

NORSOK STANDARD

PIPING AND EQUIPMENT INSULATION

R-004
Rev. 2, June 1999

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FOREWORD

NORSOK (The competitive standing of the Norwegian offshore sector) is the industry initiative to add value, reduce cost and lead time and eliminate unnecessary activities in offshore field developments and operations.

The NORSOK standards are developed by the Norwegian petroleum industry as a part of the NORSOK initiative and supported by OLF (The Norwegian Oil Industry Association) and TBL (Federation of Norwegian Engineering Industries). NORSOK standards are administered by NTS (Norwegian Technology Standards Institution).

The purpose of NORSOK standard is to contribute to meet the NORSOK goals, e.g. by replacing the individual oil company specifications and other industry guidelines and documents for use in existing and future petroleum industry developments.

The NORSOK standards make extensive references to international standards. Where relevant, the contents of a NORSOK standard will be used to provide input to the international standardisation process. Subject to implementation into international standards, this NORSOK standard will be withdrawn.

INTRODUCTION

The revision 2 of this standard is updated and partly rewritten from industry experience over the last years. Materials have been given a broader presentation. A new section is added on Qualification Requirements, addressing requirements to insulation systems, procedures and qualification of personnel.

1 SCOPE

This standard covers the minimum requirements for thermal, acoustic, personnel protection and fireproofing insulation of pipe work and equipment for offshore / onshore installations.

This standard does not cover insulation of HVAC related items, see NORSOK Standard H – 002 Piping and plumbing.

2 REFERENCES

2.1 Normative references

API RP 521	Guide for Pressure – Relieving and De-pressuring Systems
ASTM-C552	Cellular Glass Block and Pipe Thermal Insulation.
ASTM-C592	Mineral Fibre Blanket Insulation and Blanket Type Pipe insulation
ASTM-C303	Test method for Density of Pre formed Block-Type Thermal Insulation
ASTM-C177	Test method for Steady-State Heat Flux Measurement
ASTM-165	Test Method for Measuring Compressive Properties of Thermal Insulation
ASTM-D3833	Test Method for Water Vapour Transmission of Tapes
ASTM-G53	Practise for Operating Light- and Water-Exposure of Non - metallic materials
EN 253 : 1994	Pre-insulated bonded pipe systems for underground hot water networks
IMO Resolution	A.653 (16) Recommendations on Improved Fire Test procedures for Surface Flammability of bulkhead, Ceiling and Deck Finish Materials
ISO 834	Fire – resistance tests – Elements of building constructions
ISO 5660	Fire tests – Reaction to Fire – Rate of Heat Release from Building Products
NORSOK S-002	Working Environment
NORSOK M-501	Surface Preparation and Protective Coating
NT Fire 036	Pipe Insulation: Fire spread and smoke production – Full scale test
OTO 93028	Jet fire Test

2.2 Informative references

AGR EmiTeam	Insulation Handbook. Established in 1999 by Statoil, Norsk Hydro and Saga
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3 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

NORSOK	Norsk Søkkel Konkurransesjøsjsjon, the Competitive standing of the Norwegian Offshore Sector, the Norwegian initiative to reduce cost on Offshore projects.
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Functional specification	As defined in ISO 13879 and ISO 13880: Document that specifies the requirements expressed by features, characteristics, process conditions, boundaries and exclusions defining the performance of the product, process or service..
Technical specification	As defined in ISO 13879 and ISO 13880: Document that prescribes technical requirements to be fulfilled by the product, process or service in order to comply with the functional specification.
Normative references	Shall mean normative (a requirement) in the application of NORSOK Standards.
Informative references	Shall mean informative in the application of NORSOK Standards.
Shall	Verbal form used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted, unless accepted by all involved parties.
Should	Verbal form used to indicate that among several possibilities one is Recommended as particularly suitable, without mentioning or Excluding others, or that a certain course of action is preferred but Not necessarily required.
May	Verbal form used to indicate a course of action permissible within the limits of the standard.
Can	Verbal form used for statements of possibility and capability, Whether material, physical or casual.

3.2 Insulation classes

Heat conservation Class 1

The purpose is to reduce heat losses and to maintain temperatures for the efficient operation of the process.

Cold medium conservation Class 2

The purpose is to maintain low temperature and control heat input to the process.

Personnel protection Class 3

Surfaces with operating temperatures below -10 °C or above 70 °C and are confined to a distance of not more than 2,1 m vertically and 0,8 m horizontally away from walkways and normal working areas shall be guarded by screens. Insulation shall only be used where guards are not practical.

Frost proofing Class 4

Insulation/heat tracing to prevent freezing, solidification and condensation.

Fire proofing Class 5

The purpose is to reduce the heat input and limit the temperature to 400 °C on piping, vessels and equipment in a hydrocarbon fire situation lasting for 30 minutes according to ISO 834.

Fire proofing according to any other fire scenarios shall be specified in each project. Selected fire proofing shall be documented and if necessary fire tested.

Acoustic insulation Class 6, 7 and 8

The acoustic insulation is defined as the arithmetic average of the insertion loss in the three octaves bands 500 Hz, 1000 Hz and 2000 Hz.

Based on documented insertion loss, each project may select materials or combinations of materials to cover the required insertion loss at actual frequencies. Ref. Annex 2 “Insertion loss – Test procedure” for this Standard. This selection shall not conflict with any other requirement of this standard, and Company shall approve each combination.

Valves and flanges shall be insulated when and as required by Company.

Acoustic insulation Class 6

Reduction of noise in the area 500-2000 Hz by 10 dB.

Acoustic insulation Class 7

Reduction of noise in the area 500-2000 Hz by 20 dB.

Acoustic insulation Class 8

Reduction of noise in the area 500-2000 Hz by 30 dB.

External condensation and icing protection Class 9

The purpose is to prevent condensation on piping and equipment with operation temperatures below ambient.

For combination of insulation classes see clause 7.

3.3 Abbreviations

AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
DN	Diameter Nominal
EN	European Norm
HSE	Health, Safety and Environment
IMO	International Maritime Organisation
ISO	International Organisation of Standardisation
NT	Nordtest
P&ID	Piping & Instrument Diagram

4 GENERAL REQUIREMENTS**4.1 Introduction**

General requirements for thermal insulation (hot and cold) are given in this clause. Specific requirements for hot service and acoustic insulation are stated in clause 5, and cold service insulation in clause 6.

Pre insulated piping may be used in relevant classes.

Alternative insulation may be used if the proposed materials and methods satisfy the functional requirements in this specification. Approval by Company is required.

4.2 Design

4.2.1 General

Piping and equipment shall be insulated according to the insulation class, operating temperature and insulation thickness stated in the P&ID and Data sheets.

All insulation shall be covered with weather protection designed and installed to prevent ingress of water during normal operation throughout the design life.

Insulation adjacent to flanges in piping and equipment shall be terminated to allow removal of bolts without damage to insulation. Minimum free space from the flange to the nearest part of the insulation shall be equal to the bolt length +25 mm. The termination of the weather protection shall be waterproof.

When a rigid type of insulation is used, provision shall be made for longitudinal expansion and contraction.

4.2.2 Vessel insulation

Insulation of all vessels shall be supported on rings with a distance of 900 mm c/c installed on the vessel. Rings shall also be provided around nozzles above DN 200 mm.

Block insulation shall be fastened with mechanically tightened metal bands or with bonding adhesive.

Insulation on vessel heads shall be fastened with bands spaced not more than 300 mm centres. The bands shall be fixed to the fixing ring installed on the vessel.

Vessels of diameter 1500 mm and smaller shall be insulated as piping.

4.2.3 Removable insulation of flanges and valves

Removable insulation for flanges and valves, like tailor made jackets or pre formed insulation boxes, shall be suitable for quick removal and reinstallation.

All tailor made jackets shall fit the actual valve/flange/equipment and secure adequate overlap to incoming insulated pipes.

4.2.3.1 Outer material of tailor made jackets

The outer material shall be silicone rubber proofed fabric made from glass fiber. Other materials may be used provided that the material properties can be documented to be equal or better than silicone rubber.

The material shall be suitable for use against temperatures between -30 °C and +230 °C.

The silicone rubber coating shall prevent water being absorbed by the insulation material.

The outer material shall be non-combustible or at least self-extinguishing, and tested according to IMO Resolution A.653 (16) or similar.

The sewing thread shall be stainless steel reinforced kevlar thread and shall be suitable within the same temperatures as the woven glass fiber fabric. The sewing thread shall not resolve or decompose in typical offshore environment.

4.2.3.2 Insulation in fill materials of tailor made jackets

The insulation in-fill materials shall be a flexible mat of mineral fiber having a density according to insulation class, foil faced on one side.

Precautions must be implemented in the design and fabrication of the insulation jackets to avoid the insulation material from sagging causing reduction of the insulation properties of the jackets.

The insulation material shall be non-combustible.

The thickness of insulation shall be 25 mm for DN 80 pipes or smaller, and 50 mm for diameter DN 100 pipes and larger.

Other insulating materials may be used provided they have the same or better properties. Insulation thickness of other insulation materials shall be based on calculation of thermal conductivity and insulation class.

4.2.3.3 Water ingress and drainage

The design of the tailor made jackets shall be deluge proof.

Each tailor made jacket shall be provided with a hole for drainage at its lowest point. The drainage hole shall be installed in such a manner that water cannot enter into the internals of the cover and saturate the insulating fiber.

The drainage holes shall have silicone mastic between the reinforced ring and the silicone rubber sheets on both sides of the jacket.

4.2.3.4 Locking Mechanism for tailor made jackets

The locking mechanism of the tailor made jackets shall be of the velcroues flap fastener type. In exposed area the tailor made jacket shall be fastened to the pipe by stainless steel bands. The fastener type used shall be proven through experience. Minimum width shall be 100 mm for jackets applied on valves/flanges larger than DN 80, and 50 mm for jackets applied on valves/flanges DN 80 and smaller.

4.2.3.5 Metallic Parts

Any metallic parts in the design of the tailor made jackets shall be of stainless steel of quality AISI 316 or better. Grommets for reinforcing drain holes may be of brass.

4.2.3.6 Resistance against different media

The outer material shall be resistant against diluted chemicals, detergents and hydrocarbons.

4.2.3.7 Identification of tailor made jackets

Each removable insulation cover shall be provided with an identification plate with the following information:

- Vendor name
- Line number
- Tag number
- Cover number
- Certificate number

The vendor shall also identify each cover on drawings and store this information according to the vendor quality system.

The identification number system shall be easily read prior to and after installation and shall be placed under the flap fastener. The identification plate shall be made of a material resistant to water and/or chemicals.

The numbering system for identification of individual cover shall be provided by Company after contract award.

4.2.4 Insulation of instrument and instrument tubing

For insulation of instruments, insulated cabinets with hinged doors shall be used. Instrument tubing of max DN 25 may be insulated with cellular rubber for temperatures up to 100 °C. For temperatures above 100 °C, glass fibre rope and jacketing may be used.

4.2.5 Piping insulation

Insulation on long vertical pipe runs shall be supported on rings spaced on 6400 mm maximum centres installed on the piping. Width of rings shall be half the thickness of the insulation material.

4.2.6 Metallic jacketing

Flat heads are not allowed on top of vertical vessels.

Removable insulation covers shall be provided for removable vessels heads.

The bottom heads of skirt supported vessels may be covered with flat metallic jacketing.

Jacketing for flanges and valves shall be formed such that it sheds water.

Longitudinal seams of metal jackets on horizontal or sloping pipelines shall be located maximum 60 degrees away from the lowest point of the circumference.

All seams on metallic jacketing shall be provided with a metal seam sealant to become water proof.

4.2.7 Non metallic jacketing

For pipe insulation a non-metallic weather protection may be used instead of metallic jacketing for all classes except class 5. Fire proofing. The non metallic weather protection must fulfil the requirements in clause 4.3.7 and be verified with tests. Use of combustible non metallic jacketing in enclosed areas shall be subject of approval in writing with regard to HSE aspects.

It is recommended to apply aluminium foil between cellular glass and the non metallic jacketing.

4.2.8 Heat traced piping

Heat traced piping shall be wrapped with 0,05 mm aluminium foil prior to insulation to protect the heating cables and improve the heat distribution.

Where heating cables penetrate the jacketing, edge protection shall be provided to prevent damage to the cable. A permanent sealer shall be applied in order to prevent ingress of water.

4.2.9 Drains

For all insulation systems and insulation classes for piping and equipment (except for class 2, 5 and 9) there shall be 15 mm diameter drain holes in all low points, and a minimum of one hole every 3 metres on horizontal runs.

Compact pre-insulated piping system does not require low point drain.

4.3 Materials

4.3.1 General

Insulation materials for classes 1, 2, 3, 4, and 9 shall consist of cellular glass. Materials for class 5, 6, 7 and 8 shall be cellular glass in combination with mineral wool, mineral fibre or ceramic fibres. All insulation materials shall have a neutral pH value.

Insulation concept shall be non combustible, non-toxic and water tight/water repellent. The materials shall not release toxic or corrosive gases when exposed to fire. No asbestos or asbestos products shall be used. No lead or lead products shall be used unless accepted by company. These requirements are not applicable to pre-insulated pipe systems.

In dry rooms where no sprinkler deluge system exist mineral wool may be used on pipes/vessels with an operating temperature above +40 °C. Indoor areas with regular water cleaning or testing of sea-water deluge system are not considered dry. The system shall have drain holes according to clause 4.2.9.

For steam and exhaust pipe, mineral wool may be used with stainless steel jacketing.

Mineral wool shall under no circumstances be applied on stainless steel materials like AISI 316, duplex, 6Mo etc.

4.3.2 Fire insulation materials

The material shall withstand relevant temperatures while maintaining its fire protection properties. For jet fire protection high duty fibres that withstand temperatures above 1150 °C shall be considered.

4.3.3 Cellular glass

Cellular glass shall have the following properties:

Conform to ASTM C552 and be suitable for temperatures from -260 °C to 430 °C

The density shall be within 125 kg/m³ +/- 10 % as per ASTM C303

Thermal conductivity, not greater than 0,0039 W/mK as per ASTM C177

Average compressive strength per ASTM C165: 490 kPa

Water vapour transmission: Zero

Linear expansion coefficient: 8,5 x 10⁻⁶/°C

4.3.4 Mineral wool

Mineral wool shall be manufactured with a phenol binder. The specific flow resistance for the mineral wool shall be minimum $2,0 \times 10^4 \text{ Pa s/m}^2$. The density shall be within 90-120 kg/m³.

4.3.5 Sealers, Tape

Joint sealers and tape shall be permanently flexible through a relevant temperature range and shall be capable of withstanding repeated expansion and contraction.

4.3.6 Metallic jacketing

Metallic jacketing shall be stainless steel or sea water resistant Al-alloy. For fire protection the jacketing material shall be stainless steel.

4.3.6.1 Stainless steel

Stainless steel metal jacketing shall be type AISI 316, 2B finish.

Stainless steel sheets for pipes and vessels up to DN 450 shall have a thickness of 0,5 mm. For dimensions above DN 450 the thickness shall be 0,7 mm.

4.3.6.2 Aluminium alloy

Aluminium alloy jacketing shall be type AlMn1 (AA 3103) or equal.

Aluminium sheets for pipes and vessels up to DN 450 shall have a thickness of 0,7 mm. For dimensions above DN 450 the thickness shall be 0,9 mm.

4.3.7 Non metallic jacketing

4.3.7.1 Fire characteristics incl. Smoke and toxic gases

According to ISO 5660 and additional techniques. No additional acceptable amounts of smoke/fumes beyond what is produced in a HC fire. In addition to what ISO 5660 specifies, concentration of various vapours, fumes and gases shall be documented according to the chemical composition of the material. Based on these tests the material can be subject to application restrictions.

Flame spread as per IMO Res. A.653 (16) equal to self extinguishing properties.

4.3.7.2 Weathering/durability.

500 hours Weather-O-meter testing according to ASTM G53 incl. wet/dry-cycling. (UV-B313). Less than 70 % loss of lustre. The material shall maintain 90 % of its strength properties after the Weather-O-meter test.

4.3.7.3 Material parameters

Water vapour transmission:

10g/m /24h as per ASTM D3833.

Mechanical properties:

Min. Tensile strength 6.9 MPa (1000 psi).

Elongation at break min.10 %.

The material shall not decompose at temperatures from -20°C to 70°C .

Any possible shrinkage or temperature unsuitability of the tape material shall be documented.

4.3.7.4 Application

The tape material shall be suitable for application at RH up to 90 % and down to $+5^{\circ}\text{C}$. New materials shall be subject to a pilot test for verification of the application performance.

4.3.7.5 General

Storage stability of the tape shall be minimum 6 months.

Technical specifications and HSE data sheets shall be in Norwegian.

Types of non-metallic weather proofing shall be subject to Company approval.

4.3.8 Bonding adhesive

For temperatures up to 140 °C adhesive shall be used for bonding of insulation to vessels. When the adhesive cures it shall constitute a flexible bond that absorbs mechanical and thermal stress.

Bonding adhesive shall not be used above 140 °C.

4.3.9 Anti-abrasive coating

The high temperature anti-abrasive coating may be a high strength gypsum cement with inert mineral fillers applied on the inner surface of the insulation sections. When dry, the cement shall form a hard surface protection against abrasion.

Anti-abrasive coating shall be used to prevent damage to cellular glass and painting due to vibration where applicable.

The low temperature anti-abrasive coating shall be a one component urethane based coating.

The anti-abrasive coating shall be suitable for application at service temperatures.

4.3.10 Metallic foils

Aluminium foils as an initial wrapping over heat traced piping and equipment shall be soft temper foil, 0,05 mm thick.

If heat tracing is used to any type of stainless steel piping, then aluminium foil with polyester on one side shall be used.

The polyester coated side to be applied towards the pipe to prevent galvanic corrosion.

4.3.11 Accessories

Vendor to specify standard (material, dimension, type) regarding accessories such as rivets, toggle latches, bands, wires, clips, breather springs etc. all in AISI 316 materials.

4.3.12 Pre-insulated pipe systems

Pre-insulation shall consist of an insulation layer and a watertight outer jacket. Dimension of outer jacket shall be in accordance with EN 253: Casing pipe dimensions.

The insulation system must withstand minimum 0,3 MPa pressure to the outer surface. It must be designed for clamping on the outer jacket or water tight insulation of supports.

Field insulation of field joints and other accessories shall give same insulation and weather protection as for straight pipes.

The insulation system shall fulfil class 1 in accordance with NT Fire 036.

In addition to what ISO 5660 specifies, concentration of various vapours, fumes and gases shall be documented according to the chemical composition of the material.

For pipe systems with heat tracing a groove (duct) shall be formed in the insulation tight to the main pipe. The groove (duct) shall be dimensioned to allow space for the heating cable and material for the application

4.4 Installation

The Insulation Handbook established by Statoil, Norsk Hydro and Saga may be used to secure a uniform and acceptable design of the insulation work.

4.4.1 General

The insulation materials and the external jacketing shall be installed in such a way that water does not enter the insulation material or between the insulation and the pipe / equipment surface during design life.

Surfaces to be insulated shall be clean and dry. The application of the insulation shall not be started before the mechanical completion certificate for coating has been issued. Surfaces to be insulated shall be treated in accordance with NORSOK M-501.

Discontinued insulation work shall be properly covered to avoid damage and ingress of water to the insulation clean and dry.

Single layer insulation shall be applied with longitudinal joints staggered. In double-layer applications, joints of the outer layer shall be staggered with respect to the inner layer joints. All insulation shall be installed with all joints tightly glued together. Voids within the insulation are not acceptable.

If insulation work precedes testing of pipe work, welds and joints shall be left uninsulated to allow inspection during testing.

Insulation on valves shall leave the packing gland accessible.

To secure cellular glass pre-formed sections in place, adhesive glass fibre reinforced tape or stainless steel banding shall be used. Wire shall not be used.

4.4.2 Pre insulation

The service pipe, insulation and jacket shall be one compact construction. Insulation and jacket must follow the thermal movement of the service pipe. All welding must be controlled, pressure tested, documented, approved and surface treated before the final insulation is performed.

4.4.3 Metallic jacketing

The crimps on jacketing shall have the following minimum dimensions; depending on outside diameter (including insulation):

Up to 300 mm:	10 mm	5 mm radius
Between 300 mm and 600 mm:	13 mm	6,5 mm radius
Above 600 mm:	16 mm	8 mm radius

All jacketing seams shall be installed by 'roof tile' principle and the application of joint sealer shall be inside the jacketing.

Metallic jacketing for vessel insulation shall be edge crimped and overlapped 75 mm on longitudinal and circumferential seams. Vessel jacketing shall be provided with bands on all overlap seams and support rings (400 mm c/c).

Head covers on vessels shall overlap shell covers by 100 mm.

On vessel jackets, breather springs shall be used on bands if required for expansion.

On vertical vessels and piping, "S" clips shall be used to keep the jacket sheets from sliding. Minimum 4 clips per seam.

Metallic jacketing shall be fastened with stainless steel bands. Only for difficult details such as bends, T-pieces etc. pop rivets (or equivalent) may be used.

Metallic jacketing for pipes and fittings shall be roller formed and edge crimped at longitudinal seams. Circumferential seams shall be crimped 50 mm from the edge wherever possible. Circumferential seams shall be overlapped minimum 50 mm. Longitudinal seams for outside diameters up to 150 mm shall be overlapped 30 mm and 50 mm above.

5 HOT SERVICE AND ACOUSTIC INSULATION

5.1 General

This clause describes the requirements for the following insulation classes:

- Class 1, Heat conservation.
- Class 3, Personnel protection.
- Class 5, Fire proofing.
- Class 6, 7 and 8, Acoustic insulation.

5.2 Design

Guidance for the choice of insulation thickness for heat conservation and personnel protection is for cellular glass given in table 2. If a specific temperature has to be maintained, the thickness of the insulation material in question has to be specified in each case.

The following equipment shall not be insulated for heat conservation class 1 except for steam services or when otherwise specified:

1. Vessel man way covers, nozzles and flanges.
2. Exchanger nozzles and flanges.
3. Valves and piping flanges.
4. Control valves, line valves and fittings, which are to be removed periodically.
5. Expansion and rotation joints, slide valves and similar equipment.
6. Steam traps.

Flanges operating at temperatures above 450 °C shall be insulated and protected with sheet metal jacketing.

5.3 Installation

The following requirements apply in addition to those in clause 4.5
Insulation sections shall be installed according to manufacturer's standard procedure.

5.3.1 Block insulation for vessels / cellular glass

Block insulation for vessels:

1. Insulation for vessel heads shall be curved blocks or standard flat blocks cut to fit.
2. For single layer and outer layer of multi layer insulation, banding shall be placed approximately 30 mm on each side of all butt joints with intermediate bands at a maximum of 300 mm centres. The inside layer of multi layer installations shall be banded at a maximum 450 mm centres.

5.3.2 Blanket insulation on vessels / ceramic fibres / mineral wool

Blanket insulation on vessels:

1. The last piece of insulation in each layer shall have a snug fit to make all joints tight. Contraction joints are not required for resilient insulation materials.
2. The meeting edges of blankets shall be tied together with stainless tie wire.

5.3.3 Prefabricated pipe section insulation / cellular glass / mineral wool

Prefabricated insulation shall be applied as follows:

1. Insulation pipe sections shall be tightly butted together and secured to pipe with stainless steel bands.
2. Insulation shall be secured with bands over the outer layer at each side of radial joints and at the centre of each section.
3. Spacing of bands for the inner layer of multi layer insulation need only be sufficient to hold sections in place until the outer layer is secured.
4. To cover elbows and other irregular surfaces, sections may be cut and fitted in the field.

5.3.4 Blanket insulation for piping / ceramic fibres / mineral wool

Blanket insulation shall be used for dimensions where pipe sections are not available.

1. Insulation joints shall be butted firmly together and secured with stainless steel wire or bands.
2. Insulation shall be secured with bands over the outer layer at each side of radial joints and at the centre of each section.
3. Fittings and flanges shall be insulated with blankets. Insulation shall be secured by wire or band.

5.3.5 Pre insulation for piping

Pre insulation shall be applied as follows:

1. The concept shall give a compact construction.
2. Insulation ends shall be water proof

5.4 Guidance for insulation thickness

Table 1 applies to Heat conservation (class 1) and personnel protection (class 3)

Table 1. Thickness in millimetres for cellular glass.

DN mm	Maximum operating temperatures °C							
	100	150	200	250	300	350	400	420
20	30	30	30	30	50	50	50	50
25	30	30	50	50	50	50	50	50
32	30	30	50	50	50	50	50	50
50	30	30	50	50	50	50	80	80
65	30	30	50	50	50	80	80	80
80	30	50	50	50	50	80	80	80
100	50	50	50	50	50	80	80	100
150	50	50	50	50	80	80	80	100
200	50	50	50	50	80	80	80	100
250	50	50	50	50	80	80	100	100
300	50	50	50	50	80	80	100	100
350	50	50	50	50	80	80	100	100
400	50	50	50	50	80	80	100	100
450	50	50	50	50	80	80	100	100
500	50	50	50	50	80	80	100	100
600	50	50	50	50	80	80	100	100
Above 600 and flat surface	50	50	80	80	100	100	100	150

The material thickness given above is guidelines only. They shall be adjusted up to the closest standard thickness given by the manufacturer. Thickness of 80 mm and above can be built up in two layers if required.

For other materials or pre insulation the guidelines above may be used to the nearest standard thickness.

5.5 Guidelines for Steam Service and Exhaust Lines

Steam Service and Exhaust lines will normally have an operating temperature enabling eventual wet insulation to dry out. In such cases mineral wool may be used if accepted by Company.

Steam lines utilising mineral wool pipe sections shall be of nominal density 140 kg/m³. Weather protection shall be stainless steel jacketing.

Exhaust lines utilising mineral wool mattresses shall be of nominal density 105 kg/m³, with galvanised wire mesh at one side. Weather protection shall be stainless steel jacketing.

Table 2 Thickness in millimetre for mineral wool

DN mm	Steam service Operating temperatures °C				Turbine exhaust Operating temperatures °C						
	200	250	300	400	200	300	400	500	600	700	800
25	30	40	50	60							
38	40	50	50	60							
50	50	50	60	80							
80	50	50	60	80							
100	50	50	70	80							
150	50	50	80	80							
200	50	50	80	100							
250	50	50	80	100							
300	50	50	80	100							
350	50	50	80	100							
400	50	50	80	100							
450	50	50	80	100							
500	50	50	80	100	50	100	130	150	175	175	200
600	50	50	100	100	50	100	130	150	175	200	200
And above	50	50	100	100	50	100	130	150	175	200	200

5.6 Class 5, Fire Proofing

The purpose is to reduce the heat input on piping, vessels and equipment in a hydrocarbon fire situation.

If the material strength of equipment will be reduced by being subjected to a fire, this must be taken into account in the evaluations, of regulations relating to explosions and protection of installations in the petroleum activities. With regard to evaluations of depressurising time, a recognised standard such as API RP 521 may be used. If passive fire protection is used, the material strength can be retained for a longer period of time and thereby affect the depressurising time.

Required insulation thickness, and combination of insulating materials, shall be calculated on an individual basis, and the following shall be taken into consideration:

1. Extrapolations of test results are not acceptable. New systems or combination of materials shall be subject to relevant fire tests prior to acceptance.
2. Type of fire.
3. Properties of pipe work and vessel material
4. Content of pipe work and vessel
5. Depressurisation time for the exposed system
6. Properties of the insulating material
7. Only metallic weather proofing shall be used on Class 5, except on valves and flanges where removable jackets may be used. A weather proofing membrane can be installed under the metallic cladding to reduce the risk of water ingress and corrosion under insulation.

5.7 Guidelines for acoustic insulation

The acoustic pipe insulation classes can be met by various combinations of insulation materials and jacketing systems. Within the same installation one should try to limit the number of pipe insulation systems by choosing alternatives that provides combinations of sufficient personnel protection, heat insulation, cold medium conservation, fire protection and noise insulation when and as required.

Valves and flanges shall be insulated when specified.

Guidelines for the choice of various layers of pipe insulation materials is given in Annex 1:

All systems shall be tested according to approved methods, ref. Annex 2.

All materials shall also be tested and approved in the actual combination. To correct for uncertainties in materials, workmanship and measurements 3 dB shall be subtracted from the measured values.

The following applies to the materials:

1. Cellular glass as inner layer shall always be used for corrosion protection.
2. All thickness specified in the tables are a guide to minimum dimensions.
3. The “fibres” used in acoustic systems may be ceramic fibres, mineral fibres or mineral wool.
4. Heavy synthetic sheets shall be $> 6 \text{ kg/m}^2$.

6 COLD SERVICE INSULATION

6.1 General

This clause describes the requirements for the following insulation classes:

- Class 2, Cold medium conservation.
- Class 4, Frost proofing.
- Class 9, External condensation and icing protection.

6.2 Design

If a specific temperature has to be maintained for process reasons, the thickness of the insulation has to be specified in each case.

6.2.1 Vessel insulation

Where required, man ways shall be provided with removable covers of the same insulation thickness as the shell insulation. Covers shall be secured to the shell insulation and sealed to provide vapour tight joints.

6.2.2 Piping insulation

Valves and fittings shall be insulated with pre formed pipe insulation. Sections shall be cut from standard blocks, fitted and wired in place. Alternatively, tailor made jackets may be used.

Flanges shall be insulated with the same insulation thickness as the thickness on adjoining pipe run, vessel, machinery or fitting.

In order to avoid frost formation or condensation on pipe supports, insulated prefabricated pipe supports shall be used.

6.3 Installation

The following requirements apply in addition to those in clause 4.5.

A smooth outer insulation surface must be obtained to provide an effective vapour seal.

6.3.1 Block insulation for vessels

Block insulation for vessels:

1. All block edges shall be smeared with a thin coat of joint sealer when single layer insulation and the outer layer of a multi layer insulation are applied. The remaining joints shall be left dry, except where vapour seals or contraction joints are required,
2. Termination of insulation on all layers, including contact surfaces where removable insulation covers are installed, shall be vapour sealed.

6.3.2 Piping insulation

Prefabricated insulation of cellular glass shall be applied as follows:

1. All joints of single layer and outer layer of a multi layer insulation shall be applied with butt edges smeared with joint sealer before installation.
2. Anti-abrasive compound shall be applied to the inner bore and allowed to dry before application. Anti abrasive compound when required, is preferred factory applied.
3. Bands or glass fibre reinforced tape shall be used to secure each layer of insulation, including the outer layer. Bands or tape shall be installed on 275 mm centres, and at least 25 mm back from butt joints. Wire shall not be used.
4. Prefabricated flange and fitting covers shall be applied in the same manner as pipe insulation, except that non-removable joints shall be cemented with adhesive.

6.3.3 Pre insulation for piping.

Pre insulation shall be applied as follows:

1. The concept shall give a compact construction without any spaces or voids.
2. Insulation ends shall be water proof.
3. For heat tracing a groove (duct) suitable for the heat tracing cable shall run along and close to the pipe inside the insulation.

6.3.4 Guidance for insulation thickness

6.3.4.1 Frost proofing, Class 4 piping and equipment with heat tracing:

Thickness of insulation for piping and equipment shall be:

1. 40 mm up to and including nominal diameter 200 mm.
2. 50 mm above 200 mm and flat surface.

6.3.4.2 Frost proofing, Class 4 piping and equipment without heat tracing:

Thickness of insulation for piping and equipment shall be:

1. 30 mm up to and including nominal diameter 80 mm.
2. 40 mm above 80 mm and flat surface.

Table 3 applies to cold service insulation, class 2 and 9, and condensation protection.

Table 3. Thickness in millimetres for cellular glass.

DN mm	Minimum temperatures °C									
	5	0	-10	-20	-30	-40	-50	-60	-70	-80
25	30	30	50	60	60	75	75	90	90	100
32	30	50	50	60	75	75	75	90	100	100
50	30	50	50	60	75	90	90	100	100	100
65	50	50	50	60	75	90	90	100	100	125
80	50	50	60	75	75	100	100	100	125	125
100	50	50	60	75	75	100	100	100	125	125
150	50	50	60	75	90	100	100	125	125	125
200	50	50	75	75	90	100	125	125	125	150
250	50	50	75	75	100	100	125	125	150	150
300	50	50	75	75	100	100	125	125	150	150
350	50	50	75	75	100	100	125	125	150	150
400	50	50	75	75	100	100	125	125	150	150
450	50	50	75	75	100	100	125	150	150	150
500	50	75	75	75	100	100	125	150	150	150
600	50	75	75	75	100	100	125	150	150	175

The material thicknesses given above are guidelines only. They shall be adjusted up to the closest standard thickness given by the manufacturer. Thickness of 100mm and above can be built up in two layers if required.

For other materials or pre insulation the above guideline may be used to nearest standard calculated according to the thermal conductivity.

7 COMBINATION OF INSULATION CLASSES

7.1 General

Below guidelines are given for insulation systems in cases where insulation shall serve more than one purpose:

Two digits in the line number on the P&ID will indicate the insulation class and the insulation symbol will show insulation material and thickness.

Insulation Class 1 will be shown as 01 etc. Insulation systems with combination of class 1 and 5 can be identified with the two digits 15 in the line number or other project specific combinations.

7.1.1 Fire proofing (5) combined with Heat conservation (1) and or Acoustic insulation (6, 7 & 8).

Use class 5 fire proofing and relevant class for acoustic insulation builds up. Select the thickness from the insulation class with the greatest thickness. Stainless steel jacketing shall be used.

7.2 Acoustic insulation (6, 7 & 8) combined with Heat conservation (1) or Personnel protection (3).

Use Acoustic insulation build up. Select the thickness from the insulation class with the greatest thickness.

7.3 Fire Proofing (5) combined with cold service insulation (2, 4 and 9)

Use cellular glass for the cold service and add a layer with the required thickness of accepted fire protection material. A vapour barrier outside the fire protection to be included to reduce intrusion of water/vapour into the fire protection. Stainless steel jacketing shall be used.

7.4 Acoustic insulation (6, 7 & 8) combined with cold service insulation (2, 4 and 9)

Use acoustic insulation build up, but add an outer layer of cold service insulation. The thickness of the acoustic insulation will allow a similar reduction in the thickness of the cold service insulation. However, minimum thickness of the cold service insulation shall be 30 mm.

8 QUALIFICATION REQUIREMENTS**8.1 Qualification of insulation system**

The requirements for qualification prior to use are applicable to insulation class 5.

The fire resistance shall be decided in accordance with recognised standards and/or calculation models.

Tests shall be carried out on complete insulation system installed on a test piece on a relevant dimension.

The following shall identify the fire technical requirement relating to insulation materials:

1. Requirement in NPD "Regulation for explosion- and fire protection".
2. For pool fire, the insulation system shall be qualified and the fire resistance shall be decided in accordance with recognised standards and/or calculation models, for example ISO 834 "Fire resistance tests" or equivalent
3. Insulation used for passive fire protection against a jet-fire shall be tested in according with OTO 93 028 the test method "Jet-fire resistance test of passive fire protection materials".

8.2 Qualification of personnel**8.2.1 Qualification of insulation fitters**

Operators shall be qualified to tradesman level as insulation fitter or sheet metal worker.

The personnel shall have a relevant knowledge of health and safety hazard, use of protection equipment, insulation materials, application of insulation materials, insulation systems surface requirements, and how to avoid corrosion under insulation.

If not qualified to tradesman level, personnel shall be subject to a test in accordance with this for Standard classes 1, 4 and 5.

The test shall be supervised by a qualified supervisor and examined by qualified QC personnel.

An examination certificate shall be issued if the candidate passes the test. Inspection personnel shall have access to site test procedures.

The test shall be carried out on a test piece, composed of a DN 100 pipeline containing at least one valve, two flanges, one T piece, one trunnion support and one standard clamped support. Both valve box and one flange shall be insulated with AISI 316 material to insulation system Class 5.

Alternatively a suitable location on the installed pipelines, which as a minimum consist of the same parts as described for the test piece, may be selected to which the Insulation Procedure Test (IPT) shall be carried out

8.2.2 Qualification of Supervisors, Foremen and QC personnel

Personnel carrying out inspection or verification shall be qualified to tradesman level and shall be accepted as inspector by company.

Supervisors and foremen shall be qualified to tradesman level and shall have documented minimum 3 years experience with insulation work corresponding to work described in this standard. All QC- and supervision personnel shall be familiar with the requirements in this standard.

8.3 Qualification of procedures

8.3.1 Insulating Procedure Specification (IPS)

A detailed IPS based on the requirements of this standard shall be established. The IPS shall as a minimum contain the following:

1. Detailed sketches, which show the system, build up for each insulation class to be used. (also for combination of systems)
2. Type of materials to be used in the individual layer (product data sheet)
3. Type of removable insulation covers for flanges and valves
4. Dimension of materials
5. Inspection plan

The qualified IPS shall be followed during all insulation work

Following changes in the insulation application parameters requires the IPS to be re-qualified:

1. Any change of insulation material
2. Change of system build up
3. Change type/manufacture of removable insulation covers

8.3.2 Insulation Procedure Test (IPT)

An IPT shall be used to qualify all insulation procedures. A test piece (ref. 8.2.1 as applicable), alternatively a suitable location on the lines to be insulated, may be selected to which the IPT shall be performed.

The IPT shall be qualified under realistic conditions likely to be present during insulation installation.

Inspection requirements for the IPT shall be as given in clause 9 and the inspection plan in IPS.

9 INSPECTION AND TEST

Work during production, at delivery and all other pertinent phases, shall be duly inspected.

Reasonable access to workshop and personnel for inspectors shall be allowed for.

Inspection shall be carried out at each stage of the work, but as a minimum before second layer of multi layer insulation is applied and before jacketing is applied.

ANNEX A – KEY DATA FOR INSULATION SYSTEMS

Insulation class	Insulation Materials	Jacket Material	Other Comments / Build-up
Class 1 Heat Conservation	Cellular glass Mineral wool at temp. higher than 420 °C	Non-metallic weather-proofing membrane., <i>or</i> Stainless Steel / Al	
Class 2 Cold Service Insulation	Cellular glass	Non-metallic weather-proofing membrane., <i>or</i> Stainless Steel / Al	Vapour barrier
Class 3 Personnel Protection	<i>Either:</i> Class 1 – 9 <i>Or</i> Perforated sheet metal guards	In accordance with classes 1 – 9 as applicable	Perforated guards to be of stainless steel. If insulation is used, it shall be designed so that the jacket temperature do not exceed 70 °C
Class 4, Frost Proofing	Cellular glass	Non-metallic weather-proofing membrane., <i>or</i> Stainless Steel / Al	Vapour barrier
Class 5, Fire proofing	Cellular glass + Ceramic fibre <i>or</i> mineral wool when necessary	Stainless steel	Insulation materials are dependant on protection requirements, and must be accepted in writing by client for each case
Class 6, Acoustic Insulation – 10dB	Cellular glass Ceramic fibre <i>or</i> Mineral wool Heavy synthetic sheet	Non-metallic weather-proofing membrane., <i>or</i> Stainless Steel / Al	30mm Cellular glass + 25mm “fibres” + metallic jacketing (or aluminium foil + non-metallic jacketing)
Class 7, Acoustic Insulation – 20dB	Cellular glass Ceramic fibre <i>or</i> Mineral wool Heavy synthetic sheet	Non-metallic weather-proofing membrane., <i>or</i> Stainless Steel / Al	30mm Cellular glass + 38mm “fibres” + heavy synthetic sheets + metallic jacketing (or aluminium foil + non-metallic jacketing)
Class 8, Acoustic Insulation –30dB	Cellular glass Ceramic fibre <i>or</i> Mineral wool Heavy synthetic sheet	Non-metallic weather-proofing membrane., <i>or</i> Stainless Steel / Al	30mm Cellular glass + 38mm “fibres” , + 2 x heavy synthetic sheets + 25mm fibres + 2 x heavy synthetic sheets + metallic jacketing (or aluminium foil + non-metallic jacketing)
Class 9, External Condensation	Cellular glass	Non-metallic weather-proofing membrane., <i>or</i> Stainless Steel / Al	Vapour barrier

These key data are not applicable for pre insulated pipe systems.

ANNEX B – INSERTION LOSS – TEST PROCEDURE

General

The acoustic properties of pipe insulation can be characterised by the insertion loss. Today, there are no national or international test standards established for such measurements. This attachment describes a "survey" method for measuring the acoustic insertion loss of pipe insulation systems. This method should be used to determine the "Classes of Acoustic Pipe Insulation" as defined in NORSOK R-004, rev. 2.

Frequency dependent Insertion Loss

The frequency dependent insertion loss is defined by the following equation:

$$IL_i = L_{pU, i} - L_{pI, i}$$

IL_i : Insertion loss at the frequency "i"

L_{pU} : Reference measurement of the bare pipe. The noise level at 1,0 m distance from the uninsulated pipe, calculated as the logarithmic average of all microphone positions.

L_{pI} : Measurements of the insulated pipe. The noise level, logarithmic average, in the same microphone positions after the insulation system is applied.

Although the acoustic classes of insulation are described by a single value derived from the three 1/1-octave band levels 500, 1000 and 2000 Hz, measurements should be performed in 1/3-octave bands in a broader frequency range. This will provide important additional information to be used in predictions of sound radiation from various pipelines.

For all other measurements than site tests, measurements shall be performed in 1/3 octave band levels and as a minimum cover the frequency range of 100-5000 Hz.

ACOUSTIC CLASSES - Average insertion loss

The acoustic insulation is defined as the arithmetic average of the insertion loss in the three 1/1-octave bands with centre frequencies at 500, 1000 and 2000 Hz:

$$IL = (IL_{500} + IL_{1000} + IL_{2000})/3$$

The 1/1-octaveband levels shall be calculated from the measured 1/3-octaveband levels after a linearisation of the reference spectrum (L_{pU}) - i.e. a correction shall be added or subtracted to the $L_{pU,i}$ -values to obtain a "flat" (linear) spectrum. The $L_{pI,i}$ -values shall be adjusted correspondingly.

3 dB shall be subtracted from the calculated average insertion loss (IL), before defining the acoustic class of the pipe insulation as described in NORSOK R-004.

Test arrangement

A pipe of at least 5 metre length should be used for the test. The pipe diameter should be in the range of 200 - 400 mm, and the pipe wall should have a thickness of 8 – 12 mm.

If the normal pipe diameter that the insulation will be used for is outside than this range, the system may be tested for the relevant diameter. Considerations about the effect of other dimensions should be given in the test report.

The pipe may be set into vibration in several ways. For a survey purpose it may be unfeasible to use a "natural" source like for instance the noise from a valve for the test, unless there is a suitable test spot within a process area, which can be screened of from other sources.

A sound source of appropriate power to create sufficient high noise level in the pipe may therefore be used. The source must be placed in separate room or an insulated enclosure (box) with sufficient sound insulation to prevent false noise to interfere with the measurement results.

The measurements may be performed in a reverberant room, a semi reverberant soundfield or in free field conditions. The number of measurement positions should then be at least 5 randomly distributed at for instance 1 metre distance from the bare pipewall. The sound pressure measurements and averaging of the noise levels should be performed in accordance with recognised standards for such measurements. Methods described in ISO 3740 – 3746 and ISO 11200 – 11204 may be used as reference for calibration, measuring technique, microphone positions, requirements to and influence of background noise, environmental contribution from the test place (room), etc. If intensity measurements are used in stead of measurements in discrete positions the relevant intentional standard shall be given, for instance ISO 9614-2.

The noise from the source shall enter the measurement site mainly through the pipe wall, also after the pipe insulation has been applied to the pipe. Both the source end of the pipe and the opposite end (passive end) must therefor be insulated sufficiently to reduce the contribution from these sources to an insignificant level.

Measurement procedure

A system to check the "sound source" should be established in order to ensure a constant excitation during the test. This may for instance be a microphone placed at a fixed position inside the pipe. A calibration test of the instrumentation shall be carried out before and after the test. The microphone positions must be kept at the same places; to ensure that environmental reflections contributes similarly to the measured levels through all series of measurements.

The background sound level must be checked, and if the level is within 10 dB below the lowest noise level from the pipe, the measured levels shall be adjusted. Background levels which is less than 5 dB below the lowest 1/3 octaveband levels should not be accepted.

During the test one should also check any influence from "false" sources such as leaks, radiation from supports, radiation from pipe ends, radiation from source room etc.

Report

The following should be reported from the test:

Test arrangement

- dimensions of pipe
- pipe ends and support structure
- type of excitation
- test environment

Measurement procedure

- sound source check
- calibration
- measurement positions
- background noise
- limitations / influence of leaks / “false noise”

Materials tested

- name / code / vendor
- attachment with material certificates (vendor information)

Test results

- 1/3 octave band values of reference level (for instance levels inside the pipe)
- unlinearised 1/3 octave band levels outside pipe
- Linearised 1/3 octave band levels and the corresponding 1/1 octaveband levels outside the uninsulated pipe (corrected for background noise).
- 1/3 octaveband levels corrected for linearisation, and the corresponding 1/1 octave band levels outside the insulated pipe (for each system) included any corrections for background noise.
- Insertion loss for each system in 1/3 octaveband and 1/1 octavebands in the frequency range covering at least 100 – 5000 Hz.
- Calculated average insertion loss and specification of insulation class.
- Discussion of results and limitations.