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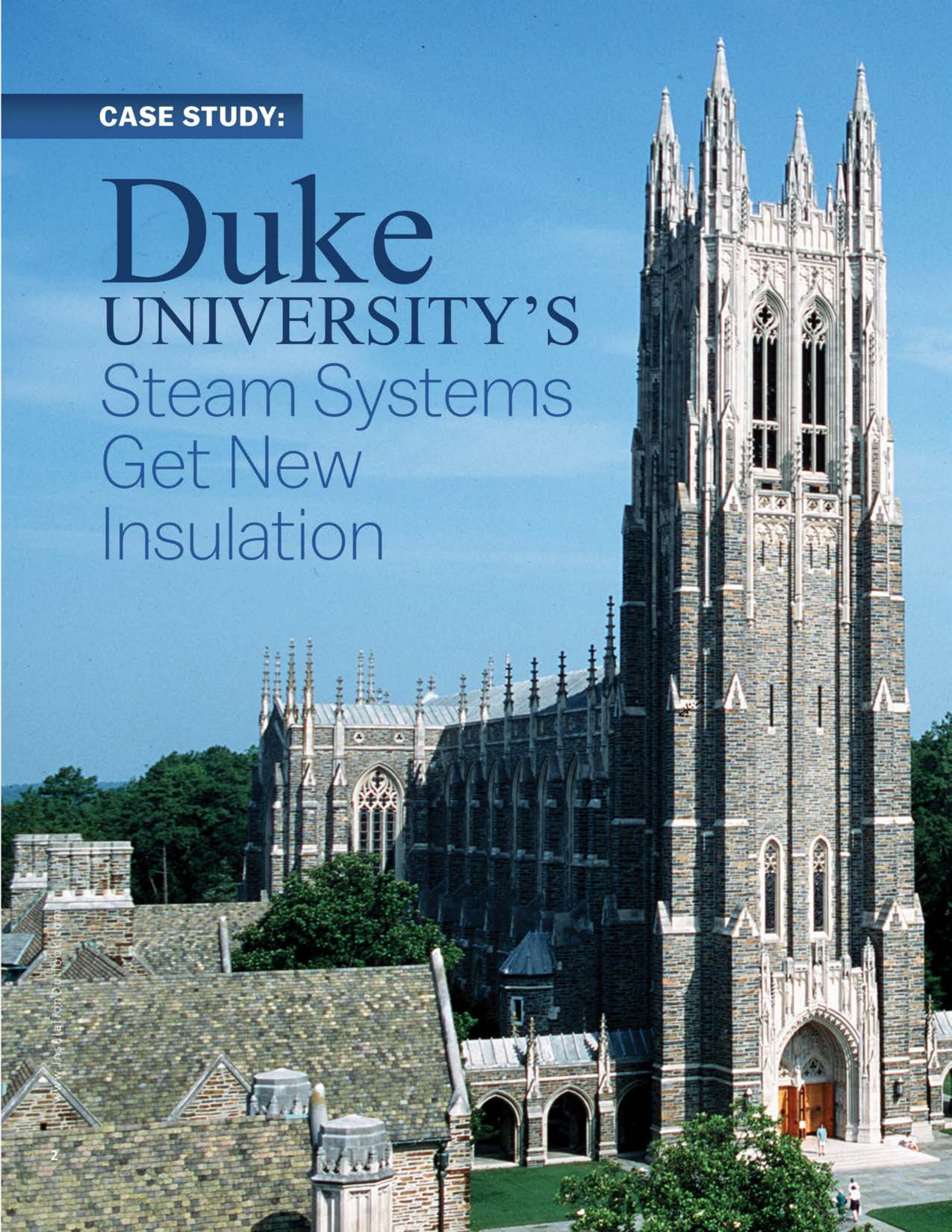
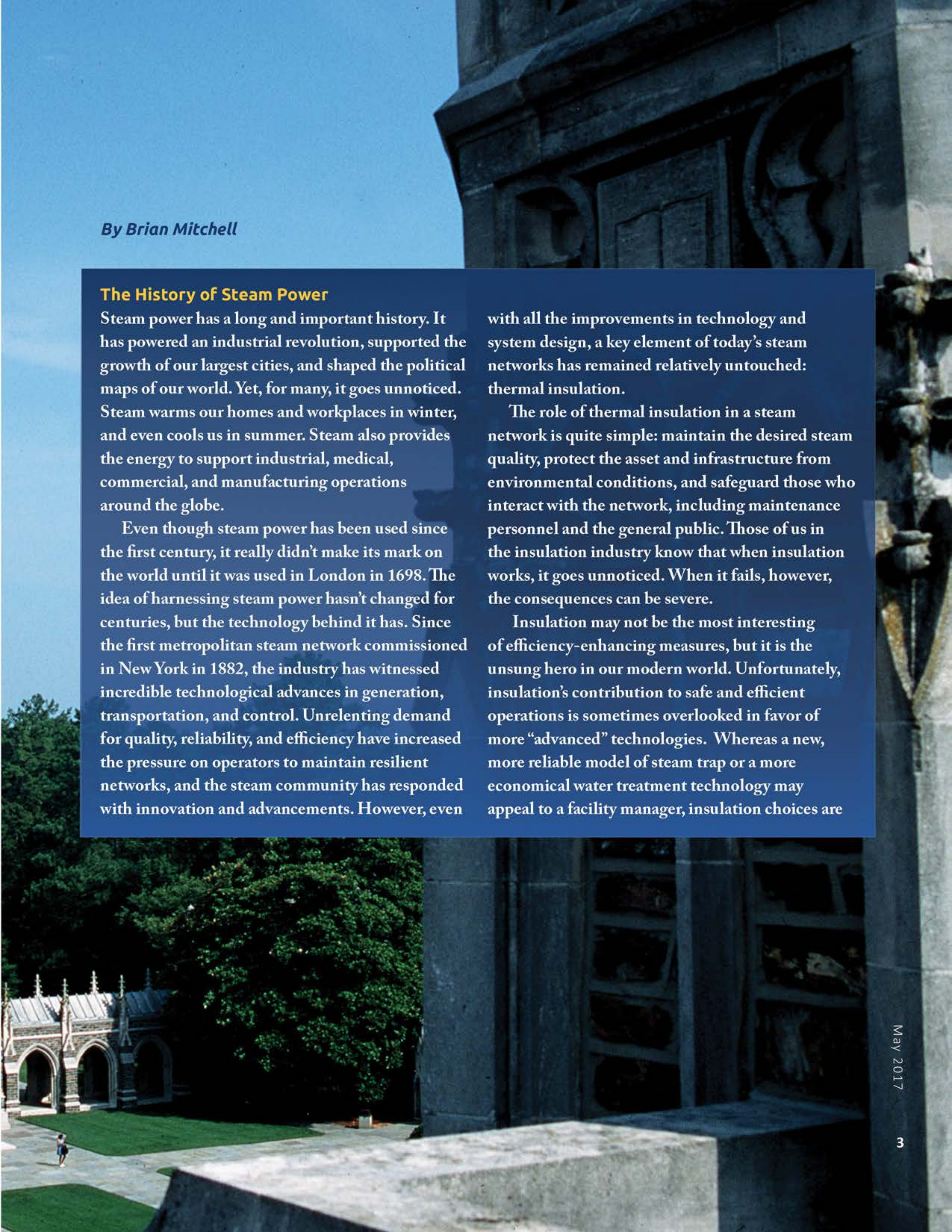


CASE STUDY:

Duke UNIVERSITY'S Steam Systems Get New Insulation



By Brian Mitchell

The History of Steam Power

Steam power has a long and important history. It has powered an industrial revolution, supported the growth of our largest cities, and shaped the political maps of our world. Yet, for many, it goes unnoticed. Steam warms our homes and workplaces in winter, and even cools us in summer. Steam also provides the energy to support industrial, medical, commercial, and manufacturing operations around the globe.

Even though steam power has been used since the first century, it really didn't make its mark on the world until it was used in London in 1698. The idea of harnessing steam power hasn't changed for centuries, but the technology behind it has. Since the first metropolitan steam network commissioned in New York in 1882, the industry has witnessed incredible technological advances in generation, transportation, and control. Unrelenting demand for quality, reliability, and efficiency have increased the pressure on operators to maintain resilient networks, and the steam community has responded with innovation and advancements. However, even with all the improvements in technology and system design, a key element of today's steam networks has remained relatively untouched: thermal insulation.

The role of thermal insulation in a steam network is quite simple: maintain the desired steam quality, protect the asset and infrastructure from environmental conditions, and safeguard those who interact with the network, including maintenance personnel and the general public. Those of us in the insulation industry know that when insulation works, it goes unnoticed. When it fails, however, the consequences can be severe.

Insulation may not be the most interesting of efficiency-enhancing measures, but it is the unsung hero in our modern world. Unfortunately, insulation's contribution to safe and efficient operations is sometimes overlooked in favor of more "advanced" technologies. Whereas a new, more reliable model of steam trap or a more economical water treatment technology may appeal to a facility manager, insulation choices are

largely based on whatever material the site has traditionally used—in spite of the cost of underperforming or failed insulation.

Water is the true enemy of thermal insulation. When insulation becomes wet, it loses its ability to conserve energy, protect workers, and maintain system performance. Thermal resistance is decimated, and the increased risk of corrosion may endanger infrastructure.

A colleague once shared the consequences of saturated insulation in an industrial steam network he had worked on in Europe. It required him to work around periodic reduced capacity and increased condensate production; overloaded steam traps; and increased consumption of fuel, water, and treatment chemicals during winter months. A near disastrous corrosion event on a heavy fuel oil tank roof and wall caused major disruption and expensive repairs. The root cause of the tank performance was corrosion under insulation (CUI), a term that was not well known at the time—he simply believed the tank had failed as the result of wet insulation.

It is critical to keep the insulation system in place and the underlying asset dry. That's easier said than done, and some facilities have abandoned steam altogether, migrating all or part of their network to pressurized hot water systems. In many cases, this decision is motivated by frustrations born of suppressed capacity, increased maintenance costs, and compromised safety conditions whenever it rains or snows.

Case Study: Insulating Steam Systems at Duke University

Duke University is one of the countless industrial, medical, commercial, and manufacturing operations around the world that generates and delivers steam via an underground network of pipes, vaults, and tunnels. Recently, the university planned to expand its steam supply to a new state-of-the-art medical center; as the University's Mechanical Engineer, I knew the steam network would need to operate at its highest performance levels to maintain sufficient capacity.

Duke's steam network consists of approximately 13 miles of underground steam pipe and over 100 vaults. Unfortunately, the vaults were susceptible to severe problems whenever it rained: fugitive steam escaping the vault, boiling water within the vault, damage to the concrete vault structure, and higher operating costs, among other issues.

What caused these problems to the steam system? Wet, damaged, or missing insulation. If a vault is prone to regular flooding, certain insulation materials will not last for extended periods of time. In addition, some thermal insulation materials have a tendency to get crushed when maintenance personnel walk on the piping or work around it.

The option that Duke University chose to mitigate these concerns was a high-temperature aerogel blanket insulation. It is thin, flexible, water-resistant, and breathable. Silica aerogels are amongst the lightest solids known to science, composed of 98% air. Long chains of open celled pores create an intricate path limiting conductive and convective heat transfer. The silica aerogel structure is extremely hydrophobic and has a low thermal conductivity. These features may allow reduced insulation thicknesses to meet local efficiency requirements. Reducing the thickness of insulation in a confined space, such as a vault or tunnel, allows for easier retrofitting or upgrade of steam and condensate lines.

I had experience with this insulation before joining Duke. I had previously tested the product on a project that required the thermal insulation to work in a trench prone to flooding. Despite the

Figure 1: Damaged Insulation in a Steam Vault Adjacent to Duke Medical Center

challenging environmental conditions, the insulation worked and was successfully integrated into the project, leading me to believe it might also be a good choice for Duke's steam network.

On the Durham campus, many vaults suffered severe problems whenever it rained, and the existing insulation had previously degraded and fallen off some of the pipework when it got wet. I focused on non-absorbent insulations, and recalling my earlier project, decided to test aerogel blanket insulation in a couple of high-risk vaults. While the layout varies slightly at each vault, the scope mandated upgrades to current campus standards, including installation of inverted bucket steam traps, standardized steam trap assemblies, and the testing or replacing of sump pumps. The insulation was applied to all steam and condensate piping and fittings, and valves were protected with removable jackets.

The results were very positive. Not only did the aerogel blanket survive, but it continued to insulate, contributing to the transformation of the existing network and safeguarding the performance of the medical center addition.

Duke is experiencing numerous benefits from these new insulation systems. Duke has more than 100 steam vaults with various pipe sizes and configurations. The facilities team estimated each vault's heat loss when fully insulated versus uninsulated: on average, an uninsulated vault costs the university around $4,750/year. When fully insulated, the cost of heat loss plummets to $359/year. Duke budgeted approximately $3,000–$4,000 per vault for installing new insulation, giving the university a simple payback of less than a year. For completely bare vaults, we will see savings up to 92%. While these savings would be true for any insulation (taking into account varying thickness to match the heat loss), the main difference with using a steam-appropriate insulation—such as aerogel—is that it can withstand flooding and remain securely on the pipe, thus saving money and resources that would have been spent on re-installation.

Figure 2: Best Practice Vault at Duke Medical Center—Aerogel Insulation on Direct Buried Pipe, Steam and Condensate Pipe, and Removable Covers

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After the first test install, I observed the system and noted there was no steaming, reduced complaints, and reduced maintenance and overtime spending—mainly due to not having to re-insulate the vault after heavy rain or a prolonged period of flooding. We now have less of a problem with sump pumps burning out prematurely due to flooding as the water does not get hot enough to damage the pump.

Insulation is vital to steam networks. Just looking at our energy/cost calculations, it is apparent that a lack of insulation cost us money and increased heat in vaults leads to brittle concrete, excessive wear on sump pumps, and unsafe conditions for entry. Additionally, excessive heat loss can quickly overload the steam traps and our condensate management system, leading to larger problems in distribution. In the past, lack of insulation on the piping had been a contributing factor to excessive condensate build up in the piping—an issue that is now mitigated.

Figure 3: Aerogel Blanket Insulation Was also Used in the Medical Facility Plant Room

For others in similar situations, I recommend testing the insulation materials in your worst wet environment. While I concede it may cost more to use an insulation that is new to installers (who may have been using the same insulation for decades), it will save money in the long run. I am pleased with the results of the new installation, which allows us to better manage ground-water infiltration and keep our steam system efficient and operational.

After a successful pilot, I changed Duke's design guidelines for steam vault insulation to use aerogel blanket insulation. Each year, we evaluate the distribution system to see which vaults are least efficient and target them for re-insulation. We have re-insulated all or part of 22 steam vaults and will continue re-insulate 5–10 vaults per year until all the vaults are well insulated and operating as efficiently as possible.

In addition to using it in our steam vaults, we have started specifying this material as the primary insulation in our direct buried piping systems. The reduced insulation thickness reduces the outer diameter of the piping system and ensures the insulation will remain effective should a major leak occur. As a side benefit, the reduced outer diameter has also decreased new vault sizes and trench widths, further lowering installation costs.

Ordinarily, expanding the steam network system for the new medical center at Duke would require additional steam-generating capacity. However, the application of new insulation made the system so efficient, that we do not require this additional capacity investment.

Conclusions

Taking system conditions and likely wear and tear is a critical part of designing an insulation system. In the case of steam systems, it is vitally important to specify an insulation that can withstand the moisture and wear typically associated with these applications. Proper specification and maintenance can reduce energy usage, guard against corrosion, and garner significant financial savings.

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