in mind that project specification indications always prevail.

FABRICATION OF INSULATION

Project specification

All parts must be manufactured starting from cured bun-stocks by referenced fabricators and in accordance with ASTM C 585.

Before fabrication, store the buns indoors for at least a half day prior to the machining process. This will allow the buns to come into a stabilized state with the surrounding ambient temperatures and relieve possible internal stress that might have developed in the foam due to thermal gap. For best fabrication outcomes, it is advisable the foam buns be cut into pipe shells in length direction to maximize flatness. Cut pieces need to mature for 1 day before the application of the secondary vapor barrier (SVB). After application of SVB, fabricated pipe shells should be installed within the next 45 days avoiding long term warehousing.

DUNA suggests, when possible, to fabricate fittings, such as valves, flanges, elbows, and tees in two pieces fly cut or CNC milled, being this the most correct fabrication method. For diameters too large for fly cutting or CNC routing, then they might be fabricated in mitred sections bonded together to have them in two halves with each half made up of equal number of sections.

Sealers, glues and mastics

Glues, joint sealers and mastics, including the solvent-based ones, may be used in contact with all DUNA insulation products. Compounds that remain flexible at the working temperature of PIR foam (-300°F/+200°F) are the ones authorized by the DUNA Group.

A vapor retarder type joint sealer shall be used on insulation longitudinal joints and butt joints to avoid moisture infiltration. Ask joint sealer original manufacturers for suitable products.

Solvent or water based glues may be employed to fix the vapor barrier to the outer surface of Insulation. Refer to vapor barrier installation guidelines and consult specialized manufacturers for a list of products and installation guidelines.

Vapor barriers

Vapor barriers are requested on all the cellular structured insulation materials.

They are normally distinguished into 2 main families:

- Secondary Vapor Barriers (SVB), also known as Vapor Retarder;
- Primary Vapor Barrier (PVB)

A double layer vapor barriers is strongly suggested for LNG applications.

The SVB shall be applied directly over the last but one layer of insulation while the PVB will be applied on the outermost layer. SVB is backing up possible failures of the PVB allowing repairing activities without compromising the system safety.

The typical SVB is consisting of Polyester-Aluminium-Polyester film (PAP) which should be factory applied by the PIR fabricator. References are made to ASTM standards C 755 and C 1136 for information on choice and specification

of vapor barriers. Refer to product literature and installation guidelines from the SVB manufacturer for recommended application instructions.
The drawings included at the end of this guide are representative of details commonly used within the field, however, they are not meant to show the only recognized method of installation but to work as an example of commonly used and standard practices.
PVBs are normally applied in-situ after the installation of the insulation, directly over the outermost layer of insulation and can be of different nature, e.g. Bitumen mastics, Butyl Rubbers, etc.
It's strongly recommended to strictly follow project specification for the selection of the approved PVB and their application.

Contraction/Expansion joints

Contraction/expansion joints must be foreseen in order to mediate the movements of insulation parts following the thermal contraction-relaxation due to thermal gaps.
Their position should be regulated pondering the expected pipe movements. They should be installed in the inner insulations layers of the horizontal piping and equipments.
Typically the joints are placed at maximum intervals of 20 feet. We recommend to inquiry the project engineer to regulate the appropriate position of the contraction/expansion joints for each system.
Contraction/expansion joints should be filled with resilient mineral fibers or approved alternatives, with fibers oriented parallel to the direction of the pipe. The filler, in relax status, should be twice the length of the contraction/expansion joint to be packed to the joint length during installation. Ask the competent engineer to regulate the appropriate contraction/expansion filler material.

Jacketing materials

Jacketing materials are mainly intended to mechanically protect the insulation and shall not be considered as vapor barrier.
Typical materials for jacketing purposes are aluminum sheets and stainless steel sheets.

Aluminum Sheet

Covering shall be aluminum alloy meeting ASTM B209-10. Use white painted aluminum jacketing for all outdoor applications and consult project specification and jacketing manufacturer for suggested thicknesses.
Aluminum jacketing for all fittings, tees, elbows, valves, caps, etc. shall be sectional, factory outlined, or field-fabricated to conform tight around insulation.
Banding for jacketing shall be 0.02" thick by 1/2" wide stainless steel. No fastener able to penetrate the primary vapor barrier shall be used to fix the aluminum jacket.

Stainless Steel Sheets

The material shall be selected meeting the requirements of ASTM A 167. Use painted stainless steel jacketing for all outdoor applications and consult project specification and jacketing manufacturer for suggested thicknesses.
Stainless steel jacketing for all fittings, tees, elbows, valves, caps, etc. shall be sectional, factory outlined, or field-fabricated to conform tight around insulation.
Banding for jacketing shall be 0.02" thick by 1/2" wide stainless steel.
No fastener able to penetrate the primary vapor barrier shall be used to fix the stainless steel jacket.

TYPICAL APPLICATION FOR PIR FOAMS

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 -320 °F) up to about 300 °F, 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)

The natural gas is condensed into a liquid by cooling it to approximately –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 -155 °F), 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.

Ammonia/Fertilizer operating temp. (-49°F)

Ammonia is a compound of nitrogen and hydrogen with the formula NH_3. 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.

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 up to -158 °F depending on the ratio of the various components.

Underground Oil Ducts

Oil pipelines are made from steel or plastic tubes with inner diameter typically from 4 to 48 inches approximately. Most pipelines are buried at a typical depth of about 3 to 6 feet approximately.
The oil is kept warm enough (about 176°F) to be fluid and this allows pumps to move it at about 3 to 20 feet/s. Thanks to the great resistance to organic attacks, PU/PIR are often applied for the insulation of these underground ducts.

Piping

Cryogenic insulation works are normally divided into three main groups, soft (chilled Water), Medium (until Ethylene T = -155°F) and hard cryogenic (down to LNG T = -265°F). Depending on the temperature of the system, the insulation thickness can be specified to be obtained with single layer parts or multiple layers system.
In general piping is insulated according to the following layering system

Insulation Thickness	Layering	Joints type
Until 2"	Single Layer	Shiplap
Between 2" and 5"	Double layer	Butt joints
Above 5"	Triple layer	Butt joints

Single layer system

When a single layer is requested, it is suggested to fabricate insulation parts with shiplap or tongue and groove longitudinal joints and shiplap ends.
Insulation in a single layer system shall be fixed to the pipe with 3/4" wide fiber strengthened tape.

2-Layer system

For double layers, all longitudinal joints between the inner and outer layers must be staggered by shifting and rotating parts of the various layers in order to avoid correspondences of joints between interior and exteriors parts; this helps to minimize the risk of thermal bridge. The best solution is to stagger the parts while installing as indicated in the pictures at the end of this guideline.
In 2-layers insulation system, internal layer shall not be placed with sealants. The internal and external layer shall remain autonomous of each other in order to allow movement between the layers.

3-Layer system

Where insulation thickness is larger than 5" and a triple layer system is requested, stagger all longitudinal joints between the inner, middle, and outer layers. The best solution is to stagger the parts while installing as indicated in the pictures at the end of this guideline.
In a 3-layers insulation system, the inner layer shall not be placed with sealants. The inner, middle and outer layer shall remain autonomous of each other in order to allow movement between the layers.

FITTINGS

Pre-fabricated insulation for fittings like elbows, tees, and valves shall be the same thickness as pipe sections and fabricated with shiplap ends or tongue and groove longitudinal joints to connect to the pipe insulation system.

INSTALLATION AND SECONDARY VAPOR BARRIER

Insulation shall be attached with fiber strengthened tape on both internal and external layers of a multi-layered systems.
External layer insulation and secondary vapor barrier (SVB) shall be fixed with fiber strengthened tape. Use a 25% overlap when secondary vapor barrier is factory applied to insulation. Fiber tape shall be positioned to the exterior of the insulation/secondary vapor barrier system.
Secondary Vapor Barrier Film should be cut to length longitudinally and covered around the circumference of the pipe with lap joint and placed facing downward abstaining from the placement of the joint at the top or bottom of the pipe. Lap joints are to be sealed using a liquid glue. Butt joints shall be protected with vapor barrier tape. Coiling wrap configuration can be employed instead of the above

installation. Coiling wrapping will necessitate adhesive placed on one edge of the vapor barrier as it is wrapped over the preceding layer.
On factory applied secondary vapor barrier film, lap joint to be sealed with Self Seal Lap Tape (SSL). All secondary vapor barrier surfaces should be free of dust, grease, oil and other materials and duly cleaned. Before positioning the SSL tape make sure that there is a good adhesion between the tape and vapor barrier. For other kinds of factory applied secondary vapor barriers, ask manufacturer's instructions on positioning.

PRIMARY VAPOR BARRIERS AND VAPOR STOPS

Vapor stops shall be used on either side of valves often removed for inspections, valve place left uncovered, or uneven fittings, elbows, tees, etc. where the possibility of moisture infiltration is superior. Install according the drawing or an authorized different design.
All insulation shall be tightly fixed and free of voids, spaces and gaps at all joints. Vapor barrier must be continual. All fasteners and ties shall be duly lined up and general work must be of high quality appearance and manufacturing.
Before jacketing can be positioned on a portion of the piping, the vapor barrier system on that portion must be terminated and continual.

OUTDOOR PIPING

Specific attention must be paid for insulation applied in outdoor areas to avoid natural agents compromising the insulation works.
Insulation shall be defended from protracted exposure to UV rays and weather upon installation. It's necessary to provide jacketing material within two weeks from positioning in order to avoid Ultra Violet degradation.
Outdoor jacketing overlap shall be a minimum of 2” at butt joints and a minimum of 2” at longitudinal joints. Jacketing shall be weather stripped before closing and banding and positioned in order to avoid water infiltration.
Straight sections of jacketing shall be duly tied with bands and seals with a maximum spacing of 9” on center. End joints shall be fixed with bands and seals centered directly over joint. Do not use screws, staples or other fasteners that could affect the vapor barrier system.

TANK, VESSEL, AND EQUIPMENT INSULATION

All insulation materials shall be the same as those used on the pipe interacting with the tank, vessel, or equipment.
Tank and vessel head segments shall be twisted cut to conform in single piece or segments to ASTM C 450. Head segments shall be cut so as to get rid of voids at the head section and in the minimum possible number of pieces.
Curved segments shall be fabricated to fit the outline of the surface in equal size pieces to fit around the vessel with a minimum number of joints. Cutting in the field shall be minimized as possible. All sections shall be tightly clenched and free of voids, space and gaps.
Vertical vessels greater than 4 feet in diameter need an insulation back up ring welded or bolted around the bottom of the tank to preclude the shell insulation from slipping down.
Seal all outer layers and single layer butt joints with joint sealer.
In multi-layer applications, the horizontal and vertical joints of the internal and external layer twisted segments shall be staggered.
Fix the shell insulation with stainless steel bands.
DUNA advises secondary vapor barrier to be factory applied by an approved fabricator. In case this is not possible, install vapor barrier film. Tightly cover the vessel or equipment insulation circumferentially with SVB film. Place the seams by a minimum of 2 inches. Seal the overlapped seams with vapor barrier tape. On vertical vessels apply the SVB film beginning with the bottom course and work upwardly. Each course should overlap on top of the lower one thus affording a joint that will naturally drop water.
The vapor barrier on curved head sections shall be mastic/fab/mastic or authorized other. Flat head sections can be wrapped with vapor barrier film.

CORROSION RESISTANT METAL COATINGS

Corrosion of metal pipe, vessels, and equipment under insulation, while not usually determined by the insulation, is still an important issue that must be taken into consideration in any mechanical insulation system. The predisposition for corrosion depends on many causes including the ambient environment and the operating temperature of the metal.
DUNA PIR foams are friendly to every type of primer solution, nevertheless we warmly suggest to corrosion engineers to work closely with the fabricator, the contractor, and DUNA's technician to help guarantee a properly designed, made, and long-lasting corrosion-free insulation system.

FULL THICKNESS SHIPLAP ELBOW FITTING

- Shiplap end cut to thickness "X" to accommodate double layer pipe insulation.
- Use instead of double layered fittings.
- Cover elbow with vapor barrier Tape.

TAPING PATTERN

- Use two wraps of tape to guarantee proper bond.
- Use nylon or glass filament type tape 3/4" wide.

DOUBLE LAYER EXPANSION/ CONTRACTION JOINT DETAIL

- Allow sealant beads to cure prior to positioning of external layer.
- Position external layer packed glass fiber between sealant dams on internal layer.
- After glass fiber in contraction joint is laid down, insulation sections on either side of contraction joint shall be compelled together as tightly as possible.

VAPOR STOP DETAILS

- Mastic should be determined on the service temperature of the system.
- Mastic shall be sealed to the pipe face and lapped back over the top of the vapor barrier if fitting is left exposed.

DETAIL OF FACTORY APPLIED VAPOR BARRIERS

- Vapor Barrier can be installed using SSL tape or using liquid glues.
- Butt joints to be wrapped a minimum of 1.5" on each side of joint by vapor barrier tape or butt strip.

TANK HEAD INSULATION DETAIL

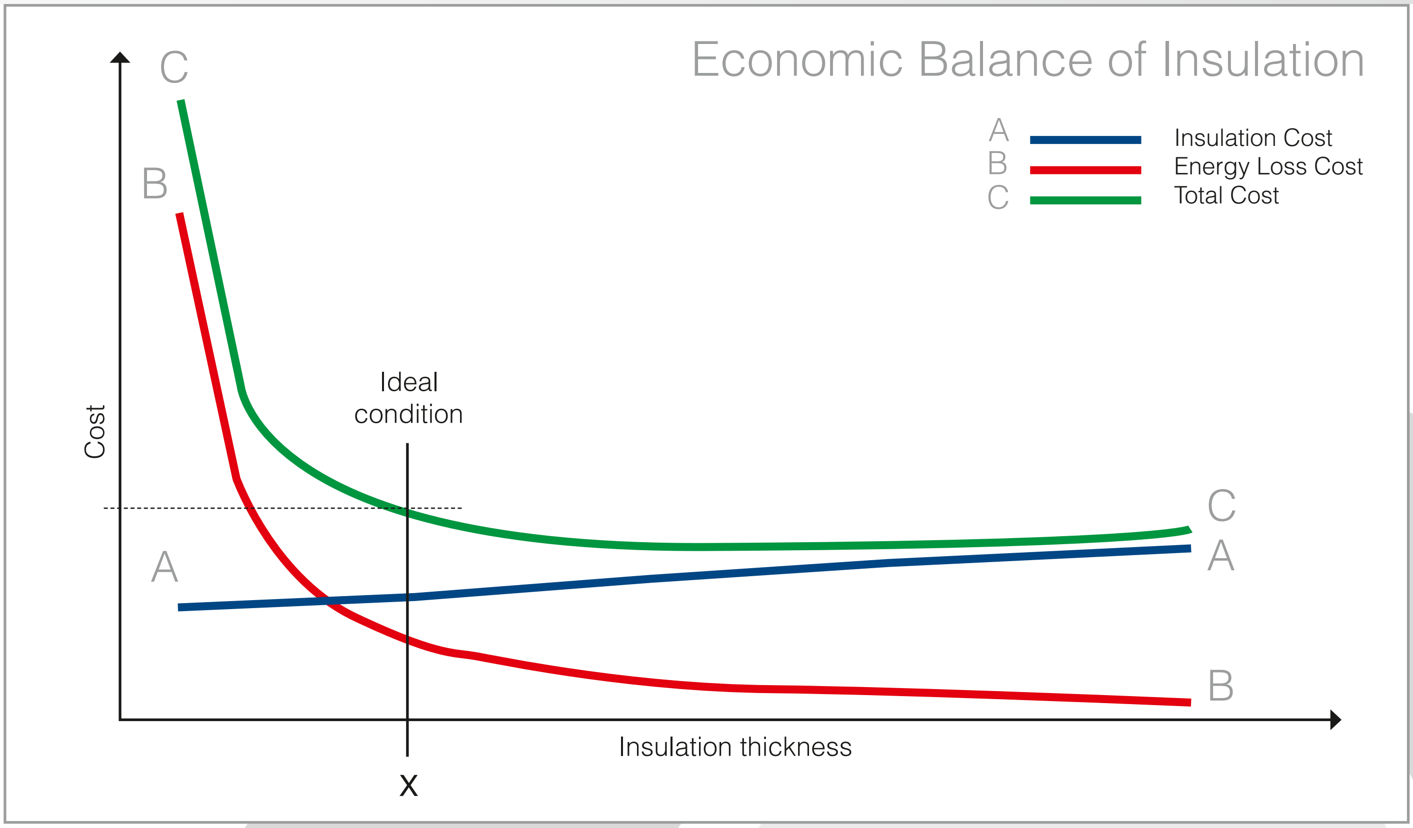
- In multiple layer systems, each layer shall be positioned so that the horizontal and vertical joints in that layer are offset from the matching joints in the previous layer by half the height or width of a full section.
- At joint between wall and head section, the external layer shall be offset below the internal layer by the thickness of a single layer.
- Where mastics or sealants are needed to fix the insulation sections to the tank head ask the manufacturer's recommendations on service and application temperatures.

INSULATION THICKNESS

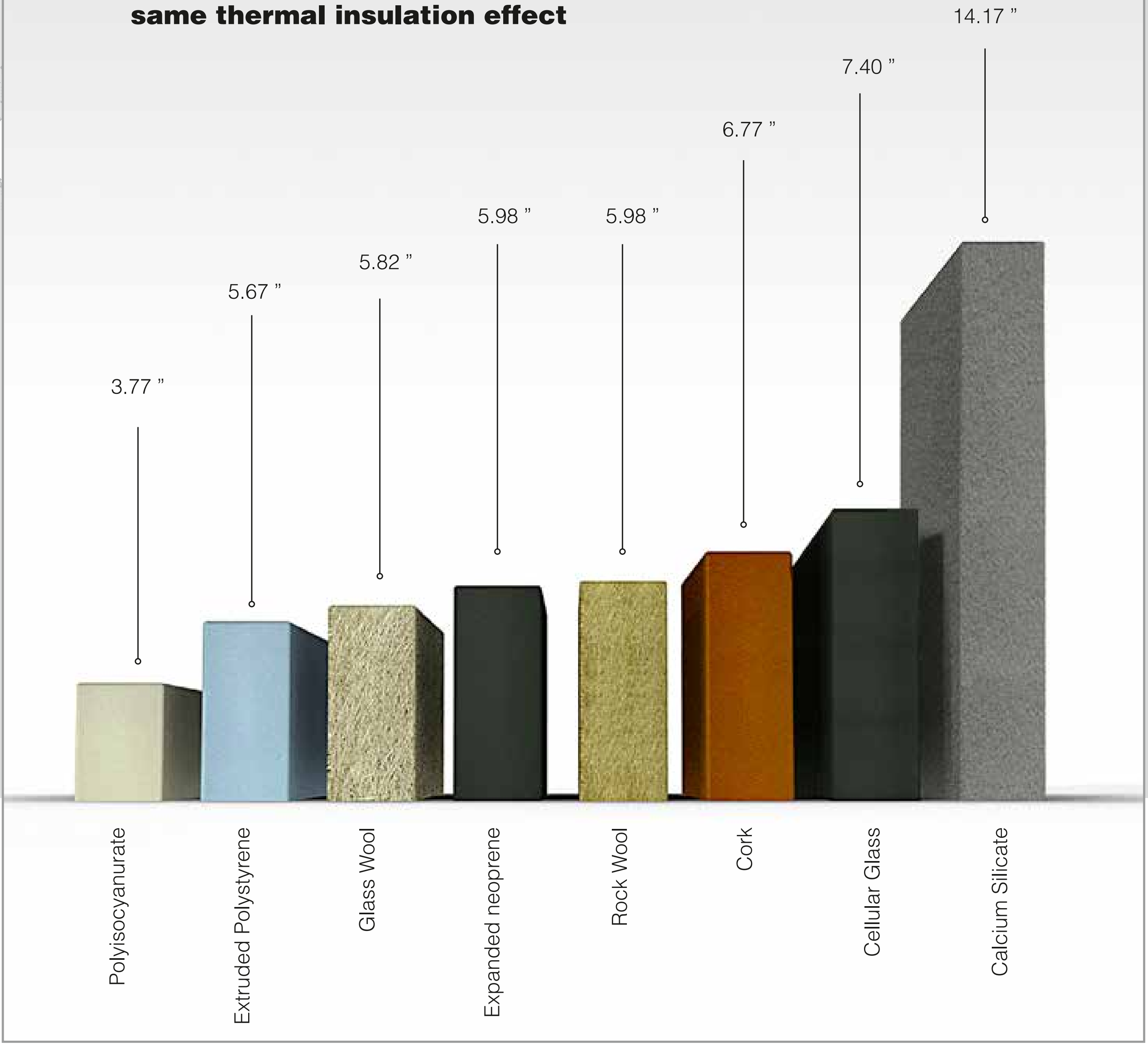
The customer's engineer should be asked to guarantee the insulation thickness necessary to avoid condensation on the external surface of the insulation system jacketing. In a few cases, the thickness must also guarantee the insulation thickness necessary to limit the heat gain to a specific value (usually 8 btu/hr·ft^2 of external jacketing surface). A number of assumptions must be made, based on indoor/outdoor, humidity, wind, cycling, safety factors, and so on. We suggest you asking a qualified engineer and have them work closely with the contractor, and DUNA to help guarantee a properly designed, positioned, and long-lasting insulation system.

ENERGY SAVINGS

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 energy loss. At low thickness values, the cost of insulation is low, but the cost of energy loss 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 energy 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.



Required thickness to achieve the same thermal insulation effect



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

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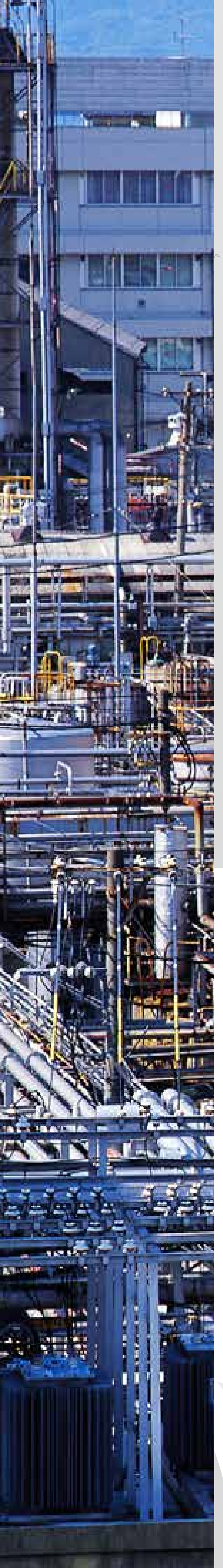
COLD SERVICE PIPE INSULATION

Insulation thickness Table (mm) Boundary conditions	Calculated for a 25 W/m² maximum heat loss		
External ambient temperature	95° F	**Relative humidity:**	80 %
Wind Speed	2.2 miles/hour	**Dew point**	88 °F
Surface Emissivity	0.4		
Designed max. heat-loss	25.0 W/m²		

DISCLAIMER: Thicknesses reported in the following table are shown for demonstrative purpose only and they are strictly related to boundary conditions reported above.
They are calculated using ASTM C680-10 algorithm, without considering any safety coefficient and assuming a perfect design and installation of insulation system.
DUNA-USA assumes no responsibility for any use of data shown in the table below.
We strongly recommend to contact a qualified insulation-design engineer for a proper thickness calculation related to any specific project.

	Pipe Service Temperature (°F)							
UP TO	**-40**	**-76**	**-112**	**-148**	**-184**	**-220**	**-265**	**-292**
Nominal Pipe Size (inch)								
1/2	1 1/2	2	2	2	2 1/2	2 1/2	3	3
1	1 1/2	2	2	2 1/2	2 1/2	3	3	3
1 1/2	2	2	2	2 1/2	3	3	3 1/2	3 1/2
2	2	2	2	3	3	3 1/2	3 1/2	3 1/2
2 1/2	2	2	2	3	3	3 1/2	3 1/2	3 1/2
3	2	2 1/2	2 1/2	3	3 1/2	3 1/2	3 1/2	3 1/2
4	2	2 1/2	2 1/2	3	3 1/2	3 1/2	4	4
6	2	2 1/2	2 1/2	3 1/2	3 1/2	4	4 1/2	4 1/2
8	2	3	3	3 1/2	4	4	4 1/2	4 1/2
10	2	3	3	3 1/2	4	4 1/2	4 1/2	4 1/2
12	2	3	3	3 1/2	4	4 1/2	5	5
14	2 1/2	3	3	3 1/2	4	4 1/2	5	5
16	2 1/2	3	3	4	4 1/2	4 1/2	5	5
18	2 1/2	3	3	4	4 1/2	4 1/2	5	5
20	2 1/2	3	3	4	4 1/2	4 1/2	5 1/2	5 1/2
22	2 1/2	3	3	4	4 1/2	5	5 1/2	5 1/2
24	2 1/2	3	3	4	4 1/2	5	5 1/2	5 1/2
26	2 1/2	3	3	4	4 1/2	5	5 1/2	5 1/2
28	2 1/2	3	3	4	4 1/2	5	5 1/2	5 1/2
30	2 1/2	3	3	4	4 1/2	5	5 1/2	5 1/2
32	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6
34	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6
36	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6
38	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6
40	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6



COLD SERVICE PIPE INSULATION

Insulation thickness Table (mm) Boundary conditions	Calculated for a 15 W/m² maximum heat loss		
External ambient temperature	95° F	**Relative humidity:**	80 %
Wind Speed	2.2 miles/hour	**Dew point**	88 °F
Surface Emissivity	0.4		
Designed max. heat-loss	15.0 W/m²		

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	Pipe Service Temperature (°F)							
UP TO	**-40**	**-76**	**-112**	**-148**	**-184**	**-220**	**-265**	**-292**
Nominal Pipe Size (inch)								
1/2	2	2 1/2	3	3	3 1/2	3 1/2	4	4 1/2
1	2 1/2	3	3	3 1/2	4	4 1/2	4 1/2	5
1 1/2	2 1/2	3	3 1/2	4	4 1/2	4 1/2	5	5 1/2
2	2 1/2	3	3 1/2	4	4 1/2	5	5	5 1/2
2 1/2	3	3 1/2	3 1/2	4 1/2	4 1/2	5	5 1/2	5 1/2
3	3	3 1/2	4	4 1/2	5	5 1/2	5 1/2	6
4	3	3 1/2	4	4 1/2	5	5 1/2	6	6 1/2
6	3	4	4 1/2	5	5 1/2	6	6 1/2	7
8	3 1/2	4	4 1/2	5 1/2	6	6 1/2	7	7 1/2
10	3 1/2	4	5	5 1/2	6	6 1/2	7 1/2	7 1/2
12	3 1/2	4 1/2	5	5 1/2	6 1/2	7	7 1/2	8
14	3 1/2	4 1/2	5	6	6 1/2	7	7 1/2	8
16	3 1/2	4 1/2	5 1/2	6	6 1/2	7	7 1/2	8 1/2
18	3 1/2	4 1/2	5 1/2	6	6 1/2	7 1/2	8	8 1/2
20	3 1/2	4 1/2	5 1/2	6	7	7 1/2	8	8 1/2
22	3 1/2	4 1/2	5 1/2	6 1/2	7	7 1/2	8 1/2	9
24	3 1/2	4 1/2	5 1/2	6 1/2	7	7 1/2	8 1/2	9
26	3 1/2	4 1/2	5 1/2	6 1/2	7	7 1/2	8 1/2	9
28	4	4 1/2	5 1/2	6 1/2	7	8	8 1/2	9
30	4	5	5 1/2	6 1/2	7 1/2	8	8 1/2	9 1/2
32	4	5	5 1/2	6 1/2	7 1/2	8	8 1/2	9 1/2
34	4	5	5 1/2	6 1/2	7 1/2	8	8 1/2	9 1/2
36	4	5	6	6 1/2	7 1/2	8	9	9 1/2
38	4	5	6	6 1/2	7 1/2	8	9	9 1/2
40	4	5	6	6 1/2	7 1/2	8 1/2	9	9 1/2

COLD SERVICE PIPE INSULATION
CONDENSATION PREVENTION

Insulation thickness Table (mm) **Boundary conditions**		**With wind speed >0**	
External ambient temperature	95° F	**Relative humidity:**	80 %
Wind Speed	2.2 miles/hour	**Dew point**	88 °F
Surface Emissivity	0.9		

DISCLAIMER: Thicknesses reported in the following table are shown for demonstrative purpose only and they are strictly related to boundary conditions reported above.
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DUNA-USA assumes no responsibility for any use of data shown in the table below.
We strongly recommend to contact a qualified insulation-design engineer for a proper thickness calculation related to any specific project.

	Pipe Service Temperature (°F)							
UP TO	**-40**	**-76**	**-112**	**-148**	**-184**	**-220**	**-265**	**-292**
Nominal Pipe Size (inch)								
1/2	1	1 1/2	1 1/2	2	2	2	2 1/2	2 1/2
1	1 1/2	1 1/2	2	2	2	2 1/2	2 1/2	3
1 1/2	1 1/2	1 1/2	2	2	2 1/2	2 1/2	3	3
2	1 1/2	2	2	2	2 1/2	3	3	3
2 1/2	1 1/2	2	2	2 1/2	2 1/2	3	3	3
3	1 1/2	2	2	2 1/2	3	3	3	3 1/2
4	1 1/2	2	2 1/2	2 1/2	3	3	3 1/2	3 1/2
6	2	2	2 1/2	3	3	3 1/2	3 1/2	3 1/2
8	2	2	2 1/2	3	3	3 1/2	3 1/2	4
10	2	2	2 1/2	3	3	3 1/2	3 1/2	4
12	2	2	2 1/2	3	3 1/2	3 1/2	4	4
14	2	2	3	3	3 1/2	3 1/2	4	4 1/2
16	2	2 1/2	3	3	3 1/2	3 1/2	4	4 1/2
18	2	2 1/2	3	3	3 1/2	3 1/2	4	4 1/2
20	2	2 1/2	3	3	3 1/2	3 1/2	4	4 1/2
22	2	2 1/2	3	3	3 1/2	4	4	4 1/2
24	2	2 1/2	3	3	3 1/2	4	4 1/2	4 1/2
26	2	2 1/2	3	3	3 1/2	4	4 1/2	4 1/2
28	2	2 1/2	3	3	3 1/2	4	4 1/2	4 1/2
30	2	2 1/2	3	3	3 1/2	4	4 1/2	4 1/2
32	2	2 1/2	3	3 1/2	3 1/2	4	4 1/2	4 1/2
34	2	2 1/2	3	3 1/2	3 1/2	4	4 1/2	4 1/2
36	2	2 1/2	3	3 1/2	3 1/2	4	4 1/2	4 1/2
38	2	2 1/2	3	3 1/2	3 1/2	4	4 1/2	4 1/2
40	2	2 1/2	3	3 1/2	3 1/2	4	4 1/2	4 1/2

COLD SERVICE PIPE INSULATION
CONDENSATION PREVENTION

Insulation thickness Table (mm) Boundary conditions		**With wind speed =0**	
External ambient temperature	77 F	**Relative humidity:**	80 %
Wind Speed	0 miles/hour	**Dew point**	70 °F
Surface Emissivity	0.9		

DISCLAIMER: Thicknesses reported in the following table are shown for demonstrative purpose only and they are strictly related to boundary conditions reported above.
They are calculated using ASTM C680-10 algorithm, without considering any safety coefficient and assuming a perfect design and installation of insulation system.
DUNA-USA assumes no responsibility for any use of data shown in the table below.
We strongly recommend to contact a qualified insulation-design engineer for a proper thickness calculation related to any specific project.

	Pipe Service Temperature (°F)							
UP TO	**-40**	**-76**	**-112**	**-148**	**-184**	**-220**	**-265**	**-292**
Nominal Pipe Size (inch)								
1/2	1 1/2	1 1/2	2	2	2 1/2	2 1/2	3	3
1	1 1/2	2	2	2 1/2	2 1/2	3	3	3 1/2
1 1/2	1 1/2	2	2 1/2	2 1/2	3	3	3 1/2	3 1/2
2	1 1/2	2	2 1/2	3	3	3 1/2	3 1/2	3 1/2
2 1/2	2	2	2 1/2	3	3	3 1/2	3 1/2	4
3	2	2	2 1/2	3	3	3 1/2	3 1/2	4
4	2	2 1/2	3	3	3 1/2	3 1/2	4	4 1/2
6	2	2 1/2	3	3 1/2	3 1/2	4	4 1/2	4 1/2
8	2	2 1/2	3	3 1/2	3 1/2	4	4 1/2	5
10	2	2 1/2	3	3 1/2	4	4 1/2	4 1/2	5
12	2	3	3	3 1/2	4	4 1/2	5	5 1/2
14	2	3	3	3 1/2	4	4 1/2	5	5 1/2
16	2	3	3 1/2	3 1/2	4	4 1/2	5	5 1/2
18	2	3	3 1/2	3 1/2	4 1/2	4 1/2	5	5 1/2
20	2	3	3 1/2	4	4 1/2	4 1/2	5	5 1/2
22	2	3	3 1/2	4	4 1/2	5	5 1/2	5 1/2
24	2	3	3 1/2	4	4 1/2	5	5 1/2	5 1/2
26	2	3	3 1/2	4	4 1/2	5	5 1/2	6
28	2	3	3 1/2	4	4 1/2	5	5 1/2	6
30	2	3	3 1/2	4	4 1/2	5	5 1/2	6
32	2	3	3 1/2	4	4 1/2	5	5 1/2	6
34	2	3	3 1/2	4	4 1/2	5	5 1/2	6
36	2	3	3 1/2	4	4 1/2	5	5 1/2	6
38	2	3	3 1/2	4	4 1/2	5	5 1/2	6
40	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6

TECHNICAL CHARACTERISTICS - CORAFOAM®

	Density	Blowing Agent	Compressive Resistance - Parallel (70°F)	Thermal Conductivity 180 days (75°F)	Closed-cell content	Fire properties		Operating temperatures
Standard **U.M.**	**ASTM D 1622** **lb/ft^3**		**ASTM D 1621** **psi**	**ASTM C 518** **BTU·in/hr·°F·ft^2**	**ASTM D 6226** **%**			**°F**
P20	2	CFCs/HCFCs-free	32	0.183	>92	ASTM E 84	FSI < 25 SD < 450	-320/+300
P25	2.5	CFCs/HCFCs-free	45	0.183	>92	ASTM E 84	FSI < 25 SD < 450	-320/+300
P30	3	CFCs/HCFCs-free	58.1	0.185	>92	ASTM E 84	FSI < 25 SD < 450	-300/+258
U40	4	CFCs/HCFCs-free	83	0.183	>92	-----		-300/+176
U60	6	CFCs/HCFCs-free	148	0.250	>92	-----		-300/+176
U80	8	CFCs/HCFCs-free	230	0.260	>92	-----		-300/+176
U100	10	CO_2	290	0.280	>92	-----		-300/+176
U150	15	CO_2	590	0.320	>92	----		-300/+176
U200	20	CO_2	1131	0.390	>92	----		-300/+176
U280	28	CO_2	2233	0.530	>92	----		-300/+176
U310	31	CO_2	2436	0.530	>92	----		-300/+176
PB 35 M1 HC	2.18	CFCs/HCFCs-free	37.7	0.186	>95	NF 92 501 DIN 4102 EN ISO 3582 ASTM E 84 ASTM D 3014	Class M1 Class B2 ≤0,39” ≤10 s FSI < 25 % Ret.>90	-310/+248
PB 40 M1 HC	2.62	CFCs/HCFCs-free	46.4	0.160	>95	NF 92 501 DIN 4102 EN ISO 3582 ASTM E 84 ASTM D 3014	Class M1 Class B2 ≤0.39” ≤10 s FSI < 25 % Ret.>90	-310/+248
PB 45 M1 HC	2.80	CFCs/HCFCs-free	52.2	0.160	>95	NF 92 501 DIN 4102 EN ISO 3582 ASTM E 84 ASTM D 3014	Class M1 Class B2 ≤0.39” ≤10 s FSI < 25 % Ret.>90	-310/+248
PB 50 M1 HC	3.1	CFCs/HCFCs-free	61.0	0.160	>95	NF 92 501 DIN 4102 EN ISO 3582 ASTM E 84 ASTM D 3014	Class M1 Class B2 ≤0.39” ≤10 s FSI < 25 % Ret.>90	-310/+248

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 C 177	Standard Test Method for Steady-State Heat Flux. Measurement and Thermal Transmission Properties by Means of the guarded Hot-Plate Apparatus
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
ASTM C 871	Standard Test Methods for Chemical Analysis of Thermal Insulation Materials for Leachable Chloride, Fluoride, Silicate, and Sodium Ions
ASTM C 591	Standard Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation
CINI 2.7.01	General specification for Polyisocyanurate (PIR) insulation rev. 2013-10-09

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Limitations and Disclaimer of Warranties and Liabilities

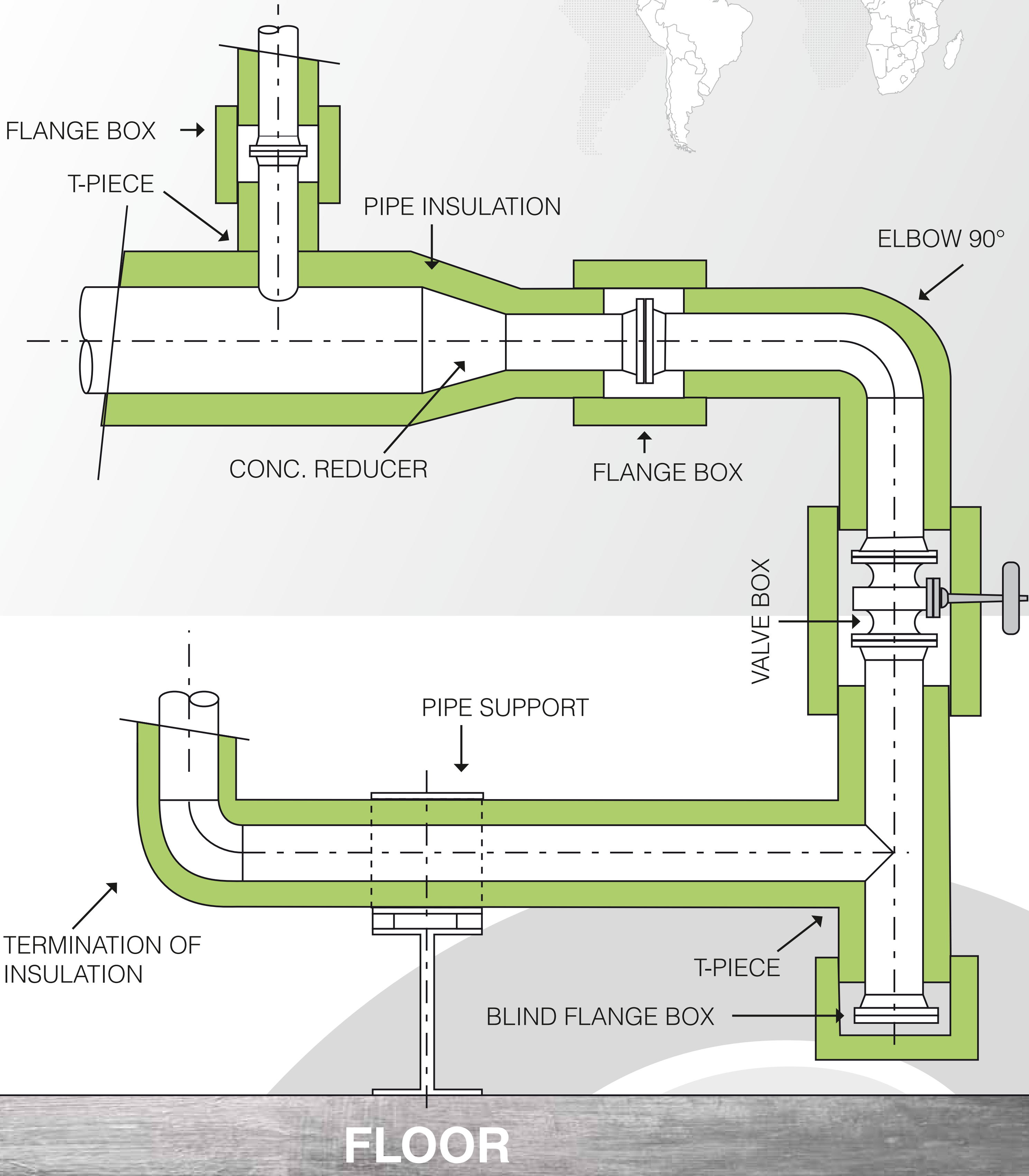
Important: The statements expressed on these pages are the general recommendations for the application of the products as outlined and written for the interpretation and application by an experienced contractor. Any deviation from these recommended procedures shall be at the sole risk of the installers. Failure to follow these instructions may result in serious damage to the application and life of this roofing product, resulting in the termination of any warranty, expressed or implied. Characteristics, properties, performance of materials, and application specifications herein described are based on data obtained under controlled conditions.

Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for their purposes and the reasonableness of the recommendations under the actual installation circumstances. DUNA-Group makes no implied warranties of any type, including without limitation, any warrant of merchantability or fitness of purpose. In no event will DUNA be responsible for damages of any nature whatsoever resulting from the use of or reliance upon this information or the product to which information refers. No agent, sales representative, or employee is empowered to change, alter, or amend this provision, unless approved in writing by a duly authorized officer of DUNA-Group.

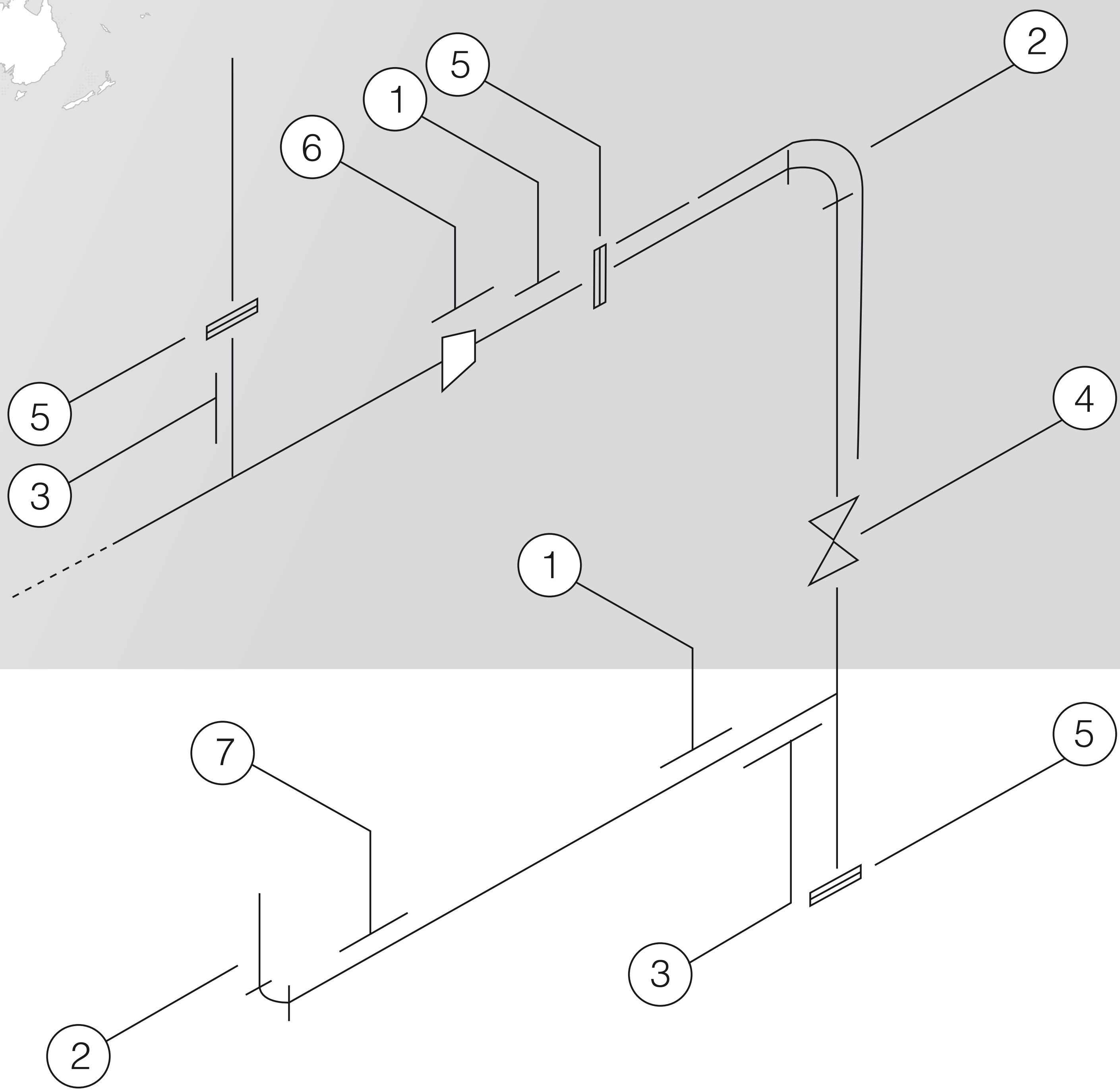
The use of certified mechanical insulation inspectors who mantain current certification by the National Insulation Association, or other certified mechanical insulation certification association, is recommended throughout the project to inspect and verify the materials are and the total insulation system has been installed in accordance with the specifications.

EXAMPLES OF INSULATING SOLUTIONS WITH DUNA-USA PRODUCTS

OVERVIEW PIPING INSULATION DETAILS

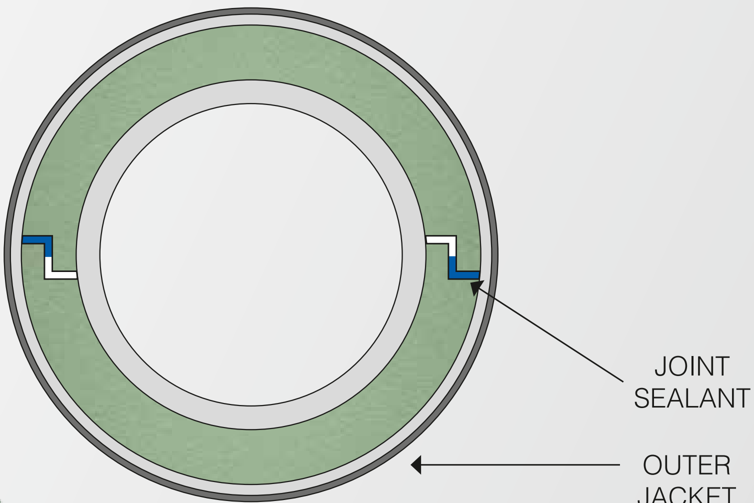


ISOMETRIC DIAGRAM



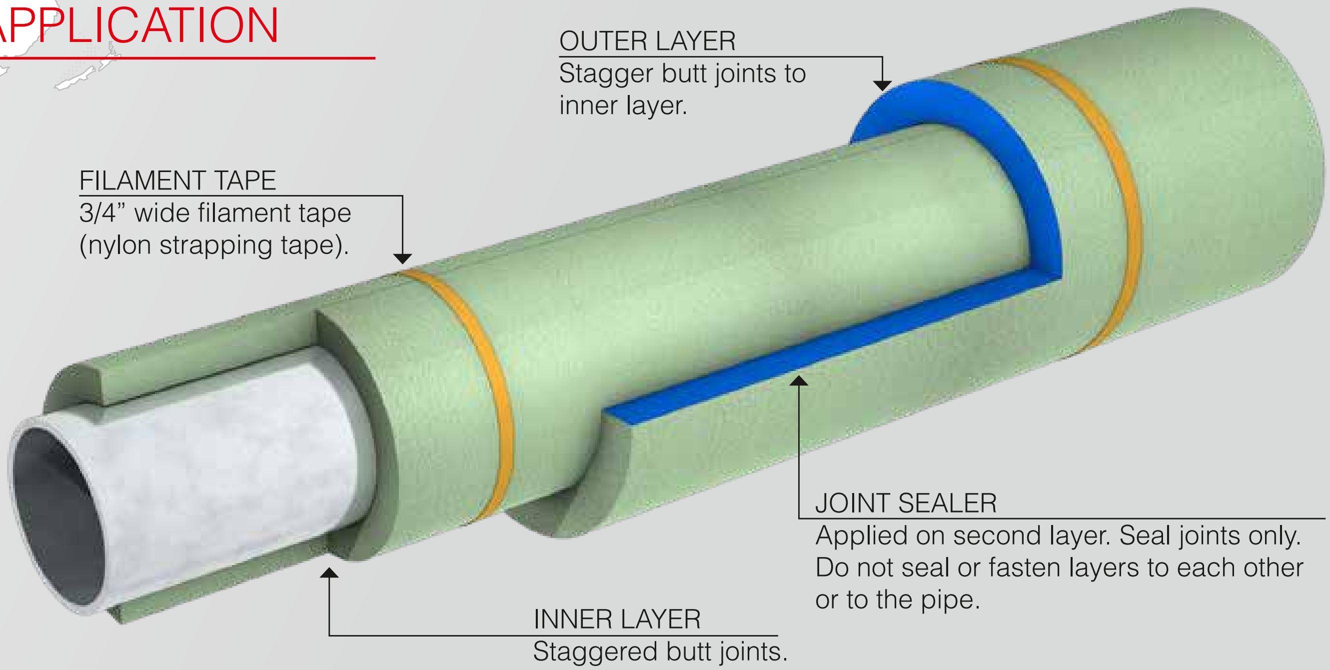
1 STRAIGHT PIPES

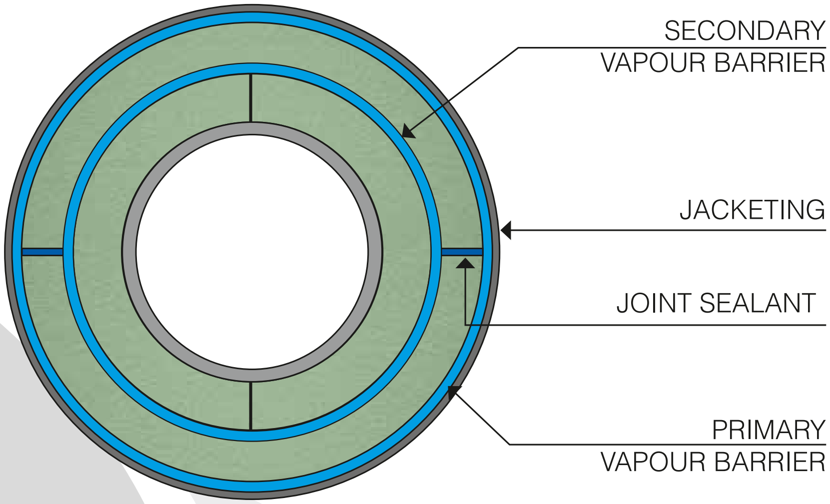
CROSS SECTION SINGLE LAYER



SHIP - LAPPED PIPE
LONGITUDINAL
+
CIRCUMFERENTIAL

DOUBLE LAYER APPLICATION

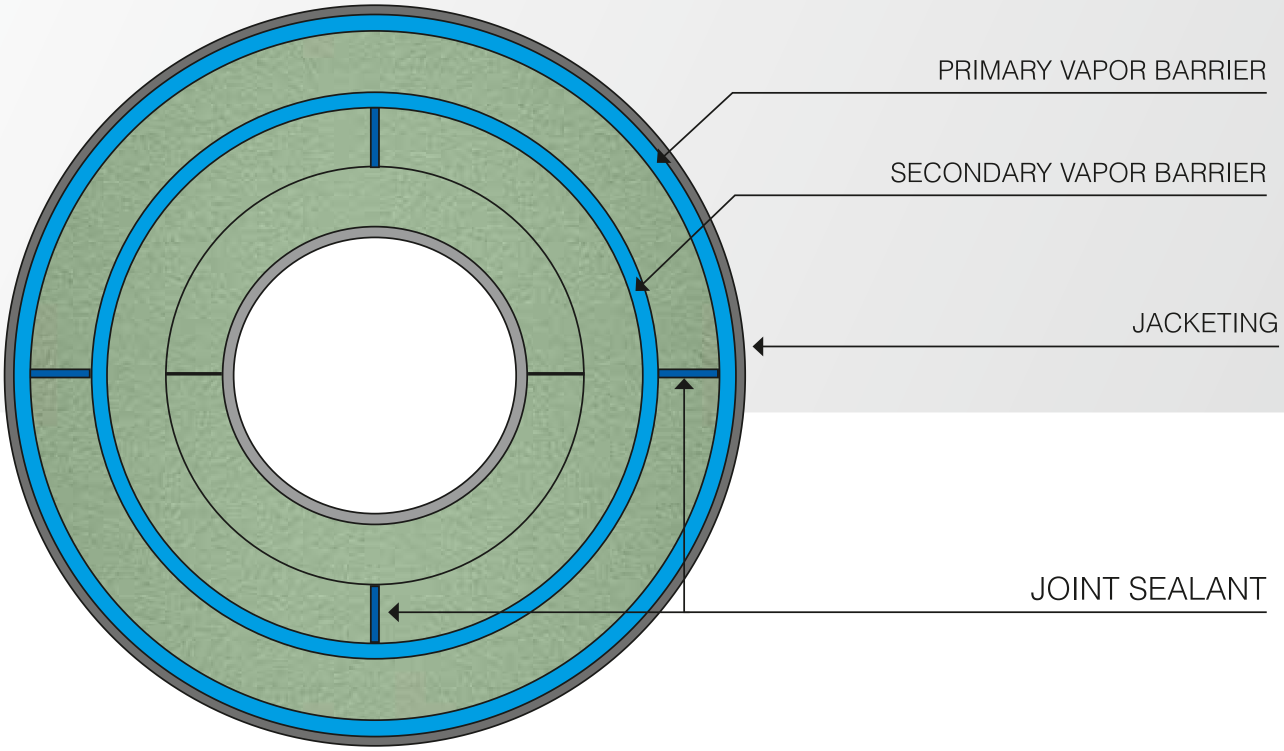




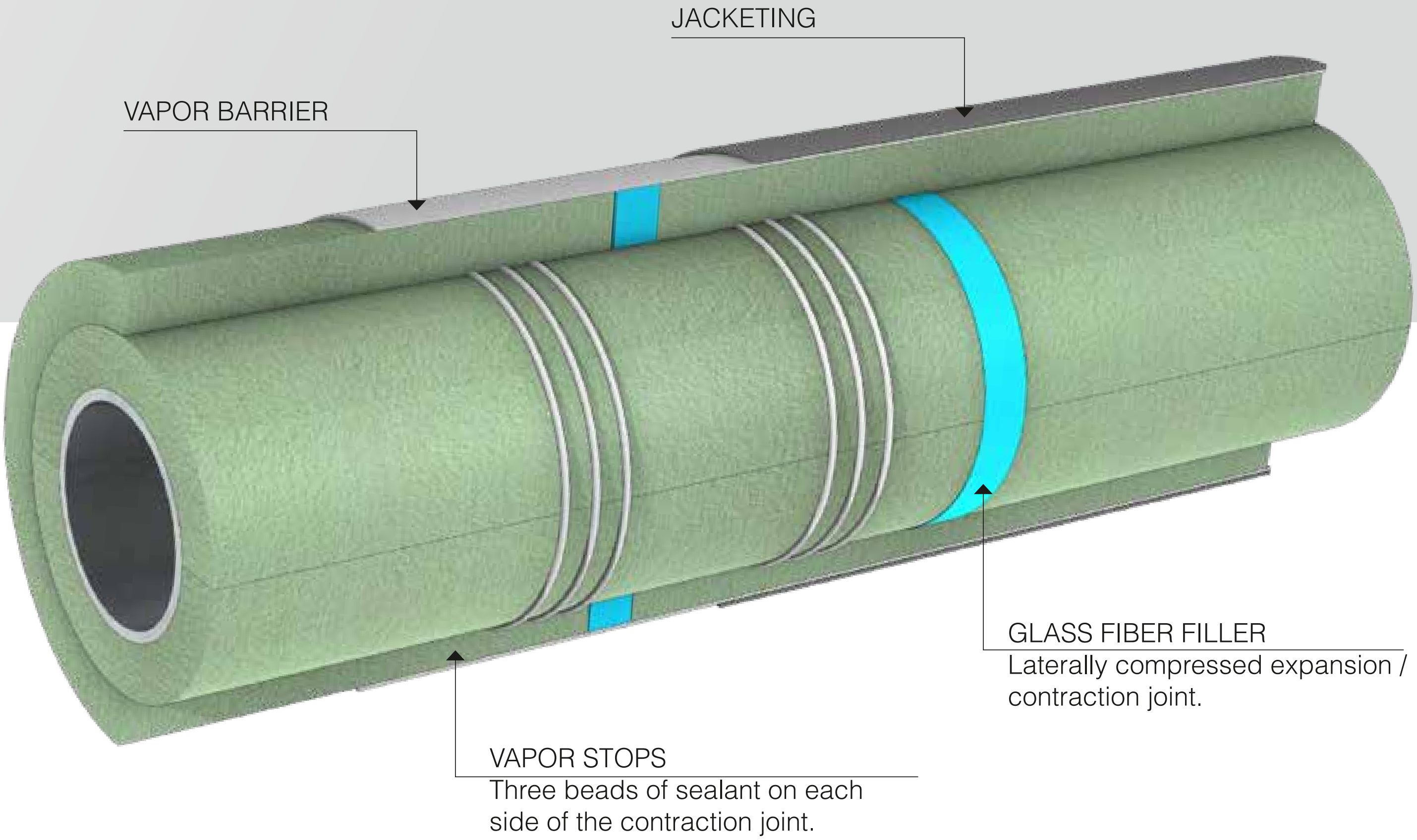
Notes:

- Apply thin coat of sealant over whole joint depth
- Stagger half round segments on each layer between the two layer
- Outer layer 3 and 9 o’clock
- Inner layer no sealant

TRIPLE LAYER APPLICATION

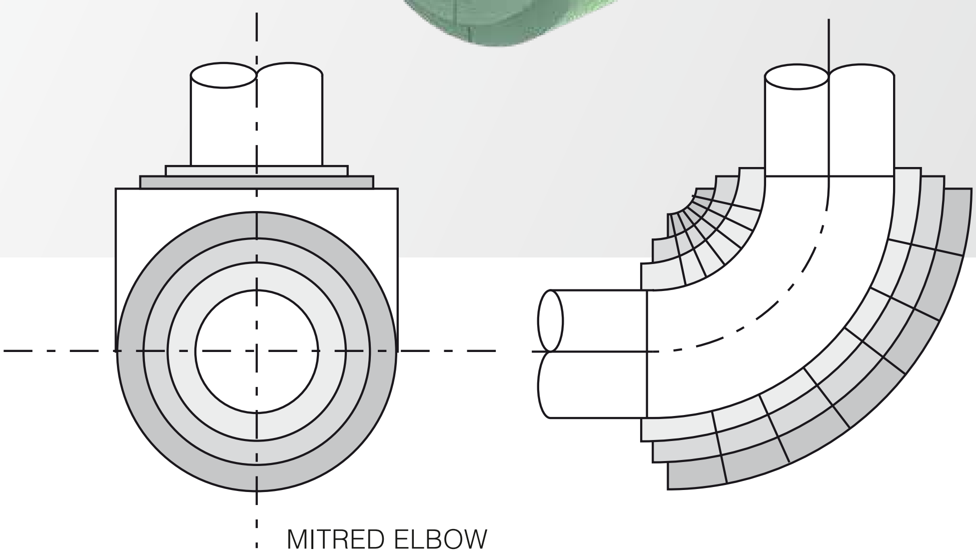


CONTRACTION JOINT DOUBLE LAYER APPLICATION

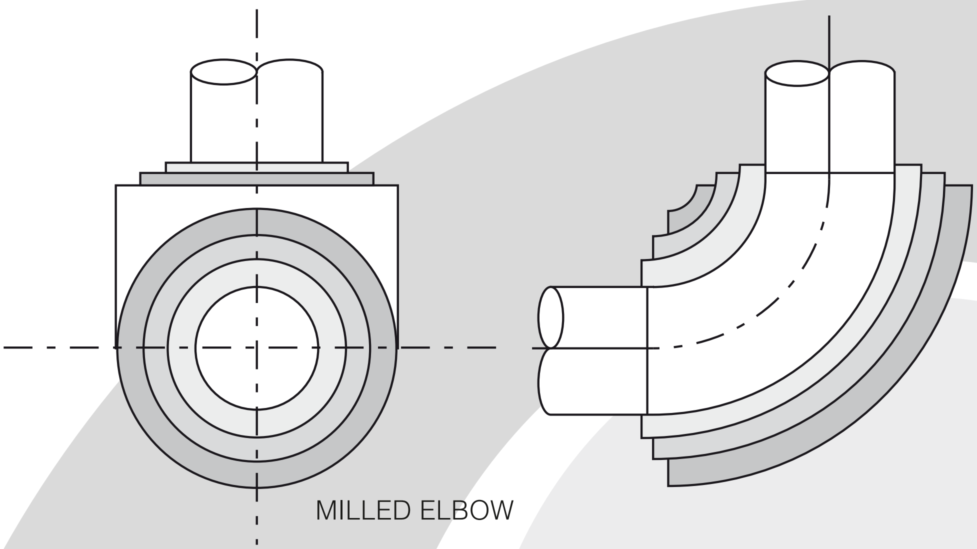


2 ELBOWS

SHIP
LAPPED ELBOW

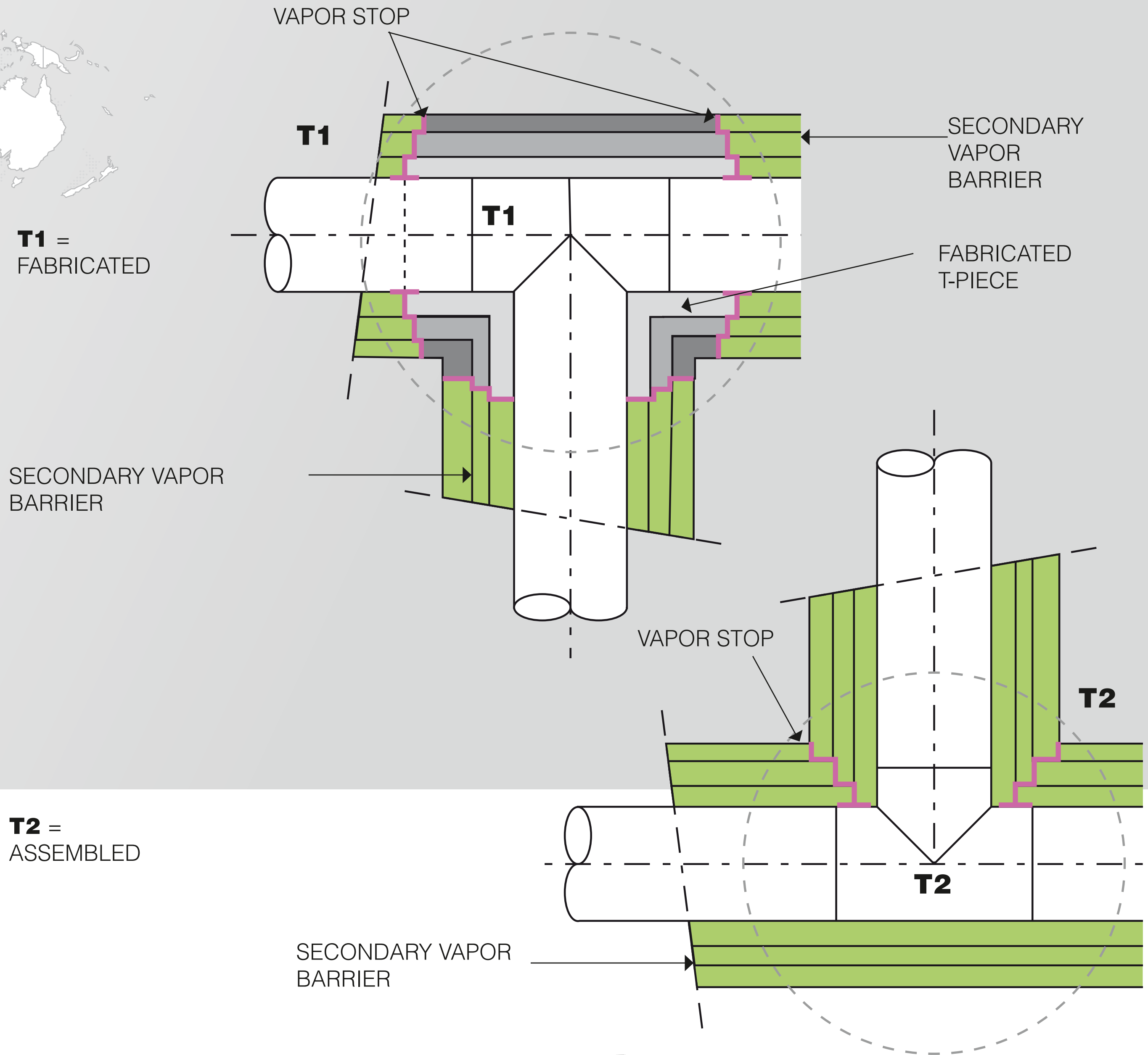


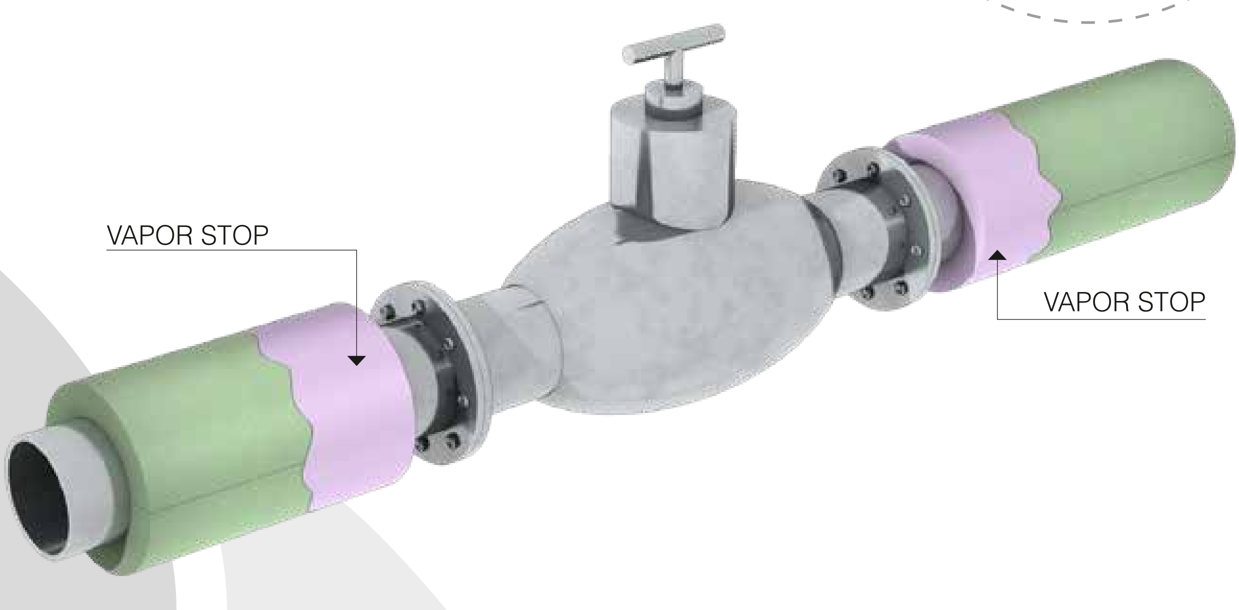
MITRED ELBOW



MILLED ELBOW

3 TEES


VAPOR STOP
T1
SECONDARY
VAPOR
BARRIER
T1
T1 =
FABRICATED
FABRICATED
T-PIECE
SECONDARY VAPOR
BARRIER
VAPOR STOP
T2
T2 =
ASSEMBLED
T2
SECONDARY VAPOR
BARRIER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Fx: 231-425-4300

Toll Free: 866-383-DUNA
www.dunagroup.com/usa
info-dunausa@dunagroup.com

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