# Code of Practice for Carrying Out Thermal Insulation Work at Above and Below Ambient Temperature in the Temperature Range -80°C To + 850°C

**FESI document 3**


FEDERATION EUROPEENNE DES SYNDICATS D'ENTREPRISES D'ISOLATION

EUROPEAN FEDERATION OF ASSOCIATIONS OF INSULATION CONTRACTORS



**May 2010**

**www.fesi.eu**

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# CODE OF PRACTICE FOR CARRYING OUT THERMAL INSULATION WORK AT ABOVE AND BELOW AMBIENT TEMPERATURE IN THE TEMPERATURE RANGE -80$^{O}$C TO + 850$^{O}$C.

**Contents**

## 1. Scope

1.1 Code of practice for carrying out thermal insulation work at above and below ambient temperature in the temperature range -80°C to + 850°C.

1.2 Thermal Insulation has one major function – that is to conserve energy. The importance of energy conservation has not yet been fully appreciated by business or individuals. This document focuses on how to save energy, efficiently, through best practice in design, execution and inspection of thermal insulation systems.

1.3 Exclusions from this document will include refractory, cryogenic, acoustic and fire insulation. However, where appropriate other documents will be cross referenced.

1.4 This code of practice does not apply to work on the building envelope, partition walls and ceilings.

## 2. Exchange of design data – plus reasons for insulation

2.1 The design phase is a very important and critical process. During the design work the fundamentals, the quality of the insulation to be installed on site, is established.

2.2 Because of conflicting requirements, there can be no “all purpose” insulation. Nor is there a “perfect” insulation for each set of requirements. It is essential that the engineer evaluates the installation and determine which requirements have to be fulfilled, and which are of lesser importance.

2.3 Too many insulation jobs have been poorly engineered. Those who know the least about the problem always seem to have the most positive opinions as to the correct answer. For this reason, it is hoped that the engineers responsible for insulation design will develop, not only their own methods of evaluating requirements for future installations, but will also analyse past installations to help determine where improvements are possible.

2.4 Only through improved engineering will the insulation industry change from a “craft” to “science”.

2.5 The purchaser should specify either:

a) precise details of the insulation requirements; or
b) the service conditions for which the insulating materials are required so that the insulation contractor can make recommendations
c) the environmental conditions that will prevail

In the case of b) and c), if required by the contractor, the purchaser should provide information recommended in 2.2.

2.6 Details of the plant to be insulated

a) whether plant is located indoors, outdoors but protected, outdoors exposed to weather, or enclosed in ducts or trenches below ground level
b) any difficult or unusual site conditions that can influence the selection or application of insulating materials or both, e.g. in regard to transport, scaffolding, weather protection or excessive humidity
c) type of material to be insulated – with details of special or unusual materials
d) dimensions of surfaces including external diameters and associated clearances, surface orientations and height, number and type of pipe fittings

2.7 Operating conditions
The following temperature conditions should be specified:

a) normal operating temperature
b) maximum and minimum temperatures that could occur
c) the range of ambient air temperatures, wind velocities and for condensation control, relative humidity
d) any requirement to prevent condensation on the outer insulated surface of pipes or vessels containing cold media

2.8 Preparation of surfaces
Special requirements such as removal of works applied coatings or application at site of coatings or other surface treatment should be clearly specified.

2.9 Types of fittings and supports
The types of fittings and supports and which of these are to be provided by the contractor, should be specified.

2.10 Type of insulation
The type of insulation material including any specific physical properties required should be detailed.

2.11 Type of cladding
The function and physical properties of the surface covering should be detailed including any onerous requirements such as foot traffic and supporting ladders.

2.12 Special service
Any special service requirements such as resistance to compression, fire resistance or abnormal vibration should be detailed.

2.13 Basis on which the thickness of insulation is to be determined

a) heat conservation
b) process control or temperature maintenance
c) personnel protection
d) cold conservation – refrigeration
e) condensation control
f) frost protection
g) Economy
h) $CO_2$

## 3. Prestart requirements and site considerations

3.1 General conditions

General job conditions stating responsibilities and business agreements between the client and the contractor. This should include the proper references in the contract making this section and the balance of the specifications a part of the contract agreement between client and contractor.

3.2 Construction preconditions

The insulation requirements should already be considered during design and construction phase. There should be consultation at the design phase to avoid unnecessary complication of the insulation work. For example the need for welded attachments to stainless steel vessels should be identified before stress relief. The hydraulic testing of the equipment to be insulated is completed and documented.

### 3.3 Preconditions to start insulation work

To allow for the effective and unimpaired insulation of an object, all earlier stage construction tasks must be completed. Especially the following preconditions must be met:

- anti-corrosion works on the object are finished – if needed
- tracer heating systems and measuring devices have been installed
- the minimum clearance distances are maintained
- attachments for insulation and /or cladding are in place
- sealing collars and sealing discs are attached to the object
- pipe stubs, manways etc are long enough for the flanges to be outside the insulation layer and allow cladding to be terminated and sealed effectively and without impediment
- supports are fitted so that insulation materials, vapour retarders and claddings can be attached correctly
- the insulation can be applied without impediment, e. g. by scaffolds
- all welding and adhesion works at the object are completed and checked,
- foundations are completed
- all surfaces to be insulated should be clean, dry and free from oil and loose scale.

### 3.4 Unusual working conditions

These should be documented and could relate to items such as elevated or reduced ambient temperature, live petro-chemical conditions, working over water or 'out of hours' work patterns.

### 3.5 Out of sequence execution

These should be documented and could include leaving valves, flanges or other portions uninsulated until certain testing is complete.

## 4. General requirements for good insulation practice

Application rules for insulation materials including hot and cold

#### 4.1.1 Joints

Insulation materials shall be applied and fastened without gaps. Thermal bridges shall be reduced to a minimum. With multi-layer applications, all joints should be staggered.

#### 4.1.2 Minimising convection

For vertical thermal insulation, e.g. on steam generators, flue-gas ducts (also horizontal ducts with large cross-sections), special measures may need to be taken to prevent convection inside the insulation system.

- In single-layer applications, the joints must be closed with compatible glues or sealing compounds.

- For multi-layer applications, the inner insulation layer shall be dry-applied. The joints in the external insulation layer are to be closed with compatible glues or sealing compounds.

- At ends, all layer shall be glued to each other and to the object, and all joints shall be sealed.

- Form pieces shall be applied according to Table 2. A vapour retarder is required. With form pieces possessing a factory-applied vapour retarder, the joints shall be closed additionally with adhesive tape of similar quality.

B.1.8 Insulation with polyurethane in-situ foam (PUR)

Polyurethane in-situ foam according to AGI working document Q 138 is a polyurethane foam, produced on transportable foaming machines at industrial installations. It shall only be produced by companies employing certified foaming specialists.

The AGI working document Q 138 applies for the production of polyurethane in-situ foam at industrial installations.

Dependent upon the production procedure, composition, facing and thickness of the insulant, the building material classes B1 (low ignitability) or B2 (normal ignitability) according to DIN 4102-1 may apply.

The minimum apparent density for $CO_2$-blown polyurethane in-situ foam, freely foamed and without taking increased border area density into account, is 45 $kg/m^3$ for temperatures ≥ –50 °C. For temperatures below –50 °C, the require d minimum apparent density is 55 $kg/m^3$.

When producing polyurethane in-situ foam, the object and the ambient temperatures must at least be 10 °C. The relative humidity must not exce ed 90% for dispensed foam and 85% for sprayed foam. In case these conditions cannot be met, special measures must be taken, e. g. pre-heating of the object. Polyurethane in-situ foam production in the open must not take place when it rains.

The surfaces in contact with the reaction mixture must be dry and free of dust, fat and oil. They may be treated with a primer to improve adhesion.

Dispensed polyurethane in-situ foam must have a minimum thickness of 40 mm.

In installations which are operated below ambient temperature, the apparent density of polyurethane in-situ foam shall be > 50 $kg/m^3$ at temperatures ≤ 50 °C. In case the polyurethane in-situ foam has a full-surface adhesion to the cladding and the seams are sealed, the cladding acts as a vapour retarder.

The full-surface adhesion between the polyurethane in-situ foam and the cladding, which is required for installations operating below ambient temperature to have the cladding act as a vapour retarder, may lead to deformations of the cladding because of the original shrinkage of the polyurethane in-situ foam and because of the thermal contraction during operation of the installation. With increasing diameter, the cladding looses stiffness. This leads to an increasing proportion of the initial shrinkage be transferred as a deformation onto the cladding. These deformations are a system condition and not a default, as long as the functioning of the cladding as a vapour retarder is not jeopardised. With building components, especially with vessels of large diameter, where this cannot be accepted for optical reasons, measurements are possible against deformation, e. g. a de-coupling of the polyurethane in-situ foam from the cladding. An additional vapour retarder is required in this case.

### B.1.9 Insulation with expanded polystyrene foam (EPS)

EPS insulant is a rigid insulation material made of welded expanded polystyrene or one of its co-polymers and possessing a predominantly open cellular structure.

Expanded polystyrene foam is predominantly produced in the form of blocks. It can be employed between –180 °C and +80 °C.

Boards, sections, segments and other form pieces for the insulation are cut from blocks or foamed into a mould.

The individual insulation elements are butted or executed with a staggered edge. Joints may be glued. For the gluing, adhesives without solving agents shall be used.

Dependent upon the production process, composition, facing and thickness of the insulant, the building material classes B1 (low ignitability) or B2 (normal ignitability) according to DIN 4102-1 may apply.

Form pieces are fastened predominantly with self-adhesive tapes. For additional fastening means see Table 2.

### B.1.10 Insulation with extruded polystyrene foam (XPS)

XPS insulation is a rigid insulation material which is produced through blowing and extruding from polystyrene or one of its co-polymers with or without a foaming skin and possessing a closed cellular structure.

XPS foam is only produced in the form of blocks or boards and it can be employed between –180 °C and +80 °C.

Sections and segments are cut or milled from blocks.

The individual insulation elements are butted or executed with a staggered edge. Joints may be glued. For the gluing, adhesives without solving agents shall be used.

Dependent upon the production process, composition, facing and thickness of the insulant, the building material classes B1 (low ignitability) or B2 (normal ignitability) according to DIN 4102-1 may apply.

Fastening means see Table 2.

### B.1.11 Insulation with cellular glass (CG)

Cellular glass is a totally closed cellular insulation material with cell walls of glass. The foaming takes place in a foaming furnace at 800 °C. The procedure allows only for the production of boards and blocks; form pieces are sawn or milled from these. Blocks for the production of large-diameter sections may be glued.

Cellular glass form pieces are water-, water-vapour- and gas-tight. They possess the building material class A1 (non-combustible) according to DIN 4102.

In case of single-layer application of cellular glass semi-sections and elbows, all joints at circumferential and longitudinal seams and at the section end towards the object are to be glued with compatible one- or two-component glues. Pressure-butted bonded joints shall be achieved. Semi-sections are to be fixed with corrosion-resistant metal bonds roughly 30 cm apart.

Segments and boards shall be similarly treated, however, with large surface gluing or point gluing to the object as application assistance. Full-surface glue application is done with a toothed trowel. Segments or boards shall be fixed with corrosion-resistant application straps at intervals of roughly 30 cm.

For the insulation of tank bottoms, the boards shall be glued full-surface with hot bitumen.

Cellular glass boards in single-layer application must neither be shock-heated nor shock-cooled during operation since otherwise the so-called thermo-shock might occur. This is a thermal contraction, respectively expansion which leads to hair-cracks through excess of the fracture elongation. No problem are temperature changes in the range between –80 °C and +120 °C.

In case of temperature changes > 100 K and the beginning or the end of the temperature change being outside the range from –80 °C to –120 °C, a maximum temperature gradient of 2 K/min is recommended for heating and cooling processes of the object.

In case this temperature gradient cannot be kept, the insulation shall be multi-layered and the inner layer shall be dry applied. This avoids crack formation in the external layer. Application advice of manufacturers shall be heeded.

With one-layer applied pipe sections of cellular glass, hair cracks may even occur at temperature gradients < 2 K/min at service temperatures above 120 °C or below –80 °C. Taking the service conditions into account, it must be decided for the insulation system whether damage can occur through crack formation (e. g. through ingressing moisture) which needs to be prevented by additional measures (e. g. multi-layer insulation or reinforced facing).

Cellular glass insulants must not be exposed to warm water above 80 °C or vapour over extended periods since these have material-changing effects.

Freeze / thaw changes of water also influence negatively an unprotected cellular glass surface and attack the closed cellular structure. For installations in the open and with ambient temperatures below 0 °C, therefore, cellula r glass surfaces have to be trowelled with mastic closing the cells.

In case insulation layers of cellular glass are load-bearing, e. g. when used as bolsters, the cells cut open must be filled and the surfaces must be evened out, e. g. with glue, hot bitumen or dry fine sand. For practical applications, the declared compression strength must only be used up to one third for full-surface glued form pieces and only up to one fifth for dry applied form pieces.

Form pieces of cellular glass are to be fastened according to Table 2. In case of repeated movement of object against insulant, an abrasion protection must be inserted between the two.

B.1.12 Insulation with flexible elastomeric foam (FEF)

Foam materials from reticulated elastomerics are predominantly closed cellular, soft foam materials made of synthetic or natural rubber, also mixed with each other or with other polymers. Their properties can be modified through mineral or organic additives.

The apparent density of these foam materials lies between 20 kg/m$^3$ and 200 kg/m$^3$. In the insulation technology, predominantly foam materials of apparent densities between 40 kg/m$^3$ and 100 kg/m$^3$ are being used.

Dependent upon the production process, composition, facing and thickness of the insulant, they can belong into building material class B1 (low ignitability) or B2 (normal ignitability) according to DIN 4102-1.

Foam materials from reticulated elastomerics should not be used under continuous mechanical load. To evaluate their creep behaviour, a dimension-change diagram may be established in relation to load and time.

The unprotected surface becomes brittle under long-term exposure to weather and UV radiation. Elastomeric foam materials shall therefore be protected, e. g. through a facing according to manufacturer advice or through a cladding. Special makes with high UV durability allow for an employment without additional UV protection.

Where elastomeric insulants are connected with cellular glass or rigid foams, the foam glass, respectively rigid foam glue surfaces shall first be richly covered with the elastomeric foam glue. After drying of this first layer, the gluing between the elastomeric foam and the cellular glass, respectively the rigid foam shall be executed according to the manufacturer's manual.

Insulants of elastomeric foam materials shall be fastened according to Table 2.

FEF insulation material is normally employed down to –50 °C; dependent upon the composition, the insulant becomes increasingly brittle with decreasing temperature. The brittleness is reversed as temperatures rise again. After consultation with the manufacturer, FEF insulation materials may be employed down to –180 °C.

The water vapour diffusion resistance coefficient $\mu$ lies between 1 000 and 10 000.

Dependent upon the water vapour diffusion resistance coefficient, the additional employment of a vapour retarder may be required. Form pieces with factory-applied vapour retarders are available. In this case, the joints shall be sealed additionally with self-adhesive tape of equal quality.

Where boards are applied to plane surfaces or at vessels, the boards shall be full-surface glued to the substrate. For pipe insulation, sealing glue barriers are to be installed at intervals of not more than 2 m. Butts and joints shall be full-surface glued.

B.1.13 Insulation with polyethylene foam (PEF)

Insulants of polyethylene are predominantly closed cellular, semi-rigid foams. They consist of polyethylene or mixed polymers with a predominant portion of ethylene. Their properties can be modified through mineral or organic additives.

The apparent density of PE foam materials is normally between 20 kg/m$^3$ and 40 kg/m$^3$.

PE foam materials are supplied as webs, boards, pipe sections and tubes. They may be faced at one or more surfaces dependent upon the form of supply with e. g. plastic foils, grid-reinforced foils with or without self-adhesion.

PE foam materials may have higher densities in their outer zones than in the core and may have profiles at the surface and/or at the edges or have a foam skin. Tubes may be slit.

Dependent upon the production process, composition, facing and thickness of the insulation material, the building material classes B1 (low ignitability) or B2 (normal ignitability) according to DIN 4102-1 may apply.

Form pieces made of PE foam are fastened with the means according to Table 2.

The flexibility of foam materials of PE is maintained down to –70 ℃; below that temperature, embrittlement occurs.

The water vapour diffusion resistance coefficient μ normally lies between 1 000 and 7 000, dependent upon the composition and the production process of the closed cellular PE foam materials.

Form pieces shall be fastened according to Table 2. Joints shall be glued full-surface.

B.1.14 Insulation with phenolic foam (PF)

Phenolic foam is a rigid foam with a predominantly closed cellular structure which is made of phenolic resin, a blowing agent (most frequently pentane) and an acid hardener.

Foam blocks of phenolic resin are processed to boards, sections, segments and other form pieces.

The individual insulation elements are butted or executed with a staggered edge. Butted joints may be glued.

PF foam materials have building material class A2 (non-combustible) or building material class B1 (low ignitability) or B2 (normal ignitability) according to DIN 4102-1.

Form pieces are predominantly fastened with self-adhesive glass-fibre-reinforced straps. Other fastening means see Table 2.

B.1.15 Insulation with melamine resin foam

Melamine resin foam materials are flexible, open cellular insulants. They are predominantly used in the building equipment in the form of boards, pipe sections or other form pieces.

Melamine resin foam possesses the building material class B1 (low ignitability) according to DIN 4102-1.

In addition to its thermal insulation properties, this insulant also possesses a high sound absorption potential.

B.1.16 Insulation with expanded perlite (EP)

Insulants of expanded perlite are mineral products in the form of dispensable granules. They are dimensionally stable even under the influence of water and air humidity.

Expanded perlite is applied through pouring or blowing as an insulation layer without cavities on substrates or behind partitions (claddings) or in cavities. The insulation layers adjust themselves to irregular geometric shapes.

The properties of the insulation are dependent upon the mode of application, e. g. loose fill or densification through stamping or vibro-compacting, and – where bonding additives are being used – upon their quality and the mixing ratio.

They possess the building material class A1 (non-combustible) according to DIN 4102-1.

For installations operating below ambient temperature, the possibilities for the use of loose-fill insulants of expanded perlite are very limited because of the danger of moistening. Employment options practically only exist when using a double-skin covering. Perlite is used for the isolation of storage tanks in the low-temperature area (e. g. double-wall liquid gas storage tanks).

Conventional pouring densities for the cold application lie between 45 kg

## B.2 Selection of vapour barriers

### B.2.1 General

The purpose of the vapour barrier is to reduce, and if possible to prevent, the ingress of water vapour into the insulating material. So the barrier should always be applied to the warmer surface of the insulating material. It can take the form of a coating or sheet material resistant to the passage of water vapour, i.e. of low permeability, and the sealing of joints and overlaps should be effective.

Where the outer surface temperature of insulation is higher than the plant on which it is used, and some part of the insulation is at a temperature below the dew-point of the ambient air, there is a vapour pressure differential across the insulation. This differential will tend to force the vapour towards the cold surface of the plant where it will condense. If the plant temperature is below freezing point, the condensed water will turn into ice.

As a rough guide, the thermal conductivity of water is about 20 times that of a typical good quality dry insulating material, and that of wet ice can be up to 3.5 times that of water. This means that internal condensation and ice formation will appreciably reduce the effectiveness of the thermal insulating material. Additionally, the increase in volume of the moisture on freezing can disrupt the physical structure of the thermal insulating material.

Insulating materials that consist of substantially closed cells possess an inherent resistance to the passage of water vapour, but open-cell insulants and loosefill porous materials are readily permeable to water vapour. Even with materials that have good resistance to the transmission of water vapour, differential movement of plant and insulation can cause joints in the insulation system to open, thus allowing moisture to penetrate towards the underlying surface. Joint sealing compounds can also fail to exclude water vapour completely, in which case the contained water or ice can form strongly conducting paths from the surface of the plant to the ambient air.

As a general rule, all insulation on plant working any time at sub-ambient temperatures should have a ‘vapour barrier’ layer over the outer (warm face) surface unless the insulation has sufficient integral vapour resistance and the joints are adequately vapour sealed. This barrier should be resistant to the passage of water vapour and it should be applied to the dry insulation immediately it has been fitted. The properties of the vapour barrier should have attained their optimum values before the plant is operated.

B.2.2 Mechanical Protection

For below ambient operation, it is preferable that the vapour barrier layer should not be exposed to mechanical damage if it is susceptible to easy perforation. Frequently it is possible to use a tough outer finish, e.g. sheet metal, GRP sheeting or vinyl-acrylic copolymer, as a protective layer over the more vulnerable vapour barrier material.

The compatibility of the vapour barrier material with the chosen insulation should be established, for example, solvent based materials should not be used over polystyrene.

B.2 3 Selecting materials for use as vapour barriers

When selecting materials for use as vapour barriers, consideration should given to the type of equipment being insulated, the design conditions, the type of insulant being used, and the environmental conditions during application and service.

Materials suitable for use as vapour barriers are as below.

B.2.3.1
Wet applied vapour barriers comprising cut-back bitumens, bitumen emulsions with or without elastomer latex, vinyl emulsions, and solvent based polymers. Frequently these are reinforced by means of cotton scrim cloth or open-mesh glass fabric.

B.2.3.2
Elastomeric sheets provide for contraction and other movements whilst maintaining good resistance to the transmission of water vapour. Joints should be sealed with adhesive and/or adhesive foil tape and the overlaps should be 40mm minimum.

B.2.3.3
Polyvinyl chloride, polyethylene, polyisobutylene, or other plastic tapes or sheets are of special value for wrapping bends on insulated pipes, or where a coloured decorative finish is required.

B.2.3.4
Epoxy and polyester resins give good resistance against mechanical damage, together with protection against the weather and against chemical spillage.

B.2.3.5
Metal foils, if used alone, should be sufficiently thick to exclude penetrations by ‘pin holes’, or they should be laminated to plastics film. The joints should have an overlap of 40 mm minimum and they should be sealed by a waterproof adhesive or mastic.

B.2.3.6
Sheet metal can give good protection, provided that the joints are overlapped and sealed with additional securing devices to maintain the system in vapour tight condition.

B.2.3.7

Glass fabric or tape, impregnated with lanolin or petroleum jelly, can be used, especially where removable insulation and finish is required.

B.2.4 Pipe supports
Where possible, supports for pipes and vessels should be external to the insulation and the vapour barrier.

## B.3 Selection of securing and support materials

### B.3.1 General
Support constructions keep the cladding in the given distance from the object where the insulation material cannot do this. In insulation systems with air gap, this is always the case.

They can only transfer forces vertically to the surfaces of object, respectively insulation layer. They constitute thermal bridges in so far as they cannot be made out of insulation materials of equal thermal resistance or are not supported by the insulant.

Support constructions are required for insulation materials of low compression strength, e.g. mineral wool mats. They are also required for mineral wool sections and boards of apparent densities below 75 kg/m$^3$, when the operating temperatures of the installation are above 200℃.

There are two sort of support constructions:
-Spacer-ring construction, they keep the cladding at the insulation thickness distance from the object and can only transfer forces vertically to the surface of object.
-Supporting structure, they transfers the loads from the insulation and of the forces effective on the insulation directly or via fixing onto the object.

Special operating conditions prevailing, e.g. vibrations, support constructions may even be required with higher apparent densities. Support constructions are dispensed with at pipes with declared diameter ≤ DN 100 and insulation layer thickness ≤ DN 50 mm. For larger diameters, compression-resistant lamella mats are available.

Where support constructions shall be dispended with at larger dimensions, a special proof is required.

### B.3.2 Dimensioning
Support constructions consist of rings or rails, e.g. of metal, and of spacers as distancers, e.g. of metal or ceramic. The spacers can be replaced with elastic distancers, e.g. omega stirrups.

In cases where the spacer is supported by the insulation surface, nap-pattern foils, corrugated sheet stripes or insulation material stripes may be used.

In case support constructions are required on pipes, they shall be positioned below the circumferential seams of the cladding. For elbows and fittings, support constructions are required at the beginning and the end of elbows, measured on the outside, exceeds 700 mm, additional support constructions are required. With containers or with large-surface building components and high wind loads, a static proof can be required. For the load assumption, DIN 1055-4 and DIN 1055-5 apply. For corrugated sheet metal, the acceptable support distances must be found in manufacturer tables.

### B.3.3 Support constructions for hot insulations

The rings consist of band steel of minimum dimensions 300 mm x 2 mm for installation components up to 1000 mm circumference. For circumferences above 1000 mm, they consist of band steel of minimum 30 mm x 3 mm. Spacers may consist of band steel of the same thickness, of metal profiles f sufficient stiffness or of ceramic cylinders of 16 mm diameter. Rings are closed with flat-head screws or countersunk head screws, minimum diameter 6 mm or with lug-locks.
The construction shall be designed aiming at minimising the heat flow from the object to the cladding. Insulating intermediate layers in the spacer are not required for thermal protection since their effect is small. However, in case different metals are being combined, an intermediate layer may be required here to prevent contact corrosion. Intermediate layers between ring and spacer contribute to the lowering of temperature peaks on the cladding.

For spacers made of steel, at least 3 spacers per ring are required. The maximum distance at the outer ring is 400 mm. When ceramic spacers are used, at least 4 per ring are required; the acceptable maximum distance at the outer ring is 250 mm.

In case these distances are intended to be exceeded, a special proof is required.

Support constructions made of insulation materials are fixed through gluing, blinding, plugging, screwing or tailing.

B.3.4 Support constructions for cold insulations
In cold insulations, predominantly sections, segments or other form pieces made of materials according to table 3 are being used as support constructions. The spacers must consist of wood, plastic or insulation material and all metallic parts shall either be corrosion-resistant or corrosion-protected.

**Table 3** – Materials for support constructions and supports in cold insulation systems (reference values)[a]

| Line | Materials [b] | Minimum Apparent density Kg/m³ | Thermal conductivity at $0_m$ = 10℃ W/ (m.K) | Acceptable compression Stress at static applied Permanent load[c] N / mm² |
|---|---|---|---|---|
| 1 | Expanded polystyrene foam (EPS) | 20 | 0.040 | 0.020 up to 0.025 |
| 2 | Expanded polystyrene foam (EPS) | 30 | 0.040 | 0.035 up to 0.045 |
| 3 | Extruded polystyrene foam (XPS) | 30 | 0.040 | 0.040 up to 0.050 |
| 4 | Extruded polystyrene foam (XPS) | 40 | 0.040 | 0.060 up to 0.075 |
| 5 | Extruded polystyrene foam (XPS) | 50 | 0.040 | 0.140 up to 0.175 |
| 6 | Polyurethane rigid foam (PUR) | 50 | 0.035 | 0.020 up to 0.030 |
| 7 | Polyurethane rigid foam (PUR) | 80 | 0.035 | 0.080 up to 0.100 |
| 8 | Polyurethane rigid foam (PUR) | 120 | 0.040 | 0.200 up to 0.300 |
| 9 | Press cork | 300 | 0.065 | 0.120 up to 0.150 |
| 10 | Press cork | 350 | 0.065 | 0.080 up to 0.100 |
| 11 | Cellular glass | 120 | 0.045 | 0.17[d] |
| 12 | Cellular glass | 125 | 0.050 | 0.27[d] |
| 13 | Cellular glass | 160 | 0.055 | 0.40[d] |
| 14 | Hard wood, quality class 1 | 650 | 0.205 | 4.00[d] |
| 15 | Hard wood, quality class 1 | 650 | 0.320 | 10.00[d] |
| 16 | Lightweight concrete, class 4 | 600 up to 700 | 0.09 up to 0.16 | 1.00[d] |
| 17 | Lightweight concrete, class 4 | 700 up to 800 | 0.18 up to 0.27 | 1.4[d] |

| | |
|---|---|
| a | Compression-resistance values in this table apply to temperatures < + 20℃ |
| b | Manufacturer information to be taken into account |
| c | The values given in lines 1 through 14 represent roughly 20% of the measured values according to DIN EN 826 |
| d | Without deformation |

## B.4 Selection of cladding – metallic and non-metallic

### B.4.1 General

The cladding is a mechanical protection and /or weather protection. Claddings are required where ambient conditions could jeopardise the properties of the insulant or the function of the vapour retarder. The material of the cladding may influence the fire behaviour of the insulation system.
Commonly used cladding sheets are given in Table 4

### B.4.2 Claddings made of plane sheets

#### B.4.2.1 Cylindrical claddings

**Table 4** - Sheet thicknesses, overlaps and bolting materials for claddings of plane sheets

<table>
<tr><th rowspan="2">Circumference Of cylindrical Cladding</th><th colspan="3">Cladding minimum Nominal thickness[a]</th><th colspan="2">Overlap</th><th colspan="2">Bolting materials Minimum dimensions[c]</th></tr>
<tr><th>Steel coated with<br>- Zinc (Zn)<br>- Aluminium (Al)<br>- Al-Zn<br>- plastic</th><th>Steel stainless Austenitic According to DIN 17441 Din 17440</th><th>Aluminium</th><th>Longitudinal seam</th><th>Circumferential seam[b]</th><th>Self-tapping Screws with Thread sizes According to DIN EN ISO 1478 and screw length</th><th>Rivets According To DIN EN ISO 14589 (DIN 7837 partially continues to apply) d1</th></tr>
<tr><td>Up to 400</td><td>0.5</td><td>0.5</td><td>0.6<br>0.8[e]</td><td>30</td><td rowspan="6">50</td><td rowspan="4">ST 4.2<br>l = 9.5</td><td rowspan="3">3.2</td></tr>
<tr><td>400 – 800</td><td>0.6</td><td>0.5</td><td>0.8</td><td>40</td></tr>
<tr><td>800 – 1200</td><td>0.7</td><td>0.6</td><td>0.8</td><td rowspan="4">50</td></tr>
<tr><td>1200 – 2000</td><td>0.8</td><td>0.8</td><td>1.2</td><td>4.0</td></tr>
<tr><td>2000 – 6000</td><td>1.0</td><td>0.8</td><td>1.2</td><td rowspan="2">ST 4.8<br>l = 9.5</td><td rowspan="2">4.8</td></tr>
<tr><td>> 6000</td><td>1.0</td><td>0.8</td><td>1.2</td></tr>
</table>

A After consultation with the client, lower thickness are possible

B For pipes, the overlap at circumferential seams are connected through interlock ball swages.

C For large-area claddings with loads, static proofs may be required. In this case, bolting materials with an official approval shall be used. For load assumptions, DIN 1055-4 applies

E Screws of stainless steel according to DIN 17440 should be used

D For polyurethane in-situ foam

#### B.4.2.2 Plane claddings

For plane claddings with cross-sections above 1500 mm x 1500 mm, the sheet thickness according to table 5 apply. Overlaps and bolting means are to be found in table 4, line > 6000.

**Table 5** - Sheet thicknesses for plane claddings with cross-sections above 1500 mm x 1500 mm and with cross sections ≤ 1500 mm x 1500 mm

| Cladding<br>Minimum nominal thickness | | | |
|---|---|---|---|
| | Coated steel | Stainless steel | Aluminium |
| Cross-sections above 1500 mm x 1500 mm | 1.0 | 1.0 | 1.2 |
| Cross-sections ≤ 1500 mm x 1500 mm | 0.8 | 0.8 | 1.0 |

B.4.3 Claddings made of shaped sheet metal

For large containers, columns, tanks, or ducts, shaped sheet metal is used because of e.g. static or esthetical reasons.

Corrugated or trapezoidal sheets are used which may consist of galvanised and / or coated steel or of stainless austenitic steel or of aluminium. The sheet thicknesses, overlaps, bolting materials and acceptable support widths are dependent upon the type of profile and the related manufacturer information.

B.4.4 Execution

B.4.4.1 Swages

Plane sheets shall be shaped; longitudinal and circumferential seams shall be swaged at sheets of thicknesses above 0.5 mm. At longitudinal seams, sheets may also be edged. Circumferential seams may be connected through an interlock ball swage where a gaping because of temperature differences is not expected. This does not apply to polyurethane in-situ foam in the open.

B.4.4.2 Bolting means

Sheet metal claddings must be connected at longitudinal seams with a minimum of six self-tapping screws or blind rivets per meter and with insulation with polyurethane in-situ foam minimum of ten screws or rivets per meter. In the open, screws with steel discs and a vulcanised sealing shall be used.

The screws or rivets should have equal distances from each other. Where two rows of screws of rivets are placed, screws or rivets shall be staggered.

Claddings of rotating installation parts and claddings exposed to shocks or vibrations shall be connected with blind rivets. For metal connections which must be opened frequently, e.g. flat-head screws with built-in or façade screws may be used.

B.4.4.3 Ends

Ends are constructed as extremities or as end caps. For oblique or vertical pipes in the open, the upper ends shall be connected funnel-shaped and liquid-averting.

To avoid thermal bridges, extremities and end caps shall not be in contact with the object where high temperatures prevail. Where objects are corrosion-protected, extremities must not come into contact with the object to avoid damage of the corrosion–protective layer.

For insulation systems with electrical tracer heating, the extremity may be dispensed with to avoid damage of the electrical tracer heating.

B.4.4.4 Rain, respectively spray-water-tight execution

Claddings in the open and in buildings with moisture exposure shall be executed rain and spray-water-tight.

The individual metal sheets shall overlap in the way of roof-tile overlapping. For installations in the open, all overlaps shall be in lee of the weather side; longitudinal seams at horizontal pipes shall be positioned roughly 45° below a horiz ontal plane through the pipe axis, measured radially from the pipe centre, however, staggered against each other. Elbows are excepted.

Claddings shall be connected rain-water-tight to exiting uninsulated pipes or to e.g. supporting profiles for galleries.

Cut-outs for penetrations of the cladding, e.g. at pipes hangers, manholes, measuring taps, must be made exactly to measure and in the open constructed rain-water-tight. They shall be equipped where required with blanks and be sealed with permanently elastic compounds. Flashing may be additionally required.

Roof-edge ring at tanks allow for a satisfactory constructive solution of the connection of the roof sheet to the vertical cladding sheets.

The roof sheets of tanks, ducts or containers shall be reinforced through reinforcing edging or through standing seams with caps.

All roof surfaces in the open shall have a minimum slope of 3 %

B.5.4.5 Air gap between cladding and insulation material
Between insulation material and cladding at installations in the open, an air gap shall always be provided for where the installation is not permanently operated at a minimum of 120 ℃. This also applies to intermittent service.

In cold insulation systems, an air gap must be provided for where screws or rivets might damage the vapour retarder.

The air gap must be sufficient in size to preclude damage, at least however 15 mm. At the bottom side, three drainage holes per metre, shall be drilled with a minimum diameter of 10 mm.

An air gap may also be required because of acoustical reasons or where the danger exists that the vapour retarder may be damaged through thermal expansion of the object – and thereby also the insulation material.

B.4.5 Cladding sheets
Galvanised, aluminised, Aluminium, Aluminium-zinc-coated, Plastic coated and stainless austenitic sheets metal can be used.

Sheets thicknesses and bolting means are to be found in table 4.

Screws and rivets must be made in a metal in accordance with the sheet metal selected.

B.4.6 Mastic
Mastic is a general term for organic coating compounds which are sprayed or trowelled. Dependent upon their properties, these compounds may also serve in the function of a vapour retarder. For selection and processing, the manufacturer information must be observed. Through reinforcement with tissue materials, a higher strength can be obtained.

B.4.7 Claddings on the basis of bitumen

B.4.7.1 Bitumen emulsions

Onto a coating of bitumen emulsion, a bandage of metal, glass tissue or gunny must be applied with a minimum overlap of 20 mm. Subsequently, another layer of bitumen emulsion is trowelled. Manufacturer information should be heeded.

B.4.7.2 Bitumen webs
Bitumen webs must overlap at least 50 mm and be fastened with corrosion-protected steel band or plastic band of a minimum width of 15 mm in distances not exceeding 250 mm.

For elbows and shaped piece, bitumen crêpe or plastic bandages are used instead of bitumen webs.

B.4.8 Claddings or rigid plastic foils
Rigid plastic foils receive during production a permanent rounding through a special shaping (roll inclination) to prevent longitudinal seams from gaping. The minimum thickness should be 0.35 mm. For elbows, branches and appliances, fitting form pieces in one or two parts of identical material as for the straight pipe shall be used. The overlaps in the cladding shall be those given in table 4.

Rigid plastic foils and the form pieces made of them, prefabricated deep-forged or as lobster-back constructions, are connected at their longitudinal overlaps through:

- Plug rivets
- Welding
- Screws

Only bolting means made of plastic or corrosion-protected metals may be used. When using plug rivets or screws, the minimum is eight pieces per meter. Several others cladding exist for specific applications which are not detailed in this document.
Claddings with cold insulation systems must not damage the vapour retarder. In case of screwed or riveted sheets, therefore, the cladding must be kept in a sufficient distance from the vapour retarder.

In cold insulations, this positioning may lead to the dew point moving into the air gap and thereby to the formation of dew between vapour retarder and cladding. Therefore, drainage, respectively aeration holes must be planned.

## C. Further information

More detailed information or advice can be obtained from the insulation contracting industry association in your country via the FESI website www.fesi.eu .