

# Corrosion and Mitigation Techniques for Fire Protection Piping Systems

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**AMPP values your input. To provide feedback on this standard, please contact: [standards@ampp.org](mailto:standards@ampp.org)**

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## Foreword

AMPP technical reports are intended to convey technical information or state-of-the-art knowledge regarding corrosion. In many cases, they discuss specific applications of corrosion mitigation technology, whether considered successful or not. Statements used to convey this information are factual and are provided to the reader as input and guidance for consideration when applying this technology in the future. However, these statements are not intended to be recommendations for general application of this technology and must not be construed as such.

## Scope

This report explains different types of corrosion phenomena and contributing factors of corrosion that can occur in fire protection systems (FPS), such as water corrosivity, MIC, trapped air (wet systems), residual water (dry systems), and pipe weld corrosion. The basis for selection of corrosion mitigation strategies for corrosion mitigation and management of FPS are also discussed.

## Rationale

Corrosion that results in pipe leakage or obstruction is the most significant issue for owners of water-based FPS or fire sprinkler systems, in terms of both cost and system reliability. Corrosion damage/products and mineral deposits can impair the effectiveness of sprinkler systems, leaving facilities vulnerable to uncontrolled fire loss even though they are equipped with fire protection systems. This report describes practices that have been successful in mitigating FPS corrosion.

## Referenced Standards and Other Consensus Documents

The latest edition, revision, or amendment of the referenced standards in effect shall govern unless otherwise dated.

### **AMPP/NACE/SSPC, [www.ampp.org](http://www.ampp.org):**

|                      |                                                                                                                             |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------|
| NACE SP0106          | Control of Internal Corrosion in Steel Pipelines and Piping Systems                                                         |
| NACE Standard TM0012 | Detection, Testing, and Evaluation of Microbiologically Influenced Corrosion on Internal Surfaces of Pipelines              |
| NACE Standard TM0106 | Detection, Testing, and Evaluation of Microbiologically Influenced Corrosion (MIC) on External Surfaces of Buried Pipelines |

### **ASTM, [www.astm.org](http://www.astm.org):**

|                     |                                                                                                                                 |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------|
| ASTM A795 /A795M-21 | Standard Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------|

### **FM Approvals, [www.fmaprovals.com](http://www.fmaprovals.com):**

|                  |                                                 |
|------------------|-------------------------------------------------|
| Standard FM 1035 | Nitrogen Generators                             |
| Standard FM 1616 | Underground Pipe Rehabilitation Systems         |
| Standard FM 1630 | Steel Pipe for Automatic Fire Sprinkler Systems |

### **General Services Administration, [www.gsa.gov](http://www.gsa.gov):**

|          |                                                      |
|----------|------------------------------------------------------|
| PBS-P100 | Facilities Standards for the Public Building Service |
|----------|------------------------------------------------------|

### **NFPA, [www.nfpa.org](http://www.nfpa.org):**

|         |                                                                                              |
|---------|----------------------------------------------------------------------------------------------|
| NFPA 13 | Standard for the Installation of Sprinkler Systems                                           |
| NFPA 25 | Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems |

### **UL, [www.ul.com](http://www.ul.com):**

|         |                                                                     |
|---------|---------------------------------------------------------------------|
| UL 2901 | Standard for Antifreeze Solutions for Use in Fire Sprinkler Systems |
|---------|---------------------------------------------------------------------|

## Section 1: Introduction

Corrosion that results in pipe leakage or obstruction is the most significant issue for owners of water-based fire protection systems (FPS) or fire sprinkler systems, in terms of both cost and system reliability as described in National Fire Protection Association (NFPA) Standard 25, "Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems."<sup>1-4</sup> The piping in these systems most often consist of either black steel piping or galvanized steel piping (under certain circumstances, CPVC and other plastic piping may be used). Repair of corrosion damage due to mechanical failure or water damage significantly adds to the lifecycle cost of sprinkler protection systems. In addition, the accumulation of insoluble deposits inside steel sprinkler piping can obstruct water flow in the pipe and/or potentially plug orifices on sprinkler heads. Therefore, corrosion damage/products and mineral deposits can impair the effectiveness of sprinkler systems, leaving facilities vulnerable to uncontrolled fire loss even though they are equipped with fire protection systems.

Corrosion and corrosion-caused pipe leakage in FPS are complicated issues. They can be caused by many factors or a combination of factors, such as residual water in dry pipe systems, trapped air in wet pipe systems, corrosive water chemistry, intermittently supplying oxygenated water into the FPS (recharging with fresh, oxygenated water during regular maintenance), stagnant water, pipe weld seam corrosion, and microbiologically influenced corrosion (MIC).

This document explains different types of corrosion phenomena and contributing factors of corrosion that can occur in FPS, such as water corrosivity, MIC, trapped air (wet systems), residual water (dry systems), and pipe weld corrosion. In addition, the basis for selecting of corrosion mitigation strategies of existing recommended directions on corrosion mitigation and management of FPS are discussed.

## Section 2: Water-Based Fire Protection Systems

Most of the fire protection systems installed today use water or aqueous-based solutions (e.g., aqueous film-forming foam [AFFF]), or glycol-based antifreeze solutions as fire-fighting agents. Currently there are four major types of water-based fire sprinkler systems on the market: wet pipe, dry pipe, preaction, and deluge systems -- depending on the requirements of service environments. All of them have been successfully developed for field application by the fire protection industry and the majority of fire sprinkler systems are installed following the requirements of NFPA Standard 13, "Standard for the Installation of Sprinkler Systems," which is adopted as fire code in most jurisdictions.

## Section 3: Corrosion Leakage in Fire Protection Systems

Corrosion and corrosion-caused leakage of fire sprinkler piping is the most significant issue for owners of water-based FPS, in terms of both cost and system reliability. The following describes the mechanisms that have been most frequently associated with FPS corrosion/leakage:

### 3.1 Oxygenated Water

#### 3.1.1 Dry Pipe or Preacton Systems

Residual water with dissolved oxygen in dry pipe or preaction systems is the leading cause for corrosion and leakage of galvanized steel pipe in these systems.<sup>5</sup> These types of systems utilize compressed air as a supervisory gas instead of being charged all the time with water. When the control systems sense a fire, the piping is rapidly filled with water and activation of the relevant sprinkler heads occur. The presence of compressed, supervisory air above the residual water results in the availability of dissolved oxygen in the water, which causes and sustain localized corrosion of galvanized steel and black steel sprinkler pipe. The use of compressed air as a supervisory gas exacerbates this effect due to the virtually unlimited availability of oxygen in the compressed air.<sup>4,5</sup>

Figure 1 shows corrosion of galvanized steel pipe (Nominal Pipe Size [NPS] 6, Schedule 10) where residual water filled approximately 40% of the pipe's volume in a dry pipe system.<sup>4</sup> Experience shows that galvanized pipe in dry and preaction systems with residual water (originating from initial hydrotesting or subsequent flow testing) can develop through-wall corrosion leaks within as little as 2-3 years after installation, due to residual water within such systems.



**Figure 1: Photograph Showing Corrosion of Galvanized Steel Pipe (NPS 6, Schedule 10) Where Residual Water Filled Approximately 40% of the Pipe's Volume in a Dry Pipe System (Image Courtesy of FM Global. Used with Permission. © 2014 FM Global. All Rights Reserved).**

### 3.1.2 Wet Pipe Systems

The same mechanism is at work in wet systems that have pockets of trapped air. Wet systems are designed to be water-solid with no entrapped air. If that is indeed the case, corrosion of such systems is self-limiting and effectively stops as soon as all of the dissolved oxygen in the water is consumed by the corrosion reaction as is evidenced by a characteristic black magnetite layer on the interior surfaces. This holds true until such time that freshly oxygenated water is introduced and when the process of oxygen depletion due to corrosion will repeat itself. In systems that contain trapped air, corrosion continues to occur due to the availability of oxygen in the slug/s of trapped air that eventually rise to and accumulate at high points in the FPS system. Localized pinholes eventually develop in the vicinity of the air/water interface. Repeated draining and recharging to repair such pinholes significantly worsen the frequency and severity of the pinhole leaks and ultimately results in replacement of significant portions of the sprinkler piping. [Figure 2](#) shows a section of black steel pipe from a wet FPS where the air pocket filled approximately 40% of the volume at that location in the pipe, providing the oxygen source for steel pipe corrosion. The through-wall leakage site is indicated and the two parallel lines point to the air/water interface within the pipe. Significant accumulation of corrosion product deposits developed over time in the bottom half of the pipe thereby creating conditions conducive to the creation of under-deposit differential aeration corrosion cells. The leakage arrow points to a large tubercle, beneath which a corrosion pit and pinhole was located. Periodic inspections and flow testing when systems are drained re-introduces oxygenated water into the steel piping system thereby also sustaining the corrosion. Note the reddish-brown color of the corrosion product deposits, which is indicative of the availability of oxygen, which facilitates the oxidation of black magnetite to the reddish-brown hematite.

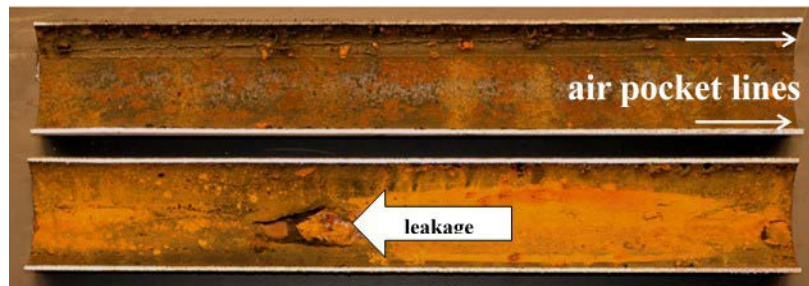


**Figure 2: Photograph Showing the Leakage Section of a Pipe where the Air Gap Filled Approximately 40% of the Volume in a Wet Pipe System**  
(Image Courtesy of FM Global. Used with Permission. © 2014 FM Global. All Rights Reserved).

### 3.2 Pipe Weld Corrosion

Preferential corrosion of the weld seam (i.e., “grooving corrosion” or “knife-edge corrosion”) in steel pipe welded by electric-resistance welding (ERW) process is another common failure mode for fire protection sprinkler systems. This kind of corrosion is attributed to microstructural changes that occur during the welding process, which may include the formation of unstable iron sulfides along with high residual stresses and microstructural changes around weld seam areas (i.e., causing anodic sites for corrosion to occur). Such areas are created during the pipe manufacturing process, and they include the weld seam and other heat-affected zones (HAZ). These changes and/or anomalies in the microstructure results in preferential corrosion of the weld seam, leaving the surrounding base metal almost untouched.

Corrosion and/or leakage of sprinkler pipe surrounding the weld seam area at the pipe bottom is frequently observed in the field due to low corrosion resistance and near-bottom (6 o'clock) orientation of the weld seam. For example, localized corrosion underneath tubercles and corrosion scale (e.g., under-deposit or pitting) requires aggressive, concentrated solution (e.g., pH ~ 2 and Cl-) to grow actively, often growing in the direction of the gravity force field. Fontana has noted “Since the dense, concentrated solution within a pit is necessary for its continuing autocatalytic activity, pits are most stable when growing in the direction of gravity.”<sup>6</sup>

Figure 3 shows an example of preferential grooving corrosion on a pipe weld seam inside an NPS 3 carbon steel pipe (after removal of corrosion product deposits) in a wet pipe system with a 1 mm pinhole leak located in the weld seam. In addition, the grooving corrosion of a longitudinal through-wall leakage in a galvanized steel pipe along its weld seam in a preaction system is shown in [Figure 4](#). The leak occurred beneath a large tubercle along the pipe’s approximate 6 o’clock installed position.



**Figure 3: Photograph Showing Preferential Grooving Corrosion on Pipe Weld Seam with a 1 mm Pinhole Leak in a Wet Pipe System, after Removing Corrosion Products inside an NPS 3 Pipe**  
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