Corrosion And Microbiological Control In Firewater Sprinkler Systems

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Abstract

Corrosion in firewater sprinkler systems has become a major concern in recent years. The causes are a diverse mixture of water chemistry, materials of construction and microbiological attack. The expense of the damage to property in the area of system leaks, plus the potential for sprinkler failure in an actual fire, has raised the need for identifying and preventing this phenomenon. In many cases, existing systems must be cleaned of foulants before effective treatment can be applied.

Introduction

SurTech Corporation first became aware of this problem by chance. A local sorority had a minor fire, but sustained major property damage when the sprinkler system sprayed out black, pungent smelling water that permanently stained anything it touched. Shortly thereafter, one of our customers replaced its existing firewater storage tank. When that one was toppled to the ground, it split open, revealing a six inch thick coating of biological slime and corrosion products on the inside surface. At that time, a concerted effort was made to contact businesses specifically engaged in fire protection services and their technical staff, besides trade associations, to learn if this was a legitimate concern. What emerged was a growing awareness that firewater sprinkler systems had a serious situation with corrosion and system failures. One major aerospace manufacturer had a sprinkler line leak in its mainframe production computer control room that shut down all manufacturing in the eastern half of the United States for six hours. The resulting cost was 16 million dollars. A five-year-old 700,000 sq. ft. warehouse had to be completely re-piped at a cost of 1.9 million dollars. Recently, a large nursing home was denied further Medicare funds until it fixed a continuing problem of leaking sprinkler lines.

Compounding this situation is the existence of two vastly different types of firewater sprinkler systems:

Wet pipe systems – The risers, cross-mains, and laterals are always filled with water. Pressure sensors located in the system will activate a low volume jockey pump to add small amounts of water to maintain constant system pressure. Due to sprinkler systems high pressure, any leak is a serious problem, and sprays water over a wide area. Almost all of the systems are deadheaded and stagnant, making chemical treatment very difficult.

Dry pipe systems – As the name indicates, these systems do not contain water until there is a fire. They are most common in freeze prone areas such as cold warehouses. They are under constant air or nitrogen pressure. When a fire occurs, the system will rapidly flood with water. It is not unusual for these systems to periodically lose pressure and fill with water. The system must be drained before it can be reset. The piping is left wet and then filled again with air, which leads to aggressive corrosion.

Whereas the causes for these failures have been present for many years, the increasing number of failures is the result of a combination of factors, which have occurred in just the past two decades.

Firewater sprinkler protection is now mandatory in most commercial buildings and also in a growing number of residential communities. The MGM Grand fire in Las Vegas on November 19, 1980 killed 84 and injured 650. Installing sprinklers in the casino could have prevented the fire from spreading, but the owners balked at the $192,000 cost. They eventually paid out $223 million to settle the lawsuits.

Many older sprinkler systems were installed using Schedule 40 or Schedule 80 steel piping. As contractors have sought to reduce weight and costs, they have moved toward piping as thin as Schedule 5 (0.065 inch wall thickness). At this thickness, it does not take much time for the steel piping to be penetrated by corrosive waters.

Due to the environmental hazards associated with dissolving lead and copper in potable water systems many municipal water treatment plants have increased the alkalinity and pH of the water they supply. Chlorine gas will lose 80 % of its effectiveness at pH 8.0, and 95 % at pH 9.0. This loss in chlorine efficacy has caused many cities to disinfect with chloramines. Chloramines are less effective against many forms of bacteria than gaseous chlorine.

Types of Corrosion

Corrosion is a natural process through which nature tries to return a material to its natural state. The purpose of corrosion control is to delay this process for as long as possible. Inevitably, all materials will fail. It is necessary to briefly list the type of corrosion that can occur before focusing on those most often associated with failures in sprinkler systems.

1. Pitting
2. Selective Leaching
3. Galvanic
4. Crevice (under deposit)
5. Intergranular
6. Stress Corrosion Cracking
7. Microbiologically Influenced Corrosion (MIC)
8. Erosion
9. Formicary (associated with copper piping)

Without diminishing the importance of some of the above forms of corrosion, we can dismiss numbers 5, 6, and 8 from the above list, as they are not yet shown to be significant factors in sprinkler system failures. Number 9, formicary corrosion, is important only if the fabricator of copper piping systems does not follow recommended cleaning standards by removing manufacturing and machining oils. These oils, when wetted by water, will form formic acid and develop what is known as "ant nest" corrosion in stagnant waters. This type of corrosion is almost invisible to the naked eye, but has typical small black specks. If the failed tube is split and then bent backwards on itself a labyrinth of corrosion lines is exposed that resembles the underground portion of an ant colony.

Of the remaining forms of corrosion listed above, pitting and MIC are the dominant forms of sprinkler system failures. Pitting is a severe localized loss of metal on the pipe or sprinkler. However, there may be many of these pits in any given section of pipe. When the pipe is cleaned, a pitted area on the surface looks as if a small drill-hole has been applied to the spot. Pitting corrosion rates are generally a factor of 10 greater than uniform corrosion rates.

Most firewater sprinkler systems use makeup water obtained from the municipality potable water system. Many of these waters come from surface water reservoirs or rivers and contain high levels of dissolved oxygen. Those that come from ground waters (i.e., well water) become saturated with oxygen systems as the water flows through the treatment plant. All sprinkler systems use minute amounts of fresh water on a regular basis. As new water flows into the sprinkler risers, oxygen is introduced. This oxygen reacts with the metal surface. Corrosion caused by oxygen differential corrosion cells formed on low carbon steel will reduce water flow through the steel piping by the formation of tubercles. Once the tubercles become larger, they will break off and move downstream to block the water flow to critical sprinkler heads. Oxygen scavengers such as inorganic sodium sulfite and organic tetrakismethylhydroxymethylphosphonium sulfate (THPS) actually may increase corrosion with their elevated salts contribution. Also, THPS is incredibly expensive and itself may attack iron and copper via chelation.

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Microbiologically influenced corrosion (MIC) is becoming a major problem in firewater sprinkler systems. The severity of MIC is great enough that the National Fire Protection Association (NFPA) adopted a new regulation in 1999 that states: "In areas where water supplies known or suspected to have contributed to microbiologically influenced corrosion (MIC) of sprinkler system piping, water supplies shall be tested and appropriately treated prior to filling or testing of metallic piping systems." This section has been added under the restructured NFPA 13 as 5-14.3.2.6. Since the majority of NFPA rules eventually become part of state and local regulations, it can be expected that tests for MIC will be required for all sprinkler systems and that they be chemically treated. It is anticipated that the insurance industry will make treatment of all sprinkler systems mandatory within a few years.

Almost all industrial and commercial firewater sprinkler systems receive their water from local drinking water suppliers. The controlling determinant for the safety of these waters is that they do not cause disease in humans. There are many bacteria that are not pathogenic, which are allowed to pass through local treatment plants. Also, the water may contain organic carbon molecules, which will nurture these bacteria. A total organic carbon level of 3-5 mg/L is sufficient to sustain the microbes. Anytime makeup water is added to the sprinkler system, fresh nutrients along with some bacteria are also added.

The damaging bacteria fall into two major groups – sulfate reducing bacteria (SRB) and acid forming bacteria. Both are known as anaerobic types of bacteria and can dominate in low flow or stagnant areas in firewater sprinkler systems. SRBs are the most easily identifiable form of anaerobic bacteria. They thrive on naturally occurring sulfate ions in the waters and metabolize sulfates into highly corrosive hydrogen sulfite. When SRBs react with the system metallurgy, they form shiny black deposit sites that release sulfide gasses. Hence, they create an odorous gas, which has a rotten egg smell, and impart a very blackish color to the water. If their biomass is large enough, they can move to partially plug sprinkler heads.

Galvanic Series	
Anode – Corrosion will occur	Magnesium and magnesium alloys
	Zinc
	Cadmium
	Steel/iron
	Cast iron
	18-8 Stainless steel (active)
	18-8 Mo stainless steel (active)
	Lead
	Tin
	Nickel (active)
	Brass
	Copper
	Bronze
	Copper nickels
	Monel
	18-8 Stainless steel (passive)
	18-8 Mo stainless steel (passive)
	Silver
	Titanium
	Graphite
	Gold
Cathode – Does not corrode	Platinum

Selective leaching can be a problem in waters capable of selectively dissolving zinc from a brass alloy. The metal will loose mechanical strength and fail. A pH level below 6.0 and high free chlorine treatment above 1.0 mg/L will contribute to dezincification. Brass is less resistant than Admiralty brass that has 1 % tin. This, in turn, is less resistant than inhibited Admiralty brass that adds low levels of antimony, phosphorus, or arsenic to inhibit dezincification.

Galvanic corrosion can be a problem if the installer of a sprinkler system neglects the impact of the galvanic series. If widely dissimilar metals are placed in contact or in close proximity to each other, an increase in corrosion of the less noble metal will occur. The less noble material is called the anode in the galvanic series while the more noble metal is called the cathode.

Connecting low carbon steel to brass or copper causes the most common type of galvanic attack. In large heat exchangers with Admiralty brass tubes and a low carbon steel tube sheet, zinc sacrificial anodes are often installed. They are bolted to the steel tube sheet and will protect the immediate surrounding area of the tube sheet from corrosion. This approach, however, cannot be applied to most sprinkler systems due to the space requirements. Also, zinc ions coming from the corrosion of the zinc anode can react with orthophosphate ions from the chemical treatment program to produce a zinc phosphate deposit elsewhere in the system and cause problems at that location.

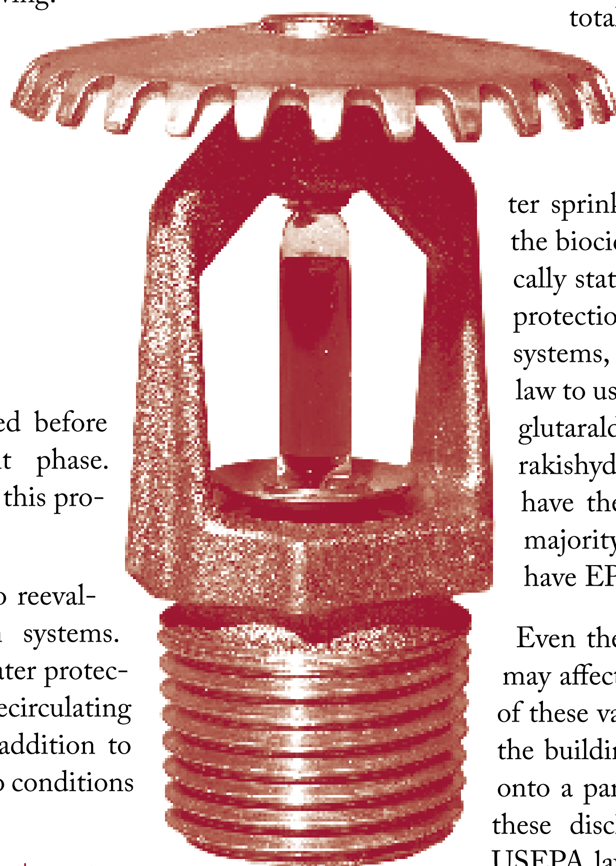
Also, note the position of zinc on the galvanic series. Even though zinc galvanized coatings are used in many applications, they should never be used in firewater protection systems. Zinc coatings are designed to fail eventually. They are used to protect more noble base metal, usually low carbon steel. However, in water service, after the coating is penetrated, the corrosion at that site is rapidly accelerated. Once the armor of zinc is breeched, all of the corrosive attributes of the water literally pour through the hole and attack the underlying metal.

Crevice or under deposit corrosion can occur if the system piping is not properly cleaned before startup. Flux or oils, which are not removed, can produce dissimilarities on the piping surface leading to corrosion. Rather than small pit formation as in pitting corrosion, the surface of the pipe has the appearance that it has been gouged. The presence of biomass from rampant bacterial growth can also cause this form of corrosion in addition to the action of acids generated by the bacteria themselves.

Treatment Protection

The preponderance of sprinkler systems in this country are not being treated for corrosion or even being tested. Most building owners are never aware that a problem exists until a leak happens. Unfortunately, by that time the options are greatly reduced. When a system has had a leak, inspection will frequently show that the entire piping has seriously deteriorated. Existing corrosion deposits and biological slime must be removed before effective treatment can be applied. This is no easy task. Cleaning can involve considerable money and time along with shutting down a portion of the facility during the cleaning operation. The owner often has to make the difficult decision of whether to attempt a thorough cleaning or whether to replace the system. While it may have cost only $0.50-$1.50 per square foot of building space to install a sprinkler system, it can cost $6.00-$7.00 per square foot to replace a sprinkler system in an existing building. Ceilings and walls must often be removed along with other existing piping and wiring to reach the old sprinkler system. Unfortunately, a majority of these systems cannot undergo remediation and have to be replaced. On the positive side, there are a growing number of inspection and testing service companies to whom the owners and sprinkler contractors can turn to get help. A full service company should offer the following:

- Laboratory testing and metallurgical services
- Consulting services
- Inspection services
- Chemical feed equipment
- Biocides
- Corrosion inhibitors
- Test kits



A detailed evaluation is needed before proceeding to the treatment phase. Do not attempt to short circuit this process to save a few dollars.

At this point it is important to reevaluate the firewater protection systems. It should be realized that firewater protection systems differ from open recirculating cooling water systems. Water addition to these systems happen under two conditions normally:

- The sprinkler contractor is testing the system
- There is a fire

If there is a fire, there is minimal concern if proper chemical treatment has been added. However, if you are a sprinkler contractor performing a test, then it is important that the system is being properly protected from corrosion problems. The test itself leads to many of the problems in the sprinkler system. All sprinkled buildings are covered by local codes that require the system be periodically tested to verify operational conformance to fire codes. The frequency of testing varies by locality from monthly to annually. A valve called the "inspector's valve" is opened to allow a rapid pressure drop in the system as would happen if a fire activated a sprinkler. This triggers the firewater main pump to activate and sets off the associated alarms. For a brief period the system is quickly filled with water to replace what is being lost. Usually the total volume is relatively small, on the order of 50 to 200 gallons. However, the incoming fresh water is normally high in corrosive dissolved oxygen and in fresh nutrients for bacteria that are already in the sprinkler water. Depending on the pretreatment of the new water, additional bacteria may also be introduced that will lead to biofouling or MIC.

Traditional closed water system treatment is not totally applicable in this type of operation. For starters, most biocides that are used in cooling water treatment are not approved by the USEPA for use in firewater sprinkler systems. If the container for the biocide being applied does not specifically state that it is approved for firewater protection systems or at least service water systems, then it is a violation of Federal law to use that biocide. Certain versions of glutaraldehyde, isothiazolinone, and tetrakishydroxymethyl phosphonium sulfate have the required approval, but the vast majority of registered biocides do not have EPA approval for this kind of use.

Even the location of the inspector's valve may affect the chemistry being used. Many of these valves are located on the outside of the building being protected and discharge onto a parking lot, street, or field. As such, these discharges are regulated under the USEPA laws applying to storm water sewer discharges or the NPDES permit for receiving waters. In either case, the owner of the property must go through an extensive registration process to obtain permission to use a specific biocide. The procedure is time consuming and in many cases is not worth the effort to obtain a biocide approved for a small use application a few times per year.

Coupled with this dilemma is the fact that almost all sprinkler systems obtain their water from potable water supplies. All new installations are required to have double backflow preventers. Many older systems are simply connected to the drinking water supply without any isolat-

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ing valves whatsoever. Some corrosion inhibitor treatment programs are deemed too toxic to be used in sprinkler systems. Some of the more successful treatments have been blended chemicals that include molybdate, azoles, and phosphonic acids. However, none of these are approved as safe drinking water additives. The only approved products for drinking water contain zinc, phosphate, or silica. This is 1940's technology and did not provide the corrosion protection of later generation products.

The major problem that was alluded to earlier is how to introduce the required chemicals in a rapid manner into the sprinkler system. It has been necessary to use a patented[1] portable chemical feed system. When water enters the fire sprinkler system it activates the pumps via a flow switch. The activation turns on a pump for corrosion inhibitor and another pump for a biocide. A probe that can sense the increase in electric resistivity imparted to the water by the chemicals then senses the chemicals. An activation-mixing chamber modulates the chemical feed pumps, thereby controlling chemical residuals. This allows the chemical blend entering the firewater sprinkler system to be uniformly mixed.

A final look at sprinkler systems brings us to the unique requirements of the dry pipe systems. Because they are regularly flooded during testing and then drained, the corrosion rates are highest in the piping for these installations. They also do not drain out completely, and ponds of water remain in low-lying areas. Both biological and oxygen corrosion can concentrate in these locations. The best approach developed to treat this type of sprinkler system is to inject both a vapor phase corrosion inhibitor (VCI) and a biocide whenever the system is flooded. VCI is a chemical that will volatilize to protect all surfaces even those that are not wetted. Hopefully, the biocide will minimize bacteria growth on wetted surfaces. This technology has been applied to firewater sprinklers besides lay up of boilers and refinery distillation units.

It is very likely that the fire codes regarding corrosion will continue to evolve to meet the changing dynamics of the sprinkler industry.

Conclusion

A new field of water treatment has been developed for firewater sprinkler systems. Traditional water treatment has been modified and adapted to the unusual conditions of these types of protection systems. Separate treatment regimens have been developed for the wet pipe and the dry pipe forms of sprinklers. It has been necessary to invent a new kind of rapid chemical injection pump and control in order to consistently and uniformly feed the required chemistry. Over the next several years the recent changes to NFPA 13 will be mandated at the local level. It is very likely that the fire codes regarding corrosion will continue to evolve to meet the changing dynamics of the sprinkler industry.

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Reference

1. O'Leary, Richard A., 2000. Portable Fire Sprinkler Chemical Feed System. US Patent 6,406,618, filed Aug 2, 2000, and issued Jun. 18, 2002.