

White Paper

Microbiologically Influenced Corrosion (MIC) IS NOT the Primary Cause of Corrosion in Fire Sprinkler Systems (October 2009)

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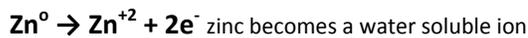
The simple fact is that the primary cause of internal corrosion (metal loss) in fire sprinkler systems is **oxygen attack** of the iron and zinc (in the case of galvanized pipe) that are used to fabricate fire sprinkler system piping. While it is true that microbiologically influenced corrosion (MIC) is often a contributing factor to the overall corrosion picture, it is not the primary cause of the internal corrosion. Moreover, the solids that are produced by the action of oxygen on the metal piping actually produce conditions that favor the proliferation of bacteria in the system.

Oxygen is present as a component in the air trapped within the fire sprinkler piping system at a level of about 21%. When oxygen dissolves in **any water** that contacts the fire sprinkler piping, it becomes available to react with the metal pipe. There are two immediate results from this reaction:

1. The **metal dissolves** into the water and leaves a void in the pipe wall
2. The metal immediately forms a **solid precipitate** which in the case of iron is commonly known as “rust”. In the case of galvanized pipe where zinc is in direct contact with the water, it is commonly referred to as “white rust”.

The chemical reactions that take place are as follows:

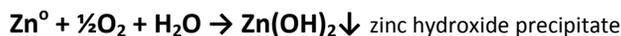
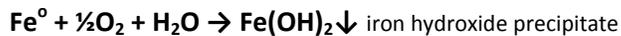
Anodic Reactions:



Cathodic Reaction:



Electrochemical Reaction:



Additional dissolved oxygen in the water causes the hydroxides to oxidize further to produce iron oxide and zinc oxide. The iron oxide will exist as two different forms, hematite (Fe_2O_3) or magnetite (Fe_3O_4). All of these corrosion reactions produce solids that are trapped within the fire sprinkler system piping. Because of the fact that the solids are more dense than water, they tend to settle into low spots in the piping. In a closed wet fire sprinkler system that has been filled with fresh water, the oxygen present in the trapped air and dissolved in the water (approximately 35 ppm @ 100 psi) will be completely consumed within about 30 days by reacting with the iron in the pipe. At that point the corrosion process will reach static equilibrium wherein the chemical

reaction slows to near zero and will remain so if left undisturbed. In a typical 1000 gallon wet fire sprinkler system, after 30 days the oxygen from trapped air and in the water will have produced approximately 34 pounds of iron oxide solids. Corrosion will restart anytime new oxygen is introduced to the system. In wet fire sprinkler systems oxygen is the rate limiting component in the corrosion reaction.

In dry and preaction fire sprinkler systems, oxygen corrosion is limited to areas of the pipe that are wet with liquid moisture. In these systems, oxygen for the corrosion reaction is in great excess and it will continue to react with the iron in the pipe. This is why oxygen corrosion more aggressive in dry and preaction systems.

Factors That Will Accelerate the Rate of Corrosion

1. More oxygen becomes available
2. Solids (e.g. iron oxides, particulate matter, etc.)
3. Microbial contamination
4. Mechanical deposit removal – iron oxide corrosion by-product
5. Draining and refilling the system
6. The low pH of condensate (dry and preaction systems)

More Oxygen

Any time oxygen enters fire sprinkler system piping the equilibrium that exists between the metal in the pipe, the water and the dissolved oxygen will destabilize. The newly introduced oxygen will dissolve in the water and react with iron or zinc to form additional hydroxide precipitates. This reaction will occur immediately and will always cause additional metal loss. The net effect is that **more solids** will precipitate and settle in the piping. The site with the highest level of corrosion activity will be at the air/water interface where dissolved oxygen is most readily available to react with the metal.

Solids

Solids accelerate corrosion by several mechanisms:

- **Under-deposit acceleration** wherein the metal under the deposit achieves an **“anodic” character** versus the adjacent metal. This anodic character will mean that corrosion will be more aggressive under the deposit and pitting attack of the pipe wall will occur.
- In oxygenated systems, the area under the deposit can become oxygen depleted and can achieve **“anodic” character** versus the adjacent metal. Once again, the corrosive attack under the deposit will become more aggressive and pitting attack of the pipe wall will occur.
- Solids provide an **ideal environment for bacteria** to colonize. In addition, depending on the chemical make-up, the solids may be nutrient sources for bacteria. For example, iron oxide solids provide a fundamental nutrient for iron related bacteria (IRB). The slimes that the bacteria create also act as deposits under which pitting attack of the pipe wall will occur.



Microbial Contamination

There are a myriad of different mechanisms that come under the heading microbiologically influenced corrosion (MIC). Depending on the type of bacteria that contaminate the system, the corrosion rate can be accelerated by the following mechanisms:

- slime formation – under-deposit pitting corrosion (especially in oxygenated systems)
- acid production – acidic (H^+) attack and pitting corrosion
- sulfide (S^-) anion production – cathodic depolarization of the corrosion cell resulting in pitting corrosion

Mechanical deposit removal

Anytime the corrosion by-product deposit is removed from the metal surface it creates a fresh new site for oxygen attack. This is especially true with hematite (Fe_2O_3) which forms a soft non-adherent deposit. Fresh metal is most often exposed at the air/water interface and repeated removal of the deposit will create crevices in the metal surface.

Draining and refilling the system

Each time a wet fire sprinkler system is drained of the water and refilled, the high rate of oxygen that exists in a fresh supply of air will remove more metal from the pipe walls. Any deposits that exist on the metal surfaces will create oxygen concentration cells in the fresh oxygen rich water and the otherwise low general rate of corrosion will be greatly accelerated and pitting attack of the pipe wall will occur.

The Low pH of Condensate

In most dry and preaction fire sprinkler systems, compressed air is used to maintain pressure within the system piping. When temperature fluctuations cause the compressed air in the system piping to fall below the dew point, water condenses on the pipe walls as small droplets. Any water that condenses is essentially distilled water which contains no dissolved mineral components. The carbon dioxide in the compressed air dissolves in the distilled water and forms carbonic acid which reduces the pH of the condensate to the acidic range of around 5.5. This acidic water greatly accelerates the corrosion of the iron in the system piping.

Root Cause Determination

Bacteria can almost always be found in water and deposit samples that are collected for evaluation from fire sprinkler systems. Analysis by scanning electron microscopy (SEM) of failed fire sprinkler piping might also reveal different strains of bacteria within the pores of the corroded metal. However, these results do not diminish the fact that oxygen corrosion is the **primary cause** for corrosive attack. Microbiologically influenced corrosion (MIC) is common but is almost always a secondary cause of the corrosion that is found.

Conclusion

Corrosion control programs for fire sprinkler systems that seek to slow down or stop the leaks and metal loss by controlling or killing bacteria without addressing oxygen as the primary cause of corrosion **WILL NOT** be successful. The most effective corrosion control strategy must include provisions to prevent attack of the fire sprinkler system piping by oxygen that is dissolved in the water. This is true for wet, dry and preaction fire protection systems.

Once oxygen corrosion is controlled, controlling or preventing microbiologically influenced corrosion (MIC) becomes much easier primarily because the system remains free of the solids that support the growth and proliferation of bacteria.

Engineered Corrosion Solutions, LLC is a corrosion management consulting firm that offers assessment and system analysis coupled with design services and a full suite of corrosion management strategies that include equipment and integrated devices for controlling corrosion in water-based wet, dry and preaction fire sprinkler systems. We understand the science of corrosion in fire sprinkler systems in a complete variety of different settings from parking structures to warehouses to clean rooms to data centers.

Engineered Corrosion Solutions, LLC offers proprietary nitrogen inerting technology which includes the ECS Protector Nitrogen Generator, Pre-engineered Skid Mounted Nitrogen Generator, SMART Manifold, SMART Vent for dry and preaction fire sprinkler systems, and new proprietary nitrogen inerting technology for wet pipe fire sprinkler systems.

For complete information about the entire line of corrosion management products and services please contact us at Engineered Corrosion Solutions, LLC, 2043 Woodland Parkway, Suite 301, St. Louis, MO 63146, (314) 432-1377 or visit www.ecscorrosion.com.

