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

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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.

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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.

The following measurements constitute an effective protection against thermal transfer through convection:

- application of the insulant without gap immediately on the object wall
- air-tight foils on the cold face of the insulant
- use of insulation materials with a longitudinal air flow resistance > $50\ \mathrm{kPa \cdot s / m^2}$.

Horizontal bulkheads between object wall and cladding interrupt convection and create several smaller convection sections dependent upon the number of bulkheads instead of a long convection circuit covering the entire height of the object wall. However they do not reduce the total heat flow rate but reduce the temperature differences between the lower and the upper parts of the insulation surface and reduce peak temperatures. They should be considered particularly for:

- penetrating bulkheads which reduce the convection both inside the insulation layer and between insulation layer and cladding, and
- bulkheads which reduce the convection between object wall and insulation layer, where the insulant due to the given contour of the object wall, e.g. through reinforcing profiles or integral-fin tubes, cannot be applied directly to the object wall.

4.1.3 Protection against the ingress of water

Moisture in the insulation material has the following undesired consequences:

- increased risk of corrosion

  The ingress of moisture into the insulation system enhances corrosion. The penetrating moisture can also lead to the accumulation of corrosion-enhancing materials in the insulation system, e. g. chloride ions, which may cause stress-corrosion cracking in stainless austenitic steels.

- increase of thermal conductivity

  Tests have proven that a moisture intake of 5 Vol.-% may lead to an increase of thermal conductivity of up to 50%.

Material changes in the insulant

  With some insulants, moisture can lead to irrevocable damage or total destruction, e. g. with microporous insulants, calcium silicate or calcium-magnesium-silicate.

The ingress of surface water into the insulation and the wetting of the insulation material can be prevented by carrying out the following constructive preconditions:

- by effecting a surface-water-tight connection of the cladding at exiting, non-insulated pipes or at pipe supports for galleries
- use of roof-edge rings to effect a constructively impeccable transition from the roof sheets to the vertical cladding sheets
- external holding fixtures for insulated pipes.

When fitting the cladding, the following application advice shall be heeded:

- the sheets shall be overlapped in weatherwise fashion

- the overlap shall be sealed additionally with a sealing strip to prevent water penetration due to wind-driven water in the open

- roof sheets at tanks, ducts and vessels shall be reinforced through downturn folds or through a standing seam with cap

- in the open, flashings shall be applied above penetrations in the cladding

- at horizontal surfaces and installation components, the cladding shall have a minimum slope of 3%.

4.1.4 Removal of condensation from the claddings of hot objects

At service temperatures below 120 ℃, the risk of w ater concentration in the insulants of thermal insulation systems with air-permeable insulation materials at objects in the open is very high. The reason is moisture condensing at the inner surface of the cladding when the cladding adopts temperatures below the temperature of the trapped air through thermal radiation to the universe in clear nights.

The cladding, therefore, should not be in contact with the insulant, but kept in a distance using spacers or nap-pattern foils. The air gap should at least be 15 mm wide. A facing on the insulation material is recommended to prevent condensation water occurring on the cladding dropping into the insulation material. This is, however, very complicated to perform. To drain the water from pipes and horizontal vessels, three holes per meter of a minimum diameter of 10 mm should be drilled at the lowest point.

A similar procedure should be applied for vertical vessels.

4.1.5 Special considerations for the operation with changing temperatures

Insulation systems for installations operated with changing temperatures, e. g. air-conditioning systems, must principally be designed as cold insulations to prevent moisture penetrating into the insulant in the operation phases below ambient temperature.

4.1.6 Thermal stress in reinforcing profiles

At reinforcing profiles directly situated on the object wall and exposed to temperatures above 350 ℃, the maximum admissible temperature stress i n the profiles must be taken into consideration when designing convection-retarding measurements and the positioning of the insulation material. The maximum acceptable temperature stress is principally dependent upon the heating / cooling periods of the object and the size of the profiles.

In case the reasons mentioned above lead to other than a contour-following insulation and the reinforcing profiles are covered with sheet metal, the sheets must withstand the temperature strain and should have a minimum thickness of 1 mm.

4.1.7 Attention to longitudinal thermal expansion

Attention to longitudinal thermal expansion of the different components of an insulation system is of special importance because:

- the materials used for the insulated object and the insulation system possess very different thermal expansion coefficients and

- great temperature differences occur between the object and the external parts of the insulation system (cladding).

Because of the resulting very different thermal changes in length of the different components of the installation, forces (pressure) occur in the insulation systems which must be taken into account in the construction where the elasticity and the acceptable material tensions of the components used are exceeded.

For every insulation system, therefore, the temperatures occurring at the different components must be established and the thermal expansion coefficient of the materials employed must be put into relation to each other to determine their respective movements. In case the relative movements exceed the acceptable material tensile capacity of the components employed, appropriate non-locating bearings, expansion seams, sacrificial layers must be planned which are compatible with the locating bearings of the installation and its compensation fixtures.

The calculation of the load-bearing capacity of the insulation system under defined thermal stress may be part of a static proof.

4.1.8 Inclusion of meteorological, dead and dynamic loads

Insulation systems must be designed to take account of the meteorological and traffic loads to be expected.

Wind and snow loads affect the insulation construction where the installation is in the open. The size of these loads and their effect on the insulation system is dependent upon its direction, its position and the geometry of the installation component. Traffic loads to be expected must already be taken into consideration in the planning phase, e. g. the question must be answered whether the insulation must withstand foot traffic.

4.1.9 Contact prevention

In areas accessible by personnel, the surface of the insulation must not lead to burns. Various European standards call for maximum surface temperatures between 50 ℃ and 60 ℃.

Additionally, the surface temperature is dependent upon many other influences – convection, solar radiation or radiation from other surfaces, age-dependent emissivity of metallic surfaces – which are not known with sufficient certainty when designing the insulation system.

For these reasons it may not be possible to maintain the surface temperature in a range precluding contact injuries through insulation technology means. In these circumstances precautions against unintentional contact must be taken such as perforated plates mounted as contact guards.

Attention must be paid to the fact that the danger of injury does not occur through the "average" surface temperature, but especially through the peak values occurring at thermal bridges which are part of the insulation system or of the installation itself.

4.1.10 Protection against corrosion

Under cold insulation systems, the object must be corrosion-protected where it is made of unalloyed or low-alloy steel.

For objects made of e. g. stainless austenitic steel or copper, the designer must check in each case whether or not corrosion protection can be dispensed with.

Objects made of stainless austenitic steel do not need corrosion protection when a temperature of 50 °C is never – not even for short periods – exceeded.

Corrosion protection can be dispensed with at

- continuously operating cryogenic installations (below –50 °C) such as storage tanks

- insulated surfaces of power plant components, e. g. boiler-pressure parts, flue-gas or hot-air ducts, steam pipes with operating temperatures permanently above 120 °C.

Corrosion protection, adhesives and insulation materials must be compatible with each other.

Where metals with different electro-chemical potential are in contact, the danger of contact corrosion arises. An isolating intermediate layer, e. g. a plastic band, shall be employed where appropriate. Contact corrosion is enhanced through the presence of moisture.

The overview given in Table 1 shows the compatibility of individual metals with each other and serves a first orientation regarding the danger of contact corrosion with metals in contact. Table 1 disregards other forms of corrosion, with other causes, e. g. stress-corrosion cracking.

Table 1 – Contact corrosion with metal combinations

Material considered		Combined with					
Metal	Surface ratio in relation to the material combined with	Zinc	Aluminium	Steel ferritic	Lead	Steel austenitic	Copper
Zinc	Small	-	M	M	S	S	S
	Large	-	G	G	G	G	G
Aluminium	Small	G	-	G	S	S	S
	Large	G	-	G	M	G	S
Steel ferritic	Small	G	G	-	S	S	S
	Large	G	G	-	G	G	S
Lead	Small	G	G	G	-	S	S
	Large	G	G	G	-	M	M
Steel austenitic	Small	G	G	G	G	-	M
	Large	G	G	G	G	-	G
Copper	Small	G	G	S	G	G	-
	Large	G	G	S	G	G	-
G Minimum or no corrosion in the material considered M Average corrosion in the material considered, e. g. in very wet atmosphere S Severe contact corrosion on the material considered							

NOTE Table 1 indicates the corrosion of the "material considered", not the corrosion of the "combined with" material. "Small" means: "small in relation to the material with which it is combined"; "large" means: "large in relation to the material with which it is combined".

EXAMPLE 1 Material considered galvanised screw combined with cladding made of austenitic steel: line "zinc small": column "steel austenitic": "S" – severe corrosion of the screw.

EXAMPLE 2 Material considered cladding made of austenitic steel, fastened (combined) with galvanised screws: line "steel austenitic large": column "zinc": "G" – the corrosive damage of the austenitic steel is negligible.

4.2 Insulation systems with additional fire protection requirements

For fire protection requirements the appropriate European standard should be referred to.

4.3 Insulation systems with additional acoustic requirements

All thermal insulation influences the expansion of air- and structure-borne noise. The acoustical properties of an insulation system may be influenced through the following constructive measures:

change of the distance between object and cladding;

change of the insulation layer thickness and/or the apparent density of the insulant;

acoustical de-coupling of the cladding from the object with elastic elements in the load bearing and spacer construction (e. g. omega stirrups, rubber elements, steel wool cushions)

increase of area weight of cladding through choice of the material or multi application

internal cover of the cladding with structure-borne noise-absorbing materials such as self adhesive bitumen, cardboard or spray-applied compounds

multi-shell insulation system with a minimum of two separate insulation layers and claddings.

These measures can be employed individually or in combination.

The effect of individual design measures or their combination for the sound attenuation index achieved is strongly dependent upon the frequency of the sound power occurring. General statements regarding the sound-protective effectiveness are therefore not possible.

Sound-protecting and heat-retention measurements may influence each other. This must be taken into account in the design.

5. Recommendations for maintaining completed insulation systems

5.1 General

Prior to completion, the contractor should discuss with the purchaser the procedures to be adopted for periodic inspection and maintenance of the insulation to ensure that the initial performance of the material will be maintained and where applicable, the methods of repair and replacement to be adopted should damage occur during service or overhaul.

5.2 Corrosion under insulation (CUI) prevention

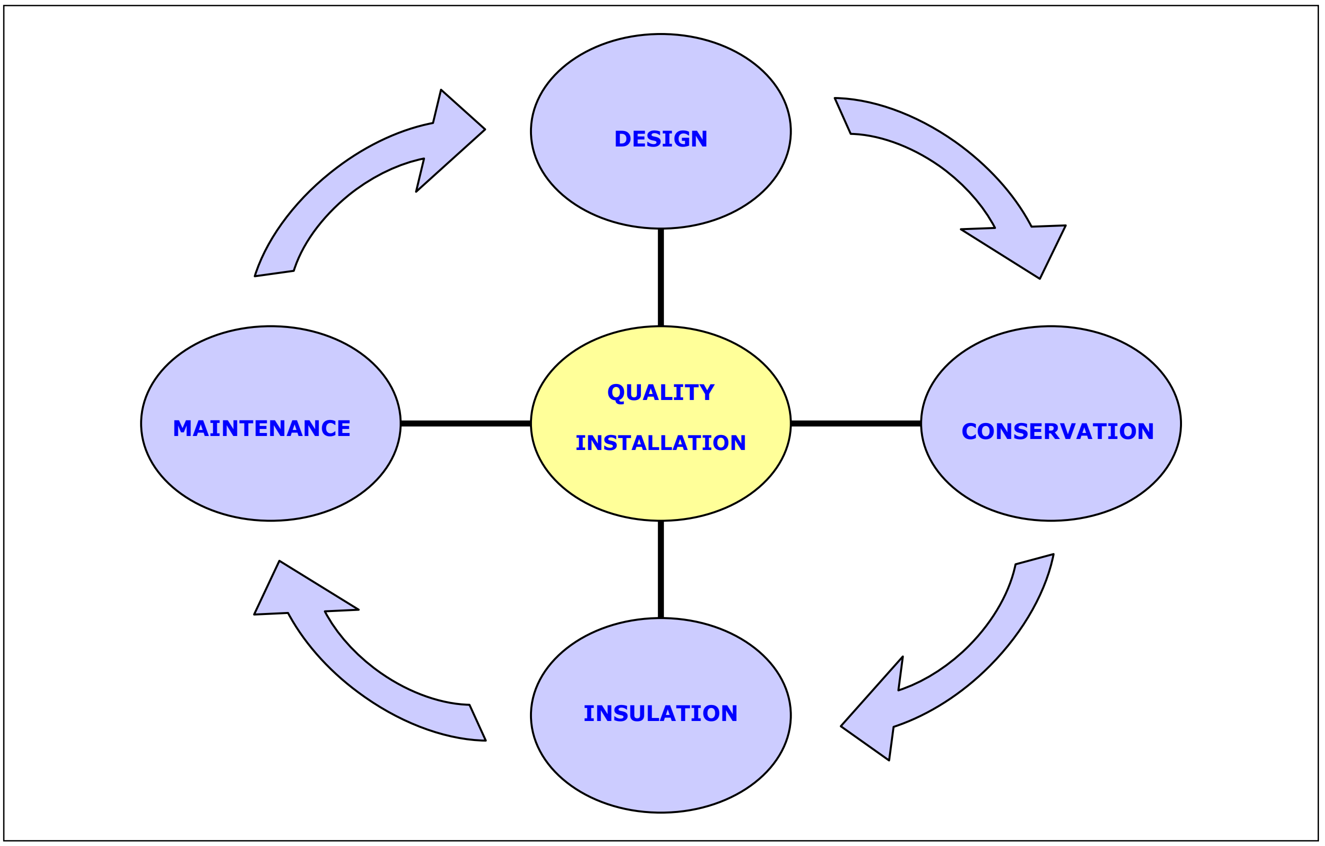


Figure 1 - Life cycle quality chain for technical insulation

5.2.1 General

Frequently, insulation is wrongly regarded as a substitute for corrosion protection. When considering the corrosion danger at the outer surfaces of cladding materials, the general principles and protection rules of corrosion protection apply, corrosion protection under insulation constitutes a special issue. On insulated installations, the start of under insulation corrosion will not be obvious, purely from a visual inspection.

Prevention or mitigation of corrosion under insulation (CUI) is only possible with a system-approach. In all phases attention needs to be paid to CUI prevention: design, paint- and coating work, the insulation system and inspection and maintenance.

5.2.2 Conservation

Paint systems, organic and in-organic, are used as ‘a last line of defence’ to prevent CUI. The failure probability of a coating system increases with the age and depends also of the operating conditions. With insulated objects, EN ISO 12944 "Corrosion protection of steel constructions by protective paint systems" envisages three coats as standard. It is recommended that at least the priming coating should be applied prior to the assembly of the object. Most painting systems fail after 10 years, after which the bare steel can be attacked by CUI. This happens first with relatively thin walled, small diameter nozzles. Field welds, often without the proper surface preparation or complete coating system, often show severe corrosion or even leaks within 5 years. Detailed description of coating and painting systems falls beyond the scope of this recommended practice but it should be clearly noticed that the utmost attention shall be made to this subject. For further reference on insulation prestart requirements: see section 3.

5.3 Inspection and maintenance

5.3.1 General

Insulation systems, no matter how well designed and originally installed, eventually lose the ability to shed water. This deterioration occurs for many reasons, including the mechanical damage in the operational phase and can be caused by the inevitable maintenance of an operating plant.

The sole criterion for corrosion damage is the impairment of the function, which must be seen in connection to the requirements demanded. Routine maintenance on insulation is usually a low priority task since many operating departments cannot easily detect the immediate effect of insulation damage. Maintenance is focussed on equipment that has a direct and easily perceived impact on operating reliability: this in spite of experience showing that CUI has a major impact on maintenance budgets.

That is why it is recommended that the purchaser should arrange for the inspection of all materials and specific application procedures before, during and after progress of the insulation work. The purchaser, or purchaser's nominated inspection authority, should have free access, at all reasonable times, to those parts of the sites carrying out the work for the specific contract.

5.3.2 Inspection

Inspection of the external surface should cover for signs of cracking, distortion, damage, corrosion, evidence of hot spots on high-temperature plants or condensation or ice build-up on low-temperature plants. Where necessary, external finish should be removed to enable an inspection of the insulation and/or fixing attachments and reinforcement. Remedial treatment should be carried out to avoid further deterioration of the insulation system. To assist routine inspection of insulation in service, non destructive testing (NDT) methods, such as thermography, pulsed eddy current (PEC), conventional gamma radiography, flash radiography (X-ray), real time radiography and neutron backscatter, can be used. The purchaser should ensure that fully qualified personnel is employed for the dismantling of existing insulation and also for the re-insulating process when repairs or modifications are to be carried out to the plant.

To determine whether CUI is under control, a proper inspection program should be set up. A scheduled method of insulation inspection should be developed.

An inspection checklist should include the following items:

- identification of those areas and/or processes on the site that have insulated pipes and equipment
- a checklist of the environment of the area where the insulated pipes and equipment are located. A field check is usually necessary. Rate the geographic areas by category (1 to 4)
- the most critical conditions, where moisture is constantly present, and contaminants, such as acids, caustics and chlorides.
- represents an area that is only exposed to weather. (If the site is in a heavy industrial area and/or near the coast [salt water], it may be a cat.1
- an area that is sheltered from the weather but may occasionally be hosed down
- indoors, in a dry area where only process or utility leaks are a consideration.
- rate the age of the insulation by category (A to C) and suffix this to the environmental categories.
- an insulation system 15 years old or greater (the lifetime of an insulation system)
- an insulation system 7 to 15 years old (system can fail in this age span if not maintained
- an insulation system less than 7 years old (shouldn't fail if installed correctly)

- identification of insulation materials
- determination of operating temperatures. First consideration should be given where the process temperatures cycle or process is shut down for several months or more. The second area of concern should be given to operating systems in the range of -5℃ to +175℃.
- setting up of areas, conditions and locations by priority
- assessment of the condition of the insulation system (material, cladding, fixation)

The inspection findings should be incorporated in a maintenance action plan upon priority. For companies that apply risk based inspection (RBI) work processes to determine the priority and inspection scope by risk ranking, the coating and insulation systems shall be an integral part.

For both coating and insulation system, it is recommended to perform a yearly visual inspection to obtain a first impression. If defects are detected, more detailed inspections and maintenance shall be executed (upon priority). For cold insulation systems a regular inspection for damage of the vapour barrier is necessary to prevent progression of the damage.

5.3.3 Maintenance

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

The recommendations for preventive maintenance refer to situations or structures that need to be modified to prevent future or repeated damage to insulation or the underlying surfaces. Damages caused by personnel or equipment can be prevented by:

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

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

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

In order to systematically control the upgrading of existing insulation in a plant, the various units should be divided into manageable areas indicated on a plot plan, and the work carried out area by area (as for inspection, see above). Simultaneously, maintenance painting in the same area should be scheduled.

When executing maintenance work care should be taken in removing existing insulation materials in order to allow their re-use.

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

After repair of damaged hot insulation the jacketing of the replaced area and its direct vicinity shall be checked to establish proper repair of the weather protection of the complete system.

For cold insulation the vapour barrier of the replaced area shall be applied with sufficient overlap on the existing undamaged vapour barrier.

The correct application of coatings along with the proper specification, installation, and most importantly, a solid maintenance and inspection program, will allow for better control of CUI and extend the life of process equipment.

6. Guarantees

Invitations to tender usually include a clause that requires the contractor to guarantee materials and workmanship and where required by the purchaser, to guarantee performance for a given period. Any defects arising from faulty materials or workmanship during this period should be rectified by the contractor, free of charge to the purchaser.

7 Health and safety

7.1 General

The contractor should take all necessary precautions for the materials in use and should advise the main contractor or purchaser when any health hazard exists.

In addition, allowance should be made for the variation in ambient environmental conditions.

Reference should be made at all times to the current requirements of health and safety legislation, and to codes of practice and guidance, and to instructions from manufacturers.

Before a material is specified and/or applied, the principal and the applicant shall take cognizance of the contents of the product information sheet and the safety information sheet (MSDS, material safety data sheet)

WARNING NOTE: chemical fumes arising from the in situ foaming or spraying of organic insulation materials, e.g. phenol-formaldehyde resins, isocyanurates and polyurethanes, can be toxic or cause bronchial irritation, sometimes with persistent sensitization effects. When materials of these types are sprayed, new hazards can arise because non volatile components are formed into respirable aerosols.

Respiratory protective equipment should be provided and, particularly in confined spaces, air-fed hoods or respirators should be used for many materials, especially isocyanurates and epoxy-resin compounds.

With certain resinous coatings, adhesives and epoxy-resin components can cause dermatitis and other skin complaints, which can occur after brief contact, long exposure leading to allergy. Associated solvents can cause damage to the eyes and skin irritation, therefore goggles and gloves should be used when necessary.

Barrier cream and adequate washing facilities should be provided. Protection should be provided against respiratory hazards when these materials are sprayed.

Precautions should be taken when using fibrous insolence that cause skin irritation.

When insulation materials are handled or mixed, precautions should be taken to minimize the risk of respirable dust particles entering the bronchial passages.

In areas accessible by personnel, the surface of the insulation must not lead to burns. Surfaces at temperatures above 70℃ and accessible from normal working areas and access ways shall be provided with personnel protection

Where personnel protection is specified for non-insulated process piping and equipment having incidental operating temperatures of minus 10℃ and below and whose location presents a personnel hazard at suddenly freezing, the surfaces shall be provided with a suitable protection to an extent to be determined at the construction stage.

Appendices

A. Definitions – terminology

A.1 Ambient conditions
ambient conditions are the atmospheric, meteorological or other conditions under which a technical installation is operated

A.2 Austenitic steel (AS) quality
AS quality is a designation for mineral wool insulants with a low chloride-ion content, not exceeding 10 ppm.

A.3 Box
Boxes are parts of the casing, e. g. at fittings, flanges, blind flanges, manholes; they are screwed onto the cladding

A.4 Cladding
Claddings protect insulation materials and vapour retarders from mechanical damage and from the weather. With polyurethane in-situ foam, the metal sheet cladding can act in the function of a vapour retarder

A.5 Cold insulation
Cold insulations are insulation systems for media which are stored below ambient temperature and for processes which are operated below ambient temperature. They preclude a heat flow towards the insulated object in excess of what storage or process operation could suffer.

They consist generally of the insulation material, load-bearing and spacer-ring constructions, vapour retarder and cladding

A.6 Cold zone
Cold zones are areas in industrial installations where heat is drawn from the medium through cooling installations at the outer wall of the object

A.7 Composite insulation
A composite insulation is an insulation system of several layers of different insulation materials

A.8 Composite sheet
Composite sheets are two metal sheets with a full surface plastic connection. They reduce noise through vibration damping

A.9 Composite system at pipes (shell-pipe system; bonded pipe system)
A composite system at pipes is an insulation system where the insulant, e. g. polyurethane rigid foam, firmly connects (bonds) object and casing through its adhesive strength. Composite systems at pipes are normally factory-made.

A.10 Convection
Convection is that form of heat transfer which occurs through the transport of heated or cooled fluids. With forced convection, the transport is caused through pumps, ventilators or wind, with free convection through temperature differences alone

A.11 Declared values
Declared values are material properties declared by the manufacturer of an insulant. They constitute guaranteed properties; quality control and liabilities are related to them.

The properties given in price lists, tenders, supply documents, technical data sheets and on labels are declared values

A.12 Design conditions
The design conditions of an industrial installation are part of the technical specification of the insulation system. Components of them are next to the environment condition and the service conditions assumptions regarding the extent, duration and probability of irregularities during operation. Related requirements regarding continued functionability of the insulation system must be defined by the operator of the installation and notified for the designer.

A.13 Diffusion
Diffusion is a material transport of gases and liquids caused by different concentrations. For example, water vapour migrates in direction of the lower water vapour partial pressure. See water vapour diffusion

A.14 Double-skin covering
A double-skin covering is an air- and diffusion-tight welded or soldered cladding of pipes and vessels to protect the insulation material against moisture and mechanical damage

A.15 End piece
An end piece is the termination or the interruption of an insulation, e. g. at pipe fittings. It can be executed as an extremity or as an end cap

A.16 Form piece
A form piece is a part of an insulation system with other than standard dimensions

A.17 Industrial installation
Industrial installations are production and distribution installations, e. g. vessels, appliances, columns, tanks, steam generators, pipe systems, heating, ventilation, hot water preparation, cold water and air-conditioning systems

A.18 Insulation
Insulation is the insulation material including all the other components of the insulation system, e. g. cladding, vapour retarder, load-bearing and spacer-ring (supporting) constructions

A.19 Insulation system
An insulation system is the insulation designed for a specific purpose

A.20 Lamella mat
Lamella mats are a form of supply of mineral wool insulants. The mineral wool lamellas are glued onto a supporting material and their fibres are predominantly pointing in a direction perpendicular to the mat surface.

Lamella mats with a compressive stress > 10 kPa at 10% deformation or a minimum compression strength of 10 kPa are termed compression-resistant lamella mats

A.21 Load-support structure
Load-bearing structures transfer the loads from the insulation and of the forces effective on the insulation directly or via fixings onto the object

A.22 Mean temperature
The mean temperature is the arithmetic mean of the temperatures at the inner and the outer border of the insulation layer

A.23 Microporous insulation material
Microporous insulation materials are tightly compacted powder insulants where the pores are smaller than the mean free-path length of air molecules at standard atmospheric pressure

A.24 Module
Modules are building components for the interior insulation of e. g. furnaces, which are folded or fixed out of high-temperature insulation material webs, e. g. of calcium-magnesium-silicate fibre

A.25 Mounting support
Mounting supports are components that are welded or screwed to the object. They transfer the loads from the insulation to the object

A.26 Multi-layer insulation
A multi-layer insulation is an insulation system of several layers of identical insulation material

A.27 Non-steady state
Non-steady state is a condition where the relevant operating parameters vary over time

A.28 Operating conditions
Operating conditions are the conditions for the process technology, pertinent for an industrial installation due to its mode of operation, its start and stop behaviour and the labour safety measurements required

Elements are, for example.:

- varying operating temperatures and pressures
- temperature changes over time, e. g. during heating and cooling processes
- vibrations and working behaviour of the installation in different operating modes
- noise emissions at different operating conditions
- thermal and chemical behaviour of materials composing the installation
- danger of media leaks at flanges, compensators and other access or connection points

The service conditions are decisive amongst others for the required maintenance and control measurements during operation.

A.29 Operating procedure
The operating procedure of an industrial installation describes the development over time of all important parameters, e. g. medium temperature, external temperature, mass flow. The planned operating procedures are an important criterion for the design of the insulation system. There are the following differences:

1) flexible operation is that procedure where the service temperatures are controlled in areas which are either continuously above or continuously below the ambient temperature
2) interrupted operation, also called "intermittent operation", is that procedure where the installation is switched off between periods of operation. In the switch-off phase, the installation can reach ambient temperature

3) operating procedure with changing temperatures is that procedure where the service temperatures alternate between temperatures below and above ambient temperature. Changes in the ambient temperature alone – despite constant operating temperature – may create the conditions of "operating with changing temperatures" for the insulation.

A.30 Operating temperature
The operating temperature, also called operating temperature range, denotes the temperature resistance of an insulant under service conditions. It is that temperature to which the insulant can be permanently exposed under service conditions and the static and dynamic stress associated with the operation, e. g. vibrations, without having its properties adversely affected

NOTE The service temperature is normally below the "maximum service temperature"

A.31 Overlap
The overlap is the cover of seams, e. g. with the cladding sheets

A.32 Pipe fittings
Pipe fittings are parts of an industrial installation, e. g. valves, stoppers

A.33 Removable box; removable covering; cap
Removable boxes are easily detachable parts of the cladding in the area of appliances which are fixed with lever fastenings. They consist of a minimum of two parts. Dependent upon their construction and purpose, their form can differ. One discerns e. g. fitting-, flange-, form-, suitcase-, manhole-boxes

A.34 Sealing collar/roof edge ring
A sealing collar is a profile welded e. g. at the border between the upper dome and the vertical wall of an object to prevent the ingress of liquids into the insulation from above

A.35 Sealing discs
Sealing discs are parts of the object, e. g. at supports and support lugs. They facilitate a water-tight connection between the object and the cladding.

A.36 Service temperature, maximum
The maximum service temperature is the declared value of an insulant's temperature resistance without any change of its performance properties. It serves the classification of insulants regarding their behaviour at higher temperatures. It is established in a laboratory through a test under defined conditions, which are dependent upon the form of delivery and which are laid down in standards.

A.37 Sheet metal forming
Sheet metal forming is the shaping of sheets. In the insulation technology, plane sheets are edged diagonally and corrugated sheets are bent in the direction of their profiles.

A.38 Spacer

Spacers are parts of support constructions, e. g. ribs made of metal, wood, ceramic or form pieces of insulation material. Normally, they are supported by the object; in air gap insulation systems and provided sufficient compression strength of the insulant, they can also be supported by the insulant.

A.39 Spacer-ring (support) construction
Spacer-ring constructions keep the cladding at the intended distance from the object in case the insulation material cannot do that. They are only able to transfer loads vertically to the object, respectively insulation material surface. They are thermal bridges in so far as they are not made of insulation material of roughly similar insulating effect or in so far they are not supported by the insulant

A.40 Step-on insulation
A step-on insulation must not be permanently de-formed when a 100 kg person – including tools carried – walks over it.

Other load capacities may be agreed upon.

A step-on insulation is not suited to carry additional loads, e. g. heavy appliances put down on it.

A step-on insulation is not "walkable" in the sense of labour (personnel) protection requirements.

A.41 stress-corrosion cracking
Stress-corrosion cracking is a specific form of corrosion which occurs e.g. with stainless austenitic steels through the influence of chloride ions, moisture and tensile stress at elevated temperatures

A.42 Sub-construction
Sub-construction is a general term for load-bearing and support constructions

A.43 Support
Supports are form pieces of load-bearing materials with low thermal conductivity. They transfer loads to the object supports are constructions which transfer loads from an industrial installation to the foundation, e. g. saddles, ring supports, support lugs

A.44 Vapour barrier
A vapour barrier in an insulation system is a construction which prevents the ingress of moisture into the insulant as a consequence of water vapour diffusion and air movement: e. g. double-skin covering

A.45 Vapour-barrier material
Vapour-barrier materials are air- and water-vapour-diffusion-tight materials with a water vapour diffusion equivalent air layer thickness of

$$s_d = \mu \cdot s \geq 1500 \text{ m}.$$

A.46 Vapour retarder
A vapour retarder is a layer diminishing the ingress of moisture into the insulant caused by water vapour diffusion and air movement. It is normally mounted on the warm side of the insulation material. The term vapour retarder is also used for constructions that consist of vapour-barring materials, e. g. metal or composite foils, which, however, at seams and penetrations cannot be connected absolutely air- and water-vapour diffusion-tight.

B. Materials

B.1 Material specifications and application rules for insulation materials
B.1.1 Mineral wool

B.1.1.1 General

Mineral wool is an inorganic insulant made of molten glass and/or rock, which contains organic additives as binders or lubricants. Boards (slabs), form pieces (pipe sections) mats and felts are made by mineral wool. Dependent upon the composition and/or the form of supply, the insulant possess building material classes A1 or A2 (non-combustible) according to DIN 4102-1.

Dependent upon the form of delivery, the service temperature range of mineral wool products extends to approximately +600 ℃ (+700℃) and a den sity between 15 – 300 kg/m^3.

Below ambient temperature, the employment of mineral wool is very limited because of the danger of moistening. Application possibilities do in practice only exist when using a double-skin covering.

In dry atmospheres, or where the ambient temperature is only a little below the medium temperature, or when the installation only occasionally operates in the cold mode, e. g. in the air ducts of ventilation installations, the surface of which is below room temperature only in winter, the employment of mineral wool insulants without double-skin covering may be admissible providing exact knowledge of the operation and the environment conditions and the exclusion of the danger of dew formation.

In case the employment of mineral wool is indispensable as a first insulation layer in cold installations, since the installations are occasionally flushed so hot for cleaning purposes that the temperature resistance of the cold insulants employed, e. g. polyurethane rigid foam or flexible elastomeric foam, does not suffice, then the outer insulation layer and its vapour retarder must ascertain diffusion- and air movement-tight sealing. Where this is not achieved, the installation may be moistened respectively iced.

There is the additional danger that moisture invading the fibrous insulation layer through diffusion, respectively air movement during normal operation, destroys the installation if the flushing is so hot that the boiling point of the penetrating water is exceeded.

B.1.1.2 Loose mineral wool

Loose mineral wool is stuffed behind wire mesh or metal claddings or into other cavities. The cavity shall be filled evenly and so tightly that the contracted stuffing density is reached and no settling of the insulant occurs.

B.1.1.3 Wired mats

Mats shall be so cut and applied that the demanded insulation layer thickness is reached everywhere. Normally, mats are stitched with galvanised wire onto galvanised wire mesh. Stitching wire and the wire mesh may also consist of stainless austenitic steel.

Wired mats shall be knitted together or combined with hooks or eyehooks at their longitudinal and circumferential seams. They may also be applied with binding wire or tension bands. Wire hooks, eyehooks and binding wire must be of the same or a better steel quality than the wire mesh.

Liquid zinc may lead to intercrystalline cracks in austenitic steel. Stitching wire or wire mesh, which come into contact with objects of stainless austenitic steel, must therefore be made of stainless austenitic steel if the object temperature is 400 ℃ or above.
Mats not stitched to wire mesh shall be fastened with binding wire or tension bands according to Table 2.

Pipe elbows shall preferably be insulated with wired mats or form pieces. They may also be stuffed with mineral wool of equal quality.

On plane surfaces, mats are fixed with pins according to Tables 2 and 3. These are either welded to the surface according to Figures 4a and 4b (according to DIN EN ISO 13918, respectively DIN EN ISO 14555) or glued or hammered into liners or screwed into eye nuts. On the pins the mats are fixed with banking discs or clips. In case the cladding is in immediate contact with the insulation material, the pins must be 10 mm shorter than the insulation layer thickness or must be bent as is shown in Figure 3. Each layer must be secured individually with clips.

Table 2 – Standard fastenings for mats[a]

Designation	Material/minimum dimension	Employment
Tension band or strap	Galvanised or stainless austenitic steel strap, width ≥ 10 mm	Minimum 4 straps per meter
	Plastic straps, width ≥ 13 mm	
Binding wire	Annealed galvanised wire, diameter ≥ 0,65 mm	Minimum 6 loops per meter. For mats stitched to wire mesh, minimum of 3 meshes on both sides overlapping, maximum distance 150 mm
	Stainless austenitic wire, diameter ≥ 0.5 mm	
Hooks, eyehooks	Galvanised or stainless austenitic wire, diameter ≥ 1,5 mm	
Connecting tongues	-	Minimum 6 connections per meter, maximum distance 150 mm
Pins	Metal pin, diameter ≥ 3 mm[b]	Minimum 6 pins per m^2, at the under side a minimum of 9 pins per m^2
	Metal pins at ventilation pipes, diameter ≥ 2 mm	
	Plastic pin ≥ 5 mm	

a Other fastening means may be compulsory at fire protection insulations, e. g. on ventilation ducts

b For power plant components, see AGI working document Q 101

B.1.1.4Lamella mats

Lamella mats consist of mineral wool lamellas glued onto a supporting material and thereby orienting their fibres predominantly vertically to the mat surface. Compression strength, but also thermal conductivity are increased compared to mats with a fibre orientation parallel to the surface. Lamella mats shall be applied jointless and with the supporting material to the outside. In case the supporting material serves as spray protection, the seams must be closed with adhesive tape. Fastening means are given in Table 2.

Lamella mats allow for the dispensation of spacer-ring constructions in case of small diameters. For larger diameters, compression-resistant lamella mats are available.

Compression-resistant lamella mats have a compressive stress ≥ 10 kPa at 10% deformation, respectively a minimum compression strength of 10 kPa. Because of their elevated apparent densities and the related lower thermal conductivity, they allow for an economic application at higher temperatures.

B.1.1.5Mattresses

B.1.1.5.1 General

Mattresses are used for re-mountable insulations. The envelope consists most frequently of wire mesh or glass tissue. As insulation material filling, unstitched mats, webs or loose mineral wool is used. The filling must be so brought into the envelope that the demanded thickness is maintained after the application and also under service conditions. Mattresses are being delivered pre-manufactured to the building site.

B.1.1.5.2 Wired mattresses

As an envelope, a mesh of (25 x 0,6 x 1000-zn) mm according to DIN EN 10223-2 or another mesh with smaller loops according to DIN 10223-2 is used. The zinc coating must have a mass per area of at least 30 g/m^2 according to DIN EN 10244-2.

The mesh may also consist of stainless austenitic steel. In this case, the minimum diameter of the wire is 0,5 mm.

The wire mesh totally envelopes the insulation material from all sides and is closed at the seams with equal quality steel wire according to Table 2 in zigzag fashion and stitched in the surface at least every 100 mm.

Where object temperatures in excess of 400 ℃ preva il, the wire mesh and the stitching wire must be made of stainless austenitic steel.

Wire mattresses must be applied and be fixed according to Table 2.

B.1.1.5.3 Tissue mattresses

Glass fibre or ceramic tissue is used as envelope. Glass fibre tissues shall have a minimum area weight of 600 g/m^2. Tissue mattresses are to be sewn and stitched at least every 100 mm in the surface with wire or identical yarn.

Standard glass fibre tissue may be used dependent upon the material basis up to 400 ℃, with special equipment up to 500 ℃. Where standard glass fibre tissue may not be used because of the temperature and/or acid atmospheres, mattresses with temperature-resistant, respectively acid-resistant tissues must be employed. The chemical durability of glass fibre tissue may be increased through coatings, e. g. with aluminium or polytetrafluorethylene (PTFE).

Tissue mattresses shall be sewn in zigzag fashion at their longitudinal seams with galvanised or stainless austenitic steel wire according to Table 2. Hooks and/or eyehooks are to be employed in distances of 100 mm. For the closing chains, adhesive tapes or straps shall be used. Other fastening means are found in Table 2.

Tissue mattresses with standard glass fibre tissue must not be used where exposure to condensate or vapour occurs.

B.1.1.6Felts

Felts with raw densities up to 50 kg/m^3 are preferably being used in hot insulations with service temperatures up to 100 ℃. Their employment is similar to that of mats (see chapter 5.1.2.2). This material is not suitable on pipes but might be used on smaller containers.

B.1.1.7 Form pieces

Sections and segments shall be fastened according to Table 2.

Boards shall be fastened mechanically, e. g. with pins or through holding straps over folding angles. A minimum of two straps per boards shall be used. Additionally, the distance between straps must not exceed 500 mm.

B.1.2 Insulation with calcium-magnesium-silicate fibre (CMS)

Insulation materials made of calcium-magnesium-silicate fibre are heat-resistant, inorganic materials which may normally be employed up to temperatures of 850 ℃; they consist of silicon dioxide and calcium and magnesium oxides. They are predominantly supplied in the form of boards, mats, felts, loose wool, strings, vacuum form pieces. Dependent upon the form of supply they possess the building material classes A1 or A2 (non-combustible) according to DIN 4102-1.

Modules are normally manufactured on order.

Their employment is e. g. required where high temperatures must be lowered down to a value where other insulants, e. g. mineral wool, may be used. In this case, the CMS fibres constitute the hot-side layer of a composite insulation system.

Products made of CMS fibres are to be employed in similar fashions as mineral wool products. Webs, felts and boards shall be fastened exclusively with fastening means of heat-resisting steel because of their high employment temperatures. The number of pins for the application at plane surfaces must be twice the number given in Table 2.

The mats shall be applied jointless.

CMS insulation materials shrink at high temperatures both in length and width and also in thickness.

In case CMS insulation materials are employed as first layer of a composite insulation system, a multi-layer application is recommended to preclude the creation of gaps caused by the shrinkage in length and width in connection with the thermal expansion of the object, which would lead to unacceptable temperature exposure of the subsequent insulation layers.

The thickness decrease at temperatures up to 800 ℃ may, dependent upon the pressure, lie between 3% and 15%. In the face of this thickness decrease, the design must ascertain through a respective excess thickness that no cavity develops between the object and the insulation layer.

Mats and felts are susceptible to point load. The resilience is notably less than that of mineral wool. The permanent deformation is up to 20% of the original thickness.

B.1.3 Insulation with ceramic fibres

Insulation materials of ceramic wool are inorganic products. They consist of silicon and aluminium oxides and their alloys. They are available as loose wool, webs, felts, blocks and form pieces. They possess building material class A1 (non-combustible) according to DIN 4102-1.

Modules are normally manufactured on order.
Ceramic fibres are classified as carcinogenic (category 2). Before employment, therefore, a substitution check must be conducted and if appropriate a substitute must be used. Ceramic wool may only be employed where it is required to lower high temperatures down to a value where other insulation materials can be used and where no other material is available for that purpose. The ceramic wool then forms the hot-side layer of a composite insulation system.

In case, however, where alternatives are available, which are not or which are less dangerous, then the employment of ceramic fibres is prohibited.

Webs, felts, modules and form pieces shall be applied jointless and slightly compressed because of the shrinkage occurring at higher temperatures, and they shall be fastened exclusively with fastening means of heat-resistant steel because of the high service temperatures.

Ceramic fibre insulants shall be fastened according to Table 2. Since they do not have a wire mesh envelope, application-specific anchors, consoles or wiring systems of different make are available. In case of special manufacturer directives concerning the fastening of e. g. modules, these shall be heeded.

High-temperature adhesives and reinforcing compounds (water glass) may support the dimensional stability and the stability of the fastening under service conditions.

During application, the pertinent technical rules for dangerous substances (TRGS 521 and TRGS 619) shall be heeded.

B.1.4 Insulation with calcium silicate (CS)

Calcium silicates can be produced through a synthesis of the raw materials lime and sand in an autoclave. Then they are not susceptible to moisture. CS products not produced in an autoclave on the other hand are destroyed by water.

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

The material has an alkaline character and is therefore not resistant against acid condensates.

Calcium silicate insulation materials possess a high compression strength, they can therefore be used in constructions under compressive loads even in the areas of high temperatures.

Calcium silicates do not have any shrinkage up to 250 ℃; up to 500 ℃, a shrinkage of < 1% occurs. Above 250 ℃, the insulation shall be multi -layered with staggered joints.

Calcium silicate boards can be cut, milled and drilled with simple wood-treatment tools.

Calcium silicate must not be used as an insulation material for objects made of aluminium or stainless austenitic steel because of its alkaline character.

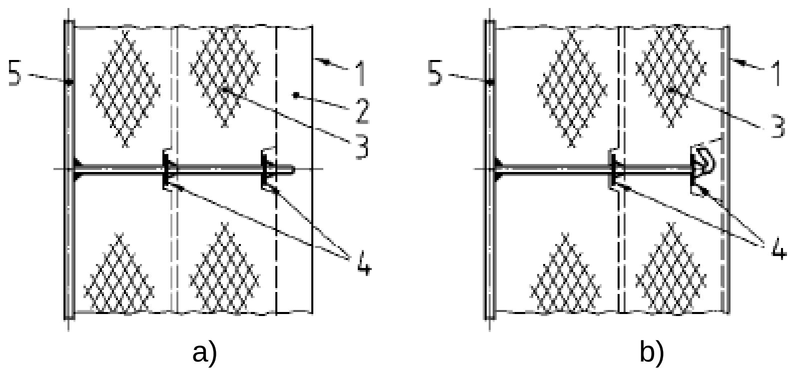
Form pieces of calcium silicate shall be fastened according to Table 2.

B.1.5 Insulation with silicate wool

Silicate wool mats are made of soluble amorphous alkaline earth silicate fibres. The chemical composition is 60% to 70% SiO_2, 25% to 40% CaO and MgO with less than 0,3% Al_2O_3.

Silicate wool possesses the building material class A1 (non-combustible) according to DIN 4102-1.
Mats are available in different thickness and in apparent densities between 64 kg/m^3 and 160 kg/m^3. Their operating temperature increases with the apparent density and lies dependent upon the apparent density between 750 ℃ and 1050 ° C.

Mats of silicate wool are to be applied in similar fashion as CMS products. They shall be fastened with fastening means according to Table 2. The number of pins for the application on plane surfaces is twice the number given in Table 2. Other fastening means are given in Table 2.



Details

1 Cladding
2 Air gap
3 Insulation material
4 Clips
5 Boiler or duct wall

Figure 3 – Fastening through pins and clips at the example of a boiler or duct wall insulation (a with and b) without air gap)

B.1.6 Insulation with microporous insulants

B.1.6.1General

Microporous insulants possess pores of dimensions smaller than the free-path length of the molecular movement of the captivated air. The microporous structure minimises the heat transfer because the thermal conductivity of the gas molecules trapped in the cavity is strongly reduced. Thermal conductivity values are obtained in this fashion which are below those of static air, since only the portion of the thermal conductivity via the solid structure remains. Also, the radiation portion contained in measured values of thermal conductivity is strongly reduced.

Microporous insulants, therefore, allow for significantly smaller insulation layer thicknesses than other insulants.

Microporous insulants consist of inorganic, non-combustible materials. They possess the building material class A1 (non-combustible) according to DIN 4102-1. They can be employed up to 1000 ℃. Because of their inner stru cture, they are unsusceptible to temperature shocks.

Since microporous insulants are susceptible to mechanical stress, they are frequently manufactured with envelopes or coatings. The most common envelopes consist of glass tissue, plastic or aluminium compound foils. When selecting the envelope, the necessity of its being adjusted to the thermal requirements must be taken into account. If need be, higher quality envelopes must be chosen or microporous insulants without any envelopes must be employed.

Microporous insulants are susceptible to shrinkage at higher temperatures. Because of this and because of the different thermal expansions of object and insulation material, specifically consequential at higher temperatures, microporous insulants shall be applied in multiple layers and with staggered joints at temperatures > 500 ℃.

Because of their mechanical susceptibility, microporous insulants shall be processed and employed without strain, if possible.

Additionally, it must be taken into account that they react sensitively to wetting media (liquids) and vapours and can be destroyed by those.

Microporous insulants shall be fastened according to Table 2.

B.1.6.2Types of material

Insulation products of microporous material come in two forms:

- solid form pieces,
- partly sintered form pieces, mechanically susceptible and therefore sewn into tissue or glued between reinforcing layers.

Manufacturer information regarding the possibilities of thermal and mechanical exposure shall be heeded.

Solid boards can be treated and fastened like soft wood (drilling, sawing, cutting, screwing, gluing, plugging and fastening with straps).

Partly sintered boards are cut with sharp knifes. When cutting boards, the cutting edges must be closed again with the envelope material (sewing, gluing). The treatment advice of manufacturers (type of envelope and adhesive) shall be heeded.

Partly sintered boards are applied through fastening with straps, through the insertion into sheet metal panels (cassettes) or through cautious pinning (pin with clips).

B.1.6.3 Form of supply

B.1.6.3.1 Slatted panels

Slatted panels consist of individual parallel board strips which are totally enveloped in a glass tissue and sewn tight at the butts. The form allows for the application on pipes.

B.1.6.3.2 Slatted boards

Slatted boards are insulants with parallel rectangular cut-outs at one surface. They can be adjusted to a curved surface.

Slatted boards are also manufactured with bevelled edges.

B.1.6.3.3 Quilted panels

Quilted panels are thin totally enveloped boards which are quilted parallel or crosswise in distances of 25 mm to 100 mm.

B.1.6.3.4 Evacuated boards

Evacuated boards are enveloped in a gas-tight foil which is evacuated to facilitate application. The employment area extends up to 1000 °C. The vacuum disappears after destruction of the foil above 150 °C.

Evacuated boards must not be confounded with vacuum panels used in building insulation. For their functioning, the continued gas tightness of the foil is required. They are employed in a temperature range of up to 90 °C.

B.1.6.3.5 Sections, segments and form pieces

Microporous insulants are manufactured in the common section and segment dimensions, but also as specially made form pieces, both out of solid and partly sintered microporous materials. They are available with and without appropriate facings. Their application is preferably with straps or adhesive tapes.

B.1.7 Insulation with polyurethane / polyisocyanurate rigid foam (PUR/PIR)

Insulants of polyurethane rigid foam are predominantly closed cellular foam materials. They are generated through chemical reaction of polyisocyanates with polyols using catalysts and blowing agents.

Their range of employment is generally between –180 °C and +130 °C. Special makes allow for an employment at higher temperatures.

The fire behaviour according to DIN 4102-1 is influenced by the composition of the product and the surface coating; the building material classes according to DIN 4102-1 are B1 (low ignitability) or B2 (normal ignitability).

For the ageing of polyurethane rigid foam not only its chemical composition is of consequence, but additionally the service conditions, e. g. temperature and external influences, UV radiation, in-diffusing air, moisture. UV radiation discolours an unprotected surface and makes it brittle.

Form pieces of polyurethane rigid foam are to be fastened according to Table 2. Joints may be glued.

For installations operating below ambient temperatures, the following additional code of practice rules shall be observed:

- 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 μ 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 °C; 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/m^3	Thermal conductivity at 0_m = 10℃ W/(m.K)	Acceptable compression Stress at static applied Permanent load[c] N / mm^2
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

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

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 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 .