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DATE | AUG/08/18 | FEB/18/19  
DESIGN | ESUP | ESUP        
EXECUTION | MARCHON | MARCHON    
CHECK | MARiano | TAMCAMPOS  
APPROVAL | JUVENTINO | JUVENTINO
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1. INTRODUCTION

This Technical Specification establishes requirements and gives recommendations for external thermal insulation of above ground surfaces of equipment, structures and piping.

Thermal insulation is applicable for the following main purposes:

- Heat Conservation through reduced heat transfer;
- Process Control through stabilization of process temperature;
- Condensation Control, Freeze Protection or boil-off control;
- Personnel Protection;
- Prevention of heat gain to surface of equipment operating at low temperatures.

The design and application of thermal insulation systems for equipment, structures and pipes operating at high temperature (hot insulation) shall follow the technical requirements and recommended practices contained in this Technical Specification.

This Technical Specification also establishes the required conditions for the design and application of thermal insulation for equipment, structures and pipes that operate at low temperature (cold insulation), but these requirements do not apply to services below -100°C.

2. NORMATIVE REFERENCES

All insulation design and services shall comply with the requirements of this technical specification, as well as the equipment/structure data sheets, design documents, and other documents as stated below and those referred to herein.

2.1. CLASSIFICATION

MANUFACTURER/PACKAGER shall perform the design and installation also in accordance with the requirements of the Classification Society.

2.2. CODES AND STANDARDS

The following codes and standards include provisions which, through reference in this text, constitute provisions of this specification. The latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used, provided it can be shown that they meet or exceed the requirements of the standards referenced below.

- ASME B 31.3 Process Piping
- API RP 583 Corrosion Under Insulation and Fireproofing;
- ASTM C 795 Standard Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel;
- ASTM C 871 Standard Test Methods for Chemical Analysis of Thermal Insulation Materials for Leachable Chloride, Fluoride, Silicate and Sodium Ions;
- ASTM C 1511 Standard Test Method for Determining the Water Retention (Repellency) Characteristics of Fibrous Glass Insulation (Aircraft Type);
- ASTM STP 880 Corrosion of Metals Under Thermal Insulation;
- CiNi Manual - 2011 Committee Industrial Insulation Standards
- ISO 1182 Reaction to fire tests for products - Non-combustibility test;
- ISO 9229 Thermal insulation - Vocabulary;
- ISO 12241 Thermal insulation for building equipment and industrial installations - Calculation rules;
- ISO 12944-2 Paints and varnishes - Corrosion protection of steel structures by protective paint systems. Part 2: Classification of environments;
Governmental codes, regulations, ordinances or rules applicable to the equipment in Brazil shall prevail over the requirements of above specification, including reference codes and standards and/or these engineering specifications, only in those cases where they are more stringent.

2.3. REFERENCE DOCUMENTS

- I-ET GENERAL PAINTING (document code as applicable to the specific project);
- I-ET METOCEAN DATA (document code as applicable to the specific project);
- I-ET PASSIVE FIRE PROTECTION (document code as applicable to the specific project).

2.4. CONFLICTING REQUIREMENTS

In case of conflicting information between this Technical Specification (hereinafter called ET) and the referred applicable standards, this ET shall prevail.

In case of conflicting information between this ET and other specific PURCHASER's Document (Data Sheet or Equipment List) see the basic design documentation priority guidelines, if applicable.

3. DEFINITIONS, MATERIALS AND ACCESSORIES

3.1. TERMS AND DEFINITIONS

Aerogel
A homogeneous, low-density solid state material derived from a gel, in which the liquid component of the gel has been replaced with a gas. The resulting material has a porous structure with an average pore size below the mean free path of air molecules at standard atmospheric pressure and temperature;

Americium 241
Nuclear isotope that emits fast, high-energy neutron radiation. Used to detect slow, thermal neutrons generated by collision with hydrogen atoms;

Calcium silicate
Insulation that is composed principally of hydrous calcium silicate and usually contains reinforcing fibers;

Cellular glass
Insulation that is composed of glass processed to form a rigid foam having a predominately closed-cell structure;

CiNi
Means Netherlands Industrial Insulation Committee, a nonprofit organization which cooperates with companies regarding standardization in the field of thermal insulation for industry.

Cold piping
Piping systems normally operating below the dew point;

CUF (corrosion under fireproofing)
Corrosion of piping, pressure vessels, and structural components resulting from water trapped under fireproofing;

CUI (corrosion under insulation)
External corrosion of carbon steel piping, pressure vessels, and structural components resulting from water trapped under insulation. External chloride stress corrosion cracking of austenitic and duplex stainless steel under insulation is also classified as CUI damage;

Dead-leg
Section of piping of a system where there is no significant flow. Examples include: blanked branches, lines with normally closed block valves, lines that have one end blanked, pressurized dummy support legs, stagnant control valve bypass piping, spare pump piping, level bridles, relief valve inlet and outlet header piping, pump trim bypass lines, high point vents, sample points, drains, bleeders, and instrument connections;

Deluge system
A network of open sprinklers that are all connected to water main pipe. When activation of the system takes place, all the sprinklers within the hazard zone are activated;
Fiberglass
Fiberglass is composed of pure glass containing various types of binders and is widely used as industrial insulation;

Fireproofing
A systematic process, including materials and the application of materials that provide a degree of fire resistance for protected substrates and assemblies;

Flexible elastomeric foams
These are flexible, closed-cell, rubber foams based on NBR or EPDM rubber. Flexible elastomeric foams exhibit such a high resistance to the passage of water steam that they do not generally require additional steam barriers;

Jacketing
The protective covering that is applied over insulation;

Mineral fiber
Insulation composed principally of fibers manufactured from rock, slag, or glass, with or without binders;

Mineral wool
A synthetic vitreous fiber insulation made by melting predominantly igneous rock, and/or furnace slag, and other inorganic materials and then physically forming the melt into fibers. To form an insulation product, there are often other materials applied to the mineral wool such as binders, oils, etc;

Mineral Fiber
Mineral fiber insulations are composed principally of fibers manufactured from rock, slag, or glass, with or without binders;

Perlite
Natural volcanic material that is heat expanded to a form used for lightweight concrete aggregate and fireproofing;

Polyurethane Foam
Polyurethane foam is an organic, closed-cellular foam that can be installed by spraying or casting in the shop or field;

Polystyrene Foam
There are two categories of polystyrene foam insulation: (EPS) foam and (XPS) foam. EPS foam is a closed-cell insulation that is manufactured by expanding a polystyrene polymer. XPS is a rigid, closed-cell insulation manufactured from solid polystyrene crystals;

Polyisocyanurate Foam
Polyisocyanurate is an organic, closed-cellular, rigid foam. It has low permeability and absorption characteristics and is typically used in cold service applications

PT
Liquid penetrant examination method;

Pulsed eddy current examination method (PEC)
An eddy current examination method that uses a stepped or pulsed input signal instead of a continuous signal used by conventional eddy current techniques. This technique has a greater penetration depth and is less sensitive to liftoff than conventional eddy current techniques;

Real-time radiographic examination method (RTR)
A nondestructive test method whereby an image is produced electronically rather than on film so that very little lag time occurs between the item being exposed to radiation and the resulting image;

Silica Aerogel
Silica aerogel is a synthetically produced amorphous silica gel that is distinctly different from crystalline silica;

Vermiculite
A group of minerals characterized by their ability to expand into long, wormlike strands when heated. This expansion process is called exfoliation.
Can
Can requirements are conditional and indicate a possibility open to the user of the standard.

May
May indicates a course of action that is permissible within the limits of the standard (a permission).

Shall
Shall is an absolute requirement which shall be followed strictly in order to conform to the standard.

Should
Should is a recommendation. Alternative solutions having the same functionality and quality are acceptable.

Environmental average temperature
- The temperature established by project documents. For Offshore projects, the environmental average temperature is specified in I-ET- METOCEAN DATA (document code as applicable to the specific project).

Metocean data
The set of meteorological data for a specific offshore project in the format of a technical document.

Insulation classes
- Hot insulation: the purpose is to reduce heat loss and to maintain temperatures for the efficient operation of the process. An additional goal of this insulation class is frost protection;
- Cold insulation: the purpose is to maintain low temperature and control heat input to the process. An additional goal of this insulation class is to prevent external condensation and ice formation;
- Personnel protection: Screening/insulation provided to keep the outside surface within a temperature range suitable to avoid safety problems due to skin contact with equipment and piping with hot or cold surface temperatures that can cause injuries or discomfort to personnel;
- Frost protection: insulation with or without heat tracing, to prevent freezing, solidification and internal condensation;
- External condensation and frost protection: Insulation whose purpose is to prevent exterior condensation on piping and equipment with operating temperatures below 20°C.

Condensation
The moisture forming on the surface of un-insulated or insufficiently insulated piping/equipment when the process temperature is below ambient. The rate of condensation depends on ambient temperature, relative humidity, and emissivity of bare surface or insulation jacketing, wind velocity and process temperature.

Boil-off
Boil-off is the vapor produced above the surface of a boiling liquid due to evaporation. It is caused by heat ingress or a drop in pressure.

Sealer
A substance, composed of various materials, used to retard the passage of water steam or liquid water into the joint formed by the mating surface of jackets and steam retarder over insulation. A good sealer will possess relatively little shrinkage. There are several types of sealers, such as non-setting, setting, and heat resistant.

Insulation professional
A skilled manual worker, usually a tradesman, in the insulation industry who has the expertise and knowledge needed to follow the insulation project requirements.

Examiner
Qualification process verification Person, employed by the Insulation Contractor, whose primary function is to supervise the apprenticeship (an on-the-job training program) program of the Insulation contractor. The examiner shall verify that all processes have been correctly followed and that all tests have been carried out in accordance with this Technical Specification. The material controller shall be part of the Quality Control team.

Material controller
Person, employed by the Insulation Contractor, who has responsibility for receipt, storage, and issuance of all materials and equipment at the construction site. The material controller shall be part of the Quality Control team.
Corrosion under insulation risk (CUI risks)
For definition of CUI risks see TABLE 1.

TABLE 1 - CUI RISK CATEGORIES

<table>
<thead>
<tr>
<th>Category</th>
<th>Vulnerability of CUI</th>
<th>Process temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Extreme</td>
<td>Cycling or dual process temperatures between -20°C and 320°C (or lower)(^\text{note 1}), inclusive</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>Process temperatures between 50 °C and 120°C, inclusive</td>
</tr>
<tr>
<td>3</td>
<td>Medium</td>
<td>Process temperatures between -5 °C and 50°C, inclusive</td>
</tr>
<tr>
<td>4</td>
<td>High</td>
<td>Process temperatures between 120 °C and 175°C, inclusive</td>
</tr>
<tr>
<td>5</td>
<td>Low</td>
<td>All process temperatures &gt; 175°C</td>
</tr>
<tr>
<td>6</td>
<td>Low</td>
<td>All process temperatures &lt; -5°C</td>
</tr>
</tbody>
</table>

Source: CiNi Manual
Note 1: Some Piping and Equipment cycling between higher temperatures (higher than 320°C) and ambient temperature are also classified as CATEGORY 1. One example is exhaust piping of diesel engines.

Principal
The Principal is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorized to act for the Principal.

Main contractor
The Main Contractor is the party that carries out all or part of the design, engineering, procurement, installation and commissioning or management of a project. The Principal may sometimes undertake all or part of the duties of the Main Contractor.

Insulation contractor
The Insulation Contractor is the party that carries out the insulation jobs, including engineering, material supply, installation and quality control.

Manufacturer/supplier/vendor
The Manufacturer/Supplier/Vendor is the party that manufactures or supplies materials, equipment and services to perform the duties specified by the Main Contractor and/or Insulation Contractor.
3.2. INSULATION MATERIALS

3.2.1. GENERAL

Thermal insulation is important to facility operations yet is often overlooked and undervalued. These materials can be used in either low- or high-temperature applications. Low-temperature insulations typically include polyurethane, polyisocyanurate, flexible elastomeric foams, cellular glass, and phenolics. These insulation types normally require a vapor barrier under the outer weatherproofing to minimize the potential for condensation of atmospheric moisture.

High-temperature insulations typically include perlite, calcium silicate, mineral wool, and cellular glass and fiberglass.

Insulation materials can be classified into one of the three categories listed below: Granular, Fibrous or Cellular.

FIGURE 1 - INSULATION MATERIALS

Table 2 lists the various types that are generally encountered in refining and petrochemical plants, along with the applicable temperature ranges specified for each insulation material in the appropriate ASTM specifications.

<table>
<thead>
<tr>
<th>Insulation Category</th>
<th>Material (ASTM)</th>
<th>Low Temperature Range</th>
<th>High Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>°F</td>
<td>°C</td>
</tr>
<tr>
<td>Granular</td>
<td>Calcium silicate (C533)</td>
<td>80</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Expanded perlite (C510)</td>
<td>80</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Silica aerogel (C1728)</td>
<td>-321</td>
<td>-197</td>
</tr>
<tr>
<td>Fibrous</td>
<td>Mineral wool (C547)</td>
<td>0</td>
<td>-18</td>
</tr>
<tr>
<td></td>
<td>Fiberglass (C547)</td>
<td>0</td>
<td>-18</td>
</tr>
<tr>
<td>Cellular</td>
<td>Cellular glass (C562)</td>
<td>-450</td>
<td>-260</td>
</tr>
<tr>
<td></td>
<td>Polyurethane</td>
<td>See Note</td>
<td>See Note</td>
</tr>
<tr>
<td></td>
<td>Polysocyanurate foam (C591)</td>
<td>-297</td>
<td>-183</td>
</tr>
<tr>
<td></td>
<td>Elastomeric foam (C634)</td>
<td>-297</td>
<td>-183</td>
</tr>
<tr>
<td></td>
<td>Polystyrene foam (C579)</td>
<td>-297</td>
<td>-183</td>
</tr>
<tr>
<td></td>
<td>Phenolic foam (C1126)</td>
<td>-290</td>
<td>-180</td>
</tr>
</tbody>
</table>

NOTE: Check with manufacturer for high and low temperature limits for rigid or sprayed materials.
3.2.2. GRANULAR-TYPE INSULATIONS

3.2.2.1. General considerations
Granular insulations are composed of small nodules that contain voids or hollow spaces. These materials are sometimes considered open-cell materials since gases can be transferred between the individual spaces. Calcium silicate and molded perlite insulations are considered granular insulations.

3.2.2.2. Calcium Silicate
Calcium silicate insulation is rigid pipe and block insulation composed principally of calcium silicate which usually incorporates a fibrous reinforcement. It is intended for use in high-temperature applications. If immersed in water at ambient temperatures, the material can absorb significant amounts of water (i.e. up to 400 % by weight)

Even when not immersed in water, the material can absorb up to 25 % by weight water in high-humidity conditions because of its hygroscopic nature. When exposed to water, the material has a pH of 9 to 10 and may be detrimental to alkyd or inorganic zinc coatings. Additionally, some manufacturers offer products with controlled or low chloride levels for specialty applications. The advantages and disadvantages for calcium silicate insulation are listed below.

- Advantages:
  - low thermal conductivity (when dry),
  - available in a variety of shapes/sizes,
  - available with low chloride levels.
- Disadvantages:
  - will readily absorb moisture,
  - fragile (i.e. brittle) and requires care to avoid breakage during installation,
  - chlorides can accumulate in service because of absorption and evaporation of water from the local atmosphere.

3.2.2.3. Expanded Perlite
Perlite is a volcanic rock containing from 2 % to 5 % bonded water. It is a chemically inert substance composed basically of silica and aluminum. The perlite is expanded by means of rapid heating at a temperature between 1475 °F and 2200 °F (800 °C and 1200 °C). The vaporization of the bonded water and the formation of natural glass results in the expansion of the perlite particles. These particles have a granular shape.

Expanded perlite insulation is either rigid pipe or block insulation composed of expanded perlite, inorganic silicate binders, fibrous reinforcement, and silicone water-resistant additions. These silicone additions provide protection from water absorption at temperatures below 600 °F (315 °C). The water resistance of the material is reduced at or above this temperature. Similar to calcium silicate, some manufacturers offer expanded perlite products with controlled or low chloride levels for specialty applications.

The required characteristics are those listed in ASTM C610 for perlite.

The advantages and disadvantages for expanded perlite insulation are listed below.

- Advantages:
  - water-resistant up to 400 °F (205 °C),
  - good resistance to mechanical damage,
  - available in a variety of shapes/sizes.
- Disadvantages:
  - more fragile than calcium silicate during installation,
3.2.2.4. Silica Aerogel

Silica aerogel is a synthetically produced amorphous silica gel that is distinctly different from crystalline silica. It is impregnated into a nonwoven flexible fabric substrate (i.e. batting) for reinforcement. Aerogels are good thermal insulators because they almost nullify convective, conductive, and radiative heat transfer. Silica aerogels have an extremely low thermal conductivity ranging from 0.03 W/m·K to 0.004 W/m·K that correspond to R-values of 14 to 105 for 3.5 in. thickness. Product forms can be as a flexible mat/blanket and include integral vapor barriers.

The required characteristics are as those listed in ASTM C1728 (for flexible Aerogel).

The advantages and disadvantages for silica aerogel insulation are listed below.

- Advantages:
  - highest thermal performance of any insulating material known,
  - significantly reduced thickness for equivalent performance to other insulating systems,
  - wide range of temperature applications (Note: may require a change in specific product to cover hot or cold insulation).

- Disadvantages:
  - aerogels may be hygroscopic,
  - need chemical treatment to be hydrophobic,
  - typically higher cost of materials (Note: installed cost and performance may provide economic justification).

3.2.3. CELLULAR-TYPE INSULATIONS

3.2.3.1. General considerations

Cellular insulations are classified as either open-cell structures where the cells are interconnecting or closed-cell structures where the cells are sealed from each other. Generally, materials that have greater than 90 % closed-cell content are considered to be closed-cell materials.

3.2.3.2. Cellular Glass

Cellular glass (also referred to as foam glass) is a closed-cell insulation composed predominantly of silica-based glass. It is made by adding powdered carbon to crushed glass and firing the mixture to form a closed-cell structure. It is commonly used on electric-traced or steam-traced piping for freeze protection or process control.

The low permeability and absorption characteristics of cellular glass make it an attractive choice for cold service and cryogenic applications. This insulation material does not wick water or liquids, and is used in hot service where the nonabsorbent/nonwicking properties are desirable. The material has a thermal conductivity rating between mineral wool and calcium silicate, and displays good compressive strength. It can be friable and brittle when subjected to mechanical abuse, and can crack when subjected to large temperature differences and thermal shock.

Cellular glass has the chemical resistance of glass. The material can suffer vibration-induced damage, and can also be prone to damage when boiling water is trapped between the pipe and the insulation. Cellular glass cells may break down over time and trap water. Stress relief cracking of cellular glass can also occur at service temperatures above 450 °F to 500 °F (230 °C to 270 °C). The manufacturer should be consulted for the best method for insulating systems operating above 450 °F (230 °C).

The advantages and disadvantages for cellular glass insulation are as follows.

- Advantages:
• does not absorb water,
• high resistance to mechanical damage when jacketed,
• thermal conductivity does not deteriorate with aging.

Disadvantages:
• susceptible to thermal shock if temperature gradient >300 °F (>150 °C);
• easily abrades in vibrating service and fragile before application;
• higher price when compared to other insulation types.

### 3.2.3.3. Organic Foams

This category of insulation materials includes polyurethane, polyisocyanurate, flexible elastomeric, polystyrene, and phenolic insulations. Except for flexible elastomeric insulation, they are classified as either rigid/closed-cell foams or flexible/closed-cell foams. Flexible elastomeric insulation is classified as flexible/closed-cell foam. These materials contain chlorides, fluorides, silicates, and sodium ions that can be leached from the insulation at temperatures above 212 °F (100 °C). The leachate produced can have a wide range of pH (i.e. 1.7 to 10). Accelerated corrosion can take place when the pH of the leachate is below 6.

The required characteristics are those listed in ASTM C534/C534M for elastomeric foam.

#### a) Polyurethane Foam

Polyurethane foam is an organic, closed-cellular foam that can be installed by spraying or casting in the shop or field.

Precast pieces are also available. Closed-cell foams are structures where all of the tiny foam cells are packed close together with no interconnected pores. The foam cells are filled with a low-conductivity gas, usually hydrochlorofluorocarbon, which helps the foam to rise and expand. It is an insulation product that is typically produced on site, and applied by certified applicators. Two liquid components, an organic isocyanate compound (i.e. diisocyanate) and an alcohol (i.e. polyol), are mixed at high or low pressure using a spray gun with the reacting mix being sprayed onto the substrate to provide a seamless seal.

Polyurethane foam is frequently used for preinsulated pipe joints. It has low permeability and absorption characteristics but can absorb water after prolonged service.

The required characteristics are as follows:

- With flame retardant;
- Chlorofluorocarbon gas free expander (CFC);
- Values of thermal conductivity according to ASTM C591 (In gutter, segment and plate) and injected;
- The required characteristics are those listed in ASTM C1029 for Injected Polyurethane.

The advantages and disadvantages for polyurethane foam insulation are as follows.

- Advantages:
  • low permeability and absorption characteristics (closed cell);
  • multiple product forms and easy to apply in the field;
  • provides a seamless seal.
- Disadvantages:
  • can be ignited and release toxic gases if exposed to an open flame;
  • sensitivity to ultraviolet (UV) radiation (sunlight);
  • can be vulnerable to some acids, caustics, solvents, hydrocarbons, and other chemicals;
b) Polystyrene Foam

There are two categories of polystyrene foam insulation:

- expanded polystyrene (EPS) foam and
- extruded polystyrene (XPS) foam.

EPS foam is a closed-cell insulation that is manufactured by expanding a polystyrene polymer. It is usually white and made of pre-expanded polystyrene beads. It is an aromatic, thermoplastic polymer made from the monomer styrene that is in solid (glassy) state at room temperature. When heated above 212 °F (100 °C), it flows sufficiently to permit molding or extrusion, becoming a solid when cooled.

XPS is a rigid, closed-cell insulation manufactured from solid polystyrene crystals. The crystals are fed into an extruder along with special additives and a blowing agent and melted into a viscous plastic fluid. After being forced through the extrusion die, the hot, thick liquid expands to become foam that is shaped, cooled, and trimmed to dimension. This continuous extrusion process produces a uniform closed-cell structure with a smooth continuous skin.

The advantages and disadvantages for polystyrene foam insulation are as follows.

- Advantages:
  - low thermal conductivity;
  - excellent resistance to water and water absorption from freeze-thaw cycling;
  - very stable and does not biodegrade;
  - resistant to photolysis.

- Disadvantages:
  - like other organic compounds, polystyrene is flammable;
  - when burned without enough oxygen or at lower temperatures, polystyrene can produce a number of chemicals including polycyclic aromatic hydrocarbons, carbon black, and carbon monoxide, as well as styrene monomers, which can irritate eyes, nose, and respiratory system;
  - primarily a cold system insulation material.

C) Polyisocyanurate Foam

Polyisocyanurate is an organic, closed-cellular, rigid foam. It has low permeability and absorption characteristics and is typically used in cold service applications. The material is flexible and has reasonable strength to provide resistance to light physical abuse. It has a low thermal conductivity. Disadvantages include combustibility and sensitivity to UV radiation (sunlight). Combustion may release toxic gases. Chemical resistance is generally good but can be vulnerable to some acids, caustics, solvents, hydrocarbons, etc.

The required characteristics are as those listed in ASTM C591 (in gutter, segment and plate).

The advantages and disadvantages of polyisocyanurate foam insulation are as follows.

- Advantages:
  - low permeability and absorption characteristics;
  - multiple product forms and easy to apply in the field.

- Disadvantages:
  - like other organic compounds, polyisocyanurate is flammable;
  - primarily a cold system insulation material;
3.2.4. FIBROUS-TYPE INSULATIONS

3.2.4.1. General considerations

This category of insulation materials includes mineral wool and fiberglass insulation. These materials are processed from molten state into fibrous form and combined with organic binders and pressed into rolls or sheets. The fiber length, fiber orientation, and type of binder used impact the ability of these materials to repel water. Upon breakdown of the binder, the wicking ability of these materials increases significantly and transmits moisture or corrosive solutions to the underlying surface. Mineral wools are unattractive to rodents but can provide a structure for bacterial growth if allowed to become wet.

3.2.4.2. Mineral Fiber

Mineral fiber insulations are composed principally of fibers manufactured from rock, slag, or glass, with or without binders. Molten glass, stone, or slag is spun into a fiberlike structure. Inorganic rock or slag is the main component (typically 98 %) of stone wool. The remaining 2 % organic content is generally a thermosetting resin binder (an adhesive) and a little oil. Though the individual fibers conduct heat very well, when pressed into rolls and sheets their ability to partition air makes them excellent heat insulators and sound absorbers. Mineral fiber has a lower thermal conductivity than calcium silicate and perlite. However, even with metal jacketing, mineral fiber is subject to mechanical damage because of its low compressive strength and lack of resiliency. This can lead to reduced insulation thickness and possibly open jacket seams where the jacket has been crimped and exposing insulation to moisture. If used at an elevated temperature, the organic binder that helps to hold the fibrous insulation together is burned away causing a further reduction in strength.

Fibrous insulations are readily permeable to vapors and liquids. For this reason, fibrous insulation is not used alone for low temperature applications where condensation can occur. Most fibers can readily wick hydrocarbons and water.

Sometimes hydrophobic treatments or coatings are applied to the insulation by manufacturer to reduce water absorption and wicking. These coatings do not eliminate water saturation when immersed, and the coating effectiveness may degrade in service after exposure to higher temperatures.

The advantages and disadvantages of polyisocyanurate foam insulation are as follows.

- Advantages:
  - has a lower thermal conductivity than calcium silicate and perlite;
  - low leachable chloride content (<5 ppm).
- Disadvantages:
  - fibrous insulations are readily permeable to vapors and liquids;
  - most fibers can readily wick hydrocarbons and water;
  - mineral fiber is subject to mechanical damage because of its low compressive strength and lack of resiliency;
  - chlorides can accumulate in service because of absorption and evaporation of water from the local atmosphere.

3.2.4.3. Fiberglass

Fiberglass is composed of pure glass containing various types of binders and is widely used as industrial insulation.

Fiberglass is mechanically weak like mineral fiber and shares the same disadvantages with respect to wicking and permeability.

The advantages and disadvantages for fiberglass insulation are as follows.
Advantages:

- noncombustible.

Disadvantages:

- compressing the material reduces its effectiveness;
- absorbs water;
- can cause skin allergies.

3.2.5. VAPOR BARRIER MATERIALS

A vapor barrier is required for cold service applications. This barrier should be continuous and is usually provided by a glass fiber reinforced mesh impregnated with three coats of an elastomeric material. This elastomeric material should be compatible with the insulation material and flexible at the lowest expected ambient temperature. If it is to be left uncovered (i.e. unprotected by metallic weather proofing), the vapor barrier should be resistant to solar radiation.

3.2.6. JACKETING

3.2.6.1. General considerations

Jacketing or weatherproofing is the final element of the system. In the form of a metallic covering, it should be considered mandatory for hot service but need only be used for cold service where the vapor barrier can be abused (mechanically damaged). Metallic jackets are manufactured from solid aluminum, zinc- or aluminum-coated sheet steel, or from stainless steel sheet metal. Jackets should be designed so that all joints are in the watershed position.

Adequate overlaps should be employed coupled with the use of elastomeric sealants to prevent ingress of water either by gravity, by capillary action, or by wind drift.

3.2.6.2 Jacketing Materials

Jacketing materials fall into two general categories, namely

a) Metallic jacketing and
b) Nonmetallic jacketing.

Metal jacketing is the most common jacketing material for insulation. Metallic jacketing materials include aluminum, steel, and stainless steel. Nonmetallic jacketing materials such as fiber-reinforced plastics and thermoplastics have limited use for jacketing applications because of their low melting temperatures and their lack of resistance to mechanical abuse.

a) Metallic Jacketing

Metal jacketing is supplied as thin sheets and can be smooth, corrugated, or embossed. The inner surface of metallic jacketing may be coated or covered with a moisture-resistant film to retard corrosion of the jacketing. The type of metallic jacketing material is type 316 stainless steel.

The primary strengths of metallic jacketing are the long service life and the familiarity with its use in refinery and chemical plant applications. The primary weaknesses of metallic jacketing are the difficulty to effectively seal jacketing against moisture ingress and the vulnerability of joints to damage in service (i.e. from foot traffic). When using metal jacketing, it is important to pay attention to draining of the insulation system as a whole and to provide a means of escape for moisture that has entered through the jacketing.

Metal accessories such as banding, fasteners, washers, elbows, etc. is typically Type 316 stainless steel.

b) Nonmetallic Jacketing

Thermoplastic jackets are made from a variety of thermoplastic materials that include polyvinyl chloride (PVC) and polyvinylidene chloride (PVDC), among others. Most often these materials are used for low-temperature applications.

They have a limited application in hydrocarbon plants usage since they have poor resistance to fire. They are used as smooth sheet materials and are often selected in applications where cleanliness is important because
they typically have better release properties than metal and are thus more easily cleaned. The plastics also have good resistance to a wide variety of chemicals and are not damaged by water. Nonmetallic jacketing falls into the following two main classes.

1) Preformed Jacketing—Preformed nonmetallic jacketing is supplied and applied in sheet form. The sheets are generally made from chlorosulphonated polyethylene synthetic rubber (CSPE). The material may or may not be reinforced with woven glass fiber reinforcement. Provided the appropriate adhesives are used, the material forms water tight joint seals. It is much less prone to damage from foot traffic than metallic jacketing.

2) Formed-in-place Jacketing—This type of jacketing is glass fiber reinforced epoxy or polyester applied to the outside of the insulation in an uncured state, and is cured in place to form a rigid jacket. Epoxy jacketing is limited to long straight pipe runs, liquefied natural gas loading lines for example, where factory based application is viable.

Polyester jacketing can be easily formed in the uncured state. The material cures rapidly when exposed to ambient UV light. If necessary, UV lamps can be used to accelerate curing. Polyester jacketing is easily sealed because of good adhesion both to itself and to metallic jacketing overlaps. Once cured, it is resistant to mechanical damage. Expansion/contraction joints may need to be installed to accommodate thermal expansion or contraction of the piping during service to prevent cracking of the material.

Nonmetallic jacketing materials need to be periodically inspected to ensure that the effects of aging are not compromising their fitness for purpose.

Metal jacketing is normally secured with stainless steel bands or screws. PVC jacketing is secured by solvent welding the seams and screws where necessary.

For storage tanks, wind conditions are one of the most critical items to consider when evaluating a jacketing system for large tanks. The tank size usually dictates the type of jacketing to be used over the insulation. Larger tanks require heavier jacketing to overcome high winds on large tank areas.

3.2.7. CAULKING

Caulking is used to seal insulation seams. Caulking is used to create a seal at junctions, terminations, and penetrations in the insulation to prevent the ingress of water. Over time, insulation caulking dries out, cracks, and loses its seal, so it is imperative to inspect for caulking deterioration and renew/replace damaged caulking to prevent moisture ingress.

Once the metal jacketing is applied, the seams are often caulked with a silicone or other type of sealant to prevent the ingress of water through the lap. In addition, there are extremely low permeability rated products such as polyvinylidene chloride resins that lock out oxygen and moisture. It is frequently used on urethane, extruded polystyrene foam, and foam glass because of their excellent vapor barrier properties.

Caulking should be done immediately after the insulation jacket is installed since moisture could enter through the open seams if left unsealed for a period of time. Protrusions or penetrations through the insulation, such as nozzles, support lugs, and so forth, should be sealed with a bead of good caulking compound. In order to achieve a satisfactory caulked joint, the separation between jacketing should not be greater than 3.2 mm (1/8 in.). A minimum of 6 mm (1/4 in.) of caulk should be applied to jacket joints. Caulking should not be featheredged since the life of the seal depends on a uniform material thickness. Feathered edges curl and pull away from the jacketing.

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Only silicone rubber caulking remains resilient for many years and is resistant to higher temperatures and many chemicals. Pigmented (i.e. colored) silicone rubber caulking provides a higher temperature and UV resistance compared to translucent-type caulk. With time, caulking materials dry out and lose flexibility.

Areas around nozzles, manways, and on vessel heads should be inspected periodically to maintain the integrity of the insulation system.
3.3. COMPLEMENTARY MATERIALS

3.3.1. INSULATING CEMENT

3.3.1.1. For Calcium Silicate
Additional requirements shall be required:
   a) Asbestos free;
   b) For the average temperature of 95°C, consider maximum thermal conductivity of 0.317 W / m.K;
   c) Maximum content of chlorides and fluorides shall meet the criteria of ASTM C795 for 300 and 400 series stainless steel equipment or piping.

3.3.1.2. For Expanded Perlite
The specifications must comply with the manufacturer’s instructions.

3.3.2. ASPHALT FINISHING MASS
Composed of asphaltic emulsion, resistant to weathering, containing reinforcing fibers, free from asbestos, and should not contain sand or diatom, and should be elastic and have a smooth and uniform surface, without cracks and without granules when applied and dried.

3.3.3. SEALANT

3.3.3.1. Non-Drying
Composition based on silicone rubber and operating temperature between –65°C and 260°C.

3.3.3.2. Dry
Composition of asphalt or elastomeric base, having as main characteristics:
   a) Continuous temperature range between –70°C and 60°C for elastomeric bases and –2°C and 60°C for the asphalt base, remaining flexible and adherent in the above temperature range;
   b) Volatile material ≤ 5%;
   c) Drying retraction ≤ 5%;
   d) Constant resilience;
   e) Must not keep the flame longer than 2 min when exposed to the burner flame “Bunsen”, for 3 min;
   f) Must be chemically compatible with the Polyurethane materials;

3.3.4. ASPHALT OR ELASTOMERIC BASE WATERPROOFING

3.3.4.1. The waterproofing of asphalt or elastomeric base or of asphalt polyurethane must be chemically compatible with the insulating materials used.

3.3.4.2. The temperature range for continuous use shall be in the following interval:
   a) Asphalt base: -20°C to 50°C;
   b) Elastomeric base: -35°C to 80°C.

3.3.4.3. Minimum percentage of solids shall be 50 % volume.

3.3.4.4. Flexibility must be such that no cracks are present when a film of thickness of 0.75 mm is folded with an arc of 120 ° on a mandrel of 3 mm in diameter.

3.3.4.5. The consistency should be compatible with the application method to be used.

3.3.4.6. The drying time must be at most 4 h.

3.3.4.7. Waterproofing agents must have the property of being self-extinguishing, of color Black, with a minimum emissivity of 0.90 or admitting a black paint application.

3.3.5. ASPHALT OR ELASTOMERIC BASE ADHESIVE

3.3.5.1. Asphalt or elastomeric base adhesives should be chemically compatible with the Insulating materials used.
3.3.5.2. Continuous temperature ranges shall be in the following ranges:
   a) Asphalt base: -20ºC to 50;
   b) Elastomeric base: -35ºC to 80ºC.

3.3.5.3. The consistency should allow application with a brush.

3.3.5.4. The maximum cure time for the polymeric adhesive should be 10 min.

3.4. ACCESSORIES

3.4.1. FIXING WIRE
Stainless steel wire, type 316, with a diameter of 1.20 mm.

3.4.2. TAPE AND FASTENING STRAP
3.4.2.1 316 stainless steel strip tape, conforming to ASTM A167 and A480 / A480M, width 12.7 mm or 19 mm and thickness 0.50 mm.
3.4.2.2 Polyester filament tape reinforced with "rayon" filaments, 25 mm wide, 0.24 mm thick, with adhesion in stainless steel sheet of 1 kgf / 25 mm, tensile strength of 60 kgf / 25 mm minimum and Elongation at the maximum rupture of 30%.
3.4.2.3 Acrylic foam tape covered on both sides with acrylic adhesive and polyethylene film to protect the adhesive layer. Basic dimensions: width 25 mm, thickness 1.2 mm and density 770 kg / m³.

3.4.3. SPRING
Helicoidal Spring, Stainless steel spring type 316, external diameter 12.7 mm; Wire diameter 2.5 mm; Useful length of 152 mm; total length of approximately 185 mm; Spring constant 7.4 N / m (0.75 kgf / mm) ± 10%.

3.4.4. SEAL
Stainless steel seal type 316, conforming to ASTM A167 and A480, 12.7 mm or 19 mm and with a thickness of 1.0 mm.

3.4.5. SCREW
3.4.5.1 Self-tapping Type A stainless steel screw type 316, 1/8 "diameter, 1/2" length, slotted pan head.
3.4.5.2 Self-tapping Type A stainless steel screw type 316, 3/16 "diameter, 3/4" length, hexagonal head with slotted, crimped.

3.4.6. WASHER
3.4.6.1 Stainless steel flat washer type 316, for 3/16 "bolt, 7/8" outside diameter, internal diameter of 7/32 inch and thickness of 1/16 inch.
3.4.6.2 Stainless steel flat washer type 316, for 1/8 inch bolt, 5/8 inch outer diameter, 5/32 inch inner diameter and 3/64 inch thickness.

3.4.7. CLIP
SAE 1010 plain carbon steel pressure clip with a thickness of 1 mm, square in dimensions 38 mm x 38 mm or round in diameter of 38 mm for 3/16 inch diameter pins coated with zinc nickel ASTM B841, Class I, type B / E, Grades 5 to 8 with stress relief and hydrogen, according to ASTM B849 and B850).

3.4.8. RIVET
Aluminum open or airtight rivet with steel mandrels with bulged flap, diameter nominal of 3.2 mm or 4.0 mm, type "pop".

3.4.9. SUPPORT
3.4.9.1 Steel support according to ASTM A36 / A36M, for the support of rigid insulation for insulation in vertical pipes or with a slope greater than 45º.
3.4.9.2 Support of treated wood (autoclave preservative treatment), polyurethane or polyisocyanurate of a minimum density of 150 kg / m³ or engineering plastic, for the support of pipes and equipment at low temperature.

3.4.10. QUICK COUPLING AND CLASP
Fastening and quick coupling of type 316 stainless steel, according to ASTM A167 and A480 / A480M.

3.4.11. ANCHOR PIN
SAE 1010 carbon steel anchor bolt, smooth, 3/16 inch diameter.

3.4.12. SUBSTRATE INSPECTION WINDOWS
Boxes for periodic measurements of thickness in pipes and pressure vessels.

4. DESIGN OF THERMAL INSULATION

4.1. GENERAL CONSIDERATIONS

4.1.1. Piping, equipment and structures shall be insulated when required by project documents. The design of thermal insulation systems for equipment, structures and pipes operating at high temperature (hot insulation) and at low temperatures (cold insulation) shall follow the technical requirements and recommended practices contained in this technical specification.

4.1.2. Piping and equipment shall be insulated according to the insulation classes, operating temperature and insulation thickness (when specified) defined in the design documents (for example: P&ID’s, data sheets, etc).

4.1.3. The required insulation thickness for the full range of operating temperatures shall be calculated with the aid of calculation software, for all pipeline diameters and flat walls. The results should be in the form of tables for easy reference.

4.1.4. General insulation thickness calculations are subdivided in two groups: hot insulation and cold insulation; both groups can be approached from different points of view.

4.1.4.1. For all calculation methods ISO 12241 shall be the basis for which insulation systems, formulas and factors are given.

4.1.4.2. For hot insulation the greater thickness resulting from the following approaches shall be used:
   a) Minimum Total Cost Method: For a given thickness the total cost is the sum of the cost of the investment itself and the cost of the energy lost through the insulation. When required by project the maintenance and operation costs shall also be considered;
   b) Personnel Protection: The calculation of the insulation thickness required for personnel protection is based on limiting the surface temperature to the maximum allowable value. This is a safety requirement;
   c) Special purpose requirements: The minimum required insulation thickness for purpose of Process Control or any other requirements established by the project.

4.1.4.3. For cold insulation the greater thickness resulting from the following approaches shall be used:
   a) Condensation control: When the process temperature is below the maximum ambient temperature, the minimum required insulation thickness which prevents surface condensation is calculated;
   b) Maximum Heat Gain: When the process temperature is below the maximum ambient temperature, the minimum insulation thickness is calculated required to achieve the maximum allowable heat gain;
   c) Special purpose requirements: The minimum required insulation thickness for the purpose of Freeze Protection, Process Control, boil-off control or any other requirements established by the project;
   d) Minimum Total Cost Method: For a given thickness the total cost is the sum of the cost of the investment itself and the cost of the energy lost through the insulation. When required by project the maintenance and operation costs shall also be considered.

4.1.5. Only thermal insulation materials and ancillary products with low total leachable chloride and fluoride concentration shall be used. These shall be tested to the standards of ASTM C 871, and the results shall fall within the range of acceptability as defined by ASTM C 795.
4.1.6. Mineral wool and Calcium silicate insulation materials shall not be applied directly over stainless materials, Austenitic Stainless steel (such as AISI 316 or AISI 316L), Duplex and Superduplex stainless steels or Superaustenitic stainless steels. An aluminum foil (wrapped around the equipment or pipe) is required to protect the base metal. Aluminum foil: composition shall be 99.9% Al and thickness 60 ± 10 µm.

4.1.7. The insulation material shall be non-combustible according to ISO 1182 (This requirement does not apply to jacketing materials).

4.1.8. Insulation systems shall be non-toxic and watertight. The use of materials containing asbestos is not permitted.

4.1.9. Clearance between the outside of insulation and an adjacent surface shall be a minimum of 25 mm, when adjacent surface is another pipe, and 150 mm for other cases.

4.1.10. When a rigid type of insulation is used, the design shall consider provision for longitudinal expansion and contraction.

4.1.11. Inspections holes shall be provided in filters, pipes and pressure vessels, in order to allow inspection for ultrasonic measurement for wall thickness loss. The location of these inspection holes shall be previously submitted for PETROBRAS approval.

4.2. THERMAL INSULATION DESIGN - HOT INSULATION

4.2.1. DIMENSIONING CRITERIA

4.2.1.1. For dimensioning the thermal insulation at high temperature, one or more of the following criteria must be adopted:
   a) Energy conservation;
   b) Personnel protection;
   c) Maintenance of the fluidity of the product;
   d) Phase stabilization.

4.2.1.2. The basic criterion for determining the thickness of the insulation(s) should be that of energy conservation.

4.2.1.3. The criteria of energy conservation, product fluid temperature maintenance and phase stabilization shall always be used in conjunction with the criterion of personnel protection, in cases where the latter is applicable.

4.2.1.4. When there is more than one design motif, the thicknesses should be calculated according to the corresponding criteria and the one with the highest value should be used.

4.2.1.5. For the dimensioning of the thickness of other insulators or for the criteria of maintenance of fluidity of the product (without steam or electric traces) and stabilization of phases, a specific calculation must be performed according to the guidelines of this Standard.

4.2.1.6. For the dimensioning of the insulation thickness by the criterion of maintenance of fluidity with use of steam or electric traces, the criterion of energy conservation, or specific calculation, must be used.

4.2.1.7. To estimate the thermal flow through the thermal insulation of equipment and piping, it is recommended to apply ASTM C 680 or ISO 12241.

4.2.1.8. When the thermal insulation is applied to 300 and 400 series stainless steel equipment or pipes, the insulation shall meet the criteria of ASTM C 795.
4.2.2. PIPING AND EQUIPMENT – MATERIAL SELECTION

4.2.2.1. Insulation material should be selected from Table 3.

TABLE 3 - PIPING AND EQUIPMENT – MATERIAL SELECTION (Hot Insulation).

<table>
<thead>
<tr>
<th>INSULATING MATERIAL</th>
<th>PIPING</th>
<th>TANK</th>
<th>PUMP AND TURBINE</th>
<th>PIPELINE</th>
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<td>VESSEL</td>
<td>HEAT EXCHANGER</td>
<td>ROOF</td>
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<td>AEROGEL</td>
<td>BLANKET</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
</tbody>
</table>

4.2.2.2. Pipe fittings or equipment should not be insulated in the following situations, except when recommended by the designer or supplier:

a) If heat loss is necessary, taking into account the process need;
b) Pumps operating at temperatures below 60°C, unless the melting point of the product is above ambient temperature;
c) Fans, blowers and reciprocating compressors, centrifugal and rotary;
d) Line flanges and flanged connections;
e) Pipes and equipment intermittently heated, such as:
   - Relief valves and relief systems (except for products with pour point above room temperature);
   - Sighs and drains (except for products with pour point above room temperature);
   - Torch system;
   - Drainage system;
f) Equipment or pipelines insulated internally (eg, coated with refractory concrete, ceramic fiber and other insulation materials);
g) Union type connections in piping;
h) Steam traps;
i) Mixers;
j) Expansion joint bellows;
k) Visual flow indicators;
l) Hoses;
m) Chillers and condensers, with their associated pipes;
n) Nameplate or other;
4.2.2.3. For removable thermal insulation (eg. bipartite boxes or thermal jackets) it is recommended to use flexible insulation.

4.2.2.4. No flexible insulation should be selected for pipes and equipment subject to vibration (except rotary equipment).

4.2.2.5. For insulation with flexible materials in places where mechanical resistance is required (eg trampling), rigid protection must be used (jacketing).

4.3. THERMAL INSULATION DESIGN - HOT INSULATION: SPECIFIC CONDITIONS

4.3.1. ENERGY CONSERVATION

4.3.1.1. The criterion of conservation of energy seeks to determine the thickness that offers the lowest total cost, considering the operational and investment costs in thermal insulation.

4.3.1.2. Operating costs are comprised of the costs of energy lost over its useful life (at current values). The costs of investment in thermal insulation are calculated from the costs of acquiring the materials and assembly the thermal insulation.

4.3.1.3. From the sum of operating and investment costs it is possible to determine the commercial thickness that offers the lowest total cost. As the sizing by this criterion depends on the energy costs, the materials and the service of assembly of the thermal insulation, then the "most economical solution" can vary over time, depending on the readjustments of these plots.

4.3.2. PERSONNEL PROTECTION AND / OR COMFORT

4.3.2.1. High temperature equipment or piping (external surface temperature above 60ºC), located in areas of access or transit of personnel for regular operational activities, shall be protected against direct contact with hot surfaces to prevent the occurrence of burns or to permit safe stay on site. This is understood as being located less than 2m from any floor or at a lateral distance of less than 1m from ladders or platforms, walkways, etc. The protection may be through a physical barrier or thermal insulation (see items below), with the exception of surface temperatures above 150ºC which shall be fully insulated.

4.3.2.2. For equipment or piping where heat loss is desirable or which are insulated internally, the use of a ventilated physical barrier, such as metallic screens (cages), shall be adopted whenever possible, in order to avoid the CUI phenomenon.

4.3.2.3. If the above is not possible or when heat conservation is necessary, when applying thermal insulation, the dimensioning of the insulation thickness should guarantee a temperature below 60ºC on the outside surface.

4.3.3. STABILIZATION OF INDUSTRIAL PROCESS PHASES

The phase stabilization criterion assumes the existence of a maximum permissible heat flow through the wall of the piping or equipment. The dimensioning of the thermal insulation thickness shall ensure that the resulting heat flow is less than that permissible for a specific service.

4.3.4. PRODUCT FLUID MAINTENANCE IN PIPES

4.3.4.1. The insulation must be dimensioned in such a way that the temperature of the product at the end of the line is at least 10ºC above its pour point.

4.3.4.2. Maintenance of fluidity of the product can be achieved by dimensioning the thermal insulation, in such a way as to reduce the energy lost by keeping the product warm, or by compensating the energy lost by heating with steam or electric traces.

4.3.4.3. When the maintenance of fluidity of the product is ensured by the compensation of the energy lost by the thermal insulation, by means of steam or electric heating, then the dimensioning of the thermal insulation must be according to the criterion of energy conservation.
4.4. THERMAL INSULATION DESIGN - COLD INSULATION

4.4.1. DIMENSIONING CRITERIA

4.4.1.1. This chapter establishes the conditions required in the thermal insulation design of equipment and pipelines operating at low temperature, but does not apply to services with operating temperatures below -100ºC.

4.4.1.2. This requirements apply to material selection and thermal insulation thickness sizing according to the following criteria:
   a) Moisture condensation control on the outer surface of thermal insulation;
   b) Heat energy conservation;
   c) Stabilization of industrial process phases;
   d) Personnel protection or comfort.

4.4.1.3. The basic criterion for determining the thickness of the thermal insulation is to use the concepts of energy conservation and moisture condensation control on the external surface of the thermal insulation.

4.4.1.4. When there is more than one design motif, the thicknesses should be calculated according to the corresponding criteria and the one with the highest value should be used.

4.4.2. PIPING AND EQUIPMENT – MATERIAL SELECTION.

4.4.2.1. Insulation material should be selected from Table 4.

### TABLE 4 - PIPING AND EQUIPMENT – MATERIAL SELECTION (Cold Insulation).

<table>
<thead>
<tr>
<th>INSULATING MATERIAL</th>
<th>PIPING</th>
<th>TANK</th>
<th>ROTATING EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AERIAL VESSEL EXCHANGER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INJECTED POLYURETHANE</td>
<td>● ● ● ●</td>
<td>1 1 2 2</td>
<td>● ● ● ●</td>
</tr>
<tr>
<td>PULVERIZED POLYURETHANE 4</td>
<td>● ● ● ●</td>
<td>● ● ●</td>
<td>● ● ● ●</td>
</tr>
<tr>
<td>PRE-MOLDED POLYURETHANE</td>
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<td>● ● ●</td>
<td>● ● ● ●</td>
</tr>
<tr>
<td>EXPANDED POLYETHYLEN</td>
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<td>1 1</td>
<td>● ● ● ●</td>
</tr>
<tr>
<td>CELLULAR GLASS</td>
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<td>● ●</td>
<td>● ● ●</td>
</tr>
<tr>
<td>ELASTOMERIC FOAM</td>
<td>● ● ●</td>
<td>● ●</td>
<td>● ● ●</td>
</tr>
<tr>
<td>AEROGEL</td>
<td>● ● ●</td>
<td>● ●</td>
<td>● ● ●</td>
</tr>
</tbody>
</table>

NOTES:
1. The injection of polyurethane in ceiling and side of tanks is allowed, providing that it is applied with removable forms to allow the execution of vapor barrier.
2. For "Cold Box" only granular expanded perlite should be used.
3. Admitted only to the support plates of the annular plate of the bottom of the tank.
4. Design and performance assurance are the responsibility of the applicator.

4.4.2.2. Pipe fittings or equipment should not be insulated in the following situations, unless recommended by the system designer or there is a risk of freezing:
   a) If heat gain is required, taking into account process requirements;
   b) Pipes and equipment sporadically cooled, such as:
      - Relief valves and relief systems;
      - Vents and drains;
      - Torch system;
4.5. THERMAL INSULATION DESIGN - COLD INSULATION: SPECIFIC CONDITIONS

4.5.1. ENERGY CONSERVATION

4.5.1.1. For the determination of the economic thickness, a specific study should be made that considers updated energy costs and installation of thermal insulation.

4.5.1.2. It is the responsibility of the designer to verify that the energy cost calculations presented in this Standard apply to his particular case or whether there are other costs to be considered, such as loss of production or loss of separation efficiency.

4.5.2. CONTROL OF MOISTURE CONDENSATION ON THE EXTERNAL SURFACE OF THERMAL INSULATION

Thermal insulation shall ensure, on the external surface, a temperature above the dew point.

4.5.3. PERSONNEL PROTECTION AND / OR COMFORT

4.5.3.1. Low temperature equipment or piping with external surface temperatures below 0°C, located in areas of access or transit of personnel for regular operational activities, shall be protected against direct contact with surfaces to prevent the occurrence of cold burns or to permit safe/comfortable stay on site. This is understood as being located less than 2m from any floor or at a lateral distance of less than 1m from ladders or platforms, walkways, etc. The protection may be through a physical barrier or thermal insulation (see items below).

4.5.3.2. The use of a ventilated physical barrier, such as metallic screens (cages), shall be adopted whenever possible, in order to avoid the CUI phenomenon.

4.5.3.3. If the above is not possible or when cold conservation is necessary, when applying thermal insulation, the dimensioning of the insulation thickness should guarantee a temperature above 0°C on the outside surface.

4.5.4. STABILIZATION OF INDUSTRIAL PROCESS PHASES

Calculation of the thickness of the thermal insulation by the concept of phase stabilization presupposes the existence of a maximum permissible heat flow through the wall of the piping or the equipment. This sizing requires an iterative calculation.
5. ASSEMBLY OF THERMAL INSULATION

5.1. SCOPE

5.1.1. This technical specification establishes the conditions required in the assembly of external thermal insulation of pipes, pressure vessels, heat exchangers, storage tanks, pumps and turbines operating at high and low temperatures, using rigid or flexible thermal insulation.

5.1.2. Storage of materials over a long period or in large quantities must be carried out in temporary or permanent warehouses, or in appropriate containers. Advanced storage of materials in the field should be limited to short term consumption.

5.1.3. Insulation materials and accessories should not be stored directly on the floor.

5.1.4. The storage of the insulating materials, accessories and others (sealants, adhesives, masses etc.) must comply with the manufacturer's instructions.

5.1.5. If the infiltration of water in hygroscopic or untreated materials waterproofing occurs, the materials should be discarded. For non-hygroscopic materials or waterproofing treatment, drying is allowed provided the material is not damaged or loses its characteristics during the process.

5.1.6. The assembly must not be carried out directly under rain, except when the site is dry and protected from bad weather.

5.1.7. Thermal insulation should not be mounted on wet surfaces with the presence of loose oxides, oily residues, greases and other foreign materials.

5.1.8. The installation of protective coatings should be done immediately after the installation of the insulation materials, in the same working day, unless the insulated materials are protected against bad weather. In addition, when there is the possibility of infiltration of water during the work shift, the thermal insulation shall not be left without the definitive protective coating.

5.1.9. Insulating materials which are soaked with water during assembly before or after installation of the definitive protective coating must be replaced. Non-hygroscopic or waterproofing insulation materials may require replacement if complete air drying is allowed prior to installation of the ultimate protective coating and no physical deterioration of the material.

5.1.10. The thermal insulation assembly should not be started until the following activities are completed:
   a) Hydrostatic or pneumatic pressure testing of equipment or piping;
   b) Coating/painting of the piping/equipment as applicable;
   c) Installation and testing of heating strokes.

5.2. THERMAL INSULATION ASSEMBLY - HOT INSULATION

5.2.1. GENERAL CONDITIONS

5.2.1.1. It is recommended that the thermal insulation be installed or disassembled when the piping or equipment is not heated. When high temperature assembly or disassembly is required, the applicable safety precautions should be taken.

5.2.1.2. The longitudinal and circumferential overlaps of type 316 stainless steel plates for insulation protection must be at least 50 mm and arranged in such a way as to avoid infiltration of water. When the longitudinal and circumferential overlaps are in a position where water infiltration may occur, the seams must be sealed with non-drying sealant.

5.2.1.3. The fastening of the fastening straps of the insulation and stainless steel plates of type 316, for protection of the insulation, must be done by means of seals, so that a minimum free length of 25 mm is obtained (see figure A-1).

5.2.1.4. When the insulation is made in multiple layers and the operating temperature is greater than 350ºC, the straps of the inner layers attached to the equipment or tubing (first layer) must be of type 316 stainless steel.

5.2.1.5. Straps, seals and wires must be of type 316 stainless steel.
5.2.1.6. The thermal insulation next to flanges must be interrupted and spaced apart in such a way as to allow the screws to be removed without causing damage to the insulation.

5.2.1.7. Weather protection from insulation termination should be performed with asphalt finishing mastic, for services up to 90°C, or with aluminum for services up to 600°C.

5.2.1.8. Stair supports, platforms, and other accessories in the junction with insulation shall be finished with non-drying sealant to prevent water infiltration. The coating Protection in these regions should be reinforced with clipping around the interference.

5.2.1.9. All bolts and rivets should be sealed with non-drying sealant to prevent infiltration of water through the hole in the protective coating.

5.2.1.10. When pipes, fittings, valves and equipment are protected by a physical barrier, instead of thermal insulation (exclusive) for personnel protection, it is recommended to install screens or perforated metal plates (See figure A-2).

5.2.2. SPECIFIC CONDITIONS - PIPING

5.2.2.1. Assembly of Rigid Insulators for Piping

5.2.2.1.1. The single-layer insulation must be assembled with the semicircular and longitudinal joints disjoined (See figure A-3).

5.2.2.1.2. The insulation in multiple layers must be assembled with the circumferential joints, semicircles and longitudinal joints disjoined from each other and those from the anterior layer (See figure A-3).

5.2.2.1.3. The attachment of each layer of rigid insulation material to piping shall be done through 316 type stainless steel wire or strap, spaced 50 mm from the ends of each piece.

5.2.2.1.4. For Piping with nominal diameter less than 6 inch, use type 316 stainless steel wire, diameter 1,25 mm, for Piping with a nominal diameter greater than 6 inch, use stainless steel type 316 tape with 12,7 mm.

5.2.2.1.5. Pipes supported directly on supports with rebar or similar shall have the insulation interrupted in the region of the support (See figure A-4).

5.2.2.1.6. Piping with skids must be insulated in the support region (See figure A-5).

5.2.2.2. Protection of Rigid Insulators for Piping

It should be in accordance with item 3.2.6 Jacketing.

5.2.2.3. Assembly of Flexible Insulators for Piping

The assembly of the flexible thermal insulation should follow the manufacturer's specific recommendations.

5.2.2.4. Protection of Flexible Insulators for Piping

It should be in accordance with item 3.2.6 Jacketing.

5.2.2.5. Bends, Tees, caps and Reductions

Pipe fittings (bends, tees, caps and reductions) should be insulated according to the following procedure described below in the case of rigid thermal insulation assembly:

a) Cut and assemble the same insulation used in the pipe, keeping the geometry of the accident, securing with wire or strap.

b) Apply a layer of insulating cement of 3 mm thick.

c) Perform insulation protection drive in accordance with item 3.2.6 Jacketing.

5.2.3. SPECIFIC CONDITIONS - VALVES, FLANGES AND UNIONS

For the thermal insulation of valves, and when necessary flanges and unions, it shall use removable bipartite boxes of 316 stainless steel plates, with a minimum thickness of 0,80 mm, using flexible insulation (See figure A-6 and A-7);
5.2.4. SPECIFIC CONDITIONS - PRESSURE VESSELS / HEAT EXCHANGERS

5.2.4.1. Rigid insulators for horizontal Pressure Vessels / Heat Exchangers

a) The circumferential joints of the insulation pieces shall be at least 1/3 of their length and the longitudinal (between layers) of half their width;

b) The horizontals shells must have, together with both heads, a ring 300 mm from the welding of the head to the shell, to tie the fastening straps of the insulation of the head;

c) For diameters less than or equal to 1800 mm, the attachment of the insulation to the shell shall be made by means of stainless steel belts of the type 316, 12.7 mm wide spaced 300 mm and covering the whole circumference of the shell;

d) For diameters greater than 1800 mm, the attachment of the insulation to the shell shall be made with stainless steel wire of type 316, 12.7 mm wide, spaced 300 mm apart and anchored to supports, spaced apart from each other by a maximum of 6000 mm;

e) For multi-layer insulation, the inner layers shall be lashed with 12.7 mm wide, with 316 stainless steel straps, spaced 300 mm apart, unless otherwise provided by manufacturers;

f) The region of the fastening brackets shall be filled with flexible material;

5.2.4.2. Flexible insulators for horizontal Pressure Vessels / Heat Exchangers

a) May use flexible materials in the formats of blanket, flexible panels or lashing modules;

b) The circumferential joints of the insulation pieces must be at least 1/3 of its length and the longitudinal (between layers) of half its width;

c) The horizontal shells must have, together with both heads, a ring 300 mm from the weld of the head to the shell, to tie the fastening straps of the insulation of the head;

d) The attachment of the insulation to the shell of the equipment must be done in such a way that there is no compression of the material by vibration of the equipment;

e) The region of the fastening brackets shall be filled with flexible insulation material;

5.2.4.3. Rigid insulators for vertical Pressure Vessels / Heat Exchangers

a) The circumferential joints of the insulation pieces shall be at least 1/3 of their length and the longitudinal (between layers) of half their width;

b) The vertical shells must have a ring 300 mm apart from the head of the top of the shell welding, together with both heads, to tie the head insulation fastening straps;

c) The shells of pressure vessels with a perimeter of more than 6000 mm and an operating temperature of more than 150 ° C shall be provided with a spring for each 6000 mm or fraction of the last layer of insulation material and of the protection plate, in the perimeter, in order to compensate for thermal expansion;

d) The thermal insulation shall be secured with 12.7 mm wide 316 stainless steel straps spaced 300 mm apart;

5.2.4.4. Flexible insulators for vertical Pressure Vessels / Heat Exchangers

a) May use flexible materials in the formats of blanket, flexible panels or lashing modules;

b) The circumferential joints of the insulation pieces must be at least 1/3 of its length and the longitudinal (between layers) of half its width;
The vertical shells must have, together with both heads, a ring 300 mm from the weld of the head to the shell, to tie the fastening straps of the insulation of the head;

d) The attachment of the insulation to the shell of the equipment must be done in such a way that there is no compression of the material by vibration of the equipment;

e) The region of the fastening brackets shall be filled with flexible insulation material;

5.3. THERMAL INSULATION ASSEMBLY - COLD INSULATION

5.3.1. Specific thermal insulation materials must be used for low temperature insulation.

5.3.2. All materials used must comply with this technical specification.

5.3.3. The guidelines of the manufacturers for the safe and correct handling of the materials must be followed.

5.3.4. For any cold insulation assembly service, a procedure for thermal insulation at low temperature, observing the aspects of health, safety and environment must be issued and followed.

5.3.5. The application procedure must be qualified for the projection or injection services of the polyurethane. The qualification of the procedure is not required for the assembly of preformed insulation.

5.3.6. The application procedure for the projection or injection services of the polyurethane, shall contain at least the following information:

   a) Distance from gun to plating;
   b) Gun operating pressure;
   c) Mixing ratio between the components of the insulation material;
   d) Application sequence indicating the thicknesses per layer and the thickness of the end insulation;
   e) Criteria and methods for the control of the quality of insulation and its constituent materials.

5.3.7. When applying polyurethane by injection, the application procedure must be qualified and contain at least the following information:

   a) Relation between the injection time and the volume of the empty space between the piece to be insulated and the box;
   b) Mixing ratio between the components of the insulation material;
   c) Positioning and number of holes for injection and / or breathing (except for tanks);
   d) Gun operating pressure;
   e) Criteria and methods for the control of the quality of insulation and its constituent materials.

5.3.8. In the application of pre-cast insulation, the application procedure shall contain at least the following information:

   a) Sequence detailing the conditions set out in this specification.
   b) Insulation materials to be applied (type, shape, dimensions, manufacturer and reference commercial;
   c) Accessory materials to be applied such as: sealants, waterproofing agents, adhesives, straps and fabrics, indicating characteristics, manufacturer and commercial reference;
   d) Method of application of sealants, waterproofing and adhesives, including method of thickness control;
   e) Criteria and methods for the control of the quality of insulation and its constituent materials.

5.3.9. Hydrostatic testing of piping, pressure vessels, heat exchangers and tanks (including Vacuum breaking valve test) must be performed prior to the application of the thermal insulation. In cases where this practice is not feasible (for example: at the seams of the pipes in insulated workshop), leave the regions to be inspected provisionally without insulation.

5.3.10. The technical recommendations and instructions of the manufacturers should be considered, except in cases of divergence to the explicitly described and recommended in this technical specification.
5.3.11. SPECIFIC CONDITIONS - PIPING

5.3.11.1. The insulation of pipe fittings must be run with the same material and thickness used for the insulation of the pipe or the unit to which they belong.

5.3.11.2. The start of the application of the insulation should only be allowed after the drying time to repaint the paint used to protect the tubing or equipment.

5.3.11.3. During application of the insulating material must provide precast protection provisionally against moisture until the steam barrier is applied.

5.3.11.4. The steam barrier must be applied, preferably during the same journey of job application of the insulating material.

5.3.11.5. Protection against weathering and mechanical damage should be applied as soon as possible, after drying of the steam barrier.

5.3.11.6. Polyurethane injection or projection services must be performed only with the following atmospheric conditions:
   a) Relative air humidity less than 85%;
   b) Ambient temperature above 10ºC;
   c) Wind speed less than 9 km/h (only for projection application);
   d) Surface temperature between 20ºC and 50ºC.

Note: The use of protections that are proven effective to conform to the conditions mentioned in the item above.

5.3.11.7. Precast insulation pieces shall be free of defects, such as or damaged limbs.

5.3.11.8. The parts of preformed insulation shall be prepared to conform to the application surfaces as well as adjacent parts.

5.3.11.9. Interference pieces shall be assembled to the same thickness as the insulation of the piping or equipment to which they belong, extending to a length equal to four times the thickness of the insulation or at least 300 mm. (See figure A-8).

5.3.11.10. The steam barrier and weather protection must be sealed at the locations of contact with the interference piece by applying a non-drying sealant based on a neutral curing silicone rubber to prevent moisture infiltration into the insulation. (See figure A-8).

5.3.11.11. In cases where the equipment or piping is subjected to high and low temperature, then a layer of rigid thermal insulation for high temperature.

Note: In cases where the selection of thermal insulation is not suitable for temperature, as per item above, then the steam-out operation should not be performed in order to preserve thermal insulation. In such cases, the use of inert gases at ambient temperature shall be provided.

5.3.11.12. The fastening of the fastening straps must be done by means of seals (see Figure A.1), so that a minimum free length of 25 mm is provided. On each side of the seal, a 100 mm overlap of the strap must be provided for future retighten.

5.3.11.13. Next to flanges, valves, nozzles, legs, among others, the insulation termination should receive waterproofing, according to Figure A.9. The waterproofing should be done as follows:
   a) Cut (chamfer) at 45° at the end of the insulation;
   b) Apply a steam barrier on the seam over the 45° cut, each side;
   c) Apply the main steam barrier, covering the barrier applied on the splice over the cut at 45° from the end;
   d) Mount the weather protection.

Note: In the case of flanges, the insulation material should terminate at a distance from the flange equal to 1.5 times the length of the flange bolt.
5.3.12. STEAM BARRIER

5.3.12.1. It must be composed of aluminized and self-adhesive elastomeric blanket with a thickness of 3 mm.

5.3.12.2. In interference parts, accessories or equipment of irregular geometry where it is not possible to apply the elastomeric asphalt blanket, the steam barrier option consisting of two layers of asphalt or elastomeric base waterproofing, interspersed with fiberglass fabric, with a total thickness of 3 mm.

5.3.12.3. Damage sustained by the steam barrier must be repaired immediately to prevent the infiltration of moisture into the insulation system.

5.3.12.4. When the finishing of the last insulation layer is porous or irregular, which does not allow the adhesion of the vapor barrier, asphalt-based paint must be applied over the insulation before installation of the steam barrier.

5.3.13. WEATHER PROTECTION

5.3.13.1. The longitudinal and circumferential overlaps of the weather protection plate shall be at least 50 mm and arranged in such a way as to avoid infiltration of water.

5.3.13.2. The fixing of the weather protection must not damage the steam barrier.

5.3.14. PRE-MOLDED INSULATOR:

5.3.14.1. Pipe-Straight Stretch

5.3.14.1.1. The first insulation layer should be applied directly onto the tubing and the subsequent layers should be applied over a continuous layer of asphalt or elastomeric septum sealant or waterproofing sealant.

5.3.14.1.2. The longitudinal and semi-circumferential joints shall be re-sealed with dry sealant or with asphalt or elastomeric base waterproofing.

5.3.14.1.3. The longitudinal joints should be offset by 90° between layers (or half of the width, in the case of plates or segments), according to Figure A.9.

5.3.14.1.4. Semi-circumferential joints of insulation parts of odd layers shall be offset at a length equal to one-half the length of the part and those of even layers of a length equal to one quarter of the length of the part of the anterior layer, as Figure A.9.

5.3.14.1.5. Contraction joints shall be provided for every 25 m of pipe length, as specified in Figure A.10.

Note: The existence of flange or valve along the stretch replaces the contraction.

5.3.14.2. Pipe-Curved Stretch or accessory

5.3.14.2.1. Isolation of curves, tees or reductions must be cut and apply the same material used on pipe keeping the geometry of the accident.

5.3.14.2.2. On flanges and valves the insulation should overlap to the insulation of the pipe in a length equal to the thickness of the pipe insulation.

NOTE 1 Valves must be insulated to the level of the gasket.

NOTE 2 For temperatures lower than -70 °C, a removable insulation for the stem and hand wheel must also be provided, so that it can be removed and reinstalled for operation valve manual.

5.3.14.2.3. The pipe supports must be insulated according to Figure A.11(1) and (2).

5.3.14.2.4. The steam barrier must be made according to item 5.3.12

5.3.14.2.5. For protection against weathering and mechanical damage of pipe fittings see item 3.2.6 Jacketing.

5.3.14.3. Heads and vessel Skirts and Rounded Heads of Heat exchangers

5.3.14.3.1. The application of insulation parts on the surface to be insulated must be started in the direction of to the bottom of the equipment.
5.3.14.3.2. The first layer of insulation must be fixed by applying an asphalt or elastomeric base adhesive to the workpiece in order to fix it to the surface of the equipment until the belts.

5.3.14.3.3. The top joints shall be offset at a length equal to one half the length or width of the insulation piece and, except for the first layer, rejoined with drying sealant.

5.3.14.3.4. The straps and seals shall be of type 316 stainless steel with a width of 12.7 mm, placed on a filamentous adhesive tape.

5.3.14.3.5. Apply asphalt or elastomeric waterproofing, with a wet thickness of 3 mm, completely covering the outer surface of the first layer of insulation, including straps and fastening seals, and should not contain bubbles or craters.

5.3.14.3.6. Apply the second layer of insulation on the waterproofing coating mentioned above, while the coating is still wet, thus allowing the second layer of insulating.

5.3.14.3.7. The joining of top joints should be done with dry sealant, constituting a sealing of all joints of the insulation piece.

5.3.14.3.8. The attachment of other layers shall follow the same procedure as described in 5.3.14.3.4, 5.3.14.3.5 and 5.3.14.3.6, wherein the outer surface of the last layer of insulation is to receive a steam barrier of according to 5.3.12.

5.3.14.3.9. The connection of the insulation of the top and that of the horizontal or vertical cylindrical vessel according to Figure A.12.

5.3.14.3.10. In the heads of pressure vessels and heat exchangers, should apply on the vapor barrier, a protection against bad weather and mechanical damage according to Item 3.2.6.

5.3.14.3.11. The isolation of heat exchangers heads must comply with in figures A.13 and A.14.

5.3.14.4. Input/output connections of equipment, Manhole and Instrument connections

5.3.14.4.1. Must be insulated according to Figures A.15 and A.16.

5.3.14.4.2. The removable insulation cover must be attached to the outer surface of the insulation layer of the equipment after application of the equipment steam barrier. Steam barrier removable should override the steam barrier in 50 mm equipment.

5.3.14.5. Horizontal Cylindrical vessel and Heat exchanger-Shell

The application of insulation should follow the described in 5.3.14.3.1 the 5.3.14.3.8.

5.3.14.6. Vertical Cylindrical Vessel- Shell

The application of insulation should follow the described in 5.3.14.3.1 the 5.3.14.3.8.
6. CORROSION UNDER INSULATION (CUI)

6.1. SCOPE

This Technical Specification also covers the design, and mitigation practices to address external Corrosion Under Insulation (CUI). The document discusses the external corrosion of carbon and low alloy steels under insulation and fireproofing and the external chloride stress corrosion cracking (ECSCC) of austenitic and duplex stainless steels under insulation.

6.2. DESIGN PRACTICES TO MINIMIZE CORROSION UNDER INSULATION (CUI)

6.2.1. GENERAL

Corrosion under insulation (CUI) is an external corrosion of carbon steel piping, pressure vessels, and structural components resulting from water trapped under insulation. ECSCC of austenitic and duplex stainless steel under insulation is also classified as CUI damage.

The design of hot and cold service insulation systems has to address certain specific requirements. Three of these requirements are common to both services and relate to coating of the substrate metal, selection of the insulation material and weatherproofing. A further requirement is the necessity for a vapor barrier in cold service. Each of these requirements is discussed in some detail below.

6.2.2. COATINGS FOR HOT AND COLD SERVICES

The coating system provides protection from corrosion when water penetrates the insulation system. The coating system needs to be capable of operation under intermittent immersion service. Intermittent service is defined in many specifications from major petroleum and petrochemical companies as 15% of time spent in the temperature range of risk. Equipment that operates or stands at ambient temperature for more than 15% of its expected life should also be coated.

Carbon steel should be coated with one of the following coating types: epoxy amine, epoxy polyamide, or zinc phosphate phenolic, all of which may be used up to the maximum temperature limits recommended by the manufacturer of the particular product. It should be emphasized that the coating manufacturer's application instructions be strictly followed to optimize coating performance. This includes such conditions as relative humidity/temperature limitations, standards of surface preparation, and the length of time between priming and topcoating to prevent intercoat adhesion difficulties. Requirements for coating shall always be in accordance with General Painting Technical Specification (I-ET-GENERAL PAINTING, as applicable to the project).

Thermal Spray Aluminum (TSA) is not considered as a suitable coating method for protecting against CUI damage.

If special protection is required, the surface should be degreased and then coated. Water glass (sodium silicate) is used to coat the surface when inhibited calcium silicate is the specified insulation material. A silicone-acrylic coating (guaranteed free from low melting point metals, e.g. zinc) is used when foam glass, mineral wool, etc., are the specified insulations. For stainless steel equipment, some operators specify wrapping the equipment with aluminum foil prior to insulating for additional protection by acting as both a physical and a galvanic barrier to preventing ECSCC.

6.2.3. CUI IN CARBON AND LOW ALLOY STEELS

CUI is defined as the external corrosion of piping and vessels that occurs when water gets trapped beneath insulation. CUI damage takes the form of localized external corrosion in carbon and low alloy steels. The factors that affect the amount of CUI damage under insulation include:

a) Duration of the exposure to moisture;
b) Frequency of the exposure to moisture;
c) Corrosivity of the aqueous environment;
d) Condition of protective barriers (e.g. coating and jacketing);
e) Equipment design issues;
f) Service exposure temperature;
g) Insulation type;
h) Condition of weather barriers and caulking;
i) Type of climate;
CUI damage is characterized by either general metal wastage or pitting due to the localized breakdown of passivity. It is a form of oxygen corrosion, and occurs on carbon and low alloy steel when exposed to moisture and oxygen.

Damage occurs when water is absorbed by or collected beneath the insulation due to breaks in the insulation or jacketing (cladding) and the moisture contacts the underlying exposed steel at metal temperatures between 32 °F (0°C) and 212 °F (100 °C). Water may come from numerous sources such as rainwater, a deluge system, spillage from process operations, leaking steam tracing, or condensation on the metal surface in humid environments.

When determining CUI susceptibility, a much broader operating temperature range should be considered, typically from 10°F to 350°F (–12°C to 175°C) because of fluctuations in operating temperature, ineffective insulation maintenance, temperature gradients within the equipment considered (long pipe runs, fractionation columns, heat exchangers, etc.), and various operating modes. Contaminants in the insulation such as chlorides and sulfides may contribute to the corrosivity of the environment.

In some instances, these differences arise because users have reported actual metal temperature for cui incidents, other users have reported actual process temperature in reports of CUI damage, and some have introduced a margin of safety. This has led to an expanding of the range where cui damage may occur. The temperature range that cui damage is most severe depends on many different factors but in many areas has been found to be at metal temperatures between 170°F and 230°F (77°C and 110°C) where corrosion reaction kinetics are the highest.

All operating conditions should be considered, including the out-of-service state, for equipment that is offline at ambient temperatures for significant periods of time. Equipment that cycles in and out of the CUI range during regeneration cycles, or is frequently out-of-service at ambient conditions, can experience aggressive CUI damage even though when in normal operation it is outside the CUI temperature range.

6.2.4. CUI DAMAGE BELOW 32°F (0°C) AND ABOVE 212°F (100°C)

The temperature range quoted for CUI can vary from one document to another, and may list temperatures where liquid water would not be predicted [i.e. below 32°F (0°C) and above 212°F (100°C)]. This is because users sometimes report the temperature where damage occurred based on the process operating temperature rather than the actual metal surface temperature. The key factor for CUI damage to occur is that a corrosive aqueous layer be present on the insulated metal surface during any operating period or during downtime.

One possible situation is where water breaches the insulation coming in contact with the metal surface temperature between 212°F and 350°F (100°C and 177°C). CUI damage could be occurring as the result of continual flashing of water at the hot metal surface that can concentrate chlorides on the metal surface. Even at surface metal temperatures up to 600°F (316°C), CUI could occur during operation if water reaches the metal surface during a shutdown period and flashes off during start-up. Another instance where CUI can occur is where deposits in a dead-leg reduce the surface metal temperature sufficiently to allow CUI to take place. Other examples include nozzles, platform support protrusions, etc. CUI damage may also occur in equipment operating at process temperatures below 32°F (0°C) as the result of cyclic exposure conditions above 32°F (0°C) or frequent unit shutdown. It is more important to determine whether water is breaching the insulation system rather than dwelling on what the exact temperature of the insulated metal surface during normal operation. It should be noted that it is very difficult for insulation jacketing/cladding systems to be leak tight. Section 7 and API 571 provide information on CUI inspection practices.

6.2.5. CUI IN AUSTENITIC AND DUPLEX STAINLESS STEELS

CUI damage in austenitic and duplex stainless steels is a form of ECSCC. As with all forms of stress corrosion cracking (SCC), cracking occurs when a susceptible metallurgy is exposed to the combined action of a corrosive environment and an applied/residual tensile stress. Susceptible materials include Type 300 series austenitic stainless steels. Duplex stainless steels, though more resistant than austenitic stainless steels, are not immune. A corrosive environment occurs when chlorides concentrate under the insulation at the surface of the austenitic stainless or duplex steel when the insulation becomes wet. Residual cold work from fabrication or residual welding stresses provides the tensile stresses necessary promote cracking.
Most CUI damage in austenitic stainless steels occurs at metal temperatures between 140°F and 350°F (60°C and 175°C) although exceptions have been reported at lower temperatures. Below 120°F (50°C), it is difficult to concentrate significant amounts of chlorides; while above 350°F (175°C), water is not normally present and CUI damage is infrequent. It should be noted that even austenitic stainless steel piping that normally operates above 500°F (260°C) can suffer severe ECSCC during start-up after insulation gets soaked from deluge system testing, from fire water, or from rain during downtime. Typically, CUI damage in austenitic and duplex stainless steels goes unnoticed until insulation is removed or a leak occurs.

CUI damage in duplex stainless steels occurs at higher temperatures than observed for austenitic stainless steels. Figure A-17 shows the results of SCC tests conducted on austenitic and duplex stainless steels. As can be seen from these results, SCC of duplex stainless steels does not occur until about 285°F (140°C) at very high chloride concentration levels. In general, there have been few reported cases of cracking in the industry, but those that have been reported were under severe conditions where SCC could be predicted. Some of the failures reported have been on offshore facilities and were attributed to ECSCC on relatively hot equipment.

6.2.6. AREAS SUSCEPTIBLE TO DAMAGE

Under the right temperature conditions, CUI damage can occur at any location that is insulated. CUI is somewhat insidious in that regard. It is not uncommon to find CUI damage in locations remote from the more predictable and susceptible locations. However, there are some areas within facilities that experience has shown have a higher susceptibility for damage. In general, areas with severe CUF damage are easier to identify visually than CUI damage because of cracks and staining of the fireproofing. Certain areas and types of equipment have a higher susceptibility for CUI damage.

6.2.7. GENERAL AREAS OF DAMAGE

There are a number of locations in oil or chemical processing facilities where CUI damage or CUF has a higher likelihood. Areas common to all equipment types are listed in Table 5.

Table 5 – Locations for CUI throughout process facilities

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Potential Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>General areas</td>
<td>Areas downstream of cooling towers exposed to cooling tower mist</td>
</tr>
<tr>
<td></td>
<td>Areas of protrusions (i.e. transition points) through the jacketing at manways, nozzles, and other components</td>
</tr>
<tr>
<td></td>
<td>Areas of protrusions through insulation for equipment/piping operating at or below ambient, or in cold service</td>
</tr>
<tr>
<td></td>
<td>Areas where insulation jacketing is damaged or missing</td>
</tr>
<tr>
<td></td>
<td>Areas where caulking is missing or hardened on insulation jacketing</td>
</tr>
<tr>
<td></td>
<td>Areas where the jacketing system is bulged or stained</td>
</tr>
<tr>
<td></td>
<td>Areas where banding on jacketing is missing</td>
</tr>
<tr>
<td></td>
<td>Areas where thickness monitoring plugs are missing</td>
</tr>
<tr>
<td></td>
<td>Areas where vibration has caused damage to the insulation jacketing</td>
</tr>
<tr>
<td></td>
<td>Areas exposed to steam vents</td>
</tr>
<tr>
<td></td>
<td>Areas exposed to process spills, the ingress of moisture, or acid vapors</td>
</tr>
<tr>
<td></td>
<td>Areas exposed to deluge systems</td>
</tr>
<tr>
<td></td>
<td>Areas insulated solely for personnel protection</td>
</tr>
<tr>
<td></td>
<td>Areas under the insulation with deteriorated coatings or wraps</td>
</tr>
<tr>
<td></td>
<td>Areas with leaking steam tracing</td>
</tr>
<tr>
<td></td>
<td>Pipe and flanges on pressure safety valves</td>
</tr>
<tr>
<td></td>
<td>Systems that operate intermittently above 250°F (120°C)</td>
</tr>
<tr>
<td></td>
<td>Systems operating below the atmospheric dew point</td>
</tr>
<tr>
<td></td>
<td>Systems that cycle through the atmospheric dew point</td>
</tr>
<tr>
<td></td>
<td>Ice-to-air interfaces on insulated systems that continually freeze and thaw</td>
</tr>
</tbody>
</table>

All equipment is shut down at some time or other. The length of time and the frequency of the downtime spent at ambient temperature may well contribute to the amount of CUI that occurs in the equipment.

6.2.8. PRESSURE VESSELS

6.2.6.1 In addition to the areas listed in Table 1, there are other areas in vessels, columns, drums, and heat exchangers where CUI may have a higher likelihood. These are shown in Table 6.
6.2.9. PIPING

In addition to the areas listed in Table 5, there are other areas in piping where CUI may have a higher likelihood and includes process piping, refrigerated piping, piping at or below grade, and pipe supports. Susceptible locations for CUI in piping are listed in Table 7.

Table 7 – Susceptible locations for CUI in piping

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Potential Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piping</td>
<td>Dead-legs, vents, and drains</td>
</tr>
<tr>
<td></td>
<td>Pipe hangers and supports</td>
</tr>
<tr>
<td></td>
<td>Valves and fittings</td>
</tr>
<tr>
<td></td>
<td>Bolted on pipe shoes</td>
</tr>
<tr>
<td></td>
<td>Steam-tracing/electric-tracing tubing penetrations</td>
</tr>
<tr>
<td></td>
<td>Termination of insulation at flanges and other piping components</td>
</tr>
<tr>
<td></td>
<td>Carbon/low alloy steel flanges, bolting, and other components in high alloy piping</td>
</tr>
<tr>
<td></td>
<td>Jacketing seams on the top of horizontal piping</td>
</tr>
<tr>
<td></td>
<td>Termination of insulation on vertical piping</td>
</tr>
<tr>
<td></td>
<td>Areas where smaller branch connections intersect larger diameter lines</td>
</tr>
<tr>
<td></td>
<td>Low points in piping with breaches in the insulation</td>
</tr>
<tr>
<td></td>
<td>Close proximity to water (e.g. wharf) and/or ground (e.g. increased absorption)</td>
</tr>
<tr>
<td></td>
<td>Wet due to flooding or submerging into water</td>
</tr>
<tr>
<td></td>
<td>Damage due to foot traffic</td>
</tr>
</tbody>
</table>

6.2.9.1. COLD PIPING

In this Technical Specification, cold piping is considered to be piping carrying liquid or gases that cool the piping to temperatures below the dew point. Cold piping is prone to corrosion because of condensation with CUI often occurring in locations remote from the predictable and susceptible locations. The condensation present can freeze in cases where the temperature of the outside surface of the piping decreases below freezing. In many cases, such as ammonia terminals, piping temperatures can swing from ambient to −30°F (−27°C) during periods when ammonia is flowing in the piping. This temperature swing leads to continuous freezing and thawing, and results in wet conditions that increase the piping system susceptibility to CUI damage. Additionally, other equipment and components such as tanks, pressure vessels, pipe supports, and flanges connected by this piping may be affected by the runoff of melting ice or condensed water.
6.2.7.3 Ice layers can form on piping operating at temperatures below freezing and can obscure the view of external surface damage due to a continuous wet environment. In many cases, piping used for these cold temperature applications is insulated. Frequent chilling and condensation accelerates corrosion at points where the insulation system is breached, which exposes the surface of the piping to the atmosphere (i.e. ice-to-air interfaces). Water ingress, due to poorly sealed insulation jacketing, can result in ice buildup causing swelling of the insulation and create a larger area of damage to the insulation system. This repeated condition creates more and more exposure and susceptibility to corrosion.

Some common areas where breaches in insulation may occur and promote condensation are shown in Table 8.

Table 8 – Susceptible locations for CUI in piping operating below the dew point

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Susceptible Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold piping</td>
<td></td>
</tr>
<tr>
<td>Pipe supports</td>
<td></td>
</tr>
<tr>
<td>Insulation</td>
<td>termination areas such as pipe-to-flange locations</td>
</tr>
<tr>
<td></td>
<td>Flanges with stud bolts where insulation bonnets are installed but not sealed</td>
</tr>
<tr>
<td>Piping below flood grade where rising water penetrates the insulation jacketing causing ice lens with swelling that causes jacketing failure</td>
<td></td>
</tr>
<tr>
<td>High foot traffic areas where insulation is degraded by contact with human traffic</td>
<td></td>
</tr>
<tr>
<td>Areas on the insulation jacket showing signs of continual surface condensation or mold</td>
<td></td>
</tr>
<tr>
<td>Holes or cuts in the insulation vapor retarder or jacket</td>
<td></td>
</tr>
<tr>
<td>Ice-to-air interfaces</td>
<td></td>
</tr>
</tbody>
</table>

6.2.9.2. PIPE SUPPORTS

The accumulation of water can occur at locations remote from the point of intrusion, especially in services where the surface temperature does not cause the water to evaporate. For example, this can occur on a horizontal line in the middle of a span between pipe supports where the insulation is missing at the supports. Yet evaporated water may also travel through the insulated system and condense in areas with a lower surface temperature.

There are many process units that operate at temperatures as low as –320°F (–196°C) in chemical plants, refineries, and LNG facilities. In addition to supporting the piping and permitting limited movement, pipe supports in these applications need to be insulated to increase the efficiency of the piping system by not allowing heat to transfer into the process fluids contained in the piping.

Whenever possible, pipe supports should be located outside the insulation system.
APPENDIX A – FIGURES

Figure A-1 – SEAL

Figure A-2 – THERMAL PROTECTION FOR VALVES
Figure A-3 – DISPOSAL OF THE RIGID THERMAL INSULATING JOINTS IN PIPES

Figure A-4 – PIPES SUPPORTED ON BRACKETS WITH REBAR
Figure A-5 – PIPES WITH SKATES

Figure A-6 – THERMAL INSULATION OF VALVES

Figure A-7 – THERMAL INSULATION OF FLANGED CONNECTION
FIGURE A-8 - PART INSULATION INTERFERENCE CONNECTED TO PIPE.

FIGURE A-9 - DISPOSITION OF PRE-MOLDED INSULATED PART.

(Note: a = Staat Barrier  
b = Protection against intereirios)
FIGURE A-10 - TYPICAL INSULATION OF FLANGED CURVES AND EXPANSION JOINTS

FIGURE A-11.1 - ISOLATED SUPPORT FOR AIRLINES

Note 1: Preservative treatment of wood in autoclave;
Note 2: For supports where there is occurrence of shear stresses, wood must be used;
Note 3: Minimum support length 210 mm,
TECHNICAL SPECIFICATION

Nº: I-ET-3010.00-1200-431-P4X-001
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FIGURE A-11.2- DETAIL OF INSULATED SUPPORT

FIGURE A-12- FIXING THE INSULATION PRE-CAST IN THE SHELL- CAP JOINT

Note 1: Dimensions in millimeters.
Note 2: The top and longitudinal joints of the 2nd layer of the insulation plates are offset from those of the 1st layer.
Note 3: Apply a continuous layer of dry sealant to all joints.
FIGURE A-13- ISOLATION OF ROUNDED HEAD OF HEAT EXCHANGERS.

Figures:
- FIGURE A-13- ISOLATION OF ROUNDED HEAD OF HEAT EXCHANGERS.
- FIGURE A-14- INSULATION OF THE HEAT EXCHANGER REEL.

Text:
- **Note 1:** Dimensions in millimeters.
- **Note 2:** a = Vapor barrier
  b = Protection against impeachment
- **Note 3:** T = Insulation Thickness.
FIGURE A-15 - INPUT / OUTPUT CONNECTION OF EQUIPMENT OR INSTRUMENT CONNECTION.

FIGURE A-16 - INSULATION OF MANHOLE.

NOTE 1: Dimensions in millimeters.
NOTE 2: a = Vapor Barrier
       b = Protection against inclement weather.
NOTE 3: The 4T measurement (min. 300) must only be obeyed for instrument connection.

To remove the removable, cut off the steam barrier in this region.

To remove the removable, cut off the steam barrier in this region.

NOTE 1: Dimensions in millimeters;
NOTE 2: a = Steam barrier;
       b = Weather protection;
NOTE 3: T = Insulation thickness.
FIGURE A-17- SCC TENDENCY OF AUSTENITIC AND DUPLEX ALLOYS.