IMM STANDARD

IMM IN01:2023

GENERAL REQUIREMENTS FOR INDUSTRIAL THERMAL INSULATION

INSTITUTE OF MATERIALS, MALAYSIA

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Foreword

Institute of Materials, Malaysia (IMM) is a non-profit professional society that promotes honourable practice, professional ethics and encourages education in materials science, technology and engineering. Engineers, academicians, technicians, skilled workers and professionals are amongst its members exceeding 6800. Registered with the Registrar of Societies on 6th November 1987, the Malaysian Materials Science & Technology Society (MMS) changed its name to the Institute of Materials, Malaysia (IMM) on 16th June 1997. The objectives of the IMM include the following:

- Training and development of individuals and companies in Malaysia to attain professional recognition in various fields of materials science, technology and engineering.
- Development of IMM standards as recommended guidelines for good technical practice for consideration and implementation by various industries of materials science, technology and engineering.

IMM IN01:2023, General Requirements for Industrial Thermal Insulation was developed by the IMM Insulation Committees and Standard Development Committees.

This standard will be subjected for review to reflect current needs and conditions. By the introduction of this standard, IMM aims to improve the overall landscape, skill and competencies of all insulation industry players in the country.

Users and other interested parties may submit comments on the contents of this standard for consideration in future versions.

Compliance with this Standard does not of itself confer immunity from legal obligations.

GENERAL REQUIREMENTS FOR INDUSTRIAL THERMAL INSULATION

1. Introduction

1.1 Purpose

This Standard is intended to provide practical guidelines to Malaysian industries by outlining acceptable current best practices in industrial thermal insulation, focusing on thermal insulation materials selection principles, under widely differing conditions. Design engineers, general contractors, fabricators and insulation contractors may find this guide helpful.

1.2 Scope

This Standard emphasizes the general requirements for industrial thermal insulation systems, which are applicable to Malaysia's climate condition and environment. This Standard covers the general thermal insulation requirements for industrial applications for the temperature range between -200°C to 800°C.

This Standard includes:

i. Insulation materials selection guidelines and basic system design in thermal insulation
ii. Industrial practical installation methods and safety protection
iii. General inspection and maintenance of the thermal insulation system

NOTE. The requirement of thermal insulation is stated in various specifications and standards, namely PTS 39.46.00.31, CINI 1.3.01 & 1.3.02a, ASTM C1696-20 and JIP 33 S-738 (to mention a few). However, not all the thermal insulation requirements in these standards are applicable to Malaysia's climate condition and some standards are limited to specific industrial purposes. IMM IN01:2022 General Requirements for Industrial Thermal Insulation was developed with respect to general practices which is applicable in Malaysia's thermal insulation industries. Hence, there is a need to establish a reference standard for thermal insulation, with an extension of the general industrial practices of thermal insulation that is suitable for Malaysia's context.

1.3 Limitation

This standard does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Although some insulation system designs can serve as fire protection, this Standard does not address the criteria specific to that need. It will however address the fire properties of insulation materials.

This Standard is not intended for the insulation of buildings, civil structures, burners, furnaces, subsea equipment and piping.

It is also not intended for insulated ducting for heating, ventilation and air conditioning (HVAC).

2. References

Applicable parts of the Practices, industry codes and standards shall be considered an integral part of this Practice. The list of these references is listed in Bibliography. Short titles will be used herein where appropriate.

3. Insulation Materials

3.1 General Requirements

3.1.1 Insulation materials and ancillaries shall be asbestos free.

3.1.2 All insulated metal surfaces shall be suitably treated and protected with a complete coating in accordance with industry standards.

3.1.3 Insulation materials for piping and equipment of austenitic stainless steel or subject to stress corrosion cracking shall meet the requirements of ASTM C795.

3.1.4 Material surface burning characteristics in general can be tested with ASTM or BS standards depending on the acceptance of the project by the Owner.

3.1.5 Material properties in Annex 1 at the last section of this Standard serves as minimum specification requirements and can be used as reference for material selection.

3.2 Categories

Insulation materials fall into the following two general categories based on the operating and service temperature range:

3.2.1 Cold insulations
3.2.2 Hot insulations

3.3 Cold Insulation Materials

3.3.1 Cold insulation materials may include:

3.3.1.1 Cellular glass
3.3.1.2 Polyisocyanurate (PIR)
3.3.1.3 Flexible elastomeric foams (FEF)
3.3.1.4 Aerogel

Note: All the materials mentioned above are approved materials as per JIP33 - S738 December 2020.

3.3.2 The closed-cell structure of these materials provides natural resistance to absorption and permeation by external water and water vapour as well as to absorption of leaking process chemicals. Closed-cell insulations are frequently chosen for low-temperature applications in which control of moisture permeability is important. ASTM E96 is a test method for water vapour permeability that can be applied to all insulation materials. ASTM C240 is a water absorption test method that is published for cellular glass. For both test methods, the lower the permeability value, the higher resistant of the material towards water absorption.

3.3.3 The acceptable temperature application of the elastomeric foams shall follow the manufacturer's recommendation. Cellular glass is made from inorganic material that gives a wider, usable temperature range and applicability in elevated temperature service in which absorption resistance is needed.

3.3.4 In applications below ambient temperature, most of the cold insulation materials should be used with a separate vapour barrier equipped with a weather-proof jacket. All outer-layer joints should be sealed using the insulation materials in consideration of condensation occurrence. Typically, fibrous materials are not designed for cold condensation control insulation.

3.3.5 Rigid insulation material typically has higher compressive strength, while flexible materials provide easier handling or installation.

3.3.6 If the application of thermal insulation is exposed to ultraviolet (UV) light for extended periods of time, it is recommended to use UV protective finishing for organic closed-cell materials that are prone towards UV deterioration.

3.3.7 Aerogel insulation blanket for cold insulation shall be flexible and hydrophobic. The material shall come with a factory-laminated vapour barrier for cold insulation applications.

3.4 Hot Insulation Materials

3.4.1 Hot insulations may include:

3.4.1.1 Mineral wool
3.4.1.2 Perlite (also known as Expanded Perlite)
3.4.1.3 Calcium Silicate
3.4.1.4 Aerogel
3.4.1.5 Alkaline Earth Silicate (AES)

Note: All the materials mentioned above are approved materials as per JIP33 - S738 December 2020.

3.4.2 The fundamental difference between the fibrous insulation and granular insulation are the raw material from which they are made. Mineral wool is spun or drawn from volcanic rock or manufactured from molten rock, slag or glass, while granular insulation (include calcium silicate and perlite) is made into granular form.

3.4.3 Fibrous insulation and calcium silicate have higher moisture permeation and can absorb water or chemicals if exposed to liquid or vapor.

3.4.4 The fibrous insulation has advantages in terms of flexibility shaping and susceptible to compression. However, it is not recommended to use as piping supportive system in damage-prone areas.

3.4.5 Granular insulations can be used as piping supportive system as they have higher density and compression strength than most fibrous and closed-cell materials.

3.4.6 When corrosion under insulation (CUI) is a concern, perlite may be used as it resists moisture permeability and combat CUI using the corrosion inhibitors that it carries.

3.4.7 Aerogel insulation blanket for hot insulation shall be flexible and hydrophobic up to 300℃. Hydrophobic aerogel insulation is commonly acknowledged to provide CUI mitigation and applicable when there is a high thermal conservative requirement or high moisture condition.

4. Jacketing Materials and Accessories

4.1 Jacketing

The jacket is a key part of an insulation system. The primary function of the jacket is to protect the insulation material from the impact of the exterior environment, such as moisture and mechanical force.

4.1.1 Aluminium Jacketing

The most commonly used jacket material in processing plant applications is aluminium. The aluminium materials are available in several thicknesses and finishes depending on the application. The two major aluminium finishes are stucco-embossed and smooth. Stucco-embossed aluminium has a rough finish that is rolled into the sheet metal during manufacture. The benefit of this finished surface is less visible when there is minor surface damage occurred. A smooth jacket surface has an advantage in ease on cleaning.

Increasing the thickness of the jacket and adding corrugations help improves the damage resistance of jacketing.

Corrugations increase the bending strength which is perpendicular to the axis of the jacket's corrugations.

Corrugated jackets should not be used on horizontal surfaces if the corrugations are oriented parallel to the horizontal axis, because water can be held in the troughs formed by the corrugations on the top surface. This water can flow to the joints in the jacket and penetrate the insulation system.

Aluminium has excellent weathering characteristics under normal industrial atmospheres. If chemical exposure such as caustics and chloride salts are likely to occur on aluminium jackets, a corrosion specialist should be consulted to determine the appropriate jacket material. Aluminium jacket can be obtained with a coating to improve its chemical resistance, provide color-coding, or increased emissivity.

4.1.2 Stainless steel jacketing

Stainless steel jacketing is used if corrosion or fire resistance is needed. Stainless steel has a higher melting point than aluminium and remains intact longer during an external fire. Stainless steel jacketing can also be used in thinner sheet and provide better damage resistance due to its high specific gravity and relatively good mechanical strength.

4.1.3 Zinc Aluminium Alloy-Coated Steel Jacketing

Zinc aluminium alloy-coated steel jacketing is used when mechanical strength or fire protection is needed.

In the event of fire, zinc aluminium alloy-coated jacketing should not be used on stainless steel pipe or equipment due to the potential risk of zinc embrittlement. Zinc embrittlement occurs when the zinc coating melts and contacts with austenitic stainless steel. The molten zinc penetrates the stainless steel surface and causes crack propagation. The welding areas are prone to this type of cracking.

4.1.4 Non-metallic Jacketing

Non-metallic jackets are also commonly used depending on project requirements and specifications. The typical non-metallic claddings are glass fibred reinforced polyester (GRP) and chlorosulphonated polyethylene (CSPE). Non-metallic shall be weather resistant.

4.2 Vapour Barriers

Insulation systems that operate below ambient dew point temperature must be protected from the internal permeation of moisture. Water vapour permeability is measured using ASTM E96 standard, and the results are reported in "perms". Lower perm ratings represent better resistance towards moisture penetration and are suitable for low temperature applications where condensation may occur. Closed-cell insulation materials have low perm ratings, while fibrous and granular materials are generally not evaluated for permeation.

As an added measure of resistance against moisture penetration, an additional vapour barrier is added to the external surface of the insulation or the internal surface of jacketing. The vapour barrier can be sheet material or vapour barrier mastic that is applied to the outside surface of the insulation material. For aluminium jacketing and stainless steel jacketing, a moisture barrier jacketing consisting of laminated polykraft or polysurlyn can be applied.

5. Insulation System Design

5.1 General

An insulation system consists of insulation material, protective covering (if needed) and accessories to secure the insulation in place.

The insulation materials are chosen depending on the main purposes of insulation. There are many criteria to be considered according to the needs in the selection of an insulation system. The criteria shall be subjected to case by case, according to the priorities of each project.

5.2 Basic Design Criteria

The selection of insulation materials should be based on the priorities of the project. The primary purpose of insulation and design criteria that can be considered are:

5.2.1 Heat conservation

Heat conservation (HC) insulation is applied to control the escape of thermal energy from process equipment and piping. An optimum thickness can be determined that balances the cost of installing and maintaining the insulation system against the value of the energy saved. This thickness is referred to as "economic thickness" and can also be defined as the insulation thickness that yields the minimum total cost of owning insulation.

For a given insulation material, energy loss is reduced by increasing the insulation thickness but impacting on the cost. The optimum economic thickness of insulation is achieved when the cost of the energy saved by adding insulation is less than or equals to the cost of adding insulation.

The calculations made to determine the economic thickness require the input of project-specific data, depending on the process conditions, ambient conditions, and economic data that is specific to the project. To determine an accurate economic thickness, these data must be obtained for each project. The software contains default values for process, ambient, and economic variables. However, the default values are subject to change and can cause inaccurate economic thickness calculations.

5.2.2 Personnel protection

Personnel protection (PP) insulation is used to prevent serious injury as the results of the contact between personnel and hot operating surfaces. The maximum allowable insulation system surface temperature is typically 60°C for metallic surfaces. However, the project owner can decide on the maximum allowable surface temperature. Higher allowable surface temperatures may be appropriate for non-metallic surfaces, as indicated in ASTM C1055 Appendix for materials with lower thermal inertia.

Two very important variables in the calculation of external surface temperature are the emissivity of the jacket material and the wind speed. As the wind speed increases, the surface temperature falls significantly due to convective cooling. The wind speed for indoor applications is low, resulting in higher personnel protection thicknesses for insulation. Choosing a jacket material with high emissivity can reduce the surface temperature and offers lower personnel protection thickness for indoor applications or for high temperature outdoor installations. If the process temperature is not significantly high, the effect of increasing the emissivity becomes less effective to lower the surface temperature.

5.2.3 Process stability

Process stability (PS) insulation is used to maintain the process temperature at a desired level. The amount of heat loss or heat gain allowed for a process depends on the nature of the process. Various softwares are available in the market that can be used to calculate both heat loss and heat gain through the insulation as a function of insulation type and process conditions.

5.2.4 Condensation control

Condensation control is used only to avoid condensation from occurring on the surface of piping and equipment that is operating at or below the ambient dew point. The design of condensation control systems is the same as cold service insulation. Thickness is designed only to raise the external surface temperature above the project design ambient dew point. Condensation control is usually important for housekeeping, safety and corrosion control. Appropriate insulation calculation tools can be used to determine the right insulation thickness for this design.

5.2.5 Cold conservation

Cold conservation (CC) is primarily intended to limit heat gain in the operating process. The maximum allowable heat gain must be determined for each process. The required insulation thickness can be determined based on the local season average hot ambient conditions. In most cases, the thickness should also be sufficient to keep the surface temperature of the jacket material above the ambient dew point temperature to avoid condensation on the jacket surface.

The control of moisture penetration in low-temperature systems is required to prevent condensation or the formation of ice inside the insulation and on the surface of the insulated item. This control is accomplished by designing an insulation system that is vapour tight. A vapour barrier with a low permeability as determined by ASTM E96, and an appropriate jacket with moisture resistant caulking at all joints and penetrations. In dual-temperature applications, the fibrous material can be used as an inner layer to compensate for thermal expansion, but it should be covered by a closed-cell outer layer and vapor barrier system to prevent condensation or ice formation on the inner surface.

5.3 Other Design Considerations

5.3.1 Location of Facilities

The ambient conditions of the project location should be used for the calculation of insulation thickness. Location plays an important role in the choice of accessories such as the jacket type and the method of securement. In high wind areas, band spacing should be reduced to keep the jacket in place. In high corrosive areas such as close to the seacoast or corrosive chemical fumes, it may be necessary to select a jacket material that is resistant to the specific corrosive condition. Equipment that is located inside a building is not exposed to weather extremes or UV light and less durable jacket materials, or in some cases no jacket material, can be suitable. Flame spread and smoke developed properties may be considered as important properties, depending on the location of insulation (e.g., indoor or enclosed) and type of facilities.

5.3.2 Strength and Durability

Physical strength and durability requirements can determine the choice of both insulation and jacket materials. In some cases, pipe support loads are carried within the insulation system. In that case, a rigid insulation material is used. Rigid insulation materials can be selected for surfaces that are easily accessible by personnel working on or around the equipment.

Jacket materials that have higher damage resistance, such as thick aluminium or stainless steel, can be used in conjunction with rigid insulation to produce a high damage-resistant system.

5.3.3 Appearance

Appearance requirements sometimes determine the type of jacket or finish material that must be used. Applications that require a continuously high degree of cleanliness can specify a jacket material that has a gloss white or polished stainless steel finish to facilitate both identification and removal of surface contamination. Embossed surface finishes on metal jacket materials can be used to make minor surface damage less visible to casual observation; however, it is more difficult to clean embossed jackets. Smooth finishes are more reflective, and damage is more easily visible.

5.3.4 Leak detection

Leak detection is a regulatory requirement for some chemical processes. If insulating piping and equipment that contains chemicals that fall within the leak detection classification, it is necessary to design the insulation to permit detection of leaks at flanges, valves, and other locations that can be prone to leakage.

Leak detection provision can be done in hot systems by not insulating leak-prone items or by using removable reusable insulation. This approach is not an option for low-temperature systems because there would be no vapour seal and condensation, or ice formation can occur. Low- temperature systems require special consideration and should be handled on a case-by-case basis.

5.3.5 Absorption Resistance

The absorption resistance of the insulation material is an important attribute if insulating piping and equipment contains flammable or explosive chemicals. If leaks occur and the insulation absorbs the chemical, it is possible to build up enough of the flammable or explosive chemical to achieve auto-ignition. It may be necessary to use an appropriate closed-cell insulation that is compatible with the chemical and does not absorb leaks. It is desirable to provide drainage to enable the leaking chemical to escape from the insulation in a controlled fashion.

5.3.6 Emissivity

Emissivity is a measure of a body's ability to radiate energy. A body that radiates a large amount of energy has an emissivity close to 1, while a material that is a poor radiator has a low emissivity. All materials have a characteristic emissivity. The new aluminium jacket has an emissivity of about 0.04. The emissivity value can change as the surface characteristics of the insulation change with time.

The surface temperature of an insulation system is a function of the emissivity of the jacket material. On a hot insulation system, with all other factors held constant, the outer surface temperature of the insulation jacket is reduced by using a higher emissivity jacket. If personnel protection is valued as an important criterion, it may be possible to reduce insulation thickness by using a high emissivity jacket. On a cold insulation system, the jacket temperature can be raised by using a higher emissivity jacket. If condensation control is an important criterion, the surface temperature can be raised by using a higher emissivity jacket.

6. Corrosion Under Insulation (CUI)

Corrosion Under Insulation (CUI) can be defined as any type of corrosion that occurs due to the presence of moisture on the external surface of insulated equipment underneath the insulation material. CUI is considered a major risk to equipment integrity with a potential safety and cost impact alongside Stress Corrosion Cracking (SCC).

CUI risks can be categorized based on the operating temperatures and conditions. The CUI risk categories are provided in Table 1.

Table 1. CUI risk categories

Operating Condition	Operating Temperature	CUI Risk
Cold or cryogenic	Less than 5 °C	Low
Very hot	More than 175 °C	Low
Ambient / Sub-ambient	Between -5 to 49 °C	Medium
Hot	Between 50 to 175 °C	High
Cyclic / Dual temperature	Cyclical temperature between -20 to 320 °C	Extreme

Stress Corrosion Cracking (SCC) is a form of specific CUI that CC occurs if a susceptible material such as austenitic stainless steel is exposed to a specific cracking agent while a tensile stress is present. Stress can be directly applied, such as internal pressure or a piping load, or it can be residual from forming or welding operations. The source of chloride can be from leachable chloride inherent in the insulation or from atmospheric chloride that enters the insulation system from rain or wash-down water.

Certain types of insulation are higher in leachable chloride than others. The insulation material shall be tested to meet the minimum requirement of ASTM C795. ASTM C871 and ASTM C692 which are part of the test standards in ASTM C795, shall be used to determine the suitability of material for the use in contact with austenitic stainless steel. SCC (Stress Corrosion Cracking) risk categories are provided in Table 2.

Table 2. SCC risk categories

Operating Temperature	SCC Risk
Less than 50 °C	Low
Between 50 to 175 °C	High
More than 175 °C	Low

The mitigation efforts for CUI include the following:

a. Use of insulation material with low leachable chloride and fluoride content meeting ASTM C795 specification.
b. Use of insulation materials with corrosion inhibitors.
c. Use of suitable corrosion protective coating to protect the metal substrate from water or moisture contact.
d. Proper design of insulation systems to reduce the risk of water or moisture ingress through cladding and material.
e. Proper installation and maintenance of insulation systems to ensure the integrity of the system in order to reduce the risk of water or moisture ingress.

7. Insulation Material Selection

7.1 General

The appropriate insulation material for a given project is selected on the basis of design criteria that are appropriate for that specific project. Some important design criteria to be considered but not limited as follows:

7.1.1 Thermal properties
7.1.2 Mechanical properties
7.1.3 Operating temperature
7.1.4 Corrosion resistance properties
7.1.5 Water / vapour resistance properties
7.1.6 Fire performance properties

Not all insulation materials perform equally well with respect to these design criteria. Each insulation type has strengths and weaknesses and the strengths of the material selected for a specific job should be matched to the most important design criteria for that job. For example, a material with low permeability should be considered for a low-temperature application in order to provide high resistance to moisture ingress to ensure long-term performance of the insulation system. A rigid high compressive strength material should be chosen in situations in which high load carrying capability is required.

7.2 Consideration in Selecting Insulation Materials

The following are some of the important material properties that support specific design criteria:

7.2.1 Apparent thermal conductivity
7.2.2 Suitable compressive strength
7.2.3 Dimensional stability at extreme operating temperature
7.2.4 Surface burning characteristic
7.2.5 Water absorption
7.2.6 Water vapor permeability

7.2.7 Water wicking
7.2.8 Water vapor absorption

By comparing the minimum performance requirements, it is possible to compare different material types to determine which is the best for a given application. However, it should be remembered that some values in a given standard are minimum requirements and that in some cases, critical values are not included in these standards for a given material.

7.3 Insulation Materials Properties Table

Annex A (at the end of this Standard), is a compilation of material standard compliance and properties for generic material types according to ASTM and other relevant standards. Not all materials are evaluated by the same ASTM tests and in those cases in which a test does not apply to a material, the material properties are left blank. The user/owner should review current ASTM and the relevant standards to confirm the relevance of the material properties listed in Annex A.

8. Insulation System Application

8.1 Scopes of Application

The scope of insulation varies depending on the design criteria. Scope of insulation refers to what can and cannot be insulated during a project for example, in the case of heat conservation, flanges, valves, or other potentially high maintenance items can be left uninsulated to facilitate leak detection and repairs.

In the case of cold conservation, piping items cannot be left uninsulated because condensation and ice formation can occur. As general rule, all low-temperature surfaces should be insulated. Both heat conservation and process stability applications should be insulated as much as possible to ensure these criteria are met.

If insulating only for mitigating personnel protection, the scope of insulation is quite different than for heat or cold conservation. Personnel protection insulation is only applied to those surfaces with which personnel can make contact under normal operating conditions. If the normal operating temperature exceeds 60°C, personnel protection insulation is required on all surfaces to 2.1 meter above grade or platforms, and 1 meter horizontally from the periphery of platforms, walkways, or ladders.

In some circumstances, guards or barriers can be substituted for insulation to provide personnel protection if insulation would impair the function of the equipment. A guard is positioned near the pipe or equipment to prevent personnel contact at a specific location. Guards can be fabricated from a variety of materials including sheet or expanded metal. Barriers or signs are used to prevent access to areas where hot equipment is present. An example of a barrier is a chain that bars access to a ladder that leads to a platform where hot equipment is operating. Hot items that typically cannot be insulated are refractory-lined vessels, condensers, or equipment that can be subject to CUI.

8.2 Service Life

One of the major concerns of a designer is to provide the owner with some assurances that insulated systems will perform as intended for an extended period. There is no handbook establishing methods of estimating the duration or “service life” periods for insulated systems in the industrial market segments. Service temperatures in industrial applications can range from cryogenics up to 1260°C and ambient conditions range from mild indoor conditions to severe outdoor exposures of temperatures, humidity, and weather.

Long service life denotes that the designed thermal performance is maintained to some high percentage of the

original design. The long service life of insulated systems requires the engineer or designer to have good knowledge of the materials in the pipes, tanks, vessels, equipment, towers, and heat exchangers. It demands the proper selection of construction materials to contain these materials safely under anticipated conditions of weather, wind, fire, shock, vibration, and seismic exposure.

It needs the proper selection of the appropriate insulation materials to meet the specific thermal design requirements of the system in service and over a long period of time. It relies on the proper design details and proper installation to reduce or eliminate the deleterious effects of expansion or contraction and excessive heat flows through parallel paths. It demands the proper selection of surfacing treatments to protect the insulated system from mechanical abuse or weather-related damage in normal service. It depends on the proper selection of maintenance procedures to inspect and repair the system regularly and quickly. All of these things should be accommodated within the cost constraints superimposed by the owner.

The long-term service life demands that the insulated system be well designed, well built, operated as designed, and well maintained. Weaknesses in any area of design, installation, operation, or maintenance will shorten the service life of an insulated system.

8.3 Safety

The design of insulation for pipes and equipment handling hazardous chemicals such as flammable or toxic materials requires special consideration in the selection of insulation materials, weather-proofing materials, and application methods.

Insulation systems required to reduce fire loading will need insulation materials and accessories rated to with- stand a hydrocarbon fire for a specific duration. Weatherproofing materials in this case will be stainless steel or coated steel jacketing since aluminium jacketing and mastic weatherproofing cannot withstand the intensity of the fire and still be functional.

8.4 Relative Humidity

The higher the relative humidity, the closer the dew point temperature is to the ambient temperature. The insulation thickness required to prevent condensation (maintain the insulation jacket above the dew point) will be thicker for high-humidity areas. In outdoor applications or in other non-climate-controlled environments, it is impossible to prevent condensation 100 % or the time because of rain or periods when the relative humidity is very high (such as early morning) or both. In hot and humid climates like Malaysia, relative humidity of nearly 100 % is common, leading to heavy dew and even morning fog.

In these environments, condensation on the jacketing of the insulation system is almost certain and must be considered in the design of the insulation system and the facility. Various sources of weather data for the nearest to the plant site and any influencing factors at equipment or pipe locations should be investigated before selecting the relative humidity design value for a given project.

In applications in climate-controlled environments, condensation on the jacketing can be prevented by selecting a design with a relative humidity greater than that which will ever be encountered in the climate-controlled area. In climate-controlled environments there is a particular risk of condensation on the insulation system jacketing if the system is operated during periods when the climate control is either malfunctioning or before it has been commissioned.

The shelf life of insulation materials and hydraulics can be affected by high humidity. These materials require special protection during transportation and job site storage. High atmospheric relative humidity can cause surface condensation and accelerate the corrosion of unprotected metal pipes and jacketing.

Non-wicking types and closed-cell insulation materials are least affected by high humidity, and they tend to retain their insulation effectiveness in these conditions. The use of low permeance vapour retarders, with appropriate attention to the sealing of joints with low vapour permeance tapes and / or mastics, minimizes the

migration of moisture into the insulation system.

8.5 On-Site Material Storage

8.5.1 On-site storage of insulation and accessory materials should provide adequate protection from damage caused by rain, moisture, and temperature. It is generally the insulation contractor's responsibility to furnish these storage facilities. Storage facilities should be located in areas that provide adequate drainage. All flammable materials should be stored away from ignition sources such as welding operations. On-site storage can be broken down into two broad categories: long-term and short-term.

8.5.1.1 Long-term storage facilities
For long-term storage facilities, these materials are often in large quantities, and they can be stored in: temporary warehouses, permanent warehouses, or shipping trailers.

8.5.1.2 Short-term storage
Short-term storage is required for materials located at or near the installation work areas. Short-term storage is generally limited to material that will be used during a single workday. Short-term storage should keep materials off the ground and provide adequate protection against moisture contamination.

8.5.2 Storage temperatures for mastics, adhesives, and sealers should be within the temperature ranges specified by the material manufacturer. All materials that are improperly stored or exposed to temperatures outside the recommended temperature range should be removed from the site and replaced with new material.

8.5.3 Insulation and accessory materials that are susceptible to water damage and may become wet during storage should be protected from the ground and dripping water, otherwise they should be replaced with dry material. This standard applies to hygroscopic (absorbing moisture) materials such as calcium silicate, dry mix materials such as insulating and finishing cements, and fibrous materials that are not treated for water repellency. Cellular glass and materials that are treated for water repellency, such as expanded perlite and some mineral wool, may not need to be replaced, provided that they are allowed to air dry before installation and there is no physical deterioration.

8.6 Protection of Installed Materials

Installed insulation materials should have the required permanent weather protection applied before the conclusion of each day of work. If that is not possible, then temporary weather protection should be provided for any insulation left exposed at the end of the workday. Temporary protection should be provided during the workday when exposed insulation could be damaged as a result of rain or other forms of atmospheric moisture. Adequacy of temporary protection should be the responsibility of the insulation contractor.

Insulation materials that become wet because of missing or inadequate weather protection, either temporary or permanent, should be removed and replaced with dry insulation. Wet insulation should be discarded and not reused. This applies to hygroscopic insulation as well as fibrous materials that are not treated for water repellency. Cellular glass, perlite and other materials that are treated for water repellency may not need to be replaced provided they are allowed to air dry before the application of permanent weather protection, including vapor-retardant systems, and there is no physical deterioration.

9. Inspection, Testing and Maintenance

9.1 General

9.1.1 It is recommended that the owner/user provide a quality assurance program that defines the inspection of all materials, MSDS sheets, and specific application procedures before and during the progress of the insulation work. The user or his inspection authority should have free access at all reasonable times to those parts of the sites carrying out the work for the specific contract. The user/owner should be allowed to select samples from the materials to be applied and reject any materials or workmanship that does not conform to the relevant specification and contract documents. The user/owner may perform acceptance tests to his satisfaction.

9.1.2 Approval by the owner/user, his inspection authority, or a waiver of inspection should not relieve the contractor of his responsibilities for the design, materials, or workmanship. The contractor should cooperate and provide the opportunity for this inspection to be carried out.

9.1.3 Finished materials should also be inspected for quality and thickness either before or during the application, depending upon the finish used.

9.1.4 It is preferable that inspection should be carried out as each stage of work is completed and before the next stage is started. The contractor should give the user/owner or his inspection authority adequate notice of the stage of completion to avoid disruption and maintain continuity of work.

9.1.5 The site organization of the contractor should be such that there is regular and systematic supervision of the work by experienced competent staff.

9.1.6 Until final acceptance of the installation by the user, the contractor should make good any damage to insulation at his own expense, unless predetermined extraneous conditions are contractually identified, so that installation is handed over in a perfect condition.

9.1.7 For the purpose of inspecting insulated surfaces, a removable section insulation or inspection port should be considered.

9.2 Insulation Quality Assurance Procedure

9.2.1 Underground granular pourable insulation should be inspected to the extent necessary to ensure the entire pipeline has been insulated per site specification requirements.

9.2.2 Work performed should be monitored as necessary to ensure design requirements are satisfied. Personnel should meet the site requirements to be qualified as inspectors.

9.3 Responsibilities of Insulation Supervisor

9.3.1 Ensure that correct material is used and complies with specifications, procedures, and drawings.

9.3.2 Ensure surfaces to be insulated are prepared, cleaned, and insulated per owner specifications.

9.3.3 Ensure all deviations from specifications are authorized by the controlling design engineer and documented in the project records.

9.4 Responsibilities of QA Inspector

QA inspector shall perform in-process inspections of work performed to ensure applicable specifications are followed. They shall record the inspection results in "Insulation Inspection Checklist" documents.

9.5 In-Process Inspection

Insulation inspection should include the following:

9.5.1 Verify that specified insulation material is used, and application procedures are followed
9.5.2 Check the surface condition before insulating
9.5.3 Inspect insulation materials for proper type, thickness, and condition
9.5.4 Inspect for dryness
9.5.5 Visually inspect insulated surfaces for corrosion protection
9.5.6 Inspect joints for tight fits and seals

9.6 Documentation of Inspection

There are three types of inspection documents, which are: in-coming materials inspection, in-process inspection, and post-insulated piping/equipment inspection.

An example of an inspection document checklist can be found in Appendix B.

Appendix A: Insulation Material Properties Table

Table A1: Insulation Materials Properties - Calcium Silicate

Material Properties	**Calcium Silicate Pipe & Block ASTM C533 Type 1**		**Calcium Silicate Pipe & Block ASTM C533 Type 1**		**Calcium Silicate Pipe & Block ASTM C533 Type 1A**	
	(Block)		(Pipe)		(Block)	
Max Temp, °C	649		649		649	
Min Temp, °C	60		60		60	
Density, kg/m³	240 (max)		240 (max)		352 (max)	
Compressive strength, min., kPa (C165, unless noted)	688		N.A.		688	
Dimensional Stability	2%, max, (C356, 649°C)		2%, max, (C356, 649°C)		2%, max, (C356, 649°C)	
Absorption, max.	4x dry weight		4x dry weight		4x dry weight	
Water Vapor Transmission/	N.A.		N.A.		N.A.	
Surface burning characteristics (E84):						
Flame spread	0		0		0	
Smoke developed	0		0		0	
Apparent thermal conductivity (k), W/mK, at mean temperature (°C)	k	°C	k	°C	k	°C
	0.059	38	0.059	38	0.072	38
	0.065	93	0.065	93	0.078	93
	0.072	149	0.072	149	0.084	149
	0.079	204	0.079	204	0.088	204
	0.087	260	0.087	260	0.092	260
	0.095	316	0.095	316	0.097	316
	0.102	371	0.102	371	0.101	371

Note: Material with specifications in accordance with ASTM or EN standard or equivalent shall be used

Table A2: Insulation Materials Properties - Flexible Elastomeric Foam (FEF)

Material Properties	**Flexible Elastomeric Foam ASTM C534 / C534M Grade 1**	**Flexible Elastomeric Foam ASTM C534 / C534M Grade 2**	**Flexible Elastomeric Foam ASTM C534 / C534M Grade 3**
Max. use temperature, °C (ASTM C411/C447)	105	150	105
Min. use temperature, °C	-50	-180	-180
Min. / Max. Density, kg/m³ (ASTM C1622)	Manufacturer to declare	Manufacturer to declare	Manufacturer to declare
Apparent thermal conductivity, max. W/mK (ASTM C177 / C518 / C335) -150 °C -100 °C -29 °C -18 °C 24 °C 50 °C 86 °C 150 °C	 0.023 0.028 0.036 0.038 0.040 0.043 0.045 N/A	 0.023 0.028 0.036 0.038 0.043 0.047 0.049 0.061	 0.023 0.028 0.036 0.038 0.040 0.043 0.045 N/A
Fire performance (ASTM E84) Flame spread index, max. Smoke developed index, max.	Manufacturer to declare	Manufacturer to declare	Manufacturer to declare
Water absorption, max. % by volume (ASTM C209)	0.20	0.20	0.20
Permeability, max. g/Pa.s.m (ASTM E96)	1.44×10^{-10}	4.32×10^{-10}	4.32×10^{-10}
Stress corrosion cracking (ASTM C795)	Pass	Pass	Pass
Linear shrinkage after exposure to maximum use temperature, max. %	7.0	7.0	7.0

Note: Material with specifications in accordance with ASTM or EN standard or equivalent shall be used

Table A3: Insulation Materials Properties – Mineral Wool Pipe (Type I,II,III &IV)

Material Properties	Mineral Wool Pipe ASTM C 547 Type I, Grade A Grade B		Mineral Wool Pipe ASTM C547 Type II, III ,,Grade A Grade B		Mineral Wool Pipe ASTM C547 Type IV, Grade A Grade B	
Max Temp, °C	454		649		538	
Min Temp, °C	N.A.		N.A.		N.A.	
Density, kg/m³	consult manufacturer		consult manufacturer		consult manufacturer	
Compressive strength, min., kPa (C165, unless noted)	N.A.		N.A.		N.A.	
Dimensional Stability	2%, max, (C356, 454°C)		2%, max, (C356, 649°C)		2%, max, (C356, 538°C)	
Absorption, max.	5% by weight (C1104)		5% by weight (C1104)		5% by weight (C1104)	
Water Vapor Transmission/	N.A.		N.A.		N.A.	
Surface burning characteristics (E84):						
Flame spread	25		25		25	
Smoke developed	50		50		50	
Apparent thermal conductivity (k), W/mK, at mean temperature (°C)						
	k	°C	k	°C	k	°C
	0.036	38	0.036	38	0.036	38
	0.045	93	0.045	93	0.045	93
	0.058	149	0.053	149	0.053	149
	0.074	204	0.065	204	0.065	204
	0.092	260	0.078	280	0.078	280
			0.094	316	0.094	316
			0.111	371	0.111	371

Note: Material with specifications in accordance with ASTM, MS or EN standard or equivalent shall be used

Table A4: Insulation Materials Properties – Mineral Wool Blanket (Type I & II)

Material Properties	Mineral Wool Blanket ASTM C592 Type I		Mineral Wool Blanket ASTM C592 Type II	
Max Temp, °C	649		649	
Min Temp, °C	N.A.		N.A.	
Density, kg/m³	160 (max)		192 (max)	
Compressive strength, min., kPa (C165, unless noted)	N.A.		N.A.	
Dimensional Stability	4%, max, (C356, 454°C)		4%, max, (C356, 649°C)	
Absorption, max.	5% by weight (C1104)		5% by weight (C1104)	
Water Vapor Transmission/	N.A.		N.A.	
Surface burning characteristics (E84):				
Flame spread	25		25	
Smoke developed	50		50	
Apparent thermal conductivity (k), W/mK, at mean temperature (°C)				
	k	°C	k	°C
	0.036	24	0.036	24
	0.039	38	0.039	38
	0.049	93	0.049	93
	0.062	149	0.060	149
	0.079	204	0.076	204
	0.101	260	0.092	260
			0.108	316
			0.124	371

Note: Material with specifications in accordance with ASTM, MS or EN standard or equivalent shall be used

Table A5: Insulation Materials Properties – Mineral Wool Board and Block (Type III, IA & IB)

Material Properties	**Mineral Wool Blanket ASTM C592 Type III**		**Mineral Wool Board & Block ASTM C612 Type IA**		**Mineral Wool Board & Block ASTM C612 Type IB**	
Max Temp, °C	649		232		232	
Min Temp, °C	N.A.		N.A.		N.A.	
Density, kg/m³	96 (max)		96 (max)		96 (max)	
Compressive strength, min., kPa (C165, unless noted)	N.A.		N.A.		1.2 (Category 2 only)	
Dimensional Stability	4%, max, (C356, 649°C)		2%, max, (C356, 232°C)		2%, max, (C356, 232°C)	
Absorption, max.	1.25% by weight (C1104)		5% by weight (C1104)		5% by weight (C1104)	
Water Vapor Transmission/	N.A.		N.A.		N.A.	
Surface burning characteristics (E84):						
Flame spread	25		25		25	
Smoke developed	50		50		50	
Apparent thermal conductivity (k), W/mK, at mean temperature (°C)	k	°C	k	°C	k	°C
	0.035	24	0.037	24	0.037	24
	0.038	38	0.040	38	0.039	38
	0.045	93	0.052	93	0.049	93
	0.053	149	0.066	149	0.060	149
	0.063	204				
	0.075	260				
	0.087	316				
	0.101	371				

Note: Material with specifications in accordance with ASTM, MS or EN standard or equivalent shall be use

Table A6: Insulation Materials Properties - Polyisocyanurate (PIR)

Material Properties	**Rigid Cellular Polyisocyanurate ASTM C591 Grade 2, Type IV**		**Rigid Cellular Polyisocyanurate ASTM C591 Grade 2, Type II**		**Rigid Cellular Polyisocyanurate ASTM C591 Grade 2, Type III**	
Max Temp, °C	150		150		150	
Min Temp, °C	-183		-183		-183	
Density, kg/m³	32 (min)		40 (min)		48 (min)	
Compressive strength, min., kPa (C165, unless noted)	150		240		310	
Dimensional Stability	4%, max, 65°C, 97% RH (D2126) 1%, max, -40°C, amb. RH (D2126) 2%, max, 100°C, amb. RH (D2126)					
Absorption, max.	2.0% by vol. (C272, Proc. A)		1.0% by vol. (C272, Proc. A)		1.0% by vol. (C272, Proc. A)	
Water Vapor Transmission/	5.8 (max), ng·Pa^{-1}·s^{-1}·m^{-1} (E96, desiccant method, 23° C)		5.1 (max), ng·Pa^{-1}·s^{-1}·m^{-1} (E96, desiccant method, 23° C)		4.4 (max), ng·Pa^{-1}·s^{-1}·m^{-1} (E96, desiccant method, 23° C)	
Surface burning characteristics (E84):	consult manufacturer		consult manufacturer		consult manufacturer	
Flame spread						
Smoke developed						
Apparent thermal conductivity (k), W/mK, at mean	(block only) (consult manuf. for pipe)		(block only) (consult manuf. for pipe)		(block only) (consult manuf. for pipe)	
temperature (°C)	k	°C	k	°C	k	°C
	0.019	-129	0.019	-129	0.020	-129
	0.022	-101	0.022	-101	0.023	-101
	0.025	-73	0.025	-73	0.026	-73
	0.027	-46	0.027	-46	0.029	-46
	0.029	-17	0.029	-17	0.030	-17
	0.027	10	0.027	10	0.029	10
	0.029	24	0.029	24	0.030	24
	0.035	66	0.035	66	0.036	66
	0.039	93	0.039	93	0.040	93

Note: Material with specifications in accordance with ASTM or EN standard or equivalent shall be used

Table A7: Insulation Materials Properties – Expanded Perlite

Material Properties	**Expanded Perlite Block and Pipe ASTM C610 MS 2562**		**Expanded Perlite Block and Pipe ASTM C610 MS 2562**	
	(block)		(pipe)	
Max Temp, °C	649		649	
Min Temp, °C	27		27	
Density, kg/m³	N/A (min) 240 (max)		N/A (min) 240 (max)	
Compressive strength, min., kPa (C165, unless noted)	483		483	
Dimensional Stability (Linear Shrinkage)	2%, max, length 2%, max, width 8%, max, thick (C356, 649°C)		2%, max, length 2%, max, width 8%, max, thick (C356, 649°C)	
Water Absorption, max.	50% by weight, @316°C (C 1763)		50% by weight, @316°C (C 1763)	
Hot Surface Performance C411	No cracks completely		No cracks completely	
Surface burning characteristics (E84): Flame spread	0		0	
Smoke developed	5		5	
Apparent thermal conductivity (k), W/mK, at mean temperature (°C)	k	°C	k	°C
	0.069	38	0.069	38
	0.076	93	0.076	93
	0.085	149	0.085	149
	0.092	204	0.092	204
	0.099	260	0.099	260
	0.108	316	0.108	316
	0.115	371	0.115	371

Note: Material with specifications in accordance with ASTM, MS or EN standard or equivalent shall be used

Table A8: Insulation Materials Properties – Mineral Wool (Type II,III, IVA &IVB)

Material Properties	**Mineral Wool Board & Block ASTM C612 (MS 1020) Type II**	**Mineral Wool Board & Block ASTM C612 (MS 1020) Type III**	**Mineral Wool Board & Block ASTM C612 (MS 1020) Type IVA**	**Mineral Wool Board & Block ASTM C612 (MS 1020) Type IVB**
Max Temp, °C	454	538	649	649
Min Temp, °C	N.A.	N.A.	N.A.	N.A.
Density, kg/m³	96 (max)	160 (max)	192 (max)	192 (max)
Compressive strength, min., kPa (C165, unless noted)	1.2 (Category 2 only)	0.6 (Category 2 only)	2.4 (Category 2 only)	2.4 (Category 2 only)
Dimensional Stability	2%, max, (C356,454°C)	2%, max, (C356, 538°C)	2%, max, (C356, 649°C)	2%, max, (C356, 649°C)
Absorption, max.	5% by weight (C1104)	5% by weight (C1104)	5% by weight (C1104)	5% by weight (C1104)
Water Vapor Transmission/	N.A.	N.A.	N.A.	N.A.
Surface burning characteristics (E84): Flame spread	25	25	25	25
Smoke developed	50	50	50	50

Apparent thermal conductivity (k), W/mK, at mean temperature (°C)	k (Type II)	°C	k (Type III)	°C	k (Type IVA)	°C	k (Type IVB)	°C
	0.036	24	0.036	24	0.036	24	0.035	24
	0.039	38	0.039	38	0.039	38	0.036	38
	0.050	93	0.050	93	0.049	93	0.043	93
	0.063	149	0.063	149	0.063	149	0.052	149
	0.079	204	0.079	204	0.079	204	0.061	204
	0.101	260	0.101	260	0.101	260	0.076	260
			0.130	316	0.123	316	0.091	316
					0.144	371	0.108	371

Note: Material with specifications in accordance with ASTM or EN standard or equivalent shall be used

Table A9: Insulation Materials Properties – Aerogel (Type III)

Material Properties	Test Standard	Flexible Aerogel Blanket ASTM C1728 Type III, Grade 1 Cat.A
Max. use temperature, °C	ASTM C411	650
Min. use temperature, °C	N/A	24
Min. / Max. Density, kg/m³	ASTM C167/C303	160 to 240
Apparent thermal conductivity, max. W/mK 24 °C 38 °C 93 °C 149 °C 204 °C 260 °C 316 °C 371 °C	ASTM C177/C518	 0.021 0.022 0.023 0.025 0.029 0.032 0.036 0.043
Compressive resistance, min, @ 10% deformation, kPa	ASTM C165	20.7
Fire Performance Flame spread index, max. Smoke developed index, max.	ASTM E84	 5 10
Water absorption, max. % by weight - without conditioning - After conditioning @ 316°C for 24h	ASTM C1763, Proc. B	 8 16
Water vapour sorption, max by weight	ASTM C1104	5
Corrosiveness to steel	ASTM C1617	MLCR ≤ that of 5-ppm chloride solution
Stress corrosion cracking	ASTM C795	Pass
Linear shrinkage after exposure to maximum use temperature, max. %	ASTM C356	2

Note: Material with specifications in accordance with ASTM or EN standard or equivalent shall be used

Table A10: Insulation Materials Properties – Aerogel (Type I & IV)

Material Properties	**Test Standard**	**Flexible Aerogel Blanket ASTM C1728 Type I, Grade 1 Cat.B**	**Flexible Aerogel Blanket ASTM C1728 Type IV, Grade 1 Cat.A**
Max. use temperature, °C	ASTM C411	125	250
Min. use temperature, °C	N/A	-196	-196
Min. / Max. Density, kg/m³	ASTM C167/C303	80 to 180	160 to 240
Apparent thermal conductivity, max. W/mK -129 °C -73 °C -18 °C 24 °C 38 °C 93 °C 149 °C 204 °C	ASTM C177/C518	 0.014 0.015 0.016 0.017 0.017 0.019 - -	 0.015 0.017 0.020 0.022 0.022 0.023 0.025 0.029
Compressive resistance, min, @ 10% deformation, kPa	ASTM C165	34.5	34.5
Fire performance Flame spread index, max. Smoke developed index, max.	ASTM E84	 25 50	 25 50
Water absorption, max. % by weight	ASTM C1763, Proc. B	8	8
Water vapour sorption, max. % by weight	ASTM C1104	5	5
Corrosiveness to steel	ASTM C1617	MLCR ≤ that of 5-ppm chloride solution	MLCR ≤ that of 5-ppm chloride solution
Stress corrosion cracking	ASTM C795	pass	Pass
Linear shrinkage after exposure to maximum use temperature, max. %	ASTM C356	2	2

Note: Material with specifications in accordance with ASTM or EN standard or equivalent shall be used

Table A11: Insulation Materials Properties – Cellular Glass

Material Properties	Cellular Glass Block ASTM C552 Grade 1, Types I, II, III	
Max Temp, °C	427	
Min Temp, °C	-268	
Density, kg/m³	98 (min) 138 (max)	
Compressive strength, min., kPa (C165, unless noted)	415 (capped per C240) 242 uncapped	
Dimensional Stability	N.A.	
Absorption, max.	0.5% by weight (C552)	
Water Vapor Transmission/	0.007 (max), ng·Pa^{-1}·s^{-1}·m^{-1} (E96, water method, 73°F to 90°F)	
Surface burning characteristics (E84):	Flame spread / smoke developed varies for Type II and III fab methods	
Flame spread	5	
Smoke developed	0	
Apparent thermal conductivity (k), W/mK, at mean temperature (°C)	(block only) (consult manuf. for pipe)	
	k	°C
	0.029	-101
	0.032	-73
	0.035	-46
	0.039	-18
	0.043	10
	0.045	24
	0.048	38
	0.058	93
	0.069	149
	0.084	204

Note: Material with specifications in accordance with ASTM or EN standard or equivalent shall be used

APPENDIX B: NON-MANDATORY INFORMATION

INSULATION INSPECTION CHECKLIST	
CONTRACTOR	*CONTACT*
PROJECT:	*AREA:*
LOCATION:	*DATE:*
DWG WITH REV NO# :	*LINE/SKETCH#:*
SCOPE :	
INSP. ACCEPTABLE DATE INITIALS:	
DESCRIPTION	*REMARKS*
1) Insulation stored properly?	
2) Correct materials insulation thickness applied?	
3) Corrosion Protection applied?(when required by specification)	
4) Substrate painted applied? (when required by specification)	
5) Are stream tracer connections outside of the insulation?	
6) Insulation fittings correct size, thickness and types applied?	
7) Insulation Joints staggered correctly?	
8) Insulation properly fitted?	
9) Insulation properly secured?	
10) Pipe and equipment properly finished, caulked, sealed, watershed etc ?	
Other:	
Comments:	
Suggestions:	
Signature (Inspector Acceptance)	*Date :*

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[13] ASTM C552 – Standard Specification for Cellular Glass Thermal Insulation
[14] ASTM C591 – Standard Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation
[15] ASTM C592 – Standard Specification for Mineral Fiber Blanket Insulation and Blanket-Type Pipe Insulation (Metal-Mesh Covered) (Industrial Type)
[16] ASTM C610 – Standard Specification for Molded Expanded Perlite Block and Pipe Thermal Insulation
[17] ASTM C612 – Standard Specification for Mineral Fiber Block and Board Thermal Insulation
[18] ASTM C680 – Standard Practice for Estimate Determination of Heat Gain or Loss and the Surfaces Temperatures of Insulated Pipe and Equipment Flat, Cylindrical and Spherical Systems by the Use of a Computer Program
[19] ASTM C692 – Standard Test Method for Evaluating the Influence of Thermal Insulations On External Stress Corrosion Cracking Tendency Of Austenitic Stainless Steel
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