



# Guide to Good Thermal Insulation Practice

FESI document 2



FEDERATION EUROPEENNE DES SYNDICATS D'ENTREPRISES D'ISOLATION  
EUROPEAN FEDERATION OF ASSOCIATIONS OF INSULATION CONTRACTORS

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# FESI DOCUMENT 2: Guide to Good Thermal Insulation Practice

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**This is what can happen if the whole life cycle of thermal insulation is not thought through, with effective controls on design, preparation, installation, operation and maintenance, and inspection and repair.**



## 1. Summary

- 1.1 Too many insulation systems fail due to poor planning, effective liaison between the parties involved, lack of attention to detail and failure to adequately maintain the system. This guide to good insulation practice sets out to highlight to the owner or client, and the contractor, what must be considered between them to ensure that an effective insulation system is installed that meets the plant requirements and functions effectively in the prevailing local conditions.
- 1.2 Detailed information on insulation systems and selection of materials can be obtained from *FESI document 3: Code of Practice for carrying out thermal insulation work at above and below ambient temperature in the temperature range -80°C to +850°C*. Alternatively, *section 7* provides details of the link to your National Insulation Contracting Industry Association.
- 1.3 Thermal insulation systems can have many functions. One most important one is – to conserve energy.
- 1.4 The importance of energy conservation by the effective use of thermal insulation systems has not always been fully appreciated by plant-designers and owners. However there are a number of additional reasons. (see 2.2)
- 1.5 This document offers a basis for good working practice so thermal insulation systems can be properly designed, installed and maintained to conserve energy in a cost efficient manner.
- 1.6 Recommendations are presented for design, installation and maintenance of insulation systems for piping and equipment. It is the attention to detail that is vital. Experience shows that where failures occur, often it is not as result of an inappropriate specification, but due to lack of forethought of how to apply the specification to complexities such as the various projections out from the pipe or equipment surfaces.

**The insulation system must not be an afterthought to the design of the equipment.**

- 1.7 For the completed insulation system to be most effective, with the least compromise to the installation process, all early stage construction work must be complete, including installation of insulation and cladding supports and the equipment designed so that all projections are long enough to allow the full insulation thickness without compromise to the cladding and moisture protection. Consideration should be given to providing cladding termination flanges on projections for effective sealing to prevent moisture egress.
- 1.8 It is extremely important for the effectiveness and efficiency of an insulation system, that regular inspections are carried out during installation and then when in operation at intervals appropriate to the type of system and the surrounding environment. It is essential that any defects highlighted be promptly rectified in order that the insulation system is kept effectively maintained so that the properties continue to be achieved.
- 1.9 This document also gives guidelines to help in the preparation of an insulation contract between the client and the contractor.

**Properly maintained insulation systems save money and protect the environment.**

- 1.10 Many owners may know what it costs to maintain their insulation. However, they do not know what savings this maintenance returns to them or the increased savings to be gained, from improving their insulation. (*see FESI Document 6: High Profitability through*

*ecologically based insulation systems).*

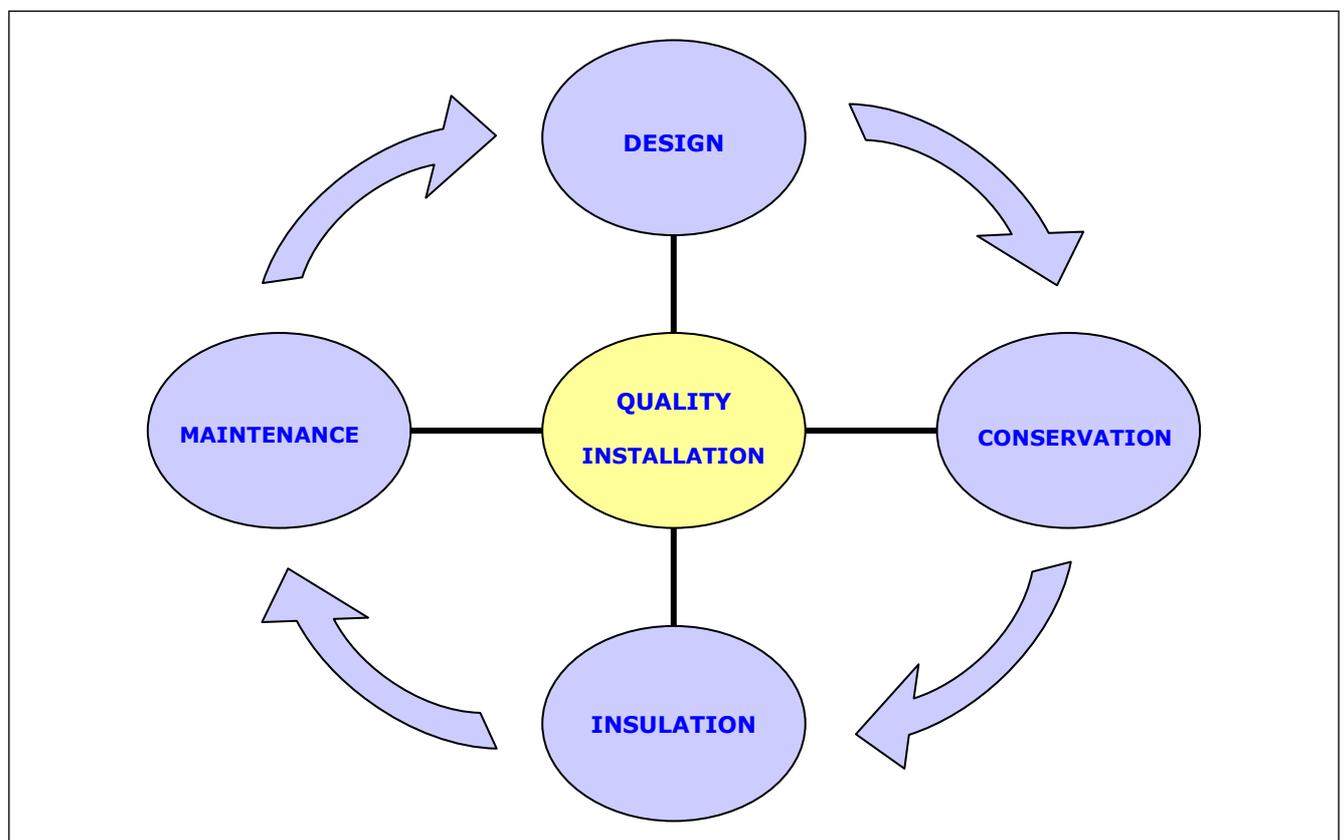
1.11 It should be made clear that all calculations of economic insulation thicknesses are based on “day one” values of correctly designed and installed insulation systems. The projected savings will not be achieved if the insulation system deteriorates due to lack of/poor maintenance.

**Insulation is an excellent investment – good maintenance protects your investment!**

1.12 Life cycle quality chain for technical insulation

Only by applying the complete life cycle quality circle will a robust and effective insulation system be produced and maintained. Without regular maintenance all of the good work, and money spent, in design and installation will be wasted.

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



## 2. Design of Insulation Systems

2.1 The design of an insulation system should include the following:

- Setting the criteria, and establishing the basic functions that the insulation system has to perform.
- Deciding the properties required of the insulation system as well as the components needed to fulfil the system's requirements.
- Selecting the insulation and cladding which will fulfil the requirements of the system.
- Calculating the insulation thickness.

2.2 When designing an insulation system it must be first established what specific function or functions the system must perform by virtue of its ability to retard heat flow.

These functions could be to:

- Conserve heat energy for economical and ecological reasons
- Conserve energy either heat or cold for process requirements
- Maintain desired temperature of fluids in pipes or equipment
- Reduce the temperature drop in equipment or along the lengths of pipework
- Prevent condensation of vapours on inner or outer surfaces
- Frost protection
- Protect personnel from burning (hot or cold)
- Fire protection
- Acoustic (noise) reduction

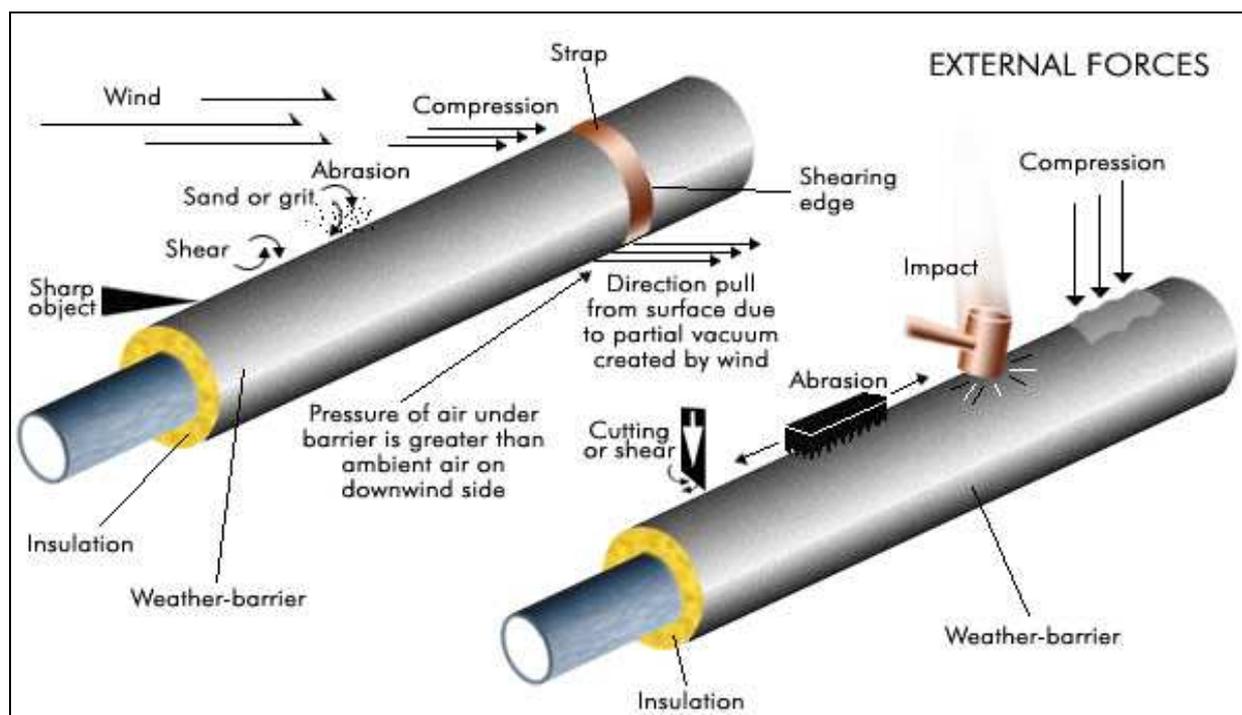
In many instances more than one of these functions is provided by an insulation system. For example it could provide heat conservation, personnel protection, fire protection and acoustic reduction.

**Extreme caution is advised when designing insulation systems to provide a warranted surface cladding temperature. There are so many unquantifiable considerations and as a result, normally it is not possible to guarantee on the basis of a theoretical calculation.**

*Reference can be made to FESI Document 5: Problems associated with the warranty of specified surface temperatures (currently under revision).*

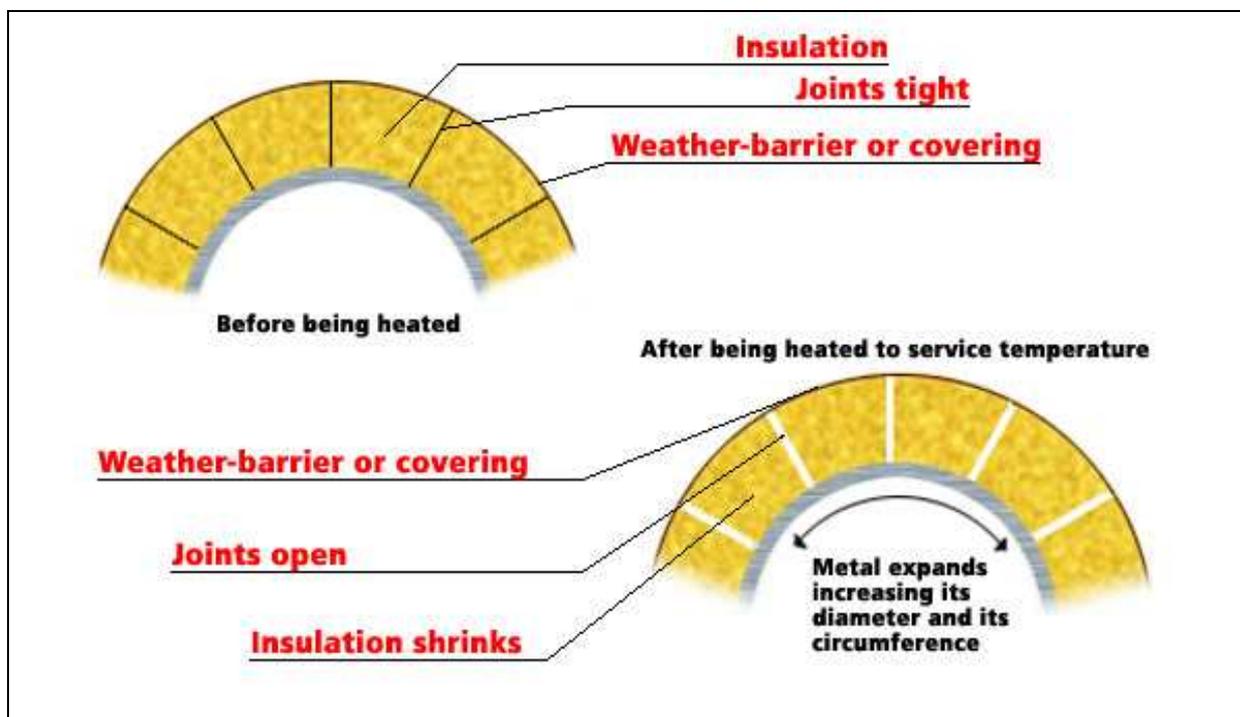
*For cold insulation more details can found in FESI Document 8: Principles of Cold Insulation and FESI Document 12: Design of cold insulation to prevent formation of condensation.*

**Designers of insulation systems must consider the effects of a complexity of external forces**



- 2.3 The economic and ecological savings from the insulation depend upon the quality of the complete insulation system and its integrity. Proper evaluation of the design and installation requirements related to industrial insulation systems is a difficult task, (which is often underestimated with serious consequences). All too often the insulation system requirements are considered long after the pipework and equipment have been designed. Often once the pipework and equipment have been manufactured and, even installed.
- 2.4 For this reason many insulation installations are incorrectly designed and installed. For example, if the need for insulation and cladding supports has not been considered prior to stress relieving of the equipment, welding of these supports may not be possible. It is intended for this document to guide engineers and contractors in this evaluation work, which is vital to gain the highest standard of insulation systems installed.
- 2.5 It is most important to establish the location of the specific insulation system. The design temperatures, humidity and the aggressiveness of the atmosphere should be considered most carefully. For outdoor installations attention should be paid to wind, rain, snow and solar exposure. This will particularly affect the choice of cladding system and its support method.
- 2.6 Design temperatures should include service temperatures and ambient temperatures and an indication of how often and for how long the system may be off load. If the service temperature cycles, or system goes off load, then effects such as expansion/contraction and passing through ambient must be considered.

#### Effect of Expansion Movement on Weather-barrier or Covering



- 2.7 If the function of the insulation is to obtain the best economics and reduction of Greenhouse gas emissions through heat conservation, information on capital investment is needed to produce the heat (energy), cost of insulation, its maintenance cost per year and years of amortization that will be required. *(see FESI Document no 6: High profitability through ecologically based insulation thickness).*

2.8 Below is an typical example of the specification information required to design an effective insulation system:

- a. Operating temperature.  
Type of installation – pipe, vessel, tankage  
Location – internal or external  
Ambient temperature – relative humidity – any aggressive media
- b. Installation requirements:  
Provide very low heat transmission  
Shall have very low vapour permeability  
Shall be fire resistant
- c. Insulation function:  
To conserve liquefied gas by reducing heat gain that would cause vaporization (for example)
- d. Insulation Selection:  
Thermal conductivity – cryogenic closed cell insulation from ..... to ..... °C,  
depending on system  
Vapour transmission values
- e. Cladding Selection:  
Metallic or non-metallic  
Environmental requirements  
Corrosion resistance requirements

2.9 Therefore, to obtain an effective, long lasting insulation system, the owner should provide the contractor with either:

- o precise details of the insulation and cladding systems requirements including insulation thicknesses
- o or all of the items detailed in paragraph 2.8

**The insulation requirements should be considered during design and construction phase.**

### 3. Prestart requirements

3.1 Construction preconditions:

- o There should be consultation at the design phase to avoid unnecessary complication of the insulation work, for example:
  - o the need for welded attachments to stainless steel vessels to provide support insulation and cladding should be identified before stress relief.
  - o if access platforms are required around and on tops of vessels, do the supports need to be attached to the vessels, and if so, how can the cladding be effectively sealed at the penetration points.
  - o for pipework operating below ambient temperature, the support brackets should be fastened over load bearing insulation, of the same thickness as adjoining insulation, complete with a vapour barrier so that the vapour barrier can be made continuous.
- o The hydraulic testing of the equipment to be insulated should be completed and documented before the insulation work begins.



**Plant and equipment must be designed to allow for effective sealing of the insulation system**

**3.2 Preconditions before insulation work commences:**

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

- any required anti-corrosion works on the object are finished
- heat tracer systems and measuring devices are installed
- the minimum clearance distances are established and maintained – so that the insulation system is not disturbed during the operation of the plant
- attachments for insulation and /or cladding are in place
- sealing collars and sealing discs are attached to the projections
- pipe stubs, manways etc are long enough for the flanges to be outside the insulation layer – allowing full bolt clearance, and to allow cladding to be terminated and sealed effectively and without impediment



**Plant and equipment must be designed to allow for the required insulation thickness**

- supports are fitted so that insulation materials, vapour retarders and claddings can be attached correctly
- the insulation can be applied without impediment - for example by scaffolds
- all welding and adhesion works on the equipment are completed and checked
- foundations are completed
- all surfaces to be insulated are clean, dry and free from oil and loose scale.

**3.3 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, 'out of hours'

work patterns or working in confined spaces.

### 3.4 Out of sequence execution

This should be documented and could include leaving valves, flanges or other portions of equipment un-insulated until certain testing is complete.

## 4. Installation requirements for good insulation practice

### 4.1 Evaluation of the requirements

With the large number of requirements to be considered, it is not possible in this compact document to provide an exhausted list of them all, but this section will be helpful in determining the significant factors deciding whether an installation is successful or unsuccessful

– making it profitable or not.

*(To consider all of these requirements, reference can be made to FESI document 3: Code of Practice for carrying out thermal insulation work at above and below ambient temperature in the temperature range -80°C to +850°C)*

### 4.2 Measurement of scope

The detailed quantities of pipework and equipment are needed. Isometric drawings will provide the best representation of this.

### 4.3 Logistics

During loading, shipping, unloading and storage, materials may encounter damage by water or moisture. The more absorbent the insulation material is, the greater the risk of excessive moisture pick-up. Weather-tight packing and careful handling is required to avoid wet insulation which will reduce the insulating properties considerably and dramatically increase the corrosion risk. This is also most relevant to the cladding materials that may become watermarked causing staining with, perhaps, the onset of corrosion.

The insulation materials are seldom used immediately upon receipt at site. Improper warehousing and handling of insulation materials can be costly.

<p><b>Water damage to the boxes of materials often results in loss of identification and damage to the contents, producing costs to replace or make good.</b></p>
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Combustible insulation should be stored with care. Fire will spread rapidly in light density materials and sealants, often producing toxic smoke when burning. Reference should be made to the manufacturers' material health and safety data sheets for the specific materials.

### 4.4 Prefabrication

Advanced techniques and workshops provide a controlled environment and have made it both practical and economical to prefabricate jacketing and preformed insulation materials for installation on site. Computerised sheet metal cutting and prefabrication equipment can be utilised to good effect. Due to high site production cost, more and more complete insulation systems are being delivered to site, reducing the site-installation time and cost to a minimum, while making it easier to maintain consistent quality levels. In these circumstances it is vital that they are suitably protected in transit from mechanical damage and from water ingress. Consideration should be given to the use of removable double skinned valve and flange muffs which will be much less likely to be damaged mechanically or by the weather during during maintenance.

#### 4.5 Site Installation

The materials must have the necessary inherent strength to withstand excessive handling damage, as storage space on most sites is limited, and the materials may be moved a number of times before they are installed.

Insulation materials should be applied and fastened without gaps and fixing bands or wires not over tightened. Thermal bridges should be reduced to a minimum. With multi-layer applications, all joints should be staggered.

When fitting metallic cladding, the sheets should be overlapped in weatherwise fashion, the overlap sealed, additionally with a sealing strip to prevent water penetration due to wind-driven water in the open. Roof sheets on tanks, ducts and vessels should be reinforced using downturn folds or standing seams with caps.

For vertical thermal insulation, for example on steam generators, flue-gas ducts and horizontal ducts with large cross-sections, special measures may need to be taken to prevent convection inside the insulation system.

#### 4.6 Mechanical Requirements to prevent insulation system failures

Insulation on pipes and equipment in industrial plant is subject to external as well as internal physical forces. The external forces may be bumps, vibration and wind. The insulation system should be sufficiently robust to resist ordinary 'wear and tear'. However, damage will be incurred by personnel walking or standing directly on the insulated surfaces. Where foot traffic cannot be avoided then the cladding and/or insulation must have increased support.

#### **Mechanical damage must be controlled**

Vibration is frequently overlooked when designing and installing the insulation system. It may cause the insulation to fragment or wear away and cladding fixings to loosen. Wind forces – both wind pressure and partial vacuum, tend to compress or pull the insulation system apart. The combination of vibration weakened systems and excessive wind forces can cause severe system failure.



#### **Insulation systems require prompt and regular maintenance**

The forces most likely to cause damage to insulation systems, are those built into the system by poor design and installation, that ignore the relative movements of pipes and vessels, mainly caused by thermal expansion and contraction in the structures both longitudinally and circumferentially.

Expansion and contraction of vessels and pipes can cause serious damage to the completed insulation system, insulation, vapour barrier and weather protection (jacketing). It can also damage and weaken the cladding fixing systems making them susceptible to wind damage.

**Ineffective sealing, cracks and openings are major causes of improper functioning of an insulation system.**

Increased overall energy loss will result from voids in the insulation and water, humidity, vapour ingress, making the insulation wet. As a rule of thumb - wetted insulation can increase its thermal conductivity by a factor of up to 15 times its dry value. Cracks in low temperature insulation and in its vapour barriers can cause even more severe damage than in high temperature systems. Entry of water (vapour) causes rapid ice formation which disrupts and ruins the insulation. Even at chilled temperatures, cracks will cause condensation formation resulting in a dripping and wet plant.

#### 4.7 Chemical Requirements

An insulation material should not be chemically corrosive to the structure to which it is installed. Ideally the insulation applied to steel should be neutral or slightly alkaline. It is most important that the system keeps the insulation dry. The ingress of moisture into the insulation system enhances corrosion as the penetrating moisture leads to the accumulation of corrosion-enhancing materials in the insulation system, such as halide ions, which may cause stress-corrosion cracking in stainless austenitic steels.

Stress corrosion and cracking in stainless steel will not be discussed here – but be aware!

*(Detail can be found in FESI Document 9: Prevention of corrosion on insulation cladding and FESI Document 10: Corrosion under insulation: Problems & Solutions)*

Consideration may have to be given to choosing cladding systems that are not affected by certain aggressive chemical environments. This may mean the use of a non-metallic cladding or covering.

#### 4.8 Thermal Requirements

The temperature requirements of an insulation system are the maximum and minimum temperatures to which the insulation will be subjected, not just the normally operating conditions.

In addition consideration must be given to whether: the processes change from hot to cold or are cyclical, whether there is rapid heat up or cool down, causing thermal shock to cellular materials.

Sudden temperature changes can be caused by the production process or rain and snow.

**It is essential that insulation systems are kept dry.**

#### 4.9 Moisture Requirements

Moisture in either liquid or vapour form will saturate the insulation system. It can enter by a variety of means;

- breaches in cladding and/or vapour barrier
- rain and process leaks
- water and/or vapour pressure

- in-gasing

#### 4.10 Quality requirements

Consideration should be given to:

- quality plans
- shelf life of materials – particularly liquid coatings, sealants and adhesives
- protection of work in progress
- storage

#### 4.11 Health and Safety Requirements

In addition to general site health and safety requirements, consideration must be given to:

- safe surface temperature for personnel protection
- manual handling and handling sharp edged materials
- observing the requirements of the material health and safety data sheets for materials with hazardous components
- local exhaust ventilation for dusts and vapours
- use of appropriate respirators
- use of personal protective equipment with particular attention to the appropriate gloves
- fire protection

#### 4.12 Environmental requirements

The following need to be managed:

- housekeeping
- spillages
- waste

**An effective inspection strategy is required throughout the lifetime of the insulation system.**

### 5. Inspections and Maintenance of Insulation Systems

5.1 Proper and intelligent inspections of industrial insulation systems should be carried out on regular basis. Provided any reports of damage or deterioration are acted upon immediately, the integrity and therefore the effectiveness of the completed insulation systems can be maintained. The inspection intervals will depend on the level of occupancy and maintenance activity in the area.

5.2 Documented inspections are required during all stages of installation:

- initial inspections to establish that work can commence
- pre-installation inspection of the work site that all preparations are completed
- pre-installation inspection of insulation materials, claddings and ancillary materials for specification compliance
- checking the quality of work in progress during the installation period
- for authorisation of extra work
- final inspection which could include inspection with infrared techniques

**Insulation systems require regular maintenance**

#### 5.3 Maintenance

There are two main reasons why:

- rectification of damaged insulation – water soaked insulation caused by weathering, mechanical and/or personnel abuse or vapour migration
- replacement of insulation that has been removed by others due to maintenance or

modification to the insulated systems.  
All insulation systems have to be kept dry.



**To remain effective and not to promote corrosion under insulation, prompt attention is needed**

Wet insulation or iced-up insulation in low temperature insulation systems, must be promptly removed and replaced. Punctured vapour barriers will allow the insulation system to be destroyed over time.

*More information can be obtained from FESI Document 10: Corrosion under insulation: problem and solutions*

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

#### 5.4 Inspection for corrosion under insulation

To minimise the risk of corrosion under insulation, a full inspection programme should be set up and a scheduled method of insulation inspection developed.

An inspection checklist should include the following items:

- identification of those areas and/or processes on the site that have insulated pipe and equipment
- a rating of the environment of the area where the insulated pipe and equipment is located. a field check is usually necessary. Rate the geographic areas by category (1 to 4).
  - 1 – the most critical of conditions, where moisture is constantly present, along with contaminants, such as acids, caustics and chlorides
  - 2 – 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 category 1)
  - 3 – an area that is sheltered from the weather but may occasionally be hosed down
  - 4 – 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:
  - A – an insulation system 15 years old or greater (the lifetime of an insulation system)
  - B – an insulation system 7 to 15 years old (system can fail in this age span if not maintained)
  - C – an insulation system less than 7 years old (should not fail if installed correctly)
- identification of insulation materials
- assessment of the condition of the insulation system (material, cladding, fixation)
- determination of operating temperatures – concerns are:
  - where the process temperatures cycle or process is shut down for several months or more.
  - Where operating systems are in the range of -5°C to +175°C.
- setting up of areas, conditions and locations by priority

The inspection findings should be incorporated in a maintenance action plan based 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 should be an integral part of this.

For both coating and insulation systems, 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.



**Regular Inspections should be carried out**

## 6. Contractual arrangements between Client and Contractor

6.1 Matters for consideration when preparing a contract for insulation work between an client and an insulation contractor.

A contract, which should always be in writing, can range from a simple few worded agreement, to a complex legal contract of many pages, a book of specifications and a

large number of drawings.

A well balanced, contract with provisions clearly defining the responsibilities of both parties in all particulars, is an advantage to both contractor and client.

### **The question of who is responsible for the engineering design is often overlooked**

Too frequently, a contractor recommends the substitution of materials and installation methods without realising that, if his recommendations are accepted, he becomes responsible for the proper functioning of the installed system.

The capability of the insulation contractors to do insulation engineering design varies considerably. It is most important that the contractor understands the implications of changing the specification and the possible effect on the performance of the plant.

For this reason, specialised engineers should be responsible for the design of major investment insulation installations.

The clearer the contract documents are, the smaller the sum of money the contractor has to add to his tender for contingencies to protect himself from possible loss. If the contractor knows exactly what is expected of him, he can accomplish the work quickly, effectively and economically, minimising delays.

#### 6.2 Contractual Check List

- General considerations
- Contract provisions - Scope
  - Contracting parties
  - Site
  - Time schedule
  - Contract documents
  - Sub contracts
- Type of contract - Lump sum - Unit rates - Target cost
- Specification, drawings, work orders, change control
- Responsibilities
  - workmanship and material
  - surface preparation
  - providing supports
- Scaffolding
- Start and completion dates
- Delays – penalties
- Out of sequence
- Unusual working conditions
- Inspections
- Housekeeping
- Site invoicing
- Progress
- Site safety
- Performance requirements
- Liabilities
- Additional work
- Guarantees

## 7. 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](http://www.fesi.eu) .

The information contained in this document is considered by us to be good practice and industry guidance. The Guidance is provided by a commission of FESI ([www.fesi.eu](http://www.fesi.eu)), and is considered to be correct at the date of publication. Whilst we are confident the information contained within it is up to date and accurate, it is a reference document only. It is your responsibility to ensure your knowledge of the matters discussed in the Guidance is kept up to date.

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