Vapor Phase Corrosion Inhibitors Protect Fire Water Systems

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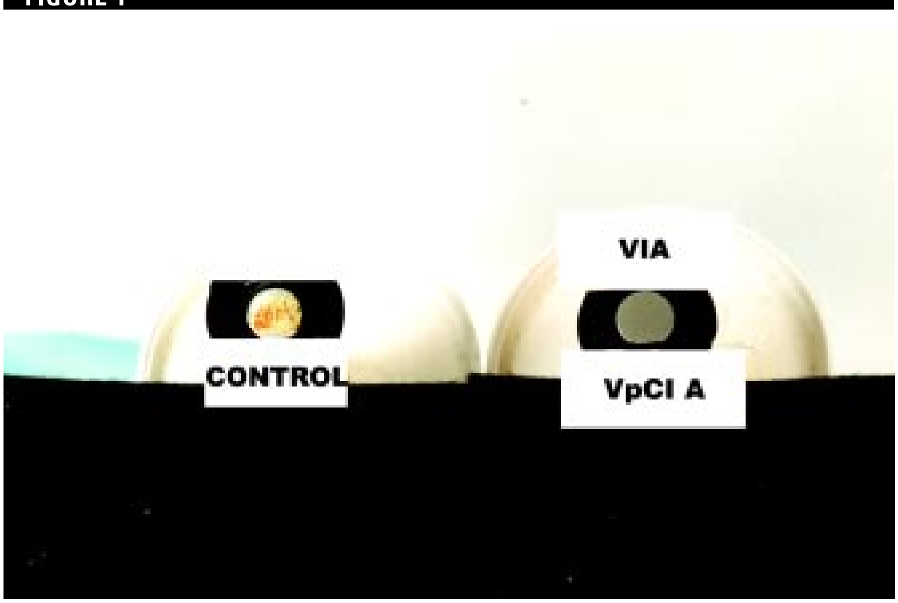
Corrosion is a problem faced by the fire sprinkler industry in both wet and dry sprinkler system piping. The ability of vapor phase corrosion inhibitors (VpCIs) to protect fire water systems was tested in the laboratory and field. The test results show that VpCIs provide protection in the conditions present in wet and dry pipe systems.

FIGURE 1



Vapor Inhibiting Ability test results for steel plugs in VpCI A.

Corrosion leads to pinhole leaks in the piping of today's fire sprinkler systems. Such systems include:

- Wet pipe systems—The most common systems, these are used in buildings where there is no risk of freezing. Wet systems are required for high-rise buildings and for public safety.[1]
- Alternative systems—As the name suggests, the pipes of alternative systems can be full of water for the summer and be drained and filled with air under pressure for the winter. Alternative systems are used in buildings that are not heated.[1]
- Dry pipe systems—The pipes in dry pipe systems are filled with air under pressure, and a control valve holds the water back. When a sprinkler head opens, the drop in air pressure opens the valve and water flows into the pipe work and onto the fire. These systems are used where the wet or the alternate systems cannot be used.[1]
- Deluge systems—These are used in special cases for industrial risks (e.g., offshore oil rigs).

FM Global (Johnston, Rhode Island), a commercial and industrial property insurer, inspected several fire sprinkler systems following reports of leakage visually identified by building owners.[2] The insurer identified leakage and related encrustation and corrosion that could prevent the sprinklers from operating as designed in the event of a fire. Often, a leak in the fire protection system is the only means of discovering internal corrosion problems.

Underwriters Laboratories, Inc. (UL) (Northbrook, Illinois) recently conducted laboratory tests on dry sprinkler systems taken from field installations. The test results indicated that exposing these sprinkler systems to harsh environmental conditions over an extended period of time may render them inoperable under certain fire conditions.[3] In dry systems, the problems go undetected until the system fails to perform when needed in the event of a fire or until a system inspection is made.

For a particular treatment program to protect fire sprinkler systems from corrosion effectively, the inhibitor must meet the following criteria:

- Prevent corrosion of systems manufactured predominantly from ferrous metals
- Prevent corrosion of systems composed of nonferrous alloys
- Have a low environmental impact
- Have low toxicity and skin irritability in case of contact with humans.

The corrosion protection properties of vapor phase corrosion inhibitors (VpCIs) were evaluated for dry and wet fire water systems. Laboratory tests were followed by field applications.

VpCI Treatment Programs

Recent VpCI treatment programs based on ambiodic inhibition (i.e., inhibition at the cathodic and anodic sites) have been developed and evaluated in the laboratory. These treatment programs protect ferrous and nonferrous alloys by providing three-phase corrosion protection as follows:

- In the water phase
- In the interphase, between water and air
- In the air/vapor phase.

VpCIs have been used by automobile manufacturers, the marine industry, and other environmentally sensitive industries to meet stricter environmental regulations. Knowing the mechanism of corrosion protection and the fact that the new generation of VpCIs are safe to use and have a low environmental impact was a good starting point for evaluating the chemicals' effectiveness in protecting fire water systems.

Corrosion and Environmental Laboratory Testing

Two VpCIs—VpCI A and VpCI B—were evaluated in the laboratory. VpCI A, made of amine carboxylates, was examined in corrosion and toxicity tests. It was identified for use in dry and wet systems involving ferrous metals. VpCI B, a blend of amine carboxylates and triazole chemistry, was tested for corrosion protection and skin irritability. (Because VpCI B is based upon chemistry similar to that of VpCI A, costly toxicity studies were not performed on this inhibitor at the time of this study.) VpCI B was identified for use in dry and wet systems involving nonferrous alloys. Although microbiologically induced corrosion (MIC) is one concern in fire water systems, these tests were devoted primarily to general and pitting corrosion. MIC historically has been addressed by using biocides. Biocides are either used to sterilize the systems with shot treatments prior to filling the fire water systems or they are added with the firewater.

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TABLE 1

VIA TEST RESULTS FOR VPCI A

Sample	Results[A]
Control	Fail
VpCI A	Pass

[A]The test procedure contains pictures showing four grades of test results (0 to 3) with varying degrees of corrosion. Zero and 1 "fail"; 2 and 3 "pass."

TABLE 2

FULL-IMMERSED AND HALF-IMMERSED RESULTS FOR VpCI B

	Time before corrosion (days)[A]	
Metal	Ambient Temperature (°C)	50°C
CS	40+	40+
CS[B]	40+	20+
Copper	60+	60+

[A]Test samples are checked several times a day for onset of corrosion. The sample is considered "failed" at the first sign of corrosion.

[B]Half-immersed test results.

CORROSION TESTS

The Vapor Inhibiting Ability (VIA) test method[4] was used to evaluate VpCI A while the Immersion and Half-Immersion Corrosion test was used with VpCI B.

VIA Test

In the VIA test, the VpCI source never comes in contact with the metal specimen. A freshly polished steel specimen was placed in a 1-L glass jar that contained a measured amount of water blended with glycerin to control the relative humidity. A control sample consisted of a jar containing only a steel specimen, while the test sample comprised the jar with the steel specimen and VpCI A. After a conditioning period during which the VpCI vapors migrated from the source to the metal specimens, the jars were placed in an oven set at 50°C for 4 h. The jars were then placed at ambient temperature and the metal specimens rapidly cooled; this led to condensation from the humid atmosphere. Effective VpCI compounds provide protection in this environment, while the control specimen corrodes heavily. The test samples were run in triplicate. Table 1 presents the results for the VIA test. Following

TABLE 3
BIOACCUMULATION RESULTS (LOG P_{OW}) FOR VpCI A

Test Method	Limit	Result
OECD 117 log P_{ow}	< 3	< 0

TABLE 4
PRIMARY IRRITATION RESPONSE CATEGORIES

Response Category	Comparative Mean Score (PII[A])
Negligible	0 to 0.4
Slight	0.5 to 1.9
Moderate	2 to 4.9
Severe	5 to 8

[A] The Primary Irritation Index (PII) is determined by adding the Primary Irritation Score for each animal and dividing the total score by the number of animals.[7-10]

the conditioning period, VpCI A protected the steel specimen in the moisture-condensing environment. Figure 1 shows the appearance of the plugs at the completion of the test.

Immersion and Half-Immersion Corrosion Test

Corrosion tests using VpCI B were performed on immersed and half-immersed carbon steel (CS) and copper panels at room temperature and at 50°C.[5] The CS panels were made from cold-rolled steel (ASTM C1010[6]) ground on both sides. The copper (CD A110) panels were sanded with 320-grit sandpaper. The panels and working electrodes were washed with methanol (CH_3OH) prior to testing. Table 2 presents the test results.

ENVIRONMENTAL AND SKIN IRRITABILITY TESTS

VpCI A was evaluated in bio-accumulation, biodegradability, and aquatic toxicity tests. VpCI B was used in the skin irritability test, which was designed to determine the dermal irritation potential of the inhibitor on the shaved skin of a rabbit as required by regulation of medical device biocompatibility.

Table 3 presents the results of the bioaccumulation test. With a value of the partition coefficient (P_{ow}) below zero, VpCI A is unlikely to have toxic effects on aquatic life over long time periods. The inhibitor's quick biodegradability, fully decomposing in <28 days, also verifies its limited effect on the marine environment.

Aquatic toxicity results showed that VpCI A is not classified as an acute toxicant to primary producers (algae and aquatic plants), consumers (fish and crustaceans), and sediment reworkers (seabed worms).

Table 4 shows the irritation response categories for the skin irritability test. At a working concentration of 0.4% of VpCI B, the Primary Irritation Index was 0—meaning that the inhibitor falls under a negligible response category for skin irritability.

Case History: Field Corrosion Testing

A large oil and gas producing company that operates several offshore and onshore installations was experiencing serious corrosion problems and nozzle blockages in the deluge fire water system. A unique method, using 5%-by-mass VpCI A concentrate solution as a corrosion inhibitor, was developed to solve the company's problem. A 19-mm predrilled plug was fitted at the junction where the pipe work terminates. A fogging nozzle connected to compressed air was inserted. Airflow was established and a measured amount of VpCI A concentrate was introduced into the amplified air stream. Wet fog emission through the sprinkler nozzle was verified to ensure proper application. This method of protection with VpCI A decreased blocked nozzles by 97.6% within the first year and 98.8% at the end of 2 years. Using VpCI A dramatically reduced corrosion problems for the operator over the span of 2 to 3 years.

Conclusions

The three-phase protection ability of VpCIs allows them to be effective in the conditions present in dry and wet fire water systems. Corrosion and toxicity testing demonstrated that new VpCIs not only provide excellent corrosion protection but also have low toxicity. Skin irritability testing showed that these compounds are safe for human contact. As environmentally sound, safe, and cost-effective compounds, VpCIs are viable alternatives for protecting fire sprinkler systems from corrosion.

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