

# Avoiding Corrosion in Dry Pipe and Preaction Sprinkler Systems

Sprinkler systems are unique mechanical systems because they remain dormant for long periods, yet their performance is essential since they provide protection of lives and property. Once a system operates it must deliver adequate water to control or suppress a fire. Requirements for the design and installation of sprinkler systems are found in NFPA 13 (2002): *Standard for the Installation of Sprinkler Systems*.

Both dry pipe and preaction sprinkler systems are commonly used for protection of areas where system components are subject to freezing. Dry pipe and preaction sprinkler systems utilize air or pressurized nitrogen under normal circumstances and allow water into the piping upon actuation of a sprinkler or fire detection device. A dry pipe sprinkler system contains pressurized air within the piping (usually between 30 and 50 pounds per square inch) and uses a specially designed check valve to hold back water. Upon fusing (heat actuating) of a sprinkler, air is released from the system, allowing water to flow into the piping to the open sprinklers.

A preaction sprinkler system utilizes fire (smoke, heat, or optical) detectors and a releasing panel (or control from the fire alarm control panel) to actuate a deluge valve, which fills the piping with water. Preaction sprinkler systems are filled with air or nitrogen at a low supervisory pressure (7 to 40 psi). Preaction sprinkler systems often are installed as an alternative to wet pipe sprinkler systems in buildings or areas where protection against water damage is paramount. Common applications include museums, libraries, telecommunications facilities, computer rooms, and other high-value or mission-critical facilities.

Corrosion and its products can limit or prevent adequate water flow to open sprinklers in dry pipe and preaction sprinkler systems, causing system failures. To prevent this, these systems must be properly designed and installed in accordance with NFPA 13 and maintained in accordance with NFPA 25 (2002): *Standard for*

*the Inspection, Testing and Maintenance of Water-based Fire Protection Systems*.

This article discusses how design, installation, and maintenance decisions can influence corrosion in dry pipe and preaction sprinkler systems.

## WHAT FORMS OF CORROSION COMMONLY AFFECT SPRINKLER SYSTEMS?

Corrosion is the destructive attack of a material, usually a metal, by chemical or electrochemical reaction with its environment.<sup>1</sup> Eight forms of corrosion, which are generally accepted and used, are identified in *Corrosion Engineering*. The eight main forms are uniform corrosion, pitting, galvanic corrosion, crevice corrosion, selective leaching (parting), erosion corrosion, environmental cracking, and intergranular corrosion.<sup>2</sup> Microbiologically influenced corrosion (MIC) may be included herein as a ninth form of corrosion, although it is usually a secondary factor that accelerates or exacerbates the rate of another form of corrosion.

The most common forms of corrosion found in dry pipe and preaction sprinkler systems are crevice corrosion, uniform corrosion, and pitting. Crevice corro-

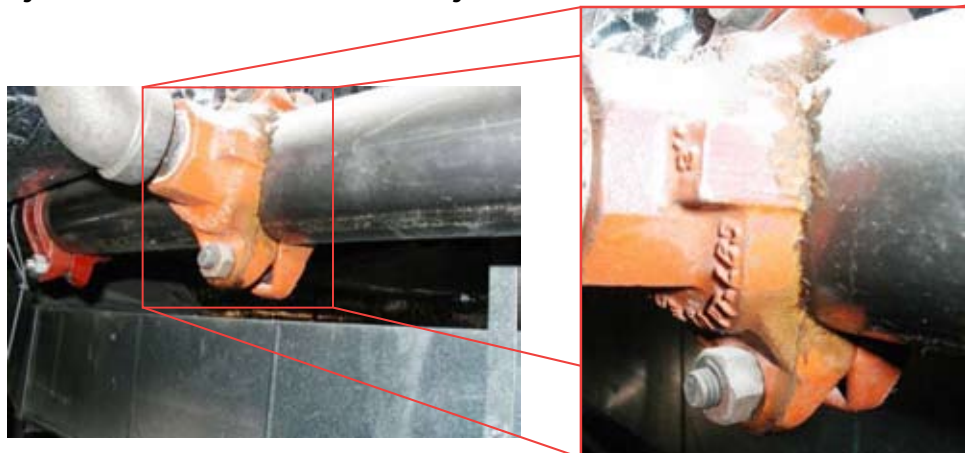
sion is a localized form of corrosion that occurs in crevices (beneath gaskets, in holes, beneath surface deposits, in thread and groove joints) exposed to a stagnant corrosive environment.<sup>2,5</sup> Uniform corrosion is a general thinning involving the regular loss of a small quantity of metal evenly distributed over a large surface area of pipe.<sup>2,3,5</sup> Pitting is a localized form of corrosion that results in covered or open holes or cavities in the metal.<sup>2,3,5</sup> Depending on the circumstances, other forms also may be found.

Galvanic corrosion typically occurs where incompatible materials are joined without separation by a non-conducting material, such as a dielectric union. Selective leaching (dezincification) can occur on brass sprinklers and valves. Weld decay (intergranular corrosion) can

Figure 1 Leak observed on exterior surface of a groove joint



Figure 2 Corrosion beneath mechanical tee housing



occur at pipes near welded pipe joints that have been cyclically heated forming a sensitized structure (precipitation of one material, carbon, at the grain boundaries).<sup>2,5</sup> This form of corrosion is observed as a thinning of the metal at the grain boundaries near the weld.<sup>2,5</sup>

MIC is rarely the only form of corrosion present in a sprinkler system. It normally exacerbates another form of corrosion, such as oxygen corrosion, crevice corrosion, or under-deposit corrosion.<sup>3</sup>

Erosion corrosion and environmental cracking typically are found in continuously operating mechanical systems. Since sprinkler systems are basically static under normal circumstances, these forms of corrosion would not be expected.

**HOW IS CORROSION DETECTED?**

Corrosion is detected in a number of ways. In some instances, trapped water freezes in the sprinkler system piping, and a leak or pipe rupture is observed. Corrosion often is discovered while the system is being repaired. Corrosion also may be observed through a typical pattern of external staining and visible external corrosion as shown in Figures 1 and 2.

Figure 3 shows a pinhole perforation through a three-year-old Schedule 10 galvanized pipe. The hole was actually about 1/4-inch diameter and was causing the air compressor to cycle on and off every two minutes.

Corrosion also can be detected as part of an inspection, testing, and maintenance program. Abnormal test results, such as brown water, solids in the water stream, or extremely long trip times, could indicate a corrosion problem. Visual inspections of the system piping as part of a NFPA

**Figure 3 Pinhole perforation through 3-inch-diameter galvanized pipe**



**Figure 4 Interior condition of preaction valve**



**Figure 5 Interior condition of dry pipe valve**



25 obstruction investigation also might reveal corrosion in a sprinkler system.

**WHY IS CORROSION A PROBLEM IN THESE SYSTEMS?**

Corrosion can prevent valves from opening. Figures 4 and 5 show the internal conditions of a preaction valve and a dry pipe valve after being installed for three years. The dry pipe valve shown in Figure 5 reportedly had been tested and cleaned three months before this photograph was taken. Similar conditions have led to the failure of dry pipe sprinkler systems under fire conditions.

Corrosion damage increases the interior surface roughness of pipes beyond the anticipated conditions reflected in the design of sprinkler systems. NFPA 13 Table 8-4.4.5 requires a Hazen-Williams roughness factor (C factor) of 100 to be used in the hydraulic calculation of dry pipe and double interlock preaction sprinkler systems using black steel pipe. A C factor of 120 is used for systems with galvanized pipe. Figure 6 shows the internal condition of a section of galvanized steel pipe in a preaction sprinkler system. The system had been in service for approximately three years when the photograph was taken.

Figure 7 shows the internal condition of a section of black steel pipe removed from a dry pipe sprinkler system. It illustrates how corrosion products can build up inside sprinkler system pipe. This system was in service for approximately 20 years at the time the photograph was taken.

Due to the formation of nodules and deposits in the pipes, as shown in Figures 6 and 7, the surface roughness exceeds the expectations

**Figure 6 Corrosion inside a galvanized steel sprinkler pipe**



**Figure 7 Corrosion inside a black steel sprinkler pipe**



assumed with C values of 100 and 120. Additionally, the corrosion deposition shown in Figure 7 has caused significant occlusion of the interior cross-sectional area. This has effectively reduced the hydraulic diameter of the pipe. Therefore, the pipes would restrict water flow and pressure provided to the sprinklers.

Figure 8 shows corrosion products lodged at the end of a dry pipe sprinkler system main. This system was approximately 10 years old at the time this photograph was taken. It is likely that loose corrosion products were continually pushed through the system each time the dry pipe valve was tested or inadvertently tripped.

The corrosion products shown in Figure 9 were removed from a different location



## FOCUS ON FIRE PROTECTION

Figure 8 Corrosion products lodged in a main



NFPA 13 Section 8.15.2.3 requires dry pipe and preaction sprinkler system mains in areas subject to freezing to have a back pitch of  $\frac{1}{4}$  inch for every 10 feet of pipe and branch lines to have a back pitch of  $\frac{1}{2}$  inch for every 10 feet of pipe. However, NFPA 13 Section 8.15.2.3.3 permits preaction sprinkler system mains and branch lines to be installed without pitch in heated areas. This is favorable when trying to fit the sprinkler system piping above a suspended ceiling with other electrical and mechanical systems. Auxiliary drains are required to drain water from system low points but often are omitted due to fear of water leaking and/or unlikely draining of the system in

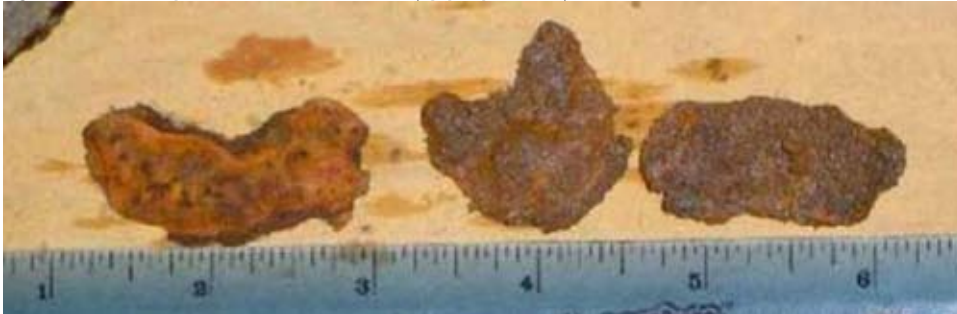
sive, and the production rate of fitters is increased. However, the arrangement can prevent complete drainage, which can provide an environment for corrosion. Although the arrangement is code compliant, it can yield water leaks in a system intended to be dry and installed to prevent water damage.

The crevices found between the pipe ends at groove couplings and roll groove indentations inside the pipe form small dams that trap water. Figure 10 illustrates how the roll groove indentations prevent drainage and cause water to pool in the pipes. Leaks can manifest within one to three years after installation in systems using Schedule 10 black steel or galvanized steel piping. The additional wall thickness provided by Schedule 40 piping will extend the useful life of sprinkler systems but will not eliminate the problem if the roll groove joining method is used.

The trapped water initiates oxygen-cell (crevice) corrosion due to the abundance of oxygen in the system. Electric transfer of oxygen as a result of dissolved oxygen in the trapped water. The areas with high oxygen content become cathodic and receive electrons from the metal during the process of corrosion. The oxygen and electrons react at the cathode either as part of water reduction or oxygen reduction reactions.

Oxidation of the metal (iron) at the anode produces metal ions with positive charge that are expelled into the water. The electrolyte (ionized water) transfers electrical current to balance the flow of electrons. Anions (negatively charged ions) move toward the anode, and cations (positively charged ions) move toward the cathode. The metal (ferric and ferrous iron) ions react with other negatively charged ions in the electrolyte, thus forming corrosion products.

Figure 9 Corrosion products removed from a dry pipe sprinkler system



in the same dry pipe sprinkler system. It is easy to see how metal deposits and dislodged nodules like these would block (clog) small-diameter branch lines and sprinklers. Therefore, poor water delivery would be expected.

### WHAT CAUSES CORROSION IN DRY PIPE AND PREACTION SPRINKLER SYSTEMS?

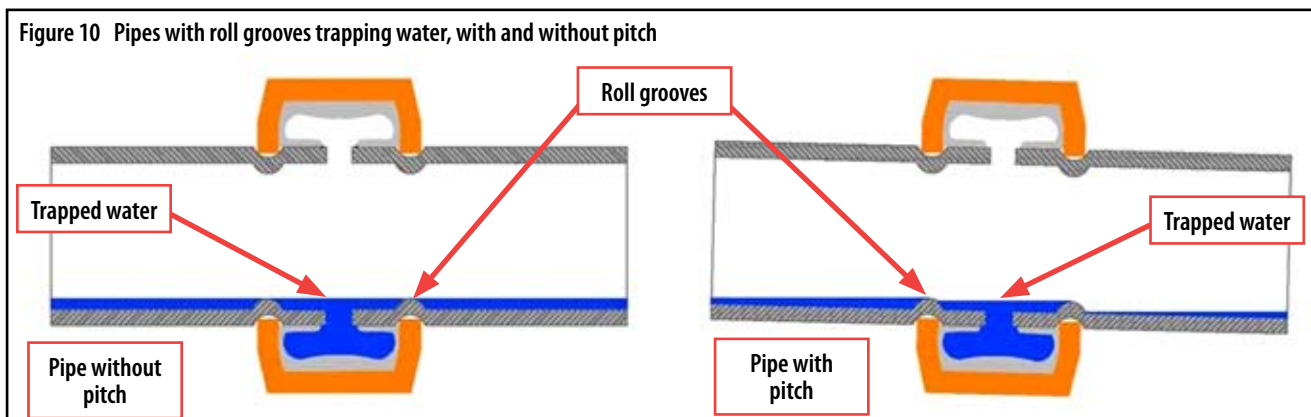
The root cause of corrosion in dry pipe and preaction sprinkler systems is trapped water. The internal environment is ideal for corrosion since the pipes are normally filled with pressurized air.

sensitive areas or for aesthetic reasons. Sometimes they simply are forgotten during design, installation, or maintenance.

Improper drainage and pitch often serve as a means for trapping water in dry pipe and preaction sprinkler systems. However, these deficiencies are not the only reasons trapped water and corrosion occur in dry pipe and preaction sprinkler systems.

Schedule 10 pipe with roll groove joints often is used to save money on the initial installation of the sprinkler system during construction. The pipe is less expen-

Figure 10 Pipes with roll grooves trapping water, with and without pitch



Corrosion occurs in all areas where trapped water is observed. As the corrosion process progresses, acidic salts resulting from corrosion reactions often accelerate the rate of corrosion in crevices.<sup>2,3,5</sup>

### HOW DOES CORROSION AFFECT THE RELIABILITY OF SPRINKLER SYSTEMS?

The reliability of sprinkler systems can be measured in terms of both operation and performance.<sup>4</sup> Operational reliability is a measure of the probability that the system or component will operate as intended when needed. Operational reliability elements usually are associated with inspection, testing, and maintenance. Performance reliability is a measure of the adequacy of the system after it has operated. Performance reliability elements are associated with design, installation, and maintenance.

The reliability of sprinkler systems includes four primary factors: design, equipment, installation, and maintenance. When any of these factors are deficient, the system inevitably will prove unreliable, and a failure will be observed. The failure could be observed as lack of response to fire conditions, operation without a fire, or inability of the sprinkler system to control or suppress a fire. Failures can be grouped into two categories: failed-safe and failed-dangerous.<sup>4</sup> Failures when no fire event has occurred are considered to be failed-safe, and failures that involve components or systems when needed are considered to be failed-dangerous. Corrosion can cause failures of sprinkler systems in both categories as previously explained.

### WHAT CAN BE DONE TO PREVENT OR MINIMIZE CORROSION?

Consideration should be given to minimizing or preventing corrosion in dry pipe and preaction sprinkler systems during design and installation. Suggested methods to help meet this objective follow:

1. Specify Schedule 40 black steel or galvanized pipe with cut groove or threaded joints for dry pipe and preaction sprinkler systems. Do not specify the use of rolled groove joints since the roll grooves trap water, causing localized corrosion at groove joints and the bottom of pipes.
2. Specify descant air dryers to reduce the amount of moisture introduced to dry pipe and preaction sprinkler system piping. This measure is only of value if all trapped water can be removed from the piping system. Evaporation of the residual water in the piping is a greater source of humidity than the amount added in the system air. As an alternative, nitrogen may be used to limit the amount of oxygen and available humidity. However, limitations such as availability, significant cost, or difficulties with transportation or delivery should be considered prior to installing the nitrogen system.
3. Specify *all* new pipe in dry pipe and preaction sprinkler systems to be back-pitched (sloped), regardless of the potential



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for freezing. Although NFPA 13 (2002) permits the pipe in heated areas to be installed without back pitch similar to wet pipe sprinkler systems, this arrangement has proven to lead to premature corrosion failure.

4. Design systems with auxiliary drains at all low points in dry pipe and preaction systems. Encourage building owners and maintenance staff to follow the NFPA 25 requirements for periodic draining of the auxiliary drains, which will reduce the moisture and related corrosion in the pipes.
5. Use dry pendent sprinklers in heated areas when supplied from dry pipe or preaction sprinkler systems. **PSD**

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