TRADE OF

Industrial Insulation

PHASE 2

Module 4

Insulation – Materials, Science and Application

UNIT: 2

Insulation Materials & System Design

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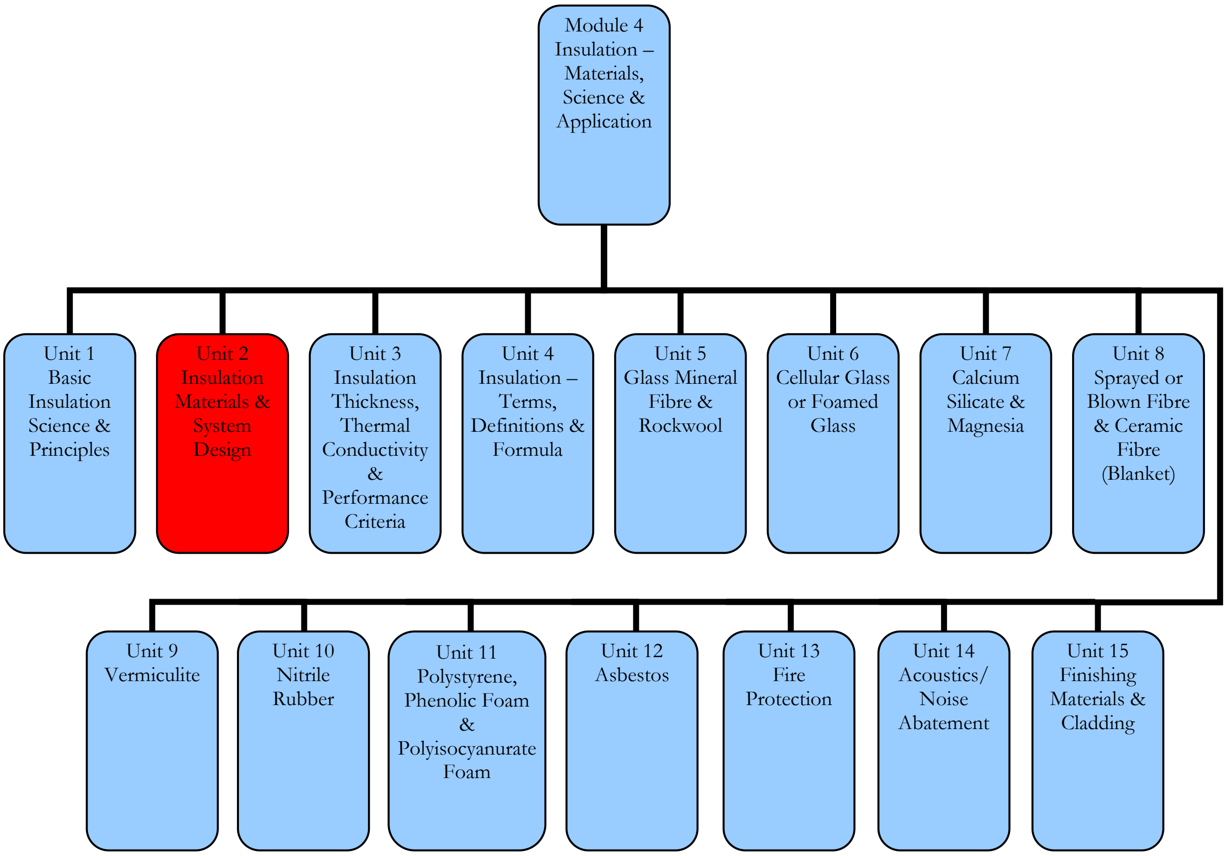
Introduction

When an insulation system is designed, there are a numbers of factors which influence the material selection for the job: (a) service temperature of the operation, (b) compressive strength of the material required, (c) thermal conductivity or the material's resistance to heat flow, (d) water absorption and (e) area required for the insulating material. In most applications, economics and performance require the use of more than one type of insulating material. All major suppliers offer guidelines and help in application and installation of insulation systems.



Unit Objective

By the end of this unit ***each apprentice will be able to:***

- State the trade names of a range of the insulation material currently on the market.
- List and describe the criteria for selection of appropriate materials for specific purposes.
- State the temperature for both hot and cold processes.

1.0 Insulating Materials

Key Learning Points

- Range of insulating materials
- Forms of supply of materials.

1.1 Types of Insulation for Hot and Cold Work

Heat flows naturally from a higher to a lower temperature. The mechanisms of heat transfer from the high to the low temperature are relatively complex, although the overall rate of flow is determined by the temperature difference between the boundaries of the flow and by the properties of materials through which the heat flows.

Energy Flows

- ***Radiation***: Through transparent media like glass.
- ***Convection***:: In fluids, such as water and gases, in which the energy is carried by hotter (lighter) fluids moving relative to colder (denser) fluid.
- ***Conduction:*** Through solids like metals, concrete and plastics in which the energy is transmitted by the vibration of molecules.

The ability of substances to transfer heat through a given temperature difference varies by factors of many thousands from metals liker silver, which are excellent conductors, to gases like argon, which are very poor conductors Insulation is essentially the use of materials of low overall conductance to reduce the energy flow for any given temperature difference.

In general (apart from vacuum) the worst conductors of heat (i.e. the best insulators) are the gases, and these insulate best when convection within the gas can be suppressed. Fibrous blankets in which the gas is trapped in a mat of low conductivity solid – such as glass or organic fibre (wool or polyester) are good insulators, and closed-cell foams in which the gas is trapped in bubbles in a poor conductor such as polystyrene or polyurethane are even better.

Common Types of Insulation Materials

There is a broad spectrum of insulation materials available on the market, with an equally broad variance in form, Performance, Sustainability, Cost-Effectiveness and Availability. Some of the keys types of insulation are set out below.

Glass mineral wool	(Fibrous)
Rock mineral wool	(Fibrous)
Cellular glass	(Cellular)

Calcium silicate	(Granular)
Nitrile foamed rubber	(Cellular)
Phenolic foam	(Cellular)
Expanded polystyrene	(Cellular)
Polyurethane foam	(Cellular)
Polyisocyanurate foam	(Cellular)

1.2 Forms of Supply of Materials

Insulation is usually supplied on one of the following forms:

- Pre-formed (slabs or sections)
- Rigid
- Flexible
- Plastic composition
- Sprayed and blown
- Glass mineral wool
- Loose-fill
- Metallic e.g. Crimped Foil
- Glass mineral wool
- Rigid slabs/lags
- Pre-formed pipe sections
- Flexible Mats
- Lamella Mat

Rock Mineral Wool

- Loose wool
- Resin–bonded slabs/lags
- Pre–formed pipe sections
- Flexible mats
- Wired mattresses
- Lamella mat
- Pipe section mat

Cellular Glass

- Slabs and pipe sections

Calcium Silicate

- Slabs/Lags

Nitrile Foamed Rubber

- Pre-formed pipe sections sheet/roll

Phenolic Foam

- Pre-formed slabs and pipe sections

Extended Polystyrene

- Pre-formed pipe sections sheet

Polyurethane Foam

- Slabs/boards/blocks.
- Pipe sections sprayed
- Sprayed

Polyisocyanurate Foam

- Slabs
- Pipe sections
- Sprayed

1.3 Typical Dimensions

General

Pro-formed insulation and factory–made mattresses which are shown below are readily available but individual manufacturers can often supply a wider range and should be consulted.

Pre-Formed Insulation

The dimensions for pre-formed materials shown in the following list should b regarded as been indicative of the range of sizes commercially available but are not intended to be a comprehensive list for all materials; not all materials are available in the full range of sizes shown.

1. *Slabs* (including pipe section mattresses)
   - Length 0.6m to 2.0m.
   - Width 0.6m to 1.5m.
   - Thickness 10mm to 100mm in increments of 5, 10 or 12.5mm
2. *Pipe sections*
   - Length 0.5m to 2.0m.
   - Diameter To fit pipe ODs from 17mm to 950mm.
   - Thickness 10mm to 100mm in increments of 5, 10 or 12.5mm
3. ***Bevelled, or radiused and bevelled, lags***
   - Length 0.6m to 1.2m
   - Diameter To fit pipe diameters of 220mm and above.
   - Width 75mm to 300mm.
   - Thickness 10mm to 100mm in increments of 5, 10 or 12.5mm

4. Mattress Insulation

The dimensions for mattress insulation should typically be as follows:

- Length up to 7.0m
- Width up to 1.2m
- Nominal thickness 25mm to 100mm

2.0 Material Selection Criteria

Key Learning Points

- Material selection criteria: fit for purpose (hot/cold), form, cost factors, fire safety, finish, thermal performance and mechanical properties.

2.1 Fit for Purpose

The thermal resistance of the insulating material should be compatible with design of process control, and economic considerations, and it should be capable of remaining so under the expected conditions of service and plant life. When a choice is to be made as to the type of insulation to be used for a specific application, attention should be paid to a number of issues such as:

- Is the type if insulation selected fit for purpose – will it do the job it is expected to do.
- Will it keep the cold – face temperature (min and max) correct.
- Will it keep the hot – face temperature (min and max) correct.
- Will it maintain its thermal conductivity values as stated by the manufacturer over the lifetime of its use.
- Will it be a fire hazard.
- Will it be a health hazard.
- Will it have the required mechanical strength.
- Will it offer protection from water ingress into the insulation system.

These are just some of the points to consider when deciding if a particular type of insulation material is suitable for a specific application and is it suitable for its intended purpose.

2.2 Cost Factors

Insulation shouldn't be considered a 'Cost',when properly done it should save on the operating expenses of a plant, allowing the owner/manufacturer to become more competitive in the market. An insulation system can actually pay itself back and then continue to earn savings of energy during operation. This can be translated directly to increased efficiencies in the plant, a lowering of expenses and potentially higher profits to the plant operators. In selecting a particular type of insulation for a particular type of application or job, a number of factors should be considered.

1. What is the most economical thickness of insulation for the job in hand so as to provide the necessary energy savings of the life of the project.
2. The location of where the insulation is going to be used is also very important. Location includes many factors that are critical to choosing the most cost-effective product for the life of the application. Material

selection based on initial price only without regard to location can be not only inefficient, but also dangerous under certain conditions. An outdoor system needs to keep water from entering the insulation. Indoor applications are generally less demanding with regards to weather resistance, but there are washing areas that see a great deal of moisture, that can effect the insulation material. There are many applications where vibrations are severe, for this application one has t go for a rigid insulation such as calcium silicate than other fibrous materials. Location in a fire-prone area can affect the insulation selection in two ways. First, the insulation system cannot be allowed to carry the fire to another area, this is a fire hazard. Second, the insulation can be selected and designed to help protect the piping or equipment from the fire. For this calcium silicate is probably the best selection.

3. Other factor to consider would be the temperature range off the insulation, the required life time of the project, and any limited factors such as an insulations resistance to water vapour, has sufficient compressive strength and good chemical resistance for example.
4. When a number of suitable types of insulation are selected for the project, the final decision will depend on; initial cost of insulation including interest charges installation costs of the insulation, maintenance costs.

2.3 Fire Safety

The fire performance of a particular insulant should be chosen n the context of the design requirements of the application for which it is intended. For further guidance, reference should be made to the current Building Regulations and the fire prevention authorities.

2.4 Finish/Facing

Various types of thermal insulation such as glass mineral wool (glasswool) and rock mineral wool (rockwool) come with a factory applied facing of class 'O' rated aluminium foil on one side of the product. This class 'O' finish complies with the requirements of the building regulations when tested to BS476:Part 6, 'Fire Propagation' and part 7, 'Surface Spread of Flame'.

Other products such as a wired mattresses can be faced with galvanised wire mesh or can be supplied to special order with galvanised wire mesh on both sides, stainless steel mesh on one side or both sides, reinforced aluminium facing underneath mesh, or without mesh ('insulation quilt').

In the case of Polyurethane foam (PUR/PIR) insulation boards, these can be faced with different facings depending on their application. The facings can serve as vapour barrier, moisture lock, optical surface or protection against mechanical damage.

Polyurethane foam (PUR/PIR) is also available as sandwich panels where the material is faced with steel, aluminium or other rigid facings for use in building construction. When some insulation products are installed outdoors they can be finished with polyisobutylene (PIB) or sheet metal cladding so as to protect the insulation from the weather. Other finished are available.

2.5 Thermal Properties of Insulation

Not all properties are significant for all materials or applications. Therefore, many are not included in manufacturers published literature. In some applications, however, omitted properties may assume extreme importance (i.e. when insulations must be compatible with chemically corrosive atmospheres.)

If the property is significant foe an application and the measure of that property cannot be found in manufacture's literature, effort should be made to obtain the information directly from manufacturer, testing laboratory, or insulation contractors association.

The following properties are referenced only according to their significance in meeting design criteria of specific applications. More detailed definitions of the properties themselves can be found in the Glossary at the end of the notes

Thermal properties are the primary consideration in choosing insulations.

- ***Temperature Limits;*** Upper and lower temperatures within which the material must retain all its properties
- ***Thermal conductance "C":*** The rate of heat flow for the actual thickness of a material.
- ***Thermal conductivity "K":*** The rate of heat flow based on 25mm (one inch) thickness.
- ***Emissivity "E":*** Significant when the surface temperature of the insulation must be regulated as with moisture condensation of personnel protection.
- ***Thermal resistance "R":*** The overall resistance of a "system" to the flow of heat.
- ***Thermal transmittance "U":*** The overall conductance of heat flow through a "system".

Thermal Conductance (c)

In term of thermal insulation, thermal resistance gives a counterpoint of thermal conductivity, bigger thermal resistance = better while smaller thermal conductivity =better. For that reason, another measure called thermal conductance is also used. Thermal conductance is simply the inverse of thermal resistance; c =1/R its unit is Wm2k. Very often, you will see the thermal conductance assimilated to the U-value defined below. It is not exact as U= value is a more subtle and complex parameter.

Thermal Conductivity (K)

The transmission of heat from ambient air to walls, floor or roof occurs via convection and radiation. Once heat entered the material, heat transmission occurs mainly via conduction, although that depending of the material, convection and radiation can still exist.

Heat conduction, is therefore the component that thermal insulation materials used in construction will be able to reduce the most. Thermal insulation materials will reduce the loss or gain of heat by preventing heat conduction to happen in their fabric. The total effect depends on the material used and on its thickness.

The physical property that measures the effectiveness of a material to conduct heat is called thermal conductivity. It is expressed in Watt per meter. Kelvin (W/mK). Very often, you will see that a number given on insulation material specifications. The smaller the number, the better the material is regarding thermal insulation.

Thermal Resistance (R-Value)

Thermal conductivity allows comparing materials and their ability to conduct heat. In practice, that alone is not enough to judge the quality of a given thermal insulation solution. The thickness of the material applied has to be taken into account.

That is the reason we use another measure called ***thermal resistance or R – value***. It is simply the thickness of the material divided by the thermal conductivity of that material. ***R=d/k Where d is thickness. Its unit is m2K/W.***

Insulation materials have tiny pockets of trapped air. These pockets resist the transfer of heat through material. The ability of insulation to slow the transfer of heat is measured in R–Values. The higher the R–Value, the better the insulation materials ability to resist the flow of heat through it. It is a measure of resistance to heat flow.

Thermal Transmittance (U-value)

The thermal transmittance or U-value represents the amount of heat, transferred through a building section, between the indoor and outdoor climate, for a unit of surface and temperature. Its unit is WM2k. It is also called the overall coefficient of heat transmission.

U-value is simply equal to the inverse of the total thermal resistance. ***U=1/Rt*** simply put, U-value rates the energy efficiency of the combined materials in a building component of section. The smaller the U-value, the better the solution is in term of thermal insulation and energy saving.

2.7 Mechanical and Chemical Properties of Insulation

Properties other than thermal must be considered when choosing materials for specific applications. Among them are:

- ***Alkalinity (P or acidity):*** Significant when corrosive atmospheres are present. Also insulation must not contribute to corrosion of the system.
- ***Appearance;*** Important in exposed areas and for coding purposes.
- ***Breaking Load:*** In some installations the insulation material must "bridge" over a discontinuity in its support.
- ***Capillarity;*** Must be considered when material may be in contact with liquids.
- ***Chemical reaction;*** Potential fire hazards exist in areas where volatile chemicals are present. Corrosion resistance must also be considered.
- ***Chemical resistance:*** Significant when the atmosphere is salt or chemical laden.

- ***Coefficient of expansion and contraction:*** Enters into the design and spacing of expansion/contraction joints and/or the use of multiple layer insulation applications.
- ***Combustibility:*** One of the measures of material's contribution to a fire hazard.
- ***Combustibility strength:*** Important if the insulation must support a load of withstand mechanical abuse without crushing. If, however, crushing or filling in space is needed as in expansion/contraction joints, low compressive strength materials are specified.
- ***Density:*** A material's density affects other properties of that material, especially thermal properties.
- ***Dimensional stability:*** Significant when the material is exposed to atmospheric and mechanical abuse such as twisting or vibration from thermally expanding pipe.
- ***Fire retardancy:*** Flame spread and smoke developed ratings should be considered.
- ***Hygroscopicity:*** Tendency of a material to absorb water vapour from the air.
- ***Resistance to ultraviolet light:*** Significant if application is outdoors.
- ***Resistance to fungal or bacterial growth:*** Is necessary in food or cosmetic process areas.
- ***Shrinkage:*** Significant on applications involving cements and mastics.
- ***Sound absorption coefficient:*** Must be considered when sound attenuation is required, as it is in radio stations, some hospital areas, etc.
- ***Sound transmission loss value:*** Significant when constructing a sound barrier.
- ***Toxicity:*** Must be considered in food processing plants and potential fire hazard areas.

2.0 General Application and Temperature Ranges

Key Learning Points

- Temperature ranges – cryogenic, refrigeration, cold water, hot water, LP and HP steam.

3.1 Thermal Insulation

Definition of Insulation

Insulation is defined as those materials or combinations of materials which retard the flow of heat energy by performing one or more of the following functions:

1. Conserve energy by reducing heat loss or gain.
2. Control surface temperatures for personnel protection and comfort.
3. Facilitate temperature control of a process
4. Prevent vapour flow and water condensation or cold surfaces.
5. Increase operating efficiency of heating/ventilating/cooling, plumbing, steam, process and power systems found in commercial and industrial installations.
6. Prevent or reduce damage to equipment from exposure to fire or corrosive atmospheres.
7. Assist mechanical systems in meeting regulations in food and cosmetic plants.

The temperature range within which the term "thermal insulation" will apply is from -73.3°C to 815.6°C. All applications below -73.3°C are termed "cryogenic", and those above 815.6°C are termed "refractory".

Thermal insulation is further divided into three general application temperature ranges as follows.

1. Low Temperature Thermal Insulation
    - 15.6°C through 0°C - i.e. Cold or chilled water
    - - 0.6°C through -39.4°C – i.e. Refrigeration of glycol
    - - 40.0°C through -73.3°C – i.e. Refrigeration or brine
    - - 73.9°C through -267.8°C – i.e. Cryogenic

2. Intermediate Temperature Thermal Insulation
    - 16.1°C through to 99.4°C - i.e. Hot water and steam condensate.
    - 100.0°C through to 315.6°C – i.e. Steam, high temperature hot water.
3. High Temperature Insulation
    - 316.1°C through to 815.6°C i.e. Turbines, breechings, stacks, exhausts, incinerations and boilers.

3.0 Fixing Methods

Heading 3

- Fixing methods.

4.1 Fixing Methods for Securing Various Thermal Insulation Products

General

Insulation systems can be permanently secured directly to the plant by means of adhesives, by mechanical means, or by a combination of both. Alternatively the insulation can be installed as a removable module to allow for maintenance or repair.

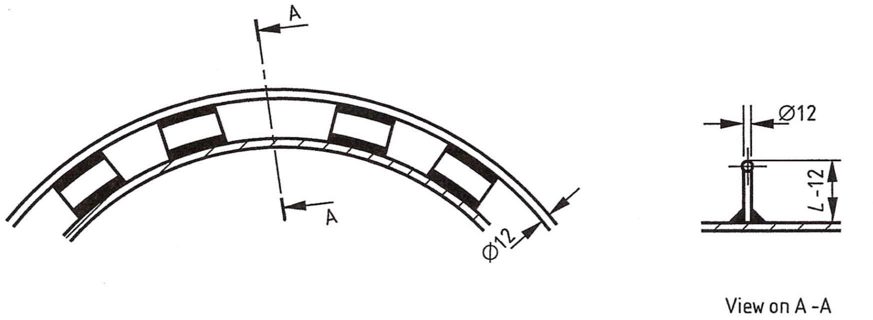
Adhesives for insulation can be classified as follows:

1. Insulation bonding adhesives: Used for securing pre-formed slabs and sections, or flexible insulating materials to themselves and to structures such as equipment and ducts.
2. "Lagging" adhesives: Used for bonding, sizing and coating surface-finishing fabrics over insulated pipe-work and equipment.
3. Facing and film-attaching adhesives: Used for attaching flexible laminates, foils and plastic films to thermal insulation, and for bonding and overlaps of these materials. This group includes a wide range of products, generally of consistency for brush and spray applications.

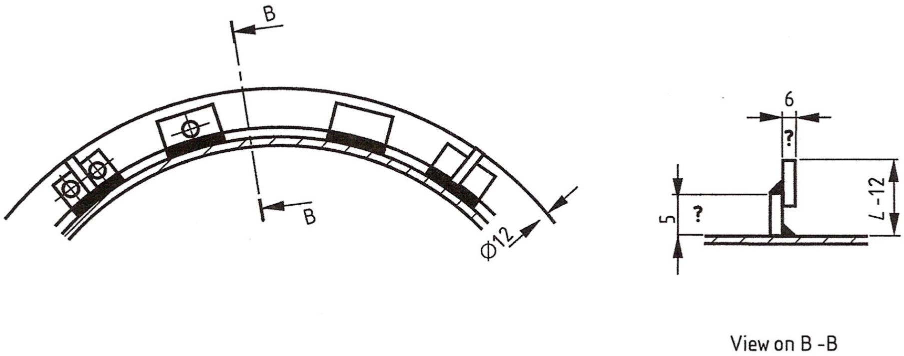
4.2 Mechanical Securing Methods

The securing materials in this category generally can be classified as welded attachments, bolted fittings, or banding and wire securements. Care should be taken to avoid bimetallic contact between metals of appreciably different electrochemical properties.

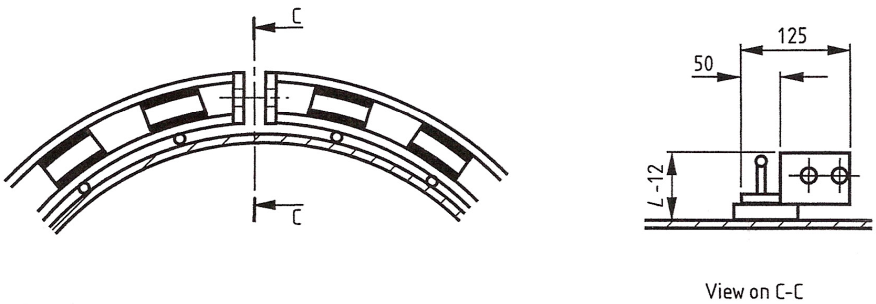
Welded attachments are used mainly on vertical piping, or vertical and down-ward facing vessel and equipment. They can be in the form of cleat, angles, pads, studs, bolts, nuts etc., that provide support for bolted fittings and permanent datum positions relative to each other. The spacing of these attachments can be varied locally to control thermal movement.



Type 1



Type 2



Type 3 (clamped)

Typical vessel support systems

4.0 Safe Handling and Storage of Insulation Materials

Key Learning Points

- Safe handling of insulation materials
- Storage of insulting materials.

5.1 Handling and Storage

Insulating materials should be packed in cartons, crates, bags or shrink films wrapping to minimize mechanical damage and to provide adequate weather protection and to avoid contamination. Preferably, insulating materials should not be unpacked on site until they are ready to b used.

The density of insulation materials is very low so the materials are therefore easy to handle and work with. It is very important to keep these properties in mind when handling or transporting the materials to site.

- When loading materials onto a lorry or truck avoid climbing or walking on the rolls or cartons.
- When unloading materials make sure to use the correct manual handling techniques to avoid injury. ***Refer to module 1 – unit 2 – manual handling.***
- When storing the insulation materials do not place too many packages or rolls upon each other.
- Insulation products should be stored in a dry area, if materials have to be stored outside ensure they are raised of the ground with a pallet and cover completely to avoid getting wet. Do not assume the plastic wrapping will keep the material dry as sometimes the wrapping can be thorn or punctured.
- Always wear the appropriate personnel protective equipment when handling insulation to avoid breathing fibres and dust.
- Always refer to the manufacturers' data sheet regarding storing of materials.

5.0 Reading and Interpreting Drawings

Key Learning Point

- First and third angle orthographic projections
- Sections showing the placement, installation and drawing conventions for insulation.

6.1 Orthographic Projection

Refer to module 2 – unit 2 – Orthographic projection.

Summary

The appropriate insulation must be selected on the basis of temperature, thermal conductivity and other factors that might limit application. The appropriate thickness must be determined for the particular application.

While doing the payback calculation on insulation, one has to consider the cost of capital investment, interest on investment, depreciation period and maintenance cost. In the long term insulation should be seen as a continuous saving due to reduced energy bills and greater efficiency from plant and equipment.

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