Insulation Fundamentals: Emissivity

Insulation Systems and the Role of Emissivity as a Design Factor

Emissivity is defined as the relative power of a surface to emit heat by radiation. The emissivity (E) of a surface material is measured on a scale where a reflective material that is not emitting any radiant energy is rated at 0, and a non-reflective material that is emitting all of its radiant energy is rated a 1. In the real world, both of these limits are impractical to attain, and measurements fall between these two extremes.

With insulation systems, the emissivity of the jacketing needs to be considered in relation to the insulation material to affect hot and/or cold piping systems with regard to heat loss or gain, surface temperature, condensation and more.

When designing a system, consider in detail how emissivity affects personnel protection, process control and the surface temperature of cold systems for condensation control. We will first discuss these three issues and then explain how the emissivity of the insulation system surface plays a role.

Personnel Protection

This is an issue with hot piping, ducts and equipment. When designing an insulation system for personnel protection, the surface temperature becomes critical. The surface temperature can increase both from outside solar heat gain and from within as heat radiates outward from a hot pipe. Questions an insulation specifier should ask include:

- What are the worst-case ambient temperatures and wind conditions to which the system will be subjected? Consider the ambient conditions that will create the hottest surface temperature, such as summer weather with no wind and a metal jacketing material;
- What is the location of the piping, and will personnel come into contact with it? If the pipe is 20 feet above ground, or in an area that is inaccessible to personnel, there may be minimal human safety concern requiring the control of pipeline surface temperatures. Limited human presence may only require a sign or a fabricated guard. Frequent human contact will require a thorough investigation into the most efficient insulation system for personnel protection.

Process Control

Process control is usually a critical design consideration in many industrial environments and can be relevant with both hot and cold piping. The questions that need to be asked here are:

- What is the worst-case temperature to which the system will be subjected?
- What are the temperature limitations of the process being controlled?
- What are the consequences in terms of the cost and safety of lost process control?

Hot Piping Systems

A loss of process control of a hot-water heating system in a commercial building would probably not cause system shutdown, product loss, process or product failure or pose a significant health and safety hazard.

But, if providing a uniform temperature heat transfer medium such as steam or heat transfer fluids to a vessel is essential to achieve a proper chemical reaction, process control is critical. Too much or not enough heat can completely change or even nullify the chemical reaction. 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

This is an issue with cold piping only. Problems associated with condensation are wetness around the piping and the related thermal degradation or corrosion, the staining of ceiling panels with interior building applications, and the health risk and discoloration due to mold and fungus growth. While insulation systems can be designed to limit or retard surface condensation, they cannot in most cases, be designed to prevent condensation. In very dry climates, the insulation system can prevent condensation most of the time. However, even in the driest desert, dew settles on the ground in the early morning hours. When dew settles on the surface of the insulation system, it is considered condensation.

In humid regions, it is not feasible from a financial or practical standpoint to consider designing an insulation system to prevent condensation 100 percent of the time. The insulation thickness required to achieve this would be unrealistic.

As with personnel protection, the outer membrane or jacketing selected for limiting condensation plays an important role in providing good condensation control. The surface temperature of the insulation system is the controlling factor in how often condensation will form and how long it will be present.

Questions to ask relating to condensation are:

- What are the average (not worst case) summer ambient temperatures and wind conditions the system will be subjected to? Use average summer conditions because the worst-case ambient weather conditions in the summer months, especially in coastal regions, are such that it is unrealistic to try to achieve condensation control.

- What is the operating temperature of the process? On a cryogenic pipeline, for example, the insulation required to provide process control will usually exceed the insulation required to provide condensation control.
- How important is condensation control in the overall performance of the process? In many applications, condensation does not present as much of a process problem as it does an aesthetic problem.

Emissivity as a Design Factor

Personnel Protection

The solution in achieving lower temperature on hot pipes is to either use more insulation or to increase the emissivity of the jacketing. If the solar load is high, a smooth metal jacketing (lower E) reflects much of the radiant heat back into the system and creates surface temperatures that are too hot to touch.

With a hot pipe, the energy flow is outward through the insulation and jacketing to the ambient temperature. Using a dull textured finish will increase the emissivity and allow more heat to escape through the jacketing to the outside atmosphere, thereby lowering the surface temperature. If the jacketing is highly reflective with a lower E, the heat is reflected back into the system, thereby retaining the heat and increasing the surface temperature. By using a jacketing with a higher emissivity value, the amount of insulation needed to achieve the desired surface temperature can be decreased, reducing the initial investment. The trade-off is that as more heat escapes from the system via the higher E material, more energy, and thus more dollars, will be required to maintain the system temperature throughout its life.

Process Control

As mentioned before, a dull finish increases the emissivity and thereby allows more heat to radiate from the system. A reflective metal finish decreases the emissivity and retains more heat within the system. Depending on the particular temperature requirement of the process, the amount of heat transferred can be controlled by both insulation thickness and the emissivity of the jacketing.

Condensation Control

On cold pipes, a dull-finished jacketing with higher emissivity results in a warmer outside temperature. This is the goal so there is less of a difference between the pipe temperature and the ambient air, thereby reducing the likelihood of condensation. A low-emissivity, reflective jacketing will reflect the cold back into the system, thereby keeping the surface temperature cooler. This increases the vapor drive toward the pipe and results in increased condensation potential.

Radiation Emittance Table

Weather-barrier and finishes used on thermal insulations

Weather-Barrier Or Surface Finish	Conditions	Emissivity
Aluminum Jacketing	Polished Gray-Dull Oxidized	0.03 to 0.10 0.10 to 0.40 0.10 to 0.60
Aluminum Paint	New After Weathering	0.20 to 0.30 0.40 to 0.70
Asbestos Paper	Clean	0.90 to 0.94
Asphalt Asbestos Felts		0.93 to 0.96
Asphalt Mastics		0.90 to 0.95
Galvanized Steel Jacketing	New-bright Dull	0.06 to 0.10 0.20 to 0.60
Paints	White-clean Green-clean Gray-clean Black-clean	0.55 to 0.70 0.65 to 0.80 0.80 to 0.90 0.90 to 0.95
Painted Canvas	Color as Painted	Will be approximately the same as E for color of paint used
PVA Mastics	White-clean Green-clean Gray-clean Black	0.60 to 0.79 0.70 to 0.80 0.85 to 0.90 0.85 to 0.95
Roofing Felts		0.90 to 0.95
Stainless-Steel Jacketing	Polished No. 4 mill finish Oxidized	0.22 to 0.26 0.35 to 0.40 0.80 to 0.85

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