White Paper

Environmental and Sustainability Considerations for Controlling Corrosion in Water-Based Fire Sprinkler Systems

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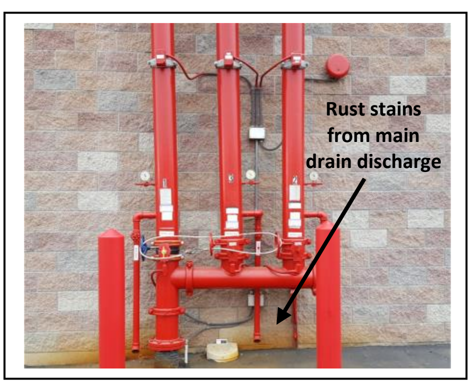
Background

Oxygen in the air is the primary cause for corrosion of metal piping in water-based fire sprinkler systems. Wet pipe fire sprinkler systems exhibit highly localized corrosion where air is trapped at high points within the piping. Dry pipe fire sprinkler systems exhibit highly localized corrosion where pools of water remain trapped within horizontal runs of the piping. In both cases, oxygen corrosion leads to three (3) results:

1. **Metal is physically removed** from the inner surfaces of the pipe wall where the oxygen corrosion occurs leaving a pit in the pipe wall. Over time the pit can deepen leading to through-the-wall penetrations and pin-hole leaks.
2. **Insoluble metal oxide sludge** is formed and deposited within the piping (iron and zinc oxides). Over time accumulations of sludge can build up within the piping to potentially inhibit the flow of water and plug sprinklers. Zinc from the corrosion process represents a significant toxic discharge risk in most municipalities.
3. **Microorganisms proliferate** in the piping leading to aerobic slimes and odors. Organisms that metabolize iron oxide as a nutrient source are found in almost all fire sprinkler systems.

Anyone who works in the fire protection industry knows that the quality of water drained from a sprinkler system is always quite different from the pristine drinking water that originally filled it. The discharge water is often discolored (orange, brown or black) and malodorous. Over time iron in the discharge water can result in staining that is impossible to remove from concrete and asphalt.



Water that is drained from fire sprinkler systems is most often disposed to the municipal sewer system or where allowable to the surface. Given the poor quality of the aged sprinkler water it would generally not be considered for reuse in the fire sprinkler system because of the plugging risk the insoluble solids in the water pose.

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A recent NFPA report on the efficacy of automatic sprinkler systems suggests that when automatic sprinklers respond to a fire but do not control the fire, the most common cause for the lack of control is that not enough water was delivered to the responding sprinkler. Impairment and plugging are generally the result of obstructions within the piping.

<u>**Fire Sprinkler System Useful Life Considerations - Sustainability**</u>

The corrosion process greatly reduces the useful life of water-based fire sprinkler systems. There are several variables that cause the corrosion process to accelerate.

Wet Pipe Systems – generally last from 20-30 years depending on these factors:

- Volume of trapped air after filling the system with water – the more trapped oxygen, the higher the rate of metal loss. Every molecule of trapped oxygen will react with the metal piping until the oxygen is completely consumed by the corrosion reaction.
- Drain and fill frequency – the more often the system is drained and refilled (testing, modifications, leak repairs) the more oxygen is introduced and the higher the rate of metal loss. The amount of corrosion that takes place is directly proportional to the amount of oxygen that is added to the system piping.
- Thickness of the piping – thin-walled piping will fail faster than thicker pipe. Schedule 7, Schedule 10 and Schedule 40 piping are routinely used for wet pipe installations.
- Do not use galvanized steel piping in wet pipe fire sprinkler systems.

  FM Global Property Loss Prevention Data Sheet 2-1 (July 2022) "Corrosion in Automatic Sprinkler Systems" states the following:

  "Do not use steel sprinkler pipe that has been internally galvanized."

Dry Pipe (Preaction) Systems – generally last from 15-20 years depending on these factors:

- Material of construction – empirical evidence from field installations indicates that galvanized steel develops leaks 3-4 times faster than black steel when there is trapped water within the piping.

  FM Global Property Loss Prevention Data Sheet 2-1 (July 2022) "Corrosion in Automatic Sprinkler Systems" states the following regarding the use of galvanized steel pipe in dry/preaction systems:

  "It should be noted that new dry or preaction systems can develop through-wall corrosion pinhole leakage from 2 to 3 years after initial installation due to residual water causing corrosion in galvanized steel pipe."

- Pressure maintenance gas leaks – the more frequently the compressor runs to maintain system pressure, the more oxygen is introduced to the piping and the faster the system will fail. Every molecule of oxygen that is introduced by the compressor will react with the metal piping.
- Volume of water that is trapped within the system piping – liquid water is required to facilitate the oxygen corrosion reaction. Corrosion will occur wherever there are trapped pools of water.
- Thickness of the piping – thin-walled piping will fail faster than thicker pipe. Generally, Schedule 10 and Schedule 40 piping are used for dry (preaction) installations.

The ambient temperature of the fire sprinkler system can also affect the useful life. Higher temperatures cause the corrosion reaction to speed up. Fire sprinkler systems in locations with elevated temperatures will fail more quickly. Every 18^{o} F increase in temperature doubles the rate of the corrosion reaction. Sprinkler systems installed in boiler rooms, above ovens, in direct sunlight and above heat producing machinery will all corrode at a faster rate and lead to a reduced service life.

How Much Fresh Water is Being Used Annually in Wet Pipe Fire Sprinkler Systems

It is estimated that there are at least 100 million water-based fire sprinkler systems (zones) installed in existing US buildings. Eighty-five percent of these systems are wet pipe systems that stand filled with fresh water and ready to instantly respond in the event of a fire. The remainder are dry (preaction) pipe systems that only fill with fresh water when a fire event is detected. Although some water-based fire sprinkler systems rely on private freshwater lagoons for the fire water, most of these systems use fresh municipal drinking water as the fire water supply.

Fire protection activities that lead to freshwater consumption in water-based fire sprinkler systems:

- **Periodic flow testing of fire sprinkler systems to verify hydraulic performance.** The fire code requires that systems be tested periodically which requires the consumption of fresh water.
- **Fire sprinkler system modifications during building remodels.** When sprinkler systems are modified to accommodate changes in the layout of the space, systems must be drained to work on the piping to relocate the sprinklers. It is common practice to drain the sprinkler systems each day so that work can be performed and refill the systems at the end of the day to provide fire protection overnight. If systems are not refilled, a fire watch would be necessary to meet the fire code requirements. It is much easier and less expensive to drain and refill the sprinkler system every day. This daily drain and refill process goes on for the entire time interval while the remodel is taking place sometimes over weeks and months.

- **Repair of damaged or leaking fire sprinkler systems.** In order to remove and replace leaking fire sprinkler pipe, systems must be drained to perform the work. Depending on the size and scope of the replacement, the daily drain and refill process can last for weeks.

It is estimated that approximately 50% of the installed wet pipe systems (42,500,000 zones) in the US are drained and refilled at least once every year. If the average volume for a wet pipe systems is 500 gallons, that would mean that more than 21 billion gallons of fresh water from wet pipe sprinkler systems are being discharged to the municipal sewer or to surface every year. This is fresh drinking water that is not available for other municipal requirements.

Nitrogen Inerting of Water-Based Fire Sprinkler Systems for Corrosion Control

The use of nitrogen gas to prevent oxygen corrosion in water-based fire sprinkler systems has a proven track record of performance within the fire protection industry for more than 12 years. Controlling the premature failure of the sprinkler piping from oxygen corrosion has been the primary objective of the nitrogen inerting process. However, in the case of wet pipe systems, an added benefit was the preservation of the water quality within the piping. In fact, the water quality in nitrogen inerted wet pipe systems remains equivalent to the water that was used to fill the sprinkler system. There is no degradation of the water quality associated with suspended solids, heavy metals or microbial contaminants.

Wet Pipe Nitrogen Inerting (WPNI)

Nitrogen was first used to control oxygen corrosion in wet pipe fire sprinkler systems in 2009. A large mission critical manufacturing facility was experiencing chronic leaking in 25 wet pipe systems protecting the facility. Wet Pipe Nitrogen Inerting (WPNI) employs a process for displacing the air from the system piping before filling the pipes with water. Removal of the oxygen from the closed vessel completely stopped the corrosion process and the leaks. Further, water drained from a nitrogen inerted system was crystal clear with no discoloration or odor. Oxygen corrosion of the sprinkler system piping was the root cause for the water quality degradation. WPNI has a 12-year record for completely controlling oxygen corrosion in wet pipe fire sprinkler systems.

> FM Global Property Loss Prevention Data Sheet 2-1 (July 2022) “Corrosion in Automatic Sprinkler Systems” states the following regarding wet pipe systems:
>
> *Pressurize the system using and FM Approved nitrogen generator.*
>
> *Purging the oxygen from the system, whether it is from trapped air or dissolved in the water, can reduce the corrosion rate. FM Global testing has shown that carbon steel with air in a wet-pipe system corrodes up to 14 times faster than a system that has been purged with nitrogen.*

Dry Pipe Nitrogen Inerting (DPNI)

A nitrogen generator was first used for pressure maintenance in place of a standard air compressor on a dry pipe system in 2009. By using a nitrogen generator, the oxygen and water that are added each time an air compressor cuts in are eliminated. Systems that employ nitrogen for pressure maintenance show no signs of oxygen corrosion.

> FM Global Property Loss Prevention Data Sheet 2-1 (July 2022) "Corrosion in Automatic Sprinkler Systems" states the following regarding dry/preaction systems:
>
> *One corrosion mitigation approach is to fill dry-pipe or preaction systems with nitrogen gas. Doing so can remove oxygen, thereby decreasing oxygen-related electrochemical reactions. Based on the results of several field trials, this technique could mitigate corrosion in dry systems. FM Global testing has shown that carbon steel using air corrodes 20 times faster than when using nitrogen.*

To this point reusing or recycling the water discharged from water-based fire sprinkler systems has never been an option given the inferior quality of the water drained from these systems. However, nitrogen inerting technology extends the useful life of water-based fire sprinkler systems by preventing the oxygen corrosion that destroys the piping. If sprinkler systems are kept under a nitrogen atmosphere to the exclusion of oxygen, they can last as long as the structures that they are protecting.

Untreated System **WPNI Treated System**

The nitrogen inerting process preserves the integrity of the water quality by eliminating the contaminants added as a result of the oxygen corrosion process. As freshwater resources get more and more stressed throughout the country, reusing fire sprinkler water must be considered to eliminate the unnecessary waste of fresh drinking water.

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Reusing Fire Sprinkler Water

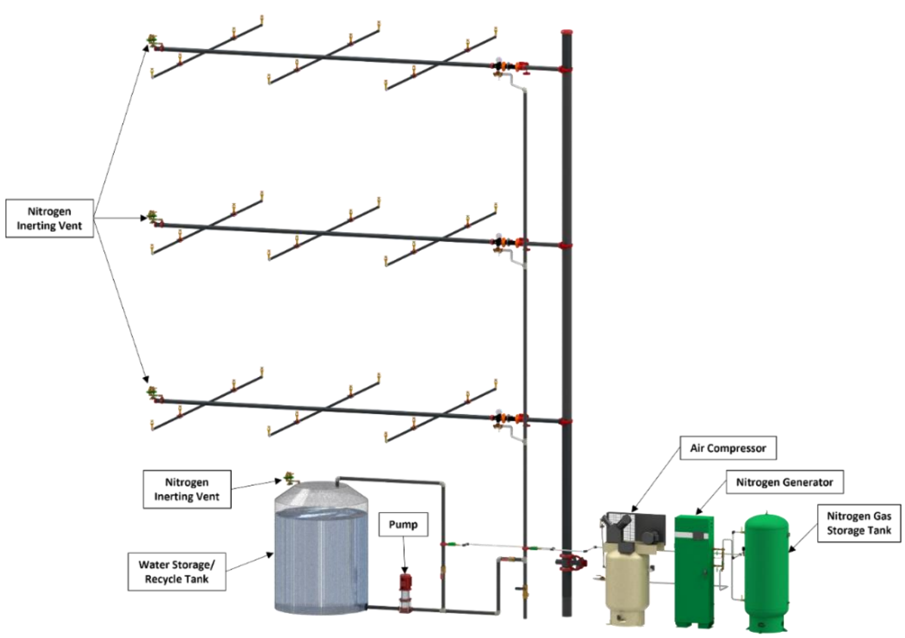
Nitrogen inerting of wet pipe fire sprinkler systems creates an opportunity to reuse the water that is routinely drained for maintenance or remodels. Integration of a water capture tank for the purpose of reusing the water from a drained system can be easily accomplished. Keeping the entire water capture system under a nitrogen atmosphere will ensure that oxygen is not introduced to the system to cause corrosion.

Benefits of Nitrogen Inerting for Corrosion Control

- Sustainability – Nitrogen inerting water-based fire sprinkler systems extends the useful life of the fire sprinkler piping by preventing corrosion
- Nitrogen inerting eliminates rust staining of buildings and parking lots where fire sprinkler water is discharged
- Nitrogen inerting eliminates potential contamination of ground water and surfaces with high levels of zinc in discharge waters
- Nitrogen inerting creates many opportunities for LEED points

Benefits of Fresh Water Recycle System

- Nitrogen inerting for corrosion control allows for the recycle (reuse) of water that has previously been sent to the sewer system or to surface discharge
- Nitrogen inerting eliminates the cost of treating sprinkler system discharge water in the municipal water treatment facilities (see California
- Nitrogen inerting prevents environmental contamination by discharging contaminated fire sprinkler water
- Nitrogen inerting of water-based fire sprinkler systems preserves available fresh water resources for other vital purposes



Installation Schematic

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References

FM Global Property Loss Prevention Data Sheet 2-1 “Corrosion in Automatic Sprinkler Systems” updated July 2022

US Patent 9,526,933 issued December 27, 2016 (Engineered Corrosion Solutions) – High Nitrogen and Other Inert Gas Anti-Corrosion Protection in Wet Pipe Fire Protection System.

US Patent 9,717,935 issued August 1, 2017 (Engineered Corrosion Solutions) – Venting Assembly for Wet Pipe Fire Protection Sprinkler System.

US Patent 10,188,885 issued January 29, 2019 (Engineered Corrosion Solutions) – High Nitrogen and Other Inert Gas Anti-Corrosion Protection in Wet Pipe Fire Protection System.

White Paper by Engineered Corrosion Solutions, May 2015 - “The Chemistry of Oxygen Corrosion in Wet Pipe Fire Sprinkler Systems and WPNI for Corrosion Control”

White Paper by Engineered Corrosion Solutions, May 2011 - “Six Reasons Why Galvanized Steel Piping Should Not be Used in Dry and Preaction Fire Sprinkler Systems”

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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.

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.

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