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USING INSULATION SYSTEM DESIGN TO OPTIMIZE DRYING TIMES AFTER WATER INTRUSION

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ABSTRACT

Most facilities design their insulation systems to inhibit water ingress. When water enters the system, it not only negatively impacts an insulation's thermal conductivity, it can also put the pipe system at risk for substantial damage from corrosion under insulation (CUI). These two compounding factors can decrease the longevity of the pipe system as a whole and cause a facility to waste substantial amounts of energy by running its systems inefficiently. However, what many system designers don't realize is that water ingress is often an inevitability in industrial insulation systems. This can happen as a result of damaged or misplaced jacketing or it can simply be from a poor installation. Regardless of the reason, ensuring that an insulation system can recover quickly from water ingress is key.

To avoid water ingress, systems are designed to be water-tight, with the jacketing acting as the first line of defense against the elements. More recently, water-repellent insulations have given specifiers and facilities an additional safeguard against water intrusion. Water-repellency is usually achieved by treating insulation with silicone-based ingredients; unfortunately, these compounds oxidize at temperatures above approximately 450°F. Therefore, insulation in systems that operate at temperatures above 450°F have little to no water repellency next to the pipe. Despite best design and installation practices, as systems age or extreme weather events occur, water ingress becomes more likely. Planning for aging and recovery from such extreme events is critical to preventing CUI.

This study examines the role of system design on insulation drying time after extreme water ingress. Experiments were conducted where insulation was immersed in water to simulate extreme water ingress conditions, then dried using different system configurations to determine which conditions and variables optimized or inhibited drying times. The systems included different types of insulations and hybrid insulation configurations. The insulations were tested "unconditioned" (as-received straight from the box) and also after a 24-hour conditioning designed to mimic in-service environments that may compromise the water-repellency at the inner core. During the tests, wet insulation was installed on a 3" pipe and the pipe was then heated. Then the pipe and insulation temperatures were monitored to determine how quickly the insulation dried. Shorter drying times allowed the system to return to optimized efficiency more quickly and lowered the risk of CUI.

The results from the study indicate that in-service conditioning and system design significantly influence the system's ability to recover after extreme water ingress. The hybrid system, consisting of an inner layer of microporous blanket and an outer layer of mineral wool, performed better than other configurations.

INTRODUCTION & EXPERIMENT

INTRODUCTION

Engineers and facility operators strive to run their facilities at optimum efficiencies to reduce energy costs, maximize employee safety, and maintain process control. In this case, what is good for business is also good for sustainability. Insulation helps achieve these financial, safety, and sustainability goals through energy conservation and waste minimization.

In order to effectively use insulation, it must remain dry. Wet insulation substantially decreases the thermal performance of the material, and it significantly increases the risk of corrosion under insulation (CUI) occurring on the pipe. As a result, system design engineers have focused on preventing water ingress into insulation systems. Unfortunately, despite the best planning, insulation will eventually get wet due to damaged jacketing, system age, poor maintenance, or catastrophic events. Water that enters the system is often contaminated with salts and other corrosive compounds, increasing the likelihood of CUI damage to the pipe surface.

Traditional approaches to mitigate water ingress have included weather-proofing the system with proper jacketing and sealing techniques, as well as regular inspections and maintenance. More recently, specifying water repellent insulations has become a popular practice. However, this approach is often too simplistic to account for all the potential water ingress scenarios. Typically, water repellency is achieved by adding hydrophobic agents such as silicones; however, these compounds can start to burn off around 450 °F. As a result, most installed insulations become hydrophilic at some point during the life of the insulation system.

Rather than relying on water-repellent insulation as the solution to preventing water ingress, a better approach is to design an insulation system around the assumption that water will eventually enter the system. For example, designers could allow for means of water egress, such as weep holes, or they could design the system to dry more quickly.

In this study, we explored various insulation system configurations, traditional and hybrid, with mineral wool and microporous blankets to determine which configuration influenced system dry time most effectively. The configurations included insulating pipes with unconditioned and conditioned insulation samples that had been soaked in water for 24 hours.

The hybrid systems used in this study were designed to capitalize on the strengths of the insulations used while offsetting their weaknesses.

EXPERIMENTAL PROCEDURE

Experimental Set-up

Three insulation configurations shown in Figure 1 and Table 1 were investigated in this study. The configurations are shown below with the materials listed in the order that they were installed on the pipe:

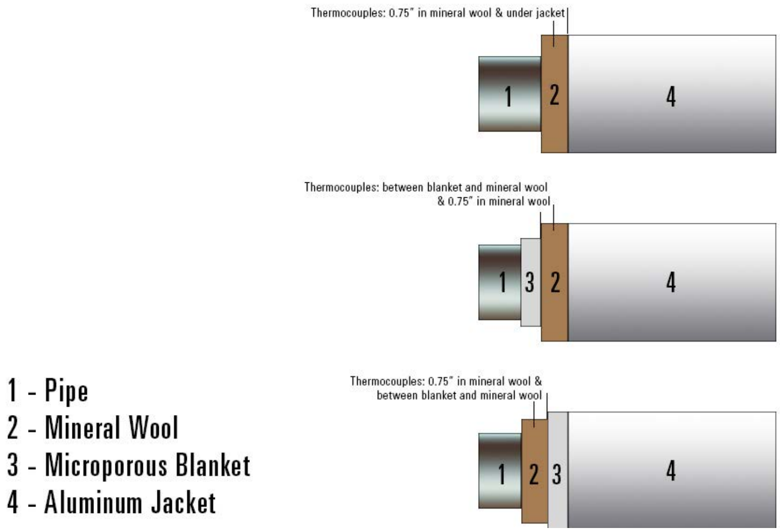
A) Pipe, mineral wool pipe insulation, jacketing
B) Pipe, microporous blanket, mineral wool pipe insulation, jacketing
C) Pipe, mineral wool pipe insulation, microporous blanket, jacketing

The insulation configurations were wrapped around a temperature-controlled, electrically heated 3” pipe, 6’ in length. The electrically heated pipe was capable of being heated to 1200°F.

Table 1: Insulation Configurations During Testing

	A	B	C
Mineral Wool	3 x 1.5”	4 x 1.5”	3 x 1.5”
Microporous Blanket (inner layer)		10 mm	
Microporous Blanket (outer layer)			10 mm

Figure 1: Schematic of the insulation designs used during the study



Aluminum jacketing was installed over the insulation configurations. The jacket was installed with a 2” overlap and was tightened with bands. The seams were not sealed during most of the experiments as the water vapor pressure caused the taped seams to fail during heat up. Multiple thermocouples were used to measure the temperatures of the pipe, and within the insulation or on the jacketing. The temperatures were logged during the entire period of the tests.

Commercially available, mandrel-wound, water repellent mineral wool pipe sections were used for all the system configurations. Depending on the system configuration, the mineral wool pipe sizes were either 3”x1.5” or 4”x1.5” (inner diameter x insulation thickness).

Commercially available, water repellent, thin microporous blanket was tested as the inner layer to help prevent mineral wool binder burnout, and as the outer layer to prevent water ingress in situations when the jacketing may be compromised. The microporous blanket was cut to size to wrap around either the 3” metal pipe when used as the inner layer or at 6” diameter (i.e., 3” pipe plus 1.5” thickness insulation) when used as the outer layer. A single, 10-mm thick layer was used for both configurations.

Experimental Conditioning

Each insulation was tested under two states:

1) Unconditioned: as-is, out of the box without any heat exposure.

2) Conditioned: the insulation was exposed to a 600°F pipe for 24 hours prior to beginning the experiment. This was designed to replicate in-service environments that may compromise the water-repellency of the insulation. Insulation was weighed before and after conditioning. Conditioning was conducted without jacketing.

Prior to being installed on the pipe for testing, all the insulation configurations, whether conditioned or unconditioned, were fully immersed in tap water for 17 hours at ambient temperature to mimic extreme water ingress conditions. After submersion in the water, the insulations were allowed to drip dry for 2 minutes to remove the excess water. The insulations were weighed after the 2-minute drain. Then the insulation configurations, jacketing, and thermocouples were installed on the 3” pipe at room temperature. Terminal ends of insulation were wrapped with foil to prevent water from leaking out. The pipe was then set to a temperature of 600°F. After reaching the setpoint, the temperature of the hot pipe was maintained for 48 hours. After 48 hours, the pipe was turned off and allowed to cool prior to removing the insulation and obtaining the final weight.

RESULTS & DISCUSSION

In-Service Conditioning

Figure 2 shows the mineral wool in Configuration A, with binder burnout (dark brown ring near the inner section of the insulation closest to the pipe) resulting from the preconditioning treatment. Configuration B, Figure 3, containing the microporous blanket used as the first layer of insulation next to the pipe, showed significantly reduced binder burnout in the mineral wool when compared to Configuration A. In Configuration C, Figure 4, discoloration attributed to binder burnout extended to the outer edges of the mineral wool when it was used as the first layer of insulation beneath the microporous blanket.

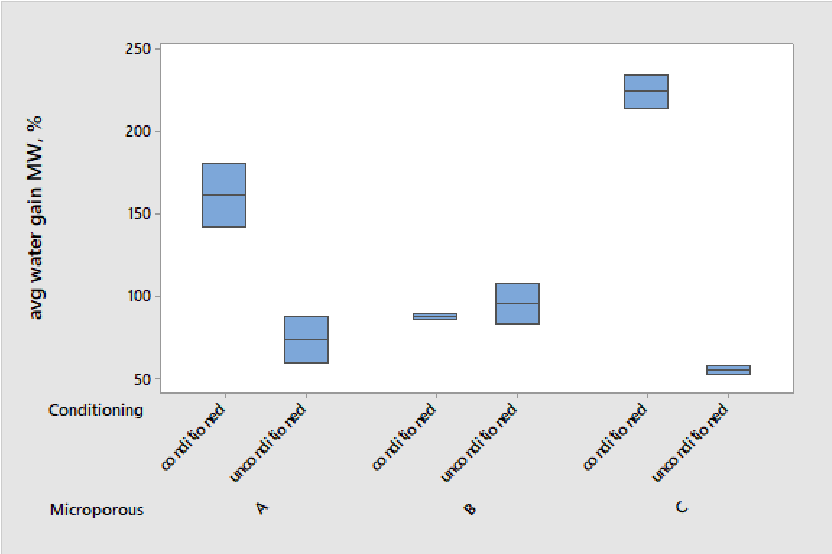
Figure 2. Configuration A: Mineral wool insulation with binder burnout after the in-service conditioning treatment

Figure 3. Configuration B: Binder burnout during conditioning was significantly reduced when the microporous blanket was used as inner layer

Figure 4. Configuration C: Binder burnout extends to outer surface of the mineral wool when microporous blanket is used on the outside.

Binder burnout and loss of water repellency due to temperature exposure are known weaknesses of mineral wool. The negative effect of temperature was seen through water absorption during submersion in water. To demonstrate the effect of in-service conditioning and binder burnout on insulation water absorption, each of the insulation configurations was tested in an unconditioned state and in the conditioned state described above. Configurations A and C, when mineral wool was used alone or with the microporous blanket as an outer layer, showed significantly higher water absorption after being conditioned compared to the unconditioned configurations (Figure 5). For Configuration B, there was minimal difference between the two states (i.e., unconditioned and conditioned) as the microporous blanket insulated the mineral wool, prevented binder burnout, and helped protect the mineral wool's water repellency.

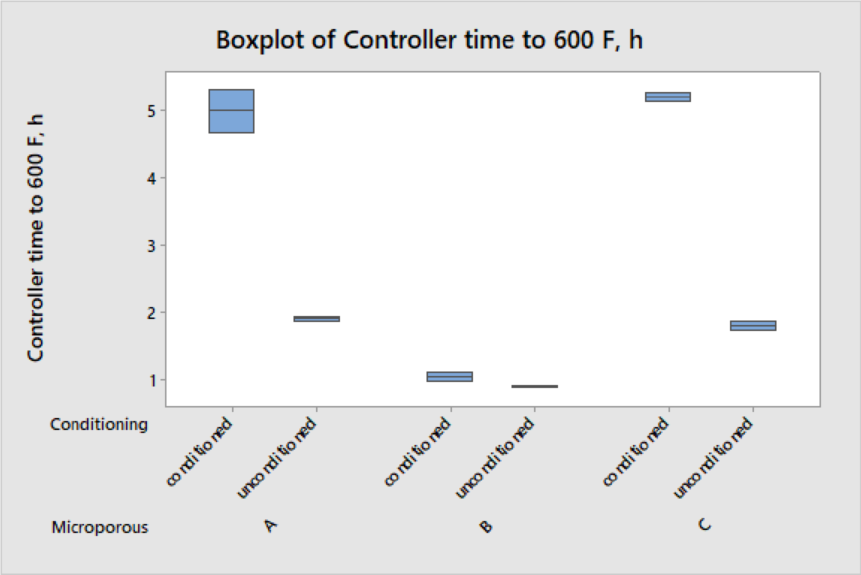
Figure 5. Average water gain for unconditioned and conditioned mineral wool samples during soaking cycles



1 Please note that there are multiple methods to assess water absorption (e.g., ASTM C1511 and BS EN13472). Each method uses different sample sizes, sample preparations, and calculations, and reports results in different units. Values reported in this study should not be compared to other methods unless test conditions were carefully reviewed.

Another result from the study was the effect of conditioning on insulation drying time and pipe heat-up time. Figure 6 shows that it takes longer for the pipe to reach the setpoint temperature of 600°F for conditioned Configurations A and C compared to unconditioned configurations.

Figure 6. Conditioning leads to more binder burn-out, more water absorption, and longer time to reach operating temperature setpoint.

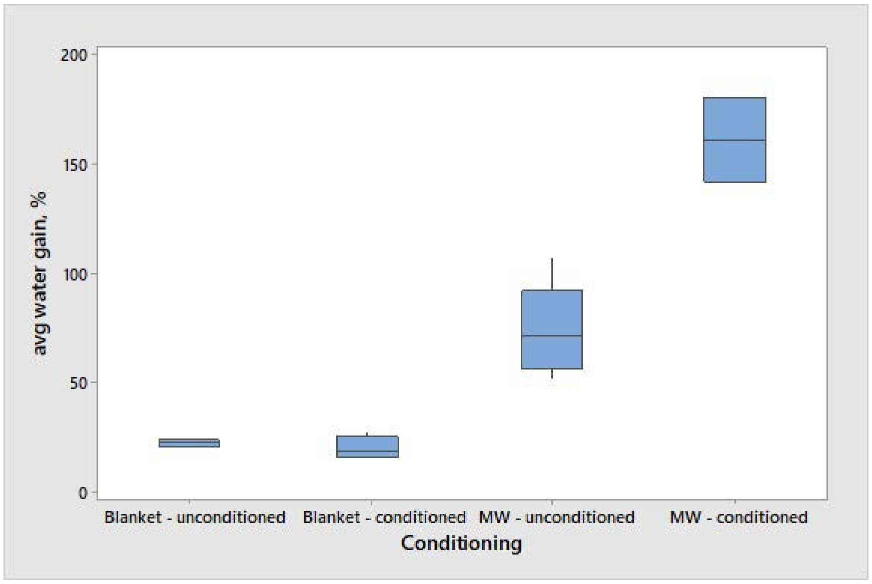


The increased water absorption of the conditioned insulations created an environment in which the wetter insulation required more time to reach the set operating temperature and to dry. Furthermore, the study indicated insulation drying time data correlates to the water absorption data. In Configuration B, where the microporous blanket reduced binder burnout and helped protect the water-resistance of the mineral wool, there is minimal difference between the conditioned and unconditioned scenarios in terms of water absorption.

Microporous Blanket

The benefits of using a microporous blanket in the inner layer of the insulation configurations have been discussed in the previous section. Characteristics of the blanket compared to mineral wool pipe include lower thermal conductivity, no binder (hence no binder burnout), and better water repellency performance. Figure 7 shows the water absorption of microporous blanket insulation averages 22% regardless of whether or not it was conditioned. The low thermal conductivity and low water absorption make the blanket a good option for a hybrid configuration with mineral wool.

Figure 7. Water gain by microporous blanket observed during soaking cycle.



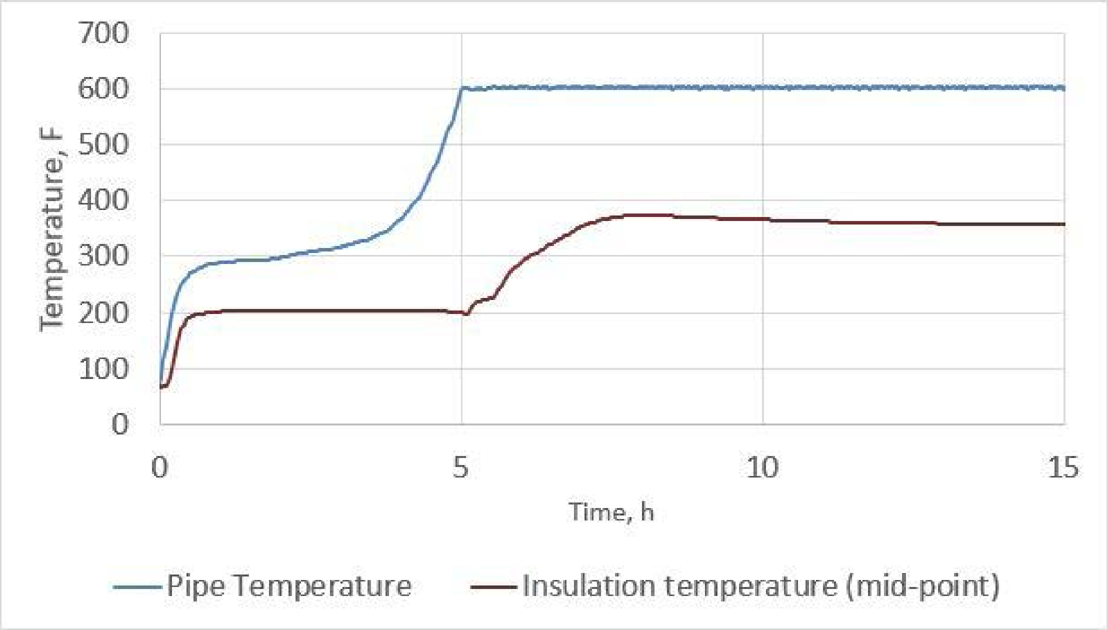
Another benefit of using the microporous blanket as the inner layer is the lower corrosion potential at the pipe compared to using mineral wool as the inner layer. Results from numerous tests have repeatedly shown that the microporous blanket used in this study has a lower mass loss corrosion rate (MLCR) than mineral wool.

The Impact of Water Egress from the System

Sealing jacketing systems (longitudinal and circumferential) is typically done with mastics; however due to long curing time for mastic, it was not practical to use for this study. Tape was evaluated for sealing of the seams, but the tape could not withstand the steam generation during heat up, and the seal inevitably broke for each configuration. Therefore water was observed escaping at the longitudinal and circumferential seams despite efforts to seal them with tape. A similar situation is likely to occur in real-world applications when water vapor forces failure of mastics, glue, caulking, or taping at seams. Therefore, it is important to inspect jacketing seams after water intrusions and then system heat-up. It may be possible to prevent damage to seams by using weep holes in the jacket and ramping up the system temperature slowly to avoid creating steam within the insulation system.

The temperature profile of the pipe and insulation, shown in Figure 8, can be used to evaluate how long it took the insulation to dry during heat up. The temperature profiles show the insulation temperature increases to 200°F while the pipe temperature reaches approximately 300°F, then both temperature readings plateau for several hours.

Figure 8. Insulation temperature stalled at 200°F during drying of insulation (Experiment: Configuration C - conditioned insulation, with microporous blanket as outer layer).



This temperature plateau is the result of the decreased efficiency of the water-logged insulation. The system takes longer to heat up because the insulation is more thermally conductive until it becomes dry enough to operate efficiently. Ultimately, after hours at approximately 200°F, the temperature of the insulation in Configuration C can be seen breaking through the plateau as it expels enough water to become thermally efficient once again.

CONCLUSIONS

Based on the conducted experiments, it was found that in-service conditioning (24 hours at 600°F) can lead to binder burnout and the loss of mineral wool's water repellency. This results in higher water absorption, which leads to longer times for the insulation to dry and the pipe to reach operating setpoints. The use of a hybrid system with microporous blanket as the inner layer of the insulation system can protect the mineral wool from binder burnout and prevent loss of water repellency. As a result, the pipe can reach operating setpoints faster, which improves energy efficiency and provides better process control than a traditional design with only mineral wool. Some microporous insulations also have a lower corrosion potential than mineral wool.

To facilitate the removal of water from the system after water ingress, the use of weep holes may also help provide a path for water and steam to escape. Depending on the operating conditions, steam can produce sufficient pressure to break the jacketing seals.

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