Dry Compressed Air as a Supervisory Gas in Dry Pipe Fire Suppression Systems

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Summary

Dry pipe fire suppression systems are, frequently, not entirely dry. Water may become trapped in the system during hydrostatic testing, or after a triggering event. Moisture may enter and accumulate in the system through the use of ordinary compressed air as the supervisory gas. Trapped and accumulated water in an ordinary compressed air system promotes corrosion in the wet areas. Interior corrosion may be general and/or localized (e.g. pitting) from the inside out. General corrosion with associated voluminous corrosion can lead to blockages. Pitting often leads to pinholes through the tube wall. Dry compressed air can suppress both general and localized corrosion in dry pipe systems, first by preventing the accumulation of moisture over time, and second by aiding in evaporation of bodies of standing trapped water.

Corrosion and Dry Pipe Systems

Dry pipe fire suppression systems ideally operate with a fully dry interior until a fire triggers the system to respond. Actual systems in service, however, often contain some trapped moisture.[1] Conditions may range from condensed moisture on interior surfaces to "ponds" of water trapped at unintended low points without proper drainage. Moisture can enter a system through several routes, for example water can become trapped after hydrostatic testing or may accumulate more slowly through the use of untreated compressed air. In the latter case the rate of moisture accumulation will depend in part on atmospheric humidity levels.

Trapped moisture inside the pipes of a fire suppression system can promote corrosion and result in premature failure.[2,3] Interior corrosion may be general and/or localized (e.g. pitting) from the inside out. General corrosion with associated voluminous corrosion can lead to blockages. Pitting often leads to pinholes through the tube wall. Corrosion is an electrochemical process that requires a specific set of conditions.[1,4] If a necessary condition is disrupted the process cannot proceed. The necessary conditions for an electrochemical reaction that results in pitting corrosion, for example, are illustrated in the schematic of Figure 1. These include:

- an anode (an area that will oxidize or corrode),
- a cathode (an area that will support a reduction reaction to consume electrons released by the oxidation reaction),
- a path for electrons to travel from the anode to the cathode (typically the body of the metal pipe itself),
- and a medium that allows ionic conduction between the anode and cathode (accumulated water with a corrosion-promoting agent, dissolved oxygen in this example).

The combination of the above conditions allows corrosion-related electrochemical reactions to go forward. If any one of these necessary conditions can be eliminated corro-

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[1] P. Su and D. B. Fuller, "Corrosion and Corrosion Mitigation in Fire Protection Systems," FM Global technical report, 2nd Edition, July 2014, p34

[2] O.J. Van Der Schijff, "MIC in Fire Sprinkler Systems Field Observations and Data", CORROSION/2008, paper no. 08508, (Houston, TX: NACE International, 2008).

[3] P. Su, et al, "Corrosion of Sprinkler Piping Under Compressed Nitrogen and Air Supervision", CORROSION/2015, paper no. 5548, (Houston, TX: NACE International, 2015).

[4] Jones, D.A., "Principles and Prevention of Corrosion", Macmillan Publishing Company, New York, NY, 1992

sion can be halted. Aqueous corrosion reactions other than those shown in Figure 1 require the same set of general conditions to proceed.

The use of untreated compressed air as the supervisory gas introduces moisture into the pipe interiors. The amount of moisture that may be carried into a system by normal compressed air will depend on the flow rate and on atmospheric humidity, which is dependent on external environmental factors. Many instances of premature failure due to corrosion associated with trapped moisture have been reported (references). An example of a carbon steel pipe removed from a dry pipe system after experiencing pinhole leaks is shown in Figure 2. In this case standing water in the bottom of the tube led to accelerated general corrosion of the interior surface as well as pitting attack from the inside out.

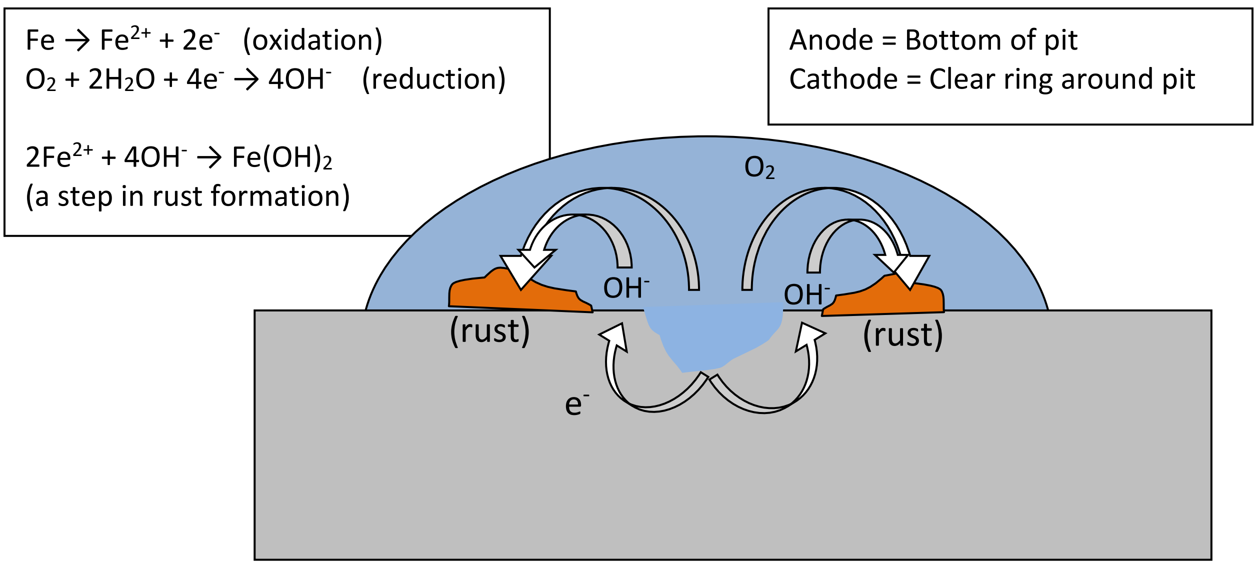

Figure 1. This schematic representation of pitting in steel shows the conditions needed for aqueous corrosion to proceed (here assuming aerated water of neutral or alkaline pH). The $Fe(OH)_2$ reaction is one of several common oxidation reactions that occur in the formation of rust, a complex mixture of iron-based oxides and hydroxides.

Water is critical for the progress of corrosion reactions in the dry pipe interior environment. If standing water and/or condensate layers on pipe walls can be minimized or eliminated corrosion reactions will likewise be slowed or halted. Without corrosion, failure events such as the one depicted in Figure 2 can be avoided and the expected service life of such systems may be greatly extended.

Figure 2. A carbon steel pipe removed from a dry pipe system after having developed pinholes is shown. Top Row: Upstream (left) and downstream (right) views show evidence of standing water in the bottom of the tube – corrosion products and wall thinning are obvious. Middle Row: Exterior (left) and interior (right) views of an example pinhole from the bottom of the tube are shown. Bottom Row: Upstream (left) and downstream (right) cross section surfaces of the sample containing the pinhole were subjected to fine grinding to better show the loss of wall thickness and the pitting at the bottom of the tube. – from AME 2009 archival report.

Methods exist to dry the air provided by an air compressor, reducing trapped moisture and thereby slowing or preventing corrosion. The benefits of introducing dry air into the system are twofold. First, less moisture is carried in with a dry supervisory gas. Second, dry air has the capability to absorb moisture through evaporation, reducing that amount of trapped moisture that may be present. Since supervisory gas flows through a system (via inherent pipe leakage or through a purge/vent device) rather than remaining stagnant, the dry air is constantly replenished. Consequently, trapped moisture can continually be absorbed, ideally until it is entirely removed.

The rate of flow for supervisory gases and the rate of moisture evaporation by dry compressed air are both affected by multiple and sometimes joint factors, and so will differ from system to system under a range of normal service conditions. The National Fire Protection Association (NFPA) provides standards and codes that identify acceptable flow rates for supervisory gases. Specifically, NFPA 13[5] allows a new system to have a leak rate of 1.5 psi in 24 hours (maximum), and NFPA 25[6] allows an existing system to have a leak rate of 3 psi in 2 hours (maximum) which works out to 36 psi in 24 hours. In practice, leaks within working systems can sometimes elevate flow rates to even higher levels while still allowing the overall system to function. Assuming a range of possible flow rates, certain generalizations regarding the behavior of a system using dry compressed air as the supervisory gas can be made.

The evaporation rate of water, whether present as moisture condensed on a surface or as standing ponds within a dry pipe system, is related to the pressure dew point of the supervisory gas. Generally, the dew point is the temperature at which moisture present in the vapor phase can condense onto a surface, forming "dew," and is a function of the actual amount of moisture vapor present at atmospheric pressure. The lower the dew point, the less vapor-phase moisture is present (the air is drier). The pressure dew point (PDP) of a supervisory gas is a function of both the degree of moisture saturation and the pressure. For untreated compressed air the PDP is higher than the atmospheric dew point because the air is under greater than atmospheric pressure. As a result, the use of untreated compressed air can lead to condensation inside a pipe even if non-condensing conditions exist outside. The use of dry compressed air with extremely low PDP avoids this condition. This concept is understood and exploited outside the fire protection industry as well. Clean dry compressed air is used in a variety of industries (i.e. food and beverage, pharmaceutical, semi-conductor and electronics, chemical) for a number of reasons including but not limited to reduced contamination, reduced moisture intrusion, and reduced corrosion of delivery systems and, in some cases, items to be protected in storage.

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[5] "NFPA 13: Standard for the Installation of Sprinkler Systems," National Fire Protection Association, Quincy, MA, current edition 2019

[6] "NFPA 25: Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems," National Fire Protection Association, Quincy, MA, current edition 2017

When the PDP of the supervisory gas is low little or no vapor-phase moisture is carried into the system, and evaporation of trapped moisture is favored. If we assume for a moment that the supervisory gas is stagnant (no flow) and all other relevant conditions remain constant, eventually an equilibrium would be achieved in which the rate of moisture condensation out of the gas would equal the rate of evaporation into the gas and no additional drying of the pipe would occur. However, when very dry low PDP air flows continuously through the system equilibrium cannot occur and evaporation continues. If moisture is present primarily as condensation on the pipe walls evaporation should proceed relatively quickly.

In cases involving a pond of trapped standing water the situation is more complex. The evaporation rate will depend in part on the surface area of the pond, which will change as evaporation proceeds. Larger surface areas support more rapid evaporation, smaller surface areas slower evaporation, regardless of the total volume of trapped water. The time to complete dryness will depend in part on the evaporation rate and in part on the total volume. Complete elimination of a trapped water pond using dry compressed air as a supervisory gas is possible but may take considerable time. It is also important to note that, like ordinary compressed air, dry compressed air will supply oxygen to the pond. Dissolved oxygen can participate in corrosion reactions such as those shown in the example provided in Figure 1 as long as moisture is present.

An example of a galvanized tube removed from a dry pipe system after approximately four years of service is shown in Figure 3. This tube, and nine others, comprised a set of samples from different galvanizing batches installed in one system and exposed to dried compressed air as the supervisory gas in service. All were found to have some loss of the galvanized (zinc) layer due to corrosion, but no corrosion of the substrate steel was found.

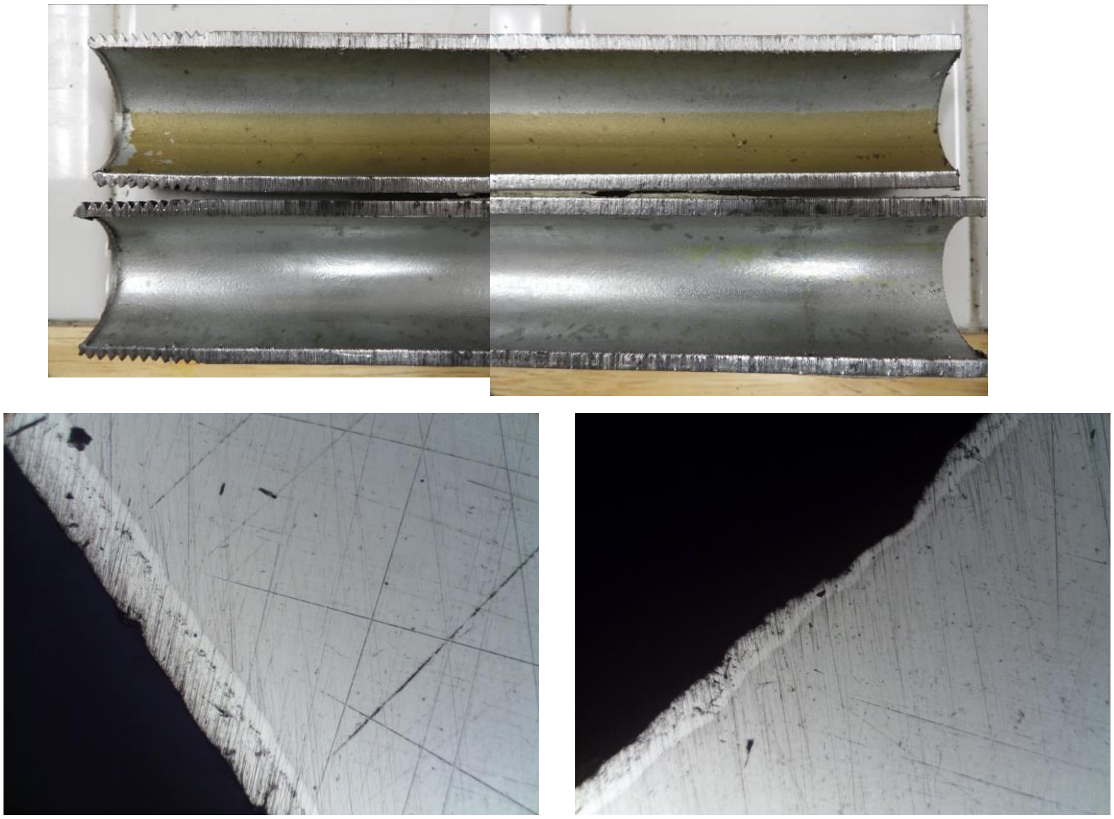

Figure 3. A galvanized pipe removed from service after exposure to dry compressed air is shown. The interior surface was generally smooth and fairly shiny with some surface foreign material and spotting. Slight haziness of the zinc surface suggested mild general corrosion of the galvanized layer. Example cross section images show nearly full thickness of the zinc and intermetallic layers around part of the inner diameter (left). In some localized spots the zinc layer was partially consumed (right), but intermetallic layers remained and no substrate corrosion was noted. Original magnification 100x. – from AME 2018 archival report.

Conclusions

It is not uncommon for dry pipe fire suppression systems to have some form of interior moisture, whether trapped during testing or accumulated over time. This wetness is a crucial component for the corrosion cycle, both general and localized. General corrosion with associated voluminous corrosion can lead to blockages. Pitting often leads to pinholes through the tube wall.

The above discussion described how dry compressed air can suppress both general and localized corrosion in dry pipe systems. Interior corrosion is controlled first by preventing the accumulation of moisture over time, and second by aiding in evaporation of bodies of standing trapped water.