White Paper

Controlling Corrosion in Wet Pipe Fire Sprinkler Systems Using Chemical Corrosion Inhibitors

(March 2011)

By Jeffrey T. Kochelek and Gerard. J. van Moorsel

Engineered Corrosion Solutions

Complete Corrosion Control.

Engineered Corrosion Solutions, LLC
11336 Lackland Road
St. Louis, MO 63146
314-432-1377
ecscorrosion.com

ECS Engineered Corrosion Solutions
ecscorrosion.com

Abstract: As the frequency of corrosion related leaks in aging fire sprinkler systems increases, an ever growing number of facilities management personnel and fire sprinkler contractors are looking for ways to combat internal corrosion of the fire sprinkler systems. In the recent past, nearly every leak that occurred in these systems was attributed to Microbiologically Influenced Corrosion (MIC), however, it is now becoming clear that the primary cause of corrosion in fire sprinkler systems, wet or dry, is oxygen corrosion. The corrosion control strategy most widely implemented to control corrosion has been the incorporation of a chemical corrosion inhibitor in the system water. Ideally, the corrosion inhibitor forms a film on the pipe wall which prevents any interaction between the corrosive specie in the water and the pipe metal. Though widely used, few of those who utilize chemical inhibitors have considered all of the factors that govern the likelihood of success in controlling corrosion in fire sprinkler systems. This paper provides a discussion on the effectiveness, and in many cases the lack there of, of utilizing chemical corrosion inhibitors in the stagnant, fouled conditions present in most fire sprinkler systems and suggests a more reliable corrosion control strategy.

Engineered Corrosion Solutions

ecscorrosion.com

1. Introduction

The environment within a water based fire sprinkler system can be characterized as a stagnant, persistently moist, oxygenated system. These are ideal conditions for oxygen corrosion of the pipe metal to occur, and given enough time oxygen corrosion will inevitably lead to pin holes leaks in the system. An increasing number of aging systems in service combined with the transition from schedule 80 and schedule 40 pipe to the much thinner schedule 10 and schedule 7 pipe in many new systems has led to an increased awareness of the detrimental effect corrosion can have on a fire sprinkler system. In an attempt to combat this corrosion and increase the service life of their fire sprinkler systems many fire sprinkler contractors and facilities managers have turned to the use of chemical corrosion inhibitors.

Chemical corrosion inhibitors are used in a wide variety of industries to slow the corrosive degradation of metal components and structures. Liquid water is a necessary component for corrosion to occur, wherein a molecule of the metal at the wetted surface gives up an electron(s) to an oxidizing constituent in the water and the metal becomes a water soluble ion. The net effect of this chemical reaction is that a void is created at the point where the metal molecule was liberated from the substrate metal surface. A pit is formed. As the process continues, the metal degrades and eventually a failure occurs. In the case of wet pipe fire sprinkler systems, a leak occurs, usually at a completely inappropriate time.

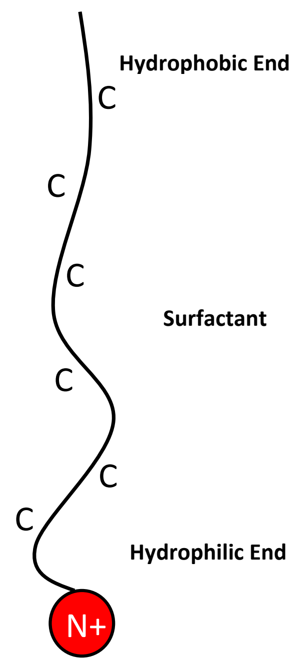

Fig. 1 Structure of Amine Inhibitor

2. Chemical Corrosion Inhibitors

2.1 Organic Inhibitors

There are a whole variety of chemistries that are used to retard the corrosion reaction depending on the specific application and environment. The intent of this discussion is not to review those chemistries. However, many corrosion inhibitor formulations use nitrogen (amine) based organic molecules that rely on surface activity to facilitate the migration of the inhibitor molecule to the metal surface. As shown in Figure 1, the surfactant typically has an alkyl group with a long chain carbon backbone that is used to impart hydrophobic character to the molecule. The positive charge from the nitrogen causes the molecule to attach to the metal surface where it inhibits the oxidation reaction and slows the deterioration of the metal. In effect, the molecule creates a barrier between the metal and the water borne corrosive specie [1], as demonstrated in Figure 2.

Engineered Corrosion Solutions
ecscorrosion.com

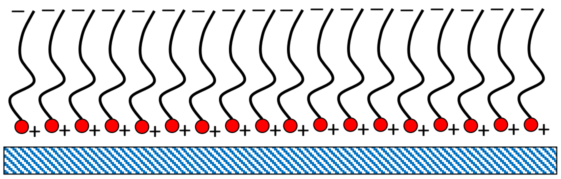

Fig. 2 Thin Film of Surfactant at the Metal Surface

In wet pipe fire sprinkler systems, dissolved oxygen is the primary corrosive specie. This discussion will focus on the unique operational constraints that exist in wet pipe fire sprinkler systems and the difficulties involved with designing an effective corrosion control strategy based on the use of chemical corrosion inhibitors.

Oxygen corrosion is the prevalent and predominant type of corrosion in wet pipe fire sprinkler systems. Once corrosion by-product solids, typically iron oxide, become trapped within the system under-deposit mechanisms accelerate the metal loss in areas where the solids settle. Trapped pockets of air also create highly localized zones within the piping where oxygen corrosion can be quite aggressive because of the proximity of the adjacent metal to large amounts of oxygen [2]. Corrosion failures with through-the-wall pits most typically occur at the air/water interface near the trapped air pockets and at the 6 o'clock position in the pipe under layers of corrosion by-product solids.

Within the fire sprinkler industry the most common corrosion inhibitor types that are currently in use are alkyl amines and quaternary amines that employ a positively charged nitrogen atom in a highly surface active molecule. Some formulations also employ wetting agents, microbiocides, chelants, and other dispersants in the package.

In a flowing regime, chemical corrosion inhibitors are most often applied by continuous, low dose addition to the water stream. Once a threshold level of corrosion inhibitor is present in the water it maintains a thin layer of inhibitor molecules at the metal surface to prevent corrosive attack. Any breach that occurs in the inhibitor film can be quickly "repaired" as inhibitor molecules move in from the flowing water to repair the breach. Empirical testing of candidate corrosion inhibitors in the subject fluids can quickly determine the following:

- **Threshold dosage** – minimum dosage required to begin inhibition at the metal surface
- **Ideal dosage** – thin film is formed at metal surface and maximum inhibition is achieved
- **Overtreatment** – where the inhibitor loses performance due to surfactant interaction

Overtreatment conditions typically occur for surfactant molecules when the concentration of the chemical in the water exceeds the critical micelle concentration (CMC). The molecules continue to aggregate and at some point a significant portion of them are no longer available to migrate to the metal surface to form the thin film that inhibits the corrosion reaction [3]. The treatment objective is to determine the ideal dosage range for the given environment without aggregating the inhibitor. The adage that if a little is good then a lot will be better is completely wrong when it comes to surface active corrosion inhibitors.

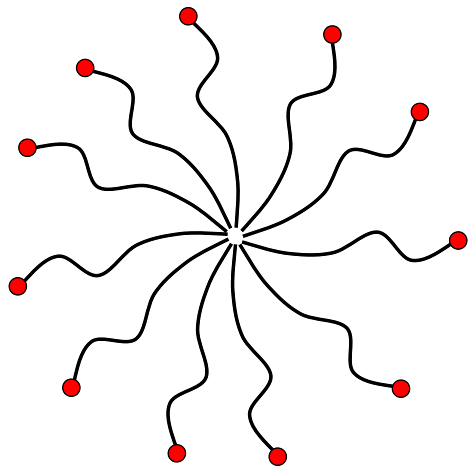

Fig. 3 Surfactant Micelle

In the stagnant environment that exists within a wet pipe fire sprinkler system, choosing a surfactant based corrosion inhibitor that is effective in controlling corrosion and identifying the proper dosage for the application can be quite difficult. Depending on the age of the system and the amount of corrosion by-product solids that are trapped in the piping, it could be quite easy to under treat or over treat the system. Surfactant molecules cannot differentiate the surfaces of the pipe from the surface areas on finely divided iron oxide solids. Even a small amount of iron oxide solids could consume a very large percentage of the corrosion inhibitor that is added to treat the system [1]. On the contrary, if too much inhibitor is added, it would be very easy to over treat the system. Both situations will not achieve the appropriate level of corrosion control. The practice of adding 5000 parts per million (5 gallons per thousand gallons of sprinkler water) as the “standard” treatment is at best a guess and will almost certainly lead to a less than optimal corrosion control situation. In effect, depending on the age and condition, every wet pipe fire sprinkler system may present conditions that require specialized treatment considerations especially when it comes to choosing the right dosage. Almost all systems will require flushing to remove as much trapped solids as is possible prior to the application of any chemical corrosion inhibitor.

2.2 Inorganic Inhibitors

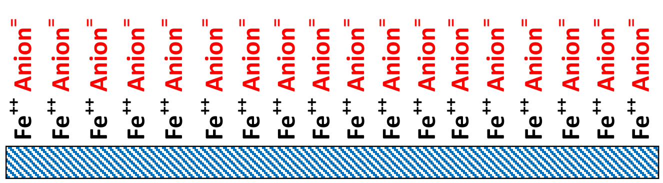

Fig. 4 Passivating Metal Salt at the Metal Surface

Another approach that has been successfully employed uses a solution of an inorganic salt to form an insoluble precipitate of iron at the metal surface. This is done by saturating the water with the appropriate anion which combines with iron to form a protective passivating layer as can be seen in Figure 4. Using this approach requires a threshold level of the anion in the water to achieve passivation and protection from oxygen corrosion but using an inorganic salt does not run the risk of overtreatment. This approach is analogous to the natural formation of an aluminum oxide passivating salt with exposure of fresh aluminum to atmospheric oxygen.

2.3 Attributes of the Ideal Fire Sprinkler System Corrosion Inhibitor

Before being considered for use in a wet pipe fire sprinkler system, any chemical corrosion inhibitor must demonstrate that it is:

- Non-toxic and does not pose an exposure threat to persons or property during storage, handling or as a discharge component in sprinkler water
- Easily deactivated for safe discharge of the fire sprinkler system water to the surface or to sanitary sewer during fire sprinkler system testing
- Completely compatible with all fire sprinkler system components including valves, sprinklers, elastomeric seals, gaskets and various metals

The ideal candidate should also have the following functional attributes:

- Demonstrate corrosion control performance in the closed, stagnant, oxygen rich environment that is found in a wet pipe system
- Provide corrosion control with both black steel and galvanized steel fire sprinkler systems
- Be very water soluble to provide quick dispersion and result in a completely mixed, homogeneous solution in fresh water
- Be chemically stable with no loss of efficacy during long term exposure to the fluctuating temperature conditions that might be encountered
- Not lose performance as a result of accidental over-treatment, i.e. adding too much inhibitor
- Provide biocidal or biostatic control of microorganisms in the fire sprinkler system
- Be safe and easy to handle and store

2.4 Problems with Alkyl Amines and Quaternary Amine Corrosion Inhibitors

2.4.1 Unfavorable Organic Inhibitor Characteristics

Alkyl amines and quaternary amines are routinely used to control corrosion in flowing fresh water conditions. They demonstrate surface adhesion and can routinely achieve 95%+ corrosion control. Additionally, the quaternary amines find application as disinfectants and microbiocides in many industries. That being said, these type inhibitors have several significant drawbacks including:

- As organic molecules, they will degrade over time (thermal, oxidative degradation)
- Many exhibit significant toxicity at higher concentrations above ½% by weight
- Most are amber to dark brown in color and will stain the fire sprinkler water
- Because of surface activity can pose foaming problems which may become an issue during discharge to surface waters or municipal sewer systems

ECS Engineered Corrosion Solutions
ecscorrosion.com

- Alkyl amines and quaternary amines exhibit compatibility problems for the most common fire sprinkler system elastomeric materials (including EPDM) and plastics including CPVC [4]
- They lose performance with over-treatment (above the CMC)
- Testing indicates that these type inhibitors do not perform well in controlling oxygen corrosion in the closed, stagnant environments that exist in wet pipe fire sprinkler systems

2.4.2 Backflow Prevention

Given the fact that the vast majority of installed wet pipe fire sprinkler systems utilize a direct connection to the municipal water supply as the water source, there is one issue to consider before implementing a chemical corrosion control program. Most Authorities Having Jurisdiction (AHJs) will require an upgrade of the backflow prevention device from a double check type to a reduced pressure zone (RPZ) type if **ANY** chemical additive is used to treat the fire sprinkler system water. This stance is taken to prevent inadvertent contamination of the municipal water supply if a backflow event should occur. This will add cost to any chemical corrosion control strategy for new construction and considerable cost when applied to an existing building. Additionally, an RPZ backflow preventer always creates a larger pressure drop than a double check backflow preventer which may require a reevaluation of the system's hydraulic calculations to ensure proper operation.

2.4.3 Sensitivity of the Materials Being Protected

One other consideration that can come into play regarding chemical corrosion control additives in fire sprinkler waters is the sensitivity of the property being protected by the wet pipe fire sprinkler system. For example, there may be reluctance on the part of the proprietors in cultural resource settings to use any chemical additives that might permanently damage artifacts and other priceless antiquities. The same might be true in areas where sensitive manufacturing environments are being protected.

One of the overarching assumptions tied to the use of chemical corrosion inhibitors for corrosion control in wet pipe sprinklers is that the corrosive specie, in this case oxygen, is an unavoidable component of the system that is being treated. Quite the contrary is true. The amount of oxygen that is available for corrosion can be reduced dramatically by adding automatic vents to vent trapped air and by testing the fire sprinkler systems with minimal frequency. To take it one step further, it is possible to completely purge wet pipe fire sprinkler systems of oxygen using nitrogen gas. Venting and purging with nitrogen may be the simplest, safest, most compatible remedy for controlling oxygen corrosion. Nitrogen gas is readily available, it is non-toxic and corrosion can be completely controlled under the inert environment that is created when nitrogen gas is used to purge oxygen from the systems and to sparge dissolved oxygen from the water.

3. Conclusions

The use of chemical additives to control oxygen corrosion in wet pipe fire sprinkler systems presents a variety of very significant challenges. The standard list of alkyl amines and quaternary amines that provide excellent corrosion control in fresh water flowing environments have a much more difficult task in controlling corrosion in what amounts to batch treating a long, narrow, stagnant, solids filled pool of water with lots of "dead ends" that periodically and regularly receives a fresh supply of oxygen. Although the inorganic salt approach seems to provide an easier pathway to acceptable corrosion control, in some settings other obstacles may preclude consideration of this approach as part of a comprehensive corrosion control strategy.

When it comes to wet pipe fire sprinkler systems, the greatest risk may be in assuming that the chemical corrosion inhibitor that has been injected into the fire sprinkler water is controlling corrosion. Unfortunately, if it takes 10 years for the "treated" system to fail and it becomes apparent that the corrosion inhibitor did not do the job, the company that made the recommendation may be long gone. The list of excuses as to why the chemical treatment failed could be endless. A corrosion control strategy with the specific aim of removing the corrosive oxygen by inerting the system with nitrogen gas provides an extremely reliable method of prolonging the useful lifespan of a fire sprinkler system.

ECS Engineered Corrosion Solutions

ecscorrosion.com

References

1. C. Smith, C. Li, T. Bedard, J. Kimler (2009) A New MIC Control Strategy in Low Velocity Gas Gathering Pipelines. SPE 120837. Presented at the 2009 SPE International Symposium on Oilfield Chemistry, The Woodlands, Texas April 2009

2. I. Matsushima (2000) Localized Corrosion of Iron and Steel. In: R. W. Revie (ed) Uhlig's Corrosion Handbook, 2nd edn. Wiley-Interscience, p 564

3. D. I. Horsup, J. C. Clark, B. P. Binks, P. D. I. Fletcher, J. T. Hicks (2010) The Fate of Oilfield Corrosion Inhibitors in Multiphase Systems. Corrosion, Vol. 66, No. 3

4. Cole-Palmer, Chemical Compatibility Search Engine. http://www.coleparmer.com/techinfo/chemcompresults.asp. Accessed 12 October 2010

ECS Engineered Corrosion Solutions

ecscorrosion.com

Engineered Corrosion Solutions, LLC is a corrosion management consulting firm that offers fire sprinkler system assessment and 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 dry pipe nitrogen inerting technology (DPNI) and wet pipe nitrogen inerting technology (WPNI), which includes the ECS Protector Nitrogen Generator, Pre-Engineered Skid Mounted Nitrogen Generator, Gas Analyzers, SMART Dry Vent, Two (2) Wet Pipe Nitrogen Inerting Vents and the industry's first real time in-situ corrosion monitoring device the ECS In-Line Corrosion Detector. Finally, we offer the first comprehensive remote corrosion monitoring system that provides live validation of the corrosion control strategy that is in place within your facility.

For complete information about the entire line of corrosion management products and services and the complete list of downloads of White Papers, FAQs, installation schematics and product spec sheets please visit the Engineered Corrosion Solutions website at ecscorrosion.com or contact us at (314) 432-1377 and one of our engineers will assist in personally answering any of your questions.

ECS Engineered Corrosion Solutions
ecscorrosion.com