Thermal Insulation Coatings: Controlling

Paints and coatings are typically used to beautify and protect, but there are many examples of specialty coatings that serve other functions.[1,2] The development of these "functional" coatings has been a trend in the industry for many years, and there are numerous examples such as soft-feel coatings for consumer electronics[3,4], sound-damping coatings for mitigating noise in automobiles[5,6], and antimicrobial coatings designed to kill microorganisms that come into contact with the coated surface[7]. Another trend in the paint and coatings industry has been the development of coatings that control the use of energy.

Access to energy is an important global driver for economic growth, and how we generate, efficiently use, and ultimately conserve energy has important consequences for the future of our environment and society. Coatings technology has an important role to play in this ongoing struggle.[8] For example, coatings that can be cured at lower temperatures inherently use energy more efficiently.

The replacement of heavier bitumen pads with lightweight liquid-applied sound-damping coatings allows auto manufacturers to remove weight from automobiles.[5,6] Reducing weight of transportation vehicles uses energy more efficiently and improves mileage. Antifouling coatings help the fuel efficiency of ships by preventing the buildup of biofouling on the hull, which increases drag and makes engines work harder to achieve the same result.[9,10]

Several types of functional coatings are targeted at managing thermal energy. Cool-roof coatings keep the interior of buildings cooler and lighten the load on air conditioning during the hot, sunny days of summer. High solar reflectivity and thermal emissivity helps the coating deflect energy in sunlight, preventing the roof from heating up as much, and thus less heat is conducted through the roof and into the building.[11,12] Cool coatings for exterior building walls also function in a similar manner.

Cool coatings also help defend against the urban heat island effect, where urban environments with large areas of dark roofs and paved surfaces tend to be warmer than nearby rural areas. Thermal insulation coatings are also used to manage thermal energy for both personnel protection and energy conservation purposes.[13] However, thermal insulation coatings rely on a different mechanism and prevent heat transfer between materials due to their low thermal conductivity.

In this article, we introduce thermal insulation coatings and the science behind how they work. First, a discussion on the physics of heat transfer and thermal conduction will provide some necessary context to understand how insulation works. A description of traditional insulation materials and some lingering problems with those materials will give perspective into why thermal insulation coatings were developed, followed by a description of how thermal insulation coatings are formulated, applied and perform. A brief comparison with cool-roof coatings will also be given to clarify common misunderstandings about functional coatings and how they each help with energy management.

Heat Flow with a Functional Coating

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MECHANISMS OF HEAT TRANSFER

The flow of heat between materials is controlled by three basic mechanisms: conduction, convection, and radiation. Consider the simple scenario of heating water in a pot shown in *Figure 1*, which is often used to explain the three mechanisms. When heat flows through a solid material, it is by conduction. An example of conduction is the flow of heat from the fire, through the metal of the pot, to the hand holding the pot handle. The rate of conductive heat transfer depends on the chemical nature and structure of the solid material. If the pot in *Figure 1* is a cast iron skillet, the cast iron handle could get very hot, and an oven mitt might be needed to touch the handle with your hand. Many pots have handles made with or covered by a different material such as wood or plastic. The conduction of heat through those materials is slower than through metal, so pots with those handles can often be held with a bare hand.

Convection is the transfer of heat by the movement of a fluid; either a gas or liquid. In *Figure 1*, heated water moves from the bottom of the pot, which is closer to the heat source, upward toward the cooler surface. In this case, convection involves the movement of a liquid. In a similar manner, convection involving the movement of a gas is a process that causes warm, lighter air to rise and cold, denser air to sink within a house, resulting in upper floors often being warmer than the lower floors. Another example of convection involving a gas is shown in *Figure 1*, where the boiling water evaporates as steam, which rises from the hot water surface and heats up the cooler air above. In these examples, convection occurs because of differences in the density and buoyancy of hot and cold regions of the liquid or gas. Hotter, less dense fluids will tend to rise, and colder, denser fluids will descend.

Heat can also be emitted from a material through radiation in the form of electromagnetic waves, such as infrared (IR) radiation. Heat transfer through radiation results in the warmth we feel when we hold our hands near a fire, as shown in *Figure 1*, or when sunlight heats a dark roof or an asphalt parking lot. Anyone walking in bare feet on hot asphalt pavement during a sunny summer day experiences the result of heat transfer by radiation. Radiation is also the mechanism through which the hot roof or asphalt pavement releases (or emits) heat into the surrounding air and cools down once the sun sets.

THE SCIENCE OF HEAT TRANSFER BY CONDUCTION

To understand heat transfer by conduction, consider the situation in *Figure 2*, where a rectangular bar of a specific material is placed in thermal contact on either end of two bodies, each held at a different and constant temperature.

The warmer body on the left is at a temperature T_{hot}, and the cooler body on the right is at temperature T_{cold}, where $T_{hot} > T_{cold}$. Assuming that the other sides of the bar are insulated to prevent heat loss from those surfaces, heat energy (Q) will flow through the bar of material, flowing from the warmer body to the cooler body. The amount of heat conducted will depend on several factors, including time, the temperature difference between the two ends of the bar, the length and cross-sectional area of the bar, and the specific material from which the bar is manufactured.

More heat flows through the bar over a longer period of time, so heat (Q) is proportional to the amount of time (t) during which conduction occurs. Heat is also proportional to the temperature difference ($\Delta T = T_{hot} - T_{cold}$), so a larger ΔT leads to more heat flowing across the bar. When both ends are at the same temperature, there will be no heat flow. Longer bars will result in lower heat transfer, and heat (Q) is therefore inversely proportional to the length (L) of the bar. This relationship makes intuitive sense if you consider that a thicker layer of insulating material will allow less heat to transfer. Finally, more heat will flow through a bar of larger cross-sectional area (A). Consider, for example, if a second identical bar was also placed into contact with the same hot and cold bodies. The total cross-sectional area doubles, and twice as much heat would flow through two bars as through a single bar. So, heat (Q) is proportional to cross-sectional area (A) of the bar.

These relationships are described by *Equation 1*, which describes the amount of heat that flows through the bar. The proportionality constant k is called the thermal conductivity and depends on the specific type of material from which

FIGURE 1—Examples of the Three Mechanisms of Heat Transfer

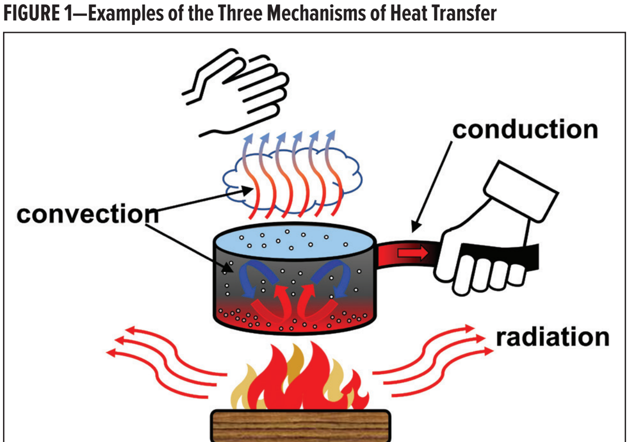
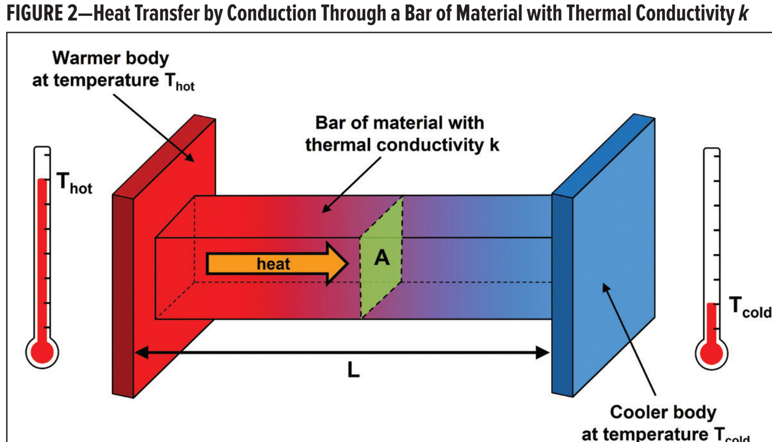


FIGURE 2—Heat Transfer by Conduction Through a Bar of Material with Thermal Conductivity *k*



the bar is composed. Materials that are good thermal conductors of heat, such as metals, have large values for *k*. Materials with low values of *k* are poor conductors of heat, and are referred to as thermal insulators.

Examples of thermal conductivity values for several materials are given in *Table 1*. Based on *Equation 1* and differences in thermal conductivity values, bars made of different materials may transfer different quantities of heat in the same amount of time when placed in the identical set-up of *Figure 1*, i.e., when the same temperature difference exists between the ends.

Equation 1:

$$Q = k\left(\frac{A\,(T_{hot} - T_{cold})\,t}{L}\right) = k\left(\frac{A\,\Delta T\,t}{L}\right)$$

Heat (*Q*) is reported in SI units of Joules (J) because it is energy. The heat flow rate (*H*) is the time rate of transfer of heat energy, i.e., the amount of heat *Q* transferred in time *t*, and is described by *Equation 2*. Heat flow rate has SI units of Watts (W), where 1 W = 1 J/s. Thermal conductivity is typically reported in SI units of Watt per meter per degree Kelvin or W/mK.

Equation 2: $$H = \frac{Q}{t} = \frac{k\,A\,\Delta T}{L}$$

Materials that are poor heat conductors are useful for insulating a building. For this reason, the concept of thermal resistance (*R*) or *R*-value is commonly used in the building trades. The *R*-value is defined by *Equation 3* for a slab of material of thickness *L*.

Equation 3: $$R = \frac{L}{k}$$

While thermal conductivity is an intrinsic property for each material, and its value does not change with thickness, *R*-value depends on the material thickness. The SI units for *R*-value are m^2K/W, but it is more commonly reported in the English units of ft^2 °F hr/Btu. When comparing different insulation materials, a reported *R*-value is only meaningful if the material thickness is also reported.

Equations 2 and *3* show that a material with a higher *R*-value leads to a lower rate of heat flow, and thus better insulation properties. *Table 1* lists the calculated *R*-values (in units of ft^2 °F hr/Btu) for some common materials, based on the thermal conductivities (*k*) listed in the same table, and assuming a 1-inch-thick slab of material. For a 2-inch slab of material, the *R*-values in *Table 1* would be doubled. When materials are added in layers, the *R*-values for each layer are added together to give the *R*-value of the composite.

The *R*-value of still, dry air is as great as that of most building materials shown in *Table 1*, and indeed the effectiveness of many common insulating materials (e.g., fiberglass batts, expanded polystyrene board, etc.) is due to entrapped pockets of air. As will be described below, incorporating a significant amount of entrapped air can also allow coatings to act as insulation.

INSULATION MATERIALS

Insulation is designed to resist the transfer of thermal energy between two materials in contact, and typically performs that function by presenting a region of greater thermal resistance between the materials where the conductive flow of heat is decreased. As described above, thermal insulators have low thermal conductivities to help reduce heat flow, and include common insulation materials such as fiberglass, perlite, rock wool, and organic foams such as polyurethane or expanded polystyrene.

While we usually think of insulation as it relates to keeping our homes and buildings warm in the winter and cool in the summer, its application is prevalent in many other industries. Examples range from the everyday use of the polystyrene coffee cup to prevent transfer of heat from the hot liquid in the cup to the hand holding it, to fiberglass batts used in wall and ceiling cavities to help maintain interior building temperatures, to the highly engineered cast-in-place syntactic foam systems used to prevent the cooling of liquids flowing through subsea pipes for deep-water oil production to assure their continued flow.

In industrial facilities such as refineries, chemical plants, and food or pharmaceutical manufacturing plants,

TABLE 1—Thermal Conductivity (*k*) of Some Common Materials, and Calculated *R*-value for 1-inch Thick Slabs of the Material

MATERIAL	THERMAL CONDUCTIVITY, k (W/mk)	R-VALUE (ft2 °F hr/Btu)
Air	0.026	5.5
Aluminum	237	.0006
Calcium silicate	0.05	2.9
Carbon steel	54	0.003
Concrete (lightweight)	0.1 – 0.3	0.5 – 1.4
Concrete (dense)	1.0 – 1.8	0.08 – 0.14
Copper	398	0.0004
Diamond	1000	0.0001
Expanded polystyrene foam	0.03	4.8
Glass (borosilicate glass)	1.14	0.13
Hollow glass microspheres	0.03	4.8
Perlite	0.03	4.8
Poly(methylmethacrylate)/Plexiglas	0.19	0.8
Polyurethane foam	0.03	4.8
Rock wool	0.04	3.6
Silica aerogel	0.012	12.0
Stainless steel (austenitic, type 304)	15	0.01
Water	0.60	0.24
Wood (Eastern white pine, oven dry)	0.09	1.6

insulation is used for multiple reasons including energy conservation (to ultimately save money), safety (i.e., protection of skin from contact with hot or cold surfaces), process control (e.g., to maintain a specific temperature for a reaction vessel, transfer piping or refrigeration unit), and the prevention of condensation on cold surfaces. The global demand for energy is ever increasing, and factors such as increasing energy costs and the harmful environmental impact of energy generation and usage have put a strong focus on energy conservation.

As useful as traditional types of insulation are in various settings, they can also present unique problems. Many types of insulation materials are porous (e.g., fiberglass) and will readily absorb moisture. As the insulation becomes wet, its thermal conductivity will rapidly increase, and its ability to prevent heat transfer is compromised.

Because effectiveness is often lost when wet, traditional insulation materials often require a moisture barrier or jacketing to keep dry. Metal cladding or jacketing is commonly used in industrial environments to protect insulation from moisture, impact damage, and other elements of weathering such as degradation by UV light.

Even with mechanical jacketing, water often finds its way to insulation. In the case of insulated steel substrates such as pipes or tanks in an industrial setting, wet insulation can lead to corrosion proceeding underneath the insulation without notice. The problem of corrosion under insulation (CUI) is a common and costly problem for facility owners.[14–16] It is typically only detected if there is a catastrophic failure, such as a breach in a tank or pipe wall, or if there is regular inspection of the substrate. Inspection can be difficult, as it requires removal of jacketing and insulation to visually observe the substrate.

Coatings technology can help prevent CUI through the development and use of coatings with improved corrosion resistance for the aggressive environment that exists under wet insulation. Another way that coatings are being used to attack the CUI problem is by replacing the insulation with a liquid-applied thermal insulation coating.

THERMAL INSULATION COATINGS

Thermal insulation coatings are functional coatings which inhibit the transfer of heat by slowing down the conduction mechanism via their low thermal conductivity. As described above, because thermal conductivity is a bulk property, the ability to insulate depends on the film thickness. Thermal conductivity of the insulation coating is not dependent on the surface of the film, i.e., it can be dirty, different colors, or covered with another coating and still provide the same insulating power.

Insulation coatings have been available for approximately two decades, and their use has grown particularly in the protective coatings segment for commercial and industrial applications. Typically employed in thick coats with total dry film thicknesses (DFT) of 40 mils (1 mm) and up, they are sometimes applied in several coats to reach the desired film thickness.

Insulation coatings are usually applied by spray, but some manufacturers also recommend brush, roll, or trowel. The film thickness will depend on the purpose and the required insulating power. Common functional uses of insulation coatings include personnel protection, energy management, and condensation control.

One typical use of insulation coatings is to provide personnel protection from accidental contact with a hot surface. In industrial settings, there are many hot metal surfaces, such as steam transfer pipes, which are above the temperature that will burn skin if touched. A person will receive a first-degree burn if their skin is in contact with a surface above approximately 60 °C (140 °F) for more than five seconds.[17]

Insulation coatings can improve safety by providing a coating surface with a lower surface temperature than the bare metal substrate. For example, it has been reported that the surface temperature of steel held at 82 °C (180 °F) was lowered to below 60 °C (140 °F) when coated with 75 mils DFT of an insulation coating with a thermal conductivity of 0.08 W/mK.[13]

Most insulation coatings are recommended for surfaces with service temperatures up to approximately 177 °C (350 °F). The degree to which the surface temperature is decreased will depend on the substrate temperature, the film thickness, and thermal conductivity of the coating. It has also been argued that the low heat flux of insulation coatings should allow a longer contact time with the coated surface versus the bare metal, as the amount of thermal energy being transferred to the skin is lower than for a bare metal substrate at the same surface temperature.[18]

Jacketed insulation is also used for personnel protection; however, when water gets under the jacketing, the insulation is less effective and the jacketing can hide CUI.[19] Insulation coatings have the advantage of being intimately adhered to the substrate or a primer, and because there is no space for water to reside between the insulation and metal surface, CUI is eliminated. The coating system only needs to be inspected occasionally to ensure it is intact and protecting the steel from corrosion.

Replacing thick layers of traditional insulation and jacketing with a relatively thin, liquid-applied insulation coating also has other advantages, including greater ease of application in terms of installation time and application to surfaces with complex geometries such as bends and valve assemblies. Insulation coating can also be used with primers and topcoats to provide an overall coating system with good insulating properties as well as durability, water resistance, and corrosion resistance.

Thermal insulation coatings are also being used for energy management, and many manufacturers are promoting their products for such uses. However, there are only a few published reports of laboratory[18,20] and field[21] studies showing the ability to lower energy consumption, such as in situations where a vessel temperature must be maintained at a certain level.

In one study, small vessels were filled with a fluid and maintained at a constant temperature, and the amount of energy required to maintain the temperature was measured over a 6-hour period.[20] It was reported that a steel vessel coated with 125 mils DFT of an insulation coating (k = 0.08 W/mK) required an average of 22% less energy compared to an uncoated vessel, across a temperature range of 82 to 163 °C (180 to 325 °F).

Preventing condensation on cold surfaces is another application recommended for insulation coatings. For example, if a cold pipe exists in a warmer space with humidity, condensation will form when the temperature of the pipe surface is below the dew point. A cold substrate with an insulation coating installed will present a warmer surface to the moist air and can prevent condensation if it is above the dew point. Mitigating condensation on cold metal surfaces can also play a role in preventing corrosion.

FORMULATION OF THERMAL INSULATION COATINGS

Most thermal insulation coatings are waterborne and based on acrylic latex or, less frequently, two-component epoxy binders. Waterborne systems are favored because they can be applied to a hot surface, allowing application while equipment is still in service, and without fear of ignition due to a low flashpoint.

To avoid the presence of solvents, insulation coatings based on 100% solids, two-component epoxy systems are also available. There are also some silicone-based insulation coatings available for use in high-temperature industrial applications, as the systems based on organic resins are usually limited to maximum service temperatures of approximately 177 °C (350 °F).

The main contribution to insulation properties is not from the binder but from incorporating high loadings of fillers with low thermal conductivities such as hollow glass and ceramic microspheres, silica aerogel, and other fillers such as perlite. In particular, effective fillers have large amounts of still air trapped in their voids and pores. *Table 1* shows the thermal conductivities (*k*) for a few fillers already mentioned.

Hollow glass microspheres, for example, are made from borosilicate glass and have a small amount of air trapped in a micron-size void. Commercially available materials have a range of mean particle sizes (about 10–75 μm) and densities (about 0.15–0.60 g/cm³). The lower density microspheres also tend to have lower crush strengths, and while expected to be more effective for insulating properties, might not be useful in applications methods where high pressures are involved (i.e., airless spray).

Silica aerogel particles are extremely porous, with about 90 to 95% porosity for grades used in insulation coatings, an open cell structure, and very small pores (~ 20 nm diameter). Water is excluded from the pores due to hydrophobic treatment of the silica. Silica aerogels are materials with very low thermal conductivities, and commercial versions useful as fillers in coatings have reported thermal conductivities of only 0.012 W/mK. The thermal conductivity of silica aerogel is actually lower than that of still air (0.026 W/mK) as a result of their nanosize pores, which ensure a mean free path of the air molecules smaller than in bulk air.

Insulation coatings are therefore composite materials composed of functional fillers dispersed in a polymer matrix. While the filler provides the low thermal conductivity needed for insulation properties, the binder provides the film with cohesive strength, adhesion to the substrate or primer, and flexibility.

A formulation based on an acrylic latex and hollow glass microspheres is shown in *Table 2*. In the example, the high concentration (74% PVC) and low density of the hollow glass microspheres (0.25 g/cm³) leads to a coating with a very low density—at only 5.2 lb/gallon, it has a wet density that is about half that of a typical paint or coating. Acrylic insulation coatings are usually formulated at very low VOC levels (< 25 g/L in most commercial products) because of the high pigment loadings and the use of latex polymers with low glass-transition temperatures (T_g).

Volume solids are typically very high (>70%) to promote fast dry between coats. Because insulation coatings are applied in such thick layers, often 25 to 50 mils DFT per coat, problems can arise due to the drying process. Issues such as mud-cracking and bubbling, which are often observed with thick film applications of normal waterborne coatings, can occur but can also be addressed through formulation or better control of the drying process.

Mud-cracking, due to film shrinkage and stress that builds up during the drying process, can often be addressed through increased volume solids, lower polymer T_g, and plasticization, for example. Bubbling of the film can occur if water is trapped in the drying film and then forced to escape quickly due to heat. Formulation methods that extend open time can help, as well as controlling the drying process between coats.

There have been some reports of studies examining various formulation parameters such as type, particle size, density, and level of filler.[18,20,22] As expected, higher loadings of filler have been found to give lower thermal conductivities in the dry films.[20,22]

Thermal conductivities of insulation coatings are often measured by one of two methods, either ASTM C177[23] or ASTM C518[24]. A survey of product literature for commercially available insulation coatings reveals values of thermal conductivities, when reported,

TABLE 2—Representative Formulation for a Waterborne Thermal Insulation Coating Based on an Acrylic Latex and Hollow Glass Microspheres

INGREDIENT	POUNDS	GALLONS
Water	40.00	4.80
Coalescent	12.00	1.52
Surfactant	2.00	0.23
Ammonia (28%)	2.00	0.26
Pigment dispersant (21%)	4.00	0.45
Defoamer	2.00	0.24
Acrylic latex (50% solids)	346.00	39.28
Hollow glass microspheres (0.25 g/cm³ density)	110.00	52.82
HEUR rheology modifier	3.00	0.34
Defoamer	0.50	0.06
Totals	**521.50**	**100.00**
Properties:	*Volume Solids*	71.4%
	Weight Solids	54.6%
	Density (lb/gal)	5.2
	VOC (g/L)	21
	PVC	74.0%

in the range of 0.035 to 0.120 W/mK. This range is significantly lower than values expected for normal coatings (i.e., without low thermal conductivity fillers) that are typically 0.200 W/mK and above.[18,20,22]

Insulation coatings are heterogeneous materials—basically composites of discrete filler particles within a polymer matrix—and being able to predict their thermal properties would be useful. A mathematical model describing the thermal conductivity of insulation coatings containing hollow microspheres has been developed.[25] The model incorporates variables such as sphere particle size, shell thickness, void volume, level (PVC), and the binder and sphere wall (e.g., glass) material thermal conductivities to simulate thermal properties such as the thermal conductivity of the binder/microsphere composite. In a similar manner, a mathematical model has also been developed for insulation coatings based on silica aerogel.[26]

DISPELLING MYTHS AND MISCONCEPTIONS

There are some common myths and misconceptions about thermal insulation coatings. In particular, confusion exists about *R*-value and claims of the ability of relatively thin insulation coatings to replace thicker layers of traditional insulation.

Also, cool coatings for roofs and walls are often discussed in terms of their insulation power. However, their mechanism for prevention of heat transfer is very different compared to thermal insulation coatings, and a brief review of the mechanisms and terminology will help in navigating discussions of the two classes of coating.

A common question about thermal insulation coatings is whether a relatively thin layer of coating can replace a much thick layer of traditional insulation, such as the 3.5-inch-thick batts of fiberglass insulation designed for use in the 2x4 walls of residential construction. Such a question is easy to answer when the concepts of thermal conductivity and *R*-value, as described above, are understood. A 3.5-inch fiberglass batt, assuming it is not compressed to a lower thickness and is not wet, is expected to have an *R*-value of 13 (assume the commonly used units of ft^2 °F hr/Btu for all *R*-values). This corresponds to a thermal conductivity of approximately 0.04 W/mK for the fiberglass. To have equivalent insulating power, a dried insulation coating should give a similar *R*-value.

For example, we can calculate that an insulation coating with a thermal conductivity of 0.1 W/mK, higher than that of fiberglass, would have an *R*-value of 1.44 for a 1-inch thickness. A 3.5-inch thickness of coating would have an *R*-value of 1.44 x 3.5 = 5.04. So, even when applied at the same thickness as an R-13 fiberglass batt, this coating would not provide the same insulating power due to its lower thermal conductivity.

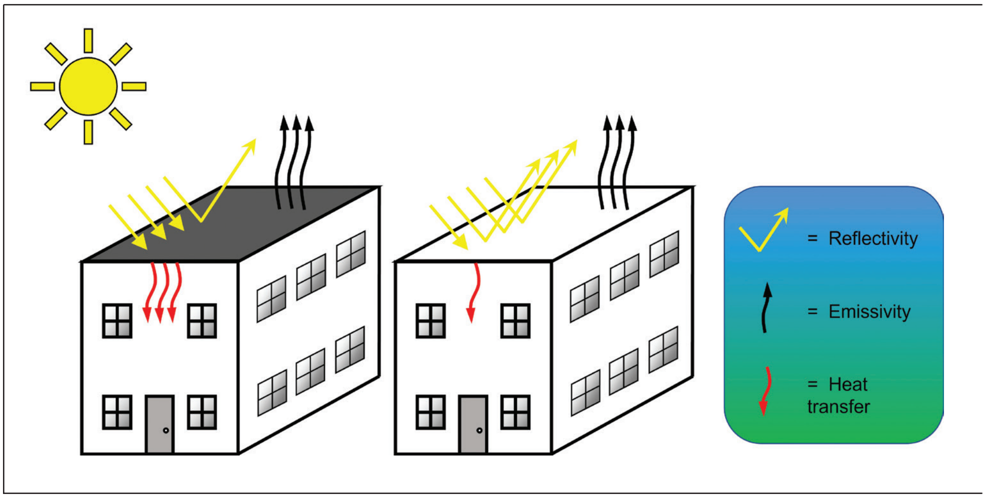
However, an insulation coating with thermal conductivity of 0.035 W/mK, similar to that of the fiberglass batt, would have an *R*-value of 4.2 for a 1-inch thickness, and an *R*-value of 14.4 for a 3.5-inch thickness. So, a thermal insulation coating with a thermal conductivity similar to that of the fiberglass can provide a similar level of insulating power, but it would have to be applied at close to 3.5 inches. Right away it can be understood that a much thinner DFT of insulation coating, for example at a typical thickness of 3 mm (0.12 inch), would not be equivalent to the thicker (3.5-inch) layer of fiberglass material.

As described at the beginning of this article, cool-roof and cool-wall coatings are another class of coating that can help with energy management.[27] Sometimes, they are talked about in terms of their insulating power, which can be confusing given the above discussion on thermal insulation coatings. In our discussion here, insulation describes the inhibition of heat transfer via a conductive mechanism. While cool-roof and cool-wall coatings prevent heat transfer from the sun to the inside of buildings, they operate by affecting the mechanism of heat transfer by radiation.

Consider the situation in *Figure 3*, where a dark roof is exposed to sunlight. The sun emits energy in the form of electromagnetic radiation (ultraviolet, visible, and infrared light) that makes its way through space and our atmosphere to the roof surface. A dark surface has a very low solar reflectance, meaning that very little (about 5 to 20%) of the solar radiation is reflected away from the roof. The dark roof absorbs most of the sunlight, which heats up the roof. Some of that energy is eventually emitted back into the surrounding environment as infrared radiation.

Most nonmetallic substrates have high emissivity, and a dark roof material such as asphalt shingles or EPDM membranes will emit much of the heat back into the surrounding environment. However, some of the heat absorbed by the dark roof is not emitted, but rather transferred to the building below, and causes a heat gain for the building. The higher heat load on the building will increase the need for air conditioning to maintain a comfortable environment inside.

FIGURE 3—Comparison of a Dark Roof and Cool White Roof for Solar Reflectivity, Emissivity, and Heat Transfer to the Building



The white roof in *Figure 3* is subjected to the same amount of energy from the sun. However, white or light-colored roof surfaces reflect much more (about 55–90%) of the sunlight compared to dark roofs. In addition to having higher solar reflectance, white roofs also have high thermal emissivity, and thus less of the energy absorbed from the sunlight is eventually transferred to the building below, leading to a smaller heat gain. Cool-white-roof coatings, often based on elastomeric acrylic latex technology, are therefore used to prevent heat gain by buildings from solar radiation and can help lower energy costs such as from air conditioning.

The high solar reflectance and thermal emissivity of cool-roof coatings help prevent the transfer via radiation of heat from the sun to the roof substrate. However, thermal insulation coatings prevent heat transfer via conduction by presenting a low thermal conductivity barrier between the hot and cold materials. Solar reflectivity depends on the surface of the coating. If the cool-roof coating becomes dirty, it is less effective at reflecting the sunlight. Thermal conductivity is a bulk property of the coating, so a dirty insulation coating would have the same ability to insulate as a clean coating.

It is possible to combine the two mechanisms into a single coating, and thus prevent heat transfer by both conduction and radiation by incorporating the principles used in formulating both insulation coatings and cool-roof coatings. A thermal insulation coating can be formulated to also have high solar reflectivity by nature of its white or light color, so if it is used on the exterior on a steel tank, for example, it can prevent heat transfer from solar radiation and insulate the tank interior from the exterior environment. A number of commercial insulation coatings are promoted as also having high solar reflectivity and thermal emissivity, and there are also literature reports[28] demonstrating the effect.

CONCLUSION

Thermal insulation coatings are a type of functional coating which impede heat transfer due to their low thermal conductivity. They have found utility as coatings for hot and cold surfaces to enhance personnel protection, energy management and condensation control. Insulation coatings are also good options to potentially replace traditional insulation in industrial situations where corrosion under insulation (CUI) is a problem.

Awareness of the mechanisms and physics of heat transfer are helpful in understanding how thermal insulation coatings are designed and perform. It also allows us to compare them with traditional insulation and other types of coatings which are useful in controlling energy, such as cool-roof coatings, and identify the differences in how they function. ❇

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