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TECHNICAL JOB SPECIFICATION

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LIQUEFIED NATURAL GAS PLANTS

LOW TEMPERATURE THERMAL INSULATION

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CHANGES LOG

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1.0 SCOPE

1.1 This specification defines the minimum application requirements for external thermal insulation of piping and equipment where the operating temperatures are within a temperature range of 21°C and -173°C.

1.2 The specification shall be read in conjunction with applicable design drawings and the Summary of Equipment Insulation.

2.0 BASIC DESIGN REQUIREMENTS

2.1 Cold service shall be defined as normal operating temperature ranges of 21°C and lower where the reduction of heat gain and the prevention of surface condensation are desired.

2.2 External low temperature thermal insulation shall be designed and manufactured for field application with a view to affecting a reduction of heat gain to less than 25.2 W/M2 and to preventing surface condensation under temperature conditions of 33°C, 83% relative humidity, a 4m/s wind speed and a surface emissivity of 0.3.

2.3 Piping and equipment in cold service shall be insulated when designated on flow sheet nomenclatures and on the Summary of Equipment Insulation.

The following symbols shall be used in designating the insulation type:

Type 6 - Sound Control (21°C and below)
Type 7 - Prevention of Surface Condensation (21°C and below)
Type 8 - Reduction of Heat Gain (21°C and below)
Type 9 - Personnel Protection (-10°C and below)

3.0 EXTENT OF INSULATION

3.1 When cold insulation is required, the entire system shall be fully insulated, including all piping components, piping/tubing of insulated instruments, drains, equipment nozzles and supports to the extent specified. Flanged, butt-weld and socket weld valves and fittings, together with flanged joints on piping shall be fully insulated.

3.2 All metal parts protrude through the insulation, shall be insulated. There shall be a minimum of 300mm of bare metal after termination of insulation. Protruding metal parts include, but are not limited to, equipment skirts, lugs, legs, saddles, clips and space frames, platform trunnion supports, pipe hangers and uninsulated connections in piping, such as vents, sample connections and uninsulated instrumentation.

3.3 Vessel clips supporting pipe support and guide brackets and platform brackets shall be insulated. No insulation is permitted on the outer flange of the clip.

3.4 When equipment is supported on metal saddles, the insulation shall be carried down the saddles (from the low point of the vessel shell) a minimum of 4 times the

insulation thickness. The saddles shall be of sufficient length to allow a minimum of 300mm of bare metal after termination of insulation. The closure plate shall be constructed in such a manner to serve as a continuous vapor barrier for the insulation. The closure plate shall be seal welded at all contact points with the saddle, including main support members and all gusset and stiffener members. The closure plate shall extend horizontally beyond the saddle an amount to support the full thickness of insulation. The vapor barrier and jacket shall extend over the edge of the closure plate and terminate on the underneath side of the closure plate.

3.5 When equipment is supported on a structural steel member, the insulation shall be extended not less than three times the thickness from the vessel insulation surface in each direction along the structural member. The member shall be of sufficient length to allow a minimum of 300mm of bare metal after termination of insulation.

3.6 Skirts supporting vertical equipment shall be insulated inside and outside for a distance from the bottom tangent line for a distance equal to four times the insulation thickness but not less than 300mm. The exception to this requirement is skirts less than 1.2 meters in diameter where requirements are as called for in paragraph 6.4. The skirt shall be sufficient length to allow for a minimum of 300mm of uninsulated skirt at the bottom.

3.7 All metal such as insulation support rings or stiffeners, which are an integral part of the vessel, shall be insulated with two thirds the intermediate and/or outer layer thickness(s). Thickness to be rounded up to next 12mm. Full thickness is required for single layer application.

3.8 Gauge glasses of insulated equipment operating at 0°C and above shall be fully insulated except for the face of the glass. Gauge glasses of equipment operating below 0°C shall be furnished with frost-free extension which shall extend a minimum of 15mm beyond the outer surface of insulation.

3.9 Nameplates, coding tags, etc. shall be insulated. A duplicate nameplate shall be installed over the outside surface of the insulation system. The method of attachment used shall not puncture the vapor seal.

3.10 Pumps and compressors shall not be insulated, except for pot mounted vertical pumps. Pot mounted vertical pumps shall be insulated, regardless of operating temperature. Thermal dams shall be provided to isolate the pump support from supporting steel or concrete.

3.11 When specified, insulation shall be provided to reduce the noise from exhausts and similar piping.

3.12 Each line shall be insulated as a single unit. A minimum clearance of 50mm shall be provided between the outer surface of insulation and any obstruction such as structural steel, electrical conduit, piping, or other insulated lines.

3.13 Piping and tubing associated with uninsulated instrumentation shall be insulated for piping or equipment operating temperatures of +2°C and below.

3.14 Pipe trunnion supporting horizontal piping or elbows shall be field frothed or foamed in place to prevent cryo-pumping from occurring.

4.0 INSULATION DESIGN

4.1 For piping and equipment operating at a temperature of -40°C and above insulation shall comprise cellular glass employing single layer application for thicknesses of 100mm and less, and double layer application for thickness in excess of 100mm.

4.2 For piping and equipment operating at a temperature of -41°C and below, insulation for thicknesses of 140mm and above shall be applied in three layers, comprising an inner layer of medium density preformed polyisocyanurate, a middle layer of medium density preformed polyisocyanurate and an outer layer of cellular glass. The outer layer shall in all cases be 50mm thick.

4.3 For piping and equipment operating at temperatures of -41°C and below, insulation for thicknesses below 140mm shall be applied in two layers, comprising an inner layer of medium density preformed polyisocyanurate and an outer layer of cellular glass. The outer layer shall in all cases be 50mm thick.

4.4 For Type 6 insulation - sound control (21°C to -40°C) the total insulation thickness shall be as required for reduction of heat gain, except that the minimum thickness shall be 75mm for pipe sizes DN50 and less, and 90mm for pipe sizes greater than DN50. Insulation shall comprise an inner layer of 50tmn thick preformed rockwool 110/150 kg/m^3 followed by an outer layer of cellular glass at least 25mm thick for pipe sizes DN50 and less and 40mm for pipe sizes greater than DN50.

4.5 For Type 6 insulation - sound control (-41°C and below) the total insulation thickness shall be as required for reduction of heat gain, except that the minimum thickness shall be 100mm where the specified thickness is 100mm or less and 125mm where the specified thickness is greater than 100mm. Insulation shall comprise an inner layer of 50mm thick rockwool 110/150kg/m^3 followed in cases where the specified thickness is greater than 100mm by an intermediate layer of polyisocyanurate and followed in all cases by an outer layer of cellular glass at least 50mm thick.

4.6 For piping and equipment requiring insulation for protection of personnel, insulation shall comprise medium density preformed polyisocyanurate employing single layer application up to 40mm thick and double layer application for thicknesses of 50mm and greater.

4.7 Where Type 9 insulation is specified for uninsulated piping and equipment having a normal operating temperature of -10°C or below and whose location presents a personnel hazard, the surfaces shall be provided with protection. This shall generally be limited to within the confines of a normal working area bounded by distances of not more than 2.0 meters vertically or 0.6 meters horizontally beyond access ways, ladders, platforms and work areas at ground level or elevations used by operating and maintenance personnel.

5.0 THICKNESS OF INSULATION

5.1 The insulation thicknesses for piping and equipment with operating temperatures from 21°C to -40°C types 7 and 8 shall be in accordance with Table 3, with thicknesses of individual layers in accordance with Table 5.

5.2 The insulation thickness for piping and equipment with operating temperatures of -41°C to -173°C, Types 7 and 8 shall be in accordance with Table 4, with thickness of individual layers in accordance with Table 6.

5.3 The thicknesses of insulation for piping and equipment requiring sound control insulation, types 5 and 6, and with operating temperatures from above 21°C to -173°C shall be in accordance with Table 1, with thicknesses of individual layers in accordance with Table 2.

5.4 The thicknesses of insulation for piping and equipment requiring insulation for protection of personnel Type 9 and with operating temperatures from -10°C to -173°C shall be in accordance with Table 7, with thicknesses of individual layers in accordance with Table 8.

5.5 Thicknesses of individual layers shall not be varied from those specified in Tables 2, 5, 6 and 8.

5.6 Where piping and tubing associated with instrumentation requires insulation, the insulation type, thickness and finish shall be identical to that specified for piping of equivalent size and operating temperature.

5.7 The thickness of the basic insulation on equipment heads shall be the same as the thickness of the cylindrical section of the vessel.

5.8 The thickness of the basic insulation on pipe fittings shall be the same as the thickness of the adjoining pipe.

5.9 The thickness of insulation for protruding parts designated as "Attachment Insulation Thickness, Ta", except vessel clips, shall be based on the fluid temperature of the pipe or equipment to which the part is attached and the "size" determined as follows:

a. For cylindrical attachments, use the nearest pipe size given in Table 4 corresponding to the diameter of the attachment.

b. For structural shapes use the longest dimension (of the nominal section size) corresponding to a pipe size given in Table 4. For example:

   i) An 8 WF is equivalent to a DN 200 pipe.
   ii) A 150mm, by 100mm angle is equivalent to a DN 150 pipe.

5.10 The thickness of insulation on vessel clips shall be tapered down from full thickness at the outside surface of the vessel shell insulation to 6mm at the inside face of the outer flange. No insulation is permitted on the outer flange of the clip.

6.0 MATERIALS

6.1 The insulation materials listed below constitute those to be used for the low temperature insulation systems covered by this specification.

6.1.1 Rigid Polyisocyanurate foam shall be of a medium density.

The material shall have the following minimum properties:

a. Rigid factory foam cured and shaped/cut into slabs, radiused and beveled segments, and half pipe sections.

b. Density not less than 40kg/m3, measured per **ELOT EN 13470** "Thermal insulating products for building equipment and industrial installations – Determination of the apparent density of preformed pipe insulation".

c. Thermal conductivity at 20°C mean temperature measured on 25mm thick foam, cut on both sides and aged at 21°C for 180 days shall be no greater than 0.023 W/(mK) per **ELOT EN ISO 13787** "Thermal insulation products for building equipment and industrial installations. Determination of declared thermal conductivity". The thermal conductivity for freshly blown foam shall be no greater than 0.019 W/(mK).

d. Closed cell content: minimum 90% by volume on average with a minimum of 85% by volume for any sample measured as per **ELOT EN ISO 4590** "Rigid cellular plastics -- Determination of the volume percentage of open cells and of closed cells".

e. Structural Properties

The density and chemical formulation of the foam insulation should be selected so that the following relation is satisfied:

$$\frac{\sigma_t (1-\nu)}{E.\alpha.\Delta T} \geq 1.5$$

where:

σ_t = Tensile strength of material at -160^{0}C – minimum value of all directions **ELOT EN 1608** "Thermal insulating products for building applications. Determination of tensile strength parallel to faces".

E= Tensile modulus of material at -160°C - maximum value of all directions. **ELOT EN 1608** "Thermal insulating products for building applications. Determination of tensile strength parallel to faces".

α= Average linear contraction coefficient from -160°C to 21°C, mm/m - maximum value of all directions.

ΔT= 181°C, Temperature difference between cold surface and ambient temperatures.

ν = 0.4, Poisson's ratio at -160°C. Estimated value. Other value can be used if substantiated by experimental data.

The formula above is essentially a safety factor, expressing the ratio of the tensile strength of material and the tensile stress induced in a one-dimensional, restrained slab by the temperature difference.

f. Water Vapor Transmission at 38°C and 100% R.H. 6.00 X 10^{-3} ugm/Ns.

g. Linear coefficient of thermal expansion 40 to 80 χ 10"6 per °C according to direction.

h. Fire resistive properties:
ELOT EN 13823 "Reaction to fire tests for building products. Building products excluding floorings exposed to the thermal attack by a single burning item"
Class 1 surface of very low flame spread.
Maximum flame spread rating of 25.
85% retention of weight (Butler chimney test).
flame penetration 20 minutes.

j. Compressive strength: not less than 240 KPa in the X Z directions and not less than 160kPa in the Y direction, **EN ISO 844** "Rigid cellular plastics - Determination of compression properties" at ambient temperature.

k. Cell structure: uniform and free from voids and bubbles in excess of 1.5mm in diameter across the rise or 5mm in depth in direction of rise, and no more than 5 smaller voids or bubbles per 250mm x 250mm area on any cut standard length of half pipe section, lag or slab.

l. Alkalinity: pH of between 7 and 9.

m. Chloride Content: 150 to 250 ppm.

6.1.2 Cellular glass shall be of an approved manufacturer. The material shall conform to the requirements of **ELOT EN 14305** "Thermal insulation products for building equipment and industrial installations - Factory made cellular glass (CG) products " and shall have the following minimum properties:

a. Rigid cellular glass, factory shaped/cut into slabs, radiused and beveled segments, and half pipe sections in 600 mm lengths.

b. Density +/- 10% : 125 Kg/M^3

c. Thermal conductivity, no greater than the following:

Mean Temp °C	W/(mK)
+20	0.045
0	0.042
-20	0.038

d. Average compressive strength: 490kPa.

e. Water vapour transmission: zero

f. Linear coefficient of thermal expansion: 8.5 χ 10-6 p_{er} or,,

g. Fire resistive properties: Non combustible. maximum flame spread rating: 5

h. Modulus of elasticity: 980 MPa

6.1.3 Low density glass fibre blanket (unfaced) for application at expansion/contraction joints and for packing voids between piping or equipment and insulation shall be by an approved manufacturer. The material shall have the following minimum properties:

a. Density: 23.0/24.0 kg/M^3

b. Thermal conductivity at 25° C mean temperature 0.034 W/ (mk).

c. Average compressive strength at 10% deformation and 24°C: 0.002 bars

d. Average linear coefficient of thermal expansion: 5.4 x 10^{-5}/°C.

6.1.4 Heavy density preformed mineral wool used in sound control applications for temperatures down to -40°C shall be a rock based material. The material shall have the following minimum properties.

a. Density 110 to 150 Kg/M^3

b. Thermal conductivity at 25°C mean temperature 0.035 W/ (mk).

6.2 Vapor barrier materials shall be the following and used as defined under Sections 6 to 12 inclusive.

6.2.1 The outer layer vapor barrier used to seal all piping and equipment insulation prior to metal cladding shall be of non-asphaltic or elastomeric materials, compatible with the insulation material and capable of remaining flexible at the environmental temperature. The material shall protect the insulation from ultra-violet radiation and shall have characteristics meeting the following minimum requirements:

a) Flammability, wet: flash point 27°C to 32°C per **ELOT EN ISO 2719.**

b) Dry Flame spread: 20 on 6 mm as per **ELOT EN 13823** and **EN ISO 11925-2.**

c) Service temperature range: -40°C to +85°C.

d) Water Vapor Presence: No greater than 0.05 metric perms when tested at a dry film thickness no less than 1.3 mm per **ELOT EN 15026** and **EN ISO**

13788 with relative humidity of 90% in chamber, and 0% at vapor sink respectively.

e) Color : White, light grey or aluminium

f) Volume Solids : 40 to 55%

g) Dry Film Thickness : As appropriate to material characteristics to meet the specified water vapor presence as per (d) above, but limited for practical reasons to an absolute minimum of 1.3mm total for two coats or 1.9mm for three coats, after allowing for filling up surface porosity.

h) Certification: For initial verification of product properties, test certificates shall be produced for all tests as per applicable European standards, carried out within the previous 12 months by a recognized independent testing authority.

6.2.2 The slip layer between the polyisocyanurate and cellular glass intermediate/outer layers of insulation shall be a lamination of 0.0254mm thick aluminium foil between two layers of polyester film serving as a vapor barrier having the following properties:

Permeability: 0.0128 grammas per 64.5 m^2 per 24 hours at 100% humidity and 38°C.

6.2.3 The vapor barrier cover for contraction joints in the outer layer of insulation shall be butyl rubber sheet 1.2mm minimum thickness, and shall be supplied complete with compatible adhesive.

6.2.4 The inner vapor barrier material to be used between the isocyanurate intermediate layer and the cellular glass outer insulation layer on irregular surfaces including fittings etc. shall be a low molecular weight butyl rubber based elastomeric two component coating.

6.3 Joint sealant materials adhesives etc. shall be the following and shall be used as defined under Section 6 to 12 inclusive.

6.3.1 The joint sealant used to seal the longitudinal and circumferential joints of all cellular glass and polyisocyanurate inner, intermediate and outer layers of insulation on pipework and equipment both above and below - 40°C shall be a single component highly filled non-hardening elastomeric butyl composition. The material shall have the following properties:

a. Solids Content: 84% minimum volume.

b. Drying Time: Essentially no drying, skins over 3 to 4 hours.

c. Water Vapor Presence **ELOT EN 15026** and **EN ISO 13788:** Less than 0.02 perms through 3.2mm dry film.

d. Service Temperature Limits: -55°C to 70°C.

e. Flammability: Dry - low flame spread.

f. Color/Physical Form: White/Soft paste.

6.3.2 The coating to be used to seal the edges of insulation terminations at vapor stops on piping operating at Temperatures -41°C and below shall be a low molecular butyl rubber based elastomeric coating/sealer. The coating shall have the following properties:

a. Solids Content: 58% by volume.

b. Water Vapor Transmission: **ELOT EN ISO 15106-1** "Plastics - Film and sheeting - Determination of water vapour transmission rate - Part 1: Humidity detection sensor method":0.013 metric perms at 0.5mm dry film thickness.

c. Service Temperature Limits: -196°C to 120°C

d. Flammability: Dry - Combustible

e. Acceptable materials: Cryogenic Coating

6.3.3 The membrane for embedding between coats of the vapor barrier mastic on fittings and between coats of Cryogenic Coating para. 6.3.2, shall be a high strength resilient synthetic fabric having 20 x 10 threads per 25mm, a weight of 33 g/m^2 and a leno weave.

6.3.4 The adhesive used to bond the edges of insulation to piping at all insulation terminations shall be a low temperature 100% solids, three component cryogenic adhesive. The adhesive shall have the following properties:

a. Solids Content: 99.9% by volume.

b. Service Temperature Limits: -196°C to 120°C

c. Acceptable materials: Cryogenic Adhesive chemically-curing composition which develops high tensile strength and adhesion, at room temperature, to a variety of surfaces including metal, wood, masonry and polyester plastics, enabling immediate bonding between non-porous surfaces without solvent entrapment problems. Operating temperature: -196 to 121°C

6.3.5 The anti-abrasive coating to be applied as a bore coating to all cellular glass applications below -40°C and at the interface between cellular glass and polyisocyanurate insulation layers shall be a non flammable fire resistive coating designed for the specified purpose and having the following properties:

a. Solids Content: 50%

b. Service Temperature Limits: -196°C to 120°C

c. Color: Off White

d. Flammability: Dry-fire resistive

e. Acceptable materials:

Fire Resistive Anti-Abrasion Coating high solids, water-based fire resistive bore coating for the inner surfaces of cellular glass, rigid polyurethane, urea-formaldehyde, or polyisocyanurate foam insulation to reduce abrasion from vibration and temperature changes of piping or vessels. To have strong adhesive qualities through a wide temperature range permit its use on extremely low temperature and dual temperature equipment.

6.3.6 The metal sealant suitable for gun extrusion to a minimum diameter of 6mm at all overlaps in the metal weather barrier shall be a tough flexible elastomer based material, comprising polymeric vapor sealant of butyl rubber and hydrocarbon resin dissolved in white spirit/ xylol blend and pigmented with neutral fillers and aluminium paste. The material shall have the following properties:

a. Specific Gravity (Approx): 1.09

b. Service Temperature Limits: -40°C to 120°C

6.4 Metallic Jacketing materials shall be the following and shall be used as defined under Sections 6 to 12 inclusive.

6.4.1 The metal jacketing weather barrier shall be aluminized steel of the specified thickness comprising cold rolled mild steel sheet hot dip coated with commercially pure aluminium or aluminium silicon alloy, to a thickness of 40 microns per side, equivalent to a coating weight of 230/270 g/m^2 including both sides. The following acceptable materials shall be used:

a. Armco Aluminised Steel Type 2 as manufactured by Armco Inc, Ohio U.S.A.
b. Aludip BQ as manufactured by Coated Metals Limited, Swansea, U.K.
c. An approved equivalent.

6.4.2 The following profiles and thicknesses shall be used:

a. Vertical equipment above 750mm diameter, 0.70mm troughed sheets, 3.0m long x 800mm overall width, with 14mm deep troughs at 100mm pitch.

b. Vertical equipment below 750mm diameter and all horizontal equipment, 0.8mm thick flat sheet.

c. Pipework up to 150mm diameter over insulation, 0.5mm thick flat jacketing in roll form.

d. Pipework between 150mm and 450mm diameter over insulation, 0.6mm thick flat jacketing in roll form.

e. Pipework above 450mm diameter over insulation, 0.7mm thick flat jacketing in roll form.

f. Removable covers 1.2mm thick flat sheet.

6.4.3 The metal jacketing combining the requirements for a weather barrier with the function of reduction of noise levels and for application over Type 6 Sound Control insulation shall be a composite aluminium jacketing with a factory laminated lining of lead sheet. The jacketing shall comprise 0.40 mm aluminium EN AW-5005 or EN AW-3003 in accordance **ELOT EN 573 series** having 1.5 mm deep parallel ridges at 4.76mm pitch and in rolls 915mm wide. The lead lining shall be 0.38mm thick bonded to the jacket with a viscoelastic film. The jacketing shall have a Sound Transmission Class Rating of STC-26.

6.5 Accessory materials shall be the following and shall be used as defined under Sections 6 to 12 inclusive.

6.5.1 The tape used to secure all inner layers of polyisocyanurate insulation where applied to pipework in two halves, shall be a pressure sensitive adhesive backed unbleached white cloth tape, 50mm wide x 0.275mm thick

6.5.2 Bands used for securing insulation and jacketing shall be of stainless steel X5CrNi18-10 (1.4301) as per **ELOT EN 10088-2**, in the hot rolled annealed and descaled condition. The banding seals shall be 0.8mm thick stainless steel X5CrNi18-10 (1.4301). Bands and seals shall be cut from coil coated on both faces with either P.V.C. or P.V.F. having a minimum thickness of 10 microns. The following sizes shall be used:

6.5.2.1 Stainless steel banding 12mm wide x 0.40mm thick with stainless steel seals in the following locations.

a. All inner layers of polyisocyanurate insulation where applied to pipework in radiused and beveled segments.

b. All outer layers of cellular glass on pipework up to 500mm outside diameter over insulation.

c. All inner and outer layers of insulation on equipment up to 500mm outside diameter over insulation.

d. All inner layers on top bottom and horizontal vessel heads.

e. All aluminized steel jacketing on pipework and equipment up to 500mm outside diameter over insulation.

6.5.2.2 Stainless steel banding 19mm wide x 0.50mm thick with stainless steel seals in the following locations:-

a. All outer layers of cellular glass on pipework in excess of 500mm outside diameter over insulation.

b. All inner and outer layers of insulation on equipment in excess of 500mm outside diameter over insulation.

c All outer layers on top and horizontal vessel heads.

d. All aluminized steel jacketing on pipework and equipment in excess of 500mm outside diameter over insulation.

6.5.3 Screw fasteners, where permitted, shall be stainless steel self-tapping type with pan head No.8 (4.17 mm) x 12mm long. Screws shall have a cross recessed head slot type 11 'Pozidrive' pattern or equal and shall be complete with tight fitting P.V.C. washers.

6.5.4 The membrane for embedding between coats of the vapor barrier mastic on straight piping, shall be Foster open weave glass cloth No. 20 or an approved equal, having 18 x 12 threads per 25mm, a weight of 81 g/m^2 and a 1 x 1 leno weave.

6.5.5 Portable polyurethane foam dispensing kits for injection of insulation at flanges, valves, reducers etc. shall be Froth-Pak as manufactured by Insta-Foam or an approved equal, having a density of 43.2 kg/m^3.

7.0 GENERAL APPLICATION

7.1 Piping and equipment shall have all welding completed and shall be hydrostatically or pneumatically tested prior to application of insulation.

7.2 Only insulation and accessory materials that have been properly stored and kept dry and free from contamination shall be used. Preformed isocyanurate foam shall be stored in an area to provide sufficient protection from moisture, ultra-violet exposure and abuse.

7.3 Surfaces to be insulated shall be free from grease, loose scale, dirt and other foreign matter. The required degree of preparation of the painted surfaces shall be a combination of hand brushing, dusting and hand application of degreasing solvent as found necessary and agreed beforehand with the Owner.

7.4 The surfaces shall in addition be free from moisture and shall have been allowed time to thoroughly dry out before commencement of insulation application.

7.5 During wet weather conditions, the insulation shall be covered at all times with effective temporary polyethylene sheeting or cladding until the final application of metal jacketing has been accomplished.

7.6 All insulation material applied in one day shall have one coat of vapor barrier applied the same day. If it is found impracticable to apply the first coat of the vapor barrier, exposed insulation shall be temporarily protected with a combination moisture/ultraviolet barrier, such as an appropriate (black) polyethylene film, and sealed to the pipe or equipment surface. All exposed ends or edges of incomplete work shall be protected before stopping at the ends of each working day.

7.7 In cases where insulation has inadvertently become wet during installation, the application of the vapor barrier and metal jacketing shall be delayed until the insulation material has been allowed to thoroughly dry out. In cases where the vapor barrier has been applied over wet insulation or where for any reason drying out is not possible, the insulation material shall be completely replaced.

7.8 Insulation shall be supported by support rings at 3.6 m intervals on vertical lines and equipment. The width of the support ring shall be such that the inner layer(s) and one-half the outer layer of insulation shall be supported.

7.9 All equipment and piping insulation shall have a metal closure plate of width equal to the full thickness of insulation located at the bottom termination of the insulation equipment with straight side height exceeding 2.4 m shall have a support ring located at the top. The vapor barrier and jacket shall extend over the edge of the closure plate and terminate on the underneath side of the closure plate.

7.10 For skirts less than 1.2 m in diameter, the entire interior cavity of the skirt shall be filled with mineral wool packed to a density of 120 kg/m^3 and the skirt opening sealed by a rigid disc inserted into the opening and sealed with a 3.0 mm coat of vapor barrier mastic. When skirts are to be insulated by filling the cavity, the bottom of the skirt cavity, including anchor bolt openings, shall first be vapor sealed with a 3.0 mm coat of vapor barrier mastic. For skirts 1.2m and over in diameter, the bottom dome shall be insulated as the rest of the vessel and the skirt shall be insulated inside for a distance equal to four times the insulation thickness but not less than 300 mm. Vents located within the skirt insulation shall have 10mm thick insulation inserted on the side of the vent to prevent plugging of the vent due to icing. Vents on skirts filled with mineral wool shall be vapor sealed.

7.11 Vapor stops shall be installed at all pipe support locations and on piping or equipment locations requiring potential maintenance, such as valves, flanges and instrumentation connections to main piping or equipment, as follows:

7.11.1 A bond shall be affected between the pipe and the insulation terminal by the application of three component cryogenic adhesive as paragraph 6.3.4 to a wet/dried film thickness of approx 2.0mm. Application shall be extended over the prepared roughened pipe surface for 50mm and up the edge of the insulation. For multi-layer application -41°C and below application shall be up the edge of the first layer only of insulation.

7.11.2 For single layer applications -40°C and above, the vapor sealing mastic as paragraph 6.2.1 shall be dressed over the cryogenic adhesive on the edge of the insulation.

7.11.3 For multi-layer applications -41°C and below, cryogenic coating as paragraph 6.3.2 shall be dressed over the cryogenic adhesive on the edge of the insulation and carried over the stepped layers and beneath the vapor sealing mastic for 50mm to effectively complete the seal provided at the vapor stop. Cryogenic coating shall be applied in three coats to provide a minimum overall dried film of 0.87mm reinforced between the first and second coats with synthetic fabric as paragraph 6.3.3.

7.12 When insulation on operating piping is to be terminated, the sealing at the termination shall be with metal collars either welded or bolted onto the line.

7.13 Contraction joints shall be installed in the outermost, intermediate and inner layers of horizontal piping and equipment, and in all single layer installations, at the intervals specified in Table 9, with a minimum of one contraction joint midway between any two pipe supports or piping protrusions more than 0.8 m apart. For single layer application, two layers shall be used at the contraction joint. The

second layer shall be the same thickness as the first, and shall extend 75 mm on each side of the contraction joint in the outer layer.

7.14 Vertical lines and equipment having support rings shall have a contraction joint immediately below each support ring, except at the bottom.

7.15 Each contraction joint shall be filled with resilient glass fibre as paragraph 6.1.3, with fibres oriented normal to the direction of joint movement. The length of joints shall be in accordance with Table 9. For the innermost and intermediate layers, the thickness of uncompressed glass fibre shall be twice the length of the contraction joint. At installation, the glass fibre shall be compressed to one-half thickness. For the outer layer, the glass fibre shall be compressed at installation by a quarter of the thickness.

7.16 Contraction joints shall consist of segments cut out from unfaced glass blanket not less than 50 mm thick for pipe sizes DN 400 and below. Cutting of the segments shall be normal to the orientation and layup of the fibres to allow for expansion and contraction of glass fibre without crushing of the fibres. Above DN 400 pipe size, straight strips cut from glass blanket and layup orientation the same as for segments is permitted.

7.17 The cover over the outer layer joint shall be formed from 1.2mm thick flat butyl rubber sheet incorporating a single 20mm wide fold. The butyl sheet shall be adhered with a compatible adhesive, with the fold centrally positioned. The length of the cover shall be 100mm plus "L" from Table 9, and shall be secured on both sides with bands. The butyl cover shall be applied over the vapor barrier before thorough curing.

7.18 Wire is not to be used to secure this system. During construction, 50mm wide adhesive cloth tape bands shall be used to secure the inner layer(s) of the insulation and stainless steel bands for the outer layer. The aluminized steel jacket shall be secured with stainless steel bands. The type and method of securement for insulation and jacketing is summarized in Section 6.5.2.

7.19 In general, this specification calls for a basic insulation system consisting of multi-layer medium density polyisocyanurate foam/cellular glass insulation, enclosed by reinforced vapor barrier mastic and aluminized steel jacket.

7.20 Where the insulation system for straight piping and equipment requires the total thickness to be supplied in two or more layers, the inner layer shall be shaped to conform to the metal surface in two or more segments. The outer layer(s) shall be formed to fit correctly over the inner layer(s) in either sectional or segmental form of the same standard length. Insulation for fittings and valves shall be in accordance with Section 9.0. For cellular glass insulation the segments shall be a nominal 600 mm length.

7.21 The use of broken pieces or defective insulation shall not be permitted. Cracks and voids in applied insulation shall not be acceptable. All joints shall be carefully fitted. The edges of blocks shall where necessary be rubbed or cut to a level so that joints are tight and uniform. Where butted joints do not fit closely, the voids shall be eliminated by refitting or replacing the insulation. Filling voids with joint sealer or mastic shall not be acceptable. Any damaged corners shall be trued before application.

7.22 Securement of metal jacketing shall be by means of metal bands in accordance with paragraph 6.5.2. The use of screws as paragraph 6.5.3 shall generally be limited to locations where banding will not provide adequate support such as for contraction joint covers, paragraph 8.21 and cryogenic valve covers, paragraph 9.7. On vertical piping and equipment, 'S' clips fabricated from stainless steel banding shall be incorporated in the circumferential joints of the jacketing where these are located between the contraction joint covers in order to prevent telescoping.

8.0 DETAILS OF APPLICATION – PIPEWORK

8.1 Insulation shall be preformed to fit the diameter of the pipe, fitting, or underneath layer of insulation, and shall be applied in staggered positions with all joints tightly fitted together. Gaps resulting from poor fit or damaged material are not permitted to be filled with joint sealer or mastic but shall be refitted.

8.2 For temperatures of -40°C and above, insulation shall comprise cellular glass to the requirements of paragraph 6.1.2 and applied in one layer up to 100 mm thick and in two layers for thicknesses in excess of 100 mm, arranged with all circumferential and longitudinal joints staggered.

8.3 The inside surface of all cellular glass insulation shall receive a bore coating of anti-abrasive compound as paragraph 6.3.5 and allowed to dry.

8.4 Prior to application of cellular glass insulation a joint sealant as paragraph 6.3.1 shall be applied at all circumferential and longitudinal joints to a wet film thickness of 3.2 mm. Application shall be to one only of the mating surfaces for the full depth of the insulation thickness before bringing the surfaces together. No sealant or adhesive shall be applied to any other insulation contact/bore faces.

8.5 Cellular glass sections shall be secured by stainless steel bands at 200 mm centers, machine tensioned and sealed. The seals shall be taped to provide a smooth surface for the outer coating.

8.6 For temperatures of -41°C and below, insulation for thicknesses of 140 mm and above shall be applied in three layers comprising an inner and an intermediate layer of medium density preformed polyisocyanurate foam to requirements of paragraph 6.1.1 followed by an outer layer of cellular glass to the requirements of paragraph 6.1.2. For thickness below 140 mm application shall be in two layers comprising an inner layer of preformed polyisocyanurate foam and an outer layer of cellular glass.

8.7 Polyisocyanurate sections shall be applied with end joints offset at least 75 mm from the inner layer and longitudinal joints offset from the inner layer as paragraph 8.14.

8.8 Prior to application of inner and intermediate polyisocyanurate insulation layers, a joint sealer/adhesive as paragraph 6.3.1 shall be applied at all circumferential and longitudinal joints to a wet film thickness of 3.2mm. Application shall be to one only of the mating surfaces before bringing the surfaces together. For butt joints, sealant application shall ensure that adhesion to the pipe or previous layer does not take place.

8.9 Polyisocyanurate inner and intermediate insulation layers where applied in two halves, shall be secured with 50mm wide adhesive cloth tape bands applied with 50% overlap. Where applied in radiused and beveled segments, securement

shall be by 12mm wide x 0.4 mm thick stainless steel bands at 400mm centers, machine tensioned and sealed.

8.10 The cellular glass outer layer shall be applied to the requirements of paragraphs 8.3 to 8.5 inclusive and arranged with end joints offset at least 75mm from the inner layer and longitudinal joints offset from the inner layer as paragraph 8.12.

8.11 A slip layer shall be introduced between the polyisocyanurate intermediate layer and the cellular glass outer layer. This shall comprise an aluminium foil/polyester laminate as paragraph 6.2.2 arranged with 50mm overlaps sealed with a compatible adhesive.

8.12 Longitudinal joints in pipe sections applied in two halves shall be offset by 90° in successive layers. Longitudinal joints in the application of radiused and beveled lags shall be arranged with an offset equivalent to half the segment width or with the maximum offset that can be obtained. The middle of the bottom innermost segment shall be placed on the vertical plane.

8.13 Contraction joints in horizontal and vertical piping shall be installed as specified in paragraphs 7.13 to 7.17 inclusive.

8.14 The entire outer surface of the cellular glass insulation shall be sealed with a reinforced double layer of the specified vapor barrier mastic as paragraph 6.2.1 and 6.5.4.

8.15 In way of valves and fittings where a metal weather barrier is not being applied, a third coat of vapor barrier mastic shall be applied. The additional coat shall extend beneath the adjacent metal weather barrier for a minimum distance of 75 mm.

8.16 The reinforced triple layer of vapor barrier as paragraph 8.15 shall also be used to seal pipe supports to piping insulation.

8.17 Insulation on cylindrical straight sections of pipework shall be covered with an additional protective metal jacket of aluminized steel sheeting to the requirements of Section 6.4. The jacketing shall be applied with minimum longitudinal laps of 50 mm and minimum circumferential laps of 75 mm. Circumferential overlaps shall incorporate an 8mm ball swage in the upper sheet, located as near to the edge as practicable. Longitudinal overlaps shall be arranged along the lower half of the pipe, weather side down at approximately 135° or 225° positions or in the case of vertical pipes away from the prevailing weather conditions. Longitudinal overlaps shall also incorporate an 8mm ball swage located as near to the edge as practicable.

8.18 All jacketing overlaps shall be sealed by the application of a gun extruded bead of flexible metal sealant as paragraph 6.3.6. The bead shall for convenience be located within the ball swage provided at circumferential and longitudinal overlaps as paragraph 8.17 and shall be a minimum of 6.0mm diameter or sufficient to provide an effective seal with the overlaps drawn tight. The jacketing shall be secured with stainless steel bands positioned adjacent to the ball swage at circumferential overlaps and intermediately at a minimum of 225mm centers. Bands shall be machine- tensioned and sealed employing stainless steel seals.

8.19 The jacketing finish is not required to extend over surfaces of double curvature, elbows, tees, flanges, valves, etc., but shall be lapped over the additional vapor barrier mastic coat as detailed in paragraph 8.15 and shall be circumferentially sealed at the jacket terminals with lap sealant as paragraph 8.18.

8.20 Vents, sample connections and uninsulated instrument connections shall be insulated. Application of the vapor barrier and metal jacket shall follow the specified requirements for piping systems.

8.21 Following satisfactory installation of contraction joints to the requirements of paragraphs 7.13 to 7.17 inclusive. 0.8mm thick flat aluminized steel protective outer covers shall be fitted. The covers shall be screwed and banded to the adjacent straight pipe jacketing from one side only in the case of horizontal pipes, or from the top side only in the case of vertical pipes. The opposite side shall be left free to absorb expansion/contraction by the formation of a folded or labyrinth joint arranged to accommodate the adjacent straight pipe jacketing in such a way as to absorb anticipated movement whilst remaining weather tight and functional in service.

9.0 DETAILS OF APPLICATION - FITTINGS, VALVES AND FLANGES

9.1 All insulation for fittings, valves and flanges shall be equal in thickness and type to that applied to adjacent or equivalent sized piping.

9.2 Individual layers of insulation for fittings, flanges and valves shall to the maximum extent be supplied and fitted in two piece fabricated covers with individual segments cemented together. For offsite shop fabrication, bitumen having a high melt point, may be employed. Application for the joints between the upper and lower halves and between the halves and adjacent piping insulation shall be in the same manner as specified for the respective insulation layers on straight piping.

9.3 Fabricated insulation shall fit the surface of flanges, fittings and valves, to the closest possible extent and with as few voids as possible. All joints shall be tightly fitted together and staggered where possible.

9.4 The jacketing finish applied to adjacent straight piping is not required to extend over surfaces of double curvature, elbows, tees, flanges, valves, etc. At all fittings the vapor barrier application shall be in accordance with paragraphs 8.14 and 8.15 and shall be triple layer as specified except that a synthetic reinforcement membrane as paragraph 6.3.3 shall be used instead of a glass membrane.

9.5 Securement of insulation shall be by stainless steel bands to the extent possible. Wire is only permitted for installations where bands could not secure the system.

9.6 The inner vapor barrier/slip layer paragraphs 6.2.2 and 8.11 in the case of fittings involving multi-layer application shall be substituted by a butyl rubber based elastomeric coating as paragraph 6.2.4. The coating shall be applied in two coats to provide a dried film of 0.5mm and may be factory applied.

9.7 Insulation for valves operating at temperatures -41°C and below shall be generally in the form of a "D" box formed from 50mm thick cellular glass. This shall be built up from the adjoining pipe insulation as necessary to provide a thickness of insulation including urethane foam as required for the valve size, and including the full thickness of insulation above the bonnet flange. Insulation shall incorporate the following requirements:

9.7.1 Adjacent to the valves, the insulation layers on adjoining pipe shall be stepped in order to provide optimum cavity conditions for foaming.

9.7.2 The valve bodies including bonnet flanges shall be initially wrapped with 25mm thick glass fibre blanket 24 kg/m^3 density prior to foam application.

9.7.3 With the exception of the top cover, the cellular glass insulation shall be built up complete with inner vapor barrier paragraph 6.2.4, outer vapor barrier paragraph 6.2.1, and aluminized steel outer cover paragraph 6.4.1 prior to foam cavity filling.

9.7.4 Urethane foam employing the dispensing kit method, paragraph 6.5.5 shall be installed at a density of 43.2 kg/m^3 to completely fill the void between the valve body, the cellular glass outer cover and the adjoining stepped pipe insulation.

9.7.5 On completion of foaming, the foam shall be shaved level with the top of the cellular glass, and the inner vapor barrier as paragraph 6.27 then applied. Application of the cellular glass top layer and associated vapor barrier, paragraph 6.2.1 shall be followed by the final application of the removable aluminized steel top cove.

9.8 Valves in LNG service will have extended bonnets/shafts of sufficient length to allow at least the full insulation thickness to be applied above the bonnet flange. The valve manufacturer will also have provided an insulation collar/drip plate at the point above which insulation must not be applied in order to allow a heating path and to ensure that the stuffing box packing remains at ambient temperature. The insulation shall be carried up such length of the valve bonnet extension as may be bare below the drip plate. Such insulation shall be of reduced thickness to ensure that the drip plate flashes over the insulation and shall be sealed at the underside with reinforced metal sealant as described in paragraph 6.3.6.

9.9 For valves without extended bonnets, the insulation shall be carried up the bonnet flange and cut back as required in order to leave the valve yolk and gland free of insulation. Where the resultant depression could result in the accumulation of water, a 20mm deep drain channel shall be formed in the top of the insulated metal box in order to drain off the water.

10.0 DETAILS OF APPLICATION - PIPE SUPPORTS

10.1 High density cradle type pipe supports shall be of approved pre-engineered design, incorporating a molded heavy density urethane layer bonded with a galvanized steel weather shield and assembled with a steel crade. The urethane layers shall be stepped and together with the metal jacketing shall be sufficiently extended to facilitate incorporation within the adjacent insulation system. The supports shall meet with the design requirements in respect of compressive strength under sustained load, thermal conductivity, coefficient of friction, service temperature and flammability.

11.0 DETAILS OF APPLICATION - EXPANSION/CONTRACTION JOINTS

11.1 Pipe expansion/contraction joints (bellows) located in lines which are insulated shall also be insulated.

11.2 The proposed design of the bellows insulation system shall be reviewed and approved by the Owner.

12.0 DETAILS OF APPLICATION - EQUIPMENT - HEAT EXCHANGERS, VESSELS, DRUMS, PUMPS

12.1 Insulation and jacketing for equipment up to 750 mm outside diameter shall be applied as described for straight pipework.

12.2 Insulation shall be preformed to fit the diameter of the equipment or underneath layer of insulation, and shall be applied in staggered positions with all joints tightly fitted together. Gaps resulting from poor fit or damaged material are not permitted to be filled with joint sealer or mastic but shall be refitted.

12.3 The innermost and intermediate layers of insulation shall be polyisocyanurate curved segments, applied with all circumferential and longitudinal joints staggered and sealed with a low temperature adhesive/sealer as paragraph 6.3.1.

12.4 The outer layer of insulation shall be cellular glass curved segments applied with all horizontal and vertical joints sealed with joint sealer as paragraph 6, 3.1.

12.5 Where vessel diameters or underneath layer of insulation can accommodate pipe covering, it shall be used.

12.6 A slip layer shall be introduced between the polyisocyanurate intermediate layer and the cellular glass outer layer. This shall comprise an aluminium foil/ polyester laminate as paragraph 6.2.2 arranged with 50 mm overlaps sealed with a compatible adhesive. In the case of flanges and irregular surfaces the inner vapor barrier/slip layer shall be -substituted by a butyl rubber based elastomeric coating as paragraph 6.2.7. The coating shall be applied in two coats to provide a dried film of 0.5mm.

12.7 The inside surface of all cellular glass insulation shall receive a bore coating of anti-abrasive compound as paragraph 6.3.5 and allowed to dry.

12.8 All layers shall be secured with stainless steel bands in accordance with paragraph 6.6.4. The outer layer shall be applied in the same manner as the inner layer(s) with joints staggered at least 150 mm from the inner layer(s). Bands supporting the insulation on vessel heads shall radiate from a 6 mm diameter stainless steel floating ring. Spacing of securement bands shall be identical to those for pipework Section 7.

12.9 The entire outer surface of the cellular glass insulation shall be sealed with a reinforced double or triple layer of the specified vapor barrier mastic as paragraphs 6.2.1 and 6.5.4 applied to the requirements of paragraphs 8.14 and 8.15.

12.10 In way of areas of double curvature, vessel heads (other than top heads), bolted joints, manways etc. the vapor barrier application shall be in accordance with paragraphs 8.14 to 8.15 inclusive and shall be triple layer as specified except that a synthetic reinforcement membrane as paragraph 6.3.3 shall be used instead of glass membrane.

12.11 Insulation on cylindrical straight sections of vessel shells shall be covered with an additional protective metal jacket of aluminized steel sheeting to the requirements of paragraph 6.4. The jacketing shall be applied with minimum longitudinal and circumferential laps of 75 mm, the laps being arranged to shed water and located away from the prevailing weather conditions. Where corrugated sheets are used a minimum of two corrugations overlap shall be employed at vertical joints.

12.12 All jacketing overlaps shall be sealed by the application of a fire resistive joint sealer to paragraph 6.3.6 in the form of a gun extruded bead of metal sealant, minimum 6.0 mm diameter. The jacketing shall be secured with stainless steel

bands at 450 mm centers. Bands shall be machine tensioned and sealed. In the case of vertical vessels, positioning of bands shall be arranged to coincide with all circumferential overlaps. 'S' clips shall be installed as required at horizontal over taps for additional support.

12.13 The jacketing finish applied to straight shell sections is not required to extend over surfaces of double curvature, vessel heads, (other than top heads) bolted joints, manways, etc., but shall be lapped over the additional vapor barrier mastic coat as detailed in paragraphs 12.10 and 8.15 and shall be circumferentially sealed at the jacket terminals with lap sealant as paragraphs 12.12.

12.14 Insulation below the metal insulation closure plates on skirts, legs and saddles is strictly prohibited.

12.15 Insulation support rings shall receive the thickness of insulation, as specified in paragraph 3.7.

12.16 Contraction joints in horizontal and vertical equipment shall be installed as specified in paragraph 7.13 to 7.17 inclusive.

12.17 For heat exchangers, and horizontal vessels, termination of insulation on saddle supports shall be accomplished in accordance with paragraph 3.4.

12.18 For vertical vessels termination of insulation on skirt, leg or lug supports shall be accomplished in accordance with paragraph 7.9.

12.19 Curved segments or beveled block shall be fabricated to fit the outside diameter of equipment or inner layers of insulation up to 3600 mm. Flat black can be used for diameters above 3600 mm.

12.20 All butt joints shall be installed without a gap.

12.21 Insulation for equipment having irregular surfaces may be field fabricated to fit the particular contours on which it is to be used.

12.22 The top heads of vertical vessels shall be protected with 0.8mm thick aluminized steel sheet arranged in segmental pattern screwed at the overlaps with stainless steel self tapping screws and flashed over corrugated shell jacket. A 25mm thick layer of heavy density 150 Kg/m^3 preformed mineral wool slabs as para. 6.1.4 shall be applied as a cushioning layer over the vapor barrier mastic, to prevent any type of puncture of the vapor barrier by the self tapping screws during application of the steel sheeting.

13.0 DETAILS OF APPLICATION - SOUND CONTROL

13.1 For combined sound control/cold insulation Type 6, the application of insulation materials including sealants, mastics, outer jacketing, etc. shall closely follow requirements for cold insulation as described under sections 8.0 to 12.0 inclusive, except that the inner layer of insulation shall consist of 50 mm thickness of preformed mineral wool, supplied in pipe sections, radiused segments or flat slabs, and securely banded into position in a similar manner as described for cellular glass.

13.2 The outer metal weather/acoustical jacketing shall be a bonded lead and aluminium laminate as paragraph 6.4.3 and shall be applied and secured as described for standard jacketing paragraphs 8.17, 8.18, 12.11 and 12.12 but shall in addition be extended over surfaces of double curvature, elbows, tees, flanges, valves, vessel heads, etc.

13.3 On all lines designated to receive sound and thermal control insulation, the piping expansion joints (bellows) if a part of the line, shall also be insulated for sound and thermal control.

13.4 The design of the sound and thermal control insulation on piping expansion joints shall be thoroughly reviewed and approved by the OWNER.

13.5 Insulation contraction joints shall be provided for sound control/cold insulation Type 6.

14.0 EUROPEAN STANDARDS AND SPECIFICATIONS

14.1 The following European standards apply:

ELOT EN 14308 "Thermal insulation products for building equipment and industrial installations- Factory made rigid polyurethane foam (PUR) and polyisocyanurate foam (PIR) products –Specifications

ELOT EN 13470 "Thermal insulating products for building equipment and industrial installations – Determination of the apparent density of preformed pipe insulation".

ELOT EN ISO 13787 Thermal insulation products for building equipment and industrial installations. Determination of declared thermal conductivity.

ELOT EN ISO 4590 "Rigid cellular plastics -- Determination of the volume percentage of open cells and of closed cells".

ELOT EN 1608 "Thermal insulating products for building applications. Determination of tensile strength parallel to faces".

ELOT EN 13823 "Reaction to fire tests for building products. Building products excluding floorings exposed to the thermal attack by a single burning item"

EN ISO 844
"Rigid cellular plastics - Determination of compression properties"

ELOT EN 14305 "Thermal insulation products for building equipment and industrial installations - Factory made cellular glass (CG) products"

ELOT EN ISO 15106-1 "Plastics - Film and sheeting - Determination of water vapour transmission rate - Part 1: Humidity detection sensor method"

TABLE 1

NOMINAL THICKNESS OF INSULATION (MILLIMETRES) – TYPE 6 (COMBINED SOUND CONTROL AND REDUCTION OF HEAT GAIN)

DN/O.T.	-20 to -20	-21 to -30	-31 to -40	-41 to -56	-57 to -71	-72 to -86	-87 to -101	-102 to -116	-117 to -132	-133 to -146	-147 to -161	-162 to -176
15	75	75	75	100	100	100	100	100	100	100	100	100
20	75	75	75	100	100	100	100	100	100	100	100	125
25	75	75	75	100	100	100	100	100	100	100	125	125
40	75	75	75	100	100	100	100	100	100	125	125	125
50	75	75	75	100	100	100	100	100	125	125	125	125
80	90	90	90	100	100	100	125	125	125	125	125	140
100	90	90	90	100	100	100	125	125	125	125	140	140
150	90	90	100	100	100	125	125	125	125	140	150	165
200	90	90	100	100	100	125	125	125	140	150	165	165
250	90	90	100	100	125	125	125	140	150	150	165	180
300	90	90	100	100	125	125	125	140	150	165	165	180
350	90	90	100	100	125	125	140	140	150	165	180	190
400	90	90	100	100	125	125	140	140	165	165	180	190
450	90	90	115	100	125	125	140	150	165	165	180	190
500	90	100	115	100	125	125	140	150	165	180	180	190
600	90	100	115	125	125	125	150	150	165	180	190	200
750	90	100	115	125	125	140	150	165	165	180	190	200
900	90	100	115	125	125	140	150	165	180	190	200	200
1050	90	100	115	125	125	140	150	165	180	190	200	230
Flat	90	115	125	125	125	150	180	190	200	230	230	230

O.T. Denotes Operating Temperature

DN Denotes Nominal Diameter of Pipe

TABLE 2

THICKNESS OF INDIVIDUAL LAYERS – TYPE 6

TOTAL THICKNESS	INNER LAYER ROCK WOOK	INTERMEDIATE LAYER(S) POLYISOCYANURATE	OUTER LAYER CELLULAR GLASS
75	50	-	25
90	50	-	40
115	50	-	65
100	50	-	50
125	50	25	50
140	50	40	50
150	50	50	50
165	50	60	50
180	50	40+40	50
190	50	40+50	50
200	50	50+50	50
230	50	65+65	50

TABLE 3

NOMINAL THICKNESS OF INSULATION (MILLIMETRES) – TYPE 7 AND 8 (PREVENTION OF SURFACE CONDENSATION / REDUCTION OF HEAT GAIN -40^{0}C AND ABOVE)

DN /O.T.	+20 to +10	+9 to 0	-1 to -10	-11 to -20	-21 to -30	-31 to -40
15	40	40	40	50	65	65
20	40	40	40	50	65	65
25	40	40	50	50	65	65
40	40	40	50	50	65	75
50	40	50	50	65	65	75
80	40	50	65	65	75	75
100	40	50	65	65	75	90
150	40	50	65	75	75	90
200	40	50	65	75	90	100
250	40	50	65	75	90	100
300	40	50	65	75	90	100
350	40	50	65	75	90	100
400	40	65	65	75	90	100
450	40	65	65	75	90	115
500	40	65	75	75	100	115
600	40	65	75	75	100	115
750	40	65	75	90	100	115
900	40	65	75	90	100	115
1050	40	65	75	90	100	115
Flat	50	65	75	90	115	125

O.T. Denotes Operating Temperature

DN Denotes Nominal Diameter of Pipe

TABLE 4

NOMINAL THICKNESS OF INSULATION (MILLIMETRES) – TYPES 7 AND 8 (PREVENTION OF SURFACE CONDENSATION / REDUCTION OF HEAT GAIN -41°C AND BELOW)

DN /O.T.	-41 to -56	-57 to -71	-72 to -86	-87 to -101	-102 to -116	-117 to -132	-117 to -132	-133 to -146	-162 to -176
15	90	90	90	90	90	90	90	100	100
20	90	90	90	90	90	90	100	100	115
25	90	90	90	90	90	100	100	115	115
40	90	90	90	100	100	100	115	115	125
50	90	90	90	100	100	115	115	125	125
80	90	90	100	115	115	115	125	125	140
100	90	100	100	115	115	125	125	140	140
150	90	100	115	115	125	125	140	150	165
200	100	100	115	125	125	140	150	165	165
250	100	115	115	125	140	150	150	165	180
300	100	115	125	125	140	150	165	165	180
350	100	115	125	140	140	150	165	180	180
400	100	115	125	140	140	165	165	180	190
450	100	115	125	140	150	165	165	180	190
500	100	115	125	140	150	165	180	180	190
600	115	115	125	150	150	165	180	190	200
750	115	125	140	150	165	165	180	190	200
900	115	125	140	150	165	180	190	200	200
1050	115	125	140	150	165	180	190	200	230
Flat	125	140	150	180	190	200	230	230	230

O.T. Denotes Operating Temperature

DN Denotes Nominal Diameter of Pipe

TABLE 5

THICKNESS OF INDIVIDUAL LAYERS – TYPE 7 AND 8 (-40^0c AND ABOVE)

TOTAL THICKNESS	INNER LAYER	OUTER LAYER
40	40	-
50	50	-
65	65	-
75	75	-
90	90	-
100	100	-
115	50	65
125	50	75

TABLE 6

THICKNESS OF INDIVIDUAL LAYERS – TYPE 7 AND 8 (-41^0c AND BELOW)

TOTAL THICKNESS	INNER LAYER	INTERMEDIATE LAYER(S)	OUTER LAYER
90	40	-	50
100	50	-	50
115	65	-	50
125	75	-	50
140	50	40	50
150	50	50	50
165	50	65	50
180	65	65	50
190	65	75	50
200	75	75	50
230	50	65+65	50

TABLE 7

NOMINAL THICKNESS OF INSULATION (MILLIMETRES) – TYPE 9 (PERSONNEL PROTECTION)

DN /O.T	-10 to -62	-63 to -73	-74 to -84	-85 to -95	-96 to -106	-107 to -117	-118 to -128	-129 to -140	-141 to -151	-152 to -162	-163 to -173
Up to50	25	25	25	25	25	25	25	25	40	40	40
80	25	25	25	25	25	40	40	40	40	40	40
100	25	25	25	25	40	40	40	40	40	50	50
150	25	25	25	40	40	40	40	40	50	50	50
200	25	25	25	40	40	40	40	40	50	50	50
250	25	25	25	40	40	40	40	50	50	50	50
300	25	25	25	40	40	40	40	50	50	50	50
350	25	25	25	40	40	40	40	50	50	50	50
400	25	25	25	40	40	40	40	50	50	50	50
450	25	25	40	40	**40**	40	50	50	50	50	65
500	25	25	40	40	**40**	40	50	50	50	50	65
600	25	25	40	40	**40**	40	50	50	50	65	65
750	25	25	40	40	**40**	40	50	50	65	65	65
900	25	25	40	40	**40**	40	50	50	65	65	65
Over 900	25	40	40	40	**50**	50	50	65	65	65	80

O.T. Denotes Operating Temperature

DN Denotes Nominal Diameter of Pipe

TABLE 8

THICKNESS OF INDIVIDUAL LAYERS – TYPE 9

TOTAL THICKNESS	INNER LAYER	OUTER LAYER
25	25	-
40	40	-
50	25	25
65	25	40
80	40	40

TABLE 9

MAXIMUM EXPANSION CONTRACTION (E/C) JOINT SPACING

	LENGTH OF E/C (L)			
OPERATING TEMPERATURE RANGE DEG^{0}C	E/C JOINT SPACING (METRES)	INNER LAYER (MILLIMETRES)	INTERMEDIATE (MILLIMETRES)	OUTER (MILLIMITRES)
-173 to -74	6.0	100	150	50
-73 to -18	6.0	500	N/A	50
-17 to +20	12.0	N/A	N/A	50

N/A = Not Applicable

E/C = Expansion / contraction joint collar having a length (L) as indicated in the Table and fitted in accordance with paragraphs 6.8 to 6.12 inclusive.