Corrosion Inhibition of Dry and Pre-Action Fire Suppression Systems Using Nitrogen Gas

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Abstract

Internal corrosion of dry and pre-action fire suppression systems is a growing concern for the fire sprinkler industry. Corrosion in these systems causes failures resulting in property damage, production downtime, and increased maintenance costs. Additionally, corrosion impacts system hydraulics and reduces the efficiency of fire sprinkler system designs. Historically, dry and pre-action fire suppression systems have used compressed air as the supervisory gas to pressurize their piping. Compressed air, however, contains both oxygen and moisture causing the system piping to corrode. Nitrogen, acting as a supervisory gas in piping, is a well documented inhibitor of corrosion and has been implemented in industries such as gas and oil, pharmaceutical and the marine transit industry. This study analyzes the corrosion-inhibiting effects of 98% nitrogen gas when applied to both carbon steel and galvanized steel, in an environment simulating a dry pipe fire sprinkler system. The weight loss methodology is utilized to examine the effects.

Introduction

Dry and pre-action systems are the world's second most common type of fire suppression system. With increasingly widespread use of these systems, the issue of corrosion was pushed to the forefront. Initially, galvanized pipe was given a preferential Hazen-Williams C factor, of 120, for use in dry or pre-action systems. This was done with the expectation that galvanized pipe would experience less corrosion. A C factor is a value used to indicate the smoothness of the interior of a pipe. The higher the C factor, the smoother the pipe, thus maximizing the carrying capacity and diminishing the friction, or energy lost, from water flowing through the pipe.

When pipe is galvanized, its walls are coated with zinc to reduce the detrimental effects of corrosion on steel. Because it is more reactive than steel, zinc acts as a sacrificial material by first reacting with corrosion-forming components, thus creating a protective layer of scale build-up and protecting the steel. Wide-scale adoption of galvanized piping in dry and pre-action systems, along with multiple decades of use, has resulted in unfavorable performance. In fact, case studies have shown that due to oxygen cell corrosion, pinhole leaks begin developing within two years after installation of a galvanized dry system, while ruptures have occurred within four years (Chakprani & Garber 2004). A survey evaluating the internal conditions of dry sprinkler systems for two decades was performed by the notified body, VdS. It indicates that more than 70% of the current dry pipe systems have to be treated for corrosion within 12½ years, of which some 20% of the systems will have to be almost fully replaced (EFSN 2009). In NFPA 13 – 2013, this C factor was reduced to 100, as the performance of galvanized pipe was recognized to be no better than that of black steel pipe.

The need for corrosion protection in dry and pre-action sprinkler systems is evident, and new techniques have been developed to extend the useful life of fire suppression systems. One such corrosion prevention technique is replacing the supervisory air with nitrogen gas. Nitrogen gas is an inert diatomic molecule that is used in a wide variety of applications because of its availability and unique properties. One key attribute is its general inability to react with metals. To comprehend why nitrogen, unlike oxygen, does not cause corrosion to propagate, it is important to understand the corrosion mechanism. Generalized corrosion reaction is caused by production of electrons at the anode $Metal = Metal^+ + e$. The electrons that are produced are then consumed in the cathodic reaction by dissolved oxygen $O_2 + 2H_2O + 4e^- = 4OH^-$. This process causes uniform corrosion, but can be inhibited by limiting one of the reactants, such as oxygen. The specific issue with dry and pre-action systems, when compared to typical wet systems, is the abundance of oxygen supplied by the air compressor. This study was specifically designed to see the relative difference between using nitrogen gas over air and its effect on corrosion rates.

Experimental Procedure

Corrosion testing of black steel coupons and galvanized coupons under simulated dry and pre-action conditions was conducted. This testing evaluated corrosion inhibiting benefits of 98% purity nitrogen gas compared to compressed air in systems half filled with water and systems which contained no significant quantity of water. The systems half filled with water were used to create a trapped water condition often found in dry and pre-action fire suppression systems due to inadequate draining, which results from system design layout limitations.

Table 1: Conditions.

	Amount of Water	Type of Gas
Condition 1	Trace	98% N2
Condition 2	Trace	Compressed Air
Condition 3	Half Filled with Water	98% N2
Condition 4	Half Filled with Water	Compressed Air

Four test manifolds were created to house triplicates of both black steel and galvanized coupons. Test manifolds were removed and evaluated after being installed for 12 months.

Figure 1: Corrosion Coupon Testing Manifold.

Three black steel coupons (C1010, Metal Samples, Munford, AL) and three galvanized coupons (Galvanized C1010, Metal Samples, Munford, AL) were electrically isolated and placed into the test manifold. The test manifold was then filled with water to simulate a hydrostatic test and then promptly drained. All water used in this test was tap water from St. Louis Public Water supply. The pH was 7.4 and the water hardness was 120 mg/L. Test manifolds designated to be half filled with water were then refilled with 1000ml of tap water. Each test manifold was subsequently pressurized to 40 psi with either 98% nitrogen gas (Air Products, St. Louis, MO) or compressed air obtained from a standard air compressor. The system was watched for 24 hours to ensure no pressure loss had occurred. The test manifolds were kept in a conditioned warehouse in St. Louis, Missouri. After 12 months, the coupons in the test manifolds were removed and photographed.

Figure 2: Photograph of uncleaned corrosion coupons at 12 months.

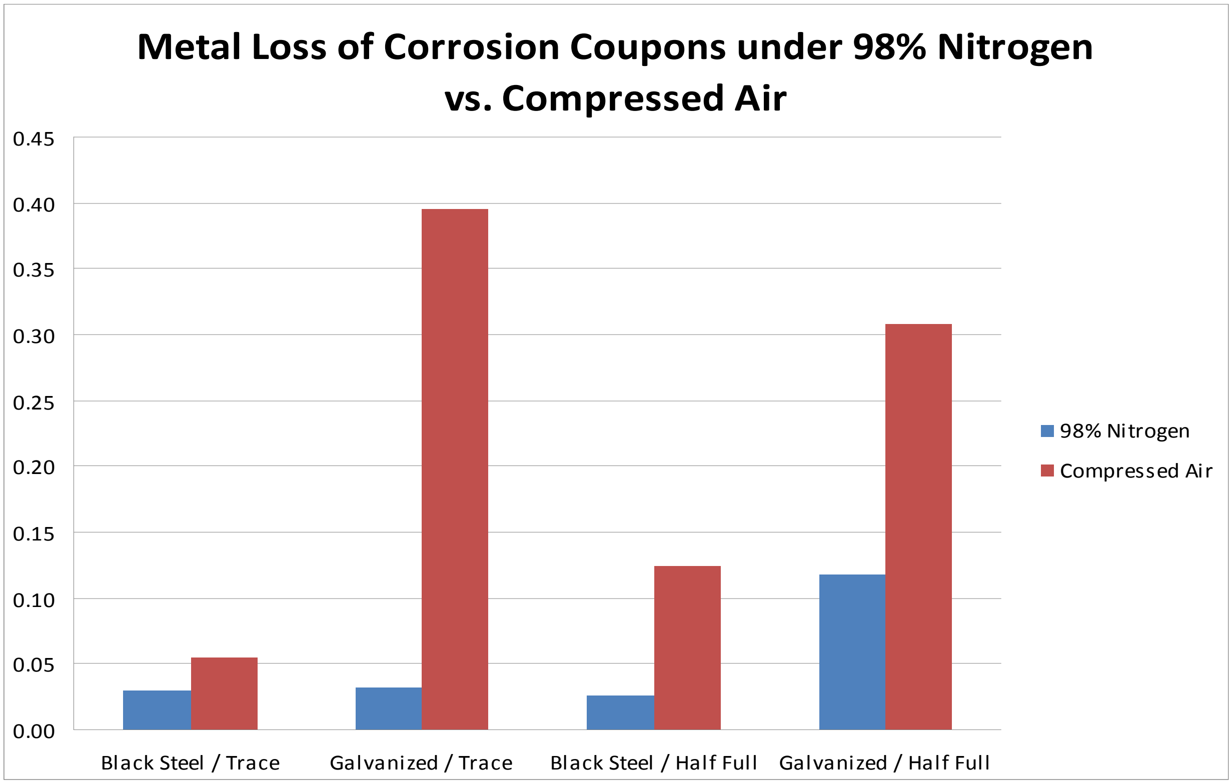
Steel Coupon Compressed Air	Steel Coupon 98% Nitrogen	Galvanized Coupon Compressed Air	Galvanized Coupon 98% Nitrogen

The coupons were then cleaned, weighed and photographed again. This was performed by a third party, ESI Laboratories. See Appendix for photos of the full set of cleaned coupons. Once all of the weight loss data had been compiled, the metal loss for each coupon was calculated. Metal loss is the uniform deterioration of metal over the exposed surface. The data from the respective sets of coupons was evaluated and averaged to give an average metal loss over 12 month time period.

Results and Discussion

The purpose of this test was to compare the relative differences between using 98% nitrogen and compressed air in a variety of different applications. Figure 3 compares the average metal loss of the coupons for 98% nitrogen with the average metal loss of the coupons for compressed air over the 12 month study. The data shows metal loss in the differing environmental conditions and piping materials to compare the effectiveness of 98% nitrogen to compressed air.

Figure 3: Average metal loss (mils) of corrosion coupons for 98% Nitrogen vs. Compressed Air.



In every environmental condition, 98% nitrogen resulted in a lower metal loss when compared directly to compressed air. This was also visibly apparent when the corrosion coupons were removed from the testing manifold. The most noticeable differences were observed when comparing 98% nitrogen to compressed air for the galvanized coupons. The corrosion coupons exposed to 98% nitrogen had more uniform corrosion deposits than those exposed to compressed air. This was evident for pipes half filled with water as well as drained pipe setups.

Table 2 highlights the inhibition effectiveness of using 98% nitrogen when compared to compressed air.

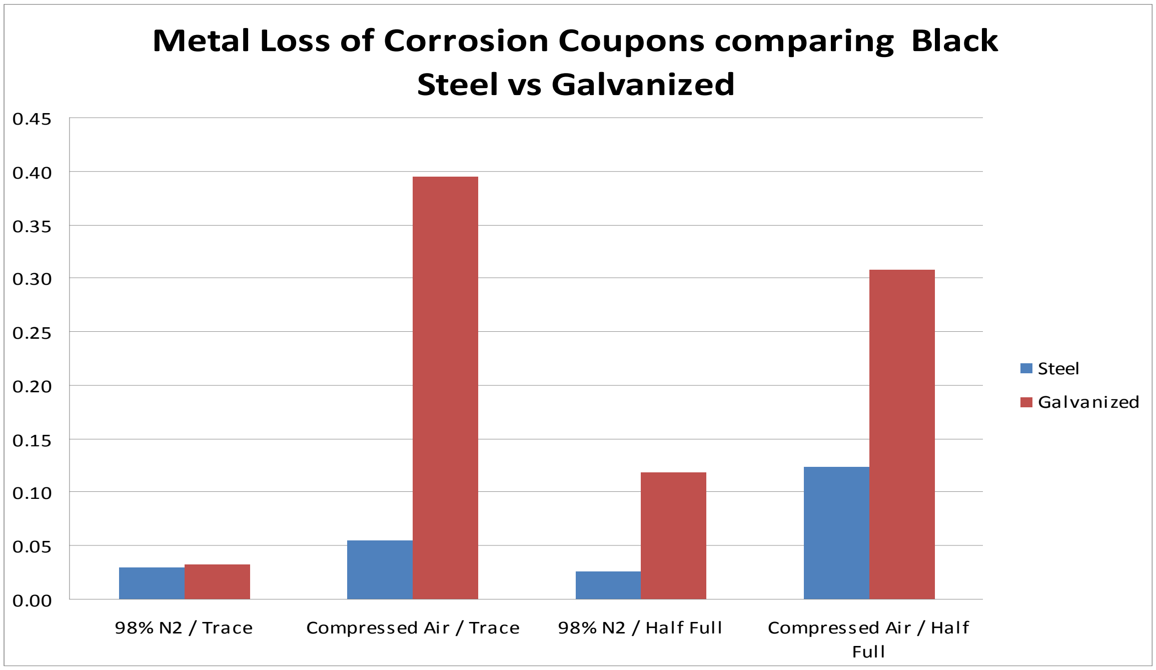
Table 2: Inhibition Effectiveness of 98% vs. Compressed Air.

Water	**Metal**	**98% Nitrogen Inhibition Effectiveness (% Protection)**	**Life Expectancy Multiplier**
Trace	Steel	45.4%	1.8
Trace	Galvanized	91.8%	12.2
Half Full	Steel	78.6%	4.7
Half Full	Galvanized	61.6%	2.6
Average		**69.4%**	**5.3**

Inhibition effectiveness is measured as the percent reduction in metal loss when using 98% nitrogen as compared to the same conditions using compressed air. Depending on the environmental conditions, using 98% nitrogen in lieu of compressed air decreased metal loss from 45.4% to 91.8% with an average of 69.4%. The largest improvement was noticed in a dry galvanized system which resulted in a 91.8% corrosion reduction. The Life Expectancy Multiplier refers to how much longer a system would last, on average, under supervisory nitrogen compared to compressed air. This was calculated using percent protection. For example, assume a steel system half filled with water has a life expectancy of 15 years when using supervisory air. If the system used supervisory nitrogen, the expected life of the system would increase from 15 to 70 years (15 years X 4.7 = 70.5). The Life Expectancy Multiplier ranged from 1.8 to 12.2, with an average of 5.3.

Figure 4 compares the metal loss of black steel and galvanized under the various conditions.

Figure 4: Average metal loss (mils) of black steel vs. galvanized under varying conditions.



The metal losses under every condition were lower when using black steel when compared to galvanized steel. Visual inspection of the galvanized coupons indicated the sacrificial zinc layer was compromised, exposing the steel to accelerated corrosion. At the exposed steel surface, a defined pitting mechanism was observed. Conversely, the black steel coupons corroded more uniformly.

Conclusions

1. The use of 98% nitrogen in lieu of compressed air as a supervisory gas reduces corrosion in both galvanized and black steel systems regardless of whether or not trapped water is present. The corrosion reduction potential ranges from 48% to 91% when compared to compressed air.
2. Using 98% nitrogen gas in lieu of compressed air increases the life expectancy of a dry or pre-action system on an average of 5.3 times.
3. The use of galvanized steel instead of black steel results in higher metal loss rates when compared in equivalent environments.
4. The use of 98% nitrogen gas in a relatively dry, black steel environment has the lowest corrosion rate overall.

Appendix

Coupons in compressed air and trace water (12 months after cleaning and weighing).

Coupons in compressed air and water (12 months after cleaning and weighing).

Coupons in 98% nitrogen and trace water (12 months after cleaning and weighing).

Coupons in 98% nitrogen and water (12 months after cleaning and weighing).

Sources

Chakrapani, D.G. PhD, PE and R.I. Garber, PhD, PE. (2004). *Some Recent Failures of Fire Sprinkler System Components: Corrosion Case Histories*. Portland, Oregon: NACE International.

European Fire Sprinkler Network. (2009). *Corrosion in Sprinkler Systems*. London, England.

National Fire Protection Agency. 2013. NFPA 13: Standard for Installation of Sprinkler Systems. International Codes and Standards. Quincy, Mass., pgs. 13-25.