White Paper

The Chemistry of Oxygen Corrosion in Wet Pipe Fire Sprinkler Systems and Wet Pipe Nitrogen Inerting (WPNI) for Corrosion Control

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There is a lot of misinformation circulating within the fire sprinkler industry regarding oxygen corrosion of steel sprinkler piping and the mechanisms associated with that process. Oxygen is a highly reactive gas constituent of the air we breathe (21%) and is the primary cause of corrosion in fire sprinkler piping. There are three physical attributes of oxygen gas that greatly affect the corrosion reaction with steel pipe.

First, oxygen gas exhibits <u>very low solubility</u> in water. This is important because until oxygen gas dissolves into the water it cannot participate in the corrosion reaction. The saturation limit, i.e. the point at which no more oxygen can dissolve into the water, is approximately 10 parts per million (0.001%) at room temperature and pressure[1]. Increasing the pressure can increase the amount of oxygen that can dissolve into the water and at 150 psig the saturation limit increases to about 40 parts per million (0.004%).

Second, once the dissolved oxygen in water contacts the steel pipe, the reaction between the oxygen and the iron <u>occurs in minutes</u>. A common example of this reaction occurs on the brake rotors of your vehicle at the car wash. After contact with the warm oxygen saturated water for only a few minutes a sheen of rust forms.

Third, oxygen molecules that are dissolved in water have <u>very poor mobility</u> in stagnant water. As a result, the corrosion reaction that occurs in wet pipe fire sprinkler systems generally occurs in very close proximity to the trapped air pocket. It occurs in other locations, but this is the primary location where oxygen corrosion will occur[2].

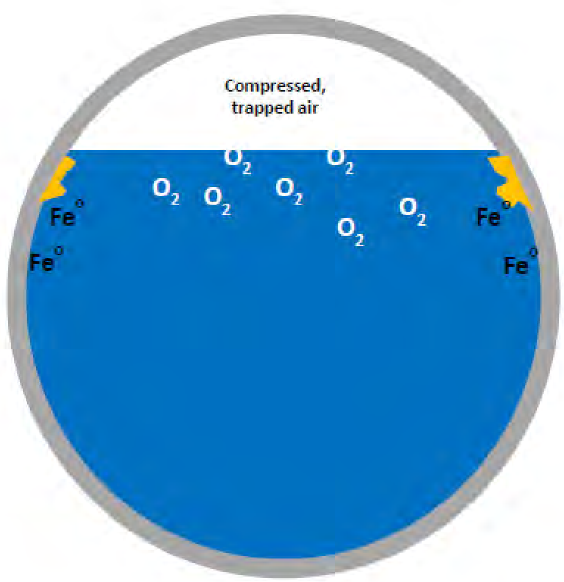

Figure 1: Corrosion Reaction at the Trapped Air Pocket

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These three physical attributes clearly explain why almost all of the corrosion that occurs in wet pipe fire sprinkler systems occurs in close proximity to pockets of trapped air within the water filled piping.

The sequence of steps in the oxygen corrosion reaction in a wet pipe systems is as follows:

1. As the system is filled with water the air that originally filled the empty pipe gets trapped and creates a void space directly above and in **intimate contact** with the water surface.
2. Some of the oxygen molecules in the trapped air **dissolve** into the water.
3. The dissolved oxygen concentration at the water surface quickly rises until it reaches its **saturation limit**. The remaining oxygen in the trapped void space remains as a gas.
4. The dissolved oxygen molecules in the water mobilize and **react with the iron** molecules in the pipe wall – once the dissolved oxygen contacts the iron, this reaction happens in minutes.
5. As a result of the chemical reaction between dissolved oxygen and iron, a **physical particle of iron** metal is removed from the pipe wall and creates a void called a pit.
6. The product of the chemical reaction between dissolved oxygen and iron is a **physical particle of iron oxide** (hematite or rust) which precipitates inside the pipe.
7. As the first dissolved oxygen molecules in the water are consumed by the corrosion reaction, the dissolved oxygen concentration in the water **falls below the saturation limit**.
8. **More oxygen** from the trapped air pocket dissolves into the water until the saturation limit is again reached.
9. As the process continues, all of the molecules of oxygen in the trapped air dissolve in to the water and are eventually consumed by the iron in the pipe wall – in the closed pipe, this consumption of the oxygen can take **90 – 120 days** depending on the pressure, the temperature, the total water surface area and the chemistry of the water.

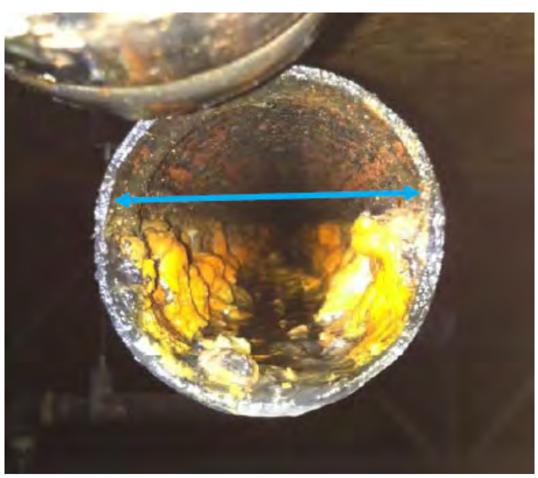

Figure 2: Air-Water Interface with Significant Oxygen Corrosion

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Some in the industry who are unfamiliar with oxygen corrosion chemistry have suggested that it is necessary to remove the dissolved oxygen from fire sprinkler supply water before it is used to fill the sprinkler system piping. However, a simple analysis of the total amount of oxygen in the piping reveals the following:

- 1000 gallons of water completely saturated with dissolved oxygen to 40 parts per million (0.004%) contains <u>0.04 gallons of oxygen</u> (assumes 150 psig pressure in the pipe)
- 1000 gallons of air that originally filled the pipe and is compressed and trapped in the piping after filling with water contains <u>210 gallons of oxygen</u>

Therefore, there is at least 5000 times more oxygen available for corrosion in the trapped gas of a wet pipe fire sprinkler system than there is in the fill water. Focusing on the very small amount of oxygen contained in the incoming water supply is costly, inefficient, and unproductive.

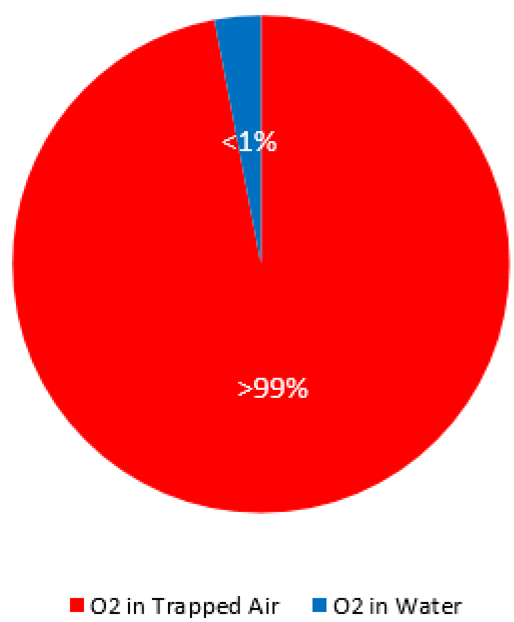

Figure 3: Source of Oxygen in Wet Pipe Fire Sprinkler Systems

If all of the oxygen in the wet pipe fire sprinkler system piping is displaced with nitrogen gas before the system is filled with water, oxygen corrosion can be completely stopped[3]. This is at the heart of the wet pipe nitrogen inerting (WPNI) process. This specific process has been used in over 1000 wet pipe zones in the past 5 years with complete elimination of oxygen corrosion in every system.

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References:

[1] US Geological Survey Dissolved Oxygen Tables - http://water.usgs.gov/software/DOTABLES/

[2] Research Technical Report "Corrosion and Corrosion Mitigation in Fire Protection Systems" FM Global, Paul Su and David Fuller, July 2014.

[3] Engineered Corrosion Solutions Wet Pipe Nitrogen Inerting (WPNI) Case Histories

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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.

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