Mitigating Corrosion Under Insulation with Improved Water Repellency

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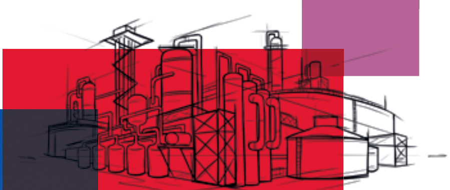


Background

Stone wool insulation possesses unique physical properties that make it ideally suited to a number of industrial applications including petrochemical processing. The open cell structure of stone wool encapsulates and restricts air movement, which gives it excellent insulation capabilities, while still allowing for water vapor to freely pass through. This means that any water that enters the insulation can also exit again. The material exhibits long-term stability and thermal properties, and being non-combustible, it also helps reduce the risk of fire propagation in thermal insulation applications.

But as with many types of insulation, the performance of stone wool is significantly impacted by the presence of water in a few important ways.

- **Water contributes to CUI.** Water trapped between the insulation and the unprotected steel surface can lead to aggressive corrosion under insulation (CUI). While this phenomenon was neglected for years, CUI is now recognized as one of the petrochemical industry's greatest potential threats. CUI can cause spills, leaks and accidents that threaten human life and raise the likelihood of fire and pollution. By some estimates, CUI accounts for up to 60% of the costs associated with pipeline maintenance. [2] CUI is so costly because it increases the frequency of repairs and shutdowns and can reduce the overall service life of the plant.

- **Water impacts thermal conductivity and heat loss.** Still air is a poor conductor and when the air encapsulated in the stone wool is displaced by liquid water, the stone wool's thermal conductivity is increased. By some estimates, just 5% water by volume in the stone wool matrix increases the insulation's thermal conductivity by approximately 25%.[1] Further heat losses result from the energy consumed to evaporate the water and drive the water vapor out of the insulation.

- **Water weighs down the entire system.** Water absorption is seldom taken into account when designing the insulation system and support structures, but water ingress can significantly change the weight of the insulation. As an example, 5 % (Vol) water absorbed in a 100 kg/m^3 (6.2 lb/ft^3) density stone wool insulation would increase the weight by 50 %.

What can be done to reduce water risks?

Both conventional wisdom and actual plant practices show that minimizing the volume of water that reaches the unprotected steel surface beneath the insulation will reduce the risk of corrosion. Therefore, an insulation material with superior liquid water repellency properties, which lowers absorption rates and prompts faster water release, should also reduce the rate of corrosion.

Water repellency is achieved in stone wool through a combination of a binder used in the stone wool and various water repellency additives. The additives work by changing the surface tension of the stone wool fibers, which makes the fibers less susceptible to wetting and delays the penetration of liquid water. The additives do not retard the diffusion of water vapor. This paper reviews three main types of additives and lists the results and analysis of performance testing.

Mineral oil based-additives are used most frequently due to their relatively low cost. When properly applied, these organic additives provide good repellency properties and minimize water ingress when the insulation is exposed to rain during installation. However, mineral oils tend to oxidize and burn off at relatively low temperatures. They can also migrate in the insulation in applications with larger temperature gradients, which raises the risk of having uneven pockets of water repellency. Loss of water repellency is typically seen at temperatures above 150 °C (302 °F).

Silicone oil is also frequently applied in industrial insulation products due to its ease of application and stability at higher temperatures. Silicone oil maintains its water repellency properties at temperatures up to 250°C (482°F). However, these oils can affect surface coatings by forming oval-shaped defects known as fish eyes—a main reason that silicone oils are banned in the automotive paint industries.

Inorganic resins are proprietary compositions that provide better and consistent water repellency up to 250°C (482°F) without having negative impacts to surface coatings.

Table 1 summarizes the advantages and disadvantages of these additives.

Table 1: Advantages and disadvantages of the major types of water repellency additives

Type of Additive	Organic/ Inorganic	Advantage	Disadvantage
Mineral Oil Based	Organic	• Cost	• Temperature Stability • Risk of Wash
Silicone Oil Based	Inorganic	• Ease of Application	• Risk of Offset of Coating Operations
Inorganic Resin	Inorganic	• Temperature Resistance • No Effect on Coating Operations	• More Difficult to Employ in the Production Process • Higher Cost

How do these additives compare at different conditions?

In addition to their performance differences at ambient temperatures, the additives exhibit different water repellency (measured as short-term water absorption) after heat aging, where inorganic additives resist higher temperatures without losing performance.

ROCKWOOL Technical Insulation wanted to investigate these performance differences further. The company commissioned several independent laboratories to run tests on the three types of water-repellent additives on stone wool under different operating conditions. Water absorption measurements of stone wool pipe insulation were conducted to document the difference in properties depending on hydrophobic treatment.

Test condition 1 – Water absorption tendency (partial immersion) according to EN 13472

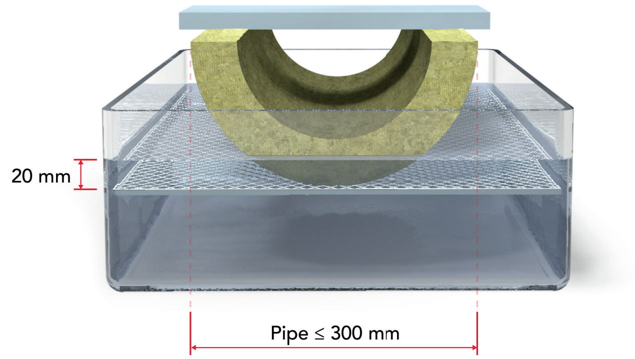
This experiment was performed in accordance with EN 13472:2012, whereby different mineral pipe wool sections treated with different types of repellency additives were partially immersed in water for 24 hours. The water uptake was then measured as the change in mass over the submerged surface area of the specimen. The method simulates short-term water exposure and absorption from one side, similar to what occurs when insulation is exposed to rain during product installation.
The test was performed on both non-heated insulation and heat-aged material that was exposed to 250°C (482°F) for 24 hours.

Results: Table 2 summarizes the partial immersion test results. With the exception of a few mineral oil samples that did not pass, all of the non-heated products performed well.

However, once samples were heat aged for 24 hours, the mineral oil based additives lost their water-repellent properties. In fact, the stone wool products went from having excellent water repellency properties to being water absorbent.

The silicone oil and inorganic resin both maintained their low level of water absorption after heat aging. However, the inorganic resin maintained the additional benefit of being coating friendly while the silicone oil is not. Some asset owners request, in their specifications, that insulation be silicone oil-free due to fears of coating defects. As a result, the owners are more widely adopting inorganic resins. This is applicable to owners sensitive to surface defects in their coating operations, such as paint shops or the automotive industry.

EN 13472 Partial Immersion test



1. A load holding the test sample in a fixed position - 2. Test sample - 3. Stainless steel mesh

Table 2: Partial water absorption per EN13472

Type of Additive	Water Absorption After 24 HR (KG/M²)	Water Absorption After 24 HR Heat Aged Material (24HR at 250C/482F)
A. Mineral Oil Based	0.5 - 1.4	30 - 44
C. Silicone Oil Based	0.1	0.1
D. Inorganic Resin	0.1	0.1

Test Condition 2 – Water absorption after cyclic heat aging to test durability

To test the durability of the inorganic resin over time compared to mineral oil additives, a series of cyclic heat aging tests was performed. Stone wool samples containing each additive were heated for 8 hours at 250°C (482°F), followed by 16 hours of cool down at 10°C (50°F). This was repeated for a total of 22 cycles, and the water absorption was measured before and after cycling.

As the results in Table 3 show, the mineral oil samples failed this test and the silicone oil and inorganic resin performed well. The inorganic resin holds up in these tests and does not show any change in its physical properties during the testing.

Table 3: Cyclic heat aging test, partial water absorption per EN13472

Type of Additive	Water Absorption Initial (KG/M²)	Water Absorption After 22 Cycles (KG/M²)
Mineral Oil Based	0.5	> 30
Silicone Oil Based	0.1	0.2
Inorganic Resin	0.1	0.1

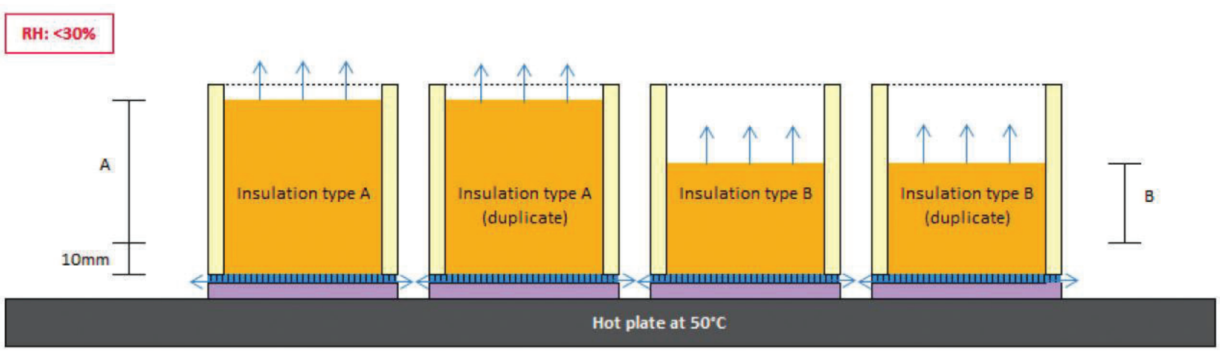
Water repellency impact on corrosion

A simple corrosion test method was developed to demonstrate the relationship between water repellency/absorption properties and corrosion. This simple test involves wet insulation in two sets—one set treated with mineral oil the other with inorganic resin. The mineral oil set was subdivided into two groups, with one group heat aged to 250°C for 2 hours and another group non-heat aged. The inorganic resin samples were separated in the same way. The heat aged and non-heat aged were then placed on top of carbon steel coupons and left to dry for 7 days (see Figure 1). The amount of corrosion was measured by weight loss of the carbon steel coupon.

The mineral oil-based additives did not maintain water repellency after heat aging and showed an increase in corrosion (as seen in Figures 2 and 3). Whereas the insulation treated with inorganic resin maintained water repellency after heat aging, and showed the same amount of corrosion as non-heat aged samples (see Figures 4 and 5).

The test results show a correlation between water repellency and corrosion, with samples that lost water repellency showing greater corrosion. This correlates with NACE's statement "the insulation system that **holds the least amount of water** and **dries most quickly**, should result in the least amount of corrosion damage to equipment" [3]. For the full details of the test see NACE white paper 10929 [4].

Figure 1: Simple Corrosion Test



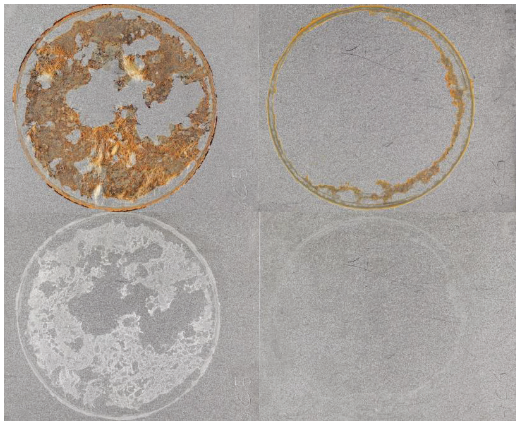


Figure 2: Corrosion Coupons with Insualation Treated with Mineral Oil, Non-heat Aged

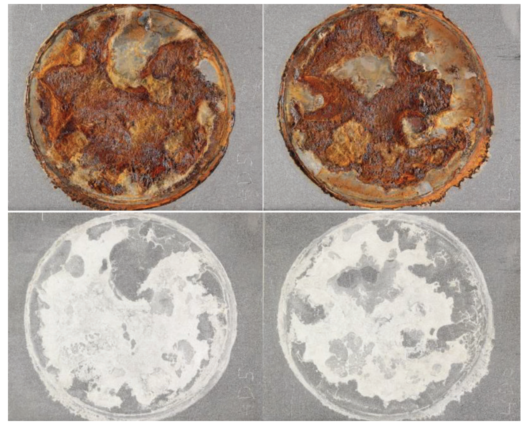


Figure 3: Corrosion Coupons with Insualation Treated with Mineral Oil, Heat Aged

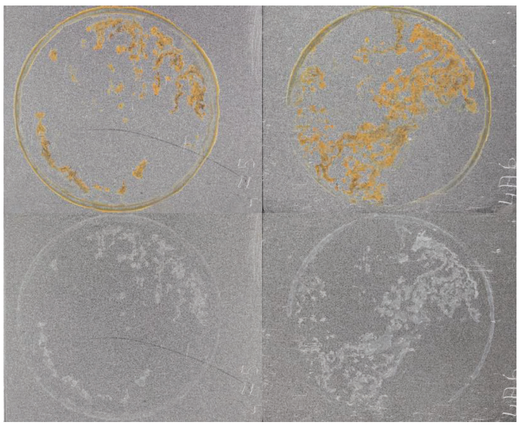


Figure 4: Corrosion Coupons with Insualation Treated with Inorganic Resin, Non-heat Aged

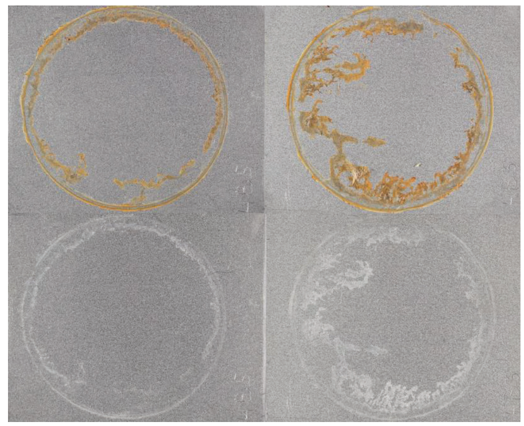


Figure 5: Corrosion Coupons with Insualation Treated with Inorganic Resin, Heat Aged

Are water repellant additives safe for coatings?

For industries that place a heavy importance on coatings, such as the automotive industry, there is an emphasis to source materials that are safe for coatings. In order to satisfy these coating sensitive industries ROCKWOOL Technical Insulation tested its ProRox series of pipe insulation treated with inorganic resin based additive. Different raw wool batches of ProRox PS 960 were tested for their influence on spray-painting or coating processes per Volkswagen (VW) test VW PV 3.10.7.

The tests consisted of placing a piece of insulation on top of a copy foil sample and then rinsing the insulation with a solvent. The idea is to capture any substances that may be detrimental to coatings on the copy foil samples.

The sample was set aside to let the solvent evaporate. The evaporated solvent sample was then covered with varnish. Any changes in the varnish covering was studied via photography and optical microscopy. The test results showed that there was no visual defects in the coat finish (see Figures 6 and 7). This confirmed that insulation infused with inorganic resins could be confidently applied to coated surfaces without concern of damaging the coating.

Figure 6: VW Test with Inorganic Resin, No Visible Defects Detected at 1:1 Magnification

Figure 7: VW Test with Inorganic Resin, No Visible Defects Detected at 7:1 Magnification

The VW test was performed on samples treated with silicone oil and mineral oil based additives with differing results (see Figure 8 and 9). In these examples, the solvent was able to wash out substances from the insulation that impacted the coating finishes.

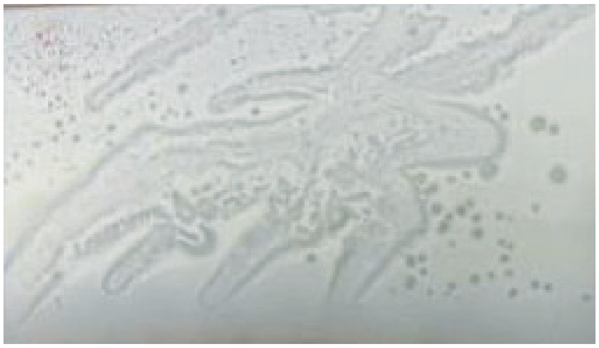


Figure 8: VW Test with Silicone Oil, Visible Defects Detected at 1:1 Magnification

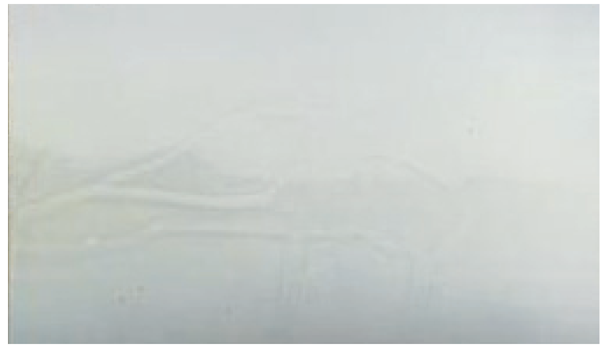


Figure 9: VW Test with Mineral Oil, Visible Defects Detected at 1:1 Magnification

Keeping CUI risks at bay

The studies highlighted here show that when it comes to minimizing water absorption in stone wool insulation, not all water repellency additives are created equal. Specifically, mineral oil based additives, while popular, exhibited greater water absorbency than silicone oil or inorganic resins. Water absorbency for mineral oils was even higher when these samples underwent heat aging, as the mineral oil degrades at high temperatures. Furthermore, as water absorbency increased in mineral oil-treated insulation, the risk of corrosion under insulation increased as well.

Silicone oil and inorganic resin treated materials generally showed greater water repellency performance under the range of test conditions. However, a series of coating tests showed that inorganic resin treatments provide a coating-safe alternative that does not impact coating applications. Therefore, inorganic resins are the better overall choice to minimize water absorption and corrosion risks.

Ultimately, these results point the way toward a safe and reliable solution to CUI in many facilities including petrochemical plants. Plant operators can minimize their risks to personnel and plant equipment, while also reducing their corrosion-related downtime and maintenance costs, by selecting the right insulation material. In many applications, stone wool insulation treated with a water-repellent and temperature-tolerant inorganic additive can offer the best long-term solution.

References

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2. B.J. Fitzgerald, P. Lazar III, R.M. Kay, S. Winnik, “Strategies to Prevent Corrosion Under Insulation in Petrochemical Industry Piping,” NACE CORROSION 2003, paper no. 03029 (San Diego, CA: NACE, 2003).

3. NACE SP0198-2016, Control of Corrosion Under Thermal Insulation and Fireproofing Materials A Systems Approach”

4. C. Zwaag and S.N. Rasmussen, “Mineral Wool and Water repellency” NACE CORROSION 2018, paper no. 10929 (Phoenix, AZ: NACE, 2018).