Overview of Insulation Materials

An Online Continuing Education Course for Engineers

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Overview of Insulation Materials

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Abstract

Substantial quantities of heat energy are wasted daily in industrial plants and buildings because of un-insulated under maintained or under insulated heated or cooled surfaces. Thermal insulation reduces heat flow from one surface to another. For hot, or above ambient applications, thermal insulation reduces heat loss. On cold, or below ambient applications, the insulation generally serves the purpose of minimizing heat gain.

It is important that due regard to the required levels of thermal insulation be given at the initial design stages of process plant. In too many cases the insulation of process plant is an afterthought. Consequently there are cases where proper levels of thermal insulation cannot be installed.

This course reviews the types, characteristics and properties of various thermal insulation materials. There is an outline of energy conservation and therefore the cost savings. The course is divided into 6 sections:

Section - 1:	Introduction and Overview
Section - 2:	Insulation Characteristics and Selection Criteria
Section - 3:	Insulation Types and Materials
Section - 4:	Insulation Application on Piping and Equipment
Section - 5:	Economic Thickness of Insulation
Section - 6:	Recommended Best Practices
Appendix -1	Thermal Insulation Calculator References
Appendix -2	Codes and References

Section - 1: INTRODUCTION AND OVERVIEW

The word "Insulation" derived from the Latin word for island (insula) is the noun describing material which insulates (cuts off) heat (or electricity) from its surroundings. It is a scientific noun and was first recorded in 1870.

Thermal insulation is defined as a material or assembly of materials used to provide resistance to heat flow. The temperature ranges within which the term "thermal insulation" will apply, is from -73.3ºC (-100ºF) to 815.6ºC (1500ºF). Typically all applications below -73.3ºC (-100ºF) are termed "cryogenic," and those above 815.6ºC (1500ºF) are termed "refractory". Usually 2300° F is the maximum temperature where insulation is applied.

Where is thermal insulation installed?

In buildings thermal insulation is installed on the building structure, roof, walls and attic spaces; domestic hot water plumbing lines, chilled water supply and return lines and air distribution ducts to improve energy efficiency and to protect the building constructional elements against thermal impact and moisture related damage. Thermal insulation in winter minimizes heat loss and in summers reduces solar heat transmission.

For industrial facilities thermal insulation is installed on process equipment, piping, steam and condensate distribution systems, boilers, smoke stacks, bag houses, furnaces, kilns and storage tanks etc for process control, energy efficiency and safety.

Why Is Insulation Required?

Principal uses of insulation are for personnel protection, process temperature control, prevention of condensation, and conservation of energy.

Personal & Fire Safety

Insulation reduces the surface temperature to a safer level. Studies indicate that the skin contact for more than 5 seconds with hot surfaces at temperatures above 136.4°F (ASTM C 1055) could result in second or third degree burns. To date, there are no mandates or statutes that govern any upper temperature limit for personnel protection. However, many industries have accepted or adopted 125°F as a common practice.

Insulation for personnel protection is generally applied only in those areas accessible to persons during normal plant operation and maintenance, and applied to a high of 7 feet above or 3 feet from platforms or work areas. As an alternate, in some applications where there is clearly no justification for insulation, the fabricated guards may be employed to restrict personnel proximity to the hot surfaces.

Process Control

Providing a stable temperature flow throughout a process system is in many cases more important than any other design criterion. Some processes may only allow for a minimal temperature fluctuation, for example, liquefied gases must be kept below their boiling points. This is usually accomplished with a combination of pressure and insulation. If the temperature of the liquid gas is allowed to exceed the process control design parameters, the consequence is either a costly loss of gas through vaporization or a potentially hazardous buildup of pressure. Erratic performance of the insulation may be extremely costly to the owner because the process is compromised.

Hot Water & Steam Distribution Systems

Hot water or steam supply at rated temperatures and pressures could be a stringent process requirement for many industrial processes. Certain processes require uniform temperature in narrow tolerances to achieve proper chemical reaction. Too much or not enough heat can completely nullify the chemical reaction or can result in liquid crystallization and the batch loss. For example, in the transport of liquid sulfur, if the temperature drops below its freezing point, the liquid becomes solid. The time and energy required to transform the sulfur back into a liquid and flowing state is more expensive than the cost of replacing the transport system altogether.

Cold Piping Systems

Process control is usually the most important guiding criteria when designing lower temperature insulation systems. In most cold processes (except for chilled water piping in climate control systems), the maximum allowable heat transfer for process control purposes is 30 to 40 Btu/h/ft. The consequences of exceeding this limit are so costly that a safety factor of 4 is frequently employed, resulting in a design limitation of 8 to 10 Btu/h/ft.

Condensation Control

In cooling and/or chilled water distribution lines, the insulation is often the target of condensation when water vapor is driven from the outside air toward the cooler piping systems. In building air-conditioning applications, the moisture condensation can cause the discoloration or staining of ceiling panels, corrosion of cold piping, ducts, chillers etc and pose health risk due to mold and fungus growth.

To prevent condensation, it is important to provide sufficient insulation to keep surfaces above the dewpoint temperature of air. Specifying sufficient insulation thickness with an effective vapor retarder system is the most effective means of providing a system for controlling condensation on the membrane surface and within the insulation system on cold piping, ducts, chillers and roof drains.

Sufficient insulation thickness is needed to keep the surface temperature of the membrane above the highest possible design dew point temperature of the ambient air so condensation does not form on the surface. The effective vapor retarder system is needed to restrict moisture migration into the system through the facing, joints, seams, penetrations, hangers, and supports.

Energy Savings

Insulation conserves energy by reducing or minimizing the heat loss or gain. Remember, insulation is merely a heat flow reducer, not a barrier to heat flow.

Substantial quantities of heat energy are wasted daily in industrial plants nationwide because of under insulated, under maintained or un-insulated heated and cooled surfaces. The reduction of heat loss by insulation is a practical means of achieving substantial economies of energy. Some estimates have predicted that insulation in US industry alone saves approximately 200 million barrels of oil every year.

Associated benefits of insulation include greenhouse gas reduction. Energy efficiency leads to reduction of CO2, NOx and other hazardous gas emissions to the outdoor environment.

Sound Attenuation

Insulation materials can be used in the design of an assembly having a high sound transmission loss. Special or standard insulation materials can be used to encase or enclose a noise generating source, forming a sound barrier between the source and the surrounding area.

Section - 2: INSULATION CHARACTERISTICS AND SELECTION CRITERIA

In order to understand how insulation works, it is important to understand the fundamentals of heat transfer. The flow of heat from one object to another is called heat transfer. There are three fundamental methods of heat transfer that must be considered when designing insulation: conduction, convection and radiation.

Conduction is the transfer of energy (heat) within a body (material) or between two bodies in physical contact. Heat is transferred through most metals ... use metal is a good conductor. For example, when people f... instantly feel the discomfort that c... ly heat is quickly trans... od insulation mate...

Conv... of a body or an objec... e usually detect a draft... e room tends to stratify... when heated and so ... window because... ns to sink. This is t... air entering a room fr...

And radi... the sun or by a fire. ... to lower temperatu... ion depends o... on becomes r... liation in form of he... .

The basic r... the flow of hea... sfer by conduction, ...

Key Terms

Heat transfe... is primarily a function of the resistance of the insulation with respect to its thickness, the operating temperature of the surface being insulated, the surface characteristics of the outer membrane (emittance) and the ambient conditions involved. Before we proceed further, let's familiarize ourselves with few standard terms relating to heat transfer that will be useful in reviewing the insulation materials.