Designer's Guide

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Piping Insulation Design Considerations

When an engineer specifies a type and thickness of insulation for a given application, there are several factors to consider to ensure the insulation will hold up to the environment and the system will be energy efficient throughout its expected life.

Condensation

When piping and equipment operate at temperatures lower than the ambient air temperatures, moisture in the air will condense, or freeze, on or within the insulation surface — or on the cold pipe surface. Unless the system is protected by sufficient thickness and by adequate vapor barrier, the insulation can become wet, causing corrosion, and causing it to become ineffective.

Specifying sufficient insulation thickness with an effective vapor barrier 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 barrier system is needed to restrict moisture migration into the system through the facing, joints, seams, penetrations, hangers and supports. By controlling condensation, the system designer may control the potential for:

- Degrading system service life and performance.
- Mold growth and the potential for health problems resulting from water condensate.
- Corrosion of pipes, valves and fittings caused by water collected and contained within insulation system.

Firestops on insulated pipes

Firestops are products specifically designed to stop smoke, toxic fumes, super-heated gases and fire from migrating from one room to another, or from one floor to another, during a fire. Firestops are used to maintain the integrity of firewalls in the structure via each individually penetrated partition.

Firestops are available in a range of products to accommodate the multitude of different types of penetrating items passing through the different size openings. Most firestopping assemblies are listed with Underwriters Laboratories (UL) and details of the firestopping at through penetrations are in the *UL Fire Resistive Materials Directory*.

All firestopping should be done in strict accordance with local building codes and National Fire Protection Association (NFPA) and Underwriters Laboratories and/or Factory Mutual Insurance Corporations guidelines. Qualified craftsmen should install firestopping material according to the manufacturers installation specifications. The proper type of firestop should be specified for insulated piping passing through firewalls.

Sound attenuation

Sound attenuation, or the limiting of sound propagation from one area to another, requires the application of special and standard insulation materials to encase or enclose the noise generating source, forming a sound barrier between the source and the surrounding area.

The purposes of applying sound attenuation materials are to:

1. Reduce obnoxious noise levels emanating from machines, equipment, pipelines or enclosures.
2. Reduce general noise level in plant areas.
3. Provide for better work conditions.
4. Comply with noise level standards of OSHAand EPA.

High temperature systems

Examples of super hot systems include high pressure steam lines, process lines, exhaust systems or any systems that operate at temperatures from 601 F to 1500 F. Reducing heat loss and protecting personnel are the primary reasons for installing insulation in hot environments.

There is insulation specially designed for high temperature systems, and selecting the right one should be based on the unique requirements of the system you are insulating. Be sure to examine the insulation thermal values and other performance values carefully. In addition, you may want to ask the following questions before providing an insulation recommendation:

1. What is the process?
2. What are the process temperatures?
3. What's in the process and in the exterior environment?
4. Is the piping located where people can come in contact with the piping?
5. Is fire an issue?

Matching insulation and application

Finding the "right" insulation begins with asking some basic questions such as:

A. What is the operating temperature of the system you need to insulate?

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In general, systems needing insulation can be divided into three temperature ranges:

Low Temperature Range (-100 F to 60 F) — Refrigeration, cold/chilled water and commercial heating and cooling systems.

Medium Temperature Range (61 F to 600 F) — Hot water and steam, power/process piping, ovens and stacks.

High Temperature Range (601 F to 1500 F) — Power generation, turbines, kilns, smelters, exhaust systems and power piping.

B. Is the system outdoors orindoors — ora combination of both?

This will help you determine whether or not the system and the insulation needs a covering or jacket to protect the insulation from weather, corrosive atmospheres, water or chemical washdowns, abuse or other conditions.

C. Is the ambient temperature constant, or will it fluctuate?

The answer to this question will guide you in the selection of the appropriate thickness to protect against condensation, heat loss or gain or other temperature control problems.

Considerations on cold process systems

Low temperature systems such as those needed for refrigeration or chilled water range from -100 F to 31 F. Supermarkets and food processing are typical of these types of systems. Domestic cold water systems such as those used for water supply and HVAC chilled water systems generally range from 32 F to 60 F.

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Cold water systems require special attention because one must design for protection against condensation and consider the effect of moisture or water vapor transmission (WVT) on the insulation system.

WVT tells you how much water will be transmitted through an insulation system under certain conditions. Different insulation systems, vapor barriers and installation methods will affect the WVT of the system.

Condensation control and process control are two major reasons for insulating low temperature systems. When equipment or piping operates at temperatures lower than the ambient air, moisture in the air will condense or freeze on, or within, the insulation surface — or on the cold pipe surface. Unless the system is protected by sufficient thickness and by adequate vapor barriers, the insulation may become wet, causing corrosion, and causing it to become ineffective.

Insulation energy life cycle analysis

An Insulation Energy Life Cycle Analysis puts actual dollar savings to Btu losses and calculates greenhouse gas emissions such as CO_2, NO_x and CE (Carbon Equivalent). A life cycle analysis is based on data supplied by a plant/energy manager and gathered during a facility walk-through. This information is used to calculate the energy used and the savings on any operating period or annual basis. Such a body of data is invaluable for companies that want to make sound decisions about a technology that offers tremendous payback over the life of their facilities.

Insulation specifications

Understanding specifications is an important part of the job. Important testing, codes and standards setting organizations critical to ensuring the performance of insulation procedures and systems include:

- ASTM — American Society for Testing Materials
- ASHRAE — American Society of Heating, Refrigerating, and Air-Conditioning Engineers
- U.S. Government, which publishes federal and military specifications for insulation materials.
- National Insulation Contractors Association Guidelines.
- The American Institute of Architects Master Specs.

Some of the performance specifications that you will need to become familiar with on the job include water vapor transmission, compressive strength and fire hazard classifications. You'll find that a 25/50 rating for fire hazard classification is required for most codes. The 25 represents the flame spread index and 50 represents smoke when compared to cement as (zero) and red oak as "100".

Check the manufacturers'specification sheets for specification compliance information.

Protective coverings and finishes

The efficiency and service of insulation is directly dependent upon its protection from moisture entry and mechanical and chemical damage. Choices of jacketing and finish materials are based upon the mechanical, chemical, thermal and moisture conditions of the installation, as well cost and appearance requirements. Protective coverings are divided into six functional types:

- Weather barriers.
- Vapor barriers or retarders.
- Mechanical abuse coverings.
- Corrosion and fire resistant coverings.
- Appearance coverings and finishes.
- Hygienic coverings.

K-factor

The K-factor (thermal conductivity factor) for an insulation material is based on the number of Btu's per hour that pass through a 1 inch thick by 1 inch square block of insulation with a one degree Fahrenheit temperature difference between the two surfaces. Materials with lower K-factors are better insulators.

Insulation materials usually have K-factors less than one and are reported at what is called mean temperature. To determine the mean temperature, measure the surface temperatures on both sides of the insulation, add them together and divide by two.

When comparing the insulating value of different types of insulation, it's important to look at both the K-factor and the mean temperature. As mean temperatures rise, so does the K-factor.

C-factor

The C-factor (thermal conductance factor) is the number of Btu's that will pass through a square foot of material with a one-degree Fahrenheit temperature difference for a specified thickness. The C-factor is the K-factor divided by the thickness of the insulation. The formula is the reciprocal of the R-factor formula. The lower the C value, the better the insulator.

R-factor

The R-factor is the thermal resistance factor. The National Commercial & Industrial Insulation Standards Manual defines R-value as a measure of the ability to retard heat flow rather than to transmit heat. R is the numerical reciprocal of C ($R = 1/C$). Thermal resistance designates thermal resistance values: R-11 equals 11 resistance units. The higher the R value, the higher (better) the insulating value.

Temperature

Temperature is a property unto itself. It is not a measurement of the amount or quantity of heat present. For example, if you pour two cups of coffee, one to the brim, and the other only halfway, the temperature will be the same in both cups, but the partially filled cup will only contain half the amount or quantity of heat (BTUs) of the full one.

Mean temperature is the average of the sum of a hot surface temperature and a cold surface temperature. Insulation conductivity (K-factor) is tested at a number of mean temperatures to develop conductivity curves that simulate actual service conditions under which insulation systems are used. All conductivity factors (K, C, and R) should be qualified by a mean temperature.

Ambient temperature is the average temperature of the medium, usually air, surrounding the object under consideration. □

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