White Paper

Weld Seam Corrosion of Fire Sprinkler Piping

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Overview

Corrosion related leaks in fire sprinkler system piping have become more common in recent years as buildings and the fire protection systems protecting them continue to age. Building owners are becoming increasingly aware of the risk posed by leaks developing on their sprinkler systems, and they are looking for answers as to why these leaks are developing and the available options for preventing their occurrence in the future. The primary cause of internal corrosion in fire sprinkler systems, both wet and dry, is the presence of oxygen within the piping network.[1,2] When oxygen dissolves in water that is in contact with sprinkler piping it is immediately available to react with the pipe metal. This process liberates metal and creates a deformation, or pit, in the pipe wall. As the process continues the pitting inevitably results in a breach of the pipe wall, releasing pressurized water onto the protected space.

The most common point of failure in fire sprinkler pipe is at the weld seam of Electric-Resistance Welded (ERW) pipe. Post mortem analysis of failed pipe samples from the field reveal that aggressive corrosion of the weld seam and surrounding area has resulted in significant removal of the weld metal. Because of its distinctive metal loss characteristics this type of corrosion is commonly referred to as "Knife Cut" corrosion.

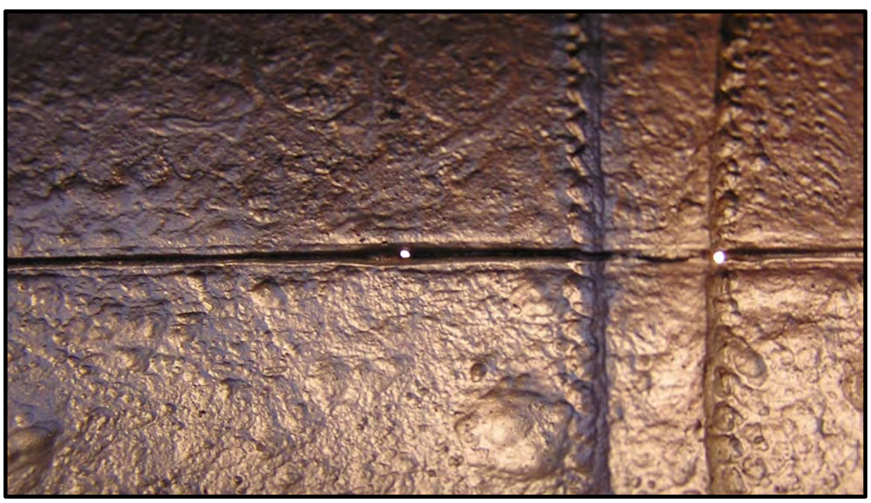

Figure 1. Classic "Knife Cut" removal of Weld Seam Resulting in Two Leaks

Anecdotal stories of "bad pipe" and non-domestic pipe that quickly develop leaks are pervasive within the fire sprinkler industry. It is not uncommon for owners, fire sprinkler contractors, and others to attribute the failures to "material defect" or to the poor manufacturing standards of foreign pipe manufacturers. This discussion aims to dispel these myths and provide a brief overview of the characteristics of ERW pipe that can lead to preferential corrosion of the weld seam and the rapid development of leaks.

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Electrical Resistance Welding Process

The manufacturing process of ERW steel pipe generally consists of the following:

- Steel sheet rolled into a tubular shape
- Electrical current induced along the edges of the rolled sheet of steel, heating the edges of the sheet to melting point
- Rollers apply pressure forcing the two molten edges together, forming the weld seam

The weld seam and the adjacent pipe metal that experience high temperature and pressure during the manufacturing process are commonly referred to as the Heat Affected Zone (HAZ). As a result of the high temperature and pressure exerted on the HAZ the microstructure of this metal changes and can differ significantly from the structure of the bulk piping. These structural differences in the steel result in the metal of the HAZ becoming anodic with respect to the rest of the pipe wall.[3] The anodic character causes the metal of the HAZ to more readily give up its electrons, or corrode preferentially, when the pipe is subject to corrosive conditions.

Acknowledging the corrosion potential inherent to the welding process, many industries require that pipe be heat treated or heat annealed following the welding process. Annealing brings the entire pipe length, including the weld seam and HAZ, up to a high temperature and allows it to cool uniformly. The result is a uniform granular structure throughout the steel reducing the potential for preferential corrosion of the metal in the HAZ. The current ASTM Standard* for the fire sprinkler industry does not require heat annealing of fire sprinkler tubing. The issue is further complicated given that within the fire sprinkler industry additional welds are used during custom fabrication of riser manifolds and branch lines where welded outlets are added as a means of connecting sections of pipe. These added welds create additional locations with potential for premature failure, as seen in *Figure 2* below.

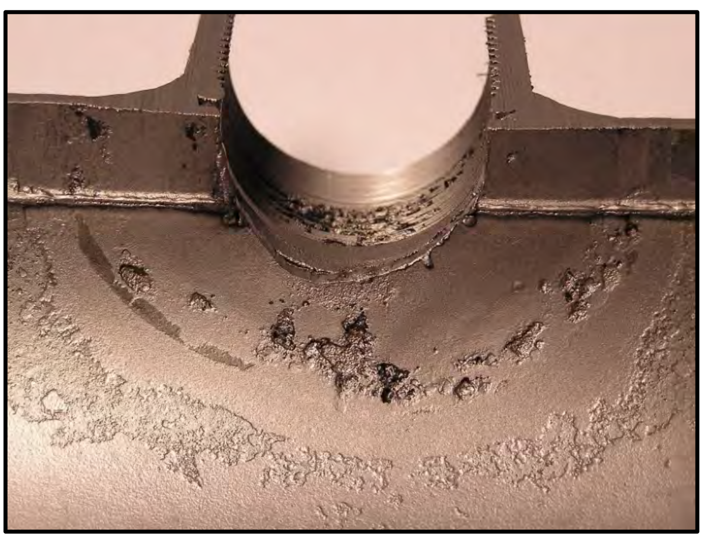

Figure 2. Preferential Corrosion of the HAZ at a Welded Outlet

Examples of Weld Seam Corrosion

Weld seam corrosion will occur in any location where non-heat treated pipe is exposed to a corrosive environment. Examples are plentiful in all type systems, including wet, dry, preaction, and deluge. Further, evidence of weld seam corrosion is found in every area of these systems including the bulk supply lines, the system risers, feed mains, and branch lines. In every case the preferential corrosion of the metal at the weld seam and HAZ resulted in the characteristic metal loss typical of weld seam corrosion.

Figure 3. **Knife-Cut Corrosion of 1" Black Steel Branch Line**

In the case of *Figure 3*, the weld metal was completely removed resulting in a pin-hole leak, with additional significant metal loss in the adjacent HAZ.

Figure 4. **Weld Seam Corrosion of 4" Galvanized Main**

As seen in *Figure 4,* weld seam corrosion is not isolated to black steel pipe. Once the zinc layer of galvanized pipe is removed, aggressive metal loss occurs at the weld seam.

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Preferential loss of the weld metal can occur from both internal and external corrosion. As seen in *Figure 5* and *Figure 6*, internal corrosion at the weld seam resulted in a leak which in turn caused significant corrosion to occur on the external surface of the pipe.

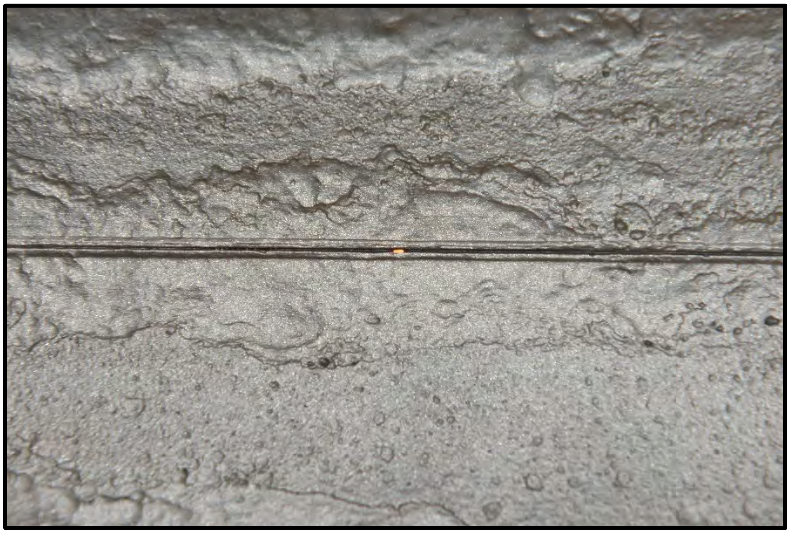

Figure 5. Internal Corrosion Resulting in the Removal of Metal from the Weld and the HAZ

The water released from the leak wetted the external surface of the pipe which led to additional metal loss on the exterior of the pipe wall, including knife cut corrosion at the weld seam.

Figure 6. External Corrosion Resulting from Leak, with additional Metal Loss at Weld

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Oxygen Corrosion in Water Based Fire Sprinkler Systems

Oxygen corrosion is the primary cause for corrosion related leaks in water based fire sprinkler systems. Preferential corrosion of the weld seam requires exposure of the subject metal to a corrosive environment. In the case of fire sprinkler piping, this occurs at any location where dissolved oxygen in the water is readily available to react with the pipe metal. This situation occurs at three primary locations in a fire sprinkler system.

1. At the high points in a wet system, where trapped air will accumulate
2. In low points of dry systems, where trapped water settles after system testing and draining
3. Any bulk piping that is subject to high volume fresh water flow. Dissolved oxygen in the source water will readily react with the pipe wall.

Under-Deposit Acceleration

Oxygen corrosion can be further accelerated when any adherent deposits are present, including accumulations of iron oxide by-product solids from the corrosion process itself and biofilms formed by bacteria in the system. Under-deposit corrosion occurs when the water beneath a deposit becomes oxygen deficient with respect to the bulk water in the pipe, resulting in the formation of an oxygen concentration cell. The metal beneath the deposit becomes anodic and will corrode preferentially. If the weld seam and HAZ are located beneath the deposits, the potential for corrosion is even greater.[4]

Figure 7. Severe Metal Loss in the HAZ resulting from Under-Deposit Corrosion (Vertical Riser Pipe)

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Managing Weld Seam Corrosion

In an attempt to mitigate the increased risk of developing leaks at the weld seam, it has been suggested that pipe should be rotated during installation to orient the weld seam at or near the top of the pipe.[5] This approach will reduce the likelihood of adherent deposits accumulating over the weld seam and thereby reduce the risk of under-deposit oxygen acceleration of corrosion. Further, this approach will help keep the weld seam out of pockets of trapped water in dry and preaction systems. However, there is the problem of practical application of this approach and the fact that this approach does not address the source of the corrosion. While corrosion rates may be lower with the weld seam removed from the corrosive environment, leaks will still develop given time.

Changing the standard to require heat annealed pipe in the fire sprinkler system may be beneficial in new construction projects, but this does not address the issues currently being experienced in existing systems. Additionally, even if the standards were changed and all pipe was heat annealed prior to leaving the manufacturing plant, the addition of welded outlets during custom fabrication would still result in locations in the system susceptible to preferential corrosion.

The only guaranteed approach to prevent corrosion related leaks is to remove the corrosive environment. In the case of water based fire sprinkler systems all oxygen must be removed from the fire sprinkler piping to completely halt leaks that are caused by oxygen. The only practical solution involves the use of nitrogen gas to displace the corrosive specie, oxygen, from the system. ECS has developed the equipment and processes necessary to accomplish the complete removal of oxygen gas from new and existing systems, resulting in an inert and corrosion free environment. Wet Pipe Nitrogen Inerting (WPNI) and Dry Pipe Nitrogen Inerting (DPNI) have been implemented in both new and existing systems throughout the country, resulting in the drastic reduction of corrosion rates within the fire sprinkler piping.

References:

[1]Kochelek, Jeffrey**.** “MIC is NOT the Primary Cause of Corrosion in Fire Sprinkler Systems*.” Sprinkler Age Magazine*. October 2009.

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

[3]Matsushima, I. "Carbon Steel - Corrosion in Fresh Waters." *Uhlig's Corrosion Handbook*. Second ed. John Wiley & Sons, 2000. 542-43.

[4]Howell, A. G. “Under-Deposit Corrosion at Weld Seams in Carbon Steel Piping.” CORROSION 97, Paper No.447, NACE International, Houston, TX, 1997.

[5]Su, P., Tatar, F. W., Chivukula, S., and W.W. Doerr, “Weld Seam Corrosion of Steel Sprinkler Pipe.” CORROSION 2013, Paper No.2140, NACE International, Houston, TX, 2013.

[*]ASTM Standard for heat annealed, stress relieved steel pipe is Grade B made in accordance with ASTM A795/A795M-13

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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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