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ENERGY is the driving force of any industrial unit. Whatever activity you do, in the organization or in the plant, it calls for consumption of energy.

The major thrust in any process industry for reducing the thermal energy is always given to optimizing the process parameters for energy reduction. Also in some cases either by using the so-called pinch technology or heat exchanger integration, one tries to reduce the thermal energy requirement of the complex. Sitting in the office and just fetching data from the control room using some software normally does all these things.

We at NIRMA do not end our activities for energy conservation here.

One of the key factors in terms of accounting of the total energy loss-taking place in the company is the insulation loss. We have regular walk-through audits and customary audits for insulation.

Let us understand the basics about insulation

What is Thermal Insulation?

Insulation is defined as a material or combination of materials, which retard the flow of heat. The materials can be adapted to any size, shape or surface. A variety of finishes are used to protect the insulation from mechanical and environmental damage, and to enhance appearance.

Where is Mechanical Thermal Insulation Installed?

Mechanical thermal insulations are materials that insulate the components of mechanical systems in commercial buildings and industrial processes.

In buildings such as shopping centers, schools, hospitals, and hotels, mechanical insulations are installed to improve the energy consumption of the buildings' cooling and heating systems, domestic hot and chilled water supply, and refrigerated systems including ducts and housings.

For industrial facilities, such as power plants, refineries, and paper mills, mechanical thermal insulations are installed to control heat gain or heat loss on process piping and equipment, steam and condensate distribution systems, boilers, smoke stacks, bag houses and precipitators, and storage tanks.

Functions of Insulation

Insulation is used to perform one or more of the following functions:

- Reduce heat loss or heat gain to achieve energy conservation.
- Protect the environment through the reduction of CO_2 , NOx and greenhouse gases.
- Control surface temperatures for personnel and equipment protection.
- Control the temperature of commercial and industrial processes.
- Prevent or reduce condensation on surfaces.
- Increase operating efficiency of heating/ventilation/cooling, plumbing, steam, process and power systems.
- Prevent or reduce damage to equipment from exposure to fire or corrosive atmospheres.
- Reduce noise from mechanical systems.

Benefits of Insulation

- Energy Savings

  Substantial quantities of heat energy are wasted daily in industrial plants nationwide because of underinsulated, undermaintained or uninsulated heated and cooled surfaces.

  Properly designed and installed insulation systems will immediately reduce the need for energy. Benefits to industry include enormous cost savings, improved productivity, and enhanced environmental quality.

- Process Control

  By reducing heat loss or gain, insulation can help maintain process temperature to a pre-determined value or within a predetermined range. The insulation thickness must be sufficient to limit the heat transfer in a dynamic system or limit the temperature change, with time, in a static system. The need to provide time for owners to take remedial action in emergency situations in the event of loss of electrical power, or heat sources is a major reason for this action in a static systems.

- Personnel Protection

  Thermal insulation is one of the most effective means of protecting workers from second and third degree burns resulting from skin contact for more than 5 seconds with surfaces of hot piping and equipment operating at temperatures above 136.4°F (ASTM C 1055). Insulation reduces the surface temperature of piping or equipment to a safer level as required by OSHA, resulting in increased worker safety and the avoidance of worker downtime due to injury.

- Fire Protection

  Used in combination with other materials, insulation helps provide fire protection in:

  - Firestop systems designed to provide an effective barrier against the spread of flame, smoke, and gases at penetrations of fire resistance rated assemblies by ducts, pipes, and cable.
  - Electrical and communications conduit and cable protection.

- Sound Attenuation

  Insulation materials can be used in the design of an assembly having a high sound transmission loss to be installed between the source and the surrounding area. Aesthetics

- Greenhouse Gas Reduction

  Thermal insulation for mechanical systems provides immediate reductions in CO2 , NOx and greenhouse gas emissions to the outdoor environment in flue or stack emissions by reducing fuel consumption required at the combustion sites because less heat is gained or lost by the system.

How does the insulation work ?

In order to understand how insulation works, it is important to understand the concept of heat flow or heat transfer. **In general, heat always flows from warmer to cooler surfaces.** This flow does not stop until the temperature in the two surfaces is equal. Heat is 'transferred' by three different means: conduction, convection and radiation. Insulation reduces the transference of heat.

Conduction

Conduction is direct heat flow through solids. It results from the physical contact of one object with another. Heat is transmitted by molecular motion. Molecules transmit their energy to adjoining molecules of lesser heat content, whose motion is thereby increased.

Convection

Convection is the flow of heat (forced and natural) within a fluid. A fluid is a substance that may be either a gas or a liquid. The movement of a heat- carrying fluid occurs either by natural convection or by forced convection as in the case of a forced-air furnace.

Radiation

Radiation is the transmission of energy through space by means of electromagnetic waves. Radiated heat moves at the speed of light through the air without heating the space between the surfaces. An example is the warmth we feel on our skin from the sun. The sun is unbelievable hot, and the space between it and us is still unbelievable cold.

The basic requirement for thermal insulation is to provide a significant resistance path to the flow of heat through the insulation material. To accomplish this, the

insulation material must reduce the rate of heat transfer by conduction, convection, radiation, or any combination of these mechanisms.
Types of insulation:

1. Mass insulation with air or another gas with thermal properties similar to air within the interstices inside the material. Many cellular insulations, and all fibrous and granular insulations are of this type.

2. Mass insulation with low conductivity gas within the interstices inside the material. Some closed cellular insulations are of this type.

3. Reflective insulation bounding one or both sides of an air space. Many insulation facings such as FSK (foil/scrim/kraft) are of this type.

Physical Properties

- Mass Insulation

  For mass insulation types, the most important physical property is thermal conductivity. Materials with low thermal conductivity allow less heat to be transferred per unit time, per unit temperature difference per inch of thickness. All other items being the same, materials with lower thermal conductivities are better insulators. Commercially available mass insulations have thermal conductivities at 75°F mean temperature less than 0.5 Btu in/(hr, S.F., °F).

- Reflective Insulation

  For reflective insulation types, the important physical property is low surface emittance. Surfaces with low emittance have high reflectance. Reflective insulations have emittance values in the range of 0.04 to 0.1.

Characteristics of Insulation

Insulations have different properties and limitations depending upon the service, location, and required longevity of the application. These are taken into account by engineers when considering the insulation needs of an industrial or commercial application.

- Thermal Resistance (R) (F ft2 h/Btu)

  The quantity determined by the temperature difference, at steady state, between two defined surfaces of a material or construction that induces a unit heat flow rate through a unit area. A resistance associated with a material shall be specified as a material R. A resistance associated with a system or construction shall be specified as a system R.

- Apparent Thermal Conductivity (ka) (Btu in./h ft2 F)

  A thermal conductivity assigned to a material that exhibits thermal transmission by several modes of heat transfer resulting in property variation with specimen thickness or surface emittance.

- Thermal Conductivity (k) (Btu in./h ft2 F)

  The time rate of steady state heat flow through a unit area of a homogenous material induced by a unit temperature gradient in a direction perpendicular to that unit area. Materials with lower k factors are better insulators.

- Density (lb/f3) (kg/m3)

  This is the weight of a specific volume of material measured in pounds per cubic foot (kilograms per cubic meter).

- Surface Burning Characteristics

  These are comparative measurements of flame spread and smoke development with that of select red oak and inorganic cement board. Results of this test may be used as elements of a fire-risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard or fire risk of a particular end use.

- Compressive Resistance

  This is a measure of the material to resist deformation (reduction in thickness) under a compressive load. It is important when external loads are applied to an insulation installation.

- Thermal Expansion/Contraction and Dimensional Stability

  Insulation systems are installed under ambient conditions that may differ from service conditions. When the operating conditions are imposed, metal surfaces may expand or contract differently from the insulation and finish applied. This can create openings and parallel heat flow and moisture flow paths that can degrade system performance.

  Long term satisfactory service requires that the insulating materials, closure materials, facings, coating, and accessories withstand the rigors of temperature, vibration, abuse, and ambient conditions without adverse loss of dimensions.

- Water Vapor Permeability

  This is the time rate of water vapor transmission through unit area of flat material of unit thickness induced by unit vapor pressure difference between two specific surfaces, under specified temperature and humidity conditions. It is important when insulation systems will be operating with service temperatures below the ambient air. Materials and systems with low water vapor permeability are needed in this service.

- Cleanability

  Ability of a material to be washed or otherwise cleaned to maintain its appearance.

- Temperature Resistance

  Ability of a material to perform its intended function after being subjected to high and low temperatures which the material might be expected to encounter during normal use.

- Weather Resistance

  Ability of a material to be exposed for prolonged periods of time to the outdoors without significant loss of mechanical properties.

- Abuse Resistance

  Ability of a material to be exposed for prolonged periods of time to normal physical abuse without significant deformation or punctures.

- Ambient Temperature

  The dry bulb temperature of surrounding air when shielded from any sources of incident radiation.

- Corrosion Resistance

  Ability of a material to be exposed for prolonged periods of time to a corrosive environment without significant onset of corrosion and the consequential loss of mechanical properties.

- Fire Resistance/Endurance

  Capability of an insulation assembly exposed for a defined period of exposure to heat and flame (fire) with only a limited and measurable loss of mechanical properties. Fire endurance is not a comparative surface burning characteristic for insulation materials.

- Fungal Growth Resistance

  Ability of a material to be exposed continuously to damp conditions without the growth of mildew or mold.

Insulation Types, Forms & Finishes

Mass Insulation Types

- Fibrous Insulation

  Composed of air finely divided into interstices by small diameter fibers usually chemically or mechanically bonded and formed into boards, blankets, and hollow cylinders.

  - Fiber glass or mineral fiber

    - Mineral wool or mineral fiber
    - Refractory ceramic fiber
- Cellular Insulation

  Composed of air or some other gas contained within a foam of stable small bubbles and formed into boards, blankets, or hollow cylinders.

    - Cellular glass
    - Elastomeric foam
    - Phenolic foam
    - Polyethylene
    - Polyisocyanurates
    - Polystyrene
    - Polyurethanes
    - Polyimides
- Granular Insulation

  Composed of air or some other gas in the interstices between small granules and formed into blocks, boards, or hollow cylinders.

    - Calcium silicate
    - Insulating finishing cements
    - Perlite

Forms of Insulation

- Board

  Rigid or semi-rigid self-supporting insulation formed into rectangular or curved shapes.

    - Calcium silicate
    - Fiber glass or mineral fiber
    - Mineral wool or mineral fiber
    - Polyisocyanurates
    - Polystyrene

- Block

  Rigid insulation formed into rectangular shapes.

  - Calcium silicate
  - Cellular glass
  - Mineral wool or mineral fiber
  - Perlite
- Sheet

  Semi-rigid insulation formed into rectangular pieces or rolls.

  - Fiber glass or mineral fiber
  - Elastomeric foam
  - Mineral wool or mineral fiber
  - Polyurethane
- Flexible Fibrous Blankets

  A flexible insulation used to wrap different shapes and forms.

  - Fiber glass or mineral fiber
  - Mineral wool or mineral fiber
  - Refractory ceramic fiber
- Pipe and Fitting Insulation Pre-formed insulation to fit piping, tubing and fittings
  - Calcium silicate
  - Cellular glass
  - Elastomeric foam
  - Fiber glass or mineral fiber
  - Mineral wool or mineral fiber
  - Perlite
  - Phenolic foam
  - Polyethylene
  - Polyisocyanurates

    - Polyurethanes
- Foam

  Liquid mixed at the time of application which expands and hardens to insulate irregular areas and voids.

    - Polyisocyanurates
    - Polyurethane
- Spray Applied Insulation

  Liquid binders or water introduced to an insulation while spraying on to flat or irregular surfaces for fire resistance, condensation control, acoustical correction and thermal insulation.

    - Mineral wool or mineral fiber
- Loose fill Granular insulation used for pouring expansion joints.
    - Mineral wool or mineral fiber
    - Perlite
    - Vermiculite
- Cements (Insulating and Finishing Muds)

  Produced with mineral wool and clay insulation, these cements may be hydraulic setting or air drying types.

- Flexible Elastomeric Foam

  Foam sheets and tubing insulation containing vulcanized rubber.

Insulation Finishes

Insulation finishes are important because the ability of an insulation system to perform as designed and specified is dependent upon protection from moisture, weather, chemical and mechanical damage. Insulation can also be used to enhance system appearance.

- Weather Barriers

  Protect the insulation from rain, snow, ice, sunlight, ultraviolet degradation, ozone and residues of chemical compounds in the atmosphere.

    - Mastic
    - Metal
    - Plastic

    - Roofing felt
- Vapor Retarders

  Retard the passage of moisture vapor from the atmosphere to the interior of the insulation system.

    - CPVC
    - FRP
    - Laminated foil-scrim membranes
    - Mastic
    - Metal
    - Plastic
    - PVC
    - Reinforced polyester resin
- Mechanical Abuse Protection

  Rigid jacketing provides protection against mechanical abuse from personnel, equipment, machinery, etc.

    - Metal
    - Plastic
- Appearance Chosen primarily for appearance value in exposed areas.
    - Fabrics
    - Laminate foil/scrim membranes
    - Painted metal
    - Paints
    - PVC

We at NIRMA follow the following practices for effective insulation:

➡ Regular and timely audits.

➡ Follow-up for completion of audits findings on regular basis.

➡ Heat balance of the system on daily basis.

➡ Communication to all concerned departments of heat losses and increase in fuel

consumption after accounting for the increase due to changes in production.

- ➡ Replacement of soaked / compressed insulation.
- ➡ Addition of insulation based on the revised temperature conditions.
- ➡ Ensuring fresh insulation material receipts as per specifications given by the licensor.

We at NIRMA have mainly two types of insulation. Generally all over the plant we have mineral wool insulation and typically in our Hydrogen generating unit we have PERLITE also as one of the insulation materials. We do use ceramic blankets and M-Boards for insulation at few places.

Selecting an Insulation - Communication is Key (mainly during the project stage of the unit)

The owner, engineer, engineering contractor, insulation contractor and insulation and accessories manufacturers must communicate with each other from the very beginning of a project in order to minimize problems in the stages of design, specification preparation, construction, operations, and maintenance.

Open and frank discussion between all parties is critical to helping the engineer establish the proper design criteria, define pipe and duct dimensions, select the insulation materials types and thickness, facings or jackets, and define the installation procedures to be followed. Ambiguities and omissions diminish when communications is encouraged.

Such a discourse, along with knowledge of the most important insulation criteria as detailed above, always helps in calculating the thickness required for the intended service.

During the running stage of the plant, our selection criterion for insulation is based on the specifications given by the licensor / engineering consultant finalized during project stage. It covers the necessary properties of thermal and physical resistance as mentioned above. As far as the cost is concerned, we mainly focus on the technical specification comparison. We have no criteria for replacement of insulation at schedule times.

Over the years of operation, we at NIRMA have identified various numbers of locations, where the maintenance is frequently done. Once the insulation is removed, then it does not go into proper place again. Either it is left open for days or just loosely tied, which is more damaging. For such locations, we have made permanent arrangements of box type / blanket type insulation, so that once maintenance is over, then there is no time delay in putting back the insulation.

I would like to present a case study which will indicate, how closely we look at insulation effectiveness:

Case Study I:

We have a hydrogenation reactor in our process unit. Normally all the hydrogenation reactions are exothermic in nature. Hence one of the means of monitoring the performance of the reactor at steady state conditions of LHSV and process composition is to monitor the delta Temperature rise across the reactor.

We observed based on analytical results of inlet and outlet streams, that for the same inlet conditions of the reactor, the conversion of reaction was high than previous day for the same conditions whereas the delta Temperature across the reactor was low. A low delta Temperature across the reactor should give a low conversion.

Upon investigating at site thoroughly revealed the fact, that the inlet TI to the reactor was located at about 50 metres before the inlet flange to the reactor. It was at the outlet of a preheater followed by a big filter also.

The previous day, because of rain and the poor insulation on the filter box and preheater outlet lines going to reactor, the actual temperature going to the reactor was low about 0.5 C and hence the outlet temperature was also low. Thus overall the delta T across the reactor which we were monitoring, came down. Misguided by the fact, that reaction is low because of low hydrogen flow, in order to maintain the same extent of conversion (i.e delta T), the hydrogen flow to the reactor was raised resulting into a higher degree of conversion.

For us, it happens to be actually a loss of production, because by increasing the conversion, we loose heavily on the selectivity that we want to maintain across the reactor. We always operate at an optimum level of conversion and selectivity.

Conclusion:

Poor Insulation affects production also and not only energy loss. Look for the minutest hot pipeline, which is open to atmosphere and not insulated. It may increase your production also.

Case Study II:

We have a recycle Hydrogen compressor. It is used to circulate nearly 32000 Nm3/hr of hydrogen at a discharge pressure of 90 ksc and discharge temperature of 75 C. This is fed to a reactor which operates at 320 C.

The insulation was done only for the line within the compressor house. After that about 50 metres of line going to the preheater over the pipe rack was left uninsulated.

This dramatically reflected in the efficiency of the pre heater furnace. Upon investigating, it was found that lot of cooling was taking place in the gas line during rains particularly, causing more fuel consumption.

Conclusion:

Regular monitoring of furnaces helps to identify the losses due to insulation, during a weather change. Once identification is done, we can arrest the losses there after.

Thus, I would conclude that our being a petrochemical complex, we are utilizing the commonly used insulation (mineral wool). It suffices our requirements. Wherever special requirements are there, like H2 plant, we have special PERLITE insulation also. The insulation criteria fixed during project stage are further followed for new modifications also. We maintain our specification requirements and cost is secondary.