

Phenolic Insulation: A Wise Choice For Chilled Water Piping

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After throwing down their bags and sighing with relief, one of the first things many hotel guests do after checking in is adjust their room's air conditioner settings. Regardless of whether they've booked a one-night layover in a motel or a lavish weeklong stay in a five-star resort, most guests consider room temperature control an absolute necessity for a comfortable stay and sleep. What they may not consider is that this precise control is often made possible by a chilled water system. And, if few guests consider their out-of-sight temperature control technology, even fewer think of the insulation protecting this system and their own safety.

Chilled water piping is prone to unique moisture problems and presents a demanding application for insulation. A successful chilled water insulation material must provide high-energy efficiency, condensation control, and precise fire code compliance. Considering these factors, phenolic insulation is often the best bet for chilled water.

Chilled Water Systems: The Basics

Commercial and residential chilled water systems are similar in principle to conventional air conditioners, but with a few key differences. Cool water is circulated to an electric chiller that lowers water temperature to around 45° F or less. The chilled water is pumped to an air handling unit, where it captures ambient heat and disperses cool air throughout the room. This is different from a conventional air conditioning system where the evaporator within the electric chiller directly cools the air rather than chilling the water.

Chilled water systems vary widely in size and complexity, and large systems often feature a precise control system of pumps, valves, and actuators. Residential systems, while quite rare, may consist of a single small chiller and minimal piping. By contrast, large commercial and industrial systems may feature chillers weighing several hundred tons and a vast network of piping. For example, the air conditioning system installed in Dubai's Burj Khalifa, the world's tallest structure, contains 21 miles of chilled water piping and produces the cooling equivalent of 10,000 tons of melting ice daily.

Chilled water systems are ideal for buildings requiring individual cooling for each room. These include schools, hotels, hospitals, and even multi-family residential dwellings. By equipping each room with its own air handler, each area of a large building can be precisely cooled using a single chilled water system. Plus, there's no practical distance limit on a chilled water pipe in a properly designed and insulated system, so chilled water is often used in large buildings such as airports and universities.

Insulation is a critical component in chilled water systems. Piping that carries water at below-ambient temperatures creates a strong vapor drive toward the pipe. In other words, ambient air — which is at higher vapor pressure — tries to push moist air toward the insulated pipe surface, where vapor pressure is lower.

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Chilled Water Pipe Insulation

Insulation is a critical component in chilled water systems. Piping that carries water at below-ambient temperatures creates a strong vapor drive toward the pipe. In other words, ambient air — which is at higher vapor pressure — tries to push moist air toward the insulated pipe surface, where vapor pressure is lower. This pressure creates the constant threat of moisture intrusion. At best, wet insulation causes a significant reduction in efficiency. Various studies have shown that for every 1% moisture gain, insulation efficiency drops by 7%-10%. But at worst, moist insulation can cause health problems for building staff due to mold and mildew growth, or even catastrophic damage to a facility. Moisture that reaches the pipe, for example, can quickly cause corrosion and eventually pipe failure. In a critical environment, such as a hospital, such failures could threaten patients and other building residents.

Chilled water pipe insulation must therefore have low vapor permeability in order to keep moisture out. Even in less humid environments, engineers must consider the fact that condensation will occur on the insulation's surface at some point during the life of the system. And once even a single spot of mold occurs, it attracts more moisture, quickly turning a bad situation worse. Formerly, fiberglass insulation equipped with an all-service jacket (ASJ) vapor barrier was the go-to choice for chilled water pipes. But many of these barriers became moldy and attracted moisture, ultimately failing completely.

What is Phenolic Insulation?

Phenolic insulation is becoming a popular solution to these problems. Phenolic materials consist of solids mixed with phenolic resin and a surface acting agent. The resulting reaction produces a network of bubbles, which is then cured into a foam.

Phenolic insulation for use in chilled water applications is produced in large buns. These buns are cut by insulation fabricators using automated computer profiling saws into pipe insulation sections to meet the required R value for a given project. Typically, vapor barrier jackets are glued to the phenolic insulation sections and shipped to the jobsite, where the pipe insulation is then installed by the contractor. The pipe insulation sections, typically three feet long, are fitted around the pipe. The longitudinal seam of the insulation is usually sealed with mastic and then the vapor barrier is sealed with a self-sealing double-coated tape. The joints between sections are sealed with tape made from the same material as the vapor barrier.

Phenolic foam is a predominantly closed-cell material, meaning it consists of millions of microscopic, unconnected bubbles. These bubbles effectively contain the blowing agent — the substance responsible for forming the foam and keeping it rigid — on a long-term basis. By contrast, in an open-cell material, the blowing agent forms linked, irregularly shaped pockets. Because the pockets are open, the blowing agent escapes and the pockets fill with air instead.

This action severely diminishes the material's thermal resistance as well as its moisture resistance. If an open-cell material gets wet, it becomes entirely saturated, whereas only the surface of the closed-cell one becomes moist because of its closed-cell structure. Plus, if a closed-cell foam is damaged, moisture penetrates only the damaged area rather than spreading throughout the material. Pairing closed-cell phenolic insulation with a good vapor barrier can result in a permeability rating of nearly 0.0, an ideal target for applications like chilled water where condensation is a concern.

Phenolic materials have a number of other unique desirable qualities for insulation applications:

- **Thermal performance:** Rigid phenolic foam offers outstanding insulating properties due to its very low thermal conductivity. Phenolic is capable of twice the thermal capabilities of other common insulating materials like cellular glass. Its high R-value and low thermal conductivity mean that an end user can buy less insulation and maintain the same performance compared to other common insulation materials.
- **Fire performance:** Phenolic has superior fire resistance, with a very low flame spread and very low levels of toxic gas emission. All phenolic foam is rated with an ASTM E84 25/50 Class A flame and smoke rating, meaning that flame and smoke spread will not exceed 25 feet and 50 feet, respectively, if the insulation ignites. Many phenolic foams do not burn at all when exposed to an E84 flame test, yielding a perfect 0/0 rating.
- **Environmental:** While phenolic is non-biodegradable, waste insulation can easily be reused and manufactured into a new product.

Making Sense of Pipe Insulation Materials

The end result of these characteristics is a product ideally suited to chilled pipe insulation. But every chilled water system varies, so when selecting insulation, a range of materials should be considered. Some other common insulation materials include:

Elastomeric insulation is a closed-cell material comprised of elastomers, granting it high elasticity and flexibility.

Cellular glass is a partially closed-cell material made up of glass processed into a rigid foam.

Fibrous glass insulation is an open-cell synthetic material made by melting silica and other inorganic material, then forming the melt into a fibrous mineral wool. Binders or oils are often included to add solidarity. Fibrous glass insulation is often colloquially referred to as fiberglass.

This table summarizes each insulation material's important specs; the bolded numbers represent the best insulation for that specification.

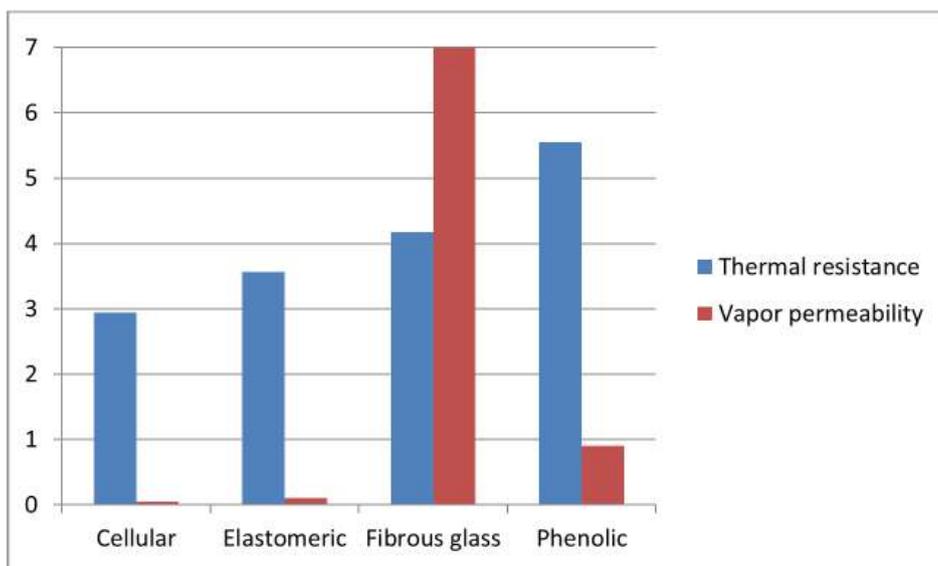
Insulation type	Maximum thermal conductivity (Btu-in/h ft ²) at 75° F	Temperature max (°F)	Temperature min (°F)	Surface burning characteristics (per ASTM E84)	Maximum water vapor permeability (Perm in)
Cellular glass	0.34	800	-450	25/50	0.005
Elastomeric	0.28	220	-297	25/50	0.10
Fibrous glass	0.24	850	0	25/50	70+
Phenolic	0.18	257	-290	25/50	0.9

Table data source: National Insulation Association

These materials are widely used in U.S. chilled water piping, and, while phenolic pipe insulation has been common in Europe and Asia, it's catching on in North America as well. Collectively, these four insulation types have similar properties, but also have subtle differences. For example, fiberglass materials have relatively good thermal conductivity characteristics but poor permeability, so a good vapor barrier is necessary to avoid moisture problems. But a vapor barrier is only as good at stopping moisture as the underlying insulation, so if it's punctured and vapor infiltrates an insulation material with poor permeability, mold and corrosion will quickly develop and threaten the pipe and system.

Conversely, cellular glass and elastomeric have excellent vapor permeability characteristics and often do not require vapor barriers, but they have relatively poor thermal conductivity, so more material is necessary to properly insulate a pipe. All of these types may be ideal for a specific chilled water system, depending on the system's design, insulation needs, and ambient environment.

The chart below shows the balance between a material's thermal resistance value ($R=1/k$, where k =thermal conductivity) and vapor permeability. High thermal resistance and low vapor permeability is desirable.



Phenolic's superior thermal performance plus low vapor permeability make it a strong, efficient contender for chilled water pipe insulation.

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ABOUT POLYGUARD

Polyguard was founded in 1953 in Oklahoma by Robert Nee and Frank McNulty. Polyguard moved to Ennis, Texas in 1978. John (current CEO) and Kathy Muncaster purchased Polyguard in 1986. In 1987, John and Kathy decided to allow the employees to directly benefit from their hard work by offering all of the employees an opportunity to be part of an Employee Stock Ownership Plan (ESOP). In December 2014, the company became 100% ESOP owned.

Think of Polyguard as an innovator and manufacturer of barriers – not just barriers against moisture and corrosion, but against contaminants like radioactive radon gas and methane. No sick buildings here.