

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE (CORE)

TECHNICAL SPECIFICATION

THERMAL INSULATION (AMENDMENTS/SUPPLEMENTS TO THE CINI HANDBOOK)

PTS 30.46.00.31

DECEMBER 2010



PTS Circular 2010



PTS No:	39.46.00.31
PTS Title:	THERMAL INSULATION (AMENDMENTS/ SUPPLEMENTS TO THE CINI HANDBOOK)

This revision of PTS 30.46.00.31- THERMAL INSULATION (AMENDMENTS/ SUPPLEMENTS TO THE CINI HANDBOOK) (JANUARY 2005, Revision 2) has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this PTS 30.46.00.31 (JANUARY 2005) will be removed from PTS binder /e-repository from herein onwards.

The custodian of this PTS is:

Name : M Hawari B Hasan

Tel. No : 603 2783 6292

Please direct any questions regarding this PTS to the above-named.

Document Approval

	Name	Designation	Date	Signature
Prepared	Azniza Azmy	Engineer (Corrosion)	10 th Dec 2010	
	Zainal Amar Zainal Abidin	Engineer (Materials)	20 th Dec 2010	
Reviewed	M Hawari Hasan	Principal (Corrosion)	20/12/2010	
Approved	Zamaluddin Ali	Technical Authority	22/12/2010	
Verified	Che Wan Ibrahim Che Wan Sudin	Head of Material, Corrosion and Inspection	28/12/2010	
Verified	Pau Kiew Huai	General Manager, Engineering, GTS	28.12.10	
Endorsed	Sazali Hamzah	Senior General Manager, GTS	06/01/11	

Revision History

Rev No.	Reviewed by	Approved by	Date
1	M Hawari Hasan	Zamaluddin Ali	December 2010

PREFACE

PETRONAS Technical Standards (PTS) publications reflect the views, at the time of publication, of PETRONAS OPU/Divisions.

They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

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

When Contractors or Manufacturers/Suppliers use PTS they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the PTS. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

The right to use PTS rests with three categories of users:

- 1) PETRONAS and its affiliates.
- 2) Other parties who are authorised to use PTS subject to appropriate contractual arrangements.
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) and 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, PETRONAS disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any PTS, combination of PTS or any part thereof. The benefit of this disclaimer shall inure in all respects to PETRONAS and/or any company affiliated to PETRONAS that may issue PTS or require the use of PTS.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, PTS shall not, without the prior written consent of PETRONAS, be disclosed by users to any company or person whomsoever and the PTS shall be used exclusively for the purpose they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of PETRONAS. The copyright of PTS vests in PETRONAS. Users shall arrange for PTS to be held in safe custody and PETRONAS may at any time require information satisfactory to PETRONAS in order to ascertain how users implement this requirement.

TABLE OF CONTENTS

PART I INTRODUCTION.....	6
1.1 SCOPE.....	6
1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	6
1.3 SUMMARY OF CHANGES FROM PREVIOUS EDITION	7
1.5 THERMAL INSULATION SYSTEMS	10
PART II INSULATION SCOPE, ENGINEERING, APPLICATION AND QUALITY CONTROL.....	11
1.0 DESIGN OF THERMAL INSULATION SYSTEMS	11
1.1 EXTENT OF THERMAL INSULATION	11
1.2 INSULATION THICKNESS	12
1.3 PERSONNEL PROTECTION	13
1.4 LAYERS OF INSULATION.....	13
2.0 MAIN CONTRACTOR AND INSULATION CONTRACTOR INVOLVEMENT	14
2.1 MAIN CONTRACTOR INVOLVEMENT	14
2.2 INSULATION CONTRACTOR INVOLVEMENT	14
3.0 ENGINEERING OF INSULATION SYSTEMS	15
3.1 CUI ENGINEERING REQUIREMENTS.....	15
3.2 DESIGN GUIDANCE FOR INSULATION SYSTEMS.....	16
3.3 DETAILED DESIGN REQUIREMENTS.....	17
4.0 MATERIALS.....	18
5.0 APPLICATION	18
5.1 METHOD OF APPLICATION	18
5.2 INSULATION CONTRACTOR INVOLVEMENT	18
5.3 SURFACE PREPARATION.....	18
5.4 JACKETING.....	19
5.5 VALVES, FLANGES, MANHOLES AND FITTINGS.....	19
5.6 SEALING PLATES AND INSULATION COLLARS	20
5.7 ROTATING EQUIPMENT	20
5.8 PIPE SUPPORTS IN COLD INSULATION SYSTEMS.....	20
5.9 IN-SITU MOULDED/DISPENSED PUR/PIR	21
5.10 SHOP APPLICATION OF SPRAYED PUR/PIR PRE-INSULATED PIPE	23
5.11 SPECIAL APPLICATIONS	26
5.12 EXPANSION / CONTRACTION BELLOWS.....	27
5.13 TANK INSULATION	27
5.14 ACOUSTIC INSULATION	28
5.15 REMOVAL AND DISPOSAL OF INSULATION MATERIALS	28
5.16 CO-ORDINATION ACTIVITIES DURING PRE-COMMISSIONING, START UP AND SHUTDOWNS....	29
6.0 QUALITY CONTROL.....	30
6.1 GENERAL.....	30
6.2 INSPECTION.....	30
6.3 TESTING	32
PART III AMENDMENTS / SUPPLEMENTS TO THE CINI HANDBOOK.....	33
PART IV INSPECTION AND MAINTENANCE OF EXISTING INSULATION SYSTEMS.....	40
1.0 INSPECTION.....	40
1.1 PURPOSE OF INSPECTION	40
1.2 INSPECTION TECHNIQUES	40
1.3 INSPECTION FREQUENCY	40
1.4 INSPECTION PROGRAMME.....	41
1.5 INSPECTION SURVEY.....	41
1.6 ITEMS TO BE INSPECTED	41
2.0 MAINTENANCE	43

2.1 PREVENTIVE MAINTENANCE	43
2.2 PROGRAMMED / CONDITION-BASED MAINTENANCE	44
2.3 EXECUTION	44
PART V REFERENCES	45

APPENDICES

APPENDIX 1 INPUT DATA FOR GENERAL APPLICATIONS	47
APPENDIX 2 LAYERING OF COLD INSULATION	49
APPENDIX 3 EXAMPLES OF NON-CONTACT INSULATION	50
APPENDIX 4 JACKETING SELECTION.....	52
APPENDIX 5 INSPECTION OF THERMAL INSULATION SYSTEMS.....	53
APPENDIX 6 PERSONNEL PROTECTION - GUARD DISTANCES AND INSULATION THICKNESS	55
APPENDIX 7 PERSONNEL PROTECTION - PHYSICAL BARRIERS.....	56
APPENDIX 8 TYPICAL DETAILS OF SEALING PLATES AROUND NOZZLES (HOT INSULATION)	57
APPENDIX 9 INSULATION COLLAR SOLUTIONS (alternatives to Standard Drawing S10.056)	58
APPENDIX 10 REMOVABLE COVER FOR SPECTACLE BLIND FLANGE IN VERTICAL PIPE (HOT INSULATION).....	60
APPENDIX 11 REMOVABLE COVER FOR SPECTACLE BLIND FLANGE IN HORIZONTAL PIPE (HOT INSULATION).....	60
APPENDIX 12 REMOVABLE INSULATION COVER FOR PUMPS (HOT INSULATION)	62
APPENDIX 13 SUPPORT PINS FOR BLANKET INSULATION ON HORIZONTAL VESSELS (HOT INSULATION).....	63
APPENDIX 14 DISPENSED PIR/PUR FOAM (COLD INSULATION)	64
APPENDIX 15 PIPE SUPPORT - MULTI-LAYER (COLD INSULATION)	65
APPENDIX 16 CONTRACTION BELLOWS (COLD INSULATION).....	66
APPENDIX 17 TYPICAL SECTION OF RUNDOWN LINE BETWEEN INTERMEDIATE ANCHORS (SLIDE THROUGH INSULATION SYSTEM)	67
APPENDIX 18 PRE-INSULATION OF PIPE LENGTH - SHEAR KEY SYSTEM –	68
APPENDIX 19 SHEAR KEY DETAILS	69
APPENDIX 20 PRE-INSULATION OF PIPE LENGTH - SLIDE THROUGH SYSTEM	70
APPENDIX 21 LONGITUDINAL SECTION THROUGH RUNDOWN LINE AND PRIMARY GUIDE.....	71
APPENDIX 21 PRIMARY GUIDE SYSTEM – TYPICAL EXAMPLE	71
APPENDIX 23 PRE INSULATION OF PIPE LENGTH - SLIDE THROUGH SYSTEM.....	73
APPENDIX 24 ALTERNATIVE TO CINI 5.2.06 INSULATION DETAIL VACUUM/SUPPORT RING – CONTRACTION JOINT (only to be used if vacuum/support rings are not installed)	74
APPENDIX 25 ALTERNATIVE TO CINI 5.9.01 MECHANICAL ENGINEERING DETAIL LUGS/SUPPORT STRIP ON COLUMNS/SKIRTS (only to be used if lugs/support strips are not installed)	75
APPENDIX 26 INSULATION COLLAR FOR PROTECTION AGAINST FLAMMABLE PRODUCTS.....	75

PART I INTRODUCTION

1.1 SCOPE

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

This PTS is based on the CINI Handbook "Insulation for Industries", English Version, dated 1st October 2004 (also known as the "2005 edition").

This PTS is a revision of the PTS of the same number dated *January 2005*; a summary of the main changes is given in (I-1.3).

This PTS is divided into six parts:

- Part I give an introduction, outline the relationship between this PTS and the CINI Handbook and explain the other parts. The CINI Handbook covers both hot and cold insulation for indoor and outdoor facilities, but not all parts of the CINI Handbook are applicable to thermal insulation practices within the PETRONAS. 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 specification. A quick reference table of thermal insulation systems normally used in PETRONAS is given in (I-1.5).
- Part II contains standard practices and procedures not covered by the CINI Handbook.
- Part III gives amendments and supplements to the CINI Handbook. For ease of reference, the clause numbering of the CINI Handbook has been used. Clauses of the CINI Handbook that are not mentioned shall apply as written. Wherever reference is made to the CINI Handbook it shall be understood to mean the CINI Handbook as amended/supplemented by this PTS.
- Part IV specifies requirements and gives recommendations for inspection and maintenance of existing insulation systems that are not covered in the CINI Handbook.
- Part V lists the publications referenced in this PTS.
- Part VI contains appendices with diagrams, tables and drawings.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorized by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS or managed by a Group company and, where necessary, to Contractors and Manufacturers nominated by them.

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

When PTS are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS 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 PTS 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 PTS as closely as possible.

1.3 SUMMARY OF CHANGES FROM PREVIOUS EDITION

This PTS is a revision of the PTS of the same number dated *January 2005*. The following are the main changes:

Section	Change
-	Update on PTS 30.48.00.31 to PTS 30.48.00.31-P
I-1.4.2	Technical definitions added
I-1.5	Non metallic weather-proofing jacketing system added
II-1.2	Insulation thickness calculation based on ISO 12241 added
II-3.2	Non metallic weather-proofing jacketing system added
V	Update on references
Appendix 4	Amendment done on Jacketing Selection table under Polymeric Compound column

1.4 DEFINITIONS

1.4.1 General definitions

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.

1.4.2 Specific definitions and abbreviations

Description	Definition
Acoustic Insulation	Insulation installed to reduce the amount of noise radiated from a surface. Acoustic insulation is often used in conjunction with hot and cold insulation
CINI	Committee Insulation Netherlands Industry
Cold Insulation	Insulation used to avoid condensation at the outer surface and to reduce heat gain for economic reasons
Condensation	Moisture forming at the surface of uninsulated or insufficiently insulated piping/equipment when the process temperature is below ambient. The rate of condensation depends on ambient temperature, relative humidity, and emissivity of bare surface or insulation jacketing, wind velocity and process temperature
CUI	Corrosion Under Insulation. Six categories of CUI are recognized, indicating the severity of problem; further described in (II-3.1)
Dual Process Temperature	Process temperature cycling between ambient and 320°C (or lower). Insulation material for this duty is normally cellular glass.
EPDM	<i>Flexible Elastomeric Foam EPDM</i>
FEF	<i>Flexible Elastomeric Foam</i>
GRE	<i>Glass Reinforced Epoxy</i>
GRP	<i>Glass Reinforced Plastics</i>
Heat Gain	Heat ingress from the outside in cold insulation systems or heat loss from the inside in hot insulation systems.
Hot Insulation	Insulation used to save energy for economic reasons; typically applied for process temperatures between 70°C and 600°C
Insulation System	Combination of insulation materials and jacketing designed to achieve the most economic solution and service life.
Metallic Jacketing	Jacketing which consists of aluminum, aluminized steel cladding Type 2 or stainless steel SS 316. The emissivity of these materials is typically 0.4.
Non-Contact Insulation	Insulation system in which spacers are used to avoid contact between bare surfaces of piping/equipment and the insulation material. The annular space between insulation material and bare surface is a non-ventilated space in which openings or drains are always located at the lowest point of the piping or equipment.
Non-Metallic Jacketing	Jacketing consisting of GRE, GRP, polymeric compound or modified EPDM; often used in conjunction with a multiplex primary vapour barrier.
PEC	<i>Pulsed Eddy Current</i>
Personnel Protection	Barrier system consisting of insulation material or metal screens, to prevent people from touching hot surfaces (or exceptionally very cold surfaces) of piping or equipment
PIR	<i>Polyisocyanurate</i>

Process Insulation	Insulation required to avoid freezing, internal condensation or solidification, or to control product viscosity. This type of insulation is often used in conjunction with heat tracing.
<i>PUR</i>	<i>Polyurethane</i>
Thermal Insulation	Generic term covering hot, cold, process and personnel protection insulation.

1.5 THERMAL INSULATION SYSTEMS

This Quick Reference Table indicates the main thermal and acoustic insulation systems and their material properties, based on the applicable process temperatures. The table may be used for quick reference only and is not a replacement for the detailed information given in this PTS and the CINI Handbook.

Category	Process temperature	Thermal Insulation Material selection	Thermal conductivity (λ) ¹ and density (D)	Insulation Material Reference to CINI Handbook
1	Cycling or dual process temperatures between -20 °C and 320 °C (or lower)	Cellular Glass + vapour barrier + UV curable GRP jacketing ² or <i>non metallic weather-proofing jacketing</i> ⁴	$\lambda < 0.038 \text{ W/m.K}$ $D = 115 \text{ kg/m}^3$	CINI 2.9.01
2	Process temperatures between 50 °C and 120 °C	Cellular Glass + vapour barrier + UV curable GRP jacketing ^{2,3} or <i>non metallic weather-proofing jacketing</i> ⁴	$\lambda < 0.038 \text{ W/m.K}$ $D = 115 \text{ kg/m}^3$	CINI 2.9.01
3	Process temperatures between - 5 °C and 50 °C	FEF or PUR/PIR or Cellular Glass (CG) + UV curable GRP jacketing ³ or <i>non metallic weather-proofing jacketing</i> ⁴	FEF: $\lambda < 0.037 \text{ W/m.K}$ $D = 50 \text{ kg/m}^3$ PUR/PIR: $\lambda < 0.021 \text{ W/m.K}$ $D > 40 \text{ kg/m}^3$ Cellular Glass $\lambda < 0.038 \text{ W/m.K}$ $D = 115 \text{ kg/m}^3$	FEF: CINI 2.3.01 PIR: CINI 2.7.01 CG: CINI 2.9.01
4	Process temperatures between 120 °C and 175 °C	Rock wool (RW) or cellular glass (CG) + UV curable GRP or SS 316 or Aluminised Steel jacketing or <i>non metallic weather-proofing jacketing</i> ⁴	Rock wool: $\lambda < 0.036 \text{ W/m.K}$ $D = 100 - 125 \text{ kg/m}^3$ Cellular Glass: $\lambda < 0.036 \text{ W/m.K}$ $D = 100 - 125 \text{ kg/m}^3$	RW: CINI 2.2.03 CG: CINI 2.9.01
5	All process temperatures > 175 °C	Rock wool (RW) + SS 316 or Aluminised steel jacketing	$\lambda < 0.036 \text{ W/m.K}$ $D = 100 - 125 \text{ kg/m}^3$	CINI 2.2.03
6	All process temperatures < - 5 °C	PUR/PIR + Primary vapour barrier + UV curable GRP jacketing or <i>non metallic weather-proofing jacketing</i> ⁴	$\lambda < 0.021 \text{ W/m.K}$ $D > 40 \text{ kg/m}^3$	CINI 2.7.01

¹ Indication of Thermal Conductivity measured at 20 °C. Exact values to be obtained from the CINI Handbook and /or related test reports.

² Non-contact insulation may be considered as an alternative.

³ For small bore piping and if electrical heat tracing is applied, FEF should be used

⁴ *Non metallic weather-proofing jacketing may be use but require the approval of the Principal.*

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, freezing, 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.

If not justified, piping/equipment shall not be insulated.

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. PTS 31.38.01.11).

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

Nameplates, identification plates and stampings shall be left clear of insulation or shall be fitted on the outside of the jacketing. For hot insulation, the details of CINI 4.2.16 shall be applied; for cold insulation, the details of CINI 5.2.10 shall be applied. Otherwise the Main Contractor shall design an alternative which shall take into account the avoidance of condensation and heat losses. All metal surfaces under insulation shall be suitably protected with a complete paint system in accordance with *PTS 30.48.00.31-P* or *PTS 70.48.10.10*.

1.2 INSULATION THICKNESS

The basis of insulation thickness should be determined by means of calculations methods based on ISO 12241 in which the several insulation systems, the formulas and factors are given. Annex C of ISO 12241 give examples of insulation thickness calculation.

1.2.1 Economic Insulation Thickness*

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

$$(Q \times CC) + P = \text{minimum}$$

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 TICIP ("Thermal Insulation Calculation Program") is available via CINI and includes insulation calculation programs for economic insulation thickness, heat losses, etc. Background and detailed information regarding insulation thickness calculations is given in CINI 6.1.00.

For new construction projects and major rejuvenation/maintenance works, computer software (e.g. TICIP) programs shall be used to determine the economic insulation thickness. VDI 2055, or other standards if specified by the Principal, shall be used to calculate the contribution of convection. The software shall comply with the information given in CINI 6.1.00 and related standards.

The thickness of hot insulation shall 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 shall be calculated on the following basis:

- The heat gain (heat ingress) for piping in off-plot areas shall be determined by the Principal. If information is not available the heat gain (heat ingress) shall be assumed not to exceed 25 W/m². Solar radiation shall be taken into account.
- For avoiding surface condensation, parameters such as ambient temperature, wind velocity and relative humidity shall be determined from historical local weather data. A report shall be made available which indicates the design parameters necessary to arrive at an economically and technically acceptable design. The report shall be subject to the approval of the Principal.

For quick reference and as a first indication, the Manufacturers'/Supplier's thermal insulation tables may be used. Appendix 1 gives the input data which should be used to check the validity of the Manufacturers'/Supplier's calculated thermal insulation thickness tables. The input data shall be used in conjunction with software (e.g. TICIP) and shall be subject to the approval of the Principal.

** Note: The Economic Insulation Thickness is applicable with the agreement between the manufacturer and purchaser.*

1.3 PERSONNEL PROTECTION

Surfaces 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 7) or hand railings and hazard markings shall be used instead of insulation if the surface process temperature is ≤ 250 °C.

For surface temperatures > 250 °C, insulation shall be used for personnel protection; the table in Appendix 6 may be used to determine the thickness if the ambient temperature is < 25 °C. For higher ambient temperatures a calculation shall be carried out to determine the minimum thickness required to achieve a surface temperature of 70 °C maximum.

Recommendations for the distances of open mesh guards and protective metal sheeting/screens from bare surfaces and the insulation thickness are given in Appendices 6 and 7.

Personnel protection for cold insulation is normally not required, only if indicated by the Principal. If required, metal screens or fencing alone shall be designed and provided.

1.4 LAYERS OF INSULATION

Hot insulation shall be applied in a minimum number of layers of commercially available thickness. 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 PTS or CINI Handbook, 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 PTS. Alternatives shall be submitted to the Principal for approval and 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. For inspection an ITP (Inspection Test Plan) shall be submitted, which indicates all phases for test and inspections of the insulation systems.

3. ENGINEERING OF INSULATION SYSTEMS

3.1 CUI ENGINEERING REQUIREMENTS

The engineering of thermal and acoustic insulation systems is mainly based on HSE, process condition requirements and economics. Most of these items are covered in this PTS.

The phenomenon of CUI is often underestimated, as it will occur years after completion of a project. The potential cost and safety implications are enormous, and therefore insulation systems shall be designed according to categories that indicate vulnerability to CUI and are related to the process temperatures. The following table indicates vulnerabilities to CUI:

Category	Vulnerability to CUI*	Process temperatures
1	Extreme	Cycling or dual process temperatures between - 20 °C and 320 °C (or lower)
2	High	Process temperatures between 50 °C and 120 °C
3	Medium	Process temperatures between – 5 °C and 50 °C
4	Medium	Process temperatures between 120 °C and 175 °C
5	Low	All process temperatures > 175 °C
6	Low	All process temperatures < - 5 °C

*Note: Often there are cold or hot bridges that locally change the process temperatures, e.g. category 4 will become category 2. Inspectors shall record any such changes.

3.2 DESIGN GUIDANCE FOR INSULATION SYSTEMS

Table for guidance on thermal insulation systems for piping/equipment/tanks:

Category	System and Material Guidance ¹
1	Preference shall be given to the use of cellular glass, finished with a vapour barrier and UV curable GRP jacketing or <i>non metallic weather-proofing jacketing</i>. A minimum of two layers of cellular glass shall be applied. The inner side of the inner layer shall be provided with a high temperature anti-abrasive compound, based on a mixture of calcium sulphate hemihydrates and Portland cement for temperatures up to + 320 °C. For temperatures up to 250 °C other suitable compounds may be used. The application and system shall be in accordance with the recommendations of the Supplier/Manufacturer of the cellular glass. <i>Other insulation systems and materials may be used, as long as an RBI analysis and/or CUI risk assessment has been carried out. The systems and materials shall perform as well as or better than the preferred system and</i>
2	Cellular glass should be used, finished with a vapour barrier and UV curable GRP jacketing or <i>non metallic weather-proofing jacketing</i>. For lower temperature ranges and especially small bore piping, FEF may be considered. As an alternative non-contact insulation may be considered as indicated in Appendix 3 and (5.11.3). <i>Other insulation systems and materials may be used, as long as an RBI analysis and/or CUI risk assessment has been carried out. The systems and materials shall perform as well as or better than the preferred system and material.</i>
3	The following materials are permitted and shall be selected according to temperature range, economics (related pipe diameter) and life time: - Flexible Elastomeric Foam (FEF). - PUR/PIR - Cellular Glass For finishing UV curable GRP or <i>non metallic weather-proofing jacketing</i> is recommended, although aluminised steel or stainless steel jacketing are allowed, as long as they are provided with sufficient drain holes. For smaller pipe diameters metal jacketing is not recommended. For temperatures lower than the maximum ambient temperature a primary vapour barrier shall be applied.
4	The following materials are permitted and shall be selected according to economics and life time: - Rock wool - Cellular Glass <i>For finishing UV curable GRP or aluminised steel or stainless steel jacketing are allowed, as long as they are provided with sufficient drain holes.</i>
5	Rock wool should be used finished with aluminised steel or stainless steel jacketing.
6	PUR/PIR should be used, covered with a primary vapour of heavy-duty multiplex foil (25/50/25 µ) and finished with UV curable GRP or <i>non metallic weather-proofing jacketing</i>. Other primary vapour barriers and jacketing systems shall have the approval of the Principal.

Note: Details of the systems and materials can be found in the CINI Handbook and/or this PTS.

Table for guidance on acoustic insulation systems

Category	Generic acoustic insulation system description ¹
1	Not applicable.
2	Non-contact insulation systems as indicated in Appendix 3. The jacketing system shall be as indicated in PTS 31.46.00.31 In general this means that aluminised steel or stainless steel jacketing shall be applied.
3	Non-contact insulation systems as indicated in Appendix 3. The jacketing system shall be as indicated in PTS 31.46.00.31 In general this means that aluminised steel or stainless steel jacketing shall be applied.
4	As indicated in PTS 31.46.00.31 In general this means that aluminised steel or stainless steel jacketing shall be applied.
5	As indicated in PTS 31.46.00.31 In general this means that aluminised steel or stainless steel jacketing shall be applied.
6	First the PUR/PIR system (including primary vapour barrier) shall be applied then the remainder as indicated in PTS 31.46.00.31. In general this means that aluminised steel or stainless steel jacketing shall be applied. Between the acoustic insulation and the jacketing a vapour barrier shall be provided that includes a heavy duty multiplex foil, covered with a UV curable GRP.

Note: Classification (e.g. thickness of acoustic insulation material and weight of jacketing) shall be in compliance with PTS 31.46.00.31 Information regarding insulation systems and material specifications can be found in the CINI Handbook and/or this PTS.

3.3 DETAILED DESIGN REQUIREMENTS

Detailed design for thermal and acoustic insulation systems should be such that ingress of water and capillary action are prevented, and that leaked product and water vapour or condensation can escape or drain off. Insulation collars, if not provided by the equipment Vendor, shall be fitted to avoid any water ingress (see Appendix 9). Cold insulation systems shall be vapour tight.

The thermal insulation and acoustic insulation systems for piping, tanks and equipment shall be able to cope with thermal expansion or contraction; therefore the insulation and jacketing shall be designed to allow expansion or contraction.

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.

For all thermal and acoustic insulation systems, detailed designs shall be produced, which shall cover:

- Avoiding of corrosion under insulation (CUI).
- Economic insulation thickness (minimum heat ingress or loss).
- Compliance with safety requirements (PP).
- Compliance with process conditions.
- Service life of 20 years (or shorter if indicated by the Principal). Life cycle costs calculations shall be carried out to arrive to the lowest cost, based on the service life of 20 years.
- Acoustic insulation systems shall comply with PTS 31.46.00.31.

4. MATERIALS

Materials for insulation, fastenings and jacketing shall comply with and shall be selected from the materials described in the CINI Handbook as amended/supplemented by Part III of this PTS. All materials and application methods shall be selected to suit local weather and environmental conditions.

Insulation materials shall be free of asbestos. No CFCs or HFC C141-b 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 tarpaulins 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. The basic premixed chemicals for in-situ moulded foam shall be transported and stored 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 their service 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 CUI of carbon steel and low alloy steel equipment/piping or stress-corrosion cracking of austenitic stainless steel. To prevent CUI on all steel surfaces shall be suitably painted with a paint system in accordance with *PTS 30.48.00.31-P* or *PTS 70.48.10.10* 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 and piping shall be protected with jacketing systems, e.g. metal, reinforced mastic, tapes, modified EPDM, polymeric compound or GRE/GRP finishing.

The jacketing shall provide protection against water and weather, fire (if required), oil spillage, mechanical wear or other damage. Due consideration shall be given to the choice of jacketing system in terms of safety, life cycle cost (service life), environmental/climate conditions (weatherproofing), 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 passive fire protection of piping/equipment and for cold insulation.

The jacketing selection for cold and hot insulation systems in Appendix 4 recommends the jacketing system to be applied.

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 on the inside fastened with clips. If frequent removal is needed, covers shall be provided with quick-release toggles that 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 10 and 11.

Alternatively, mattresses may fit in complicated configurations, but water ingress shall be avoided. The use of proprietary designed mattress jackets, provided with quick release toggles, may be considered.

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 pre-formed sections shall be used. In-situ moulded/dispensed PUR/PIR (see (5.9.3)) may be used for flange/valve boxes.

As an alternative the following solution may be applied:

- Wrapping of rock wool blankets around valves/flanges/fittings.
- Sealing of rock wool with multiplex foils, so that water and vapour will not penetrate.
- Covering insulation material made of FEF or modified EPDM foam.

If pre-formed PIR/PUR insulation sections are used, the insulation shall be pre-formed or fabricated in single matched halves to the maximum extent possible. The last layer of pre-formed section may include the primary vapour barrier and jacketing. In that case the joints shall be finished in the field. 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

Insulation collars, to prevent water ingress, shall be fitted 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 standard drawing S-10.056.

If the insulation collars are not applied in accordance with standard drawing S-10.056 and the temperature is > 150 °C they shall still be fitted by the Insulation Contractor around all protruding parts of tanks, vessels and columns with operating temperatures between ambient and 350°C or with intermittent operation, to prevent water ingress. These collars shall be executed in accordance with Appendix 9. A sealing plate shall be fitted around all protruding parts with sealed seams in accordance with Appendix 8.

For flammable products, insulation collars of Cellular Glass shall 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. welded collars or insulation cement applications. A typical solution is given in Appendix 26.

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 12.
- Insulation with e.g. sealed rope or flexible cell rubber (e.g. FEF or EPDM foam) 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

High Density 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 (e.g. isometric drawings).

The maximum stresses in the foam shall be limited to 0.2 times the ultimate compressive strength, ultimate tensile strength and shear 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. Depending on the loads, the high density shall be between 100 and 320 kg/m³. The mechanical properties, such as compressive strengths, tensile strengths, shear strength and stress-strain behaviour etc., shall be sufficient to withstand all service loads and thermal stresses.

The thermal conductivity of the high density PUR/PIR, measured at 20 °C, shall not exceed 0.036 W/mK.

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 multiplex vapour barrier (with a sufficient overlap of 50 mm) covered with a bonded 1.5 mm thick EPDM foil and 0.6-0.8 mm thick metal support sheet. The top metal sheet shall overlap the bottom metal sheet and the top part of the EPDM foil shall overlap the bottom part and shall be bonded together.

The EPDM foil protects the multiplex foil against mechanical damage.

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 withstand any stresses and strains, 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 Handbook (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 the 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 so that the performance of the injection foam (PUR/PIR) can be guaranteed. 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/m³, 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. GRP) vapour barrier shall be applied. For a metallic primary vapour (see (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 45 kg/m³. 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:

- a) If the process temperature is higher than -50 °C and a secondary vapour barrier is not required;
- 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 to 23.

5.10.2 Single sprayed monolithic PUR/PIR (System a)

The PUR/PIR insulation shall have the properties specified in CINI 2.7.01. The minimum density shall be 40 kg/m³.

PUR/PIR shall be shop sprayed onto 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 Handbook). The temporary insulation termination shall be finished with pre-formed PUR/PIR sections in accordance with the requirements of the CINI Handbook.

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 (System b)

The PUR/PIR insulation shall have the properties specified in CINI 2.7.01. The minimum density shall be 40 kg/m³.

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:

- a) **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).
- b) **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 17).

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

1. The existing coating shall be abraded at the shear key location.
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. Compressible and 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 (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 that 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 (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 un-reinforced 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 Handbook. 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 consist 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/m² and shall be composed of filaments of 5-20 µm diameter.

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

The Main Contractor and/or Insulation Contractor shall submit all design, engineering and application details and method statements of these systems 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. This combination may also be used for normal insulation systems if economic (based on service life and life cycle costs) justified.

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 and jacketed with a curable GRP or polymeric compound. For jacketing systems reference is made to Appendix 4 Jacketing Selection.

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.

5.11.3 Non-contact insulation

Non-contact insulation is an insulation system in which there is limited contact between bare surface of pipe/equipment and the insulation material. An annular space between 25 mm and 30 mm is created between the bare surface and insulation material. Spacers are used to ensure the annular gap. The annular gap shall not be ventilated and shall be designed as a non-ventilated annular space. The annular space will allow condensed water and incoming rainwater to be drained off via the lowest point in the insulation system. Non-contact insulation is used for:

- Avoiding corrosion under insulation if process temperatures are between + 50 °C and 120 °C.
- Insulation for dual or recycling process temperature conditions.
- Acoustic insulation system, if hot insulation is not required.

In Appendix 3 guidelines and details are given to arrive to a detailed design of non-contact insulation.

5.11.4 Proprietary pre-insulated bonded pipe systems

Proprietary mold (UK)-injected PUR/PIR pipe systems are available and may be considered for loading/rundown lines of import or export LNG or LPG terminals. The system shall have the approval of the Principal.

The design of these systems is based on EN 13941 and EN 253; these standards may be used in addition to the requirements mentioned in this PTS to arrive at an acceptable design and installation specification. Test, calculations, test certificates, detailed specification of supports, contraction bellows or loops, fixed or sliding points shall be provided. For piping requirements, reference shall be made to the applicable pipe design and inspection codes which do not form part of this PTS.

5.12 EXPANSION / CONTRACTION BELLOWS

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

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: Details A, B and C).

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

Applicable to hot storage tanks with an operating window between ambient and + 180 °C.

5.13.1 Insulation with pre-formed mineral fibre boards

The tank wall insulation system shall be as specified in CINI 1.3.04

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 CUI, 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 tank roof insulation system shall be as specified in CINI 1.3.04.

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.

PUR/PIR shall not be applied if 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 which 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. If corrosion under insulation may occur (Process temperature conditions falling in categories 2 and 3), non-contact insulation shall be designed and applied.

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 PTS 31.46.00.31. An example of the application of non-contact insulation is given in Appendix 3.

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 might 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 PETRONAS HSE Guide "Asbestos" and any national or local regulations shall be consulted.

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

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

To ensure that the co-ordination activities of pre-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 (ITP) 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 shall 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 shall 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 shall 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? Are supports properly installed, e.g. for cold insulation in the so-called "hot-mode" or for hot insulation in the so-called "cold-mode"?
- 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?
- 5) Electrical tracing stations/hangers - Is sufficient protection against incoming rain and other water provided (e.g. water deflectors, etc.)?

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 (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 traceability 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

All parties involved when the system is considered complete or as soon as possible thereafter shall conduct a final inspection. After final completion of a system, a “release for system insulation completion” shall 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 may be used after start-up to verify proper thermal performance of the insulation system(s).

Cold insulation systems shall be subjected to thermo-graphic survey between 9 - 12 months after initial 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 batch date or manufacturing date.

In case of non-conformance all defective materials shall be replaced.

PART III AMENDMENTS / SUPPLEMENTS TO THE CINI HANDBOOK

Tab 1	General Requirements + Installation Instructions		
CINI 1.2.01	Heat Insulation Diagram		
Sheet 1	Not applicable (Remark: May be used for information only)		
Sheet 2	Not applicable (Remark: May be used for information only)		
CINI 1.2.02	Cold Insulation Diagram		
Sheet 1	Not applicable (Remark: May be used for information only)		
CINI 1.3.01	General requirements for the thermal insulation of “hot” pipelines and equipment		
1.3	Replace this clause by: For the conservation of insulated metal surfaces, see PTS 30.48.00.31-P or PTS 70.48.10.10, as applicable.		
2.1.3	<i>Clarification:</i> The cited Chapter 4 is Tab 4 and gives many detail drawings related to hot insulation.		
2.4.1	Replace this clause by: The information of Chapter 6 (or Tab 6) may be used along with the requirements mentioned in Part II, Section (1.2) of this PTS.		
3.1	Insulating materials according to specifications CINI 2.1.02....2.10.03 Add this clause: The following materials shall ne applied for hot insulation (1):		
	Hot Insulation Materials	Tab 2 Ref. CINI Specification	Temperature and Category
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 in this case be obtained from the Principal. Rock wool shall also be used in conjunction with non-contact insulation systems and acoustic insulation systems. Suitable insulation material for categories 2, 4 and 5.
b)	Cellular Glass	Tab 2 CINI 2.9.01	Application for product temperatures < 427 °C, as fire protection in conjunction with other insulation materials and as collars to avoid water/product ingress and capillary working. Suitable for categories 1, 3 (also in conjunction with electrical tracing), 4 and 6 (for passive fire protection)
c)	Flexible Elastomeric Foam	Tab 2 CINI 2.3.01	In general for insulation of small bore piping and appendages of pump/compressor skids and the like, but also for larger pipe diameters. Subject to economic considerations. Limited temperature range. Application shall be considered for category 3 and partly category 2.

Note: (1) Other insulation materials of the CINI Handbook 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 as indicated in Appendix 4. Aluminium sheeting may only be used in process temperatures (category 5) > 175 °C and preferably in utility areas (e.g. piping/equipment of steam systems). In areas with potential fire hazards, only aluminised steel type II or stainless steel sheeting shall be used (see Appendix 4). No combustible materials shall be applied on the metal jacketing. Removable covers for flanges; valves etc. shall be made of 1.0 mm sheets, irrespective 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 20 years, taking into account environmental and climate conditions. For SS 316 the following minimum thickness may be adopted: <table> <tr> <td>Outside diameter insulation in mm < 140 mm :</td><td>0.4 mm</td></tr> <tr> <td>Outside diameter insulation in mm 140 - 300 mm:</td><td>0.5 mm</td></tr> <tr> <td>Outside diameter insulation in mm > 300mm:</td><td>0.6 mm</td></tr> </table>	Outside diameter insulation in mm < 140 mm :	0.4 mm	Outside diameter insulation in mm 140 - 300 mm:	0.5 mm	Outside diameter insulation in mm > 300mm:	0.6 mm
Outside diameter insulation in mm < 140 mm :	0.4 mm						
Outside diameter insulation in mm 140 - 300 mm:	0.5 mm						
Outside diameter insulation in mm > 300mm:	0.6 mm						
3.5	Add to this clause: Only the specifications of CINI 3.2.01 and 3.2.11 shall apply. <i>Clarification: Other cited specifications are seldom used and may be omitted.</i>						
3.6	Add to this clause: In so far as applicable.						
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, provided with rigid insulation slabs or proper fixed blankets and secured by hinges and quick-release toggles, self-tapping screws or removable strapping bands. The rigid insulating material shall be fixed by clips or metal strips riveted to the inside of the metal cover. Blankets shall be properly fixed with straps or wires. 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 4.1.11	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.						

4.3.1	Change this clause by: Delete "For thermally galvanized, thermally galvanized self-tapping screw or blind rivets shall be allowed."
4.3.5	Change this clause by: "Delete the wording "If necessary".
4.3.9	Change this clause by: Delete: "a cord of flexible elastomer or silicone paste.", and add: "sufficient UV curable GRP wrapping material (see Tab 3 - CINI 3.2.11)". <i>(Example: Especially horizontal elbows are vulnerable. Often they will be damaged and water can easily penetrate. The topside should therefore always be covered by UV curable GRP or similar non-metallic material.</i>
New clause 4.4.8	Add new clause: Prefabricated sections/segments of insulation material, provided with UV curable GRP are allowed. Special UV curable GRP tape shall be used to seal the joints. The application shall be as described for the finishing of UV curable GRP sheets (see 4.4)
CINI 1.3.02	General requirements for the thermal insulation of "cold" pipelines and equipment
1.4	Replace this clause by: For the conservation of insulated metal surfaces, <i>PTS 30.48.00.31-P</i> or <i>PTS 70.48.10.10</i> shall apply.
1.5	Add to this clause: "and the latest edition of this PTS.
2.2.1	Add to this section: For cold services the following insulation materials shall be applied: • Polyurethane (PUR) / Polyisocyanurate (PIR) Foam (see Tab 2 - CINI 2.7.01) • Cellular Glass (see Tab 2 - CINI 2.9.01) and only in conjunction with PIR/PUR • For small bore pipe FEF or EPDM foam (depending on process temperature and related properties of FEF and EPDM foam) Other insulation materials shall have the approval of the Principal.
2.2.1.4	Add to this clause: Metal cladding shall only be applied if approved by the Principal. Preference shall be given for the application of UV curable GRP. If metal cladding is allowed, a space of 25 mm between primary vapour barrier and cladding shall be provided with sufficient drain holes (diameter 20 mm). For spacers FEF or EPDM foam or "polyethylene burls foil" material shall be used.
2.2.1.5	Add to this clause: For further information, reference shall be made to (5.9) of this PTS. The requirements as mentioned in (5.9) of the PTS shall be adopted.
2.2.2.2	Add to this clause: As alternative, the supporting solution as indicated in Appendices 24 and 25 of this PTS.
2.3.2.2	Add to this clause: Reference is made to (5.8) of this PTS.
2.3.6	Add to this clause: Personnel protection for cold insulation is normally not required, only if indicated by the Principal. If required, the requirements as stated shall be complied with.
2.4.1	Add to this clause: Chapter 6 (Tab 6) shall be use in conjunction with the requirements as mentioned in part I of this PTS.
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 PTS. The Principal shall give the local environmental/climate condition.
2.4.6	Delete this clause.

3.2.1	Delete: “Extrude polystyrene foam (XPS)”	
3.3.3	Add new clause: CINI clause 3.3.1 and 3.3.2 shall be used for repair and/or maintenance of existing cold insulation system only. For new cold insulation systems the primary vapour barrier shall consist of multiplex foil, factory applied and complies with the material specification of CINI 3.3.10 (Tab 3). The field seams shall be tapped together with a minimum overlap of 50mm in accordance with the material specification of CINI 3.3.11 (Tab 3). The non-metallic jacketing finishing shall complete and protect the primary vapour barrier.	
3.5	METAL FINISHING MATERIALS in conformity with specification CINI 3.1.01 through CINI 3.1.05. Add to this clause: Metal jacketing shall only be used if indicated by the Principal and in if passive fire protection is required. In general metal jacketing shall not be used for cold insulation applications. For jacketing the jacketing selection of Appendix 4 shall apply. The lifetime of the jacketing shall be 20 years. The composition of Stainless Steel 316 cladding shall be in accordance with ASTM A 167; type SS 316. The cladding specified in CINI 3.1.03 and 3.1.04 shall not be applied. If metal finishing shall be applied, the following shall be applicable: – Removable covers for flanges, valves etc. shall be made of 0.8 mm sheets. – Corrugated (wave type) SS 316 shall be used with a pitch between 75 and 85 mm, and a height between 18 and 30 mm for equipment/large vertical piping (> 24”).	
3.5.1	Replace this clause by: If applicable, the thickness of the stainless steel 316 cladding shall be:	
	Outside Diameter insulation in mm	Minimum Thickness of the SS 316 sheeting in mm
	< 140	0.4
	140 - 300	0.5
	> 300	0.7
3.5.2	Replace this clause by: If passive fire protection (fireproofing) is required, stainless steel 316 metal finishing shall be used in conjunction with PIR/PUR and Cellular Glass, as indicated in (5.11 .1).	
3.5.3	Replace this clause by: Galvanised cladding shall not be used.	
4.3	Add to this clause: The Insulation Contractor shall make detail drawings for the application of non-metallic jacketing systems combined with contraction joints.	
4.4.3	Add new clause: CINI clause 4.4.1 and 4.4.2 shall be used for repair and/or maintenance of existing cold insulation systems only. For new cold insulation systems the primary vapour barrier shall consist of multiplex foil, factory applied, and comply with the material specification of CINI 3.3.10 (Tab 3). The field seams shall be tapped together with a minimum overlap of 50 mm in accordance with the material specification of CINI 3.3.11. The non-metallic jacketing finishing shall complete and protect the primary vapour barrier.	
4.5	Add to this clause: In so far as applicable.	
CINI 1.3.03	General requirements for the thermal insulation of “hot” pipelines, fittings and equipment with mattresses.	
1.1	Add to this clause: The use of mattresses shall have the approval of the Principal.	

3.1	Add to this clause: The use of glass wool shall have the approval of the Principal.
CINI 1.3.04	General requirements for the thermal insulation of “hot” storage tanks
2.1.3	Add to this clause: If special structures are required the Main Contractor shall design the required structures.
2.1.4	Add to this clause: Approval of the commercially available tank insulation systems shall be obtained from the Principal.
CINI 1.3.10	Installation instructions for the thermal insulation of “hot” pipelines: MINERAL WOOL
1.1	Add to this clause: Glass wool may only be used if approved by the Principal.
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 13). 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.
2.3.3	Add to this clause: Galvanizing wire and hooks shall not be used. Only stainless steel or aluminised steel wire and hooks shall be used.
2.3.4	Add to this clause: The bands shall be equipped with expansion elements (springs) to compensate for equipment expansion.
CINI 1.3.11	Installation instructions for the thermal insulation of hot piping, fittings and equipment: FLEXIBLE ELASTOMERIC FOAM (FEF).
1.1	Add to this clause: And shall be used for small-bore piping. For normal piping/equipment approval shall be obtained from the Principal.
2.1.3	Change this clause by: Deleting: “metal cladding” and add: “UV curable GRP or modified UV resistant polymeric compound.”
CINI 1.3.12	Installation instructions for the thermal insulation of “hot” pipelines and equipment: CALCIUM SILICATE (CS)
1	Add to this clause: This material shall normally not be used. If it is the intention to use this material, approval shall be obtained from the Principal.

CINI 1.3.13	Installation instructions for the thermal insulation of “hot” pipelines and equipment: POLYETHYLENE FOAM TUBING (PEF)
1	Add to this clause: This material shall normally not be used. If it is the intention to use this material, approval shall be obtained from the Principal.
CINI 1.3.14	Installation instructions for the thermal insulation of “hot” pipelines and equipment: VERMICULITE (VC)
1	Add to this clause: This material shall normally not be used. If it is the intention to use this material, approval shall be obtained from the Principal.
CINI 1.3.15	Installation instructions for the thermal insulation of “hot” pipelines and equipment: HIGH TEMPERATURE GLASS FIBER (HT-GF)
1	Add to this clause: This material shall normally not be used. If it is the intention to use this material, approval shall be obtained from the Principal.
CINI 1.3.18	Installation instructions for the thermal insulation of “hot” pipelines and equipment: PERLITE (PL)
1	Add to this clause: This material shall normally not be used. If it is the intention to use this material, approval shall be obtained from the Principal. Perlite may be used for filling of LNG tank walls. A separate specification shall be produced by the Contractor and shall not be part of the CINI specification and this PTS.
CINI 1.3.19	Installation instructions for the thermal insulation of “hot” pipelines and equipment: PERSONNEL PROTECTION
1.1	Add to this clause: This material shall normally not be used. If it is the intention to use this material, approval shall be obtained from the Principal.
CINI 1.3.20	Installation instructions for the thermal insulation of “hot” pipelines and equipment: MICROPOROUS (MPS)
1	Add to this clause: This material shall normally not be used. If it is the intention to use this material, approval shall be obtained from the Principal.
CINI 1.3.21	Installation instructions for the thermal insulation of “hot” pipelines and equipment: SILICA (S)
1	Add to this clause: This material shall normally not be used. If it is the intention to use this material, approval shall be obtained from the Principal.
CINI 1.3.51	Installation instructions for the thermal insulation of “piping, fittings and equipment with cold medium in the temperature range from ambient to – 40 °C: FLEXIBLE ELASTOMERIC FOAM (FEF)
2.1.3	Change this clause by: Deleting: “metal cladding” and replace by: “UV curable GRP or UV resistant polymeric compound or EPDM sheeting.”
CINI 1.3.52	Installation instructions for the thermal insulation of “piping, fittings and equipment with cold medium in the temperature range from ambient to – 40 °C: EXTRUDED POLYSTYRENE FOAM (XPS)
General	Delete this section
CINI 1.3.53	Installation instructions for the thermal insulation of “piping, fittings and equipment with cold medium in the temperature range from ambient to – 200 °C: POLYISOCYANURATE FOAM/POLYURETHANE RIGID FOAM (PIR/PUR)

1	Change this clause by: Deleting “CINI Spec. No. 3.3.05, 3.3.06, 3.2.02, 3.2.03 and 0” and replace with “CINI Spec.No. 3.3.10, 3.3.11 and 3.2.11”. Note: The above change concerns the primary vapour barrier and finishing jacketing. This vapour barrier shall be made of multiplex foil of which the seams are tapped with multiplex foil. The finishing shall be UV curable GRP. Other non metallic finishing systems shall have the approval of Principal.
2.2.1	Delete this clause and replace by: The insulation thickness shall be in accordance with the requirements as mentioned (1.2) of this PTS.
2.2.1	Delete this clause and replace by: The layering of the cold insulation shall be in accordance with appendix 2 of this PTS.
2.2.3	Add to this clause: Preference shall be given to system 1. For system 2 approval shall be obtained from the Principal.
CINI 1.3.54	Installation instructions for the thermal insulation of “piping, fittings and equipment with cold medium in the temperature range from ambient to –200 °C: Cellular Glass (CG)
1	Change this clause by: Deleting “CINI Spec. No. 0 – Weather resistant mastic” and replace with “CINI Spec.No. 3.2.11”. Note: The above change concerns the finishing jacketing of CG passive fire protection. The finishing shall be UV curable GRP or a polymeric compound, covered by corrugated or flat stainless steel 316 cladding.
2.2.1	Delete clause and replace by: The thickness of cellular glass shall depend on the passive fire protection requirements. Note: For example, a thickness of 50 mm will be sufficient for 30 min period of protection.

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”
CINI 3.2.1.11	Weather resistant UV-curing glass fibre reinforced polyester
7	Add: The material may also be used as tape. The adhesive properties shall be similar to or better than the properties given in CINI 3.3.11.

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) of this PTS shall apply.

Tab 7	Conservation of insulated piping, equipment, and tanks
CINI 7	Conservation of insulated piping, equipment, and tanks Replace this Section by: PTS 30.48.00.31 or PTS 70.48.10.10 shall apply.

PART IV INSPECTION AND MAINTENANCE OF EXISTING INSULATION SYSTEMS

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

Routine maintenance practice should be extended with a system of scheduled inspections, preventive maintenance and long-term maintenance programme, based on RBI modules. In Appendix 5 inspection guidance and an example of an inspection record is given. Shortcomings can then be detected at the earliest stage, preventing uncontrolled deterioration of the insulation system with consequential risk of CUI. In particular, inspection surveys should be carried out after shutdowns, as during shutdowns insulation systems are sometimes removed and not properly re-installed or the systems are damaged, e.g. due to falling scaffolding poles.

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 CUI.

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.

The frequent removal of insulation for visual inspection of CUI is usually impractical but still effective. Inspection methods using thermography, pulsed eddy current (PEC), conventional gamma radiography, flash radiography (X-ray), real time radiography and neutron backscatter can be used for these inspections.

Thermography using an infrared camera can reveal hot or cold spots on the insulation. Thermography is not suitable for sizes less than DN 200.

PEC is a method that may be used for detection of corrosion under insulation (CUI). The PEC method has the following restrictions:

- The method is not suitable close to and at protrusions/nozzles of piping and equipment.
- The PEC method is suitable for insulated systems installed with metal cladding provided the metal is not ferro-magnetic (such as aluminum).
- PEC is not suitable for insulation material installed with wire mesh.

For straight insulated piping, the guided wave ultrasonic technique may be applied for the detection of wall loss.

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

Neutron Backscatter method can be used for moisture detection. This system is designed to detect wet insulation on pipes and vessels. A radioactive source emits high-energy neutrons into the insulation. If there is moisture in the insulation the hydrogen nuclei attenuate the energy of the neutrons. The instrument's gauge detector is only sensitive to low-energy neutrons. The count displayed to the inspector is proportional to the amount of water in the insulation. Low counts per time period indicate low moisture presence.

Moisture in insulation may also be checked by means of drilling a hole in the jacketing and the use of a moisture-measuring probe.

1.3 INSPECTION FREQUENCY

The optimal frequency of inspections depends on a number of factors such as critically class (based on Risk & Reliability Management, determined via RBI modules), 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. In particular, inspection surveys should be carried out after shutdowns, as during shutdowns insulation systems are sometimes removed and not properly re-installed or the systems are damaged, e.g. due to falling scaffolding poles.

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 categories of vulnerability. 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 5.

Via a maintenance management system and risk based inspection, a plan of action and a budget should be generated based on RRM principles (Risk & Reliability Management).

1.5 INSPECTION SURVEY

The insulation inspector in close co-ordination with the mechanical/static equipment inspector should carry out the inspection survey. A typical insulation inspection survey overview and an example for a inspection record is given in Appendix 5. In the absence of an insulation inspector, the static piping/equipment inspector shall be trained to undertake the insulation inspections.

1.6 ITEMS TO BE INSPECTED

The integrity of the weather protection and vapour barrier and the thickness of the insulating material are of prime importance and inspection is therefore required.

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 CUI in the main product lines.
- Piping or equipment at an operating temperature between -5 °C and 175 °C, or with intermittent or recycling temperature 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.
- Areas exposed to mist over spray from cooling water towers.
- Areas exposed to steam vents.
- Areas exposed to deluge systems.
- Areas subject to process spills, ingress of moisture, or acid vapours.
- Carbon steel piping systems, including those insulated for personnel protection, operating between -5°C and 175°C.
- Carbon steel piping systems that normally operate in-service above 175° C but are intermittent service.
- Dead legs and attachments that protrude from insulated piping and operate at a temperature different than the active line.
- Austenitic stainless steel piping systems that operate between 50° C and 200° C. These

systems are susceptible to chloride stress corrosion cracking.

- Vibrating piping systems that have a tendency to inflict damage to insulation jacketing providing a path for water ingress.
- Steam traced piping systems that may experience tracing leaks, especially at the tubing fittings beneath the insulation.
- Piping systems with deteriorated coatings and/or wrappings.
- Locations where insulation of valves/flanges has been removed to permit spading and maintenance and is sometimes wrongly reinstalled should receive particular attention.
- Insulated piping/equipment system exposed to seawater splash or salt spray.
- Insulated piping damaged by human traffic during maintenance work.
- Insulated spool pieces lifted out for maintenance.

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 or designated 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 nearest 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.
- Areas exposed to mist over-spray from cooling water towers.
- Areas exposed to deluge systems, particularly those containing salt or brackish water.
- Areas subject to process spills, ingress of moisture, or acid vapours.
- Carbon steel piping systems, including those insulated for personnel protection, operating between -5°C and 120°C.
- Carbon steel piping systems that normally operate in-service above ambient temperature but

are intermittent (cycling or dual) service.

- Dead-legs and attachments that protrude from insulated piping and operate at a temperature different than the active line.
- Vibrating piping systems that have a tendency to inflict damage to insulation jacketing providing a path for water ingress.
- Piping systems with deteriorated coatings and/or wrappings.
- Locations where insulation of valves/flanges has been removed to permit spading and maintenance and is sometimes wrongly reinstalled should receive particular attention.

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 firewater 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 accordance with the RRM principles.

In order to systematically control the upgrading of existing insulation in a plant, the various units should be divided into manageable areas indicated on a plot plan, and the work carried out 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 PTS, reference is made to the following publications:

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

PETRONAS STANDARDS

Painting and coating of new equipment	PTS 30.48.00.31-P
Piping – General requirements	PTS 31.38.01.11
Acoustic insulation for piping	PTS 31.46.00.31
Maintenance painting	PTS 70.48.10.10
PETRONAS HSE COMMITTEE	Asbestos
PETRONAS HSE COMMITTEE	Waste Management Guide

STANDARD DRAWINGS

Support ring for insulation	S 20.003
<i>Typical details of insulation collar for carbon, low-alloy steel and stainless steel apparatus</i>	<i>S 10.056</i>

AMERICAN STANDARDS

Process piping	ASME B31 .3
<i>Issued by:</i> <i>American Society of Mechanical Engineers</i> <i>Three Park Avenue, M/S 10E</i> <i>New York</i> <i>NY 10016</i> <i>USA</i>	
Standard Practice for Inner and Outer Diameters of Rigid Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS System)	ASTM C 585
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
<i>Issued by:</i> <i>American Society for Testing and Materials</i> <i>100 Barr Harbor Drive</i> <i>West Conshohocken</i> <i>PA 19428-2959</i> <i>USA</i>	

DUTCH STANDARDS

CINI Handbook "Insulation for Industries"

Issued by:

Commissie Isolatie Nederlandse Industrie,

Puntweg ,7

3208 LD Spijkenisse,

The Netherlands

CINI Handbook "2005 edition"

(1st October 2004)

EUROPEAN STANDARDS

District heating pipes – Preinsulated bonded pipe

systems for directly buried hot water networks –

EN 253

Pipe assembly of steel service pipe, polyurethane
thermal insulation and outer casing of polyethylene

Design and installation of pre-insulated bonded pipe
systems for direct heating

EN 13941

Issued by:

CEN

Rue de Stassart 36

B-1 050 Brussels Belgium

Copies can also be obtained from national standards organizations

INTERNATIONAL STANDARDS

*Thermal Insulation for building equipment and
industrial*

ISO 12241

Installations – Calculation rules

Issued by:

International Organisation for Standardisation Case Postale 56

Geneva 20 Switzerland CH-1211

Quality management systems - Requirements

ISO 9001

Issued by:

International Organisation for Standardisation Case Postale 56

Geneva 20 Switzerland CH-1211

Copies can also be obtained from national standards organizations.

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 un-insulated pipeline
2. The temperature change of a flowing fluid in an insulated pipeline
3. The time in which a stagnant fluid in an un-insulated 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 un-insulated 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 EXAMPLES OF NON-CONTACT INSULATION

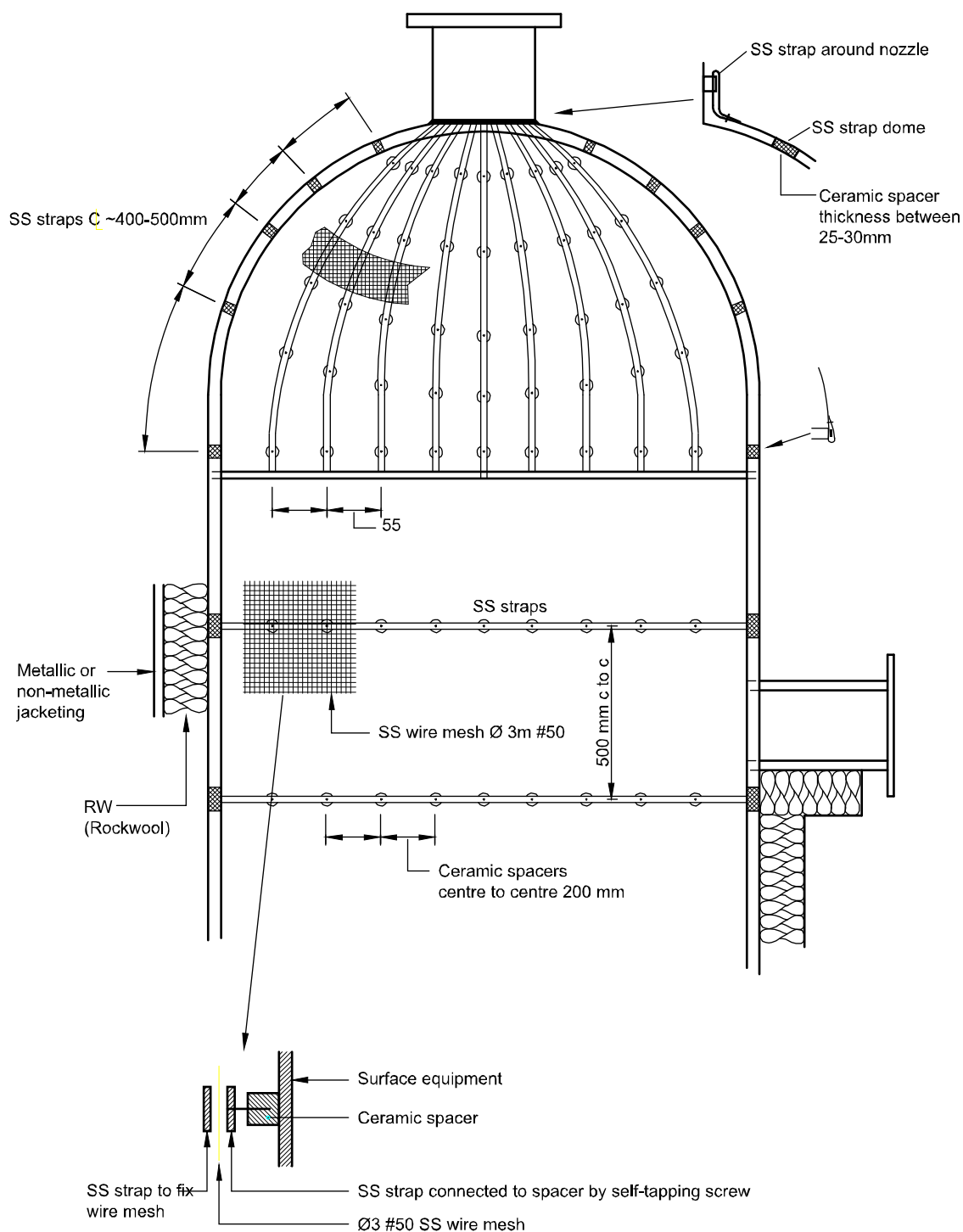
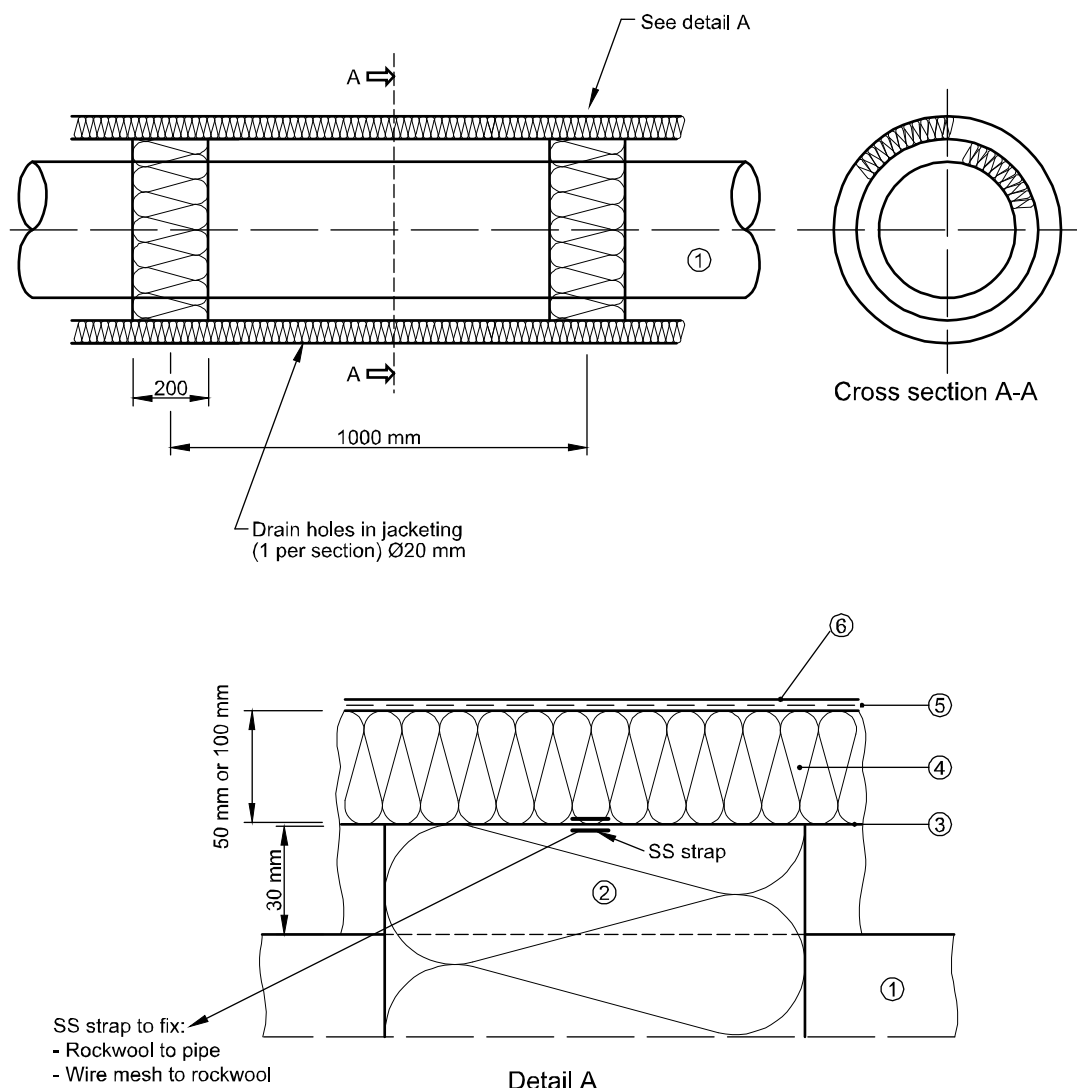


Figure 3 A: Non-contact insulation of equipment



NOTES:

- ① pipe
- ② 50 mm mineralwool, preformed sections, density: 150 kg/m³
- ③ SS wire mesh Ø 3 # 100 mm
- ④ 50 mm mineralwool, slabs, density: >100 kg/m³ or 100 mm
- ⑤ 4,2 mm damping layer, mass loaded thermoplastic sheet 7,9 kg/m² (if required)
- ⑥ 1,25 mm steel sheet, (if required) (aluminimised Type 2 or SS 316)

Figure 3 B: Example of acoustic non-contact insulation

APPENDIX 4 JACKETING SELECTION

The table below gives recommendations for selecting a jacketing system. The jacketing system should be reviewed or assessed with account being taken of economics (e.g. competitive prices), availability, maintainability, lifecycle and environmental conditions. Other non-metallic jacketing systems may be used, but require the approval of the Principal.

Conditions for jacketing	UV curable GRP	Polymeric Compound	SS 316	Aluminised Steel Type 2	Aluminium
Passive Fire Protection (Fireproofing)	-	-	+++	++	-
Category 1	++	++	+	o	-
Category 2	++	++	+	o	-
Category 3	++	++	+	o	-
Category 4	+	++	+	++	o
Category 5	o	o	+	++	+
Category 6	+++	+++	+	-	-

- o May be used, but not recommended
- Not recommended
- +
- ++ Recommended
- +++ Strongly recommended

Category	Process temperatures
1	Cycling or dual process temperatures between approximately - 20 °C and 320 °C
2	Process temperatures between 50 °C and 120 °C
3	Process temperatures between – 5 °C and 50 °C
4	Process temperatures between 120 °C and 175 °C
5	All process temperatures > 175 °C
6	All process temperatures < - 5 °C

APPENDIX 5 INSPECTION OF THERMAL INSULATION SYSTEMS

Example of Thermal Insulation Inspection Survey

Check the following deficiencies/defects	Tick box if applicable	Consequences
⇒ Caulking/Sealant that has hardened and separated ⇒ Circumferential cracks in GRE/GRP jacketing ⇒ Corrosion cladding ⇒ Damaged or loose cladding ⇒ Damaged vapour barrier/stop ⇒ Failure at bends (open joints) ⇒ Foot traffic damage ⇒ Gaps due to uncontrolled expansion/contraction ⇒ Hot/Cold Spots ⇒ Icing and/or condensation ⇒ Longitudinal cracks in GRE/GRP jacketing ⇒ Missing insulation (not re-installed after shutdowns) ⇒ Missing self-tapping screws, rivets or SS bands ⇒ Rust staining and bulges in metal cladding ⇒ Sagged insulation and cladding ⇒ No termination at flanges/valves ⇒ No termination in a vertical pipe or piece of equipment ⇒ Water ingress at penetrations (e.g. nozzles)	⇒	➤ Corrosion under insulation ➤ Deterioration of insulation system ➤ Soaked insulation material ➤ Substandard thermal performance ➤ Water ingress ➤ Fungal growth ➤ Ice formation and slippery areas

If any of the above deficiencies/defects have occurred, the extent or amount shall be reported to the static/mechanical inspection department and/or to the reliability/integrity department, so that they can take action and implement the information into their RBI module.

The next page gives guidance on the set up of an inspection record that is part of the reporting system.

Example of Thermal Insulation Inspection record

Insulation Inspection Record	Description, Explanation and Input
Insulation Inspection ID	Create Unique Number
Inspection Date	Input 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
Installed in Year	Give year of installation
Drawing list	Connected to Database file
Isometric number	Connected to Auto Cad File or Database file
Operating Temperature	Can be checked via supervisory systems or otherwise obtained.
Operation Mode	Constant, Cycling temperatures, Ambient to 100 °C, Ambient to 200 °C, Ambient to 300 °C and Minus to Ambient
Remarks on Operation	E.g. long down time periods
Climate conditions	Indicate climate conditions, e.g. marine and tropical (rainfall > 2000 mm) or marine and desert. This information is required assessing the corrosion rate if insulation and painting systems don't give sufficient protection.
Local environmental conditions	Indicate the local environmental conditions, such as: - Areas exposed to mist over spray from cooling towers. - Areas exposed to steam vents. - Areas exposed to deluge systems. - Areas subject to process spills, ingress of moisture, or acid vapours.
Piping/Equipment material	Carbon, low carbon steel or stainless steel, etc.
Insulation Material	Rock Wool, PUR/PIR, Flexible Elastomeric Foam etc.
Description of Insulation System	E.g. cold insulation of PUR and finished with mastic vapour barrier and stainless steel cladding.
Number of Damaged Penetrations	Could be given per isometric drawing or could be indicated in the drawing.
Description of Damaged Penetrations	The nature of damage, e.g. failure of the sealant.
Cause of Damaged Penetrations	Substandard Workmanship, Substandard Design, Ageing or Damaged by third party
Amount of Missing Cladding	Metres 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	Indicate the amount per isometric
Description of Missing Terminations	Indicate what is missing, e.g. material not reinstalled after modifications etc.
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	Indicate the amount per isometric
Description of Missing Valves/Flanges insulation	Indicate what is missing, e.g. material not reinstalled after modifications etc.
Cause of Missing Valves/Flanges insulation	Substandard Workmanship, Substandard use, Substandard Design, Damaged by Third Party
Description of Deficiencies/defects	Give a description as indicated in the lat page.
General Condition Insulation	Good, Moderate and Substandard
Inspection Findings and Consequential Damage	Give your judgement regarding CUI, Thermal losses etc.,
Action required?	Yes or No
If action is required, indicate when!	First opportunity, during shutdown, within 1 year or within 2 years, etc..
Inspection Sequence	Every 6 months and/or after every shutdown
Next Inspection Date?	Date or combined with mechanical inspection. Results will depend on the outcome of the RBI module.
Quantities and Cost of Replacement/Repairs	Indicate roughly the quantities and cost. The cost-estimating department should work out information.
Amount of total costs	Indicate roughly

APPENDIX 6 PERSONNEL PROTECTION - GUARD DISTANCES AND INSULATION THICKNESS

For process temperatures from 70 °C to 250 °C barrier protections should be applied, without insulation (e.g. 60 % rigid perforated sheets or wire mesh, as indicated in Appendix 7).

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

Criteria for the table below are:

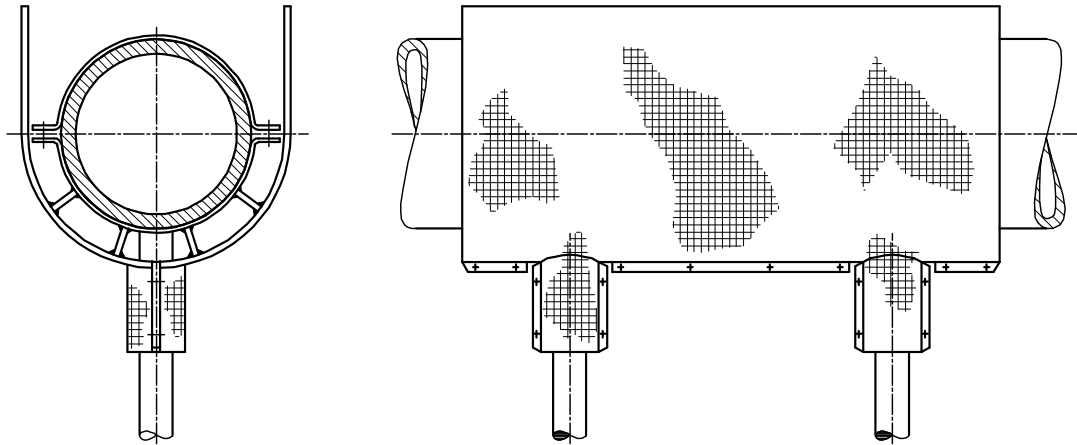
- Ambient temperature: 25 °C.
- Wind velocity: 1 m/s.
- Surface temperature protection: max. 70 °C

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

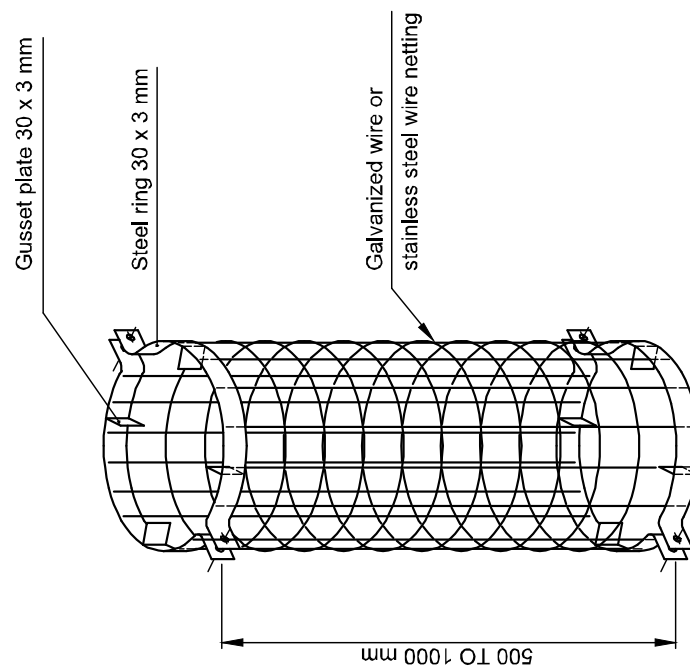
Table: Recommended distances between perforated metal sheet/guards and bare surface, and insulation thickness for personnel protection

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 7 PERSONNEL PROTECTION - PHYSICAL BARRIERS



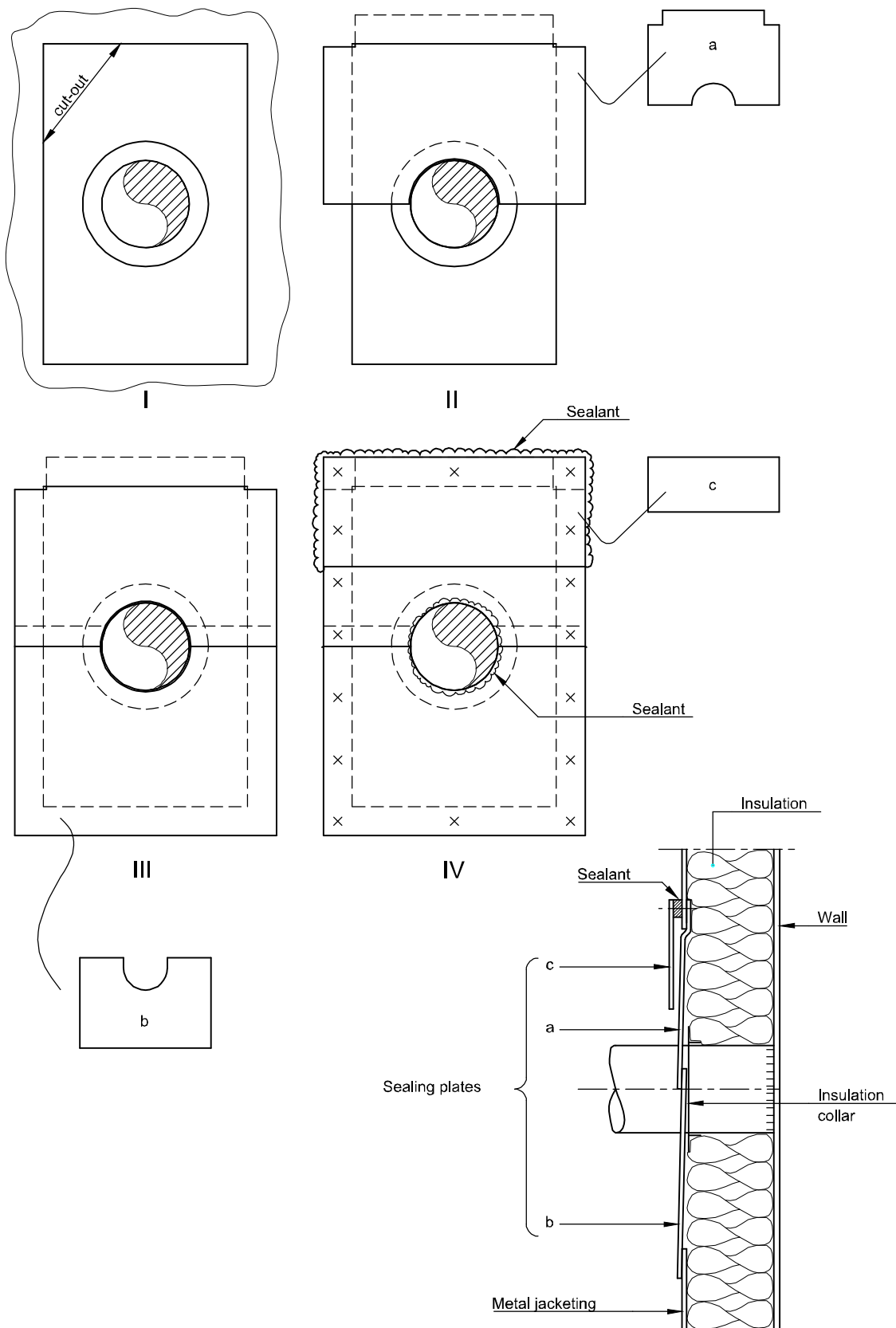
PERFORATED METAL SHEET



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

MESH GUARD

APPENDIX 8 TYPICAL DETAILS OF SEALING PLATES AROUND NOZZLES (HOT INSULATION)



APPENDIX 9 INSULATION COLLAR SOLUTIONS (alternatives to Standard Drawing S10.056)

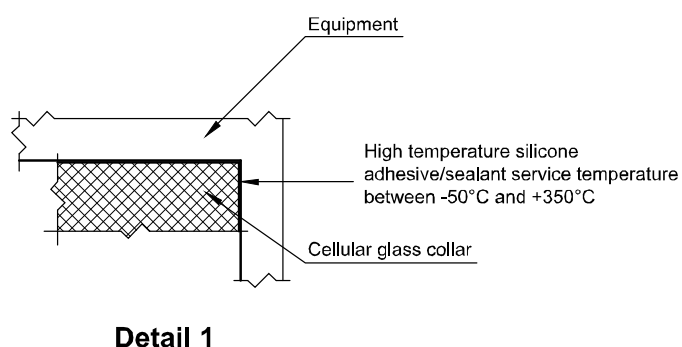
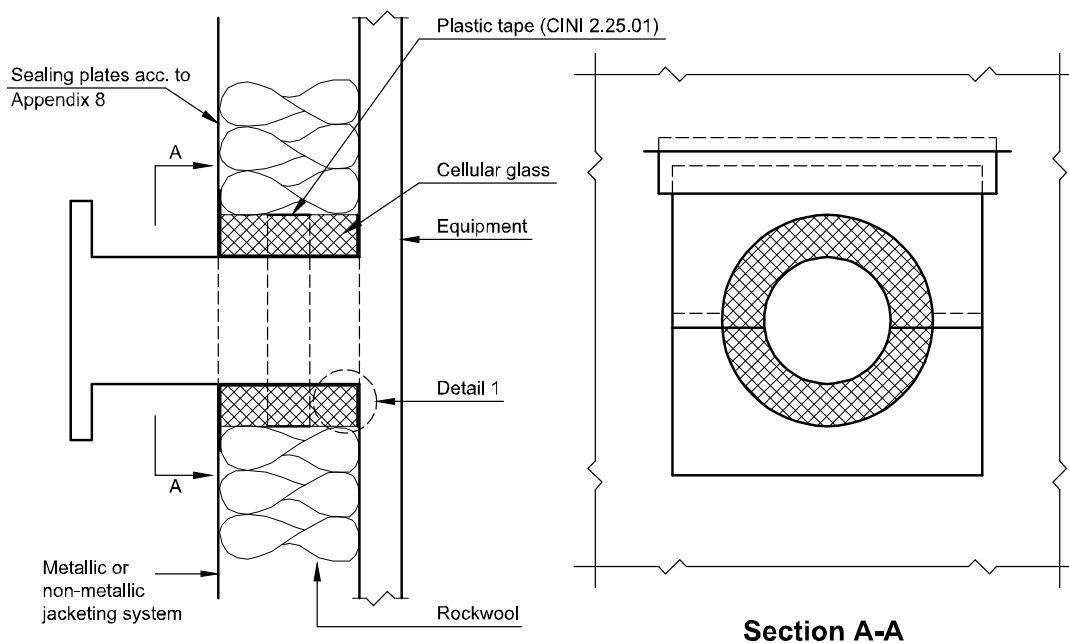


Figure 9 A Cellular glass around nozzle (hot insulation)

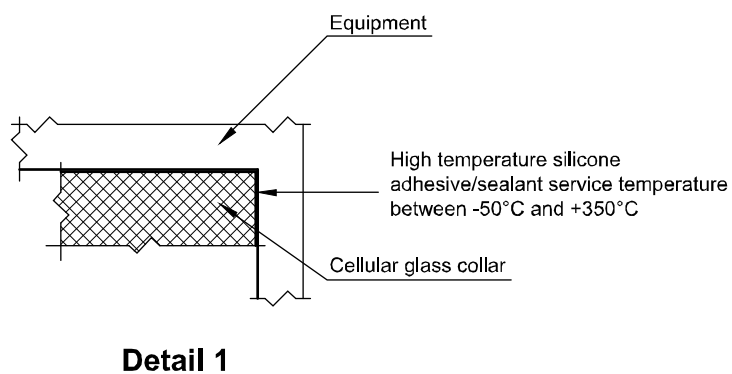
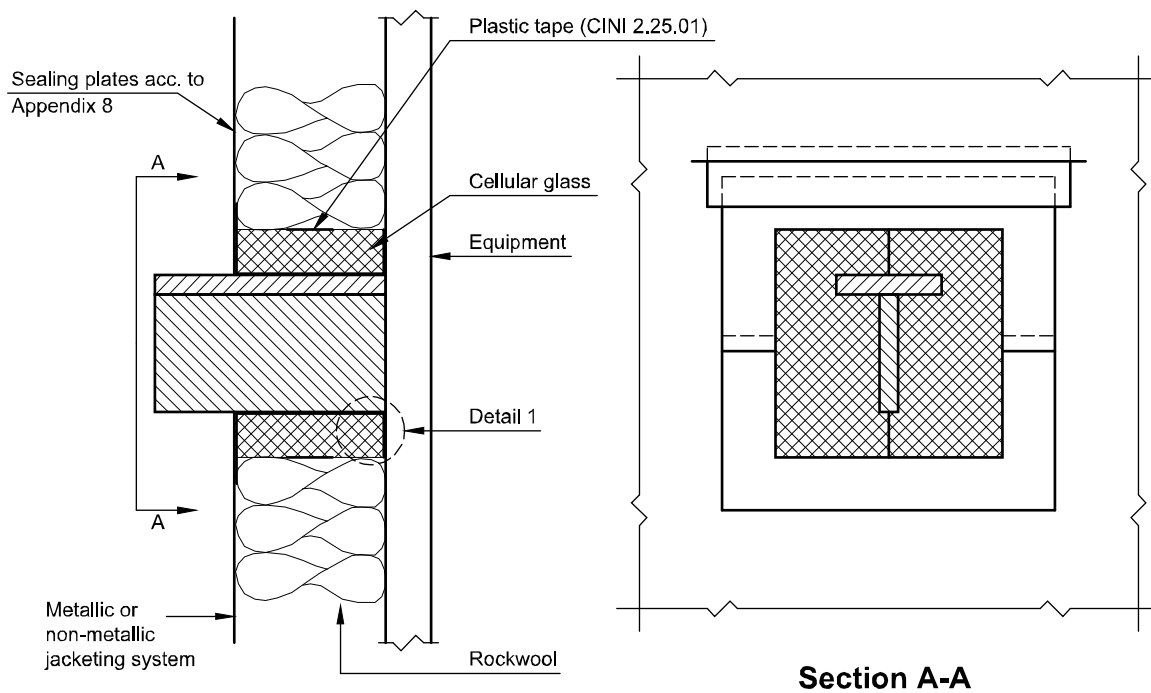
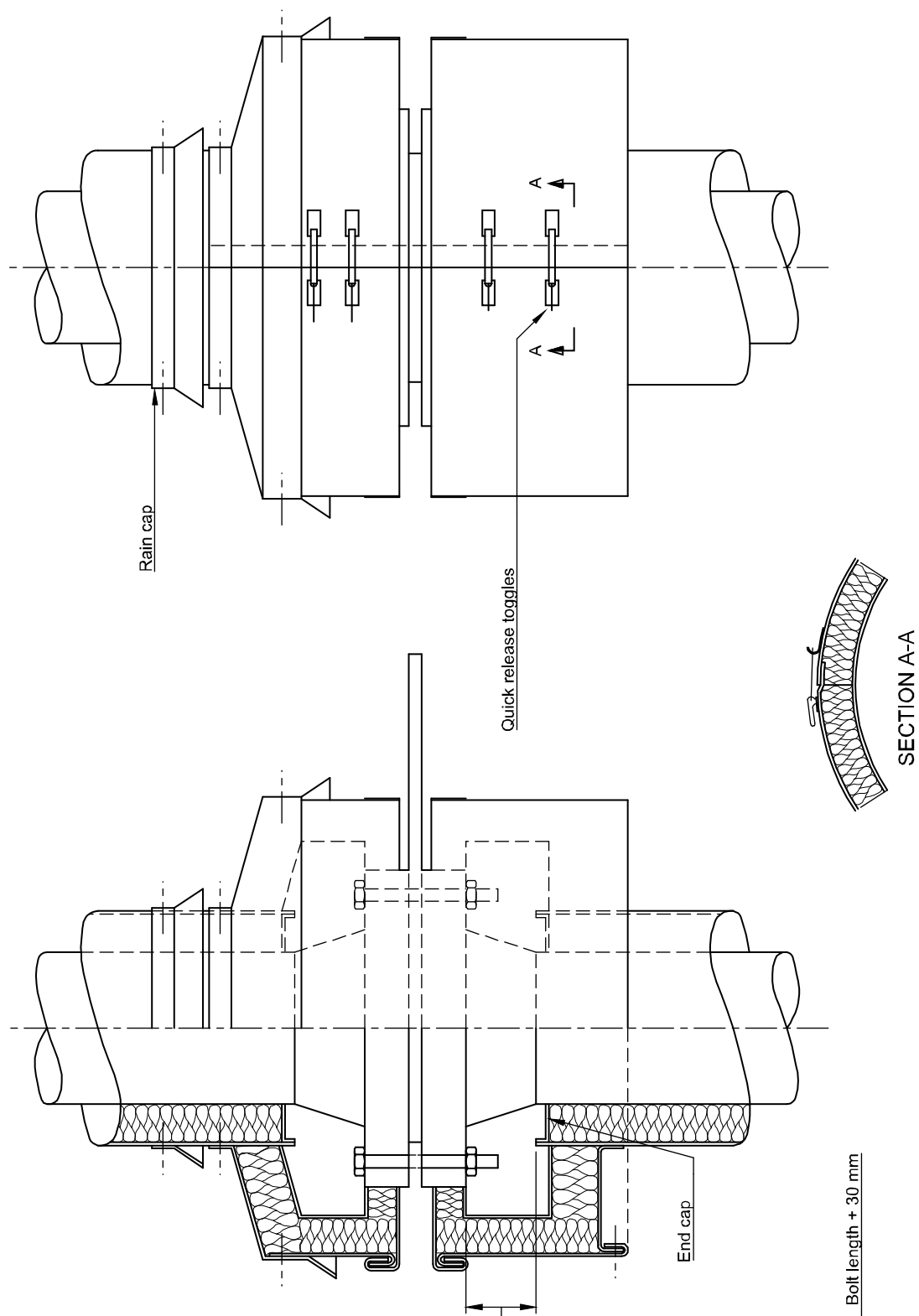


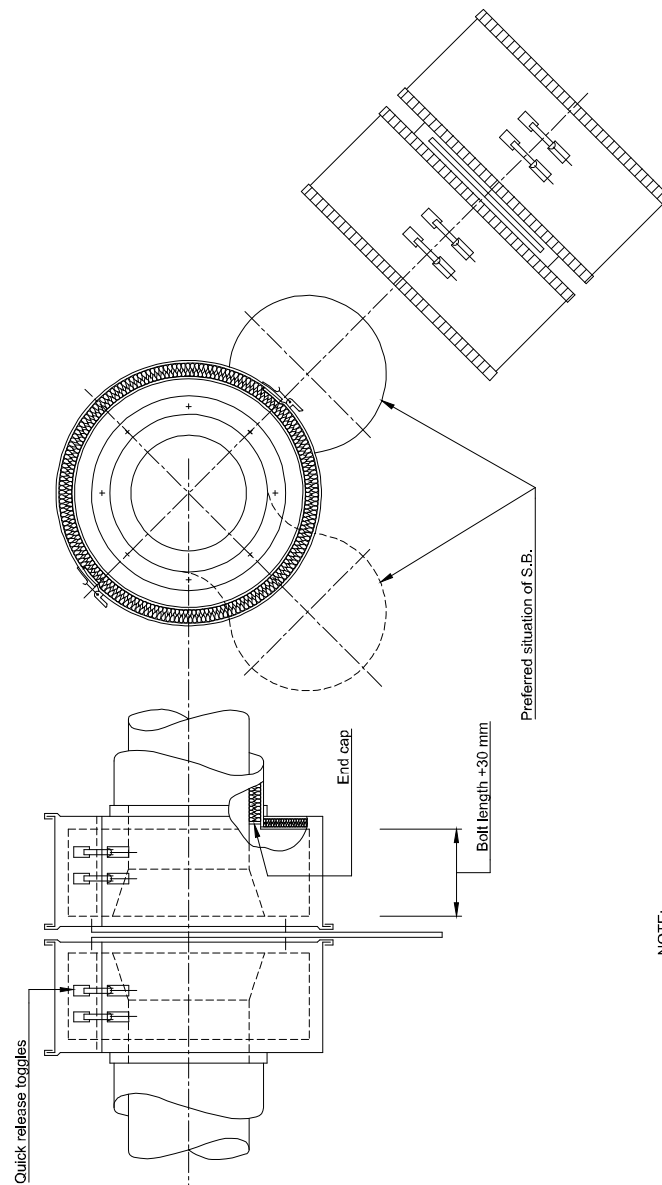
Figure 9 B Cellular glass around protrusion (hot insulation)

APPENDIX 10 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

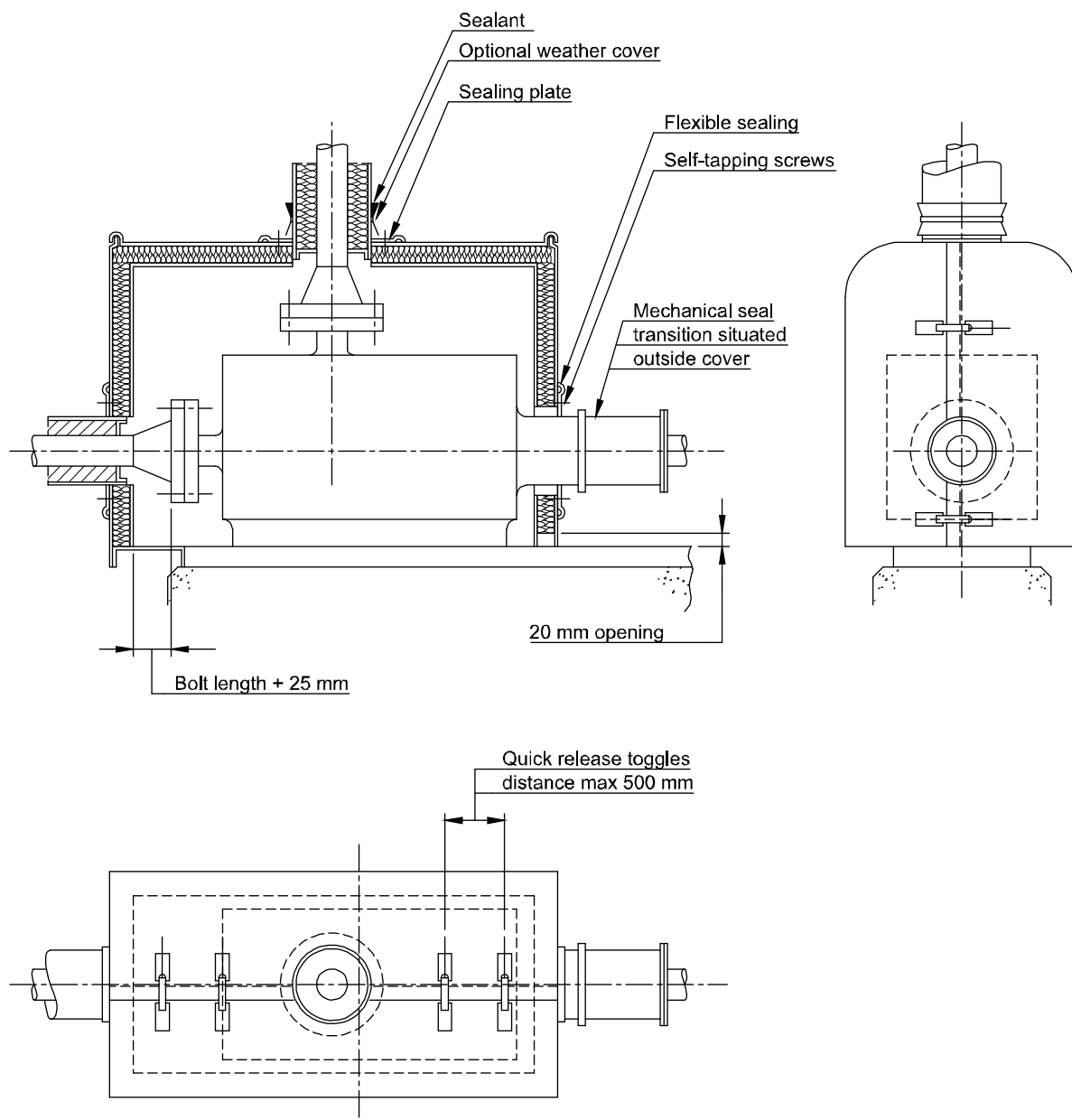
APPENDIX 11 REMOVABLE COVER FOR SPECTACLE BLIND FLANGE IN HORIZONTAL PIPE (HOT INSULATION)



NOTE:

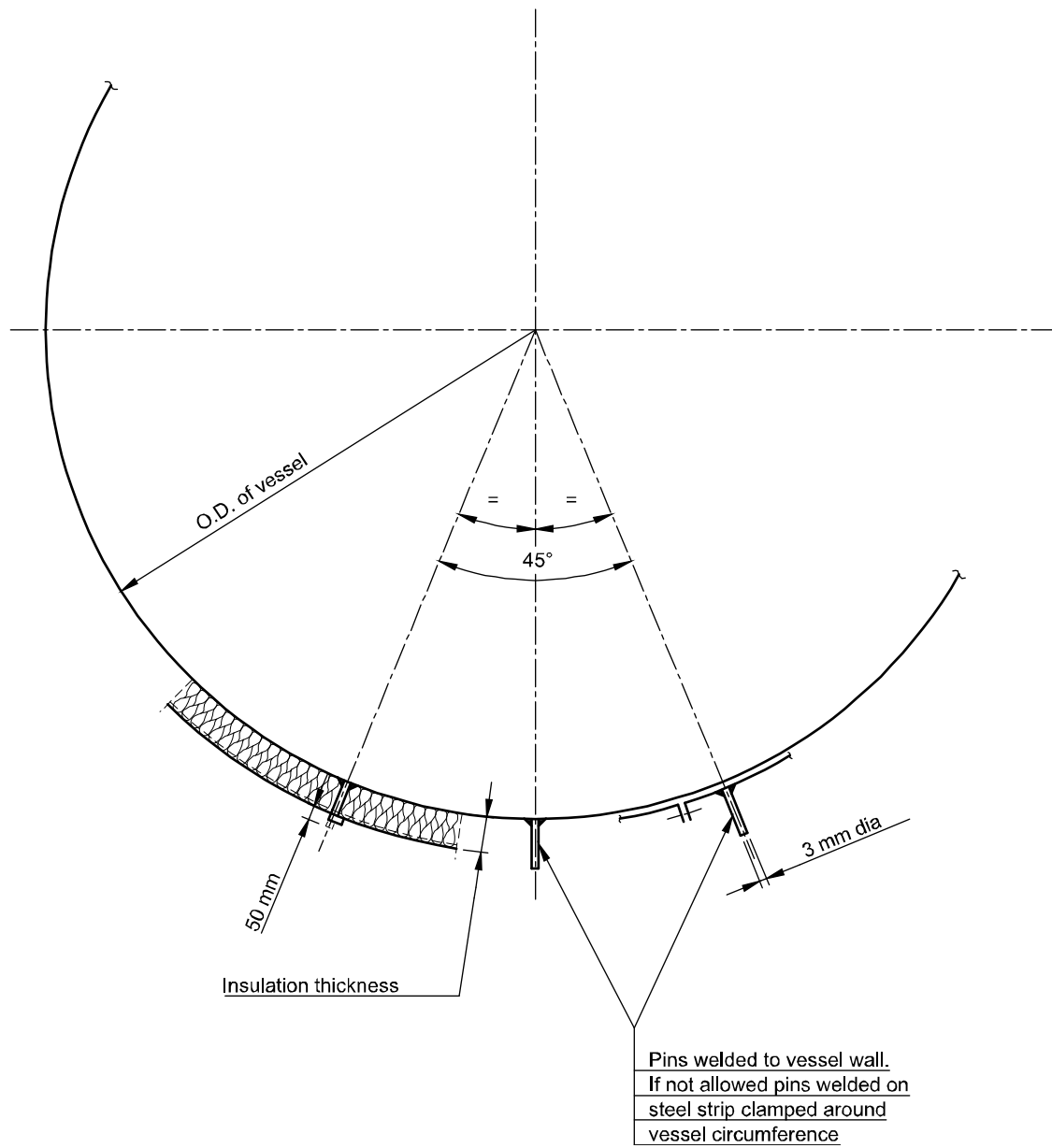
1. Cover to be executed as double wall or single wall insulation, secured by pins.
2. Alternative cylindrical cover.

APPENDIX 12 REMOVABLE INSULATION COVER FOR PUMPS (HOT INSULATION)

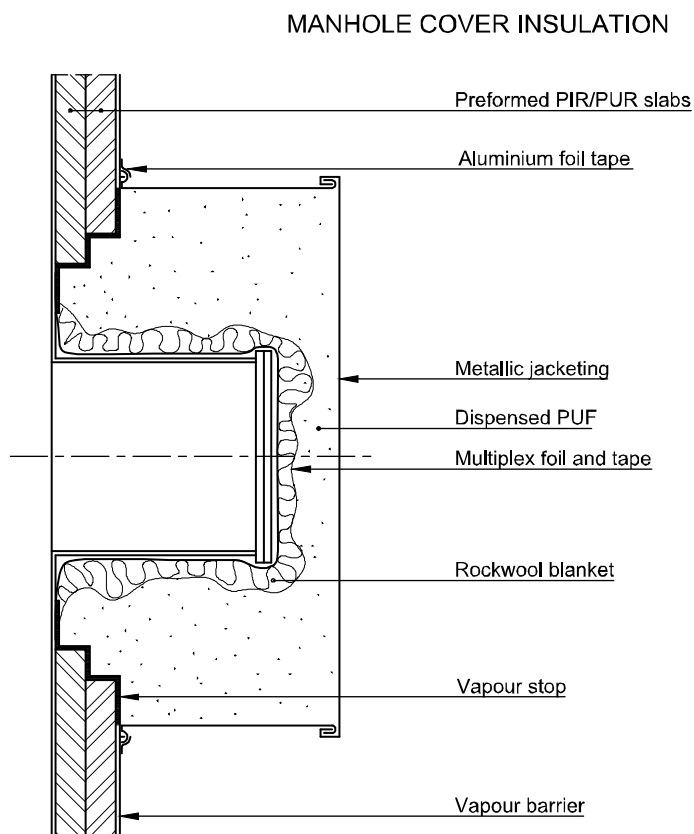
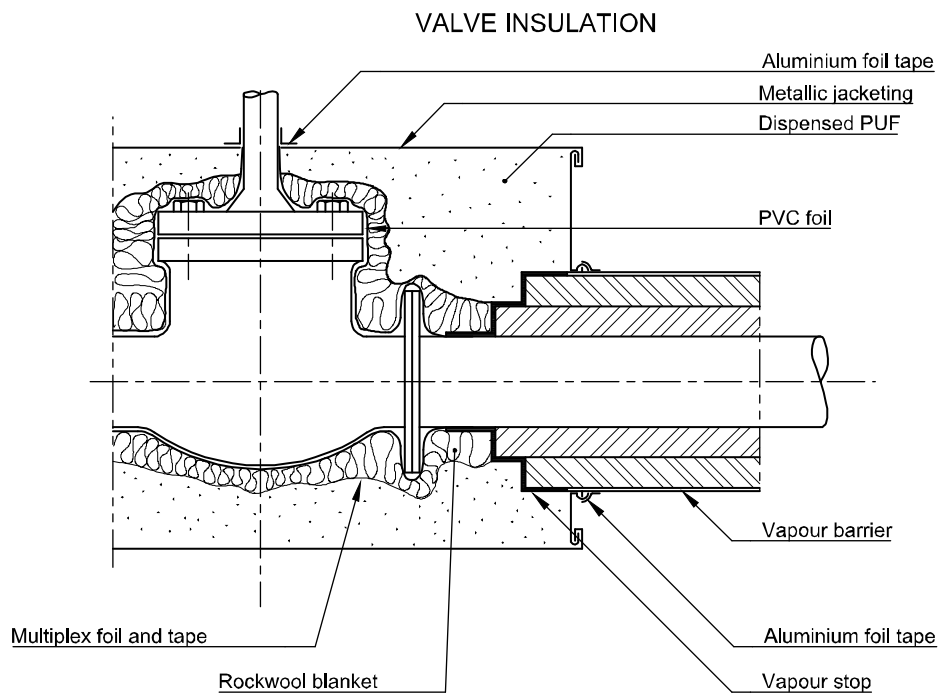


Note 1: Insulation shall not be applied on pumps handling liquid hydrocarbon products.

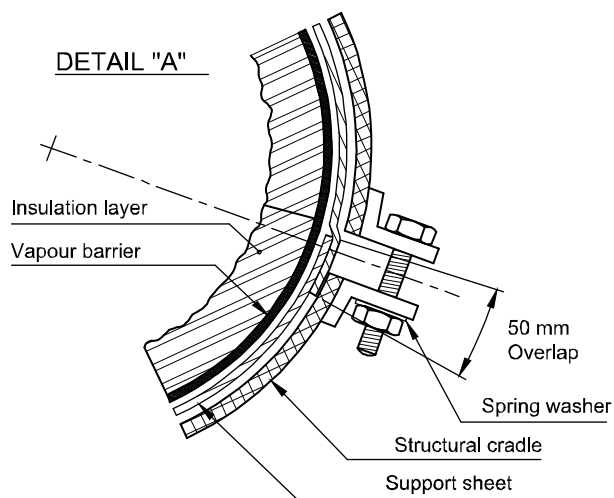
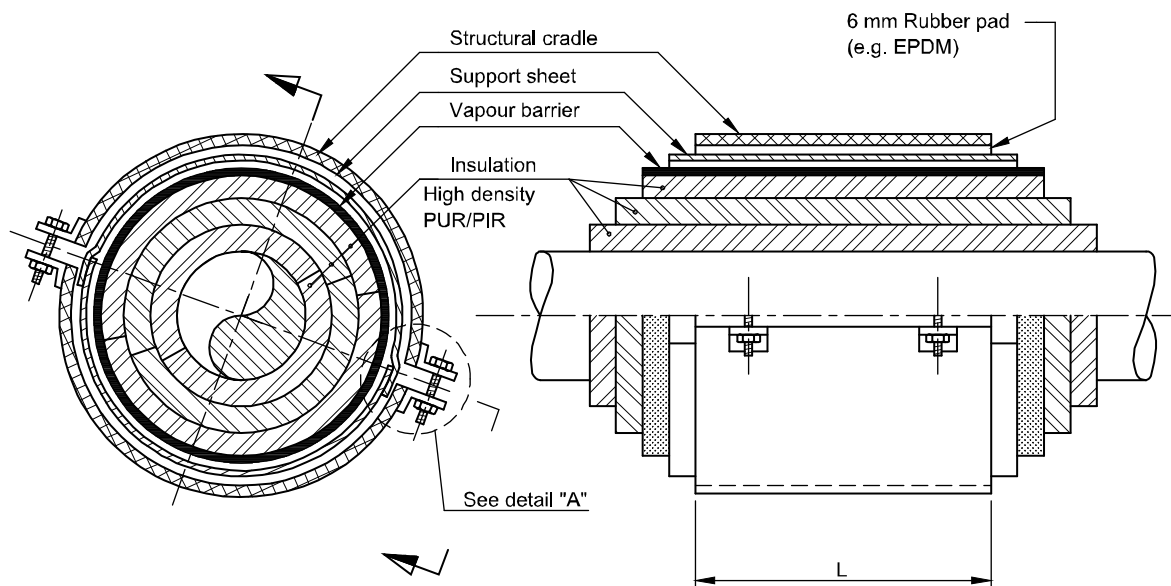
APPENDIX 13 SUPPORT PINS FOR BLANKET INSULATION ON HORIZONTAL VESSELS (HOT INSULATION)



APPENDIX 14 DISPENSED PIR/PUR FOAM (COLD INSULATION)

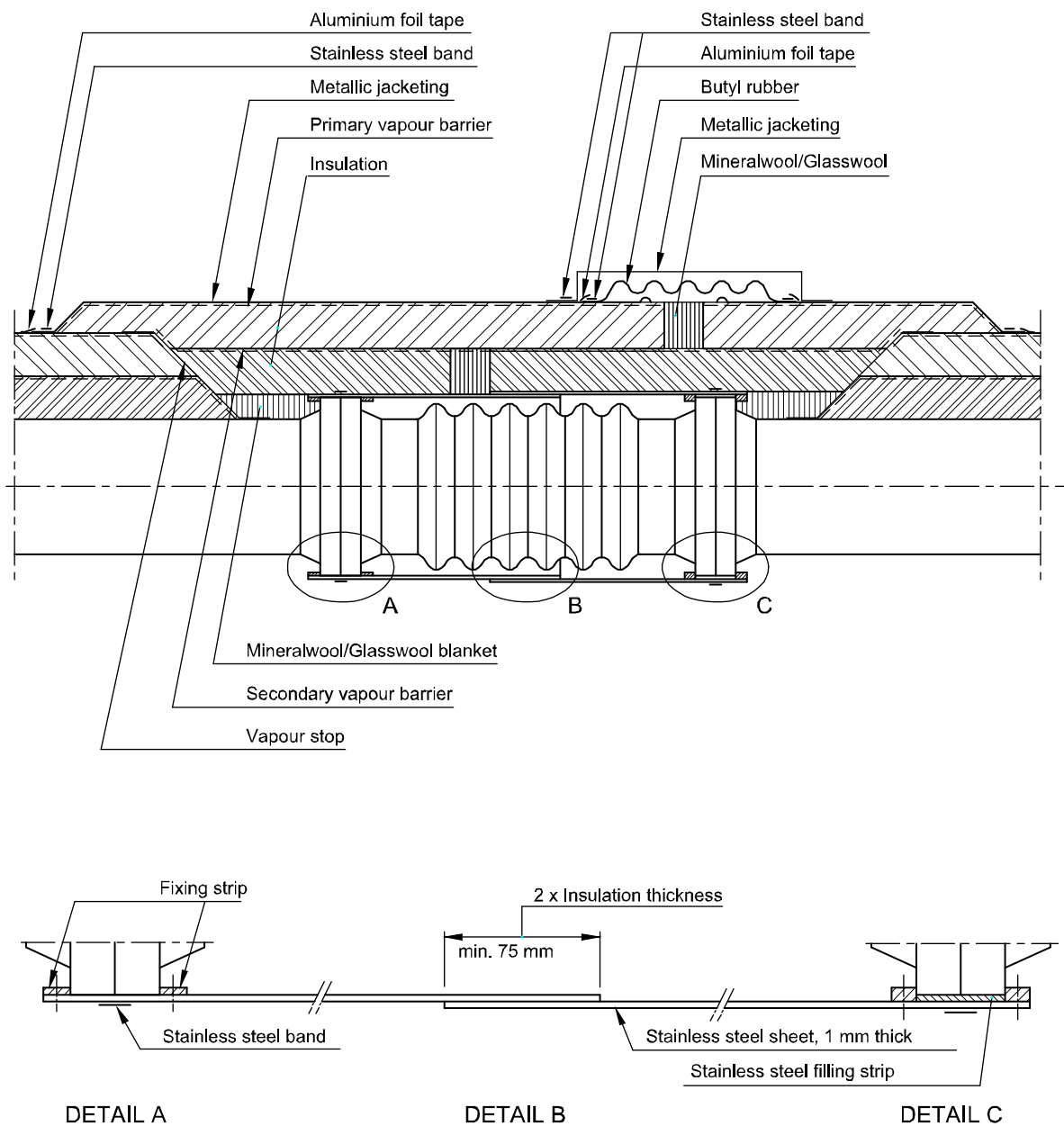


APPENDIX 15 PIPE SUPPORT - MULTI-LAYER (COLD INSULATION)

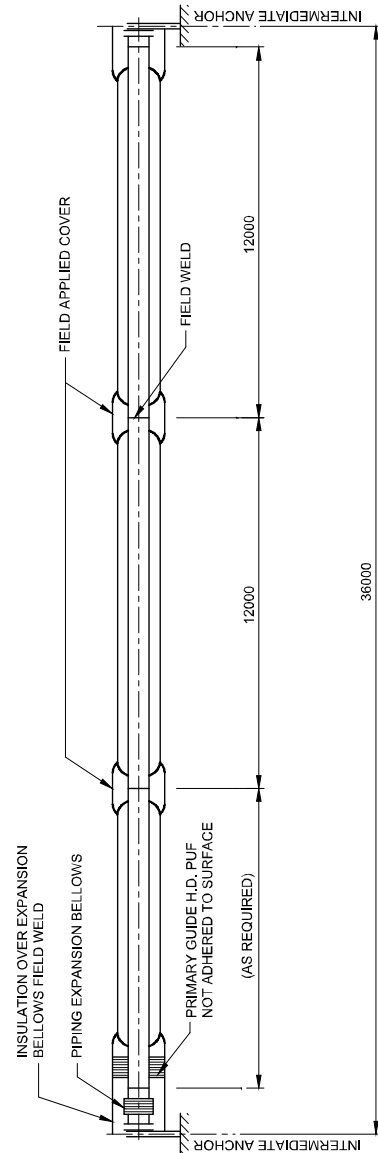


NOTE: Tolerances in accordance with ASTM C 585.

APPENDIX 16 CONTRACTION BELLOWS (COLD INSULATION)



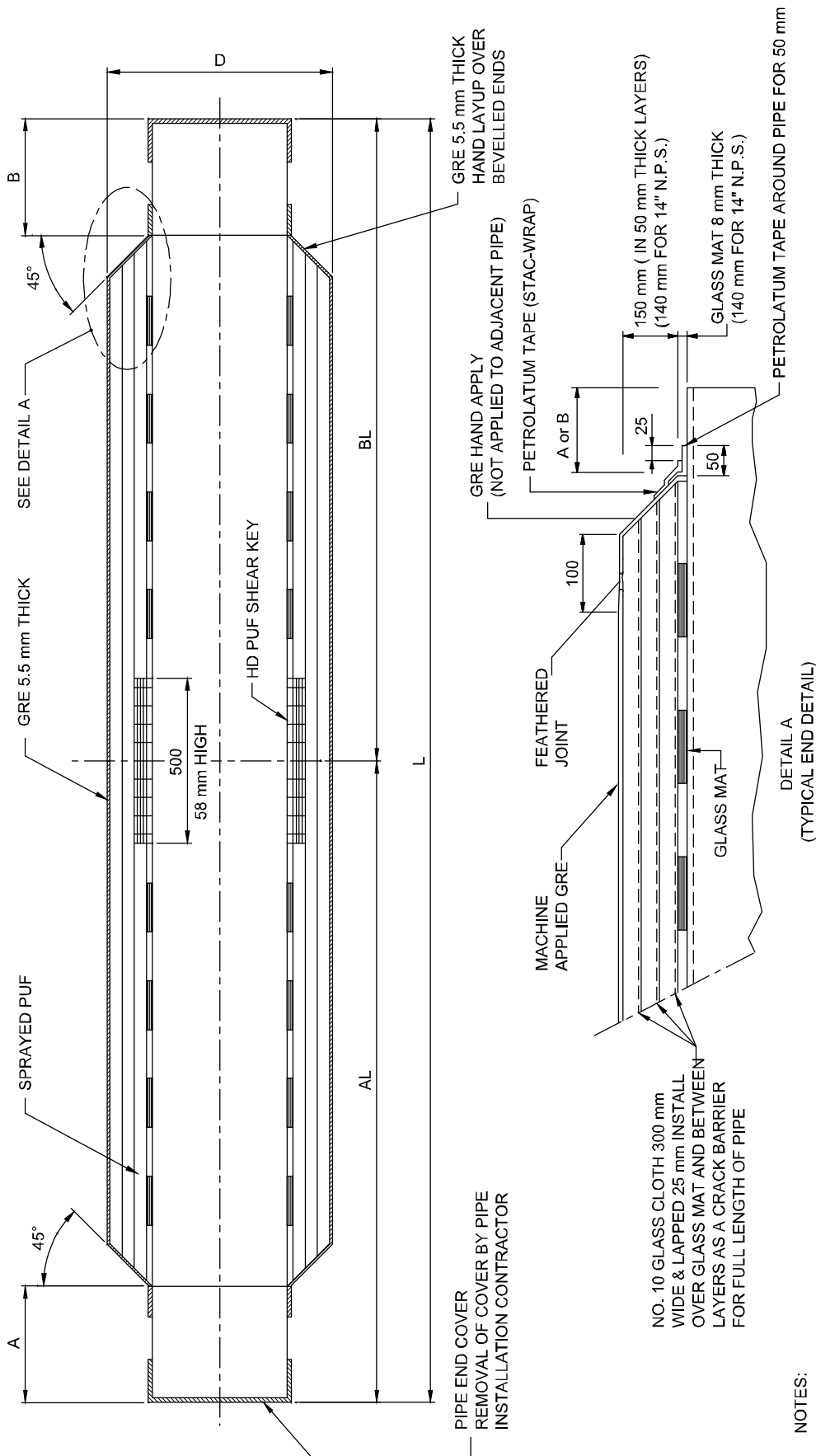
APPENDIX 17 TYPICAL SECTION OF RUNDOWN LINE BETWEEN INTERMEDIATE ANCHORS (SLIDE THROUGH INSULATION SYSTEM)



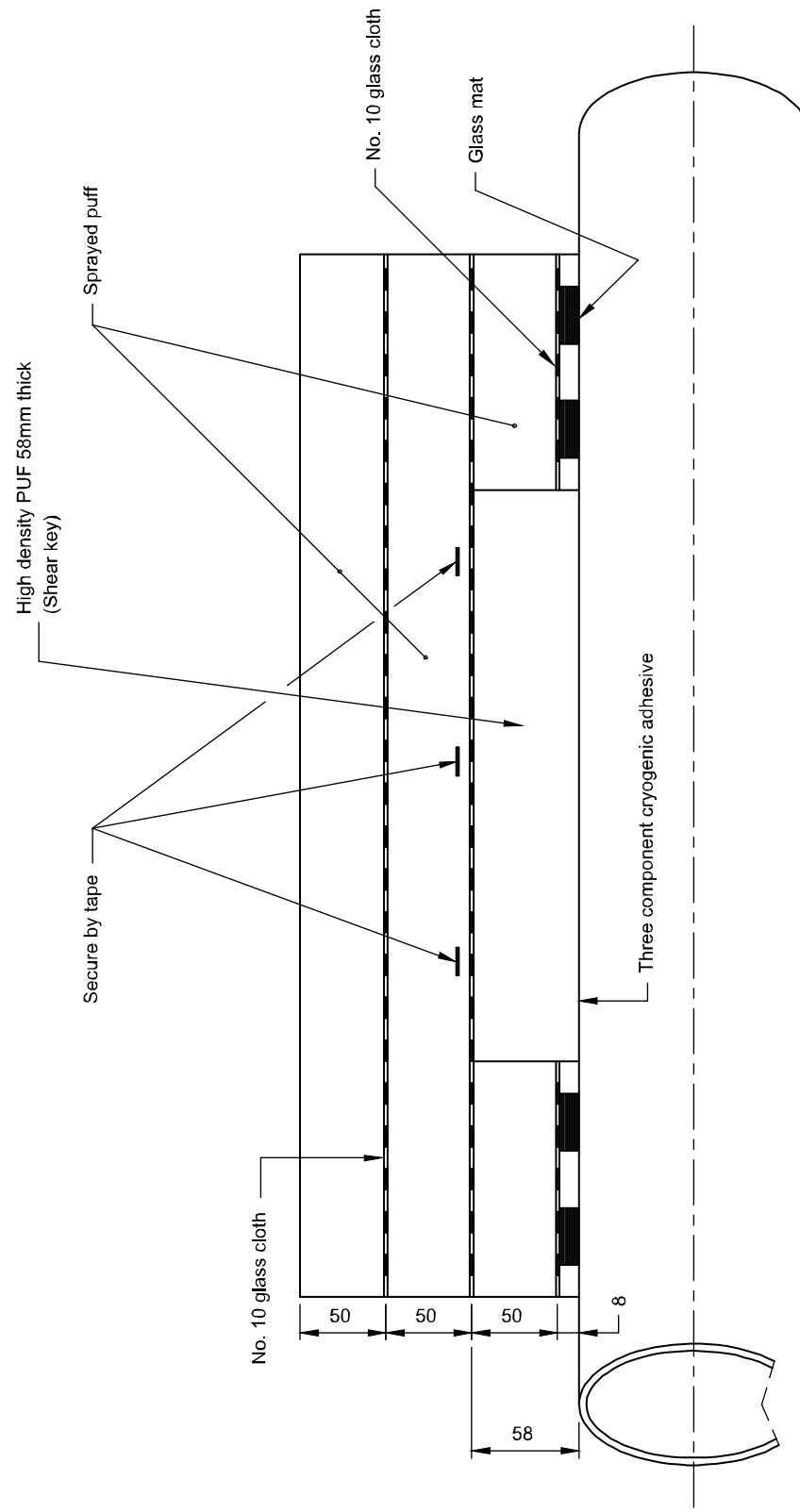
NOTES: DIMENSIONS INDICATED ARE FOR A TYPICAL 36 METRE SECTION OF PIPE MADE UP IN THE LENGTHS SHOWN. THE ACTUAL DESIGN MAY INVOLVE SOME MODIFICATION TO PERMIT VARYING PIPE LENGTHS.

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

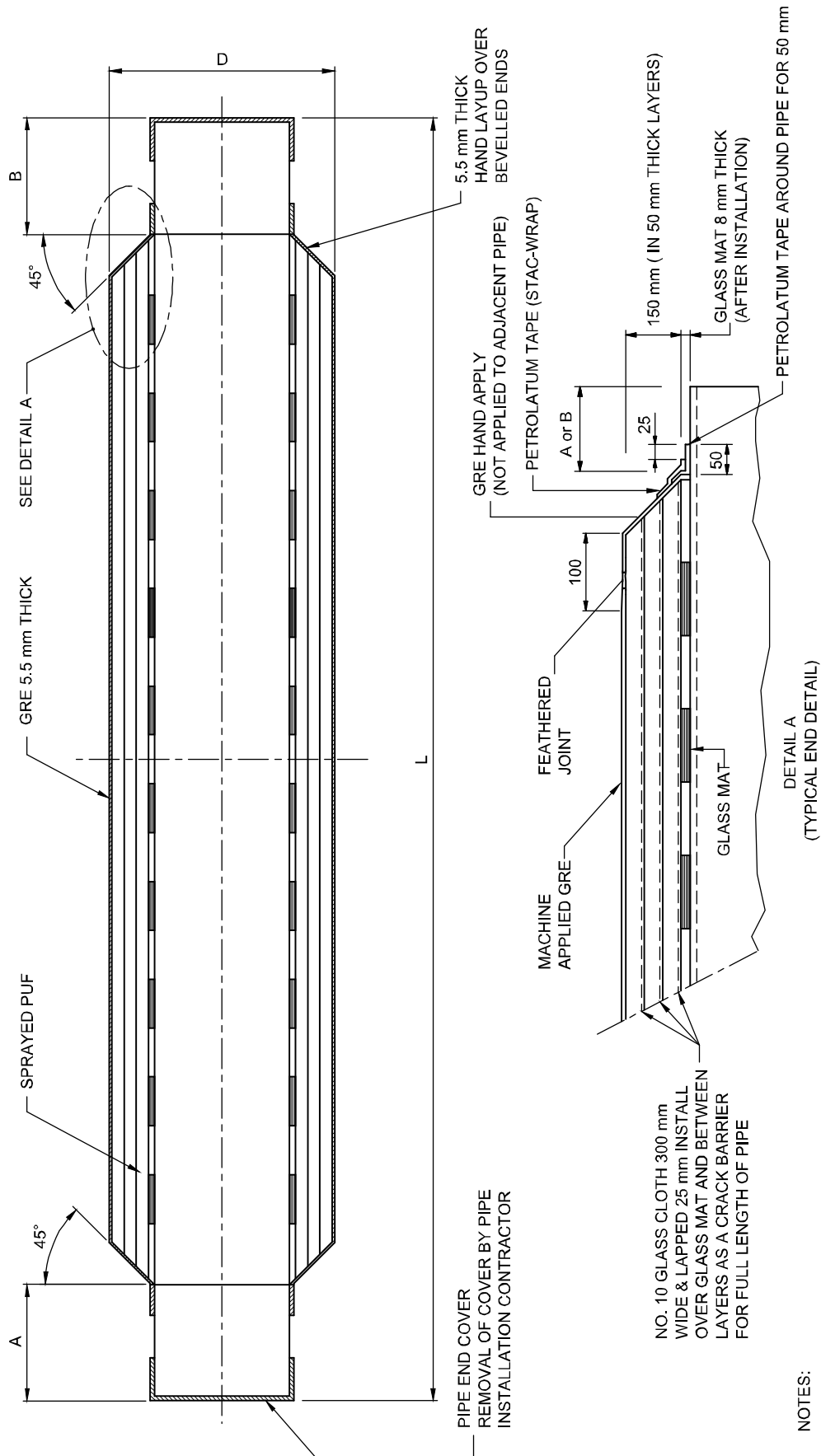
APPENDIX 18 PRE-INSULATION OF PIPE LENGTH - SHEAR KEY SYSTEM -



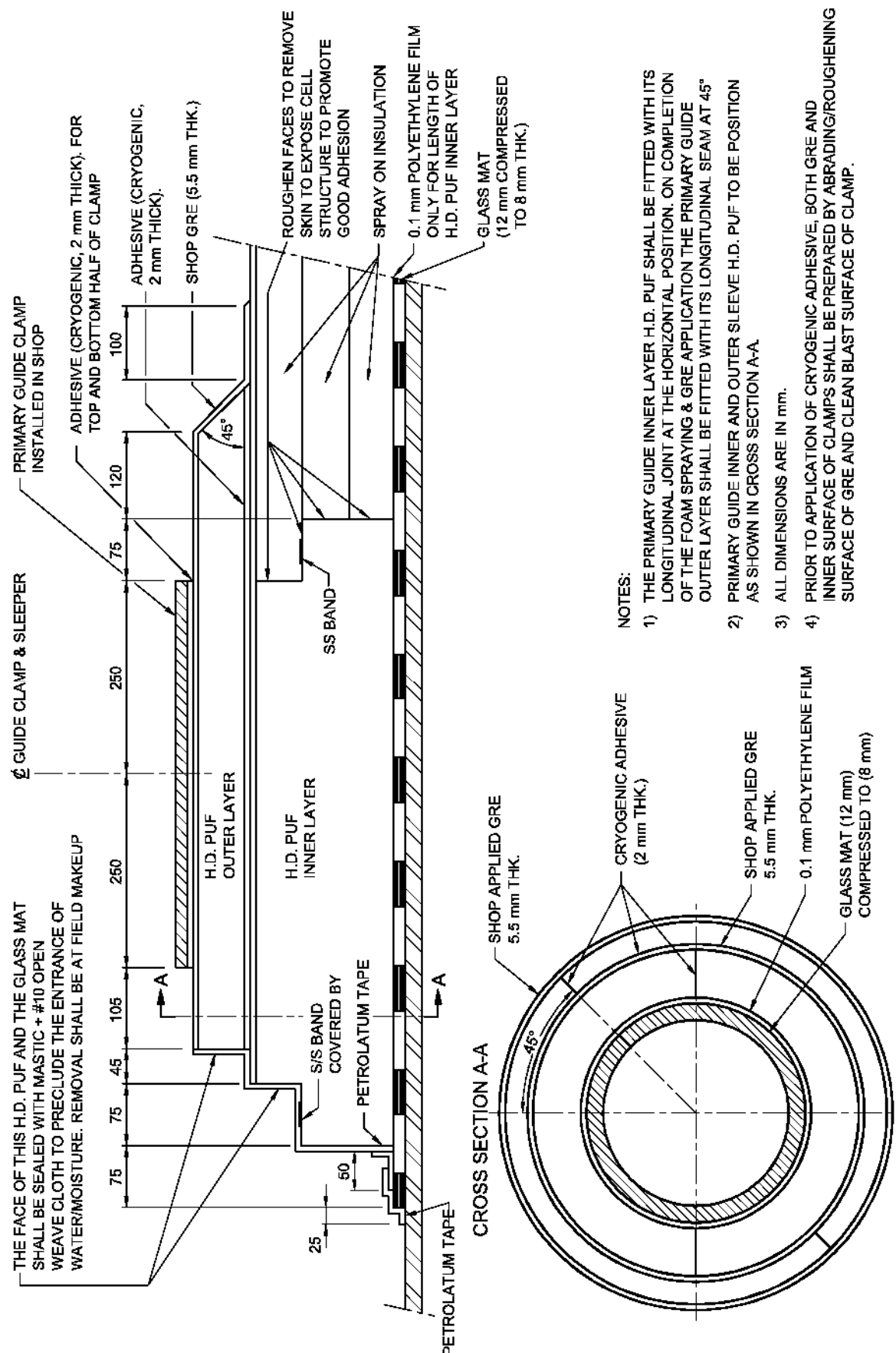
APPENDIX 19 SHEAR KEY DETAILS



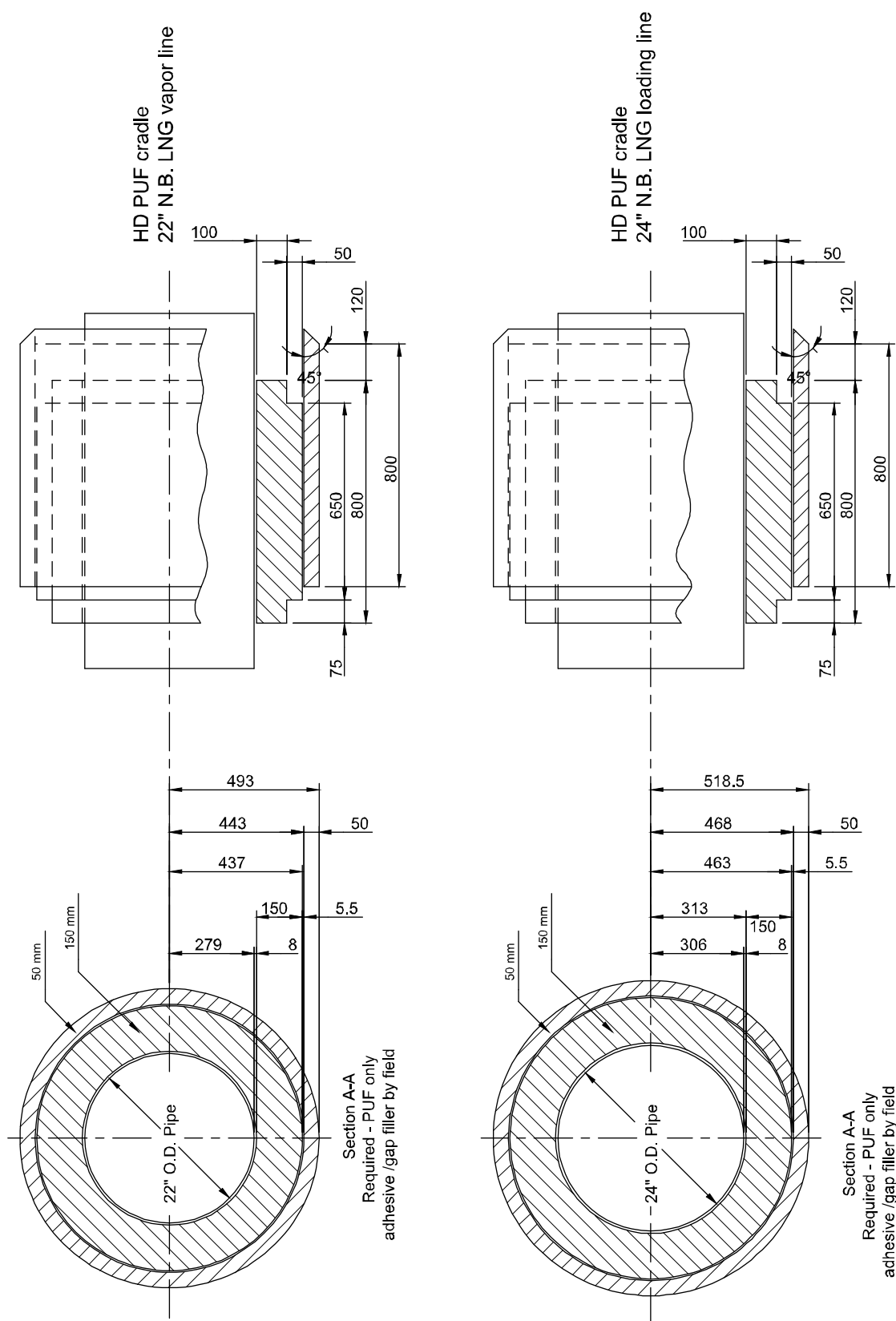
APPENDIX 20 PRE-INSULATION OF PIPE LENGTH - SLIDE THROUGH SYSTEM



APPENDIX 21 LONGITUDINAL SECTION THROUGH RUNDOWN LINE AND PRIMARY GUIDE



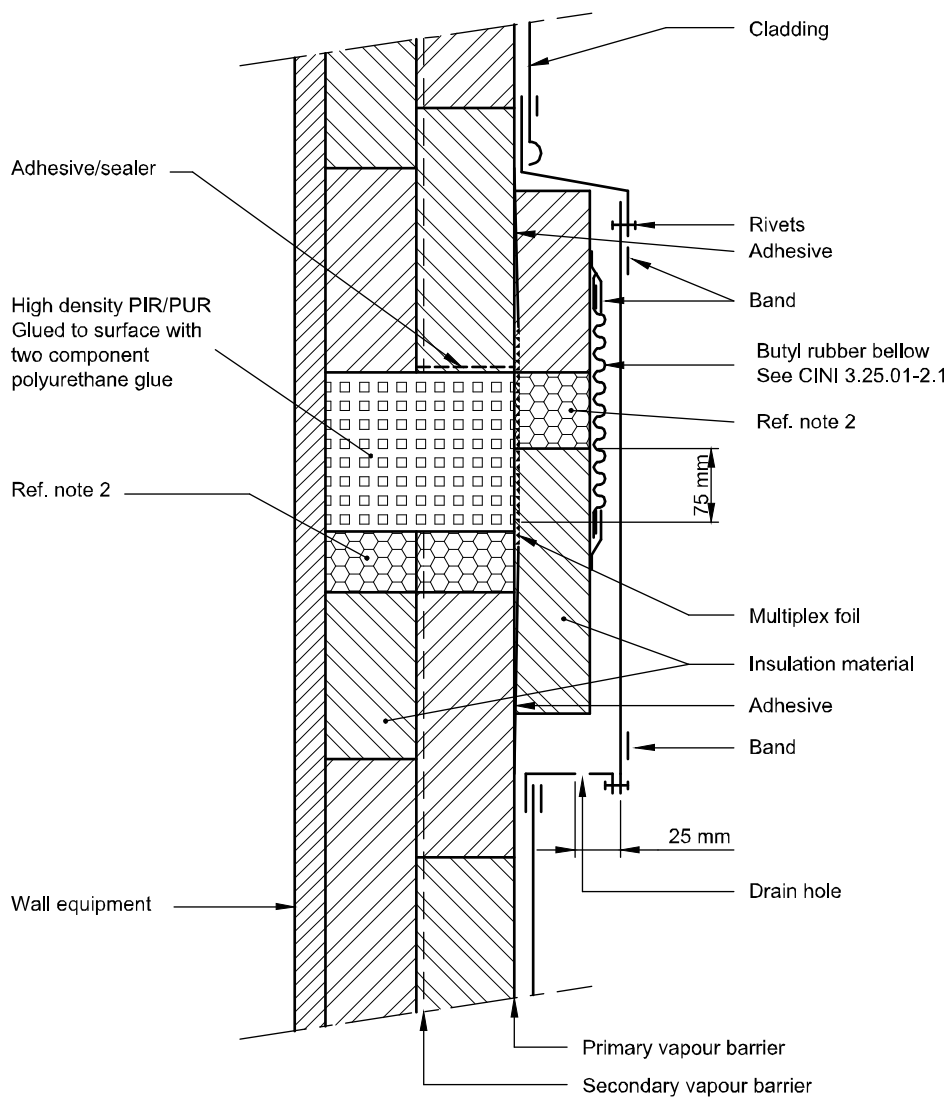
APPENDIX 22 PRIMARY GUIDE SYSTEM - TYPICAL EXAMPLE



**APPENDIX 24 ALTERNATIVE TO CINI 5.2.06 INSULATION DETAIL VACUUM/SUPPORT RING –
CONTRACTION JOINT (only to be used if vacuum/support rings are not installed)**

COLD-INSULATION

Insulation/finishing detail
Vacuum/support ring - contraction joint
Alternative for support ring



NOTE

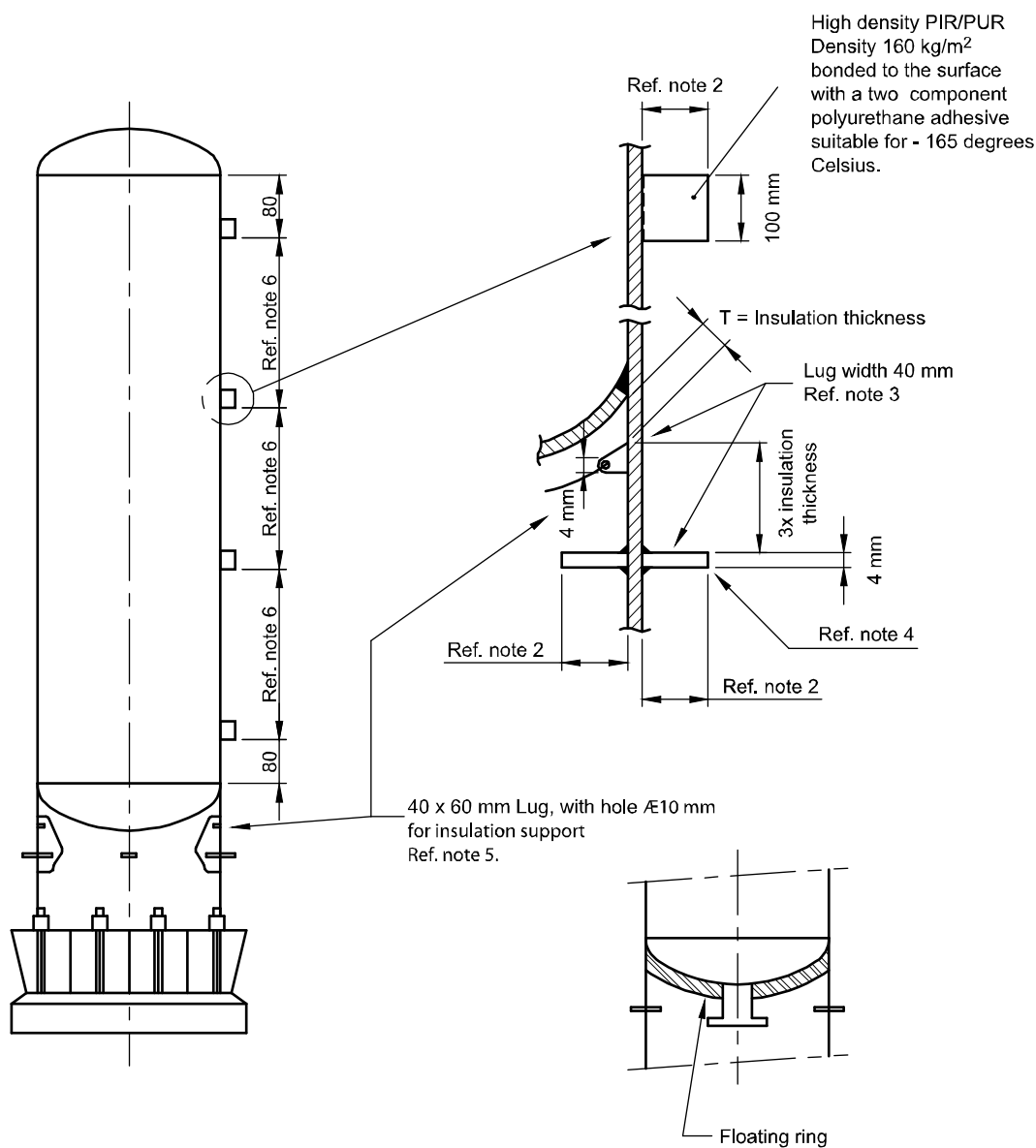
- 1 Materials and finishing in accordance with installation instructions and specification.
- 2 Contraction joint to be filled with compressed wool or (uptil -50 °C) with FEF.
(See installation instructions)
- 3 Metal jacketing to be applied only if so specified.
25 mm Clearance, for application of screws or rivets if so required.
Drain hole to be applied at the lowest point.

APPENDIX 25 ALTERNATIVE TO CINI 5.9.01 MECHANICAL ENGINEERING DETAIL LUGS/SUPPORT STRIP ON COLUMNS/SKIRTS (only to be used if lugs/support strips are not installed)

COLD-INSULATION

Mechanical engineering detail
Lugs/support strip on columns/skirts

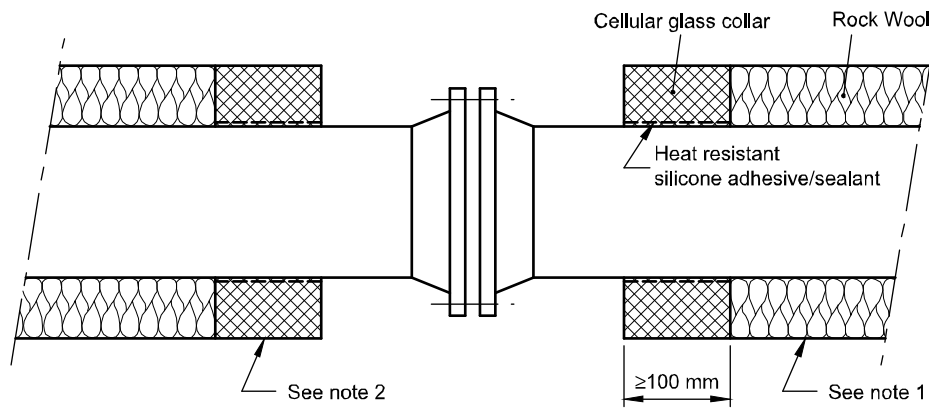
Alternative support



NOTE

- 1 Materials and finishing in accordance with installation instructions and specification.
- 2 At a single layer system 1/2 x insulation thickness, at a double layer system 3/4 x insulation thickness and at a triple layer system 5/6 x insulation thickness.
- 3 Number of lugs min. 4 pcs.; maximum spacing 500 mm.
- 4 At cryogenic operation temperatures, instead of lugs, a continuous strip to be installed, seal welded.
- 5 Lugs at the inside of the skirt for floating ring. (See CINI 5.2.05)
- 6 Support rings at equipment wall, max. spacing 4500 mm.

APPENDIX 26 INSULATION COLLAR FOR PROTECTION AGAINST FLAMMABLE PRODUCTS



Note 1: For metal jacketing detail see CINI 4.1.07.

Note 2: Cellular glass collar shall be bonded to pipe surface with heat resistant silicone adhesive.