A New Method for Corrosion Control in Dry Fire Protection Systems

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There are currently two accepted methods for managing corrosion in fire protection systems. These methods include controlling the environment or treating the system with a chemical corrosion inhibitor. One method of controlling the environment is to use a nitrogen blanket and dehumidification, which can be costly. Chemical corrosion inhibitors are appropriate for wet and dry systems, but can be difficult to apply in a dry system. A new method is being developed to apply vapor-phase corrosion inhibitors to dry systems, which can address the concerns with existing methods. This entails saturating the system with vapor phase inhibitor using airflow to carry the inhibitor throughout the system. Lab evaluation and analogous field studies are presented that can identify this new application method as viable for managing corrosion potential in dry fire protection systems.

Current methods for corrosion control in dry fire protection systems include nitrogen blanketing, dehumidification using compressed air, and the use of chemical corrosion inhibitors. In addition, systems are often designed using galvanized steel in place of black steel to increase the useful service life of a system.

Correct use of each method can reduce the corrosion rate in a dry system with different degrees of success. The method generally considered to be the most effective is the use of nitrogen generator with a drying system (>98% nitrogen). Compared to compressed air, it has been shown that using nitrogen can reduce the corrosion rate in a dry system 70 to 90% for black and galvanized steel.[1]

The downside of such methodology is that the capital investment required can be quite high. Nitrogen generation systems typically cost upwards of $20,000 depending on the size of the sprinkler systems, and whether there is a need for ancillary equipment such as air compressors or dryers.

For systems designed using galvanized steel rather than black steel, there is also a rather substantial capital investment. This choice is made primarily based on the desired service life, when corrosion potential is significant. The incremental increase of material cost is generally between 35 to 50% additional costs for galvanized over black steel.[2]

When compressed air is used alone, the potential for corrosion can still be quite high in a dry system. This is because water pooling and moisture content can still be quite high in such a system. This can occur at low points in the system, or if there is a lack of a good system to remove all of the moisture, especially in systems that have been hydrotested.

A new method is under development to utilize vapor-phase corrosion inhibitors (VCIs) in combination with compressed air in order to provide corrosion protection in a dry sprinkler system. This would alleviate the need for a nitrogen generator or blanketing system. Based on analogous applica-

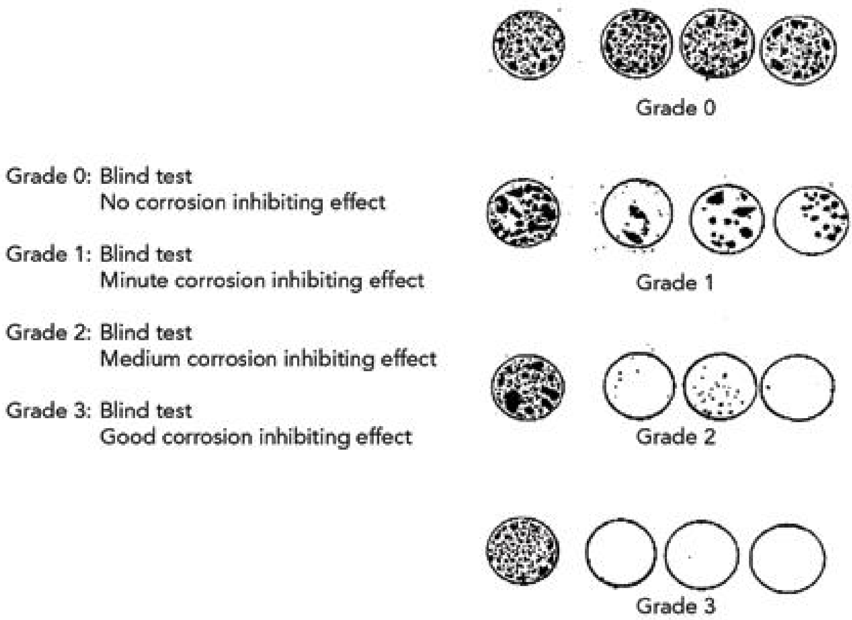

FIGURE 1 The VIA grading scheme.

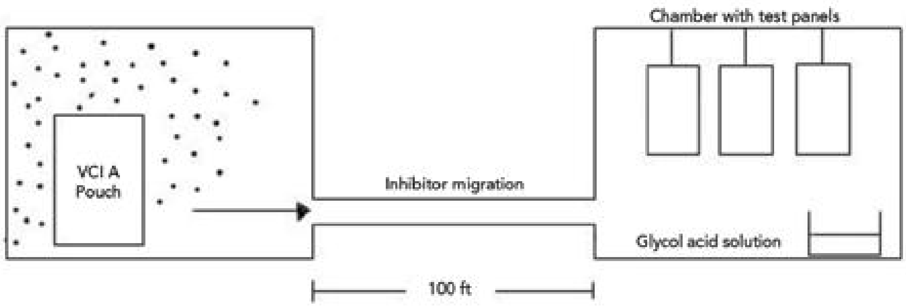

FIGURE 2 Diagram of the migration test.

TABLE 1. VIA RESULTS FOR VCI A

Sample	Grade	Result
Control	0	Fail
1	2	Pass
2	3	Pass
3	3	Pass
4	3	Pass

tions, it is believed that such a system can yield similar results to the use of nitrogen with a lower capital investment required.

Experimental Procedures

Vapor Corrosion Testing

To illustrate the efficacy of a corrosion inhibitor, the test most commonly used is a Vapor Inhibiting Ability (VIA) test. The test used polished carbon steel (CS) samples placed in 1-L glass jars that contained either 0.05 grams of inhibitor VCI A or remained empty for the conditioning period. The jars are sealed to allow for the plugs to condition in the environment that contains corrosion inhibitor. After the conditioning period, 10 mL of a 3% glycerin solution were added to the container. The container was sealed and placed in an oven at 38 °C for 4 h. The plugs were then removed and inspected for corrosion. The corrosion level was rated on a scale of 0 to 3 according to standards seen in Figure 1. A rating of 2 or 3 is considered passing while 0 and 1 are failing.

When the treated plugs were evaluated, they all showed good corrosion inhibition. Three of the plugs had ratings of 3 and one displayed some slight corrosion so it was graded a 2. These samples all compared favorably to the control plug, which had a grade of 0, showing convincingly that VCI A provides corrosion protection. Table 1 summarizes the data.

Inhibitor Migration Test

To determine how effective VCI A pouches would be diffusing in a static system, the migration properties over long distance were tested. The test apparatus included two 5-gal (19-L) containers connected by a tube 100 ft (30.5 m) in length. The first container contained the material to be tested, either a VCI A pouch or no inhibitor as the control (Figure 2). The second container contained three steel test panels and a solution of 3% glycerol and 0.1% hydrochloric acid (HCl) in deionized water. The solution is similar to that used in the VIA test to initiate corrosion.

The test apparatus shown in Figure 2 was set up with inhibitor pouches added to the first container while the steel test panels were placed into the second container, which was sealed. The inhibitor was given three days to migrate through the tube from the first container to the second container. The second container contained steel test panels to evaluate the level of corrosion. After the conditioning period, 300 mL of corrosive solution were added to the container with the steel panels and the panels were allowed to stand for two additional days. This test was performed with and without inhibitor pouches in the first container to determine if the inhibitor will migrate 100 ft and effectively reduce corrosion.

The result, which is illustrated in Figures 3 and 4, was that the control panels displayed corrosion while the panels treated with VCI A were clean. This comparison shows that the inhibitor is volatile enough to migrate at least 100 ft in distance even when it is unassisted by forced air.

Field Testing of VCI A

The Severn Bridge in the United Kingdom was built in 1966 using a suspension cable design in which cables run within ducts along the entire 1,598-m length of the

FIGURE 3 Control panels.

FIGURE 4 Panels treated with an inhibitor.

TABLE 2. COMPARISON OF STRAND STRENGTH BEFORE AND AFTER TREATMENT

	2006 Data		2007 Data	
Wire Group	Tensile Strength (N/mm^2)		Tensile Strength (N/mm^2)	
	Mean	Standard Deviation	Mean	Standard Deviation
2	1,604	33	1,650	28
3	1,574	67	1,606	42
4	1,546	67	1,587	41
5	1,487	87	1,534	111

bridge. After concern was raised about deterioration and breaking of cables in these types of bridges, a study was initiated to look into methods for reducing corrosion. In 2006 a dehumidification system was installed on Severn Bridge that was designed to reduce moisture buildup around the cables. The system included the use of VCI A emitters that would be installed to allow the dehumidification system to force inhibitor through the cables.

The heated air of the dehumidification system is forced through a plenum, which contains the inhibitor emitter. The inhibitor moves though the system with the forced air and there are sensors throughout the length of the duct used to measure the inhibitor content in the air (sensor locations are shown in Figure 5). The inspection points are used to monitor and ensure that the VCI A molecules are present.

The strength of the cables was evaluated when the VCI A system was installed in 2006 and again in 2010 after it was operational for 4 years. The data in Table 2 show that the strength of the cables in all segments is improved after the corrosion inhibitor was added to the system. Since the implementation of the corrosion inhibiting system, there have not been any cable wire failures, which is down from a rate of 5%.

Both the corrosion rate and the monitoring system show that VCI A has the capability to migrate long distances and effectively reduce corrosion.[3]

Environmentally Friendly Qualities

Biodegradation is a measure of the length of time over which a substance will remain in the environment. The OECD 306 test guideline[4] is primarily used for biodegradation in marine environments. Chemical compounds are subjected to a 28-day Biochemical Oxygen Demand (BOD-28) test. The start of degradation occurs when 10% of the substance has been degraded. In order to be rapidly degradable, at least 60% degradation of the substance must be attained within 10 days of the start of degradation.

VCI A degraded 10% in less than two days. At Day 7, it was 76% degraded and after 27 days was completely decomposed. Ten days after the start of the degradation, the level of biodegradation was above 60%, indicating that VCI A could be classified as a rapidly degradable substance. The results can be seen in Figure 6.

Acute oral toxicity is a measure of the dosage of a substance that is required to reduce mortality in half of the subject animal population. This measurement is referred to as the lethal concentration 50 (LC50). Typically the test is performed with rats over a 14-day period and that data can be used to compare the toxicity level between different substances. A lower toxicity value indicates that a substance is more lethal.

VCI A was tested and determined to have an LC50 in rats of 5,000 mg/kg. For comparison, the LC50 of common table salt in rats is 3,000 mg/kg.

VCI A is a less significant health concern than sodium chloride (NaCl). Also, when discharged with water it will rapidly degrade and not pose an environmental concern.

Results

Based on the corrosion data that we have, VCI A would be an ideal inhibitor for a dry sprinkler system. In VIA testing, VCI A has proven that it significantly decreases corrosion levels on CS. The migration studies show that the inhibitor migrates long distances, particularly under forced air, which allows it to be used in long runs of pipe.

In a dry sprinkler system VCI A would be implemented in Tyvek† pouches that contain the corrosion-inhibiting powder. In the

†Trade name.

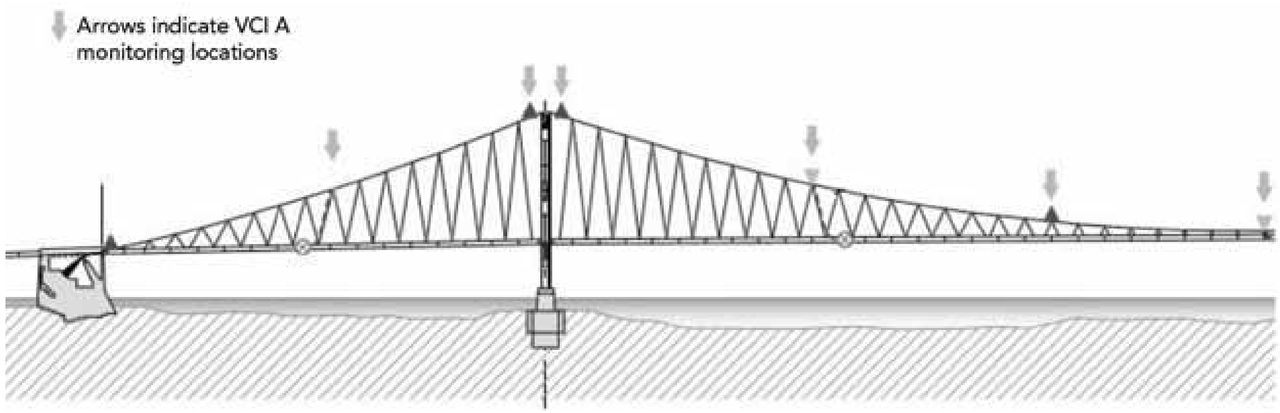

FIGURE 5 Each arrow in the diagram represents a monitoring site for the inhibitor, which is forced through the ducts by the dehumidification system located at the anchor point on the left side.

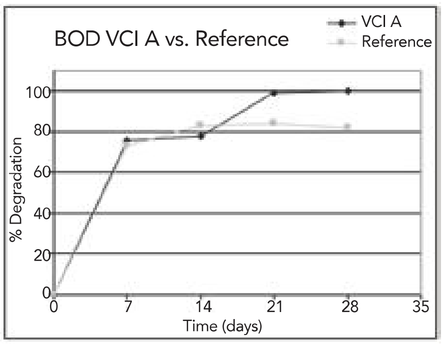

FIGURE 6 The biodegradability of VCI A compared to a reference sample.

FIGURE 7 An example of a plenum that could be installed to introduce VCI A to a sprinkler system.

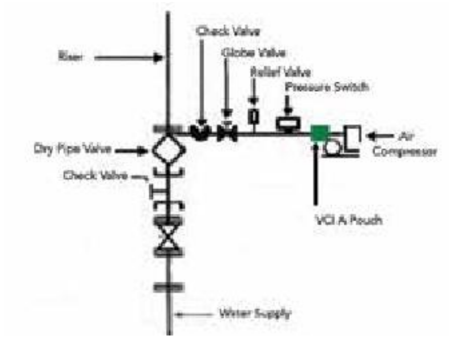

FIGURE 8 A diagram of the dry system with the inclusion of a VCI A delivery system.

sprinkler system, a plenum containing the VCI A pouches would be added downstream from the air compressor used to maintain a positive pressure in the sprinkler system. Figure 7 shows an example of the type of plenum that would be added in the air compressor line. The diagram in Figure 8 shows where the inhibitor would be implemented within the sprinkler system.

Conclusions

VCI inhibitors have been proven to significantly reduce corrosion rates in steel systems and they have the ability to migrate long distances. The VIA testing indicates the dramatic difference in corrosion protection between untreated metal surfaces and those treated with VCI A. The migration testing demonstrates the ability of the inhibitor to travel long distances both unassisted and when it is under pressure. Use of VCI A will be a good alternative for corrosion prevention by reducing costs as well as limiting additional equipment needed to maintain the corrosion inhibitor.

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