MULTI-CERAMICS THERMAL INSULATION COATINGS HELP GEORGIA-PACIFIC SAVE SIGNIFICANT ENERGY AND STOPPED CUI

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ABSTRACT

The conventional open cell method of insulation aims to slow the heat flowing through materials filled with air such as fibreglass batts, while new coatings that use fillers like aerogel and beads follow the same open cell thermal methods. In this paper we discuss an alternate method of closed cell thermal insulation management with multi-ceramics that block heat and stop air/moisture transfer. These thin and thick heat-block insulation coatings have evolved into a distinct, high-performance formula that far exceeds conventional insulation standards. They also provide energy-savings and carbon emission reductions, while stopping corrosion under insulation and giving additional genuine personnel protection and safety.

This paper discusses results of a recent three-year pilot field study (2020-2023) conducted by Georgia-Pacific, an American pulp and paper company based in Atlanta, Georgia, on a digester tank, where the multi-ceramic heat-block coating was applied. This pilot showed energy loss reductions cut by half, creating annual savings in the hundreds of thousands of dollars for one tank annually. The coatings also prevented corrosion under insulation, reduced CO_2 emissions and slashed maintenance costs. This demonstrated how these multi-ceramic coatings help provide a future pathway for industries to achieve substantial energy savings and carbon reduction working towards net zero by 2050 and beyond.

Keywords: thermal insulation coating, ceramics, carbon emissions, energy savings, CUI, corrosion, heat

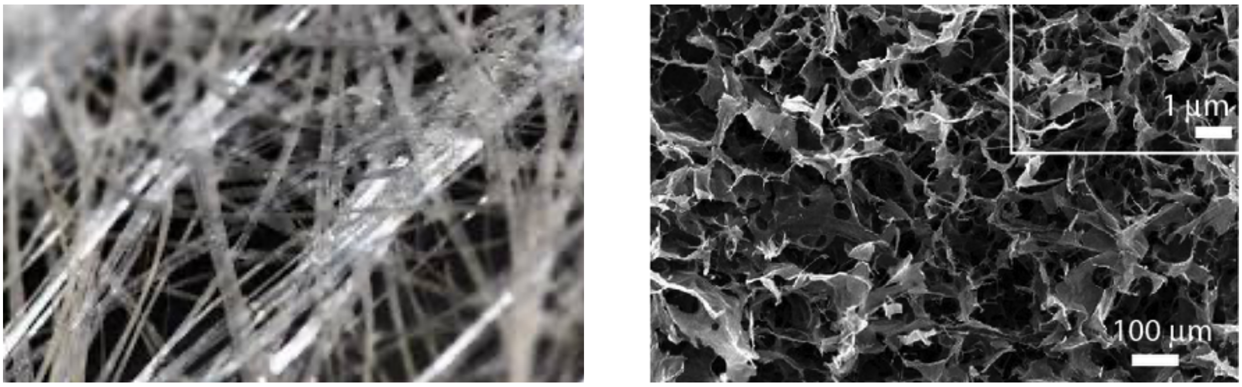
INTRODUCTION TO DIFFERENT TYPES OF INSULATION STRUCTURES

There are two different types of thermal insulation methods available with open and closed cell properties.

BULK INSULATION MATERIALS (BIM) - OPEN CELL

Open cell materials with low-density mineral-fibre insulation such as fibreglass batts (see Figure 1a) and Rockwool are primarily marketed based on their R-values. There are various test methods such as ASTM C518 [1] for bulk insulation materials which are tested at ambient temperatures around 23°C/75°F since 1977 [2]. These materials are very fragile, so to maintain even a baseline laboratory performance, BIMs must be carefully protected from environmental factors and weatherisation.

Moisture trapped underneath the insulation material is a leading cause of corrosion under insulation (CUI). The global cost of corrosion is estimated to be US$2.5 trillion, which is equivalent to 3.4% of the global GDP (2013) [3]. However, preventing this moisture ingress can be very difficult. Conventional insulation materials need to be wrapped, clamped, taped, or otherwise attached to piping systems. Moisture can easily travel into tiny spaces [4]. When it gets hotter, this insulation method cannot stop the heat; only slow it down and once full it's at heat flux.



(A) (B)

FIGURE 1: EXAMPLES OF TRADITIONAL THERMAL INSULATION STRUCTURES.
A) MICROSTRUCTURE OF OPEN CELL BULK INSULATION MATERIAL FIBREGLASS [5],
B) CROSS-SECTIONAL MORPHOLOGY FOR OPEN CELL COMPOSITE AEROGEL. IMAGE: RESEARCHGATE [6]

THERMAL INSULATION COATINGS (TIC) - OPEN CELL

Open cell coatings first emerged in the 1980s as solar reflective paints, and have since developed into a widely diverse category. Over time, TIC formulations began to incorporate various filler compounds, such as single ceramic beads, hollow glass spheres and aerogel, with air or solar reflectance as the main 'insulating' properties. Many of these coatings were essentially acrylic white paints with a single compound formula unable to block the total heat spectrum due to air transfer and science.

Most TICs use an acrylic paint base, which generally lasts between 5 and 10 years and often highlight metrics like the Solar Reflectance Index (SRI) or K-values to demonstrate effectiveness. K-value measurements are typically taken under controlled lab conditions at temperatures near 23°C, similar to how conventional insulation materials are tested. More recent TIC variations have appeared on the market, featuring thicker coating applications—often exceeding 1mm—in an attempt to claim improved performance. However, genuine field performance data in this sector is often unclear, leading to confusion among consumers about the true efficacy of these coatings and paints.

Aerogels for example are open-porous (that is, the gas in the aerogel is not trapped inside solid pockets) [7] (see Figure 1b), however due to the porous structure, it is generally accepted that the heat transfer in silica aerogels includes heat conduction via solid backbone, heat conduction through the gas phase, and thermal radiative [8]. Similar to conventional insulation, the air heats up and given enough time will reach heat flux or full of heat and resistance is mostly lost. Given everyday use and constant heat in real world application these methods of TICs are challenged by environmental factors and high heat vessels. Generally aerogel is only used in blankets because if mixed in paint, it's wet and does not perform well as has been tested. Glass spheres tend to break when mixed so become a challenge and single component ceramic hollow spheres can work but don't cover the full range of nanowaves for infrared heat and will allow heat transfer.

HEAT-BLOCK MULTI-CERAMIC COATINGS (HBC) – CLOSED CELL

Closed cell multi-ceramic coatings (HBCs) have been specifically engineered to prevent heat penetration using advanced heat transfer principles. These coatings are formulated with a precise combination of sub-micron sized ceramic compounds integrated into a proven and durable resin system. Unlike conventional insulation methods with BIMs and TICs, which absorb and slow down heat transfer, HBCs work by blocking the initial heat load on a hermetically sealed surface, as explained by Georgia-Pacific engineers in the case study.

There are two types of heat-block multi-ceramic coatings, thin coatings like SUPER THERM, which block the solar radiation at 250 microns, and thick coatings like HPC COATING, which start are greater than 2mm. These thick coatings hold and block heat on the surface of a vessel as per this case study. This significantly reduces the amount of heat that can pass through the material, hence why multi-ceramic tiles survived 1400°C space shuttle re-entry temperatures. Closed-cell structures ensure the cells or bubbles within the material are completely enclosed and do not allow air or moisture to pass through. The coating endeavours to form a true, hermetically sealed surface.

The original 1989 NASA co-development on a ceramic insulation coating, assisted in part, the inventor J.E. Pritchett to distinguish the correct ceramic compounds [9]. From this research of over 4000 compounds, a handful of specific ceramics were selected as the best to block the heat waves for the design of a closed film thin coating. Engineering studies were performed to determine which radiation heat waves were the most concentrated representing the total heat load from solar radiation, which included radiation, convection and conductive heat.

Certain ceramics are capable of blocking temperatures over 600°C so HBCs are transforming heat management by stopping heat at its source and saving energy. This approach contrasts with conventional BIMs and TICs, which allow heat to transfer through slowly. Research from Imperial College London supports the effectiveness of ceramics, highlighting them as some of the best materials for heat resistance, particularly at high temperatures. Recent breakthroughs from Imperial College have set records for heat-resistant materials, positioning ceramic-based insulation coatings as vastly superior to many conventional insulation products available today [10].

FIGURE 2: MICROSTRUCTURE OF CLOSED CELL CERAMICS [11]

Some examples of the benefits of HBCs include:

- Improved energy efficiency, which is closely linked to both cost reduction and CO_2 emissions reductions (see Figure 3)
- Safe surface temperatures on equipment and piping reduces the risk of burns and other heat-related injuries (see Figure 4, 5)
- Solution to the major global challenge of corrosion under insulation (CUI)
- Advantages in terms of application and maintenance – no shut down required for application
- Exceptional longevity and durability (see Figure 6)
- Consistency of performance with linear thermal conductivity (see Graph 2)

(A) (B)

FIGURE 3: (A) STEAM PIPE BEFORE APPLICATION AT 470°C+ AND (B) AFTER 30 MM OF CLOSED FILM HEAT BLOCK MULTI-CERAMIC COATING DOWN TO 40°C

FIGURE 4: AN EXAMPLE OF A FIRST DEGREE BURN. (SOURCE: THE WELL [12])

FIGURE 5: HBC IS SAFER FOR PERSONNEL WITH 30 MM OF COATING APPLIED TO 470+°C STEAM PIPES TO 40°C

(A) (B)

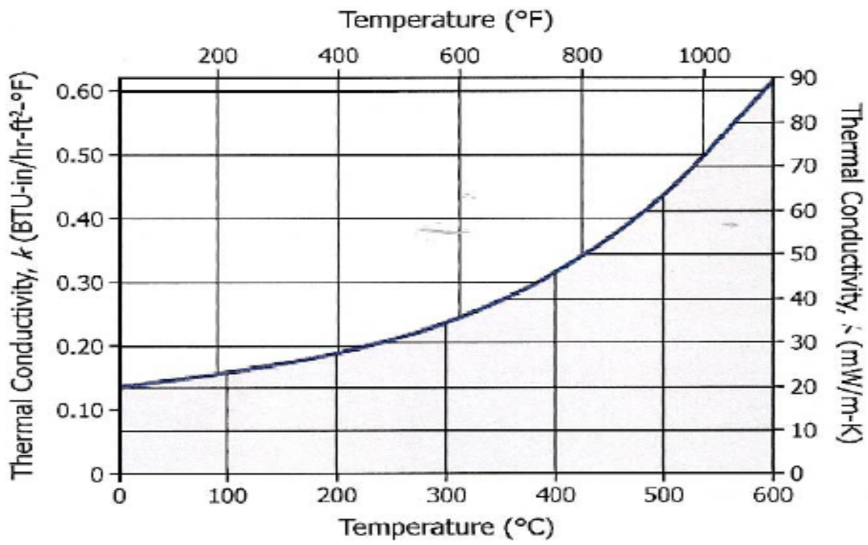
FIGURE 6: (A) 2014 SHORTLY AFTER APPLICATION 2014 GULF OF MEXICO PLATFORM WITH MULTI-CERAMIC HEAT-BLOCK INSULATION COATING
(B) 2024 COATING. STILL PERFORMING, ZERO MAINTENANCE AND CORROSION WITH CONSTANT EXPOSURE TO EXTREME OCEAN WEATHERISATION INCLUDING CYCLONES, WAVES AND SALT

WHY FIELD STUDIES ARE CRUCIAL

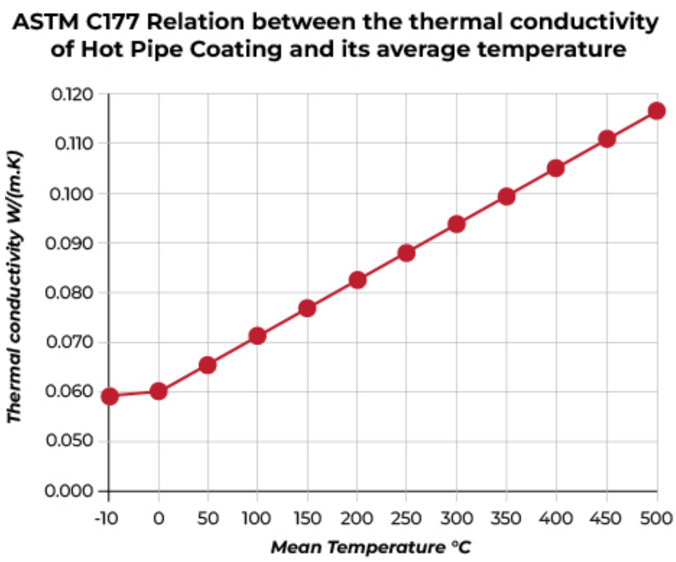
Field studies are crucial for delivering accurate data on the actual performance of thermal insulation strategies. Laboratory tests conducted in a controlled, low ambient environment with steady-state conditions (see Figure 7) fail to capture real-world performance. In contrast, field conditions involve constantly changing factors such as temperatures, humidity, acids, weather and physical impacts, making them more reflective of operational realities.

Unfortunately, ambient temperature standards [2] at very low and are theoretical based. They exclude durability and field influences. Converting lab results to the field doesn't offer substantial or accurate insights into how a product will perform in the field. There is little evidence of competitor performances, yet plenty of CUI reports.

R-values and K-values are often used to measure thermal performance, but these figures cannot be extrapolated accurately for higher temperatures and field results. The curved (Graph 1) results of R and K-values highlight discrepancies and raises questions about the reliability of these values as predictors of insulation effectiveness in the field and ever-changing environments. HBC coatings show linear (Graph 2) growth in their performance metrics at elevated temperatures, which shows consistency and high performance with field results.



GRAPH 1: THE THERMAL CONDUCTANCE K-VALUE OF AEROGEL INSULATION [13]



Mean Temperature °C	Thermal Conductivity W/(m.K)
-10	0.059
0	0.060
10	0.061
20	0.062
30	0.063
50	0.066
100	0.071
200	0.083
300	0.094
400	0.106
500	0.117

GRAPH 2: ASTM C177 THERMAL CONDUCTIVITY MULTI-CERAMIC COATING K-VALUE TESTED TO 500°C [14]

Research engineers assume that the R and K-values are an all-encompassing unit of measure to assess the thermal properties of products. However, this assumption is misled due to the fact that the values only account for the thermal resistance of a surface to conduction alone. Field-testing gives understanding how thermal insulation will actually perform. This approach stands in stark contrast to controlled laboratory tests since 1977 [2], which fail to account for the dynamic and unpredictable conditions that materials face in actual applications. While ASTM tests are important to create a benchmark, they don't incorporate more demanding performance assessments. Claims of low lab based R and K-values often lack evidence of sustained performance over years of weatherisation making field studies a priority for decisions to validate the durability and effectiveness of insulation coatings that equate into energy savings, cost reductions, safety and carbon emissions reduction.

FIGURE 7: FIBREGLASS INSULATION TESTED TO LAB CONDITIONS OF 23°C, NOT REAL WORLD. CREDIT CSIRO [15]

MULTI-CERAMIC INSULATION PILOT FIELD CASE STUDY

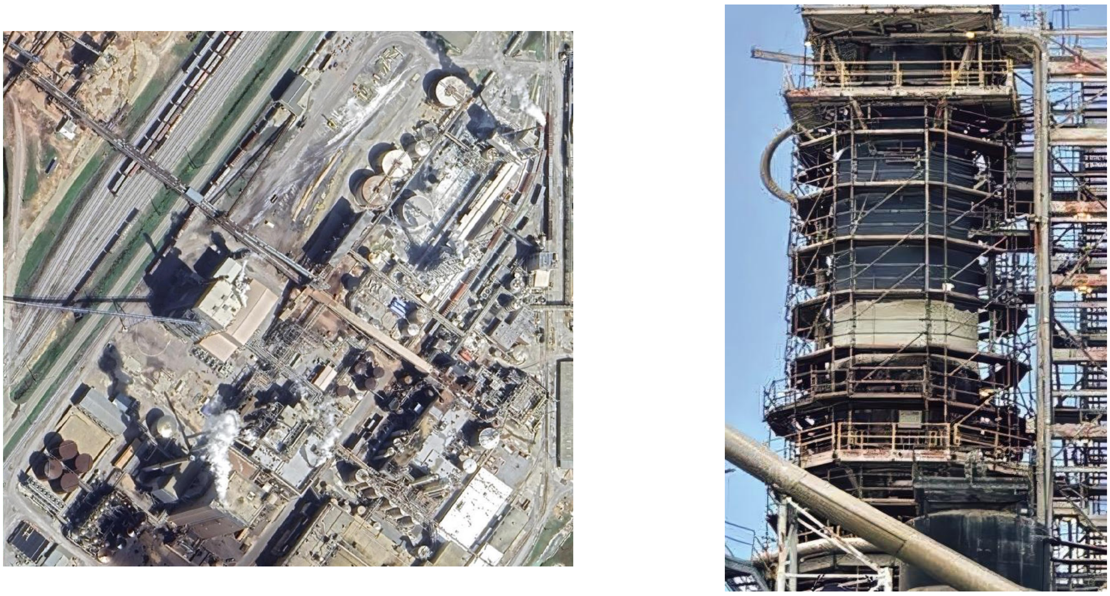
This pilot field case study reviews a recent three-year evaluation by Georgia-Pacific engineers (together with Flint Hills Resources) of insulation solutions at their Naheola mill in Pennington, Alabama. Georgia-Pacific is a prominent manufacturer of tissue, pulp, paper, packaging, building products and related chemicals. Part of Koch Industries, Georgia-Pacific utilised high heat multi-ceramic heat-blocking insulation coatings to deliver on performance which has halved their energy loss to 49%, saved $332,000 per annum and effectively eliminated their corrosion challenges while reducing tonnes of carbon emissions on just one digester tank.

In 2020 a Georgia-Pacific digester tank (see Figure 8b) was insulated using a multi-ceramic heat-blocking insulation coating in a side-by-side comparison to conventional wraps and jacketing insulation. This was a significant transition away from convention towards a new thermal management strategy by Georgia-Pacific.

DIGESTER TANKS IN HIGH HEAT INDUSTRIES

The insulation coating pilot project was a digester tank, which cooked wood, chips at high temperatures to obtain the pulp fibres used to make paper products. During the process, the wood chips are loaded into the digester and chemicals are added. The temperature is then raised to near 190°C, and the pressure is increased to several atmospheres. This high temperature and pressure helps to break down the lignin in the wood, which acts as a natural glue, allowing the cellulose fibres to separate.

A digester unit in the context of industries like oil, gas, and energy is typically a vessel or system where biological decomposition of organic material takes place. This process is commonly used in waste management, wastewater treatment, and biogas production. Digesters break down organic matter, often in the absence of oxygen (anaerobic digestion), to produce biogas, which can be used for energy and digestate, nutrient-rich substances used as fertiliser. This is an energy intensive process and a new insulation management strategy aligned well with their sustainability, carbon reduction and efficient goals.



(A) (B)

FIGURE 8: A) GEORGIA-PACIFC, PENNINGTON MILL, ALABAMA,
B) DIGESTER TANK RECEIVING MULTI-CERAMIC HEAT-BLOCKING COATING

The requirements of the pulping process usually determine the length of the cooking process; in particular, the length of the cooking process depends on the yield and hardness of pulp. Cooking usually lasts 5-6 hours, during which cooking temperature should be kept at between 160°C and 190°C depending on the pulp's need. Pulp digesters are not only used for kraft process (wood into wood pulp) but also sulfite process (chemical reactions). The raw materials of a digester have carbon steel structure, composite steel structure, and dual phase stainless steel due to the difference of alkaline pulping and acid pulping process. This is a tough, high-energy demanding process that the Georgia-Pacific engineers wanted to test for the purpose of saving energy, chemical stability, carbon emission reduction and reducing maintenance costs because of corrosion under insulation (CUI).

Project Costs and Returns

- **Total cost of project:** $407,000 USD ($626,558 AUD)
- **Annual energy savings:** $332,000 USD ($511,099 AUD)
- **Annual process throughput improvements:** $114,000 USD ($175,497 AUD)
- **ROI:** 13-18 months

Project Benefits

- 49% energy savings
- One unit saved $332,000 USD
- Minimal maintenance – less annual operating expense
- Zero corrosion after testing
- Exceptional employee personnel protection
- Quantifiable carbon emissions reductions in high heat vessels
- Longevity with 15+ years
- Better cooking process and quality

Lessons Learned

There are many key lessons learnt:

- Multi-ceramics are transforming how we manage heat in the future
- CUI can be stopped with a closed cell insulation strategy with no gaps, air or moisture
- Ceramics can withstand thousands of degrees C
- An excellent solution for carbon emission reductions, energy savings and personnel safety
- Personnel can feel safe knowing all their surfaces are very safe to touch longer than 5 seconds
- Make current testing and standards also field based and more challenging for the changing climate
- Move lab based ambient testing from 23°C to 40°C for both R and K-values. The environment is changing and testing standards need to move within lab performance results
- Most forms of open air based cell insulation do not perform well in high heat
- K and R-values are not linear in open cell insulation; they are on a curve; multi-ceramics are linear
- The future is getting hotter, strategies and policies need to work to reduce carbon now

2023 EPA Energy Star Energy Saving Award

For their thermal insulation project, Georgia-Pacific was awarded the prestigious ENERGY STAR award by the U.S. Environmental Protection Agency (EPA) for its innovative application and use of a multi-ceramics heat-block insulation coatings [16].

Energy Savings and CO_2 Reduction in the Field

Georgia-Pacific engineers recognised that older, conventional insulation methods that involved wrapping a blanket over a hot surface, putting a jacket with seams then having staff make regular inspections, monitoring CUI, and replacing the insulation as it had deteriorated from leaks while causing corrosion was futile. Hence the adoption of a new insulation strategy was needed.

Genuine innovation, driven by the mission to solve significant challenges, often results in ground-breaking solutions. Georgia-Pacific's ability to achieve a 49% energy savings through heat retention is remarkable. The pilot field study involving a tank in situ, demonstrated the innovative performance of multi-ceramic heat-blocking coatings. These measurable results represent a major step toward energy savings and meeting net-zero carbon goals, all while also stopping CUI, better personnel safety, reduced maintenance and staff efficiency.

Senior engineers at Georgia-Pacific highlighted the coating's transformative potential for the thermal insulation industry. With proven benefits in energy efficiency, corrosion prevention, and personnel safety, this technology is gaining widespread adoption as the future of modern thermal insulation strategies. This report underscores the need for more effective insulation and heat management strategies and solutions to meet future climate targets.

Following the success of this pilot project, Georgia-Pacific began deploying multi-ceramic heat-blocking coatings at other mills. Beyond energy savings, these coatings offer substantial enhancement of the manufacturing process by maintaining desired internal temperatures and pressures, improving both energy efficiency and quality control. Less input of energy = more cost savings.

The potential savings across Georgia-Pacific's plants are very significant. One unit saved $332,000 annually and assuming 5 years saving would be approximately $1.6 million per year. When more tanks per plant are included and tanks are able to generate higher savings, the total savings would be even greater.

SUMMARY

This paper has highlighted three core and key areas critical to the future of energy saving thermal insulation strategies. First, it explains the difference between open and closed heat transfer methods. Conventional open-cell insulation materials, like fibreglass, Rockwool and many thermal insulation coatings, slow down heat transfer by trapping air in pockets or fillers, these air pockets eventually get hot and transfer. In contrast, advanced closed-cell multi-ceramic heat-blocking coatings prevent heat transfer by forming a tightly sealed barrier that stops heat at the surface. This innovative method significantly improves heat management, especially in high-temperature environments, as shown in the pilot field tests conducted by Georgia-Pacific.

Second, the paper emphasises the importance of pilot field studies in validating true insulation performance. Laboratory tests based on controlled, low ambient temperatures of 23°C fail to reflect the real-world influences on performance of insulation products in dynamic, high-temperature or harsh environments. These limitations of determining an R-value questions how could this value ever realistically be used outside a laboratory in the field? The multi-ceramic HBC field pilot by Georgia-Pacific conducted over three years by engineers, side-by-side to wrapped insulation proved the coating's effectiveness in situ with halving energy loss, stopping corrosion under insulation and significantly reducing CO_2 emissions. The success of this field study underscores the necessity of rigorous, field-based testing to understand the true durability and performance of insulation materials.

Lastly, the case study from Georgia-Pacific sets new future industry benchmarks for sustainability, efficiency, and durability in the thermal insulation market. The use of heat-blocking coatings on a digester tank resulted in an energy savings of 49%, and saving $332,000 annually per tank with a return on investment in 13-18 months. This marks a significant jump forward in energy management strategies. As industries move towards carbon neutrality, such advancements are increasingly important, especially considering future government regulations aimed at reducing future carbon emissions. Whether you're trying to reduce power plant emissions or just save money, at a certain point, it becomes wiser to stop with the old insulation methods and invest money and time on the strategies that, dollar for dollar, will yield far better results and performance.

Advanced and continuing technology is what industry needs with insulation solutions and associations with raw material suppliers that provide the latest in new technology is where heat-block coatings are positioned. If insulation or coating companies only offer a limited capability to solve heat transfer problems, then they are limited in their technologies no matter how large they may appear to be. Investing in proven heat management technologies will become crucial as regulations tighten and the need for sustainable solutions intensifies while driving down costs for companies and industry. This Georgia-Pacific pilot with multi-ceramic heat-block coatings demonstrates the substantial cost savings, asset protection, and significant CO_2 reductions, which supports global efforts to reach net-zero emissions by 2050 and beyond. This is a major win-win for the triple bottom-line of social, environmental and economic benefits across the board, for industry and the planet.

ACKNOWLEDGMENTS

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For over two decades Shane has committed to ceramic thermal insulation coatings and corrosion solutions that empower industries, communities, and governments to passively reduce energy costs, CO_2 emissions and learn more about heat and asset protection. Shane as the Australian and New Zealand Distributor for Superior Products International II, Inc. USA is focussed on thoroughly tested, world-leading heat insulation and corrosion coatings that create passive and remarkable pathways for clienteles regarding heat mitigation. This mission is to empower the world to reside in safer buildings, reduce CO_2, reducer costs, safeguard valuable assets and foster a healthier environment.

Joseph E. Pritchett

Joseph E. Pritchett (J.E.) is a Ceramic researcher and formulator from Superior Products International II, Inc. USA holding a Bachelor of Science from University of Arkansas and Paint Technology courses from University of Missouri. J.E. worked with NASA from 1989 to 1995 developing closed film thermal insulation coatings based on blocking the solar heat load. After this world-class innovation, J.E. developed thick closed film insulation coatings performing insulation 600+°C surfaces and further research to fire rated water based coatings with specialised ceramics and resin formulas. His research and development never stops - 24/7. Improving current systems continues while finding new formulas to accomplish the needs of the most demanding circumstances.

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Greg Allen is a professional Business Growth Strategist with over 43 years of business development and leadership experience in several industries with corporate ownership of both domestic and international business teams. Greg has spent 27 years as an Authorized Distributor for Superior Products International 11, Inc. Which has enabled Greg to developed an extensive knowledge base regarding energy conservation and asset protection issues that business face along with verifiable solutions that solve energy and asset protection issues, while enhancing Shareholder' Value with the goal of maximizing profits. Greg initiated and managed the project with Georgia-Pacific.