

THE IMPORTANCE OF CORROSION PROTECTION IN LISTED ANTIFREEZE FOR FIRE PROTECTION SYSTEMS

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WHITE PAPER



National Fire Protection Association (NFPA) requirements require sprinkler system antifreeze to be listed and factory premixed to assure maximum protection in a fire. But not all antifreeze products are created equal when it comes to resisting damaging corrosion in steel systems. This paper examines (1) the causes of corrosion in sprinkler systems and how it compromises sprinkler performance, (2) how antifreeze can be instrumental in resisting corrosion and (3) how commercially available listed products compare in corrosion protection properties as determined by lab testing.





INTRODUCTION

Wet fire sprinkler systems should hold water and reliably activate as they are designed to do for as long as 50 years. Steel and other fire suppression systems are prone to various forms of corrosion, including galvanic corrosion, general corrosion and microbiologically influenced corrosion (MIC), that not only can render a system unable to hold water, but also compromise the system's designed flow and pressure values. Debris from corrosion builds up, pinhole leaks form, and friction from surface roughness obstructs flow in sprinkler drops and feed mains.

Building owners need assurance that their fire protection systems are reliable and are functioning to lower the risk of an uncontrolled fire loss. Fire suppression system contractors need confidence that the systems they install will not freeze and will provide the best corrosion protection on the market. Fortunately, per NFPA, listed antifreeze products must now be able to prove corrosion resistance and be factory-premixed in new systems, and by September 30, 2022, in existing systems. The factory-premixed requirement eliminates the potential risk of the antifreeze being mixed at the wrong proportions onsite and igniting when discharged from a sprinkler.

THE PROBLEM OF CORROSION IN DRY AND WET SPRINKLER SYSTEMS

Fire suppression systems are either wet or dry. In dry systems, the pipes are not constantly filled with fluid, whereas the wet system's pipes are always filled. Both types of systems can suffer from damaging corrosion, compromising functional integrity and the life expectancy of the system.

With dry systems, corrosion issues arise because these systems are never completely dry; moisture enters through hydrostatic testing and from the air pumped through the system. Thus, without significant intervention, dry systems tend to fail via generalized corrosion, which presents as rust and degradation around the pipes. End users and service companies have had to go to extreme lengths, such as filling the system with nitrogen gas, to mitigate the problem.

In wet systems, high levels of corrosion are typical due to the constant presence of water and oxygen in contact with the metal pipes and fittings, or galvanic corrosion when the system is not comprised of only one metal.

Yet another form of corrosion can attack these systems, however: microbiologically influenced corrosion, or MIC, has become a significant challenge encountered in the field. According to FM Global, MIC is responsible for 10-30% of corrosion in all piping systems in the U.S.

Unlike general corrosion, MIC is the localized – or non-uniform – rapid development of metallic corrosion. It appears in the form

of pitting, crevices and craters caused by the growth of certain aerobic and anaerobic bacteria, or hybrids of the two. These bacteria tend to form biofilms, which create a sub-environment with different flow characteristics, pH levels and chemical concentrations, which together can spur MIC. MIC is separate from, but can combine with, the more well-known nonbiological corrosion caused by oxygen and acidic exposures. In addition to the formation of MIC in steel piping, other areas susceptible to it include caps, valves, fittings and supply tanks.

The MIC problem has been difficult to control because it has multiple possible root causes in both wet and dry sprinkler systems. These include:

- In wet systems, the presence of stagnant water, especially in the mains
- Components made of lower quality imported steel
- Aggressive municipal water treatment methods
- Water quality incompatible with components
- Coated components
- Subpar welding practices





In areas subject to freezing conditions, another key factor that can worsen the growth of MIC is the use of antifreeze that lacks high-quality corrosion protection. Antifreeze solutions, particularly those that are glycerin-based, can add to the acidity of sprinkler system water.

The annual costs of combating corrosion in dry nitrogen systems and systems with specially coated steel pipe, as well as heat trace methods, can be prohibitive. If the damage goes too far, corrosion can lead to the need for complete system replacement. Wet systems are subject to the stringent requirements of NFPA 25, the standard for the inspection, testing and maintenance of water-based fire protection systems. These requirements, too, carry high maintenance costs.

HOW ANTIFREEZE MAY HELP RESIST PREMATURE SYSTEM FAILURE FROM CORROSION

In addressing the market need for listed products to protect people and property from the risk of combustion when sprinkler systems activate in a fire, Lubrizol Advanced Materials met NFPA's challenge – to formulate an antifreeze that could achieve a listing for use in new fire sprinkler systems right away and in existing systems by September 30, 2022.

UL's concern extended beyond combustion issues. UL 2901, "Standard for Antifreeze Solutions for Use in Fire Sprinkler Systems," establishes product testing protocols that must be met or exceeded to ensure that corrosion rates in metal-based sprinkler systems will be significantly reduced. Approved premixed antifreeze solutions must not cause the corrosion to exceed 1.0 mils/year (0.025 mm/year) for ASTM A108, Grade 1010 steel; ASTM B16, H02 (Half Hard) brass; or Type 304 stainless steel, among other metallic materials that might be used in sprinkler applications with antifreeze.

Building on more than 30 years in fire protection, Lubrizol formulated freezemaster™ antifreeze, a safe-to-use, premixed freeze protection technology meeting these corrosion resistance requirements, with cold temperature protection down to -12°F (-24°C). But Lubrizol went further; freezemaster™ antifreeze achieves elevated levels of corrosion protection through the development of a corrosion inhibitor that outperforms the other UL-listed alternative in corrosion performance.

BRINGING THE FIRE PROTECTION MARKET A BETTER CORROSION-RESISTANT ANTIFREEZE

As an additives manufacturer, Lubrizol has a core competency and a leadership position in the metal protection industry, i.e., parts manufacturing, steel, automotive and industrial-related markets. Lubrizol has developed and acquired a broad range of extended performance additives that meet various industry performance demands. Lubrizol elected to incorporate several additional metalworking tests into its examination of the best antifreeze formulation for the sprinkler market, and one variation on a third test that UL required, to evaluate whether freezemaster™ antifreeze could stem the tide of corrosive action sooner and better than the alternative listed commercial product.

The battle against corrosion begins right away, because the piping on new fire suppression systems may already have a thin layer of corrosion, and metal fines can be left on the surface from manufacturing and the installation work itself. These particles add to the surface area of the system capable of corroding and ultimately contributing sedimentation that can clog the system. Thus the first test method, IP 287 "Determination of Rust Prevention Characteristics of Water Mix Metal Working Fluids," was intended to evaluate the expected corrosion behavior of freezemaster™ antifreeze on these metal fines, compared to the other listed antifreeze.

In a modified version of the IP 287 test, Lubrizol compared the corrosion behavior on cast iron chips placed on filter paper and saturated with freezemaster™ antifreeze or the other listed antifreeze. After two hours, the chips were removed, and the filter paper rinsed to expose the area covered by the chips and arrive at a resulting percentage of rust. Figure 1 shows that freezemaster™ antifreeze presented no corrosion while the other commercially available listed fluid gave rise to 65% rust during the test, indicating inferior corrosion protection.

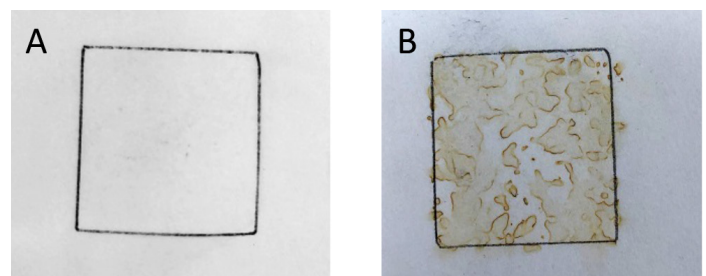


FIGURE 1. Modified IP 287 test highlights high level of corrosion protection provided by (A) freezemaster™ antifreeze versus (B) the other listed antifreeze.





Fire suppression systems are rarely comprised of only one metal type, or identical grades of a single metal type. When dissimilar metals are in direct contact with one another or are connected by a conductive fluid, a galvanic cell can form in the sprinkler system where one of the dissimilar metals will corrode preferentially over the other. The second test derives from ASTM G71 “Standard Guide for Conducting and Evaluating Galvanic Corrosion Tests in Electrolytes.” The purpose of this test is establishing the behavior of two dissimilar metals in electrical contact in an electrolyte under low-flow conditions. When this test is conducted, color changes and sediment in the antifreeze solution will not occur if corrosion is not present.

Lubrizon built and tested several galvanic cell couples to measure electrical current over time while immersed. UL requires monitoring for 90 days, but in only seven days, it was possible to tell that the voltage versus time curves were radically different between the two solutions (see Figure 2), indicating galvanic corrosion occurred more readily in one instance. In addition, the commercial product took on a blue color during the test, indicating that copper was being leached into the solution. This color change did not occur with freezemaster™ antifreeze.

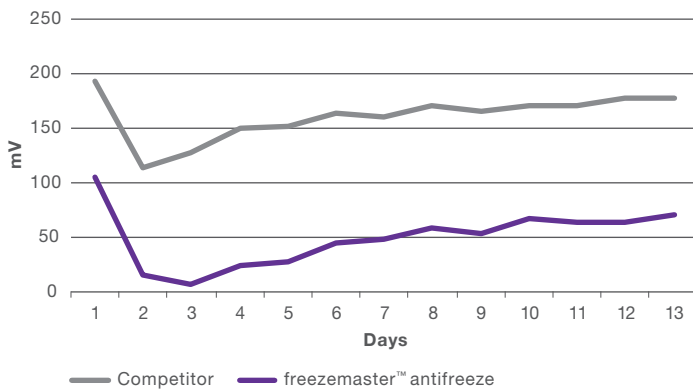


FIGURE 2. Voltage was plotted versus time (days) for brass-steel galvanic cell couples. The freezemaster™ antifreeze exhibits lower voltage over time than the competitive fluid. Although both fluids show similar trends over the 14 day period, it should be noted that the freezemaster™ antifreeze shows a lower voltage than the competitive fluid, clearly indicating that better corrosion control should be expected from it versus the competitive fluid.

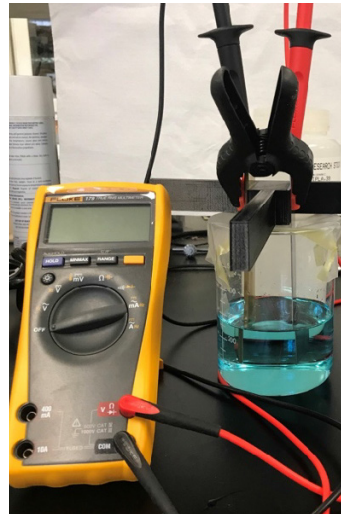


FIGURE 3. ASTM G71 test apparatus is comprised of a multi-meter, a glass beaker, a non-conductive bracket to hold test coupons, plastic clamps to hold metal coupons in place, and wax film covering the beaker to prevent evaporative loss.

A long-term pipe storage test was also conducted to simulate real-world fluid-pipe contact. Using Schedule 40 pipe capped with half-hard brass fittings, a sample port was drilled in the top for ease of filling and sampling and sealed with a nylon screw. (See Figure 4). Samples of freezemaster™ antifreeze and the other commercially available antifreeze were added to the pipes and stored at 25°C and 40°C. At the end of 90 days, the pipes were cut open and visually inspected as well. It can be seen from the photographs in Figure 6 that corrosion began to appear in the competitive listed solution in that time. The freezemaster™ antifreeze product did not allow any corrosion to occur.

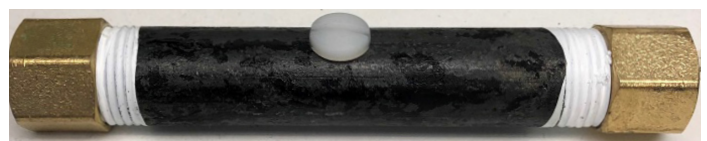


FIGURE 4. Black Schedule 40 pipe capped with half hard brass fittings. A sample port was drilled in the top for ease of sampling and sealed with a nylon screw.



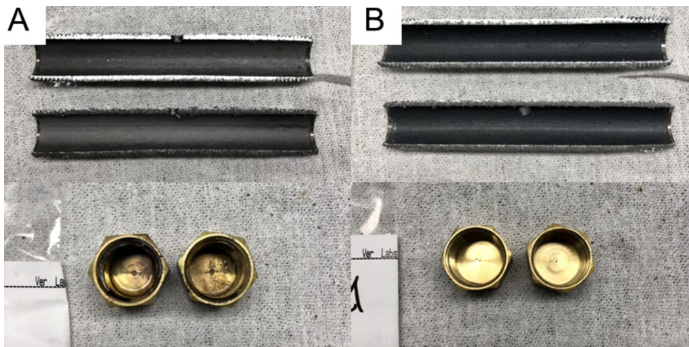


FIGURE 5. Cross sections of pipe protected with freezemaster™ antifreeze after 7 months. (A) Test pipe stored at 40°C. No ferrous corrosion observed. Slight staining of brass fitting observed. (B) Test pipe stored at 25°C for 7 months. No ferrous or brass corrosion observed.

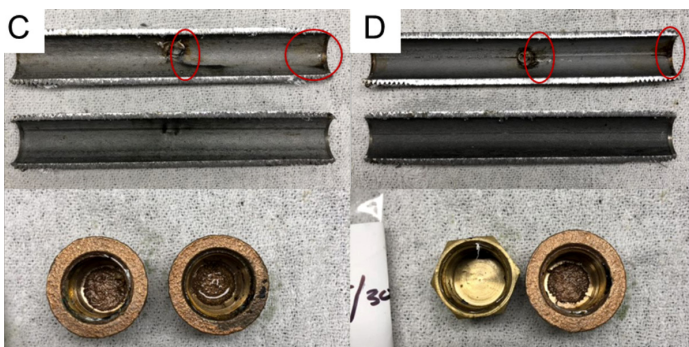


FIGURE 6. Cross sections of pipe protected with the competitive listed antifreeze. (C) Test pipe stored at 40°C. Ferrous corrosion and heavy brass staining was observed. (D) Test pipe stored at 25°C. Ferrous corrosion and staining on the brass caps was clearly visible.

COMBATING THE DESTRUCTIVE EFFECTS OF MIC

Finally, in an effort to establish freezemaster™ antifreeze's MIC resistance versus the other listed antifreeze solution that is commercially available, Lubrizol contracted with one of the world's leading laboratories in analyzing metallurgical failure and corrosion behavior. A screening test was developed to explore the conditions conducive to MIC. This lab then conducted accelerated testing to simulate flow around suspended carbon steel coupons that had been inoculated with sulfate-reducing bacteria (*desulfovibrio vulgaris*) as shown in Figure 7.

Sulfate-reducing microorganisms are common in anaerobic environments where they aid in the degradation and reliability of the surfaces they inhabit. After 336 hours of this testing, neither solution showed signs of corrosion, but only the freezemaster™ antifreeze, as determined by DNA testing, lacked any sign of continued biofouling from bacterial growth, setting up the conditions for a future problem with MIC.



FIGURE 7. Flow-loop system used to simulate a fire suppression system. Antifreeze fluids were inoculated with sulfate-reducing bacteria (SRB), *desulfovibrio vulgaris*.





THE RESULTS ARE IN: FREEZEMASTER™ ANTIFREEZE IS BEST IN CLASS

In order for fire sprinkler systems to do their lifesaving work, they must be protected from damaging corrosion, which can flourish in both wet and dry sprinkler systems because neither are ever 100% dry. In wet systems using listed antifreeze, the chosen formulation has a significant and measurable bearing on just how well corrosion is resisted. Lubrizol, building on its extensive expertise in metallurgy, invested in a series of corrosion tests in addition to those required by UL to demonstrate the superior performance of freezemaster™ antifreeze in resisting corrosion of both biological and non-biological origin.



References

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