AEROGEL for Highly Thermally Insulative Coatings

Recognizing the advantages of a high performance insulative coating, some advanced coatings manufacturers are exploring the use of silica aerogel as an additive to paint to achieve significantly lower thermal conductivities. These coatings, a new class of materials called highly thermally insulative coatings (HiTICs), are designed to offer energy savings along with burn protection.

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CURRENT THERMALLY INSULATIVE COATINGS

Within the insulative coatings space, there traditionally have been two main additives promoted as providing an insulation benefit: glass and ceramic spheres. These mysterious little balls are hollow in nature, and trap a small amount of air inside. This trapped air can be considered "still" in nature, and contribute an impressive thermal conductivity of 0.015 BTU/ft.hr.°F (26mW/mK). Factoring in the glass or ceramic shell that holds the air, individual spheres in the range of 0.029–0.115 BTU/ft.hr.°F (50–200 mW/mK) are easily produced in a variety of sizes and wall thicknesses. When mixed with paints at high loadings, they can achieve an overall thermal conductivity of 0.046+ BTU/ft.hr.°F (80+ mW/mK). This performance, though far from the still air value of 0.0015(26), is still significantly better than paint alone with a typical thermal conductivity of 0.115 BTU/ft.hr.°F (200+ mW/mK) (lower is better for reducing heat transfer). If shear forces can be controlled well enough during mixing and spraying, it is possible to eventually build up (with 20–50 coats) enough thickness to have a meaningful R-value of approximately 1.7 per in. of dry coating. Unfortunately, if the control is insufficient, spheres break down, creating 0.517 BTU/ft.hr.°F (1000 mW/mK) thermal shorts in the coating.

HIGHLY THERMALLY INSULATIVE COATINGS

Highly thermally insulative coatings (HiTICs) represent coatings that have achieved a step change in performance on multiple fronts, making them far more effective thermally, while also delivering vastly improved characteristics from an installation and use standpoint. These products have been tested to ASTM C518 and are shown to consistently deliver thermal conductivity less than 0.029 BTU/ft.hr.°F (50 mW/mK) at room temperature, and can be applied at no less than 60 mils per wet coat using conventional spraying technologies. These performance attributes enable the building of a coating with quantifiable R-value much more quickly, delivering the properties shown in *Table* 1.

ENERGY SAVINGS

Historically, the position on insulation and energy efficiency has been that if a little is good, a lot must be better. Government regulations and legacy practices have promoted an environment where insulation needs to be installed in inches to be meaningful, thereby ignoring the potential benefit that minimal insulation can provide.

In actuality, when reviewing the theoretical benefit of even conventional insulation, the vast majority of the energy savings comes from the first fractions of an inch of material. After that, the percent of potential payback curve becomes much flatter, and more insulation does little to impact the total energy saved. For cases where highly conductive surfaces lack any insulation at all, the potential benefits of a thin insulative coating are obvious.

In *Figure* 1, the potential energy savings of a vessel that goes from having no insulation to one inch thickness is shown. In this example, the thermal conductivity of HiTIC A is used with no active air movement. This shows that while more insulation is certainly better for maximizing the energy saved, the vast majority of the benefit is achieved in the first 200 mils (5 mm). After that, the slope of the curve becomes significantly more flat, and the incremental benefit of the insulation decreases significantly.

The energy savings benefit has been demonstrated in the laboratory using small steel tanks filled with water (*Figure* 2). The tank shown on the right side in *Figure* 2 was insulated with 200 mils of HiTIC A, while the tank on the left was not. The water in the tanks was heated and well mixed, and the tanks were monitored by temperature probes and energy totalizing equipment. Over the three days of testing, the insulated tank used approximately 45% less energy than the control tank. In addition, the insulated tank showed significantly lower surface temperatures, mitigating the potential risk of burns due to incidental skin contact.

SAFETY

While there are currently no OSHA standards for making a surface safe to touch from a burn standpoint, OSHA clearly articulates the need to protect workers and mandates the need to provide some degree of insulation where accidental contact could occur [OSHA 1910.261(k)(11), 1910.262(c)(9)].[a]

Several options are available to address the need for personnel protection. Traditionally, physical guarding, jacketed insulation, and/or administrative controls such as the warning sign shown in *Figure* 3 have been used. However, physical guarding and signage can be unreliable, and often the high cost of implementation and risk of potential corrosion under insulation (CUI) from other insulation methods have left many hot surfaces a risk for incidental contact. Under these circumstances, an insulating paint can truly make a difference. This premise is backed by ASTM standards C1055 and C1057 related to burn hazards.

In essence, these test methods show that the surface temperature of a substrate is not what determines whether a burn will occur. Instead, the risk of a burn is a

Table 1—HiTICs vs. Conventional Insulating Paint

Product	Resin	Insulating Additive	Thermal Conductivity BTU/ft hr°F (mW/mK)	Single Coat Wet (mils)	R-Value per in.	Coats to Build R>0.5
HiTIC A	Epoxy	Aerogel	.029 (50)	160	2.9	2
HiTIC B	Acrylic	Aerogel	.026 (45)	60	3.2	3
Product C	Acrylic	Ceramic	.049 (86)	22	1.7	14
Product D	Acrylic	Ceramic	.050 (87)	20	1.7	16
Product E	Acrylic	Ceramic	.060 (103)	30	1.4	12

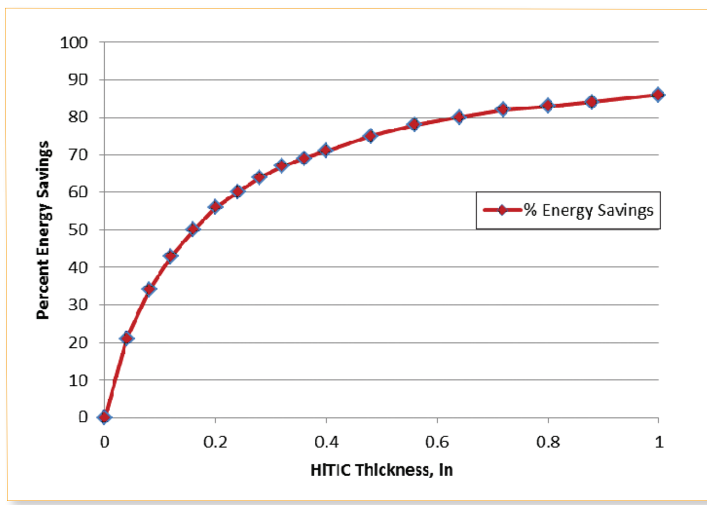

Figure 1—Percent of energy savings for HiTIC-insulated tank vs. uninsulated tank.

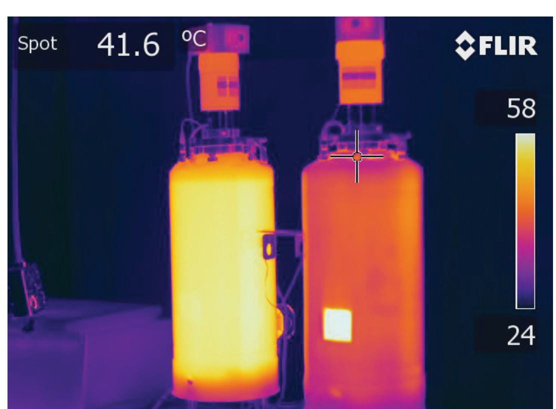

Figure 2—Uninsulated (left) vs. insulated (right) steel tanks.

(a) **Section 5(a)(1) of the OSHAct:** *Each employer shall furnish to each of his employees, employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees.*

Figure 3—Caution sign on industrial steel surface.

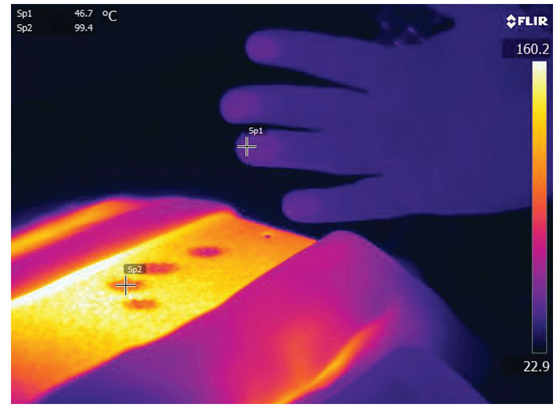

Figure 4—HiTIC-coated hotplate.

function of whether or not there is enough energy transferred between the surface and the tissue to get the skin to the necessary temperature to become damaged [58°C (136°F) for a first degree burn]. This level of potential damage is calculated using multiple physical properties such as the substrate's thermal conductivity, density, and heat capacity, and can be used to explain why touching a thick piece of aluminum at 66°C (150°F) feels much hotter than touching a similar sized piece of wood that is also 66°C (150°F). Test methods also provide the necessary logic and equations to model the potential safety benefit offered by an insulating coating.

In the case of the thermal world, an infrared (IR) picture tells the full story. In the IR image provided in *Figure* 4, a hotplate is brought to a constant temperature of 392°F (200°C) and left for several hours to reach equilibrium. On top of the hotplate is a 160 mils thick aluminum panel coated with 80 mils of HiTIC A. In the portions of the figure shown in bright yellow, the layer of aerogel coating dropped the hotplate temperature by approximately 104°F (40°C) to achieve a surface temperature of 320°F (160°C). By conventional wisdom, this surface would still be unsafe to touch. Yet, as can be seen by the fingertips shown in the figure, after five seconds of constant contact time with the surface, the skin temperature is only slightly elevated and far from the 136°F (58°C) burn threshold.

Further evidence of the effect is shown by the decrease in surface temperature of the coating where the fingers were pressed in the image. This image proves that the skin is able to pull energy away from the surface faster than the coating allows it to be replenished, making this an extremely effective safety coating.

THE FUTURE OF INSULATIVE COATINGS

For years, coatings that make similar claims have come and gone from the market. Some stated thermal benefits have been so misleading that they have resulted in FTC intervention, casting further doubt on an already questionable subject. These issues have only served to damage the thermal insulative coatings concept as a whole and make market acceptance of these products more challenging, despite real and quantifiable benefits.

With this new generation of HiTICs utilizing aerogel with thermal conductivities comparable to bulk commodity insulation, the industry can now consider insulating surfaces that have been difficult to insulate due to topography, humidity, chemical exposure, and maintenance or space requirements. HiTICs can deliver measurable benefits in protection from temperature extremes, energy savings, and process stability. CT

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