TECHNICAL SPECIFICATION

THERMAL INSULATION
(AMENDMENTS/SUPPLEMENTS TO THE CINI MANUAL "INSULATION FOR INDUSTRIES")

DEP 30.46.00.31-Gen.

July 1999

DESIGN AND ENGINEERING PRACTICE

PREFACE

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The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for external thermal insulation of above ground surfaces of equipment and piping.

This DEP is based on the *CINI Manual "Insulation for Industries" (English Version), dated 1997-11-03.

Note: * CINI = Committee Insulation Netherlands Industry

This DEP replaces the DEP of the same number dated December 1988. This revision also incorporates the relevant contents of DEP 30.46.00.32-Gen. dated October 1988 and that DEP is now withdrawn.

This DEP is divided into six parts:

- Part I gives an introduction, outlines the relationship between this DEP and the CINI Manual and explains the other parts. The CINI Manual covers both hot and cold insulation for indoor and outdoor facilities, but not all parts of the CINI Manual are applicable to thermal insulation practices within the Shell Group. However, the applicable material specifications and the numerous construction details, obtained from different disciplines and years of experience, form a good basis for a proper insulation standard.
- Part II contains standard practices and procedures not covered by the CINI Manual.
- Part III gives amendments and supplements to the CINI Manual. For ease of reference, the clause numbering of the CINI Manual has been used. Clauses of the CINI Manual that are not mentioned shall apply as written. Wherever reference is made to the CINI Manual it shall be understood to mean the CINI Manual as amended/supplemented by this DEP.
- Part IV specifies requirements and gives recommendations for inspection and maintenance of existing insulation systems which are not covered in the CINI Manual.
- Part V lists the publications referenced in this DEP.
- Appendices, containing diagrams and drawings.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors nominated by them (i.e. the distribution code is "C", as described in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, onshore and offshore oil and gas production facilities, loading and unloading terminals, and supply/ marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

For the purpose of this DEP the following definitions shall apply:

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorised to act for the Principal.

The **Main Contractor** is the party that carries out all or part of the design, engineering, procurement, installation and commissioning or management of a project. The Principal may sometimes undertake all or part of the duties of the Main Contractor.

The **Insulation Contractor** is the party that carries out the insulation works, including engineering, material supply, installation and quality control.

The **Manufacturer/Supplier/Vendor** is the party that manufactures or supplies materials, equipment and services to perform the duties specified by the Main Contractor and/or Insulation Contractor.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

PART II INSULATION SCOPE, ENGINEERING, APPLICATION AND QUALITY CONTROL

1. DESIGN OF THERMAL INSULATION SYSTEMS

1.1 EXTENT OF THERMAL INSULATION

Thermal insulation is required for:

- Thermal conservation of equipment and piping if economically justified.
- Temperature control of processes or products, e.g. to avoid condensation, solidification, or too high a viscosity.
- Personnel protection, i.e. on surfaces with a temperature of 70 °C or higher if these present a danger.
- Preventing or reducing damage to equipment and piping from exposure to freezing conditions.

In the engineering stage attention shall be paid to the insulation design, bearing in mind optimal life cycle costs, process requirements, maintenance aspects of insulated lines during operation and possible corrosion under insulation.

Insulation shall not be applied to piping or equipment that has been designed to emit heat or where cooling is required or acceptable by the process (e.g. piping to air coolers, blow down systems and condensate return lines) if there is no heat recovery at the end of the line.

Each line should be insulated separately; a common insulation cover should not enclose adjacent lines.

If approved by the Principal, deviations shall be shown on the piping drawings.

Valves, flanges and nozzles shall be insulated, unless other requirements are overruling, e.g.:

- Flanges in hydrogen service shall not be insulated.
- Flanges in systems containing hydrocarbons above their auto-ignition temperature shall not be insulated.
- The 80% rule for bolting has been applied to flanges in accordance with ASME B31.3 (ref. DEP 31.38.01.11-Gen.).

Valves and flanges in piping shall be provided with removable insulation covers.

Nameplates and stampings shall be left clear of insulation or shall be fitted on the outside of the cladding.

All metal surfaces under insulation shall be suitably protected with a complete paint system in accordance with DEP 30.48.00.31-Gen. or DEP 70.48.10.10-Gen.

1.2 INSULATION THICKNESS

The insulation thickness shall be determined by means of the following formula:

Q x CC + P = minimum

in which

Q = Insulation cost per unit for flat surface or unit of pipe length, including material, fastening, weather-proofing, labour, packing, transportation and tax cost (variable costs) at the time of installation.

Fixed costs, such as scaffolding and metal surface preparation cost, shall not be included.

Since a large insulation thickness may result in considerable extra capital costs for pipe bridges, civil work, etc., the extra costs per unit of insulation thickness shall also be included in Q.

CC = Capital Charge % based on required return on invested capital, service life, depreciation scheme and tax rates which should be determined for each insulation project. Payout time calculations are not recommended.

P = Annual operating costs, i.e. the cost of heat loss per unit of flat surface or unit of pipe length.

Computer software called TICP ("Thermal Insulation Calculation Program") is available via CINI and includes insulation calculation programs for economic insulation thickness, heat losses, etc.

For new construction projects and major rejuvenation/maintenance works these programs should be used to determine the economic insulation thickness. Other software may be used to arrive at an economical insulation thickness, as long as the same parameters and formulae are used as in the TICP software. The use of other software shall require the approval of the Principal.

Thickness of hot insulation should be calculated on the basis of local data on insulation, energy costs and capital charge factor. Furthermore, if for process reasons the allowable temperature drop is limited, e.g. to avoid condensation, solidification, etc., the required insulation thickness shall be calculated separately, but should not be less than the economic insulation thickness.

The thickness of cold insulation systems should be calculated on the following basis:

- The heat gain for piping in off-plot areas shall not exceed 28 W/m^2. Solar radiation shall be taken into account.
- For in-plot process areas surface condensation at the vapour barrier surface shall be allowed for a limited period only, based on local weather conditions and economics.

For quick reference and a first indication, thermal insulation tables of Manufacturers'/Supplier's could be used. Appendix 1 gives the input data which could be used to check the validity of the Manufacturers'/Supplier's calculated thermal insulation thickness tables.

1.3 PERSONNEL PROTECTION

Surfaces operating at temperatures above 70 °C and accessible from normal working areas and access ways shall be provided with personnel protection to a height of 2000 mm above the walking level. The protection shall be restricted to a distance of not more than 800 mm horizontally from access walkways and normal working areas.

If personnel protection is required, physical barriers such as open mesh guards, protective metal sheeting/screens (see Appendix 6B) or hand railings and hazard markings shall be used instead of insulation, if the surface process temperature is $\leq$ 250 °C.

For surface process temperatures > 250 °C, insulation is to be used for personnel protection; its thickness shall not be less than 25 mm. The economic insulation thickness should be sufficient for personnel protection. The insulation thickness should be obtained by calculation (TICP or other approved software).

Recommendations for the distances of open mesh guards and protective metal sheeting/screens from bare surface and insulation thickness are given in Appendix 6a and 6b.

1.4 LAYERS OF INSULATION

Hot insulation shall be applied in a minimum number of layers of commercially available thicknesses. Its total thickness shall be as close as possible to the economic insulation thickness and shall be rounded off to the upper commercially available thickness.

To reduce heat losses, insulation applied in two or more layers shall have staggered joints. Circumferential joints between segments in adjacent lengths of pre-formed rigid insulation shall also be staggered.

If economically attractive, a combination of not more than two different insulating materials may be used.

The layering of cold/cryogenic insulation should comply with the layering as indicated in Appendix 2.

2. MAIN CONTRACTOR AND INSULATION CONTRACTOR INVOLVEMENT

2.1 MAIN CONTRACTOR INVOLVEMENT

The Main Contractor shall prepare a detailed specification, isometric drawings and line designation tables for the Insulation Contractor according to the materials selected, including tables showing operating temperatures, type of insulation and economic insulation thickness, all of which shall be approved by the Principal. For items that are not covered in the DEP or CINI Manual, the Main Contractor shall carry out a detailed design of the insulation system.

The extent of thermal insulation shall be in accordance with Section (1.1) of Part II.

The method for calculating the economic thickness of insulation shall be in accordance with Section (1.2) of Part II.

2.2 INSULATION CONTRACTOR INVOLVEMENT

The Insulation Contractor providing the insulation for new construction or maintenance projects shall also supply the insulation materials, jacketing and fastening materials, unless otherwise stated by the Principal. The insulation system and the materials selected shall comply with this DEP. Alternatives shall be submitted to the Principal for approval. The alternatives shall be supported by references (e.g. track records) and test certificates from a qualified laboratory and/or test reports. Tests shall be carried out in accordance with the applicable test methods.

For the execution of the work the Insulation Contractor shall submit a method statement including the execution plan, materials, skills and QA/QC procedures. The method statement shall cover hot and/or cold insulation, depending on the nature of work.

3. ENGINEERING OF INSULATION SYSTEMS

Design requirements for a hot insulation system should be such that ingress of water and capillary action are prevented, leaked product can drain off and water vapour or condensation can escape or drain off. Insulation collars shall be fitted to avoid any water ingress (see Appendix 8). Cold insulation systems shall be vapour tight.

The thermal insulation system for piping, tanks and equipment shall be able to cope with thermal expansion or contraction; therefore insulation and metal jacketing shall be provided with expansion or contraction joints.

Insulation adjacent to flanges in piping and equipment shall be terminated to allow removal of bolts without damage to that insulation. Bolt clearance from the flange to the insulation jacketing shall be at least the bolt length +30 mm.; for certain flange bolts, hydraulic bolt tension or torque equipment shall be used which requires greater bolt clearance. Mechanical/piping specifications should be consulted for these clearances.

The termination of the jacketing shall be water/vapour tight. Removable hot insulation around flanges, valves, etc. shall be designed to withstand frequent removal/re-installation without losing its properties. The mass of removable parts shall be less than 25 kg.

4. MATERIALS

Materials for insulation, fastenings and jacketing shall be selected from the materials described in Part III of this DEP and the CINI Manual. All materials and application methods shall be selected to suit the local weather and environmental conditions.

Insulation materials shall be free of asbestos. No CFCs shall be used in the production of PUR/PIR foam materials.

In hot insulation applications blankets shall only be used for shapes for which pre-formed pipe sections are not available.

If PUR/PIR foam materials are transported by ship, protection against salt spray and weathering shall be provided by wrapping them in ultraviolet-resistant polyethylene sheets or tarpaulin or by storing them in closed containers.

Basic premixed chemicals for in-situ moulded foam shall be produced freshly and used within the Manufacturer's advised shelf life of the product, taking into account all transportation and storage time spans. Transport and storage of the basic premixed chemicals for in-situ moulded foam shall be done in accordance with the Manufacturer's instructions.

5. APPLICATION

5.1 METHOD OF APPLICATION

Consideration should be given to various alternative methods for the manufacture, transport and application of insulation systems, e.g. prefabrication and installation of a complete insulation system on piping or equipment prior to transport, erection or installation. The use of mobile manufacturing facilities (e.g. for PUR/PIR materials) may be considered.

The insulation materials and their weather protection shall be installed so that water does not enter into the insulation material or between the insulation and the pipe/equipment surface during the design life.

5.2 INSULATION CONTRACTOR INVOLVEMENT

The Insulation Contractor shall be responsible for proper co-ordination of his work, the co-ordination with the Principal and other disciplines and the proper storage of the materials and equipment.

The application of insulation may be started once the systems are released for insulation. This means that testing, painting and electrical/steam tracing (if applicable) have been completed.

Before insulation work commences the Insulation Contractor shall observe the weather conditions and shall take temporary precautions if necessary to ensure proper application.

Boxing up schedules and/or sequences for spading points should be made available to the Insulation Contractor to ensure a safe and smooth start up.

5.3 SURFACE PREPARATION

Ingress of rainwater and corrosive products or condensation of water vapour in the insulation can cause severe underlagging corrosion of carbon steel and low alloy steel equipment/piping or stress-corrosion cracking of austenitic stainless steel. To prevent underlagging corrosion all steel surfaces shall be suitably painted with a paint system in accordance with DEP 30.48.00.31-Gen. or DEP 70.48.10.10-Gen. as applicable.

As an alternative, austenitic stainless steel may be cleaned with fresh water and, after being dried, wrapped in 100% pure aluminium foil, approximately 60 µm thick. Joints and ends shall be taped with self-adhesive aluminium tape. This aluminium foil will act as both a barrier coat and inhibitor.

Before the insulation is applied, the surface to be insulated shall be clean and dry.

5.4 JACKETING

All insulated equipment (except for PUR/PIR on tank shells) and piping shall be protected with a jacketing system, e.g. metal, reinforced mastic, tapes or GRE/GRP finishing.

The jacketing shall provide protection against water and weather, fire, oil spillage, mechanical wear or other damage. Due consideration shall be given to the choice of weatherproofing in terms of safety, life cycle cost, environmental/climate conditions, vulnerability to corrosion, effectiveness and maintainability.

If metal jacketing is used, sufficient space and drainage shall be provided to avoid internal accumulation of water caused by condensation, water vapour diffusion, capillary action and water ingress.

Aluminium sheets shall not be used as metallic jacketing for fire proofing of insulation.

The jacketing matrix in Appendix 3 indicates the recommended jacketing system.

5.5 VALVES, FLANGES, MANHOLES AND FITTINGS

Hot insulation of valves, flanges, manholes and fittings in piping and removable equipment dome heads shall be provided with removable insulation covers, with insulation wool at the inside fastened with clips. If frequent removal is needed, covers shall be provided with quick-release toggles which shall be locked when installed. Quick-release toggles shall not be fitted in overhead lines above walkways.

Typical removable covers for spectacle blind flanges in vertical and horizontal pipes are shown in Appendices 9 and 10.

Alternatively, mattresses may fitted in complicated configurations, but water ingress shall be avoided.

Attention shall be paid to the insulation details to prevent leaking product from entering into the line insulation during operation and/or when flanges are opened up during maintenance work. Drainage outlets should be provided to give visible indication of possible valve or flange leakage.

For cold/cryogenic insulation in-situ moulded/dispensed PUR/PIR (see Section (5.9.3)) or pre-formed sections shall be used.

If pre-formed sections are used, the insulation shall be pre-formed or fabricated in single-matched halves to the maximum extent possible. Where multi-layering is necessary, longitudinal and circumferential joints shall all be staggered. All individual segments shall be cemented together with suitable fabrication adhesive.

5.6 SEALING PLATES AND INSULATION COLLARS

Water-retaining insulation collars shall be fitted by the Insulation Contractor around all protruding parts of tanks, vessels and columns with operating temperatures between ambient and 150°C or with intermittent operation. These collars shall be executed in accordance with Appendix 8. A sealing plate shall be fitted around all protruding parts with sealed seams in accordance with Appendix 7.

For flammable products, insulation collars should be applied near flanges in order to prevent product from entering the insulation system. Alternative solutions for special cases may be submitted to the Principal for approval, e.g. cellular glass collars or insulation cement applications.

5.7 ROTATING EQUIPMENT

Pumps and compressors are normally not insulated, unless acoustic insulation is required. Protective fencing or perforated jacketing may be considered for personnel protection.

If insulation is necessary, e.g. for steam and gas turbines and boiler feed water pumps or electric traced cooling systems, it shall be applied by one of the following methods:

- Insulating blankets applied over the housing, stitched together with binding wire and covered with aluminium or aluminised steel cladding.
- Removable insulation mats or mattresses with glass fibre fabric finish, tailor made over the housing and fixed by lacing.
- A removable metal box, reinforced with angle iron and filled with loose insulation materials. A typical removable insulation cover for pumps is shown in Appendix 11.
- Insulation with e.g. sealed rope or flexible cell rubber around small bore tubing.

Insulation shall not be applied on pumps handling liquid hydrocarbon products.

5.8 PIPE SUPPORTS IN COLD INSULATION SYSTEMS

5.8.1 General requirements

PUR/PIR foam supports shall be designed and furnished as a complete assembly.

Supports shall be designed to withstand all service loads. Service loads shall include thermal stresses resulting from differential contraction of the foam and the pipe, thermal stresses resulting from the temperature gradient through the thickness of the insulation, clamping forces, mechanical loads applied by the piping system and any other loading that may be present at the support. The mechanical (vertical and horizontal) loads should be obtained from the pipe support drawings.

The maximum stresses in the foam shall be limited to 0.2 x the ultimate compressive strength and ultimate tensile strength respectively.

The PUR/PIR cradles shall be designed for all specified operating conditions, including differential expansion and contraction between PUR/PIR cradles and pipe.

The design shall also cope with tolerances of the outside diameter of the pipes and the inside diameters of the HD PUR/PIR supports.

The Main Contractor shall submit a proposal, supported by data sheets, test certificates, calculations, method statements of installation, etc., which shall cover all related requirements (e.g. thermal conductivity, mechanical properties, stresses, tolerances, etc.) to the Principal for approval.

5.8.2 Materials

The material for pipe supports shall be high density PUR/PIR, e.g. 160, 240 or 320 kg/m^3, with a minimum ultimate compressive strength of respectively 2, 4 or 7 MPa at 20 °C. The mechanical properties, such as compressive strengths, tensile strengths and stress-strain behaviour etc., shall be sufficient to withstand all service loads and thermal stresses.

The material shall be either moulds of applicable sizes or cut from bun stock.

Test results of the mechanical properties shall be submitted to verify the suitability of the service loads and the thermal stresses.

5.8.3 PUR/PIR support structure

PUR/PIR supports may be of either single or multi-layer construction and each layer shall consist of two seamless half-pipe sections. The layer thickness shall be identical to the line insulation and shall be staggered (see Appendix 15).

The factory-assembled support shall have a bonded extended vapour barrier covered with a bonded extended 0.6-0.8 mm thick metal support sheet. The top metal sheet shall overlap the bottom metal sheet.

All layers of PUR/PIR, vapour barrier and metal sheets shall be extended beyond the structural steel cradle.

For multi-layer systems, the half-pipe sections shall be factory-bonded into one integral unit. The adhesives shall remain flexible to accommodate contraction within the foam and remain effective within the required temperature range.

Unless otherwise specified, 360° assembled PUR/PIR supports for all pipe sizes shall have their top and bottom structural cradles fitted with bent lugs or welded angles to accept stainless steel bolts and nuts.

All carbon steel parts shall be hot dip galvanised.

Galvanic corrosion by contacts of different metals shall be avoided by the use of synthetic membranes.

All exposed cut surfaces of the PUR/PIR foam shall be coated with a layer of fire-retardant vapour barrier mastic, in order to protect the foam during the period between installation and line insulation application.

A typical pipe support is described in the CINI Manual (see CINI 5.1.09) and shown in Appendix 15.

5.9 IN-SITU MOULDED/DISPENSED PUR/PIR

5.9.1 General

In-situ moulded or dispensed PUR/PIR foam should only be applied in exceptional situations by the following methods:

a) via injection in a temporary mould around piping or equipment;

b) via injection (or pouring*) in an installed metallic jacketing (box) that acts as primary vapour barrier;

c) sprayed foam (e.g. on tanks walls, shop fabricated piping systems).

* Note: Pouring shall only be allowed for emergency maintenance, if injection equipment is not directly available.

Method (a) is the normally preferred method for dispensed PUR/PIR foam since the quality can be checked after removing the mould. Method (b) shall only be used for items that need to be removed for shutdowns (e.g. valve boxes and flange boxes). Method (c) is normally used for tank walls (ref. Section (5.13.3)) and in shop application of cold piping systems (e.g. LNG loading lines).

5.9.2 Injection Application (methods a and b)

The foam injection process shall be in accordance with the recommendations of the Manufacturer. Atmospheric site conditions (e.g. relative humidity, maximum and minimum temperatures) shall be provided to the Manufacturer to guarantee the injection foam (PUR/PIR). The product should be delivered on site in two components ready for use. The PUR/PIR foam shall have the properties as specified in CINI 2.7.01.

Pre-formed spacers shall be of PUR/PIR monolithic half-pipe sections, with a minimum density of 50 kg/m^3, designed to form compartments for the in-situ moulding operation. Spacers shall be fastened securely by means of stainless steel bands, filament tape or glue. The placing of the pre-formed spacers will depend on the location of supports, welds, auxiliaries, etc. and the dimensions of the formwork.

Spacers shall be accurately distanced in order to limit and define the necessary injection volumes.

The metal jacket mould shall be installed with overlaps of at least 50 mm over the pre-formed spacers with temporary bands; vapour barrier jacketing shall be installed with bands and with all joints and overlaps sealed. Sufficient ***injection and de-aeration*** holes shall be provided to ensure proper injection and sufficient drain holes shall be provided at the bottom to discharge condense/rain water

Clamps or special tools shall be fitted over the metallic jacketing in order to withstand the pressure loads resulting from foam expansion.

The cavity shall be injected in accordance with the recommendations of the Manufacturer, which shall determine the required time and calculated volume. The injection equipment shall comply with the recommendations of the Manufacturer and shall be suitable for that time and volume.

After the PUR/PIR has cured the clamps and formwork shall be removed. If the foam is found in good order the primary (e.g. mastic) vapour barrier shall be applied. For a metallic primary vapour (see Section (5.9.1b)) barrier the jacketing shall be inspected by knocking in order to detect voids. All voids shall be filled and all injection points and de-aeration/drain holes shall be closed with plastic grommets. All joints of the jacketing and the points/holes, closed with grommets, shall be sealed with aluminium jointing tape.

5.9.3 Valves, flanges, and manholes

If dispensed PUR/PIR is used, insulation valves, flanges, and manholes shall be insulated as follows (see Appendix 14):

PVC foil and a rock wool blanket, backed with aluminium foil and sealed off with tape, shall be wrapped around the valve, flange or manhole to avoid adhesion of the foam.

Shop-fabricated metal boxes, designed to withstand the pressure generated by the foam, shall be positioned and secured to encase the valve/flange/manhole. Prior to placing the box, all joints on the inside shall be covered with bitumen tape (CINI 3.3.02) and all the inside of the box shall be completely coated with an appropriate form release agent to allow re-use of the metal box after removal for maintenance.

The space inside the metal box shall be injected with PUR/PIR foam to a minimum density of 40 kg/m^3. After installation all seams and penetrations of the metal box shall be sealed with bitumen tape (CINI 3.3.02) or equivalent.

The thickness of the rock wool blanket, backed with aluminium foil, which acts as a secondary vapour barrier will depend on the dimensions of the valve/flange/manhole. The minimum thickness of the injected PUR/PIR foam shall be the same as the insulated thickness of the adjacent piping or equipment PUR/PIR insulation.

5.10 SHOP APPLICATION OF SPRAYED PUR/PIR PRE-INSULATED PIPE

5.10.1 General

Shop application of sprayed PUR/PIR is employed for the following cold temperature conditions:

System a) If the process temperature is higher than -50 °C and a secondary vapour barrier is not required;

System b) If the process temperature is lower than -50 °C.

In system (a), the PUR/PIR foam is sprayed onto straight pipe in a single monolithic application. The thickness does not require a secondary vapour barrier or multi layering. The process temperature for system (a) is generally between ambient and about - 50 °C. The primary vapour barrier shall be a GRE/GRP or a flexible flame retardant wrap jacketing.

Longitudinal contraction joints and fixed point shall be designed to avoid gaps due to contraction differential between pipe/equipment and PUR/PIR.

In system (b), two types of shop sprayed PUR/PIR foam insulation systems may be applied. This system is often applied to rundown and LNG loading lines. The two systems are the “slide through” and “shear key system”. With the “slide through system”, the pipe is free from the encapsulating insulation and slides through it. With the “shear key system”, the insulation is fixed to the pipe by a bonded high density PUR/PIR shear key, which anchors the insulation to the pipe at one point, only while the remaining pipe length slides through it. The process temperature for system (b) is generally between -50 °C and -165 °C. The primary vapour barrier shall be a GRE/GRP jacketing.

System (b) is indicated in Appendices 17 - 23.

5.10.2 Single sprayed monolithic PUR/PIR

The PUR/PIR insulation shall have the properties specified in CINI 2.7.01. The minimum density shall be 40 kg/m^3.

PUR/PIR shall be shop sprayed applied to straight pipe in a single monolithic application.

The primary vapour barrier shall be a GRE/GRP flexible flame retardant jacketing system. The flame spread shall be 5 mm, in accordance with ASTM D 635. All systems shall be UV resistant. The primary vapour barrier shall be applied over the PUR/PIR sprayed foam insulation.

Temporary insulation termination at field joints, contraction joints, and high density supports shall be protected from weather conditions with e.g. heat shrinkable sleeves or other suitable materials (e.g. coatings, sealants, adhesives and membranes, see CINI Manual). The temporary insulation termination shall be finished with pre-formed PUR/PIR sections in accordance with the requirements of the CINI Manual.

A detailed design including detail drawings and method statement shall be provided, with internal and external stresses due to loads and contraction taken into account. The method statement shall also include QA/QC procedures.

5.10.3 Slide Through and Shear Key Sprayed PUR/PIR

The PUR/PIR insulation shall have the properties specified in CINI 2.7.01. The minimum density shall be 40 kg/m^3.

The Main Contractor shall prepare a detailed design with drawings and a method statement, which shall contain application and QA/QC procedures. The design shall cover all aspects, e.g. temporary termination, contraction joints, internal and external stresses etc.

The system can be described as follows:

(1) **Shear Key**: A high density PUR/PIR shear key is bonded to the pipe for the inner layer of insulation only. This serves to anchor the insulation system at this point. The

remaining line portion is basically the slide through system, with the pipe sliding inside the insulation towards the shear key (see Appendices 18 and 19).

(2) **Slide Through**: The line must be allowed to slide easily through the foam during all stages of pipeline cool-down and warm-up when in operation. The insulation shall not be bonded to the pipe or forced to move with the pipe by attachments, branch connections or other restraints (see Appendix 20).

The shear key system shall be applied and built up as follows:

1. The existing coating shall be abraded.
2. Shear keys shall then be adhered to the pipe surface, employing cryogenic adhesive to a 4 mm wet film thickness and temporarily secured by three machine tensioned 20 mm x 0.5 mm thick stainless steel bands. Any excess cryogenic adhesive shall be cleaned off the pipe and the shear key.
3. Temporary bands shall be removed after the adhesive has fully cured.
4. Step 4 of the slide through system shall be followed as the shear key is applied.

The slide through system shall be applied and built up as follows:

1. Resilient layer of needle glass mat of 12 mm thickness, which will be compressed to 8 mm.
2. A first layer of sprayed PUR/PIR, with a thickness of approximately 55 mm.
3. After trimming of the first layer, an open weave glass cloth shall be spiral wound, with 50 mm overlaps, on top of the first layer.
4. On top of the open weave glass cloth, a second layer of sprayed PUR/PIR foam shall be applied, with a thickness of approximately 55 mm.
5. After trimming of the second layer of foam, an open weave glass cloth shall be spirally wound, with 50 mm overlaps, on top of the second PUR/PIR layer.
6. On top of the open weave glass cloth, a third layer of sprayed PUR/PIR foam shall be applied to the required thickness.
7. After trimming of the third layer and bevelling of the ends (termination), an initial spray coat of epoxy resin shall be applied to the insulation outer surface.
8. Before the epoxy resin gels, a layer of chopped strand glass mat shall be spirally wound onto the surface, with a 5 mm overlap. The mat shall be manually rolled with metal rollers to ensure it is thoroughly wetted out and any entrained air is released. This process shall be repeated a minimum of five times to build up to a 5.5 mm minimum thickness.
9. A final UV resistant resin rich layer shall be sprayed, into which surface tissue is spiral wound with a 50 mm overlap.
10. The bevelled ends of the PUR/PIR shall be covered with a hand lay-up of GRE, applied wet on wet with a 100 mm overlap feathered into the GRE coating on the pipe insulation. Caution shall be exercised to ensure GRE is not extended over the glass mat layer and onto the pipe.
11. The GRE coating shall be fully cured by heating at a time/temperature relationship recommended by the epoxy resin Manufacturer. The heating source should best be obtained by means of infrared radiation.

5.10.3.1 Primary Guides

High density primary guides shall comply with the requirements of Section 5.8, but shall be part of the “slide through system” (see Appendices 21, 22 and 23).

The primary guides shall be applied as follows:

1. Install the resilient layer of needle glass mat.

2. Wrap the area which is to receive the primary guide with polyethylene film. This film will prevent adhesion between the mat and the guide.

3. The “primary guide inner layer section” shall be checked for fit around the pipe and mat. Any mismatch shall be corrected by sanding. The tolerances shall be as indicated in Section 5.8.

4. The outer surface and edges of the inner layer shall be abraded by light blast cleaning with garnet or other suitable means to remove moulding wax and the foam skin to promote bonding between the sprayed polyurethane and GRE.

5. Mating longitudinal faces of the inner layer half sections shall be bonded using cryogenic adhesive, applied 2 mm thick to the faces, and banded in place.

6. The fixing of the inner layer shall be strong enough to maintain its concentric position and lateral location to the pipe in the rotation mode during the application stages of glass cloth, polyurethane foam and GRE.

7. As noted above, prior to spray application of foam, the edges of the guide inner layer that will be in contact with sprayed foam shall be abraded to expose the cell structure, to ensure adhesion with the sprayed foam.

8. The pipe section shall then be insulated with spray-applied reinforced polyurethane foam as stated in Section 5.10.3 above, while maintaining the correct position of the primary guide, and then finished with GRE.

9. After application of the GRE, the outer layer of the guide shall be checked for fit around the installed guide inner layer. Any mismatch shall be corrected by sanding. All surfaces of the guide outer layer shall be abraded by light blast cleaning with garnet or other suitable means to remove moulding wax and the foam skin to promote adhesive bonding and GRE bonding.

10. Mating faces of the guide outer layer half sections and the outer guide layer shall be bonded at the GRE on the guide inner layer using cryogenic adhesive, applied 2 mm thick to the surfaces.

11. The outer surface of the HD PUF outer guide layer shall then be sanded, checked for Outside Diameter tolerance, and vacuumed prior to application of the outer layer of GRE. The GRE shall be hand applied to achieve a minimum thickness of 5.5 mm (5.0 mm reinforced and 0.5 mm unreinforced surface layer). The Outside Diameter shall be maintained for guide clamp installation.

12. After the GRE outer layer has cured, the primary guide clamp shall be bonded to the GRE using cryogenic adhesive, at a thickness necessary to correctly position the lower clamp. The top half of the clamp shall be bonded with trowellable epoxy adhesive to seal the gap for the poured cryogenic adhesive.

13. The exposed face of the primary guide inner and outer layers shall receive temporary protection against ingress of moisture by applying three coats of primary vapour barrier mastic, with glass cloth reinforcement between the first and second coats. Petrolatum tape (see CINI 3.3.04), 75 mm wide, shall be applied to the pipe adjacent to the exposed guide edge, and the reinforced vapour barrier mastic extended 50 mm onto the tape on the pipe. A second wrap of petrolatum tape shall be applied over the mastic extension on the pipe and back on the exposed guide edge. The temporary protection shall be completely removed just prior to field insulation. This primary guide face shall be covered with polyethylene and maintained by the Insulation Contractor until final insulation is applied at this joint.

5.10.3.2 Field application

In areas where the spray method is not practicable and for field welds, pre-formed PUR/PIR shall be used and shall be finished in accordance with the requirements of the CINI Manual. The GRE cover shall be installed by the hand lay-up method. A method statement shall be provided.

5.10.3.3 GRE vapour barrier

The vapour barrier shall consists of a chopped strand glass fibre reinforced mat with epoxy resin applied by the winding method to form a vapour-tight, weather-resistant cover for the insulation material, strong enough to give mechanical protection and to take up contraction forces during cool-down.

The epoxy resin shall be Epikote 815, Epikote 215 or equivalent suitable for the chopped strand glass mat filament winding method and shall contain sufficient pigmentation to resist ultra-violet light exposure. Other composite laminates may be used provided they comply with the physical properties listed below.

Glass fibre reinforcement mat shall comprise continuous glass chopped strand roving made of E-glass, i.e. low-alkali glass of first quality and shall have a finish such as silane which is compatible with the epoxy resin. The continuous chopped strand shall have a mass of approximately 220 g/m^2 and shall be composed of filaments of diameter from 5-20 µm.

The GRE shall have the following physical properties:

Properties/Dimensions	Standard	Requirements/Remarks
Tensile Strengths (longitudinal and circumferential)	ASTM D 3039	minimum 45 MPa
Water vapour permeability	ASTM E 96	in accordance with procedure, E < 0.02 metric perms
Hardness	ASTM D 2583	minimum 40 on M-935 scale
Wind angle	N/A.	between 55° and 70° from longitudinal
Thickness	N/A.	minimum 5.0 mm reinforced
Flame Spread	ASTM D 635	< 5 mm

All design, engineering, application details and method statements of these systems shall be submitted by the Main Contractor and/or Insulation Contractor for the approval of the Principal.

5.11 SPECIAL APPLICATIONS

5.11.1 Combined PUR/PIR - Cellular Glass systems

In special situations where a combination of insulation and fireproofing is required, a combined insulation system shall be applied.

After the inner layer(s) of pre-formed PUR/PIR has (have) been installed a secondary vapour barrier shall be applied. The outside layer of cellular glass shall be installed and shall be coated with primary vapour barrier mastic.

5.11.2 Small bore pipes / Instrument tubing of equipment

Pipes with a diameter < 25mm or instrument tubing of equipment (e.g. pumps, compressors) are often complex configurations (e.g. bends, pressure gauges, temperature meters, small valves etc.) which should be insulated with suitable insulation materials , e.g. glass or rock wool rope or flexible elastomeric foam.

A proposal, supported by data sheets, test certificates, etc., which shall cover the general requirements of this specification (e.g. thermal conductivity, fire rating etc.), shall be submitted for approval.

5.12 EXPANSION / CONTRACTION BELLOWS

Expansion or contraction bellows located in insulated pipes shall also be insulated. For cold insulation the following precautions shall be applied.

A 1.0 mm thick stainless steel sheet shall be cylindrically formed over the outer diameter of the bellows in order to ensure free movements of the bellows. The cylindrically formed sheets shall be fixed to the bellows flanges. The length of the cylinder shall be the maximum expanded length of the bellows plus twice the insulation thickness (see Appendix 16).

The covered bellows shall be insulated in the same way as a standard pipe with a two-layer system of prefabricated insulation material.

The Main Contractor shall submit the bellows insulation design for the approval of the Principal.

5.13 TANK INSULATION

5.13.1 Insulation with pre-formed mineral fibre boards

The tank wall insulation system for tank diameters up to and including 12 m shall be as specified in CINI 4.5.00.

For tank diameters above 12 m the insulation system shall be as indicated in Appendix 13.

The insulation shall be protected with metal jacketing arranged with 50 mm overlaps (with rivets/screws) and strapped all around with stainless steel bands.

The storm bands, as described in CINI 4.5.05, shall be provided with a spring system to ensure sufficient clamping stress to keep the wall cladding in place during heavy storms. The plate to keep the storm band in place shall provide sufficient space to allow circumferential movements of the storm band.

Rain water shields and ring caps shall be installed to prevent water entering the insulation.

Hand railing on insulated tank roofs should be installed in accordance with CINI 4.5.23 and no water vapour transport shall be allowed between roof and wall insulation.

5.13.2 Tank roof insulation

Tank roofs at temperatures up to 120 °C are usually not insulated for heat conservation, as they are vulnerable to ingress of water and subsequently underlagging corrosion, but it may be necessary for process reasons.

If the tank roofs are to be insulated the mechanical design shall anticipate all insulation requirements as mentioned under Part II, Sections 1 and 3.

The conventional metallic jacketing system shall not be applied for tank roof insulation. For tanks up to 12 m diameter, the sides of the sheets shall be bent straight upward and covered with a U-shaped profile (see CINI 4.5.21).

For tanks with a diameter of more than 12 m, the upward bent flanges of the sheets shall be folded and rolled over each other in order to produce a strong sealed joint.

5.13.3 Sprayed rigid polyurethane foam (PUR/PIR) for tanks

Sprayed PUR/PIR is intended for use on tank shells with operating temperatures above ambient but not above 90 °C.

Application of PUR/PIR shall not be performed when the weather conditions are outside the limits specified by the PUR/PIR supplier/applicator. If necessary, temporary weather protection and a heater shall be used.

Due attention shall be paid to prevent over-spray.

The temperature of the liquid foam components shall be between 15 °C and 25 °C at the time of application.

The temperature of the surface to be insulated shall be between 20 °C and 40 °C during spraying.

The insulation shall not be sprayed during rain or when the wind speed is above 5 m/s.

The insulation shall be sprayed on a painted surface that is compatible with the sprayed PUR/PIR.

The insulation shall end at a sufficient height above the tank base to prevent contact between ground water and insulation, e.g. after rainfall.

The PUR/PIR shall be sprayed in layers of maximum 15 mm thick until the specified thickness is obtained.

The average thickness after spraying the PUR/PIR onto the total tank surface shall be between 5 and 10 mm above the specified final thickness. After cutback the thickness shall be measured using a non-destructive instrument.

The minimum final insulation thickness of PUR/PIR shall be 25 mm.

Provisions shall be made to enable the removal of the insulation from parts which have to remain accessible or remain free of contamination, e.g. staircases, railings, manholes, gauge glasses or other accessories shall temporarily be covered with plastic foil.

Junctions between permanent and removable insulation shall be properly sealed against ingress of moisture.

The insulation shall be made smooth and properly sealed, including the seams where supports, nozzles, stair steps, etc. protrude through the insulation.

PUR/PIR used on tank roofs and shells shall be protected against ultraviolet radiation and weather conditions by applying an elastomeric coating of acrylate polymers.

Sprayed PUR/PIR without metal sheet covering shall not be used on roofs of tanks since damage to the PUR/PIR will cause severe corrosion of the roof plates. However, special “proprietary tank roof insulation systems” containing PUR/PIR that are free from these effects may be acceptable.

5.14 ACOUSTIC INSULATION

If hot insulation is required as well for acoustic insulation the same material may be used. The thickness of the insulation layer shall be determined by the more stringent of the two requirements.

For cold services the cold insulation system shall be applied first (without cladding) and the acoustic insulation shall be applied on top of a secondary vapour barrier. To prevent condensation inside the acoustic insulation a primary vapour barrier shall be applied at the outside of the acoustic insulation layer and shall be finished by the applicable acoustic jacketing requirement (e.g. aluminised steel type 2 or SS 316L cladding).

Specific requirements and recommendations for acoustic insulation are given in DEP 31.46.00.31-Gen.

5.15 REMOVAL AND DISPOSAL OF INSULATION MATERIALS

Insulation materials, (including ancillary materials), their application and the disposal of waste or surplus materials and containers shall comply with applicable national and local regulations for health, safety and environment.

Materials that can be re-used shall be removed carefully and stored in a proper place .

Insulation materials applied in the past may contain asbestos.
Prior to stripping insulation, material tests shall be performed to determine if asbestos is present. For that purpose and in case asbestos is present and should be removed, the Shell safety publication on “Asbestos” and any national or local regulations shall be consulted.

For the disposal of waste materials, including asbestos, reference shall be made to the Shell HSE “Waste Management Guide” and any national or local regulations.

5.16 CO-ORDINATION ACTIVITIES DURING COMMISSIONING, START UP AND SHUTDOWNS

To ensure that the co-ordination activities of commissioning, start up and shutdowns are not in conflict with the requirements stated in the specifications, a number of measures should be taken as follows:

- At an early stage of the project, it should be decided which flanges need to be insulated and when.
- The Principal should be consulted in order to establish what has to be inspected in relation to insulated surfaces, and to specify where removable insulation panels should be fitted.
- Detailed planning should take place with other disciplines to avoid damage of newly installed insulation.

6. QUALITY CONTROL

6.1 GENERAL

The Main Contractor shall submit to the Principal a quality system manual based on ISO 9001. The quality system shall include specific QA/QC procedures for the work and test procedures for all materials.

The QC procedure shall include an inspection and test plan with references to all test procedures, number of samples, hold-points and witness points, acceptance and rejection criteria and frequency of tests.

The Main Contractor shall provide facilities for the inspection of all materials and application procedures before and during the insulation work, up to the contractual completion date.

Inspection shall be carried out during and after completion of any stage and before commencement of the following stage, beginning with material checks and ending with final performance checks.

6.2 INSPECTION

6.2.1 Inspection of Materials

Inspection of materials shall be performed either at the Manufacturer's works or in the field.

Laboratory test results for various insulation and ancillary materials obtained by independent test laboratories shall be submitted prior to the commencement of the work together with the data sheets, Manufacturer's instructions and method statements of the Main Contractor.

Should the material be delivered in multiple production batches, one laboratory test shall be performed at the Manufacturer's works and the test results submitted. For all other batches a "Compliance Certificate" shall be submitted certifying that the materials are in accordance with the technical specifications of the first production batch. Each batch used on site shall be clearly marked to allow rapid tracing of the origin of the supply should discrepancies be noted.

6.2.2 Pre-Insulation Survey and Inspection

After a piping/equipment system has been "released for measurement", a pre-insulation survey and measurement of the system shall be performed by the Insulation Contractor to verify the designed system and as built situation. Deviations should be notified to the Principal.

After "Released for Insulation" (normally after completion of hydrostatic testing, painting and if applicable testing of electrical/steam tracing), the Insulation Contractor should inspect the following:

(1) Surfaces - Are the surfaces coated and clean/dry? In coastal areas, the surfaces should be washed with fresh water to remove salt deposits and should be dried.

(2) Hangers/Supports - Are all hangers and supports of the correct size, and properly located according to the specifications? Are all supports, anchors, guides or hangers on low temperature piping free from obstructions to allow sufficient space for support insulation application and condensation control treatment, and normal expansion and contraction of the system?

(3) Expansion/Contraction joints - Are all positions for installation of the expansion/contraction joints in the insulation clearly defined and marked?

(4) Clearances - Has sufficient accessibility and clearance been provided for both the insulation thickness to be applied and the space necessary for workmen to apply it?

6.2.3 Inspection during installation of hot / cold insulation systems

Inspections shall be carried out on material and applications to ensure compliance with the specifications.

6.2.4 Inspection Procedure for In Situ Moulded / Dispensed PUR

Foam injection shall be done only after the control scheme has been examined for each unit to be insulated.

The Main Contractor shall draw up the inspection procedure and control sheets will be established for each pipe/spool in order to assess the step-by-step inspection status on a continuous basis.

The inspection procedure shall include but not be limited to the following tests, documented in appropriate data sheets and performed daily:

- For each machine each day and before the start of dispensing work, a sample shall be made in a closed mould to simulate conditions in practice. Each sample shall be examined for density, closed cell content, thermal conductivity and visual appearance . Samples shall be tested in accordance with Section 6.3.
- Machine foaming test in free expansion to determine the same values as specified.

- Measuring and recording of all data such as:
  - ambient temperature;
  - relative humidity;
  - operating and re-circulation pressures for the pouring machines.
- Inspection of the cavities to be injected for the following:
  - temperature;
  - humidity / water pockets;
  - accessibility;
  - properly placed pouring and vent holes.
- Inspection of the foamed cavities by examination of the quantity and quality of the foam escaping from the de-aeration, drain and injection holes.
- Daily checks by cutting samples. On these samples the compressive strength shall also be tested.

Injection control data sheets shall be maintained for all insulated pipes/spools to record all operating and material data for easy cross-reference in case of failure.

All samples shall be numbered to ensure full trace ability and shall be stored by the Insulation Contractor under such conditions that they remain suitable for further testing if necessary, until all dispensing work has been completed.

Test results shall be submitted weekly.

6.2.5 Final Inspection and Release

Final inspection shall be conducted by all parties involved when the system is considered complete or as soon as possible thereafter. After final completion of a system, a “release for system insulation completion” should be issued. The Insulation Contractor shall be kept responsible for the performance of insulation system(s) till the contract completion date and warranty period has expired, unless the systems are not operated within the design envelope or are damaged by others.

The application shall be inspected to determine that the insulation is of the proper thickness and that its materials, workmanship and finishes meet the specifications.

Infrared inspection technique can be used after start-up to verify proper thermal performance of the insulation system(s).

Cold insulation systems shall be subjected to thermography between 9 - 12 months after start up to identify deficiencies. These deficiencies shall be marked and shall be made good at the earliest opportunity (e.g. the next shutdown).

6.3 TESTING

The Insulation Contractor shall submit test reports and adhere to the quality control requirements on all insulation materials.

For the In Situ Moulded/Dispensed PUR or sprayed PUR/PIR the Insulation Contractor shall establish a site laboratory to carry out the daily testing in accordance with the QA/QC programme and testing of the foam characteristics.

For each day production of pre-formed foam or whenever a fresh blend of chemicals is used the following tests shall be carried out according to the standards mentioned in CINI 2.7.01.

- density;
- thermal conductivity at ambient temperature;
- closed cells content;
- cell structure: uniform and free of voids and bubbles in excess of 1.5 mm. in diameter across the rise of the foam, or 5 mm in depth in direction of rise. No more than 5 smaller voids or bubbles per 250 x 250 mm area on any cut standard length of half pipe section or slab shall be allowed. The surface shall be free of striations, sheared cells, and planes of weakness and uncured areas;
- compressive strength;
- tensile strength;
- flammability;
- dimensional tolerances;

Results of the above Quality Control tests shall be recorded for two samples of foam from each batch of chemicals and reported to the Principal. Serial number and expiry shall identify batches date or manufacturing date.

PART III AMENDMENTS / SUPPLEMENTS TO THE CINI MANUAL

The amendments/supplements are based on the CINI Manual Update, dated 97-11-3

Tab 1	General Requirements + Installation Instructions

CINI 1.3.01	General requirements for the insulation of “hot” pipelines and equipment

1.2.	**Replace this clause by:** For the conservation of insulated metal surfaces, see DEP 30.48.00.31-Gen. or DEP 70.48.10.10-Gen., as applicable.		
2.4.1	**Replace this clause by:** The insulation thickness shall be determined in accordance with Part II, Section 1.2 of this DEP.		
3.1	Insulating materials according specifications CINI 2.1.02….2.10.03 **Add to this clause:** The following materials are recommended to be applied for **hot** insulation (1) :		
	Recommended insulation materials	Tab2 Ref. CINI Specification	Temperature Ranges and remarks
a)	Rock Wool Products (2)	Tab 2 CINI 2.2.01 to 2.2.07	Application for product temperatures between 80 °C and 600 °C and prefabricated section or slabs should be used. If not available blankets may be used. Approval shall be obtained from the Principal.
b)	Cellular Glass	Tab 2 CINI 2.9.01	Application for product temperatures < 427 °C, as fire protection in combination with other insulation materials and as collars to avoid water/product ingress and capillary working.
c)	PUR/PIR materials	Tab 2 CINI 2.7.01	Application for product temperatures between ambient and 100 °C. Sprayed rigid PUR/PIR may be used only on tanks and only under conditions as specified in the supplier/applicator’s specifications. Note: Preferred material for cold insulation.
d)	Flexible Elastomeric Foam	Tab 2 CINI 2.3.01	For insulation of small bore piping and appendages of pump/compressor skids and the like.

Note: (1) Other insulation materials of the CINI Manual may be used, as long they do not cause or influence corrosion increase of piping/equipment. The other materials shall have the approval of the Principal.

(2) Depending on the type of resin used as the binder in rock wool materials, an initial temperature increase rate during the start-up of the unit shall be not more than 50°C/h, in order to avoid auto-ignition reactions of the resin. During the design the start-up conditions shall be verified to avoid a higher initial temperature increase rate.

3.4	Metallic jacketing according to specifications CINI 3.1.01 to 3.1.05 Add to this clause: Galvanised or aluzinc sheeting shall not be used**,** reference shall be made to the metallic jacketing of the jacketing matrix of Appendix 3. In areas with potential fire hazard, only aluminised steel or stainless steel sheeting shall be used (see Appendix 3). No combustible materials shall be applied on the metal jacketing. Removable covers for flanges; valves etc. shall be made of 1.0 mm sheets, independent of the type of material. For covers smaller than diameter 600 mm, 0.8 mm sheet shall be used. The choice of the cladding material shall be based on a lifetime of 15 years, taking into account environmental and climate conditions.
4.1.6	Replace this clause by: There shall be a minimum space of 50 mm between the thermal and/or acoustic insulation finishing (e.g. cladding) and the adjacent surfaces (see also CINI 2.3.1.2).
4.1.8	Add to this clause : The covers/boxes shall be made in halves from metal sheets, lined with rigid insulation slabs and secured by hinges and quick-release toggles, self-tapping screws or removable strapping bands. The insulating material shall be fixed by clips or metal strips riveted to the inside of the metal cover. Overlapping edges of the box shall be furrowed and be installed so as to shed rainwater. The thickness of insulation over the flanges should be of the same thickness as the insulation over the pipe, with a minimum of 25 mm.
New clause 4.1.9	Add new clause: All covers subject to frequent removal e.g. those on heat exchangers and manholes shall be provided with a box made of metal sheets, lined with insulation slabs having a thickness of at least half of that of the vessel insulation. Each box shall be made of one or more pieces, each piece being of such size and shape that two persons can easily handle it. Securing in position shall be done by quick-release toggles, see Tab 4, CINI 4.4.02.
4.3.9	Add to this clause: Normally the ball swaged seams in hot insulation cladding shall not be sealed in order to allow penetrated or condensed moisture inside the cladding to escape.

CINI 1.3.02	General requirements for the insulation of “cold” pipelines and equipment

1.4	Replace this clause by: For the conservation of insulated metal surfaces, DEP 30.48.00.31-Gen. or DEP 70.48.10.10-Gen. shall apply.
2.2.1	General Add to this section: For cold services the following insulation materials should be applied: • Polyurethane (PUR) / Polyisocyanurate (PIR) Foam (see Tab 2 - CINI 2.7.01) • Cellular Glass (see Tab 2 - CINI 2.9.01) Other insulation materials shall have the approval of the Principal.
2.4.1	Replace this clause by: The insulation thickness shall be determined in accordance with Part II, Section 1.2 of this DEP.
2.4.2	Replace this clause by: The parameters to be used in the CINI insulation calculation program shall be based on Part II, Section 1.2 of this DEP. The Principal shall give the local environmental/climate conditions.
3.5	METAL FINISHING MATERIALS in conformity with specification CINI 3.1.01 through CINI 3.1.05. Add to this clause: For jacketing, the metal finishing materials of the jacketing matrix of Appendix 3 shall apply. The lifetime of the jacketing shall be > 15 years. The composition of Stainless Steel 316 L cladding shall be in accordance with ASTM A 167; type SS 316 L. The cladding, as specified in CINI 3.1.03 and 3.1.04, shall not be applied. Removable covers for flanges, valves etc. shall be made of 1.0 mm sheets.
4.5.1	Replace this clause by: Metallic jacketing shall be applied only at places where mechanical damage to the vapour barrier can occur. The locations shall be determined and indicated on the isometric drawings. The jacketing (cladding) shall be constructed and be installed so that any moisture can drain from the jacketing. (E.g. drain holes shall be provided at the underside, as indicated in Tab 5, Cold insulation, INSULATION/FINISHING DETAILS FOR PIPING, CINI-detail 5.1.05). Alternatively, the metal sheets may be installed with the longitudinal joint without overlap, slightly open, at the underside of horizontal pipes. In any case, accumulation of water at the inside of the jacketing, due to condensation, water vapour diffusion, capillary working and water ingress, shall be avoided.

CINI 1.3.10	Installation instructions for the insulation of “hot” pipelines: MINERAL WOOL

2.1.2	Add to this clause: The blankets shall be applied with the wire mesh on the outside.
2.1.4	Add to this clause: If there are two or more layers of different thickness, the thicker layer shall be applied at the inside.
2.2.3	Add to this clause: Insulation on the lower half of horizontal vessels shall be supported by 4 to 6 pins per square metre, tack-welded to the bottom side of the shell (or to carbon steel strips, bolted around the vessel circumference), at intervals of 500 mm. The insulation shall be pressed over the pins and the protruding ends of pins bent over at 90 ° (Appendix 12). After application the blankets shall not be compressed by more than 3 mm.
2.3.2	Add to this clause: For vertical piping with more than one insulation layer the wire mesh of each blanket shall be fastened to the upper support ring. After application, the blankets shall have the required insulation thickness. On vertical pipes of nominal size DN 100 and larger, clamped support rings shall be applied at the upper end and under each flange. Mineral wool rope lagging should be applied to instrument lines and pipes of nominal size DN 15 to DN 40 inclusive, and weatherproofed as described in CINI 1.3.02 - 4.4.2.
2.3.4	Add to this clause: The bands shall be equipped with expansion elements (springs) to compensate for equipment expansion.

Tab 2	Insulating materials + auxiliary materials

CINI 2.25.01	Auxiliary materials for the application of hot insulating materials

2.7	Self-tapping screws Delete the words:" aluminium or galvanised steel"
2.8	Blind rivets Delete the words: "or galvanised steel"

Tab 3	Finishing materials + auxiliary materials

CINI 3.1.05	Stainless steel cladding for the finishing of insulation

2	Replace "type 304" by "type 316 L"

CINI 3.25.01	Auxiliary materials for the application of cold finishing materials

New clause 2.3	Add new clause: Synthetic fabric for mastic layer reinforcement Polyester fabric, with minimum 20 x 10 threads per 25 mm and a mass of 33 g/m^2, or an open weave glass cloth with minimum 18 x 12 threads per 25 mm.

Tab 6	Economic insulation thickness

CINI 6	Economic insulation thickness Add to this Section: This section is for information only. Part II, Section 1.2 shall apply.

Tab 7	Conservation of insulated piping, equipment, and tanks

CINI 7	Conservation of insulated piping, equipment, and tanks **Replace this Section by:** DEP 30.48.00.31-Gen. or DEP 70.48.10.10-Gen. shall apply.

PART IV INSPECTION AND MAINTENANCE OF EXISTING INSULATION SYSTEMS

Properly designed and installed insulation systems should normally require little maintenance. However, the consequences of failing insulation systems are very often detected only in an advanced state and are reflected in high repair and maintenance costs.

Routine maintenance practice should be extended with a system of scheduled inspections, preventive maintenance and long-term maintenance programme. Shortcomings can then be detected at the earliest stage, preventing uncontrolled deterioration of the insulation system with consequential risk of underlagging corrosion.

1. INSPECTION

1.1 PURPOSE OF INSPECTION

To detect shortcomings at the earliest possible time in order to prevent uncontrolled deterioration of the insulation system and underlagging corrosion.

1.2 INSPECTION TECHNIQUES

Visual inspection is still the most widely used method of inspection for insulation systems and on surfaces of pipelines or equipment for corrosion checks.

However, the frequent removal of insulation for visual inspection of underlagging corrosion is impractical. Inspection methods using thermography, pulsed eddy current (PEC), conventional gamma radiography and flash radiography (X-ray) are used in these inspections.

Thermography is done with an infrared camera that can reveal hot or cold spots on the insulation.

PEC is a method still under development but may be used for detection of corrosion under insulation (CUI). The method is not suitable close to and at protrusions/nozzles of piping and equipment.

Flash radiography has proven to be a quick and effective method of assessing the external condition of piping under insulation.

1.3 INSPECTION FREQUENCY

The optimal frequency of inspections depends on a number of factors such as plant size, previous maintenance programmes, climate and the type of insulation. Inspections shall be executed at least prior to shutdowns in order to establish the scope of possible repair work.

Since timely patch-up repair of damaged jacketing or vapour barriers will prevent major damage to insulation systems and mechanical installations, visual surveys shall be executed more frequently. Visual surveys should be carried out once a year and after shutdowns.

1.4 INSPECTION PROGRAMME

The plant should be divided into a number of areas or zones. In each area an inspection route should be chosen so that all major equipment and pipelines can be inspected. All the items to be inspected should be listed on an inspection sheet, with unique tag numbers of piping systems and equipment. The inspection sheet should be linked to piping systems and equipment records, via a maintenance management system. An example of the inspection sheet is given in Appendix 4.

Via a maintenance management system, a plan of action and a budget should be generated based on reliability centred maintenance (RCM) techniques.

1.5 INSPECTION SURVEY

The insulation inspector in close co-ordination with the mechanical/static equipment inspector should carry out the inspection survey. The typical insulation inspection survey diagram in Appendix 5 gives guidance and an example for the survey.

1.6 ITEMS TO BE INSPECTED

Of prime importance is the integrity of the weather protection and vapour barrier and the thickness of the insulating material.

Hot insulation

- Damaged or loose jacketing shall be immediately rectified (closed/sealed) to prevent further deterioration and water ingress.
- At locations with sagged insulation (e.g. pipelines or horizontal vessels) or at transitions from vertical to horizontal pipes corrosion may be expected. The condition of hot water and steam tracing lines is crucial, as minor leaks in these lines will promote underlagging corrosion in the main product lines.
- Piping or equipment at an operating temperature between -5 °C and 150 °C, or with intermittent operation, is very susceptible to corrosion.
- Leaks or spills. The leak shall be repaired, the insulation shall be removed and replaced as required and consideration shall be given to installation of protective flashings or the use of non-absorbent materials at these locations.

Cold insulation

Because of the difficulty in repairing cold insulation in service, frequent inspection for breaks, tears or punctures of the vapour barrier shall be conducted during service.

- Damaged vapour barrier or metallic jacketing

  Minor damage to the vapour barrier or the metallic jacketing shall be brought to the attention of the civil maintenance department for direct repair to avoid further penetration of moisture. Major damage to the vapour barrier shall be scheduled as a shutdown activity.

- Condensation or frost on cold surfaces

  Moisture on the surface of cold insulation finishes (e.g. cladding) indicates either insufficient insulation thickness or a wet insulation system (usually indicating total deterioration of the insulation material beneath it, due to ice build-up).

- Breaks or shrinkage cracks in weather/vapour barriers.

  Proper patching shall include the use of the reinforcing fabrics with weather/vapour barrier mastics in accordance with the Manufacturer’s requirements.

- Gaps or unsealed joints

  The presence of gaps may indicate the need for expansion/contraction joints. If so, gaps shall then be constructed as contraction/expansion joints and shall as such be incorporated into the insulation system.

- Not re-installed insulation

  Insulation is often not re-installed, nor is proper protection given to the adjacent insulation. Insulation shall always be dismantled at places limited by the closest vapour stops.

- Locations of protrusions/nozzles

  Specific attention shall be given to those areas where there are protrusions/nozzles. The seals and the vapour stops shall be inspected at regular intervals to see if they are free from cracks/holes, disintegration of sealant, etc.

2. MAINTENANCE

2.1 PREVENTIVE MAINTENANCE

After an inspection survey has been completed the reported damage and remarks should be translated into a plan of action for remedial and preventive maintenance.

The recommendations for preventive maintenance refer to situations or structures that need to be modified to prevent future or repeated damage to insulation or the underlying surfaces.

Technical shortcomings in design should be rectified, for example:

- repositioning of supports and brackets to eliminate water ingress.;
- the installation of rainwater shields;
- see also Part II, Section 3.

Damages caused by personnel or equipment can be prevented by:

- installation of a walkway and/or platforms over insulated pipes in a pipe track or at piping manifolds;
- re-routing of pedestrians by putting up hand railings;
- avoidance of fire water spraying during fire drills on insulated tanks or equipment;
- instruction and monitoring of third parties, such as painters, cleaners and scaffolders.

Damaged or saturated insulation should be discarded and the insulated metal surfaces cleaned, de-rusted and painted before installing the new insulating material.

2.2 PROGRAMMED / CONDITION-BASED MAINTENANCE

Based on the results of inspection surveys, the scope of long-term insulation maintenance can be determined and priorities can be set.

In order to systematically control the upgrading of existing insulation in a plant, it is recommended to divide the various units into manageable areas, indicated on a plot plan, and to carry out the work area by area. Simultaneously, maintenance painting in the same area should be scheduled.

Progress of work can then be properly recorded and costs for scaffolding will decrease substantially as compared to when pipelines are followed or when work is carried out randomly throughout the plant.

2.3 EXECUTION

When executing maintenance work care should be taken in removing existing insulation materials in order to allow their re-use. Slabs, pipe sections or pre-formed covers for valves, fittings, etc. shall be removed carefully and properly stored.

Temporary protection shall be provided to adjacent insulation to prevent damage or water ingress during mechanical maintenance work.

After repair of damaged hot insulation the jacketing of the replaced area and its direct vicinity shall be checked to establish proper repair of the weather protection of the complete system. For cold insulation the vapour barrier of the replaced area shall be applied with sufficient overlap on the existing undamaged vapour barrier.

PART V REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments, supplements or revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Painting and coating of new equipment	DEP 30.48.00.31-Gen.
Piping – general requirements	DEP 31.38.01.11-Gen.
Acoustic insulation for pipes, valves and flanges	DEP 31.46.00.31-Gen.
Maintenance painting	DEP 70.48.10.10-Gen.

STANDARD DRAWINGS

Support ring for insulation	S 20.003

SHELL HSE COMMITTEE

Asbestos Waste Management Guide

DUTCH STANDARDS

CINI Manual "Insulation for Industries"

Issued by:
Stichting Isolatie Nederlandse Industrie (CINI)
c/o Ceintuurbaan 182, 1403 AK BUSSUM, The Netherlands
Tel. +31 35 6920 225
Fax +31 35 6920 225

CINI Manual

AMERICAN STANDARDS

Process piping	ASME B31.3

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York NY 10017
USA

Standard test method for rate of burning and/or extent and time of burning of plastics in a horizontal position.	ASTM D 635
Standard test method for indentation hardness of rigid plastics by means of a barcol impressor	ASTM D 2583
Standard test method for tensile properties of polymer matrix composite materials	ASTM D 3039
Standard test methods for water vapor transmission of materials	ASTM E 96

Issued by:
American Society for Testing and Materials
1916 Race Street,
Philadelphia Pa 19103
USA

APPENDIX 1 INPUT DATA FOR GENERAL APPLICATIONS

Table 1-1 specifies the required input data for the following calculation cases:

Hot insulation 1. Economic insulation thickness

2. Personnel protection

Cold insulation 3. Prevent surface condensation

4. Maximum heat gain

Description	**Calculation case**			
	1	**2**	**3**	**4**
Process data				
Maximum medium temperature (°C)	**x**	**x**	**x**	**x**
Max. allowable surface temperature (°C)		**x**		
Max. allowable heat gain (W/m^2)				**x**
Air side data				
Average yearly ambient temperature (°C)	**x**			
Design ambient temperature (°C)		**x**	**x**	**x**
Average yearly wind velocity (m/s)	**x**			
Design wind velocity (m/s)		**x**	**x**	
Relative humidity (%)			**x**	
Air side film coefficient (W/m^2.K)	**x**	**x**	**x**	**x**
Calculation method applied	**x**	**x**	**x**	**x**
Constructional data				
Line pipe diameter (m)	**x**	**x**	**x**	**x**
Selected insulation material (-)	**x**	**x**	**x**	**x**
Thermal conductivity (W/m.K)	**x**	**x**	**x**	**x**
Allowances on Material / Application (%)	**x**	**x**	**x**	**x**
Selected sheeting	**x**	**x**	**x**	**x**
Complexity code	**x**			
Cost data				
Local Currency (LC)	**x**			
Basic Currency (BC)	**x**			
Currency Rate	**x**			
Additional cost (BC/m)	**x**			
Investment escalation factor	**x**			
Capital Charge	**x**			
Cost of heat (BC/GJ)	**x**			
Operating days per year (days/year)	**x**			

Table 1-2 specifies the required input data for the following specific calculations:

1. The temperature change of a flowing fluid in an uninsulated pipeline
2. The temperature change of a flowing fluid in an insulated pipeline
3. The time in which a stagnant fluid in an uninsulated pipeline changes to a certain temperature
4. The time in which a stagnant fluid in an insulated pipeline changes to a certain temperature
5. The temperature change of a stagnant fluid in an uninsulated pipeline in a certain time
6. The temperature change of a stagnant fluid in an insulated pipeline in a certain time
7. The insulation thickness for a pipeline to limit the temperature change of a flowing fluid to a certain value.

Table 1-2 Input data for specific calculations

Description	1	2	3	4	5	6	7
Process data							
Inlet temperature of fluid (°C)	x	x	x	x	x	x	x
Outlet temperature of fluid (°C)			x	x			x
Fluid flow rate (kg/s)	x	x					x
Fluid density (kg/m^3)			x	x	x	x	
Fluid specific heat (J/kg.K)	x	x	x	x	x	x	x
Inside film coefficient (W/m^2.K)	x	x	x	x	x	x	x
Time required for temp. change (s)					x	x	
Air side data							
Ambient air temperature (°C)	x	x	x	x	x	x	x
Wind velocity (m/s)	x	x	x	x	x	x	x
Air side film coefficient (W/m^2.K)	x	x	x	x	x	x	x
Calculation method applied	x	x	x	x	x	x	x
Constructional data							
Line pipe diameter (m)	x	x	x	x	x	x	x
Thickness of pipe wall (m)	x	x	x	x	x	x	x
Thermal conductivity pipe wall (W/m.K)	x	x	x	x	x	x	x
Length of pipeline (m)	x	x					x
Selected insulation material (-)		x		x		x	x
Thermal conductivity (W/m.K)		x		x		x	x
Allowances on material/application (safety factor in %)		x		x		x	x
Insulation thickness (m)		x		x		x	
Selected sheeting		x		x		x	x
Number of intermediate steps	x	x	x	x	x	x	

APPENDIX 2 LAYERING OF COLD INSULATION

Total insulation (mm)	Pre-formed PUR/PIR (mm)	Cellular Glass (mm)
30	30	30
40	40	40
50	50	50
60	30/30	60
70	30/40	70
80	40/40	40/40
90	40/50	40/50
100	50/50	50/50
110	50/60	50/60
120	30/40/50	60/60
130	30/50/50	60/70
140	40/50/50	70/70
150	50/50/50	70/80
160	50/60/50	80/80
170	50/70/50	80/90
180	50/80/50	90/90
190	50/90/50	90/100
200	50/100/50	100/100
210	50/50/60/50	70/70/70
220	50/50/70/50	70/70/80
230	50/50/80/50	70/80/80
240	50/50/90/50	80/80/80
250	50/50/100/50	80/80/90

Note: Individual layers in multiple layers constructions are shown as innermost layers at the left and outermost layers at the right of the combination

APPENDIX 3 JACKETING SELECTION

The matrix below gives recommendations for selecting a jacketing system. It is recommended to review/assess the jacketing system, with economics (e.g. competitive prices), availability, maintainability, lifecycle and environmental conditions taken into account.

Conditions for jacketing	Type of jacketing system					
	Aluminium Cladding	Aluminised Steel Cladding Type 2	SS 316 L	Water Resistant Elastomer based primary mastic vapour barrier	GRE/GRP Primary Vapour Barrier	Flexible Flame Retardant Wrap System
Fire hazard		**X**	**X**			
Process temperature < ambient		**X**	**X**	**X**	**X**	**X**
Process temperature between ambient and 120 °C		**X**	**X**		**X**	
Process temperature > 120 °C	**X**	**X**	**X**			
Vulnerable to mechanical damage		**X**	**X**			
Vulnerable to corrosion due to environmental conditions e.g. tropical and high temperatures close to the shore (2)	**X**		**X**	**X** (1)	**X**	

NOTES: 1. Additional measurements to be taken to protect mastic vapour barrier against UV radiation, e.g. a two layer (DFT 100 µm) water borne acrylic paint.

2. Areas in which salt spray is common shall be included.

APPENDIX 4 MAINTENANCE AND INSPECTION CONSIDERATIONS

Table 4-1 Example of civil maintenance insulation sheet

Insulation Inspection Sheet	Description and Explanation
Insulation Inspection ID	Unique Number
Inspection Date	
Insulation Tag Number	Line number or equipment number
Insulation Unit Number	Process unit
Kind of Thermal Insulation	Hot, Hot/Acoustic, Cold, Cold/Acoustic, PP and Others
Age of Insulation	
Drawing list	Connected to Database file
Isometric	Connected to Auto Cad File or Database file
Operating Temperature	Can be checked via supervisory systems or otherwise obtained.
Move of Operation	Constant, Cycling temperatures, Ambient to 100 °C, Ambient to 200 °C, Ambient to 300 °C and Minus to Ambient
Remarks on Operation	
StFPE*	Susceptibility to Failure of Piping and Equipment
RRM Criticality Class*	RRM Criticality Class Matrix
Environmental Conditions	Tropical marine climate with mist over spray of cooling water towers etc.
Insulation Material	Rock Wool, PUR/PIR, Flexible Elastomeric Foam etc.
Description of Insulation Material	Sections, blankets or slabs
Number of Damaged Penetrations	Could be given per isometric drawing.
Description of Damaged Penetrations	The nature of damage
Cause of Damaged Penetrations	Substandard Workmanship, Substandard Design, Ageing or Damaged by third party
Amount of Missing Cladding	metre lengths of pipe or m^2 equipment per isometric.
Description of Missing Cladding	Type of cladding, swages
Cause of Missing Cladding	Substandard Workmanship, Substandard use, Substandard Design, Not re-installed during shutdown.
Number of Missing Terminations	per isometric
Description of Missing Terminations	
Cause of Missing Terminations	Substandard Workmanship, Substandard use, Substandard Design, Damaged by third part, Not re-installed during shutdown
Amount of Missing Valves/Flanges insulation	per isometric
Description of Missing Valves/Flanges insulation	
Cause of Missing Valves/Flanges	Substandard Workmanship, Substandard use, Substandard Design, Damaged

insulation	by Third Party
General Condition Insulation	Good, Moderate and Substandard
Inspection Findings and Consequential Damage	CUI, Thermal losses etc.
Action required?	Yes or No
When is action to be taken?	1st Opportunity, During shutdown, within 1 year, within 2 years or no action.
Inspection Sequence	Every 6 months and/or after every shutdown
Next Inspection Date?	Date or combined with mechanical
Quantities and Cost of Replacement/Repairs	Linked to Database
Amount of total costs	Currency

* Note: An example is given to determine the influence of Susceptibility to Failure of Piping and Equipment and the classification in probability and consequence. The information is obtained from the RRM Manual. Failure modes are given in Appendix 4. Inspection recommended survey intervals are given in the table: Inspection Survey Intervals.

Table 4-2 Susceptibility to failure of piping and equipment (StFPE)

Corrosion under insulation	Susceptibility to Failure	Category
Severe external corrosion (e.g. 60 °C to 20 °C with high humidity and/or spray, condensation, cycling conditions, damaged insulation)	High	H
Serious external corrosion (e.g. -5 °C to 60 °C or 120 °C - 150 °C and humid climate, damaged insulation)	Medium	M
Minor external corrosion under normal operating condition (< 0.05 mm/year)	Low	L
No foreseeable external corrosion (not insulated or >150 °C)	Negligible or none	N

Table 4-3 Recommended inspection survey intervals

Class	twice per year	for every shutdown	after shutdowns	yearly	once per two years or more
High	x	x	X		
Medium		x	X	x	
Low		x	X	x	
Negligible		x	X		x

Table 4-4 RRM Criticality Matrix

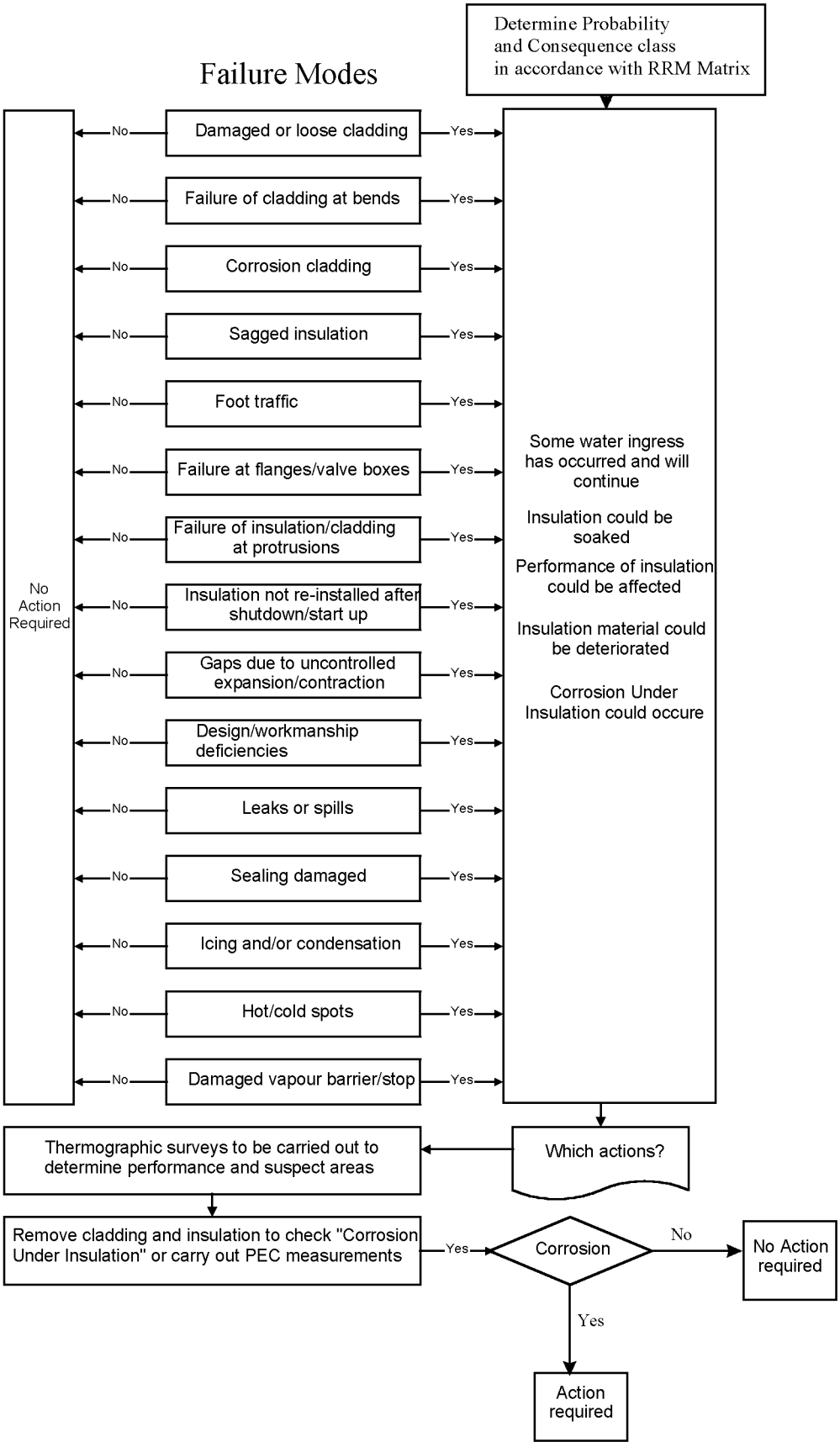
Probability class	RBI STF	RRM Criticality class				
H	High	L	H	E	X	X
M	Medium	L	M	H	E	X
L	Low	N	L	M	H	E
N	Negligible	N	N	L	M	H

	Economics (USD)	Slight Damage <10k	Minor Damage 10-100K	Local Damage 0.1-1M	Major Damage 1-10M	Extensive Damage >10M

Consequence Category						
	Health and Safety	Slight Injury	Minor Injury	Major Injury	Single Fatality	Multiple Fatality
	Environment	Slight Effect	Minor Effect	Localised Effect	Major Effect	Massive Effect
Consequence class		N	L	M	H	E

RRM = Risk and Reliability Management
RBI = Risk Based Inspection
STF = Susceptibility to Failure

APPENDIX 5 EXAMPLE INSULATION INSPECTION SURVEY DIAGRAM



APPENDIX 6A PERSONNEL PROTECTION - GUARD DISTANCES AND INSULATION THICKNESS

For process temperatures from 70 °C to 250 °C metal protection should be applied, without insulation (e.g. 60 % rigid perforated sheets or wire mesh, as indicated in Appendix 6B).

For process temperatures > 250 °C, rock wool with metal cladding is recommended.

Criteria for the table below are:

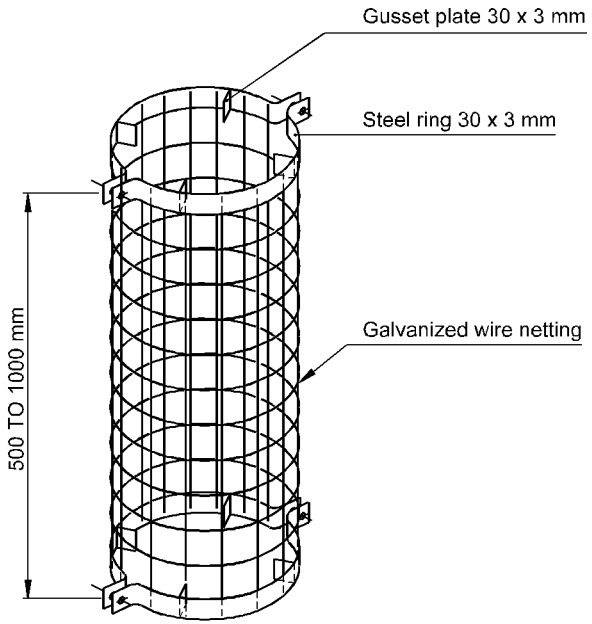
- Ambient temperature: 25 °C.
- Wind velocity: 1 m/s.
- Surface temperature protection: max. 70 °C

NOTE: Criteria could be different for other locations and so shall be determined/reviewed per location.

Table 6A-1 Recommended distances between perforated metal sheet/guards and bare surface, and insulation thickness for personnel protection

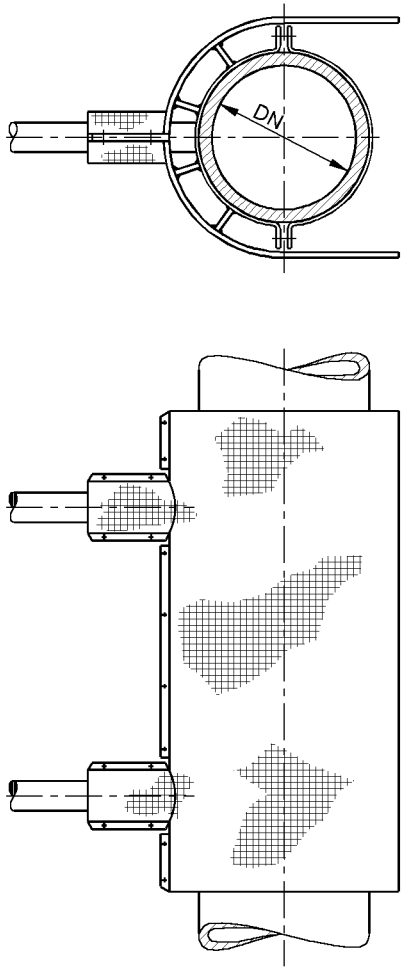
Nominal pipe diameter (DN)	Normal operating temperature (°C)						
	70 to 250	> 250	350	400	450	500	600
	Distance from sheet/guard to bare surface (mm)	Insulation thickness (mm)					
< 25	50	25	30	40	40	50	60
25	50	25	30	40	40	50	60
40	50	25	30	40	50	60	70
50	50	25	40	40	50	60	70
80	50	30	40	40	50	60	80
100	50	30	40	50	50	70	80
150	50	30	40	50	60	70	80
200	50	30	40	50	60	80	80
250	50	30	40	50	60	80	100
300	100	30	40	50	60	80	100
350	100	30	40	50	70	80	100
400	100	30	40	50	70	80	100
450	100	30	40	50	70	80	100
500	100	40	40	50	70	80	100
Equipment Channels/Flat Surfaces		40	40	50	70	80	100

APPENDIX 6B PERSONNEL PROTECTION - PHYSICAL BARRIERS



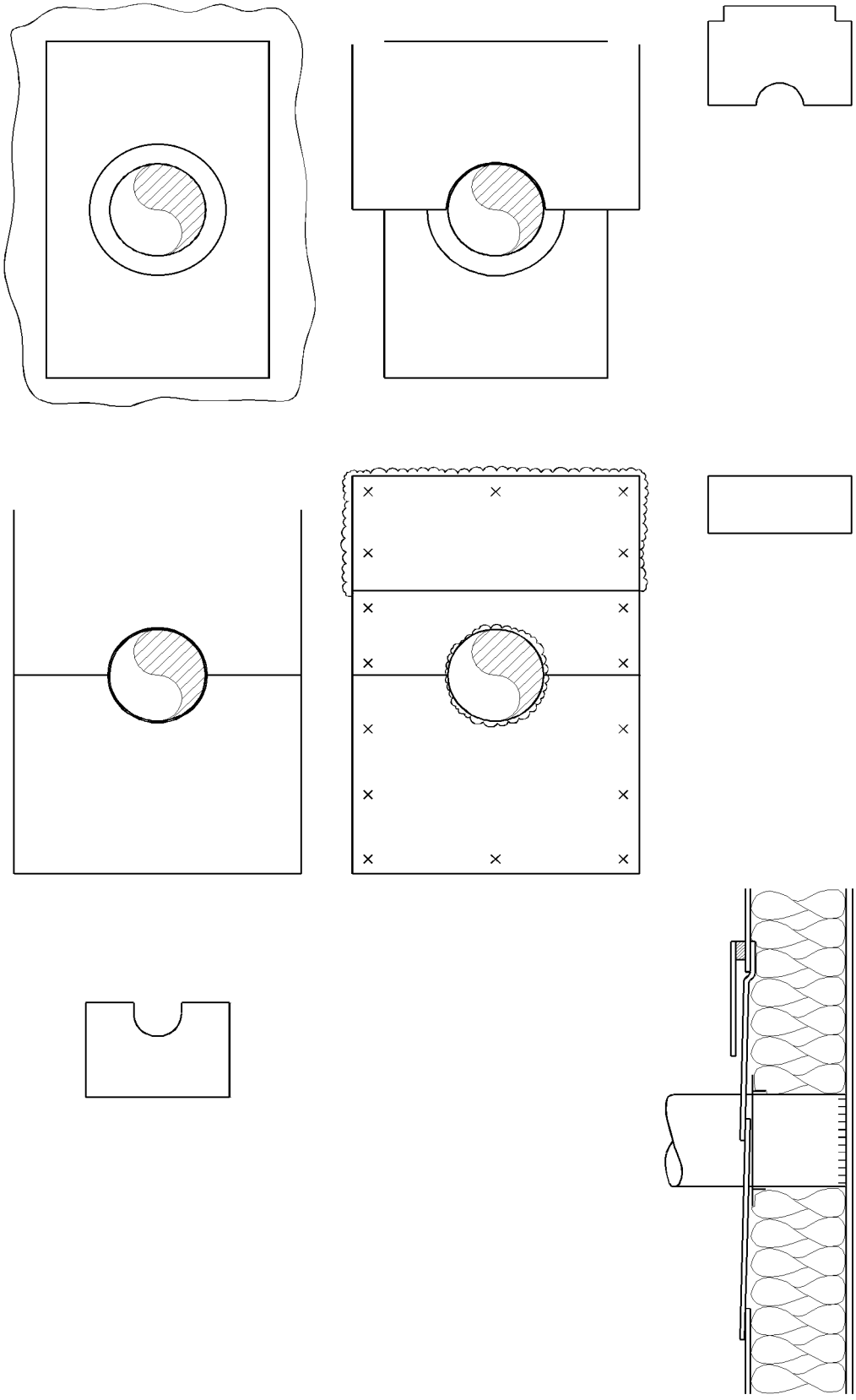
Number of gusset plates:
One per 100 mm circumference,
but minimum 4 numbers

MESH GUARD

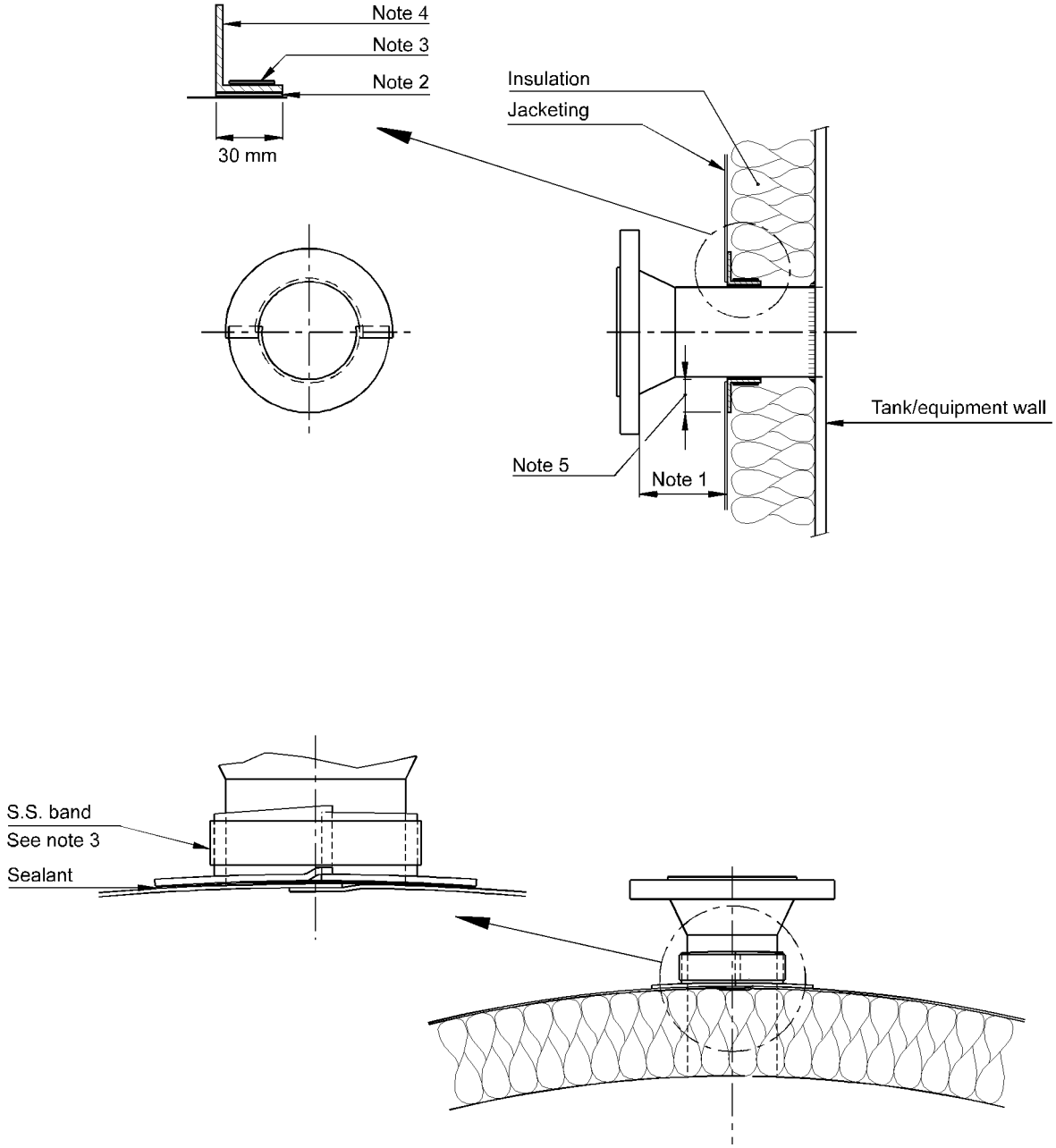


PERFORATED METAL SHEET

APPENDIX 7 TYPICAL DETAILS OF SEALING PLATES AROUND NOZZLES (HOT INSULATION)



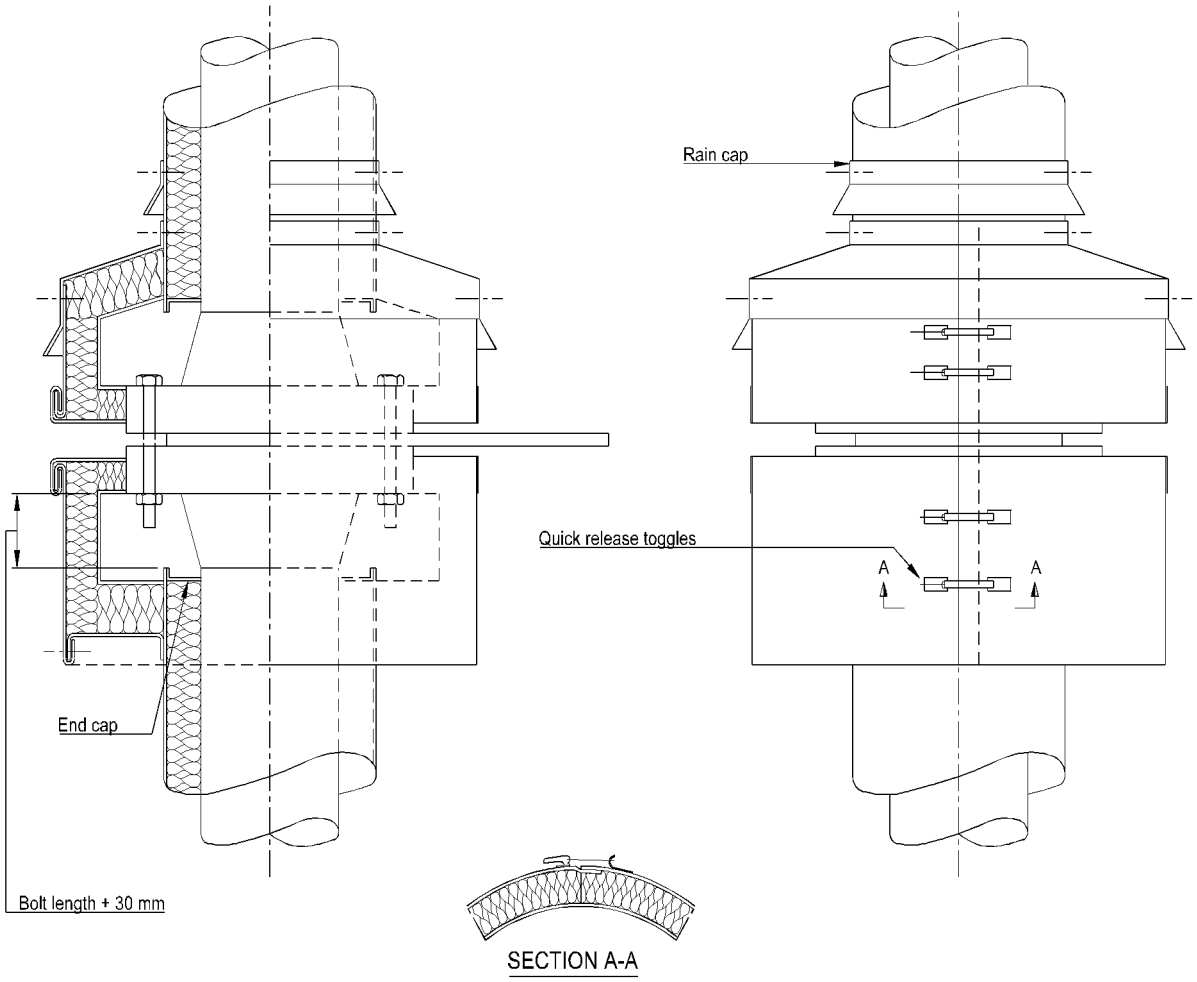
APPENDIX 8 INSULATION COLLAR AROUND NOZZLE (HOT INSULATION)



Notes:

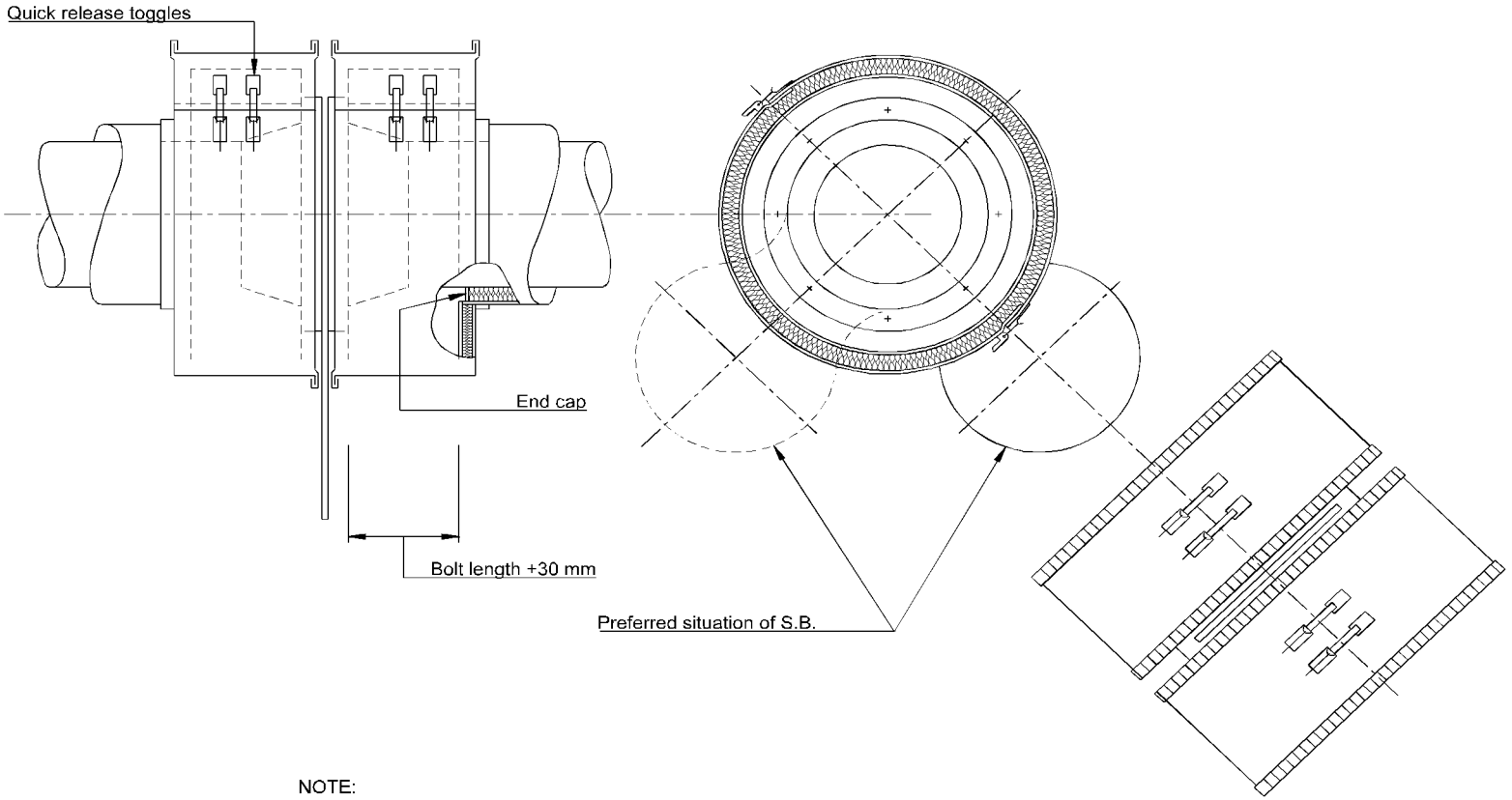
1. Distance = bolt length + 30 mm or more (depending on torque equipment)
2. Butyl rubber tape, see CINI 3.3.03 or sealant (CINI 3.2.01)
3. 19 mm stainless steel band with seal, see CINI 2.25.01
4. Aluminium plate 1 mm thick, see CINI 3.1.01
5. Width of collar 50 mm min.

APPENDIX 9 REMOVABLE COVER FOR SPECTACLE BLIND FLANGE IN VERTICAL PIPE (HOT INSULATION)



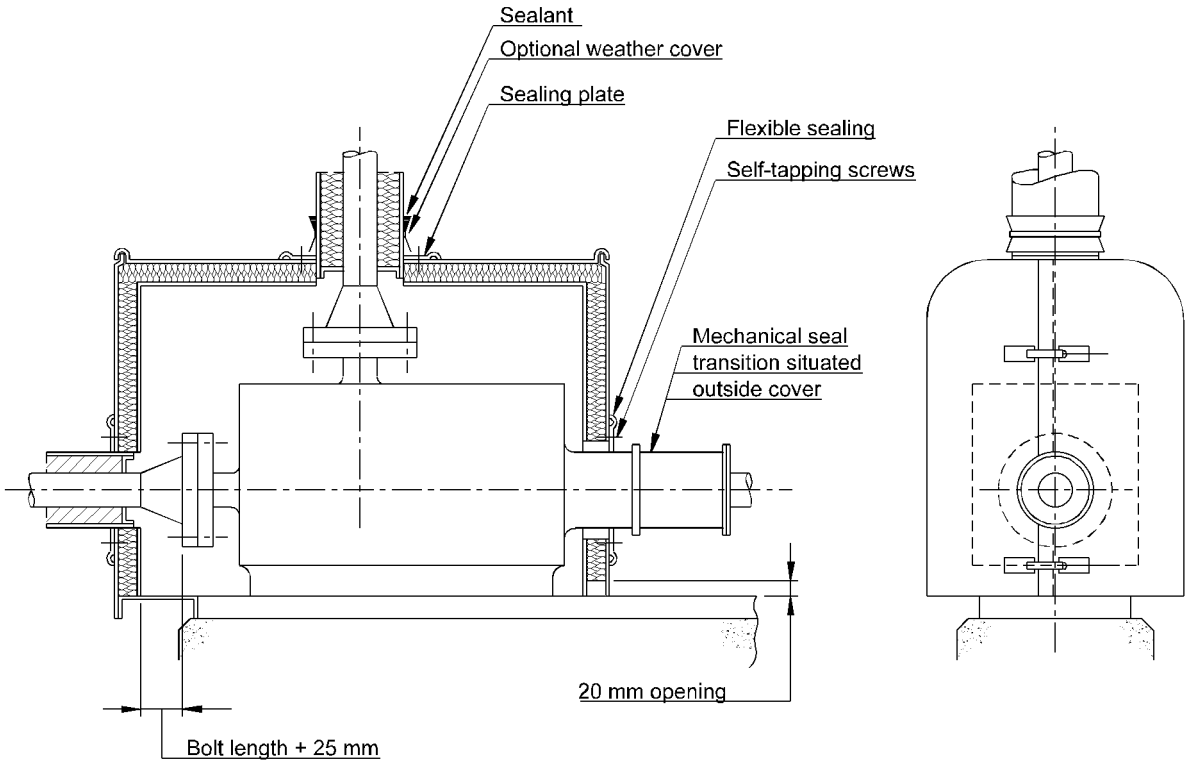
NOTE:
Cover to be executed as double wall or single wall insulation, secured by pins

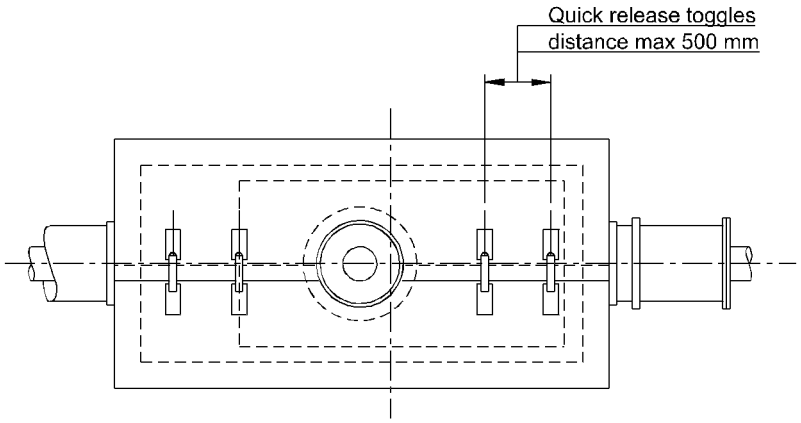
APPENDIX 10 REMOVABLE COVER FOR SPECTACLE BLIND FLANGE IN HORIZONTAL PIPE (HOT INSULATION)



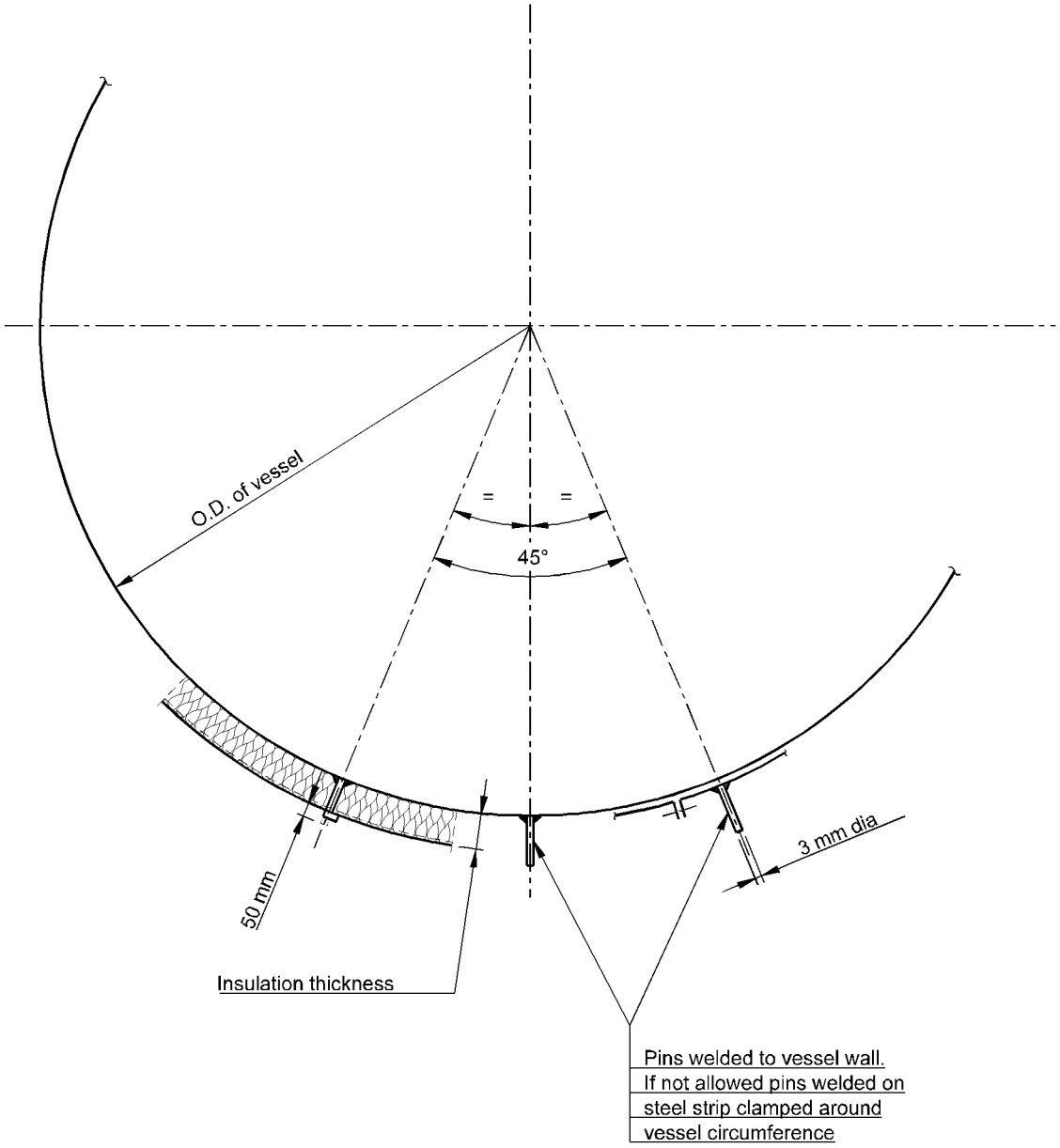
NOTE:
1. Cover to be executed as double wall or single wall insulation, secured by pins.
2. Alternative cylindrical cover.

APPENDIX 11 REMOVABLE INSULATION COVER FOR PUMPS (HOT INSULATION)

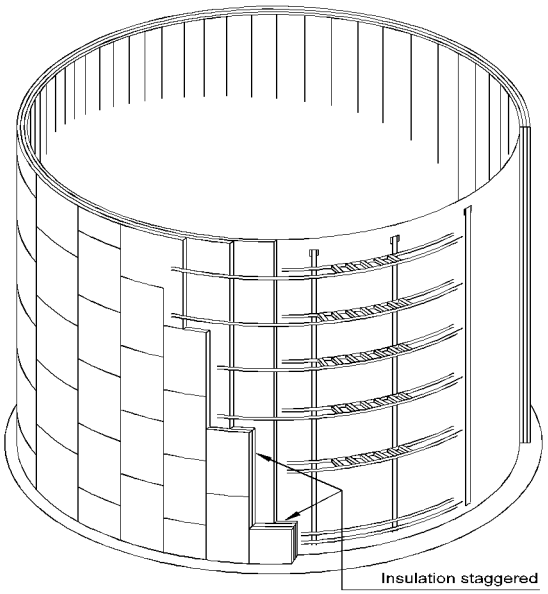

Sealant
Optional weather cover
Sealing plate
Flexible sealing
Self-tapping screws
Mechanical seal
transition situated
outside cover
20 mm opening
Bolt length + 25 mm

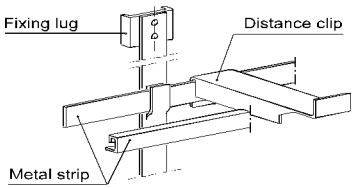

Quick release toggles
distance max 500 mm

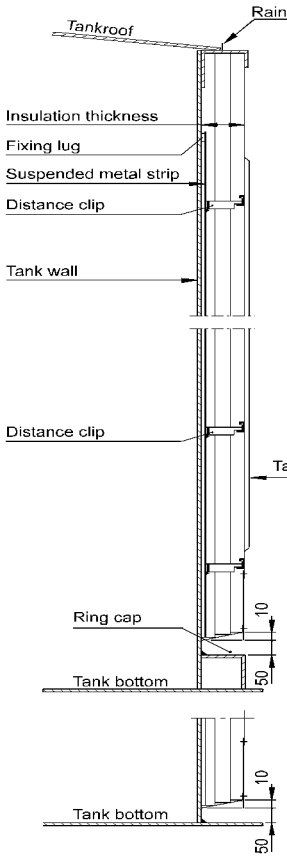
APPENDIX 12 SUPPORT PINS FOR BLANKET INSULATION ON HORIZONTAL VESSELS (HOT INSULATION)

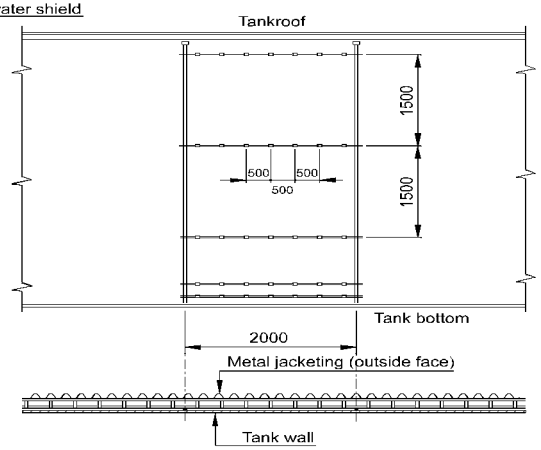


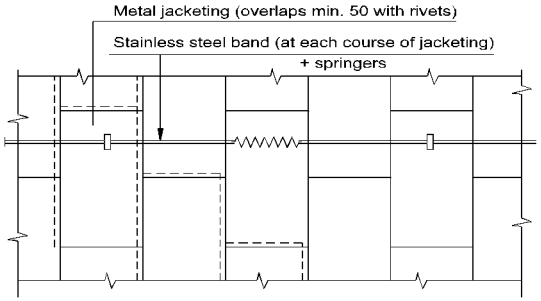
APPENDIX 13 TANK WALL INSULATION FOR DIAMETERS ABOVE 12m (HOT INSULATION)







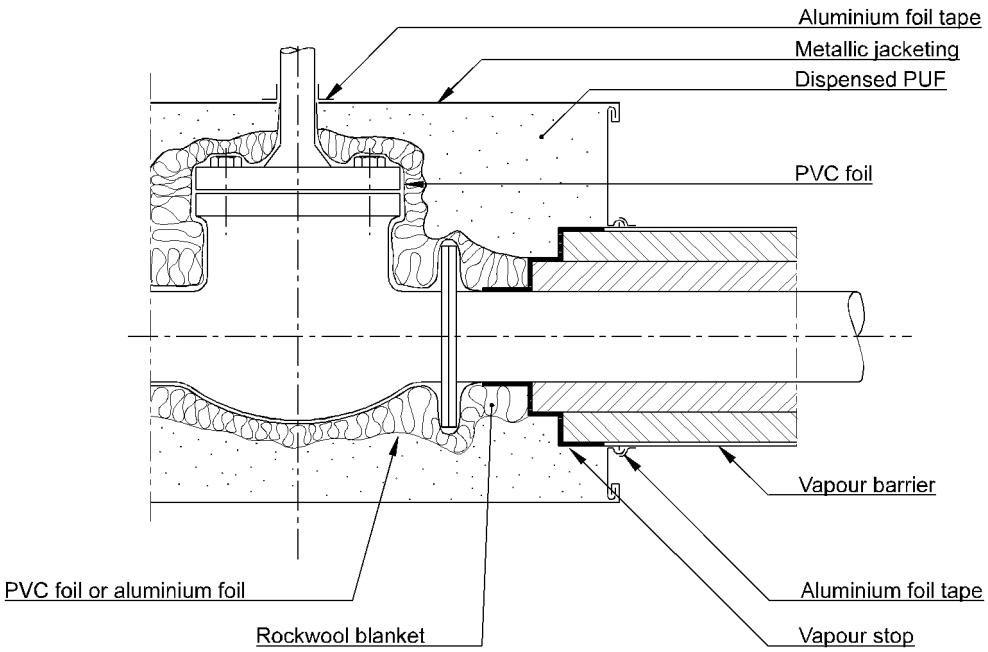




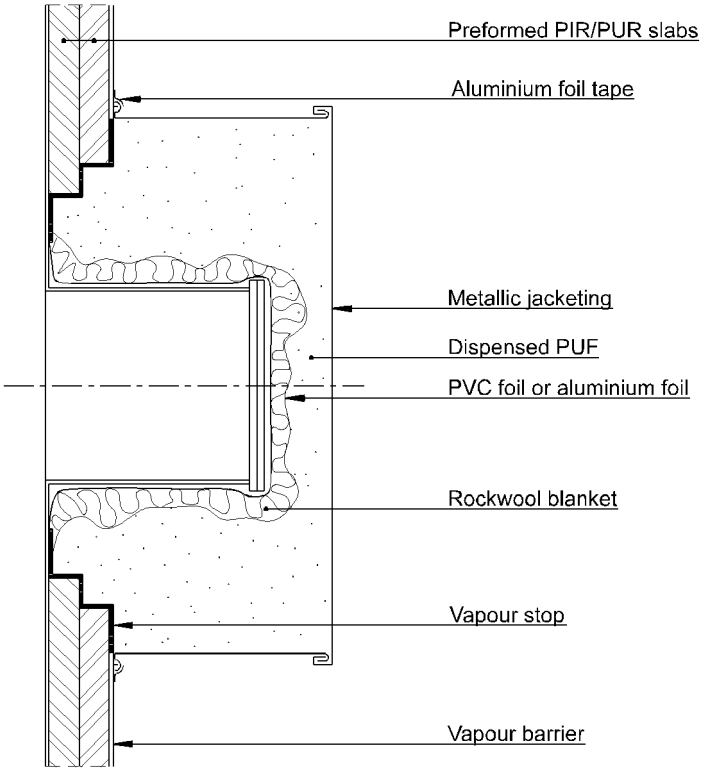
Dimensions in mm

APPENDIX 14 DISPENSED PIR/PUR FOAM (COLD INSULATION

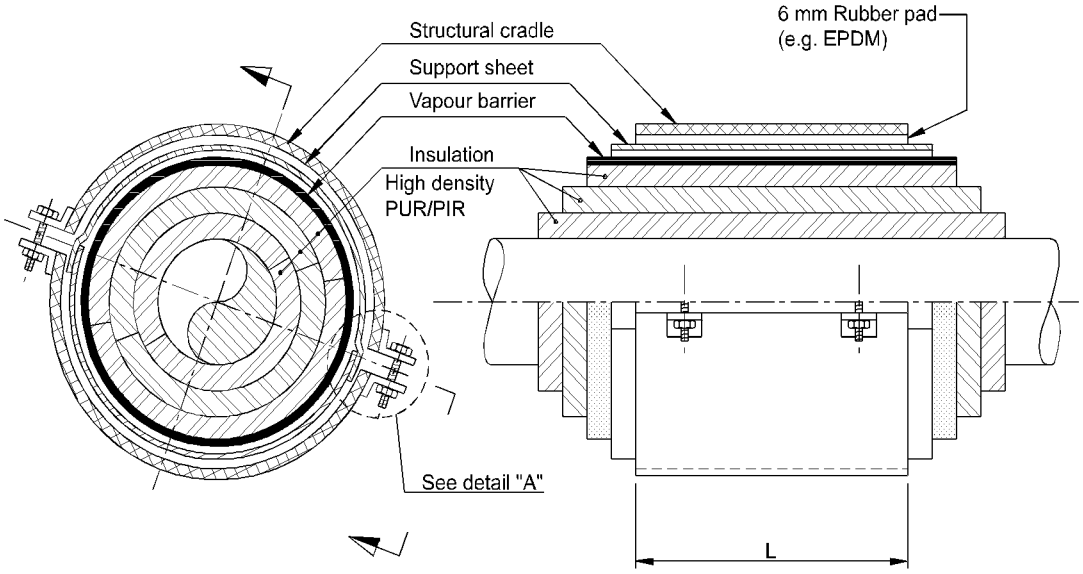
VALVE INSULATION

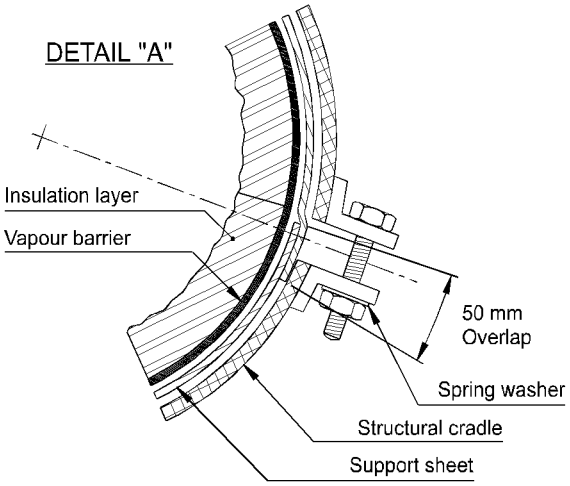


MANHOLE COVER INSULATION



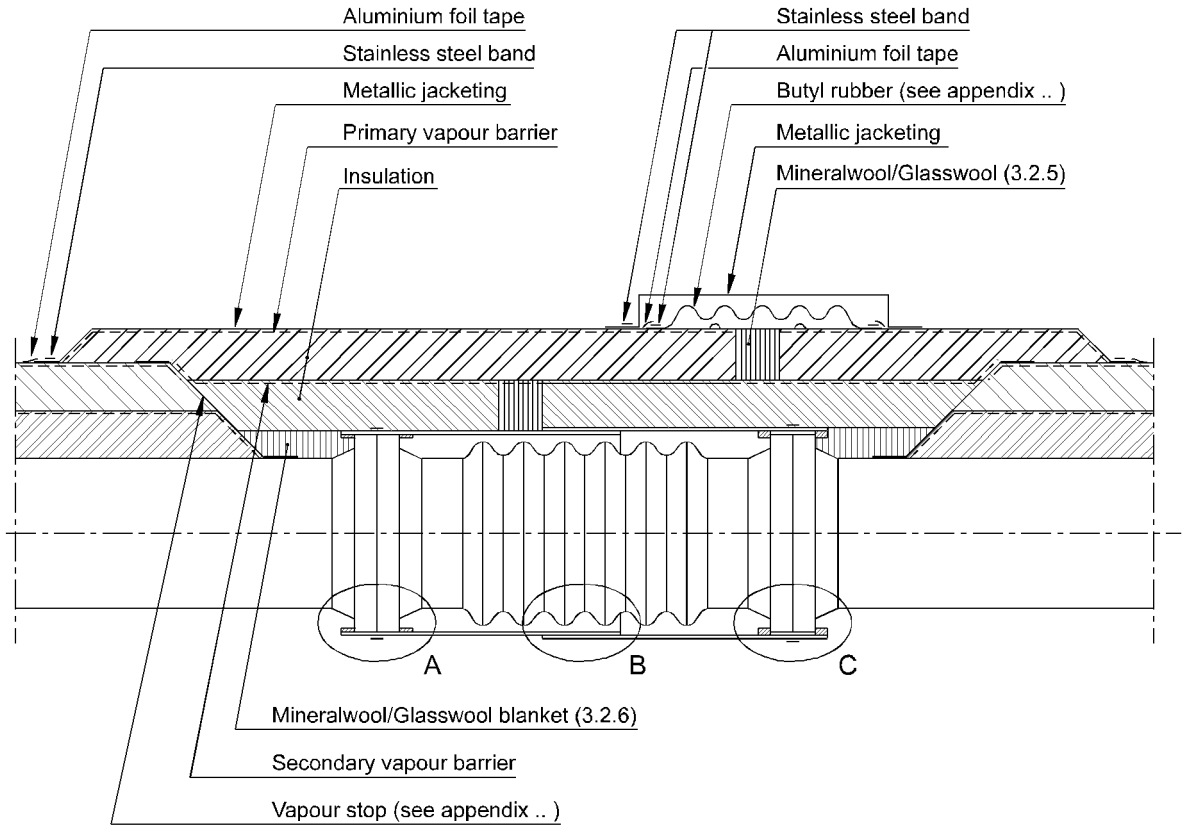
APPENDIX 15 PIPE SUPPORT - MULTI-LAYER (COLD INSULATION)

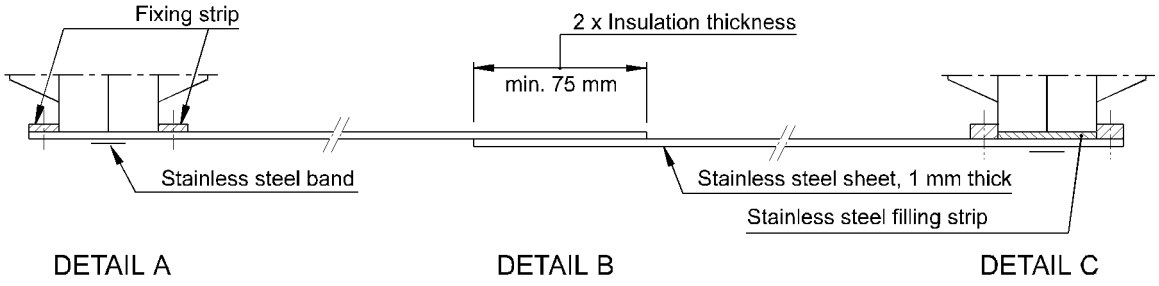




NOTE: Tolerancies in accordance with ASTM C 585.

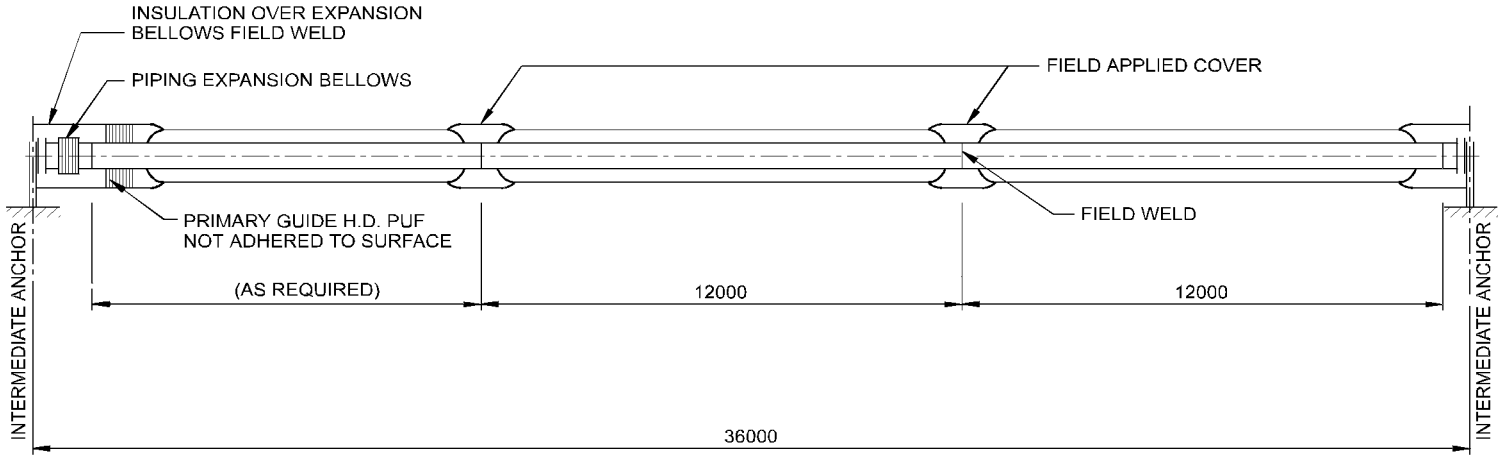
APPENDIX 16 CONTRACTION BELLOWS (COLD INSULATION)





DETAIL A DETAIL B DETAIL C

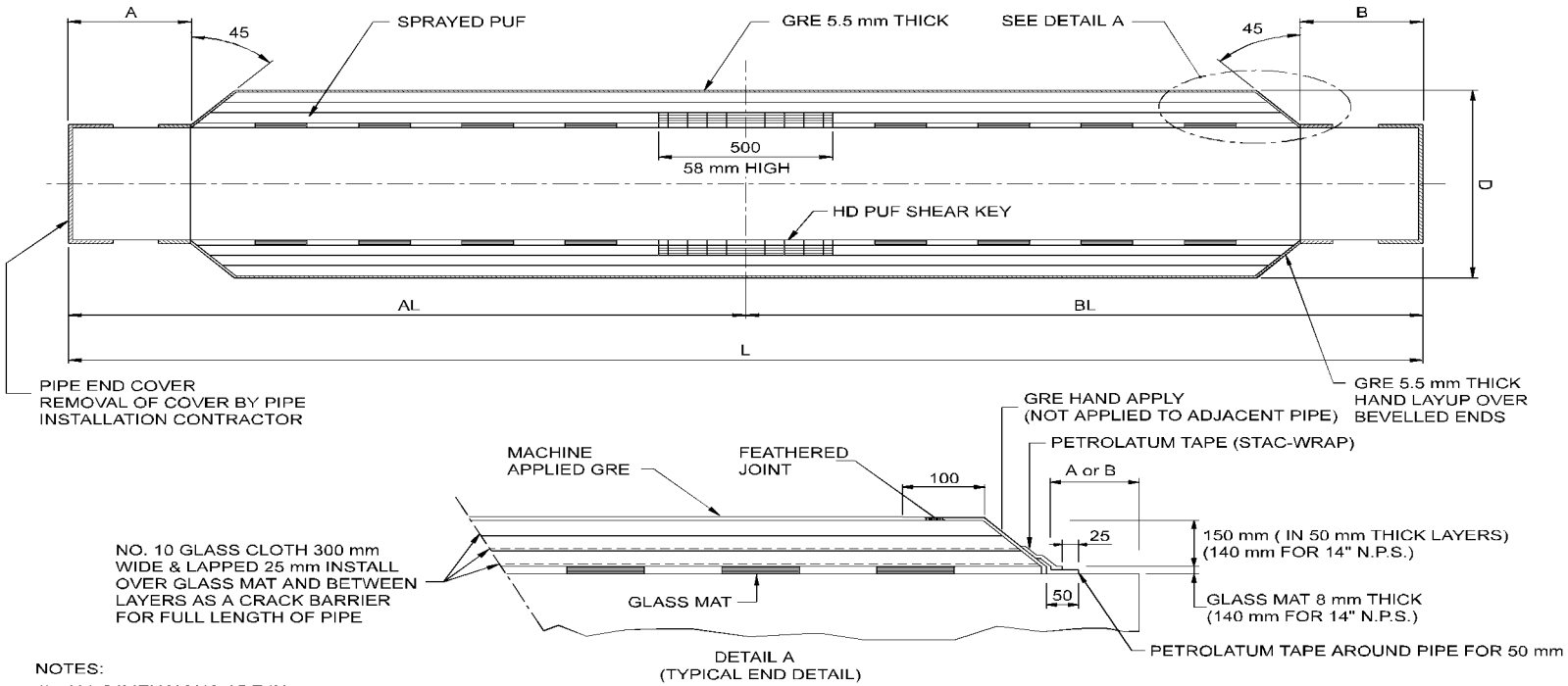
APPENDIX 17 TYPICAL SECTION OF RUNDOWN LINE BETWEEN INTERMEDIATE ANCHORS (SLIDE THROUGH INSULATION SYSTEM)



NOTES: DIMENSIONS INDICATED ARE FOR A TYPICAL 36 METRE SECTION OF PIPE MADE UP IN THE LENGTHS SHOWN. THE ACTUAL DESIGN MAY INVOLVE SOME MODIFICATION TO PERMIT VARYING PIPE LENGTHS.

INTERMEDIATE H.D. PUF SUPPORTS, LOCATED ON 9000 mm CENTRES, ARE NOT SHOWN.

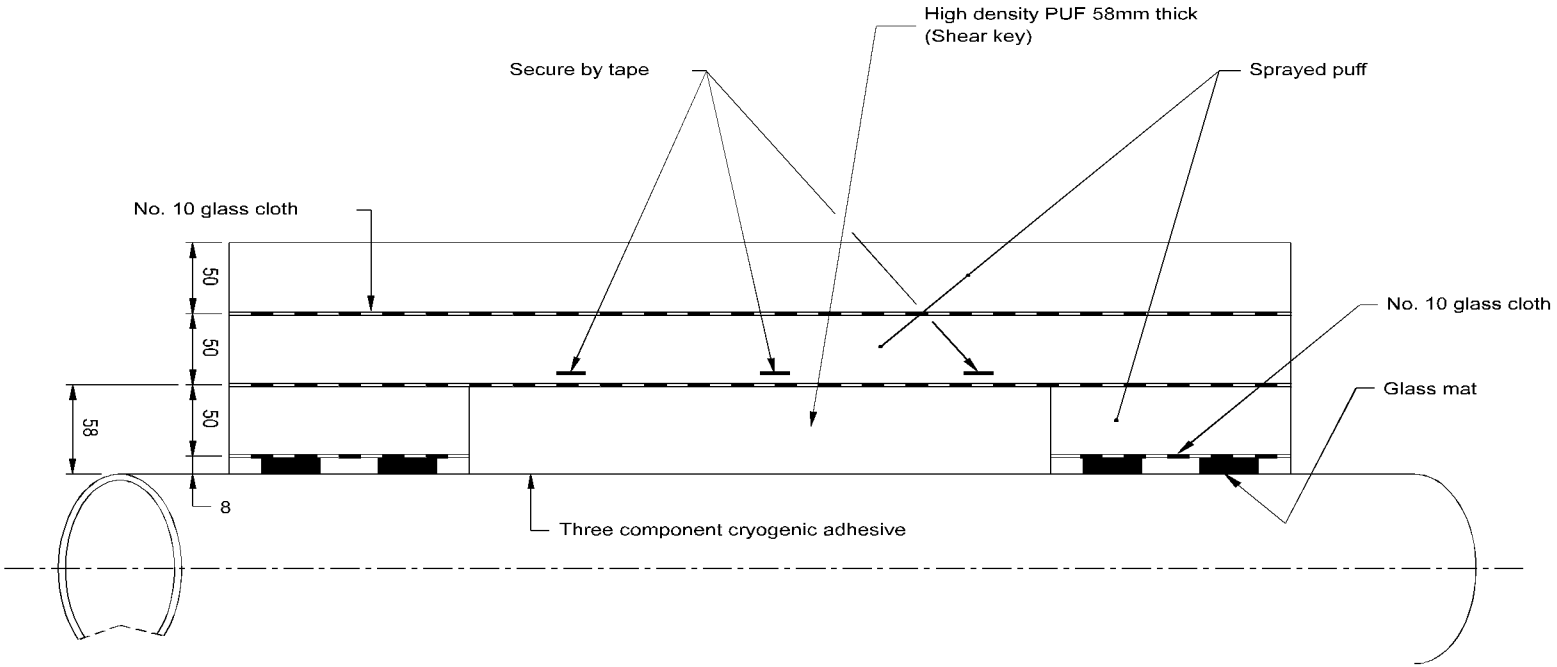
APPENDIX 18 PRE-INSULATION OF PIPE LENGTH - SHEAR KEY SYSTEM -



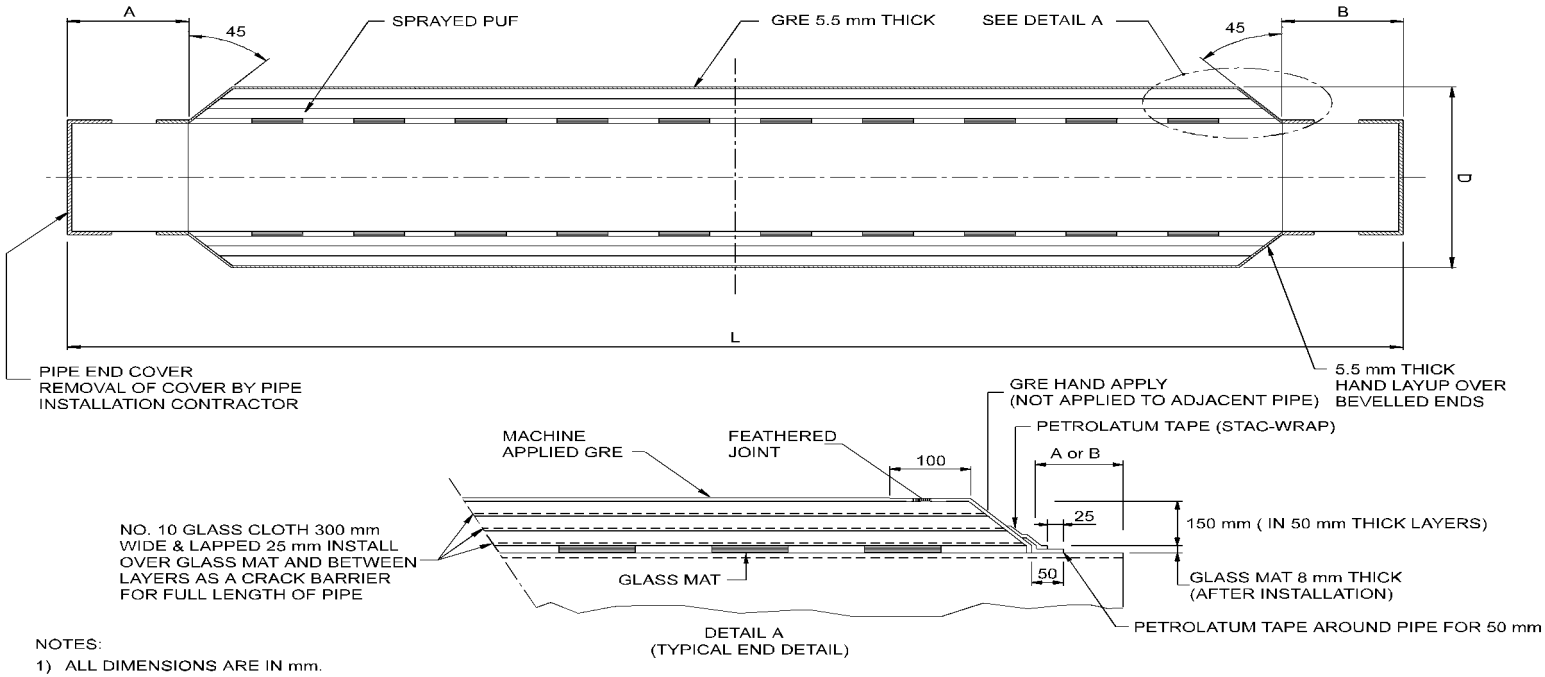
NOTES:

1) ALL DIMENSIONS ARE IN mm.
2) GRE DENOTES GLASS REINFORCED EPOXY
3) THE GRE SEAL OVER THE PUF BEVELLED ENDS AND THE GLASS MAT OVER THE PIPE SHALL BE SEALED & TAPED TO THE PIPE TO PREVENT INGRESS OF MOISTURE. THE TAPE & THE SEAL SHALL BE REMOVED WHEN THE FIELD JOINT IS INSTALLED. (SEE DETAIL A)

APPENDIX 19 SHEAR KEY DETAILS



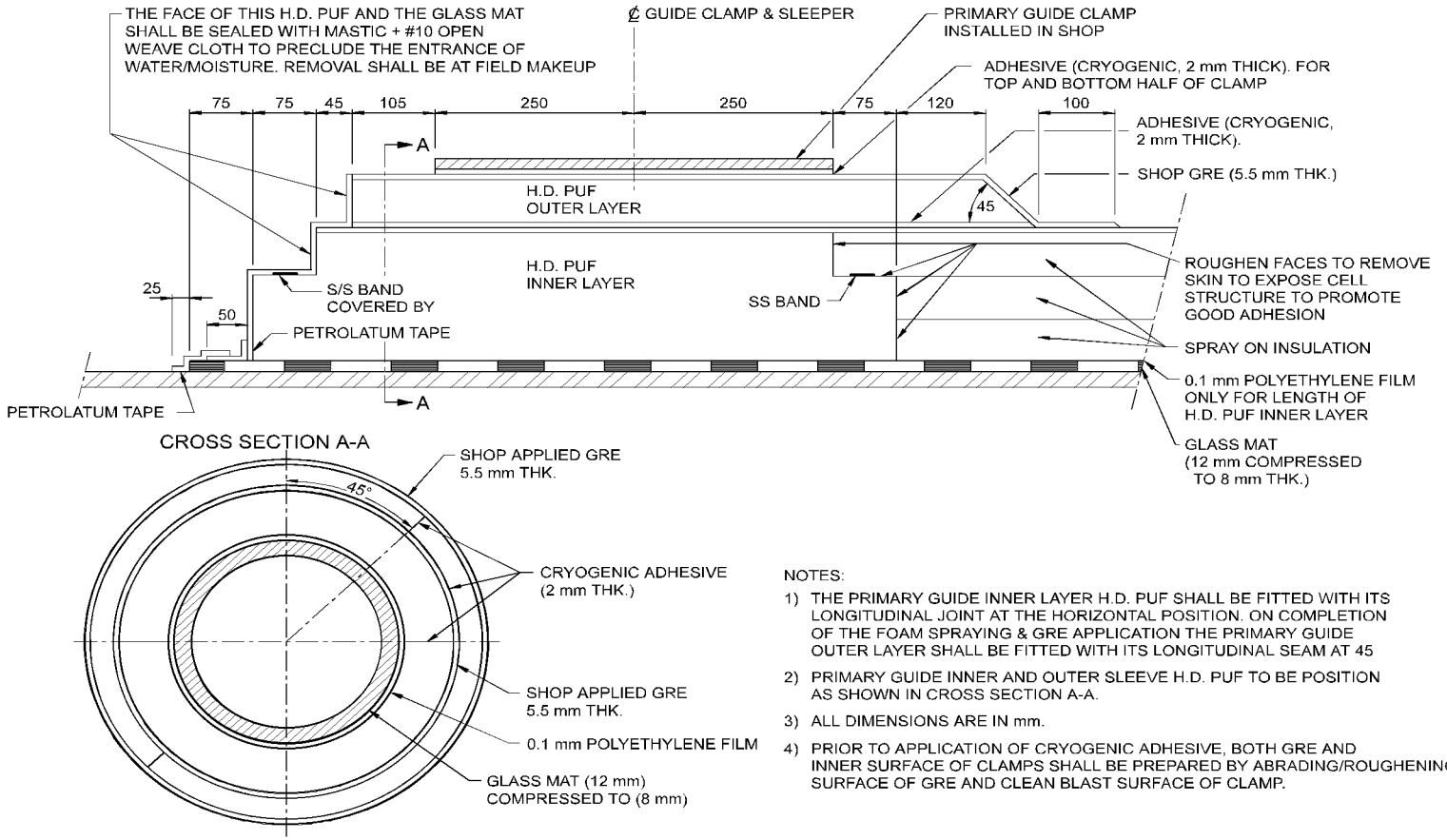
APPENDIX 20 PRE-INSULATION OF PIPE LENGTH - SLIDE THROUGH SYSTEM



NOTES:

1) ALL DIMENSIONS ARE IN mm.
2) GRE DENOTES GLASS REINFORCED EPOXY
3) THE GRE SEAL OVER THE PUF BEVELLED ENDS AND THE GLASS MAT OVER THE PIPE SHALL BE SEALED & TAPED TO THE PIPE TO PREVENT INGRESS OF MOISTURE. THE TAPE & THE SEAL SHALL BE REMOVED WHEN THE FIELD JOINT IS INSTALLED. (SEE DETAIL A)

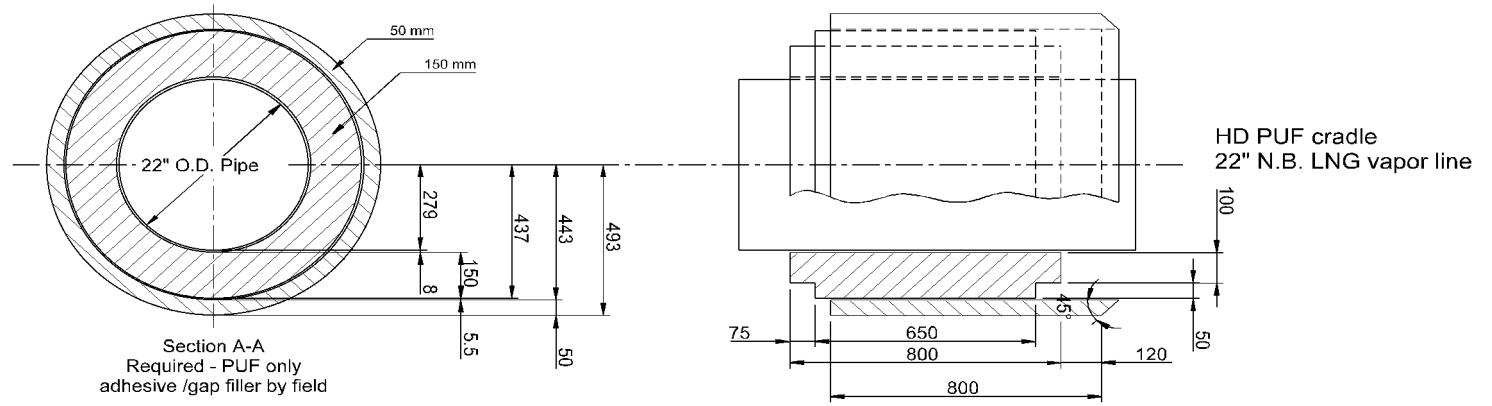
APPENDIX 21 LONGITUDINAL SECTION THROUGH RUNDOWN LINE AND PRIMARY GUIDE

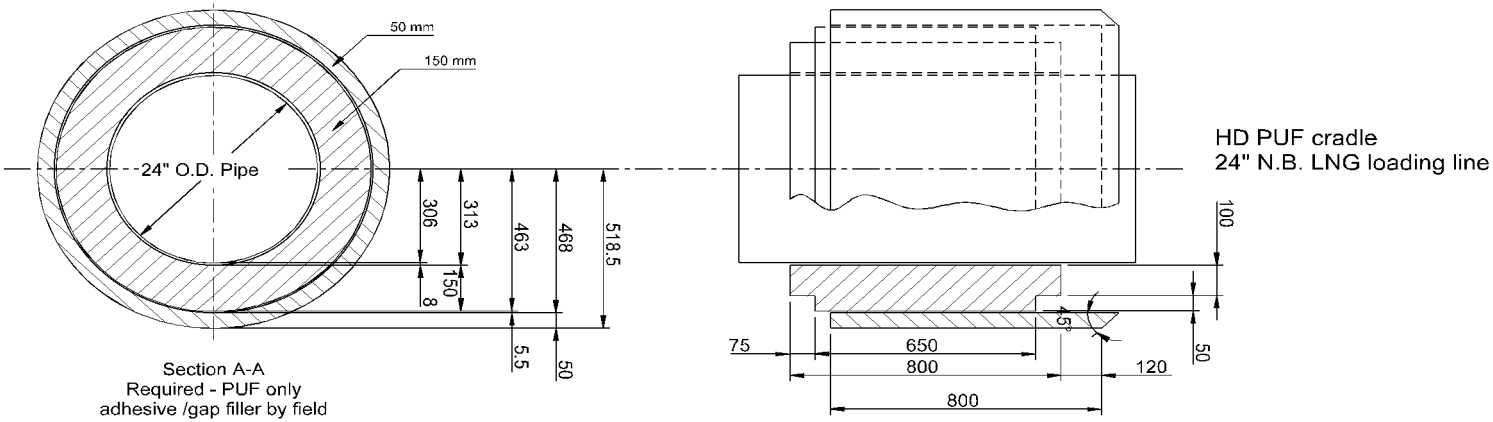


NOTES:

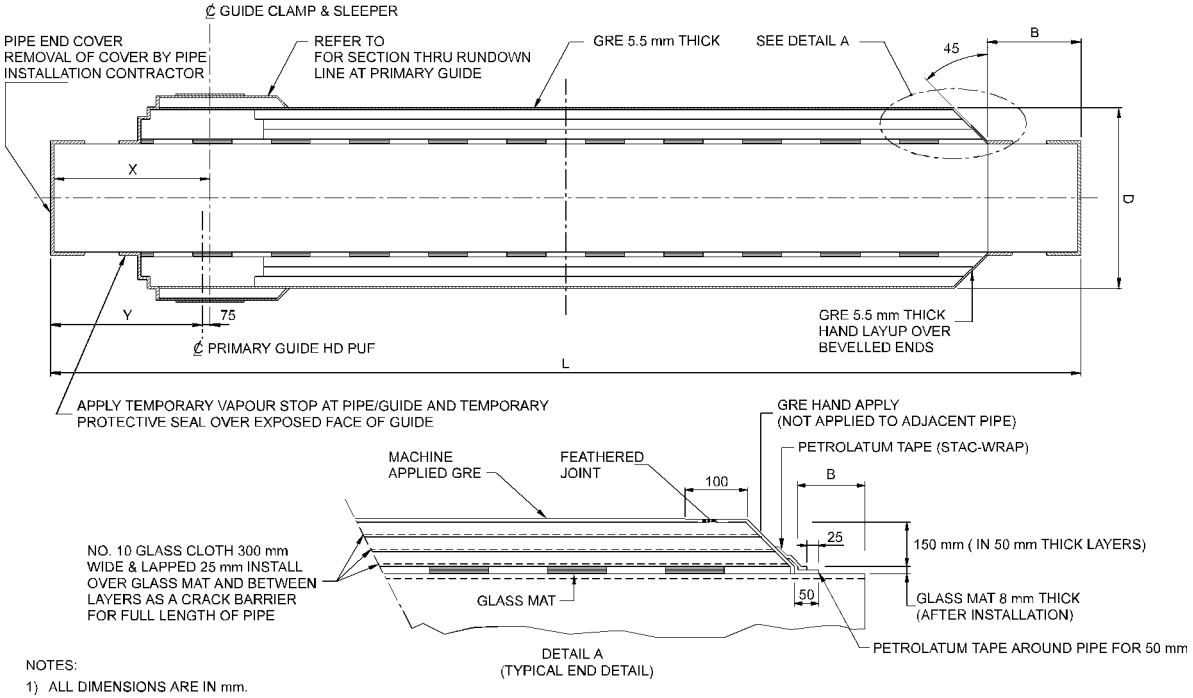
1) THE PRIMARY GUIDE INNER LAYER H.D. PUF SHALL BE FITTED WITH ITS LONGITUDINAL JOINT AT THE HORIZONTAL POSITION. ON COMPLETION OF THE FOAM SPRAYING & GRE APPLICATION THE PRIMARY GUIDE OUTER LAYER SHALL BE FITTED WITH ITS LONGITUDINAL SEAM AT 45
2) PRIMARY GUIDE INNER AND OUTER SLEEVE H.D. PUF TO BE POSITION AS SHOWN IN CROSS SECTION A-A.
3) ALL DIMENSIONS ARE IN mm.
4) PRIOR TO APPLICATION OF CRYOGENIC ADHESIVE, BOTH GRE AND INNER SURFACE OF CLAMPS SHALL BE PREPARED BY ABRADING/ROUGHENING SURFACE OF GRE AND CLEAN BLAST SURFACE OF CLAMP.

APPENDIX 22 PRIMARY GUIDE SYSTEM - TYPICAL EXAMPLE





APPENDIX 23 PRE INSULATION OF PIPE LENGTH - SLIDE THROUGH SYSTEM



NOTES:

1) ALL DIMENSIONS ARE IN mm.
2) GRE DENOTES GLASS REINFORCED EPOXY
3) THE GRE SEAL OVER THE PUF BEVELLED ENDS AND THE GLASS MAT OVER THE PIPE SHALL BE SEALED & TAPED TO THE PIPE TO PREVENT INGRESS OF MOISTURE. THE TAPE & THE SEAL SHALL BE REMOVED WHEN THE FIELD JOINT IS INSTALLED. (SEE DETAIL A)