White Paper

Fire Sprinkler Riser Corrosion

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Introduction

Oxygen corrosion is the primary and pervasive cause of degradation of fire sprinkler piping in water based fire sprinkler systems. The most common manifestations of oxygen corrosion in fire sprinkler systems are leaks in the system piping that result from the periodic introduction of air into the system. Wet pipe fire sprinkler systems generally develop leaks in pitched branch lines that are in close proximity to where air gets trapped. The reservoir of oxygen gas (21%) in the trapped air dissolves slowly over time in the water and reacts with the pipe metal. A pit is formed on the interior surface of the pipe near the air/water interface and eventually the cumulative metal loss breaches the entire thickness of the pipe wall.

In dry and preaction fire sprinkler systems the pressure maintenance compressor adds warm, moist oxygen every time it cycles on/off to maintain the system pressure. Here again oxygen from the injected air dissolves in trapped pools of water in the sprinkler mains where it reacts with the pipe metal and corrodes the bottom of the pipe.

Heretofore much of the efforts to control oxygen corrosion in water based fire sprinkler systems have been focused on the overhead sprinkler system piping. By removing the oxygen and preventing its introduction by inerting the systems with nitrogen gas, corrosion can be completely controlled. **Dry Pipe Nitrogen Inerting (DPNI)** and **Wet Pipe Nitrogen Inerting (WPNI)** are proving to be the most effective solution for corrosion control in the overhead sprinkler system piping[1].

The discussion in this paper will focus on oxygen corrosion that is occurring in the fire sprinkler riser assembly itself. Recent work performed on the vertical piping in the risers have elucidated a new location within the fire sprinkler system where chronic oxygen corrosion is degrading not only the riser piping but also the system control valve assemblies and the riser check valve assemblies.

Fire Water Delivery Loop

Fire pumps are used to provide a reliable supply of pressurized fire water to fire sprinkler systems. Fire pumps can service individual structures with multiple fire sprinkler risers, multi-story high rise buildings or they can be used to support a fire water loop in a campus setting with multiple buildings. Fire pumps come in a variety of configurations including vertical inline, vertical turbine, split case and end suction to name a few. They can be either electric or diesel powered. Vertical pumps are typically installed above the fire water supply reservoir while the other configurations deliver fire water from horizontal water supply piping that is generally attached to a municipal water supply.

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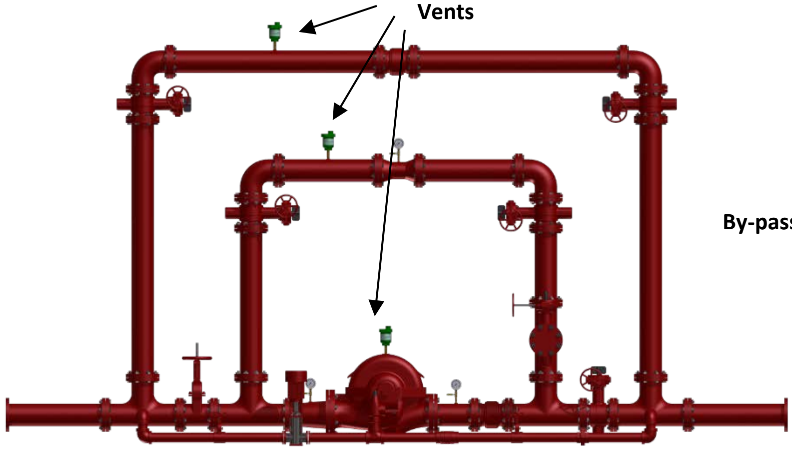
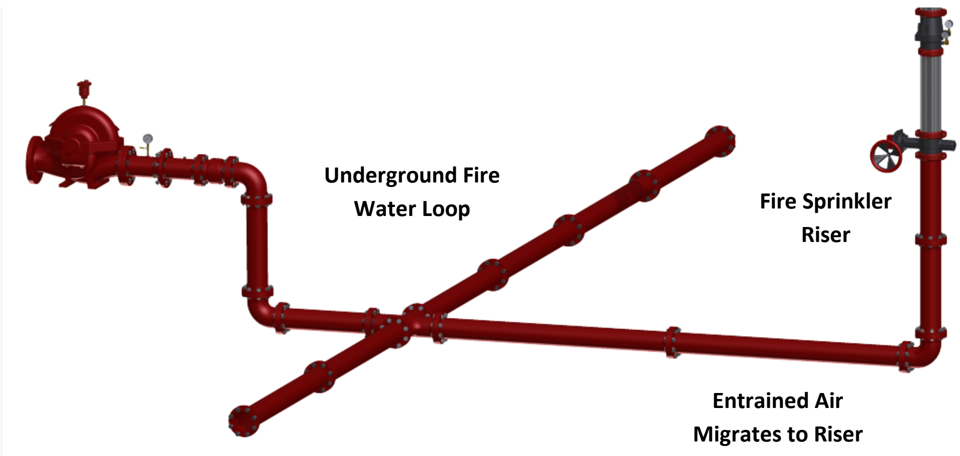


Many fire pumps and the bypass loops associated with them are equipped with float valve vents to release any trapped air that might accumulate within the water delivery piping. Venting trapped air can reduce cavitation and the resultant loss of pump efficiency. Eliminating trapped air ensures that the fire pump can deliver fire water within the design constraints of the fire water delivery system.



Oxygen corrosion is very common in the piping on the discharge side of the fire pumps. Although the exact location and mechanism for oxygen ingress has not as yet been determined, failed pipe analysis of the fire water delivery piping downstream of the fire pump discharge provides conclusive evidence that oxygen gas is entering the fire water supply lines. Examples of oxygen corrosion have been found in the fire water piping downstream of the pump, in the riser piping below the control valve and in the piping between the control valve and the riser check.

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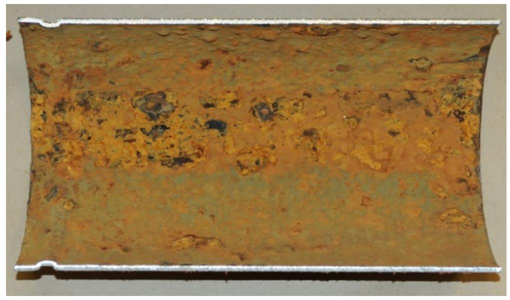
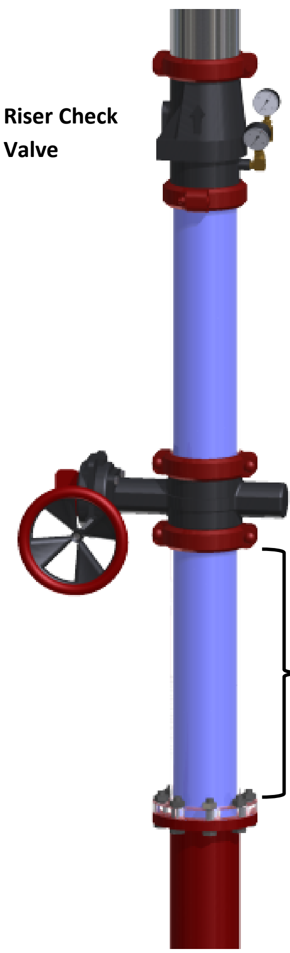
Underground fire water loops that employ ductile iron cement coated piping do not exhibit oxygen corrosion on the internal surfaces of the piping. The cement lining generally prevents oxygen attack of the underlying black steel. Failures in ductile iron cement coated underground piping are most commonly due to external corrosion. When standard black steel piping is employed as part of the fire water delivery system, oxygen corrosion on the interior surfaces is very common.



Oxygen Corrosion of Black Steel Piping in the Supply Main

Fire Sprinkler Riser Assembly



Generally, the fire sprinkler riser assembly is the first section of piping within the fire water delivery system that is in a vertical orientation. Any air that is entrained in the fire pump discharge as small bubbles eventually accumulates and migrates into the vertical piping. The field evidence suggests that those fire sprinkler zones closest to the fire pump on the fire water supply loop capture the most trapped air.

Evidence from field pipe samples where corrosion related failures have occurred indicates that in many instances the riser check valve is acting to trap accumulations of air below the clapper. It is common for the pressure in the overhead piping above the riser check valve to increase to a level above the standing pressure within the fire water deliver piping. This generally occurs because of temperature increases in the overhead piping associated with the heating of the day and air that is always warmer against the ceiling. In areas of the country that employ outside risers, direct sunlight can also heat up the riser and overhead piping. The underground piping will remain more or less constant at the temperature of the earth. The net effect of this temperature variance is that the pressure

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above the riser check valve is almost always higher than the pressure below the check valve.

Oxygen gas must dissolve into water in order for the oxygen corrosion reaction with metal to take place. The amount of oxygen gas that can dissolve into a given volume of water is limited by its solubility characteristics. In fresh water at room temperature and pressure the saturation limit for oxygen in water is approximately 10 parts per million (ppm). Pressure, water chemistry, and temperature exert a minimal affect on the saturation limit. For example, many fire water supply systems equipped with a fire pump maintain a pressure of approximately 160 psig. At that pressure the saturation limit for oxygen is approximately 50 parts per million (ppm). Even at this elevated pressure, the vast majority (>95%) of the oxygen that is available for corrosion is in the trapped air pocket and not in the water.

Oxygen Corrosion of Riser Piping (external view at pinhole leak)

Oxygen Depleted Zone at Rolled Groove of Riser Piping

Oxygen Corrosion of Riser Piping

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Although the oxygen corrosion reaction at the pipe surface occurs in minutes, the process of dissolving into the water and mobilizing through the quiescent water can be quite slow. Thus, trapped air pockets in the piping act as oxygen gas reservoirs that slowly but consistently provide oxygen to the corrosion reaction until all of the oxygen in the trapped air pocket is converted into iron oxide by the following equations:

Anodic Reaction (corrosion occurs):
$Fe^{o} \rightarrow Fe^{+2} + 2e^{-}$ iron becomes a water soluble ion

Oxidation of Iron (precipitation of solids):

$2Fe^{o} + O_2 + 2H_2O \rightarrow 2Fe(OH)_2$
$4Fe(OH)_2 + O_2 \rightarrow 2Fe_2O_3 + 4H_2O$
$2Fe_2O_3 + 2Fe(OH)_2 + O_2 \rightarrow 2Fe_3O_4 + 4H_2O$

From a physics and chemistry standpoint it is certain that every molecule of oxygen gas that enters the fire sprinkler piping system, whatever the source, will eventually be consumed by the iron in the pipe and precipitate as iron oxide (rust).

Riser Corrosion Mechanism

By evaluating the physical evidence from the corroded riser pipe samples that have been collected, it is possible to describe the corrosion mechanism:

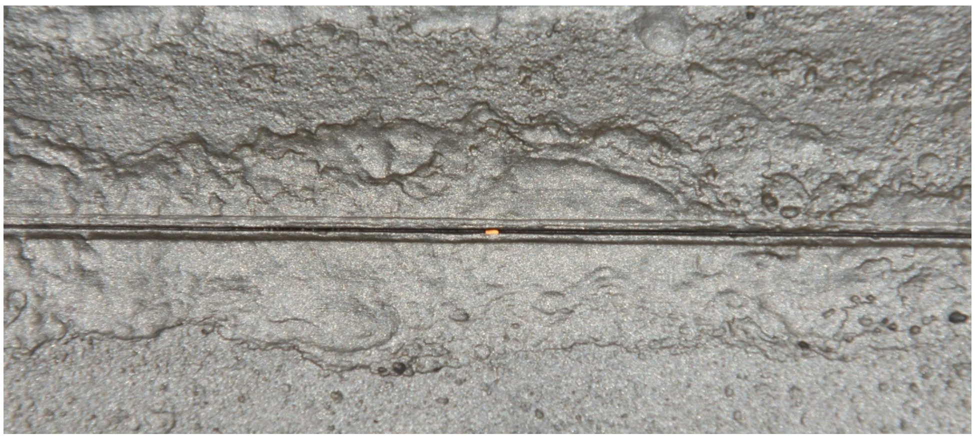
1. **Corrosion is Oriented Vertically** – the pattern associated with the corrosion by-product deposits and the actual metal loss indicate that the entire piece of pipe is filled with trapped air. If there were an air/water interface within the pipe section the corrosion would appear as a "ring" of corrosion at the air water interface. The physical evidence from the pipe samples indicates that the corrosion is longitudinal along the vertical axis of the pipe.

2. **Evidence of Evaporation/Condensation** – the underside of the check valve indicates that water is condensing and "dripping" off of the clapper (see picture). In this process water evaporates from the pool at the bottom of the pipe and rises up to re-condense at the top of the pipe and on the underside of the closed check valve clapper. Water drips off of the clapper and runs down the sides of the pipe. As the liquid condensate water runs down the pipe dissolved oxygen from the trapped air reacts with the sidewalls of the pipe.

3. **Oxygen Depletion Corrosion** – the oxygen depleted zone in the small gap at the middle of the rolled groove connection shows evidence of oxygen corrosion. When the pipe ends become anodic, they become "hot spots" for rapid acceleration of the metal loss.

4. **Under-Deposit Oxygen Acceleration** – as the corrosion by-product builds on the vertical walls of the pipe the corrosion rate accelerates. The net effect is a continuous build-up of corrosion debris on the sidewalls of the pipe until a pinhole leak occurs.

5. **Weld Seam Corrosion** – the weld seam in the vertical piping is vulnerable to oxygen corrosion attack. Piping that is used in fire sprinkler systems is not heat annealed and as such is subject to weld seam attack as evidenced in the pictures of the metal loss on the piping.



Oxygen Corrosion of Riser Piping with pinhole leak at weld seam (internal view)

Oxygen Corrosion of Riser Piping with pinhole leak at weld seam (external view)

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Evidence of Trapped Air Under Riser Check Valve

The pictures below show two aspects of oxygen corrosion in the riser assembly. First it is evident that the check valve housing does not exhibit evidence of oxygen corrosion attack. This is because there is not trapped air on the top side of the check valve. The check valve housing and the piping above the check valve are fluid packed. Second, it is clear that oxygen corrosion tubercles have formed at the top point of the piping just below the riser check valve. If the check valve stays closed, the air accumulates just below the riser check where it can continuously provide oxygen for the corrosion process.

Riser Check Valve Housing
Note Corrosion Below Clapper

Condensate Corrosion on Underside of Clapper

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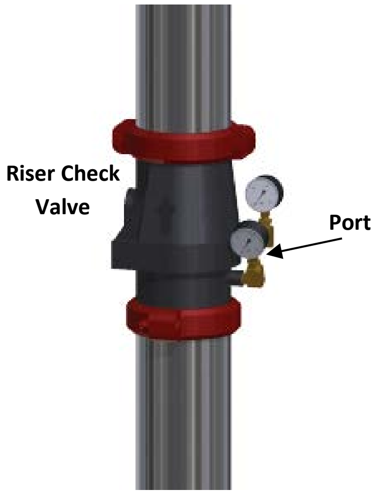
Vent Trapped Air Below the Riser Check

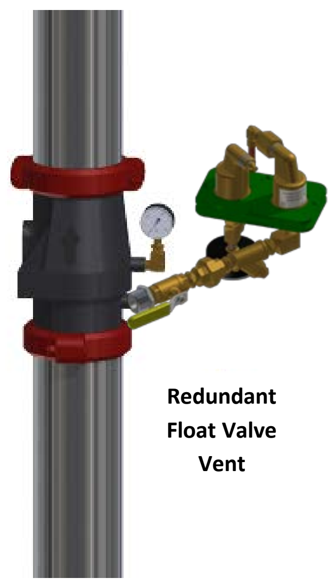


A simple solution to the oxygen corrosion problem in the fire sprinkler riser is to use an automatic vent to release the accumulated trapped air. To prevent any possible water leakage, a redundant configuration should be used. This redundant valve approach would eliminate the need for plumbing the vent assembly to drain in buildings where water leakage at the riser could not be tolerated. This approach has already proven successful in providing reliable automatic venting on the fire sprinkler system piping[2].

Most riser check valves provide a tapped port for the installation of a pressure gauge above and below the clapper. The port on the lower side of the check valve can be used as the exhaust port for the automatic vent assembly.

Benefits of the Automatic Air Vent

Venting the trapped air under the check valve is a very effective means of reducing or preventing oxygen corrosion in the riser assembly. This approach should extend the service life of the riser check valve, the control valve and the riser piping by eliminating the oxygen that causes the corrosion of those components. Trapped air contains 21% oxygen by volume and once it enters the piping it fuels oxygen corrosion reaction within the riser. If trapped air can be automatically vented, the reduction in oxygen corrosion of the riser components will be instantaneous and very significant.



References

[1]"Using Nitrogen Gas to Remove Corrosive Gases in Fire Sprinkler Water" by Jeffrey T. Kochelek, ECS WHITE Paper

[2]ECS Ejector Automatic Air Vent – Product Spec Sheet PAV-W (US Patent 8,636,023)

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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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