All About Insulation

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All About Insulation

By Ramesh Paranjpey

Chapter 1
Basics of Insulation

When there is a temperature difference between two objects, heat flow is inevitable. Heat will always flow from higher temperature to lower temperature irrespective of the size, mass or position of the objects.

Air conditioned or refrigerated space is normally at a lower temperature than the surroundings and heat would therefore try to penetrate from outside to the inside colder area.

Refrigeration/air conditioning is a process where the temperature is lowered by pumping out heat from the colder place where heat is not required to a place where it is not objectionable, and thus is exactly the reverse of the natural phenomenon; therefore, to achieve it requires external energy.

Cold insulation is therefore required where operating temperatures are below ambient temperatures to prevent/reduce heat gain, condensation or freezing.

Thermal insulation provides a layer of material in which thermal conduction or heat ingress is reduced and thermal radiation is reflected rather than absorbed by the lower temperature body.

Heat Transfer

Heat transfer takes place in three different ways: conduction, convection and radiation.

Thermal Conduction is the molecular transfer of heat due to a temperature gradient.

Convection mechanism of heat occurs in liquids and gases, whereby flow processes transfer heat.

Free convection is the flow caused by differences in density as a result of temperature differences.

Forced convection is the flow caused by external influences (wind, ventilators, fans, etc.).

Thermal Radiation mechanism occurs when thermal energy is emitted similar to light radiation.

Heat transfer through insulation material occurs by means of conduction, while heat loss to or heat gain from the atmosphere occurs by means of convection and radiation.

Heat passes through solid materials by means of conduction, and the rate at which this occurs depends on thermal conductivity (expressed in W/m.K) of the material in question and the temperature difference.

In general, the greater the density of a material, the greater is the thermal conductivity; for example, metals have high density and high thermal conductivity.

Materials that have low thermal conductivity are those that have a high proportion of small voids containing air or gas.

If the density of insulation is low, air or gas voids are comparatively large, and it is then the best insulation for low to medium temperatures.

Thermal insulation materials fall into this category. Thermal insulation materials may be natural substances or man-made.

What is Thermal Insulation?

Thermal insulation is a material used in the air conditioning and refrigeration industry to act as a resistance or a barrier to transfer of heat from higher temperature to lower temperature.

The temperature range within which the term thermal insulation is applicable is from minus 75°C to +815°C.

All applications below minus 75°C are termed cryogenic, and those above +815°C are termed refractory.

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

Low Temperature Thermal Insulation

1. From 15°C to 1°C, e.g. cold or chilled water and fresh fruit/vegetables storage cold rooms.
2. From 0°C to -40°C, e.g. refrigeration or glycol brine chillers, frozen food storages.
3. From -41°C to -75°C, e.g. blast freezers, plate freezers, IQF, refrigeration and brine process plants.
4. From -76°C to -273°C (absolute zero), e.g. cryogenic (not addressed in this series of articles).

Intermediate Temperature Thermal Insulation

1. From 16°C to 100°C, e.g. hot water and steam condensate.
2. From 101°C to 315°C, e.g. steam, high temperature hot water.

This series of articles is meant for Refrigeration and Air Conditioning practicing engineers, consultants and technicians. It is not meant to replace a text book and hence uses information in a manner that is easy to understand for all users. The information is restricted to cooling applications and does not cover heating insulation requirements. It supersedes all the publications earlier issued by ISHRAE on the subject of Insulation.

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About the Author

Ramesh Paranjpey is a mechanical engineer with an M. Tech. in refrigeration from IIT Bombay, having over 35 years' experience. He has worked in very senior positions with Kirloskar Pneumatic in Pune, Carrier Transicold in Bangalore and Singapore and Voltas-Air International in Pune. Presently, he works as a technical advisor and consultant. He is an ASHRAE Fellow, Past President ASHRAE W.I. Chapter and Past President ISHRAE Pune Chapter.

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High Temperature Thermal Insulation

1. From 316°C to 815°C, e.g. turbines, breechings, stacks, exhausts, incinerators, boilers.

Why is Insulation Necessary?

A thermal insulation system is a combination of material, ancillaries for application, and application methodology that resists the flow of environment heat to the inside of a building or enclosure that is supposed to be maintained at much lower temperature than outside (a typical Indian situation mostly where ambient temperatures are higher during most part of the year).

Thermal insulation will resist the flow of heat by acting as a barrier. The most effective insulation material will provide the maximum resistance and will be defined by a particular R value, which will depend upon its thermal conductivity value and thickness.

Lower the thermal conductivity of an insulation material, the more effective it will be.

Higher the resistance R, better is the insulation.

Further, the mass of the insulation material is also important, defined as adequate density of the material to be selected.

A higher density will increase the heat capacity of the material and result into a lower thermal diffusivity value.

A material having lower diffusivity value will be able to maintain a constant temperature or slow rise in temperature inside a building in a situation when internal cooling is switched off or not working.

What are the Benefits of Using Insulation?

1. Reduces heat gain or heat loss
2. Prevents moisture penetration and acts as a vapour barrier
3. Acoustical performance of insulating material helps in reducing noise level in ducting, equipment, etc.
4. Prevents condensation, water dripping from ducting, piping, drain pans, ceiling, etc.
5. Prevents ice accumulation and protects the freezer
6. Enhances process performance, reducing energy consumption
7. Controls surface temperatures to avoid contact burns (hot or cold) – personnel protection
8. Fire safety – helps in slowing spread of fire in buildings
9. Provides more accurate control of process temperatures by minimizing fluctuations and protecting the product
10. Prevents gas condensation inside the pipe
11. Limits temperature change of process fluid and freezer protection
12. Improves appearance of equipment, piping, AHUs, etc.
13. Helps in reducing carbon emission

Moisture and the Need for Vapour Retarders

Temperature is an easily measurable parameter. However, moisture in air is in vapour form and is invisible. Presence of moisture in the air is an important parameter for insulation selection. As heat flows from higher temperature to lower temperature, moisture travels from higher vapour pressure of outside air to lower vapour pressure of inside air.

Since moisture is a good thermal conductor, its presence in an insulation system is highly detrimental; refrigeration systems face increased energy cost and condensation, which often leads to complete system failure.

With today's high energy costs, the design thickness of insulation in almost all refrigeration applications is dictated by what is needed to prevent moisture penetration and condensation, rather than by economic payback.

The importance of thermal insulation as a vapour barrier would be discussed in greater details in a later chapter on Cold Storage Applications.

What are the Insulation Applications in Air Conditioning and Refrigeration?

1. The major use is in cold storages for walls, ceiling and flooring as well as for doors. Cold storages can be for positive or negative temperature use. Blast freezer rooms, IQF and plate freezers also require some insulation.
2. For refrigerant pipe lines that are at lower temperature than ambient.
3. Refrigeration equipment such as shell and tube water/glycol/brine and other special-fluid chillers, inter-stage coolers, low pressure/temperature vessels, surge drums, knock out drums, accumulators, suction/liquid line heat exchangers, refrigerant and chilled water circulation pumps and any other equipment that has temperature lower than ambient.
4. In air conditioning applications, insulation is used for water chillers, refrigerant piping, air handling units and ducting.
5. The transport refrigeration industry uses insulation for constructing truck bodies.
6. Package chillers installed on a terrace use insulation for the casing.
7. Ice plants like block ice makers use insulation for tanks; flake ice and tube ice makers use insulation for ice makers.
8. Ice rinks and amusement parks with ice rooms require insulation.
9. Morgues, since they are maintained at low temperatures.
10. Super markets, display cabinets, etc.

In brief, as explained above, wherever the temperature is maintained at a lower level than the surrounding temperature by artificial means, to resist heat from flowing from the higher temperature to the lower temperature area, insulation is essential to save energy.

In subsequent sections we shall discuss each application in more detail to assist design application engineers and installers.

Insulation Materials Used in Cooling Applications

Insulation can be open cell structure, or closed cell structure, or semi open structure.

Closed cell foam has higher R value compared to open cell foam and is a better insulation.

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Examples of these insulation materials are:

Open Cell

i. Rock wool (mineral wool)
ii. Glass wool (mineral wool)
iii. Cork
iv. Melamine foam
v. Expanded polystyrene (EPS)
vi. Polyurethane foam

Semi Open Cell (Microporous)

I. Polyisocyanurate
II. Extruded polystyrene (XPS)
III. Polyethylene

Closed Cell

I. Foam glass (foam)
II. Cross linked polyethylene (XLPE)
III. Nitrile butadiene rubber foam (NBR)
IV. Polyolefin foam – physically cross linked
V. Polyurethane foam

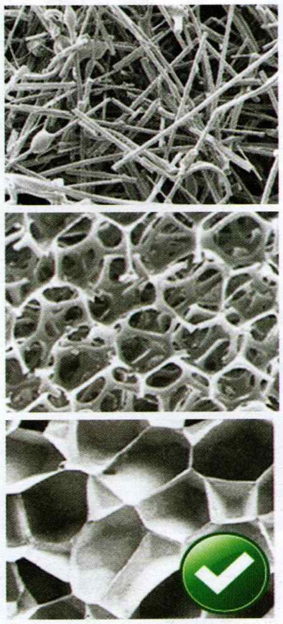

Figure 1: Open cell structure, microporus structure, and closed cell structure

Note: *Polyurethane foam comes in two forms:*

1. Open structure for indoor applications
2. Closed cell for outdoor applications

Flexible Elastomeric Forms

As elastomer is a polymer with the property of elasticity. It is a polymer that deforms under stress and returns to its original shape when the stress is removed. The term is a contraction of elastic polymer. The elastomer group consists of the following:

- Nitrile butadiene rubber (NBR)
- Ethylene propylene diene rubber (EPDM)
- Styrene butadiene rubber (SBR)
- Neoprene

Cross Linked Polyolefin or Polyethelene

Polyolefin is the name of a group of plastics. Polyethylene (PE) is the specific name of one type of polyolefin. The plastics in this group are:

- Polyethylene (PE)
- Polypropylene (PP)
- Polymethyl pentene (PMP)
- Polyethylene Vinyl Acetate (PVA)

Types of Insulation

1. Fibrous Insulation

It is composed of small diameter fibers that finely divide the air space. The fibers may be perpendicular or parallel to the surface being insulated, and they may or may not be bonded together. Silica, rock wool, slag wool and alumina silica fibers are used. The most widely used insulations of this type are glass fiber and mineral wool. Glass fiber and mineral wool products usually have their fibers bonded together with organic binders that supply the limited structural integrity of the products.

2. Cellular Insulation

It is composed of small individual cells separated from each other. The cellular material may be glass or foamed plastic such as polystyrene (closed cell), polyurethane, polyisocyanurate and elastomeric.

3. Granular Insulation

It is composed of small nodules that may contain voids or hollow spaces. It is not considered a true cellular material since gas can be transferred between individual spaces. This type may be produced as a loose or pourable material or combined with a binder and fibers or undergo a chemical reaction to make a rigid insulation. Examples of such insulations are calcium silicate, expanded vermiculite, perlite, cellulose, diatomaceous earth and expanded polystyrene.

4. Vacuum Insulation

Insulation for cryogenic applications uses vacuum to eliminate convection paired with multiple layers of material. These layers are normally of aluminum, copper or gold, separated by small air spaces. This type of multilayer insulation may contain as many as 60 layers per inch, and with each layer of metal emitting as little as 2-3% of insulation, radiation is virtually eliminated as well.

5. Reflective Insulation

Reflective paints and surfaces are added to the surface to lower long wave emittance thereby reducing radiant heat transfer from the surface.

Forms of Insulation

Insulation materials are produced in a variety of forms suitable for specific functions and applications. The combination of form and type of insulation determines its proper method of installation. The forms most widely used are:

- Rigid boards, blocks, sheets, and pre-formed shapes such as pipe insulation, curved segments and lagging: cellular, granular, and fibrous insulations are produced in these forms.
- Flexible sheets and pre-formed shapes: cellular and fibrous insulations are produced in these forms.
- Flexible blankets: fibrous insulations are produced in flexible blankets.
- Cements (insulating and finishing): produced from fibrous and granular insulations and cement, they may be of the hydraulic setting or air-drying type.
- Foams: poured or froth foam is used to fill irregular areas and voids; spray is used for flat surfaces.

Common Insulation Materials Used by AC&R Industry

The most common insulation materials known to the air conditioning and refrigeration industry are:

- Fiberglass
- Mineral wool
- Polystyrene
- Polyurethane
- Polyisocyanurate
- Polyolefin and elastomeric rubber

More details of each insulation material will be given in Chapter 3.