

Case Study: Rehabilitation of a Preaction Fire Protection System affected by internal corrosion

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Executive Summary

The purpose of this case study is to examine the effect that the use of 98%+ pure Supervisory Nitrogen has had on internal corrosion of a Preaction Fire Protection System in a mission-critical facility. This facility was commissioned in 2005 with a compressed air supervised, Preaction sprinkler system comprised of schedule 40 galvanized steel. Within 2 ½ years after commissioning, pinhole leaks stemming from internal corrosion were developing throughout the system. Due to the extent of the corrosion and time in which it had developed, a root cause analysis was conducted to determine the possible cause/s and the best way of mitigating the corrosion damage. It was discovered that the piping wasn't adequately sloped and therefore residual moisture could not effectively drain from within the piping after hydrotesting, etc. As a result, localized pitting initiated and grew to through-wall pinholes due to the combined effect of the presence of water, a susceptible material and the availability of oxygen in the supervisory compressed air. Following this conclusion, more than \$1 million was spent to replace damaged sprinkler pipes, adjust branch lines to improve drainage, install and reposition auxiliary drains and deploy a high pressure nitrogen cylinder station. The intent was to inhibit corrosion by eliminating air (containing 20.9% Oxygen) from the sprinkler piping, thus preventing the corrosion reaction from initiating and propagating. Approximately 1 ½ years later, facility management learned that they could utilize a Nitrogen generation system to maintain Supervisory Pressure in place of the high pressure Nitrogen cylinders. A turn-key Nitrogen generation system was installed for roughly \$30,000, including labor and materials. Now, four years later (a combined total of 5 ½ years utilizing Supervisory Nitrogen including the use of high pressure Nitrogen cylinders), the facility has operated uninterrupted with no pinhole leaks or pipe replacement. The source of city water has remained the same since the facility was commissioned in 2005. Replacing Supervisory compressed air with 98%+ pure Supervisory Nitrogen has proven to be very effective in the Preaction Fire Protection System of this mission-critical facility.

Complete Report

A mission-critical data processing, video post-production, and broadcasting facility started to experience pinhole leaks in their Preaction Fire Protection System approximately two-and-a-half years after completion and commissioning of the facility (**Figure 1**).

The Preaction system was constructed of galvanized, schedule 40 steel pipe and supervised with compressed air.



Figure 1. Pinhole leaks on galvanized, Schedule 40 piping from 2 ½ year old Preaction system.

After occurrence of numerous pinhole leaks, the building owner hired a 3rd party industry expert to conduct internal video-borescoping which revealed areas of residual water with significant accumulation of white corrosion product deposits (originating from the zinc corrosion) interspersed with reddish-brown tubercles (originating from the corrosion of the underlying steel). A representative video-borescope image of the as-found internal condition of the pipe is shown in Figure 2.



Figure 2. Representative image of pipe interior approximately 2 ½ years after installation.

A subsequent investigation and failure analysis confirmed that the residual water was widespread throughout the system and that the corrosion and pinhole leaks were invariably associated with these areas of residual water. Pipe and water samples removed from various locations in the system showed significant wall thinning at localized pits, which coincided with the reddish-brown tubercles. Microbiological culturing to investigate the possibility that microbiologically influenced corrosion (MIC) was fully or partially responsible for the rapid penetration of the pipe wall was negative for bacteria that are associated with MIC. Water chemistry was found to be normal and not corrosive in any way. Metallurgical analysis of pipe samples indicated that the corrosion was the result of the combined effect of residual water and Oxygen-rich compressed air. The following series of photographs show the morphology localized pitting associated with such areas (Figure 3 through Figure 7).

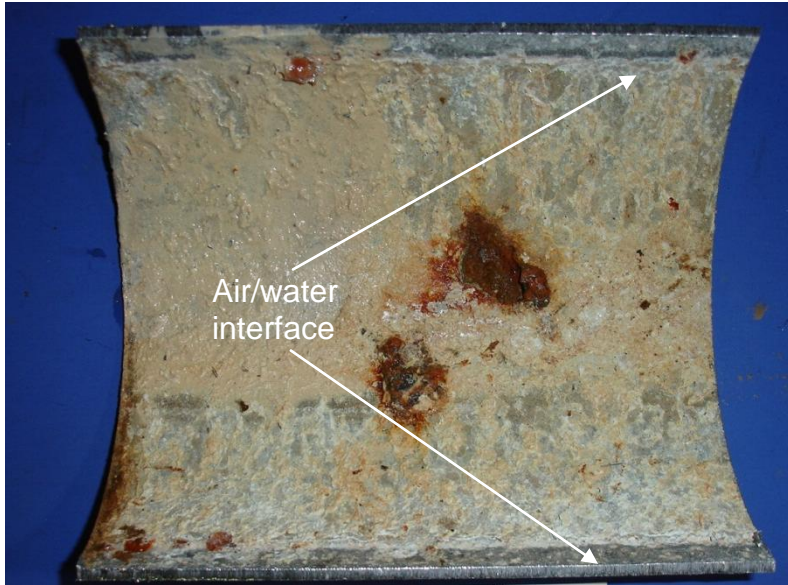


Figure 3. Overall view of as-found condition of bottom half of 6" main pipe sample after longitudinal sectioning (Note indicated air/water interface and localized tubercles).



Figure 4. Close-up view of localized tubercles under air/water interface on interior surface of pipe sample (Note reddish-brown color of tubercles indicative of ongoing corrosion of the underlying steel pipe wall).



Figure 5. Overall view of as-found condition of bottom half of 6" main sample after removal of corrosion product deposits.



Figure 6. Close-up view of interior pipe surface condition of bottom half of 6" main sample after removal of corrosion product deposits (Note shiny localized pits indicative of active, ongoing localized corrosion).

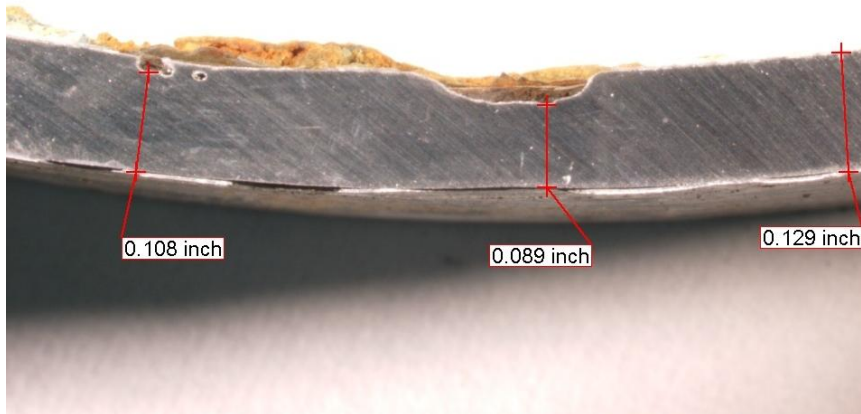


Figure 7. Cross-sectional view of corrosion pit in 6" pipe sample showing penetration of approximately 34% based on nominal wall thickness of 0.134" (Magnification: 5X).

Elevation surveys revealed that the Preaction system was installed with incorrect or a lack of adequate slope to facilitate complete drainage after initial hydrotesting and the required flow tests. In addition, inadequate provision was made for auxiliary drains to facilitate manual draining of trapped water at low points in the system.

Based on these results it was concluded that the observed corrosion was the result of the combined effect of residual water and the Oxygen in the supervisory air. The supervisory compressed air acts as a source of Oxygen to sustain localized corrosion in the areas where a two-phase system (residual water with a blanket of compressed air above it) exists. Localized pitting had occurred underneath the corrosion product deposits resulting in the formation of localized differential aeration cells, subsequent through-wall corrosion and loss of wall thickness of the surrounding base material.

Based on the overall condition of the piping and the unpredictability of pitting penetration rates, a decision was made to replace the 4" and 6" mains along with the cross mains throughout the seven Preaction systems. The General Contractor bore the majority of the costs to replace the affected sprinkler piping. Due to the requirement that the facility was to remain fully operational during the entire pipe replacement project and the presence of other installed equipment such as ducting, electrical service, cooling and heating piping, communications and video wiring, a complete re-sloping

of the system was impossible. A decision was made to install and/or reposition manual, auxiliary drains wherever deemed necessary and convert the system to a Nitrogen-supervised system to prevent the recurrence of Oxygen-driven, internal corrosion. At the time, the only viable source of high-purity Nitrogen was either liquid Nitrogen from an outside tank or high pressure cylinders. A custom designed manifold was installed with two banks of high pressure Nitrogen gas cylinders to facilitate an uninterrupted Nitrogen supply during a switch from one bank to another.



Figure 8. Nitrogen cylinder manifold for supervision of the Preaction system

This system performed satisfactorily for approximately 1 ½ years, but the effort and danger associated with the ongoing shuttling of Nitrogen cylinders made it less than optimal. In addition, the cylinders provided only a finite supply of Nitrogen gas and therefore required personnel and time to constantly monitor the supply of Nitrogen within the cylinders.

With the advent of Nitrogen Generation Systems designed to be integrated into Fire Protection Systems, it was advantageous to replace the bottled Nitrogen manifold with a single, pre-packaged Nitrogen Generation System, thus eliminating the risks associated with high pressure Nitrogen cylinders.



Figure 9. Nitrogen generator system for supervision of Preaction system

This turn-key system was installed approximately four years ago and has performed above expectations. The maintenance has been minimal, requiring only annual oil changes and compressor air filter replacements. Annual inspections to assess the condition of the newly installed piping have revealed no indications of recurrence of the localized corrosion. The source of city water being utilized for hydrotesting and the working conditions of the piping remain unchanged. Currently, the corrosion penetration rates are negligible and no pipe replacement has been warranted since the introduction of Supervisory Nitrogen approximately 5 ½ years ago.