



Corrosion under Insulation Problems and Solutions

FESI document 10



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1. THE PROBLEM

Corrosion under insulation costs the Chemical and Petrochemical industries, in particular, a large amount of money.

By its very nature 'corrosion under insulation' tends to go undetected unless the insulation system is opened up. Once water has penetrated the cladding and entered the insulation, corrosion will begin and will continue. In this paper guidance is given on the items that should be considered at the design stage and the installation techniques that should be employed to minimise the risk.

Some significant aspects of metal corrosion have been dealt with already, in FESI Document 09 "Principles of metal corrosion". These will also apply to the problem areas discussed in this FESI document.

The presence of water is essential for the onset of corrosion: if there is no moisture and/or no water then there is no corrosion. So the prevention of water penetrating the insulation system is paramount.

Water can penetrate insulation systems in three different ways:

- Gaps or openings in the cladding can allow the ingress of rain, spilt water or other liquids.
- Water vapour can get inside the insulation system due to air movement through gaps or openings in the cladding.
- Water, in gaseous form, can penetrate the insulation system by water-vapour diffusion.

So the greatest dangers are the ingress of rain, spilt water, and the penetration through gaps or openings in the cladding, by water vapour as a result of air movement.

The risk of water penetration as a result of air movement is most likely with cold insulation, where the saturated vapour pressure inside the insulation system is lower due to the lower temperature. It should also be noted that hot insulation systems also are occasionally "cold" when they are off load, the temperature inside the insulation system may fall below the ambient temperature.

2. SCOPE

This document addresses three aspects:

- Advice to owners / operators of industrial installations that insulated objects are at risk of corrosion under insulation, and that the objects should be designed to allow for effective sealing of the cladding and must be corrosion-protected.
- Advice to insulation contractors that moisture in any insulation not only renders the insulation ineffective, but additionally poses great corrosion risks to the installation itself and so must be avoided at all costs.
- Advice to operators of industrial installations and insulation contractors that although the anti-corrosion work on industrial installations to be insulated is not an integral part of the insulation work, it can be carried out by the insulation contractor if specifically defined in the contract as an additional activity.

This paper therefore deals predominantly with measures to be taken:

- to avoid water penetration wherever the insulation system is exposed to rain or spilt water,
- to ensure effective drainage of any liquid that has penetrated the cladding or leaked from the object that has been insulated,
- to ensure effective drainage of condensed water, occurring in the air space between a cladding and the water vapour retarder of a cold insulation,
- to ensure effective drainage of condensed water, occurring in the air space between the cladding and the insulation material of thermal insulation systems outside, whenever the medium temperature drops below 120 °C, even if this only happens occasionally,
- to protect against the ingress of water into cold insulation systems through the employment of closed-cell insulation materials, water-vapour-repellent application techniques and a water vapour retarder.

3. WHAT THE DESIGNER SHOULD CONSIDER

3.1 Introduction

The designers of pipe work, vessels, tankage and associated equipment should be encouraged to consider the effective installation of 'liquid proof' insulation systems at the design stage. This will require installation of a mechanical means of termination of the insulation cladding. As a result the type and thickness of insulation must have been considered at the same time as the fabrication of the objects to be insulated.

Specific items that should be considered include:

- Ensuring there is sufficient clearance between the plant item and other plant items or fixtures such as walls, to allow the full insulation thickness and cladding to be correctly installed.
- Providing the means for the cladding to run through pipe supports or hangers without interruption.
- Providing termination flanges, allowing full insulation thickness, on man ways, pipe stubs, walkway supports and other penetrations of the insulation cladding, to enable cladding to be mechanically fixed. Designers should be reminded that simple cladding cut outs, patches and sealants will not normally withstand weathering, foot traffic and the rigours of mechanical maintenance.
- Where possible valves should be installed with the spindles horizontal or below in order to minimise the risk of liquid ingress, into insulated valve boxes, around the spindle.
- Ensure that the appropriate insulation is used in the right places.
- Ensure the use of the correct cladding materials in places where they can give the best protection.
- Use the correct material application specifications, and check the details so that it is known, what to expect.
- Be aware that extra precautions will be needed to prevent water ingress where the installation is outside or only covered by a roof.
- Protect all surfaces, that will be insulated, with a protective paint system or foil.

The principal considerations on corrosion are dealt with in FESI Document 09: All recommendations given there concerning the anti-corrosion treatments of metals used in industry apply also in the context of "prevention of under insulation corrosion".

Additional constructive advice follows.

3.2 General

The ingress of moisture into the insulation system and the consequential concentration of chlorides in the insulation enhances the corrosion of insulated parts of the installation. Moisture may even lead to the concentration of corrosive substances from the atmosphere in the insulation system. Therefore consideration must be given to how corrosion of the object can be prevented through appropriate anti-corrosion applications and/or design of the insulation system.

With the intake of moisture, the insulating effect of the insulation material decreases. A rough estimate, supported by research data, suggests that a 1 vol.-% of water in the insulation material leads to an approximate 4% increase in the thermal conductivity. A water concentration of 5 vol.-% of the overall insulation material's volume, increases the λ value by 20%. This renders the insulation ineffective.

Also, the moisture absorption can lead to physical changes, e. g. frost heaving, or mechanical damage. Water leads to the breakdown of some insulation materials, including such as microporous material, calcium silicate and mineral fibres.

Hydrophobic treatment of insulation materials does not protect against moisture concentration and the ingress of chloride ions. It only constitutes a temporary protection against the ingress of rain water during assembly of the insulation. It does not replace weather protection.

Chloride ions can cause stress-corrosion cracking in 300 series stainless austenitic steels. Insulation with mineral wool requires, for example in Germany, the use of AS-quality mineral wool according to AGI working document Q 135 (Annex 1). In the UK, the use of aluminium foil applied to the surface of the object prior to insulation, is required.

Practical experience has shown that the presence of moisture in insulation systems must be taken into consideration. The absorption of moisture normally occurs in three different ways:

1. Ingress of water (rain or spilt water)

This can be caused by mistakes in design and construction, e. g. wrongly positioned branches and fittings, missing flashings / rain deflectors, and damage to the cladding allowing the penetration of water. Imperfect installation of the insulation may be an additional reason.

2. Condensation formed in the insulation caused by water vapour diffusion

This moisture mainly occurs when parts of an installation are operating below ambient temperature.

3. Formation of condensation in the insulation caused by air exchange with the ambient atmosphere

This mostly occurs when installations are operated in interrupted service, but also with installations outside, where the ambient temperature influences are consistently changing. The reduction in ambient temperature, which can also be caused by rain or thermal radiation at night, results in a lower saturated vapour pressure in the insulation, resulting in moisture being transported into the insulation with the ingressing ambient air.

This leads to large amounts of water vapour being transported into the insulation system in short periods. Warming-up of the insulation system, for example as the installation is switched on again, causes an increase in vapour pressure leading to a reversal of the air movement, however, the moisture generally remains in the insulation as condensation.

3.3 Selection of anti-corrosion coating systems

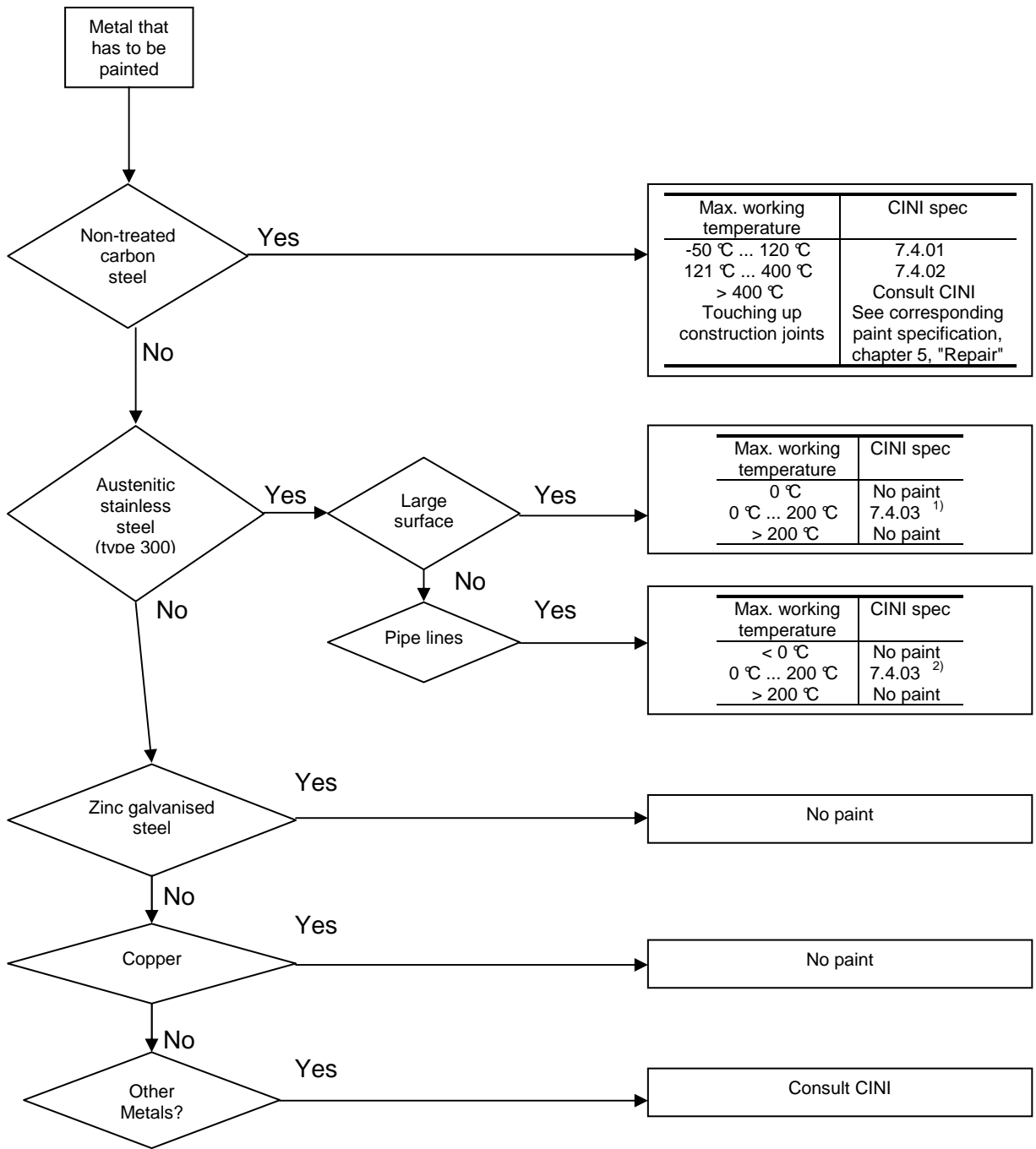
It should be noted that anti-corrosion coating systems, that may work well in the open air, may fail when covered by insulation.

The design engineer and the owner / operator responsible, must consider the requirements for insulation and prevention of corrosion at the same time.

For the selection of the anti-corrosion system, it must be ensured that coatings, adhesives and insulation materials are compatible.

Examples of tested anti-corrosion systems are given in AGI working document Q 151 and Annex A 18 and A 19 and the CINI book, chapter 7.

Recommendations regarding the anti-corrosion systems to be selected are given in the flow-chart below. The type of paint must be agreed between client and contractor in each individual case.



Note: ¹⁾ System B or C
²⁾ System A, B or C
 For manual, see below
 For general requirements, see 7.3.01

Selection diagram

Instructions for selection diagram

The selection diagram is based on criteria such as:

- a. the substrate of the coating system whether carbon steel, stainless steel, hot-dip galvanised steel or other metals.
- b. the operating temperature.

For piping, equipment and tanks that are cleaned by steam, "traced" or operate at various temperatures, the highest temperature shall always govern the selection of the coating systems.

Piping, equipment and tanks provided with personnel protection shall be coated with the paint system required for non-insulated surfaces.

The advised paint systems are based on the available systems in industrial painting practices.

The specified paint systems are applicable for new construction projects.

3.4 Protection against the ingress of moisture

Before the insulation of an object is designed, it should be established whether or not it is likely to be exposed to rain and/or spilt water. This consideration and the operating temperature will determine whether sealing discs should be welded to parts of the object, or whether flashings / rain deflectors should be used as part of the cladding.

Sealing collars must be fixed to all vessels and tankage that are to be insulated.

Objects in the open and in buildings, where they are subject to spilt water, must have sealing discs welded to all protrusions penetrating through the cladding.

It is recommended that the sealing discs and sealing collars as well as those parts of the installation, which are not insulated are made of stainless austenitic steel. If made of ferritic steel, all surfaces must be coated prior to the application of the insulation. Inside buildings, this provision applies only to cold insulations.

In AGI working document Q 152, construction examples are given for different ambient conditions.

The sealing of flashings / rain deflectors with sealing compounds is normally the responsibility of the insulation contractor.

The decision as to where welded sealing discs and collars shall be used, is normally the responsibility of the installation designer but should involve the insulation company.

The minimum thickness of sealing discs for vessels is 4 mm, for pipes 2 mm. The welding must not cause deformation.

4. WHAT THE CONTRACTOR SHOULD CONSIDER

The general rules for the execution of insulation work on industrial installations are given in AGI working document Q 03 AND BS5970. The interface between the components of the installation and the insulation applied to it are fully described in AGI working document Q 05 "Design of industrial installations".

4.1 Standards

4.1.1 General

The following preconditions should be incorporated into the quality control system to allow for the professional insulation of the object:

- Final check of corrosion-protection system.
- Corrosion-protection works on the object are finished according to the specification.
- Minimum distances, for example as in figures 1 through 7 of AGI working document Q 05, have been maintained.
- A final check that there is sufficient space for the insulation (insulation-layer thickness plus adequate installation space).
- Objects that will penetrate the insulation should be in place and properly protected.
- Appropriate sealing collars and sealing discs are welded to the object.
- Nozzles are of sufficient length that their flanges are outside of the cladding and with enough bolt clearance that they can be opened and closed without impediment.
- Supports are fitted so that insulation materials, vapour retarders and claddings can be attached correctly.
- The insulation can be applied without obstruction, e. g. by scaffolds.

4.1.2 Insulation

Insulation systems and insulation materials are selected to meet the particular technical requirements and the physical and other prevailing conditions. (As described in previous FESI documents.)

Selection should also consider factors that could affect the risk of under insulation corrosion such as location, space available, risk of foot traffic and chemical aggressiveness of the atmosphere.

4.2 Application of insulation materials

4.2.1 Polyurethane (PUR) in-situ foam

PUR in-situ foam together with the cladding forms an insulation system, which is mainly used in cold insulation. If the cladding is used as vapour retarder, as is usual, sufficient adhesion between PUR in-situ foam and cladding is required.

This insulation system is highly dependent on good site quality control with the mixing and dispensing process carried out strictly in accordance with the manufacturers instructions. If the foam is not generated to the highest quality, unreacted material and/or voids can be left under the cladding which will lead to corrosion on the surface of the object.

The difference in temperature between the object and the cladding causes tension forces to form in the insulation system. The size of these tensions is dependent upon the temperature difference, the material properties and the geometry of the insulated object.

4.2.2 Preformed pieces

Preformed pieces are fitted to the surface shape of the object. They are applied with closed and staggered joints. For single layer applications, joints shall be completely glued, with multi-layer insulation, this applies at least to the joints of the outer layer. Cavities allowing for an air exchange must be completely filled with adhesive or sealing compound.

Preformed pieces are to be glued or fastened e. g. with tapes.

Each layer must be secured with corrosion-resistant tapes.

The inner diameter of sections shall respond to the outer diameter of the pipe. The thickness of anti-corrosion and adhesive layers shall be taken into consideration.

4.3 Water vapour retarder

Water vapour retarders are normally made of water-vapour-diffusion-resistant material such as aluminium foil. However, since they cannot be completely sealed at seams and penetrations absolutely water-vapour-diffusion-tightly, the appropriate term is "water vapour retarder".

They are not only installed to prevent water vapour diffusion and the moisture ingress into an insulation associated with it, but even more importantly to prevent the moisture ingress by air movement.

Any sort of damage to the water vapour retarder, either during its installation or during the operation of the installation must be avoided. Simple rules to observe are:

- Screws of the cladding must not penetrate the water vapour retarder.

- No sacrificial layer is to be employed between water vapour retarder and cladding, however the air space between the two must be wider than the length of screws or rivets holding the cladding.
- At end-pieces, sealing discs and end plates, the water vapour retarder must be tightly connected to the surface of the object.

Water vapour retarders must be adhered completely to the complete surface of the insulation material. They must be fully effective also at bulk heads, end-pieces, penetrations, reductions, tees and pipe supports. The surface to which the water vapour retarder is adhered must be dry and free of pollution such as dirt, oil or separating agents. Rough unevenness of the surface must be levelled.

4.3.1..... Vapour retarder for polyurethane (PUR) in-situ foam

For polyurethane (PUR) in-situ foam, the cladding serves as vapour retarder if the foam adheres to it. Circular and longitudinal seams must be sealed with elastomeric sealing compounds or joint-fillers. For external vessels, columns and tanks, sealing discs must be placed at all terminations and penetrations of the insulation. For pipes, these are not normally required.

4.3.2..... Vapour retarder for insulation systems made of preformed pieces

Vapour retarders for insulation systems made with preformed pieces may consist of foils totally adhered to the surface of the insulant. These foils may be metal or plastic, or of coating compounds.

Foils must overlap at least 50 mm, tapes or bandages by at least 50% of their width. The minimum overlap for tapes or bandages is 25 mm.

Coating compounds may be sprayed or trowelled. The coating shall be evenly thick without air bubbles. In case a reinforcement is applied, open-meshed material shall be used so that individual layers of the coating are firmly connected with each other. The reinforcement must be applied in more than one layer so that it is totally covered by the coating compound. The thickness mentioned is the dry film thickness.

4.4 Corrosion protection of cold insulated systems

4.4.1..... General

Cold insulations are physically unstable systems which react very sensitively to damage. They must be maintained regularly including a routine inspection of sealings, penetrations and interruptions.

Their vulnerability to the ingress of moisture must be given utmost attention by owners and insulation contractors when designing and constructing a cold insulation system. As has been discussed already, moisture not only reduces the thermal resistance significantly, thereby rendering the system useless, but additionally the resulting corrosion can destroy the entire installation.

Claddings must completely protect the insulation system from rain and splash water.

To minimise the problems that are associated with the ingress of water into cold insulation systems, the use of water vapour retarders and a closed cellular insulation material is recommended. The "pumping effect" resulting from varying air pressure between the ambient air and the air encapsulated in the cold insulation system – the most dangerous moisture inroad into the system – can only be countered by closed cellular insulation material. Minute damages, cracks in the water vapour retarder, the less than complete sealing at seams etc. can never be prevented, and small damages might also occur during operation due to thermal shocks or vibration. It is therefore only the combination of the two:

- water vapour retarder,
- closed cellular insulation material.

That gives some certainty of a "dry" cold insulation system.

Therefore the corrosion protection of all metallic parts of the system is of utmost importance.

4.5 Claddings

The cladding is a mechanical protection and/or protection against the weather. It plays a decisive part in the water protection of the insulant and thereby in the prevention of corrosion in the entire system.

Claddings are required where external influences might reduce the properties of the insulation material.

Claddings must not damage the vapour retarder. As indicated in 4.3, provisions must be made to prevent screws or rivets from damaging the vapour retarder. The use of mineral wool "sacrificial layers" or like materials as a water-vapour-retarder protection is not advised.

4.5.1 Cladding made of non-profiled sheets

Sheet metal must be formed, longitudinal and circular seams must be swaged. Sheets with thickness below 0,5 mm need not to be swaged. Longitudinal seams can also have turned edges. Circular seams may be connected with interlocking ball swages if gaps are not likely to open as result of temperature influence. This does not apply to polyurethane (PUR) in-situ foam used externally.

In dry rooms and for small pipe diameters, overlapping ball swages are acceptable also for polyurethane (PUR) in-situ foam if the sealing is ensured through additional measures such as closed-cell polyurethane bands or through glueing.

Claddings for rotating installation components and components subject to concussion or vibration should be connected with blind rivets.

For metal sheet joints that must be frequently opened, machine screws with riveted nuts or facade screws may be used.

Cuts for interruptions of the metal casing such as for pipe supports, manholes, measuring nozzles, must be made to fit tightly. If necessary, they can be equipped with sealing plates such as according to

AGI working document Q 152 and sealed with a permanently flexible compound. Flashings / rain deflectors can be mounted additionally.

At the ends of pipe claddings, end plates are inserted into the swages (end cap).

For cold insulation, end plates should be avoided to prevent damage to the water-vapour-tight sealing. At the ends of the cladding of vessels, end plates should be fastened in swages (end cap); for vertical vessels and for oblique or vertical pipes, the top ends shall be connected funnel-shaped and flashed with the metal cladding. End plates must not be joined with the object to avoid damage to the corrosion protection.

Overlaps, swages etc. must be adjusted to prevent liquids entering the insulation. Individual metal components should overlap, following the principle of roof tiles. Externally, all overlaps should be on the weather side for longitudinal seams at horizontal pipes, the overlap should be placed about 45° above the horizontal centre line of the pipe, measured radially from the centre of the pipe wherever possible. Also, they should be staggered.

Overlaps shall be joined on longitudinal seams with a minimum of 6 screws or blind rivets per metre. To protect the vapour retarder, the cladding can also be fastened with corrosion-resistant bands. For polyurethane (PUR) in-situ foam, 10 blind rivets or tapping screws with UV-resistant plastic discs shall be applied per metre. The screws should be of stainless austenitic steel.

The screws or blind rivets must have equal distances. If two rows of screws or rivets are applied, screws or rivets shall be staggered. Aluminium screws must not be used.

The sheet metal thickness, overlap and assembly mean minimum dimensions dependent upon the circumference of the casing are given in Appendix B. An overview of the most common types of sheet metal is in Appendix C.

For claddings without mechanical strain, sheet metal thicknesses and overlaps according to Appendix D are permissible.

4.5.1.1 Galvanised steel sheet

Galvanised steel metal of steel 1.0226 with a minimum zinc coverage of 275 g/m² (total of both sides) according to DIN EN 10142, ASTM A525M OR BS 2979 is being used.

4.5.1.2 Aluminised steel sheet

Aluminised steel sheet is steel sheet coated in the Sendzimir-method with aluminium of 99,3% purity. It provides the surface characteristics of aluminium in connection with the higher strength and fire-resistance duration of steel.

The minimum aluminium coverage is 305 g/m² (total of both sides) according to ASTM A463M T2-100.

4.5.1.3 Al-Zn-plated steel sheet

Al-Zn-plated steel sheets are cold-forged steel sheets, the surfaces of which are covered with an alloy consisting of 55% aluminium, 43,4% zinc and 1,6% silicon. The coating is at least 185 g/m² (total of both sides) according to ASTM A792M.

This Al-Zn-alloy shows a better corrosion resistance in industrial atmosphere than galvanised steel.

4.5.1.4 *Plastic-coated steel sheet*

Plastic-coated steel sheets consist of galvanised steel sheets, which are equipped with a one-sided or two-sided plastic coating in an additional manufacturing process.

With one-sided coatings, the backside gets a protective varnish. Sheets are available in thicknesses between 0,5 mm and 1,5 mm. Allowable surface temperatures are determined by the characteristics of the plastic coating, for example they must not exceed 60 °C for PVC.

The plastic coating must not be damaged during the processing, the transport or the application of the sheet metal, since there is a danger of underfilm corrosion.

4.5.1.5 *Stainless austenitic steel sheet*

The employment of stainless austenitic steel sheets is recommended for strong chemical exposure. The chemical resistance must be checked in each individual case in the resistance tables in the manufacturer's information. Stainless austenitic steels are susceptible to stress-corrosion cracking caused by chloride ions.

These sheets are also used where only weak chemical exposure prevails, but maintenance work is difficult to execute or creates high extra costs.

The processing of stainless austenitic steel sheet requires a higher effort compared to galvanised steel sheet.

4.5.1.6 *Aluminium sheet*

Sheet thicknesses, overlaps and assembly methods for aluminium sheets are given in DIN EN 485-2, type H 24, according to the circumference of the cladding. Details are also given in ASTM B209M and BS5970.

4.5.2.....Cladding made of profiled / corrugated sheets

For large vessels, columns, tanks, ducts or for load-bearing insulations, profiled or corrugated sheets may be used for wind loading or aesthetic reasons.

Profiled, corrugated or tapered sheets may be made of galvanised, coated or stainless austenitic steel sheet or of aluminium. The overlaps and joints are dependent upon the profile and the respective manufacturer's information.

Otherwise, chapter 4.5.1 applies.

4.5.3.....Non-metallic Cladding

Where it is considered difficult to seal or maintain the sealing of the cladding, a non-metallic cladding material can be considered. The difficulty may be due to the complexity of the equipment i.e. with many penetrations such as walkway supports, nozzles, manways, thermocouples etc. and particularly if they are upward facing. It may also be due to the result of foot traffic and mechanical damage particularly in high access areas.

The materials that can be considered where mechanical damage is a significant problem are:

- Chloroprene rubber sheet
- UV-cured Glass-Reinforced Plastic (GRP) sheet
- PVC backed Tape

There are other acrylic based coatings that will provide an effective weather shield where mechanical damage is not an issue.

By the nature of these materials they are seamless as they are chemically bonded to themselves. They can be easily repaired by cutting out the damaged area and bonding a patch of the material into place. The manufacturer should be consulted to establish the maximum service temperature limit of the material.

5. GUIDANCE FOR PRACTICAL INSULATION WORK

5.1 Introduction

There are a number of specific points that should be considered during the installation and application of the insulation system. Reference is made to the CINI manual "Insulation for Industries".

5.2 Hot Insulation – Pipelines

1. Protrusions through insulation and cladding, if an engineered solution is not possible then use a sealing compound.
2. On vertical end plates do not use standing seams. See CINI 4.1.07
4.1.13
3. For cladding joints on vertical pipes or vessels the overlaps should always be installed so as to shed water (weatherwise – roof tile method). See 4.1.03
4.1.14
4.1.19
4. Spindle protrusions on valve boxes are likely point of liquid ingress. Special care is needed for sealing. See CINI 4.1.20
5. Longitudinal cladding seams should be installed on the side away from the prevailing weather where ever possible. The joint should be weatherwise and more than 90 degrees from the vertical. See CINI 4.1.05
6. Where electrical or steam tracing penetrates the pipe work cladding, the position should be away from prevailing weather and more than 90 degrees from the vertical.
7. On high service temperature applications expansion joints should be installed to prevent seams opening up. This will also apply to long horizontal pipes between two fixed points. See CINI 4.1.06
4.2.11
8. The overlap on the circumferential and longitudinal seams should be sufficient. See CINI 4.1.05
4.2.12

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| 9. Pipe supports are a likely source of liquid ingress. The line of insulation and cladding should be continuous through the pipe support. | See CINI 4.1.09 |
| 10. Drain holes should be installed at the low points in all cladding. The holes should be drilled from inside to out. | See CINI 4.1.10 |
| 11. A water shed cover should be installed above all pipe hangers. | See CINI 4.1.11 |
| 12. Wherever possible, a tee piece connection with the pipe cladding should be installed with the joint weatherwise. | See CINI 4.1.12 |
| 13. Check on small ball or plug valves that there is an extended spindle to allow the full thickness of insulation. | See CINI 4.1.21 |

5.3 Hot Insulation – Vessels, Columns and Tanks

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| 1. Ensure there is sufficient distance between the flange face and vessel wall for insulation thickness and bolt length. | See CINI 4.2.09 |
| 2. Ensure the length of name plates, thermocouples, ladder supports and other projecting items, project sufficiently to allow full insulation. | See CINI 4.2.07
4.9.05 |
| 3. Establish the termination points for anchoring the bands on the tops of columns and vessels. | See CINI 4.2.02 |
| 4. Ensure that the top plates of vertical manholes always slope. | See CINI 4.2.05 |
| 5. Ensure that the cladding on vacuum rings is always fitted weatherwise. | See CINI 4.2.15 |
| 6. Ensure that insulation cladding around projecting vessel supports is installed so as to shed liquid. | See CINI 4.3.02 |
| 7. Preferably make the vessel top insulation thicker so that the lifting lugs are enclosed by the insulation so as to shed liquid. | See CINI 4.3.03 |
| 8. Cladding of vertical connections should always be installed with joints weatherwise so as to shed liquid. | See CINI 4.4.03 |
| 9. Leave tank bottom edge free of insulation for inspection, and install an eaves flashing / rain deflector when tank roof is not insulated. | See CINI 4.5.02 |
| 10. Ensure that all tank roof cladding is fitted weatherwise. | See CINI 4.5.21 |
| 11. Check that the kicking plate on the tank roof hand rail allows sufficient clearance for the full insulation thickness to be applied. | See CINI 4.5.23 |
| 12. Use clips for insulation support rings than flat steel angle to support the insulation and cladding. | See CINI 4.2.13
4.9.04 |

5.4 Cold Insulation - Pipelines

1. Self-tapping screws should not be used to close the seams of the cladding. Stainless steel bands should be used instead. See CINI 5.1.01
2. Careful consideration must be given to the installation of contraction joints. See CINI 5.1.06
5.2.06
3. Where insulation is terminated, the end of the insulation should be covered with an extra layer of mastic rather than metal capping piece / end plate. See CINI 5.1.07
4. Check the valve of flange box connection onto the pipeline cladding. See CINI 5.1.08
5. The connection between the pipe support material and the insulation should be a stepped joint. See CINI 5.1.09
5.1.10
6. Bands should be used on elbows to close the seams. See CINI 5.1.14
7. Drain holes should be installed at every low point. Holes should be drilled from inside to outside. See CINI 5.1.20
8. Wherever possible, valve spindle protrusions should be better insulated. See CINI 5.1.23
5.1.25

5.5 Cold Insulation – Vessels, Columns and Tanks

1. On vertical vessels and lines, S clips should be used to support the cladding. See CINI 5.2.01
2. Support bands with clips so that they do not fall down. See CINI 5.2.03
3. Insulate skirts of columns down three times the insulation thickness. See CINI 5.2.05
4. Install a thermal break between support and vessels. See CINI 5.2.09
5. The steel on which the vessel is supported should be insulated. See CINI 5.3.02
6. Where possible, prefabricated head segments should be used on vessel and column ends and tops. See CINI 5.3.21
7. Insulate the saddles of horizontal vessels along three times the insulation thickness.
8. Ensure that the vapour retarder is free of pin holes and has an even thickness.
9. If the vapour retarder is black in colour then in summer protect the surface to prevent it drying out too fast and trapping solvent. This trapped solvent could result in pin holes.

10. Check that there are enough supports for the insulation and that these supports are not too long. See CINI 5.9.01
5.9.02
5.9.03

6. MAINTENANCE CONSIDERATIONS / WHAT THE OPERATOR SHOULD CONSIDER

6.1 Introduction

All insulation systems should be regularly inspected for damage to the cladding and for points of weakness' that could eventually allow water into the insulation system. The results and dates of these inspections should be recorded. Damaged cladding on outdoor installations should be rectified immediately, to prevent water penetration of the insulation system, which would reduce the insulation's properties and initiate corrosion under the insulation. Damaged vapour barriers must be sealed as soon as possible or else water vapour will enter the insulation through the damaged area. In areas where the cladding is damaged, the insulation should be removed to allow inspection of the substrate for corrosion. As part of the inspection programme, 'high risk' areas for corrosion should have the insulation system removed on a regular basis to detect possible corrosion under insulation as early as possible to reduce maintenance cost. Consideration should be given to preparing inspection points that will cause minimum disruption to the cladding and therefore make the resealing of the system most effective.

6.2 What the operator should look for

- Production processes and environments with the potential to cause harm.
- Construction features of the plant with potential to allow water penetration and corrosion.
- Damage to the cladding that could allow water to penetrate the insulation system.
- Observation of 'rust water' or deposits of rust.
- Ice, which could be due to vapour barrier damage.

6.3 Where to look

- Carbon steel piping systems operating between -4°C and $+120^{\circ}\text{C}$.
- In areas around supports, hangers, ladders and other items penetrating the cladding.

- In systems with dual service requirements i.e. service temperatures above and below ambient.
- In areas exposed to spray from cooling towers, steam vents or deluge water.
- In steam traced systems.
- Halide stress corrosion cracking could occur in systems made from austenitic, stainless steel operating between + 60°C and + 204°C.
- Systems that vibrate will often damage the cladding by loosening or shearing the cladding fixings.

6.4 Inspection techniques

- Periodic systematic visual inspection of the insulated systems.
- The most effective method is to remove the insulation in representative areas in accordance with, for example, API 570.
- Indirect methods such as thermal imaging and others can also be used to track possible under insulation corrosion.

- Stress-corrosion cracking: Stress-corrosion cracking mainly occurs with stainless austenitic steel and copper under the attack of water soluble chloride ions.
In insulation systems, the stress-corrosion problem with stainless austenitic steel, caused by the attack of water soluble chloride ions, is the most important.
- Chloride content: Chloride content is the amount of water soluble chloride ions in the insulant, which in combination with moisture and heat leads to corrosion, especially with stainless austenitic steels (stress-corrosion cracking).
- Circumferential / Longitudinal joint / seam: The longitudinal or circumferential connection of any components of the insulation or the cladding.
- Density of moisture flow rate: Mass of moisture transferred to or from a system divided by time and area.
- External installation: External installations are industrial installations that are not or not fully inside buildings.
- Water vapour retarder: System which reduces water vapour transport by diffusion and/or convection.
Materials used are water-vapour-diffusion-tight, i. e. possess a moisture-vapour-resistance air equivalent $s_d > 1\ 500\ m$. Nevertheless, the system is called "retarder" and not "barrier" anymore, since joints and connections cannot be installed absolutely water-vapour-diffusion-tight.

APPENDIX B SHEET THICKNESS, OVERLAPS AND ASSEMBLY MEANS FOR CLADDINGS OF NON-PROFILED SHEETS

Circumference of cladding mm	Material of cladding			Overlap		Assembly mean Minimum dimensions ²⁾	
	Steel Coated with zinc Al-Zn plastic mm	Steel Stainless Austenitic DIN 17440 mm	Aluminium mm	Longitudinal Seam mm	Circular ¹⁾ Seam mm	Tapping screws ³⁾ DIN EN ISO 1478 Ø / length in mm mm	Blind rivets DIN 7337 Ø in mm
Up to 400	0,5	0,5	0,6 0,8 ⁴⁾	30	50	4,2 / 9,5	3,2
400 up to 800	0,6	0,5	0,8	40	50	4,2 / 9,5	3,2
800 up to 1200	0,7	0,6	1	50	50	4,2 / 9,5	3,2
1200 up to 2000	1	0,8	1	50	50	4,2 / 9,5	4
Above 2000	1	0,8	1,2	50	50	4,8 / 9,5	4,8

¹⁾ For pipes, no overlap at circular seams is needed if they are connected or inlock ball swages.

²⁾ For casing with large surfaces and high wind load, static calculations may be required. For load assumption, DIN 1055 applies.

³⁾ Screws of stainless steel according to DIN 17440 are recommended.

⁴⁾ Sheet thickness 0,8 mm for PUR in-situ foam.

APPENDIX C TYPES OF SHEET METAL

Type	Area of application	Quality, material	Standards, directives
Steel sheet, Galvanised	Standard sheet in construction of industrial installations with weak atmospheric exposure, resistant against alkaloids (alkaline area)	1.0226 (formerly: St 02Z)	DIN EN 10142 DIN 4140
Steel sheet, Aluminium-coated	Similar to aluminium sheet; with better strength and fire resistance	1.0226 FAL Type 2	DIN EN 10142 Manufacturer's informations
Steel sheet, Al-Zn-coated	Similar to galvanised steel sheet, better corrosion resistance	1.0226 AZ 185	DIN EN 10142 Manufacturer's informations
Steel sheet, Plastic-coated (PVC, PVDF)	Dependent upon coating in acid-, alkaline- or solvent-added atmosphere	1.0226	DIN EN 10142 Manufacturer's informations
Steel sheet, Stainless, Austenitic	– for strong chemical exposure	1.4571 ¹⁾	DIN 17440 DIN 17441
	– in weakly aggressive atmosphere, town atmosphere	1.4301 ¹⁾ 1.4541 ¹⁾	
Aluminium sheet	Media in the low-acid area, sea atmosphere	AlMg 2 Mn 0,8 ¹⁾ AlMg 3 ¹⁾	DIN EN 573-3 DIN EN 485-2
¹⁾ The selection of materials must be suited to the special location of employment.			

APPENDIX D SHEET METAL THICKNESSES AND OVERLAPS FOR CLAD-DINGS WITHOUT MECHANICAL STRAIN

Circumference of casing mm	Sheet metal thickness Minimum mm	Overlap	
		Longitudinal minimum mm	Circumferential minimum mm
up to 1000	0,3	30	50
above 1000	0,4	30	50

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FESI Documents issued so far:

- 01: Insulation work on industrial plant - Ancillary work-calculation (September 1986).
- 02: Rules for carrying out thermal insulation work (working temperature higher than ambient temperature) (June 1988).
- 03: Rules for carrying out thermal insulation work (working temperature lower than ambient temperature) (January 1993).
- 04: Working manual: System for measurement and recording for industrial insulation cladding (February 1995).
- 05: Problems associated with the warranty of specified surface temperatures (October 1994).
- 06: High profitability through ecologically based insulation thicknesses (October 1994).
- 07: Heat insulation of refrigerated premises and buildings - Technical clauses (1995).
- 08: Principles of cold insulation (1997).
- 09: Principles of metal corrosion (1998).
- 10: Corrosion under Insulation; Problems and Solutions (2002).
- 11: Problems of thermal stress in metal reinforcements of large-dimensional objects with elevated service temperatures (1998).
- 12: Design of cold insulation to prevent formation of condensation (May 1998).
- A-1: Industrial and Building Acoustics - Code of Guarantee (May 1994).
- A-2: Basics of Acoustics (September 2001, 3rd revised edition).
- A-3: Product Characteristics – Acoustic Insulation, Absorption, Attenuation (2002).

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