

# Thermal Efficiency



The task of thermal insulation is to provide reliable and long-term thermal resistance despite potential harsh environmental and service conditions. Reliable and long-term insulation efficiency is a prerequisite to safe and economical plant operation. But, long-term insulation efficiency doesn't just happen. It must be built into the facility through the use of proper materials and systems. If the goal of long-term efficiency is compromised, severe technical and economical problems will result.

Many insulations are degraded by the very same harsh environments and service conditions in which they were designed to operate.

## PROBLEMS

- *Operating Costs*

Degraded thermal insulation increases operating costs and may never provide a payback. However, constant insulation efficiency provides reduced lifetime costs and rapid payback.

- *Moisture*

Moisture, usually as water, is the prime threat to efficiency because it increases heat flow and operating costs.

- *Process Control*

Problems like excessive boil-off, product loss, production interruption due to viscosity changes, operating equipment destruction and even shutdowns that arise from compromised insulation efficiency can severely affect product quality and quantity.

- *Corrosion*

Absorption/adsorption of water in liquid or vapor form can lead to a variety of corrosion problems.

- *Personnel Protection*

Insulation degradation on high-temperature systems—due to moisture, aging, cracking, etc.—no matter how minor, may lead to skin burns or other tissue damage. Even limited moisture retention can allow insulation surface temperatures to increase by 40°F (22°C) or more—which is enough to result in serious injury.

- *Water's Effects*

Insulations containing liquid water exhibit thermal conductivity up to 15 times greater than when dry. Under freezing conditions, conductivity may increase 60 times or more. With fibrous insulation, heat transmission 24 times the dry state has been reported when wet; up to 100 times when frozen.

Depending on the porosity of an insulation, heat flow can increase up to 300% with a presence of just 20% moisture, by volume. Even 1% moisture, by volume, can increase conductivity by 30%. This is particularly true for fibrous glass and mineral wool insulations.

Because the conductivity of ice increases rapidly with decreasing temperature, insulation performance degradation under cryogenic conditions can create a particularly serious compromise in thermal efficiency: a potential conductivity increase of over 200 times.

- *Water Intrusion*

Moisture can enter an insulation directly through gaps in joints and sealants, openings in jacketing, breaks in mastics or from the inside out via pipe or vessel leakage. Consequently, it is

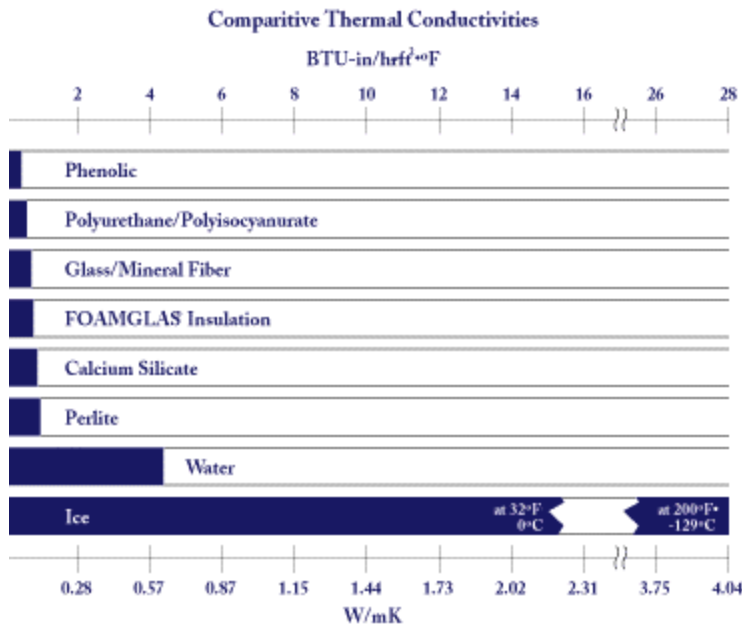
more critical that an insulation has a low moisture absorption and vapor transmission rate than an initially low thermal conductivity.

Some closed-cell materials, such as cellular plastics, slowly "breathe" water vapor and require protection. However, even with vapor retarders, diffusion can still occur through cracks from structural distortion or mishandling.

On cryogenic systems, even a pinhole breach can result in icicles on the pipes in a few days. Experiments with phenolic foam in a thermal gradient have shown that diffusion/condensation can produce thermal conductivity approaching that of water in three weeks with just 50% saturation, by volume. With polyisocyanurate, conductivity can increase 260% in the same period. Even with "waterproofing," warm, moist air has been shown to penetrate and condense unabated in porous insulations.

- *Hygroscopic Behavior*

Some insulations, such as calcium silicate, exhibit a natural tendency to take up moisture by hygroscopic action. Calcium silicate, in fact, will often have residual moisture as received from the manufacturer—sometimes as high as 50%, by weight.



## DEGRADATION MYTHS

- *Myth No. 1:*

"Insulation will dry out in hot systems." In reality, moisture may only be moved around in the system to areas below 212°F (100°C) and, even if it is reduced, will likely be reintroduced.

- *Myth No. 2:*

"Vapor barriers protect the insulation system." Vapor "barriers" are only "retarders," so the longer a system operates at low temperatures, the more moisture is collecting. Also, retarders are not perfect. Cracks, pinholes and imperfect seals allow water vapor and air to enter. Even carefully sealed systems will allow vapor migration. In a study with vapor retarders over urethane, the elimination of moisture was almost 300% slower than its introduction.

- *Myth No. 3:*

"Waterproofing agents will protect the insulation on high-temperature systems from absorbing water or steam." Waterproofing agents have been shown to burn off and allow the absorption of

water. These agents also can have a tendency to absorb, and be destroyed by, simple hydrocarbons. And waterproofing does not inhibit the flow of water vapor.

### **There are additional problems associated with compromised thermal efficiency in insulation.**

- *Material Aging*

Insulation degradation due to aging, or thermal drift, results from gas diffusion through cell walls. It's influenced by time, temperature extremes, chemicals and radiation.

Plastic foam insulations are particularly prone to these influences. Over time and related to temperature, air diffuses into the foam, while intracellular gases diffuse out. Air is twice as thermally conductive as certain foaming agents.

Gas transmission is due to differences in gas concentrations between the inside and the outside of the cells, and temperature-induced internal/external pressure differences. The process is accelerated by increases in temperature and relative humidity of the industrial environment. The result can be thermal conductivity levels significantly above the published values and a dramatic loss of thermal efficiency.

Tests have shown that after 180 days, polyisocyanurate samples averaged 20% above their labeled k factor. Other studies have shown that aging can continue for as long as 22 years after insulation installation, and that thermal conductivity can increase as much as 40% above published values—due solely to natural aging.

- *Liquid Chemical Absorption*

The thermal conductivity of spilled, leaked—or even atmospheric—chemicals may add to the increased conductivity of already wet insulation. Plus, any destruction due to chemical attack can further degrade thermal efficiency and physical strength. As a result, the chemical durability of an insulation in a potentially corrosive application can play a direct role in a system's long-term thermal efficiency. Chemical absorption can also increase fire risk.

The foamed plastics are susceptible to a loss of thermal performance due to chemical absorption. Fibrous insulations such as fibrous glass and mineral wool are also prone to chemical absorption, particularly when previously weakened by moisture. With these insulations, physical degradation of an insulation's binders and waterproofing agents can occur.

- *Compression and Vibration*

Both contribute to insulation degradation, particularly in highly compressible, fibrous materials. Yet, compressive strength is often overlooked. In tests of mineral wool at U.S. petrochemical facilities, new material was found to be compressed up to 10% by its own weight; older material up to 50% by both compression and vibration. The result is that thermal performance, influenced by insulation thickness and density, can be adversely affected.

The effect of compression or vibration on insulation performance can be particularly significant for tank foundations, digesters and underground installations, floors with heavy loads, pipe supports, roofs and self-supporting walls. For many insulations, increased temperature results in decreased compressive strength and thermal performance.

- *Convection*

The movement of air can have a degrading effect on the insulation system. In studies of various insulations on different pipe systems, joints equal or greater than 0.1" (2.5mm) significantly affect thermal performance. A 0.25" (6.4mm) opening reduced performance by 15%.

In experiments, openings within systems—due to dimensional instability or poor application—have been shown to allow degradation of up to 200%.

Cracks in vapor retarders, sealants and the insulation itself—arising from dimensionally unstable insulations—contribute to heat loss via thermal radiation, conduction and convection.

In cryogenic systems insulated with urethane, induced natural convection at the pipe joints increases heat gain due to greater air density and thermal contraction of the urethane. In a double-layered system, heat gain was found to be 33% higher than expected for a -303°F (-186°C) system. With induced condensation of the air at -320°F (-196°C), excessive heat gain increased 174%.

Phenolic and polystyrene foams also can suffer convectional problems from reversible thermal expansion/contraction or irreversible dimensional shrinkage.

- *Thermal Bridges*

Inclusions of high conductivity materials such as metal, paths of direct radiation or convective heat can be sources of heat loss or gain.

Tests of pipe hangers and supports have shown that they can increase heat loss up to 40% compared with uninterrupted, insulated pipe sections. Although losses cannot be eliminated entirely, hanger and support systems of cellular glass insulation have been experimentally shown to keep losses at about 5%.

- *System Damage*

On low temperature systems, degraded insulation can allow ice formation leading to equipment damage and further insulation degradation. Where LNG tanks are involved, compromised insulation can allow the subsoil to freeze and expand, leading to tank foundation destruction.

## **The FOAMGLAS® Cellular Glass Insulation Solution**

The constant thermal efficiency and physical integrity of cellular glass insulation enhances a system's ability and control, and increases long-term energy savings. Cellular glass maintains better efficiency on cold systems. Cellular glass "overfit" directly on wet insulation in hot systems truly does allow a system to dry out. The consistent efficiency of cellular glass frequently makes it the insulation of choice.