AEROGEL-BASED, FLUID-APPLIED COATINGS:

Solution for Thermal Bridging of Steel and Concrete

BY GREG POPE

Thermal bridging issues facing designers of modern-day buildings have long been a major challenge. With architects searching for more than flat curtainwall designs, as well as trying to satisfy net-zero building requirements, the need for a true "thermal break" has never been greater. This article offers a unique solution to the thermal bridging issue by using fluid-applied aerogel-based coatings—both to control condensation within a wall cavity and to mitigate energy loss for steel and concrete construction.

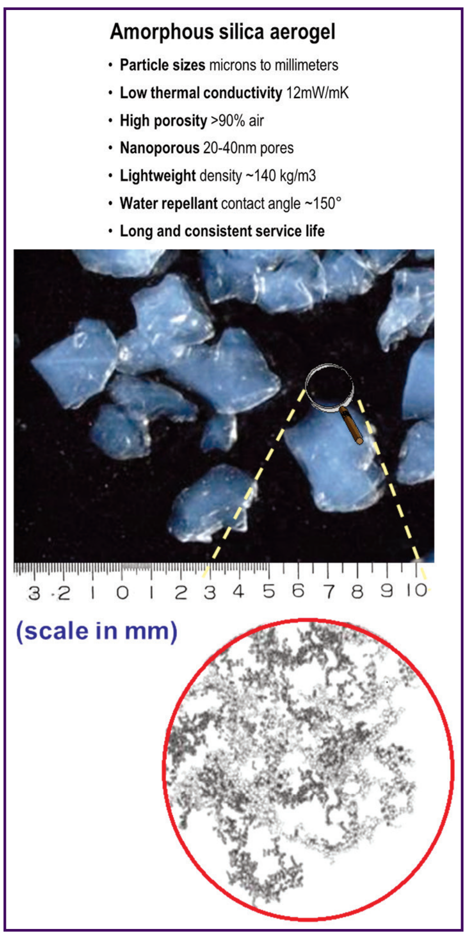

Figure 1– Aerogel-filled coating (AFC). (Cabot Corporation)

Discovered inadvertently while attempting to develop a new form of intumescent coating in 2010, the first aerogel-filled coating (AFC) was developed by a U.S. coating supplier. In this same time period, the world's leading manufacturer of particulate aerogel began testing similar coatings for "safe-to-touch" applications for burn protection.

Aerogel is an amorphous silica particle (see *Figure 1*) used in many applications, from cosmetics to deep-sea pipeline insulation. Known for its ultra-low thermal conductivity, silica aerogel is 50% more thermally efficient than still air (12 mW/m-K for aerogel vs. 26 mW/m-K for still air). This material property of the aerogel particles can reduce overall heat transfer on steel and concrete by 45-50% for coating thicknesses 100-150 mils. It is this level of performance that has resulted in a rapidly growing interest in aerogel-filled coatings as a thermal break solution.

The design community needed a solution by which the heat transfer on steel cantilevered beams, concrete balconies, roof penetrations, canopies, spandrel glass, and ornamental architectural features could be sufficiently reduced in order to mitigate moisture formation. The presence of water through condensation in wall cavities and façades can potentially lead to the growth of mold and mildew and a myriad of other issues. Through selective use of aerogel-based coatings, the likelihood of condensation and energy loss can be dramatically reduced.

STEEL PENETRATIONS USING AFC

Existing market solutions, such as the thermal break pad technology shown in *Figure 2*, have become the "go-to" solution to address thermal bridging issues. However, while these pads represent an improvement over steel beams, their comparatively high thermal conductivity (259 mW/m-K) and their high cost of installation limit their effectiveness and acceptance. Design, fabrication, and erection of these "thermal pad connections" currently cost $450 to $2,500 per connection, depending on the depth of the steel section. From the fabrication perspective, buried in the overall cost of steel fabrication and erected bid work, an additional $300 to $500 for "special picks" is typically included by the erector. These costs and use of "pad thermal breaks" do little from an energy perspective and virtually nothing to mitigate moisture/condensation from entering the building envelope. Hence, an alternative was desired.

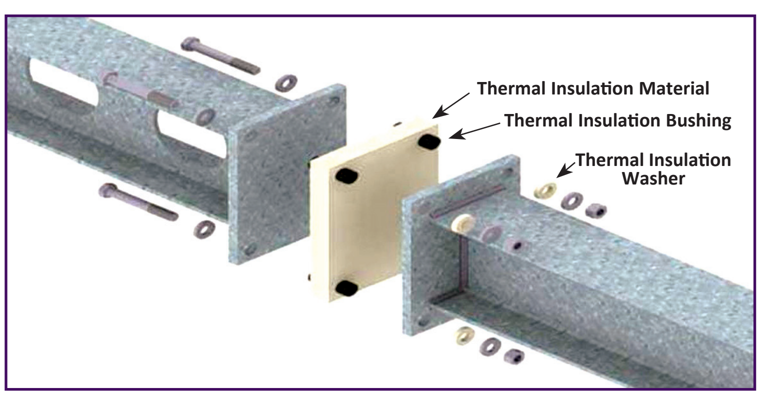

Figure 2 – Mechanical thermal break.

The advent of AFCs with thermal conductivities of 35 mW/m-K (six to seven times more efficient than thermal pads) give building designers dramatically more design flexibility, and their resultant performance can effectively reduce condensation formation by altering the dew point in the areas of concern. *Figures 3A* and *3B* show how the use of such a coating system can have a dramatic impact on the likelihood of condensation formation as compared to thermal break pads.

Thermal 3-D modeling, conducted by Morrison Hershfield, a Vancouver engineering firm, confirmed that while coating steel beams with an AFC does reduce overall heat transfer and alter surface temperature, the risk of condensation is dramatic as well. AFCs also satisfy the designers' need for durability in architecturally exposed structural steel (AESS) applications, especially in exterior environments. Formulation of high-performance AFCs has now achieved a new status, passing NORSOK 501 Rev 6. This Norwegian exposure standard, used as an offshore oil and gas testing protocol, demonstrated that the aerogel-based coating system is capable of maintaining thermal performance in immersion conditions and severe environments, including offshore oil platforms or exterior exposures. Designers now have options for use on steel and concrete elements and can address heat loss and—to a greater degree—moisture mitigation in wall cavities.

Not only have AFC fluid-applied thermal breaks been shown to perform, they have become the low-cost solution. Referring back to *Figure 2*, there are a number of hidden costs that come into play with thermal break pad systems. These include the cost of fabricator detailing during shop drawings, added steel fabrication time and erector labor to install the pads in the field (see washers and bolts required in *Figure 2*), and additional design review costs by structural engineers and architects for seismic load and viability of all connections. These are all costs associated with achieving a thermal break

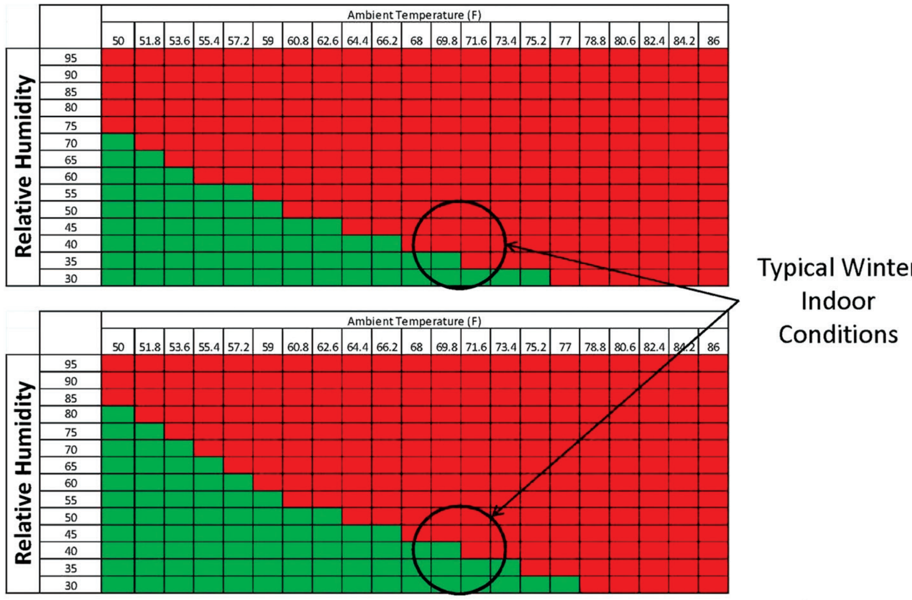

Figure 3A – Condensation risk for bare steel vs. mechanical thermal break and Fabreeka beams. (Data from Cabot Corporation.)
Note: Red zone indicates condensation risk; green zone is where no condensation will occur.

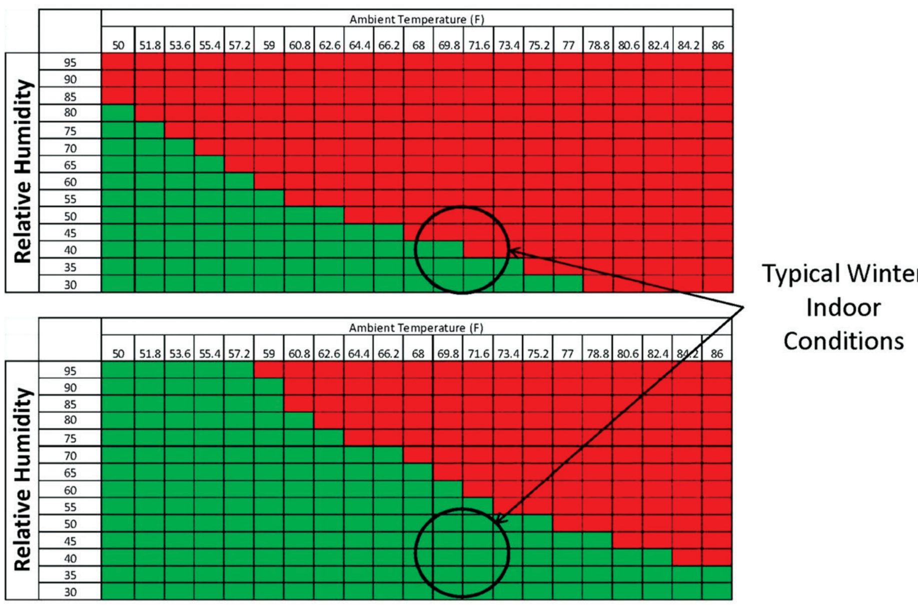

Figure 3B – Condensation risk for mechanical thermal break vs. AFC fluid-applied thermal break. (Data from Cabot Corporation.)
Note: Red zone indicates condensation risk; green zone is where no condensation will occur.

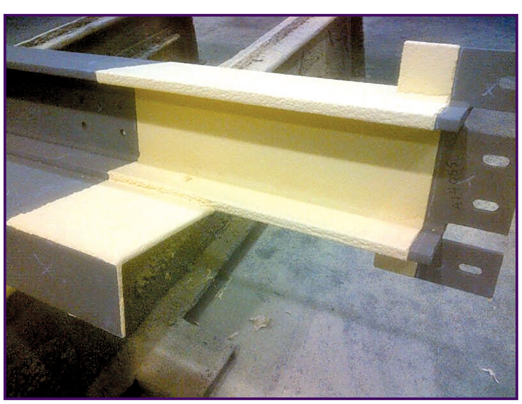

Figure 4 – AFC fluid-applied thermal break, shop-applied.

Figure 5 – AFC used in conjunction with bolted AD moment connections (blocked out) and touched up in field.

Figure 7 – Precast balconies placed directly on AFC-coated outriggers.

Figure 6 – Shop-applied AFC fluid-applied thermal break coating applied to outriggers on 20-story mixed-use project.

that can more effectively be addressed by a spray-applied solution, resulting in shop or field application (*Figure 4*) of aerogel-based coatings that is less than 50% the cost of pad technology (*Figure 5*).

So why does an AFC work on steel and concrete? Heat transfer occurs along a heated perimeter of an element, whether that element is steel or concrete. The definition of a thermal break is "a thermal barrier of lower thermal conductivity in an assembly to reduce or prevent the flow of thermal energy between conductive materials." AFCs with thermal conductivities of 35 mW/m-K are significantly better insulators than carbon steel with a thermal conductivity of 19,000 mW/m-K. The use of these coatings allows for an approach that can alter surface temperature enough to move the dew point outboard of the air barrier. With AFC tightly bonded to a substrate (steel or concrete) with no air gaps to conduct heat transfer across the "heated perimeter," surface temperature can be altered to move dew point outboard of the building assembly (*Figures 6* and *7*).

Figure 8 – Concrete balconies coated with 100 mils of AFC beneath pavers (ICON Architects, Righter Group.)

CONCRETE SLAB EDGES AND BALCONIES

Continuous concrete pours for concrete balconies have been and continue to be a method used throughout the U.S. and Canadian markets. The use of aerogel-filled coatings on concrete can solve both condensation and energy loss problems. Morrison Hershfield thermal models demonstrate that the use of these coatings in thicknesses ranging from 100 to 200 mils can result in energy savings in southern and northern climates of 19 to 24.5% (see *Figure 8*). Since these concrete balconies essentially represent heat transfer fins on the outside of buildings, the coating only needs to be applied over the first two feet outboard of the interior studs.

Coating beyond this point is unnecessary, as at that juncture, the "fins" can be considered infinite, and their temperature will very closely approximate that of the exterior environment. Protruding steel beams and concrete structures on buildings have long been identified as thermal issues in new building construction in desperate

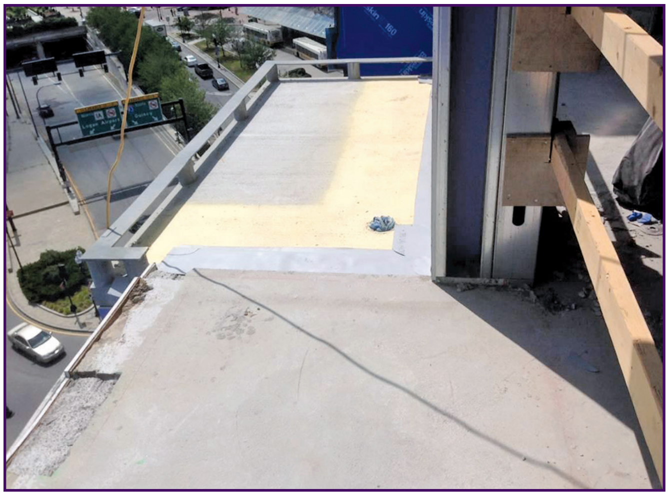

Figure 9 – AFC spray-applied to concrete 24 in. outboard of studs (ICON Architects, Righter Group.)

need of a viable solution. The inadvertent development of an aerogel-based coating system provides designers and architects with a workable solution to a nagging problem. Beyond the thermal benefits, these coatings have demonstrated compatibility with air and vapor barriers, along with cementitious, intumescent fireproofing and roof cutoff coatings—all in a low-to-no VOC formulation that meets LEED v4 requirements.

Condensation reduction (formation of water on concrete floors), as well as "heat loss" through a concrete balcony can be solved with a simple and effective coating process. By applying AFC 24 inches (*Figure 9*) onto all sides of the concrete, returning the material to indoor ambient conditions (to inside face of studs or further) can result in reduced condensation on interior floor slabs, and also reduce energy loss (*Figure 10*). The increase of AFC thickness above 100-250 mils can reduce additional energy loss up to 24.5%, according to documentation by Morrison Hershfield (*Figure 11*).

The incremental capital cost was assumed to be $35/ft^2 of installed surface area. The coating is applied to a 2-ft.-wide strip along the base of the balcony on both the top and bottom surfaces. While the quantity of the floor slab that has [a] balcony strongly affects the effective wall R-Value, the change in energy cost savings with and without [aerogel-filled] coating is proportional to the additional installation cost of the coating over a greater surface area. As a result, the simple payback period changes very little based on balcony quantity, typically with less than 0.2 years' decrease in payback period for 25% [of] balconies compared to 100% [of] balconies.[1]

Figure 10 – AFC applied to concrete balconies of a residential tower in Boston, MA.

Aerogel-Filled Coating Scenario	U-Value of Slab BTU/hr•˚F•ft² (W/m²K)	Slab PSI Value BTU/hr•˚F•ft (W/mK)	% Reduction in Slab U-Value
No coating	0.554 (3.14)	0.645 (1.116)	–
Coating 100 mil 2 ft.	0.452 (2.57)	0.527 (0.912)	18.3%
Coating 100 mil full	0.452 (2.57)	0.527 (0.912)	18.3%
Coating 150 mil 2 ft.	0.438 (2.49)	0.510 (0.883)	20.9%
Coating 200 mil 2 ft.	0.427 (2.43)	0.498 (0.861)	22.9%
Coating 250 mil 2 ft.	0.418 (2.37)	0.487 (0.843)	24.5%

Figure 11 – Energy savings on concrete balconies at different coating thicknesses. Energy savings could be maximized up to 24.5% (Morrison Hershfield and Tnemec Company).

OVERALL BUILDING IMPACT

Data analyzed by Morrison Hershfield is shown in the remaining figures. *Figure 12* shows a concrete balcony with raised window wall on curbs with different coating scenarios, while *Figure 13* shows an infrared thermal profile and temperature locations for the balcony and window wall. *Figure 14* shows application of AFCs from 2 to 7 ft. showed no difference in energy loss, based upon fin theory analysis. Additional analysis (not shown) determined as much as 2.9% overall energy impact for the building with multiple balconies can be realized. This 2.9% savings is a significant impact for thermal modelers looking for additional energy savings on passive house, green building, and LEED designs. Aerogel-filled coatings used as a "fluid-applied thermal break" in lieu of other mechanical thermal breaks is an alternative during value engineering exercises, as cost savings of up to 60% per square foot have been documented by Morrison Hershfield.

The final figure (*15*), also developed through the analysis done by Morrison Hershfield, depicts a payback chart using AFCs with different building components in various areas of North America.

As building designers look for incremental efficiencies in energy loss, AFCs can help solve multiple design issues. As a result, AFCs will significantly alter field construction costs for construction managers and building owners.

FOOTNOTE

1. Morrison Hershfield, thermal modeling data. Total Building Model Energy Study.

SOURCES

Aerogel data dew point charts
James Pidhurney and Peter Pescatore, Cabot Corporation, Billerica, MA.

Thermal modeling data
Morrison Hershfield, Vancouver, BC
Tnemec Company, Kansas City, MO

One Canal Place project
Architect: ICON Architects, Boston, MA
Steel fabrication: Canatal, Parcel, BC
Coating installation: Drytec, Terrebonne, PQ and EMC, Boston, MA

Trip Advisor project
Architect: Elkus Manfredi Architects,

Scenario	U-Value of Slab BTU/hr•°F•ft² (W/m²k)	Slab PSI Value with Adjacent Window Wall BTU/hr•°F•ft² (W/mK)	% Reduction in Slab U-Value
No coating	0.554 (3.14)	0.65 (1.12)	–
Aerogel 2-ft. band	0.452 (2.57)	0.53 (0.91)	18.3%
Aerogel full 7 ft.	0.452 (2.57)	0.53 (0.91)	18.3%

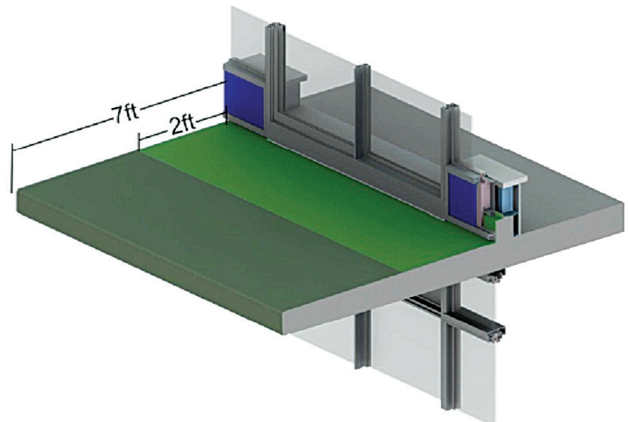

Figure 12 (left) – Concrete balcony with raised window wall on curb showing coating scenarios (Morrison Hershfield and Tnemec Company).

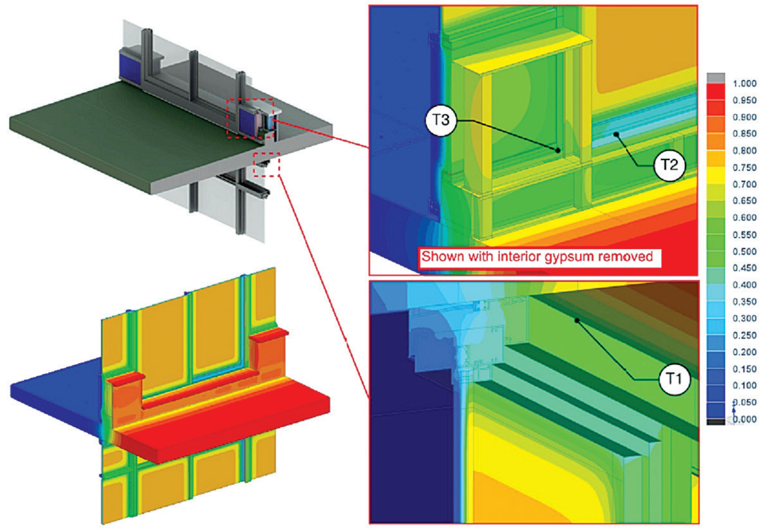

Figure 13 – Thermal profile and temperature locations for concrete balcony with window wall (Morrison Hershfield and Tnemec Company).

Scenario	U-Value of Slab BTU/hr•°F•ft² (W/m²k)	Slab PSI Value with Adjacent Window Wall BTU/hr•°F•ft² (W/mK)	% Reduction in Slab U-Value
No coating	0.859 (4.88)	0.57 (0.99)	–
Aerogel 2-ft. band	0.691 (3.92)	0.46 (0.80)	19.5%
Aerogel full 7 ft.	0.819 (4.65)	0.46 (0.80)	19.6%

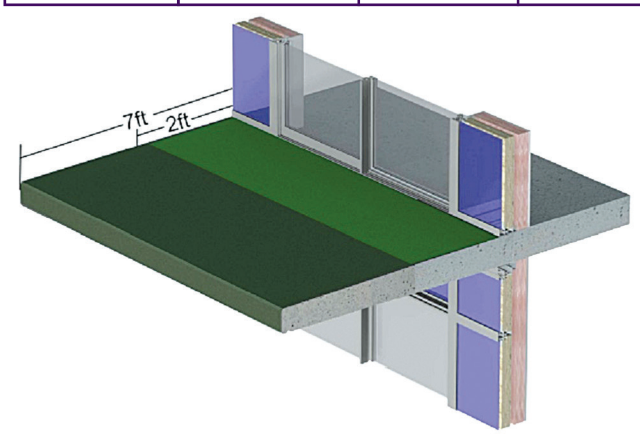

Figure 14 (left) – Concrete balcony with window wall. Note: Data on concrete balconies with respect to energy loss. Application of AFC from 2 – 7 ft. showed no difference in energy loss based upon fin theory analysis (Morrison Hershfield and Tnemec Company).

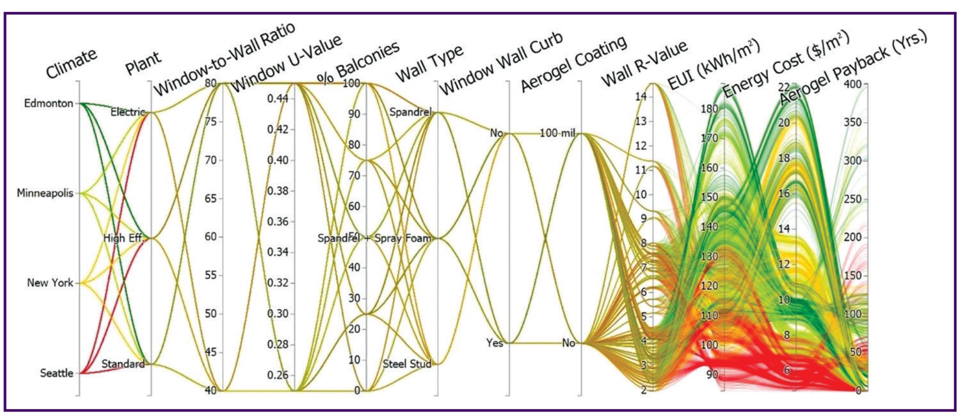

Figure 15 – Payback chart for different building components in different regions of North America based on kilowatt uses and types of energy sources (Morrison Hershfield and Tnemec Company).

Boston, MA
Steel fabrication: Ocean Steel & Construction Ltd., Saint John, NB

Elkus Manfredi project
Architect: Elkus Manfredi Architects, Boston, MA

Mass DOT Material Lab project
Architect: Elkus Manfredi Architects, Boston, MA
Iron works: Novel Iron Works, Inc., Greenland, NH

Greg Pope

Since 1980, Greg Pope has been a key member of Righter Group, Inc., for which he now serves as vice president in his Wilmington, MA, office. In 2013, Pope assisted in the development of the first fluid-applied thermal break coating utilizing aerogel-filled coating technology. Pope has been a longtime member of the Society for Protective Coatings (SSPC) and NACE (the worldwide corrosion authority), and is a NACE Level II coatings inspector and consultant. He is the past technical director of the Boston chapter of CSI.