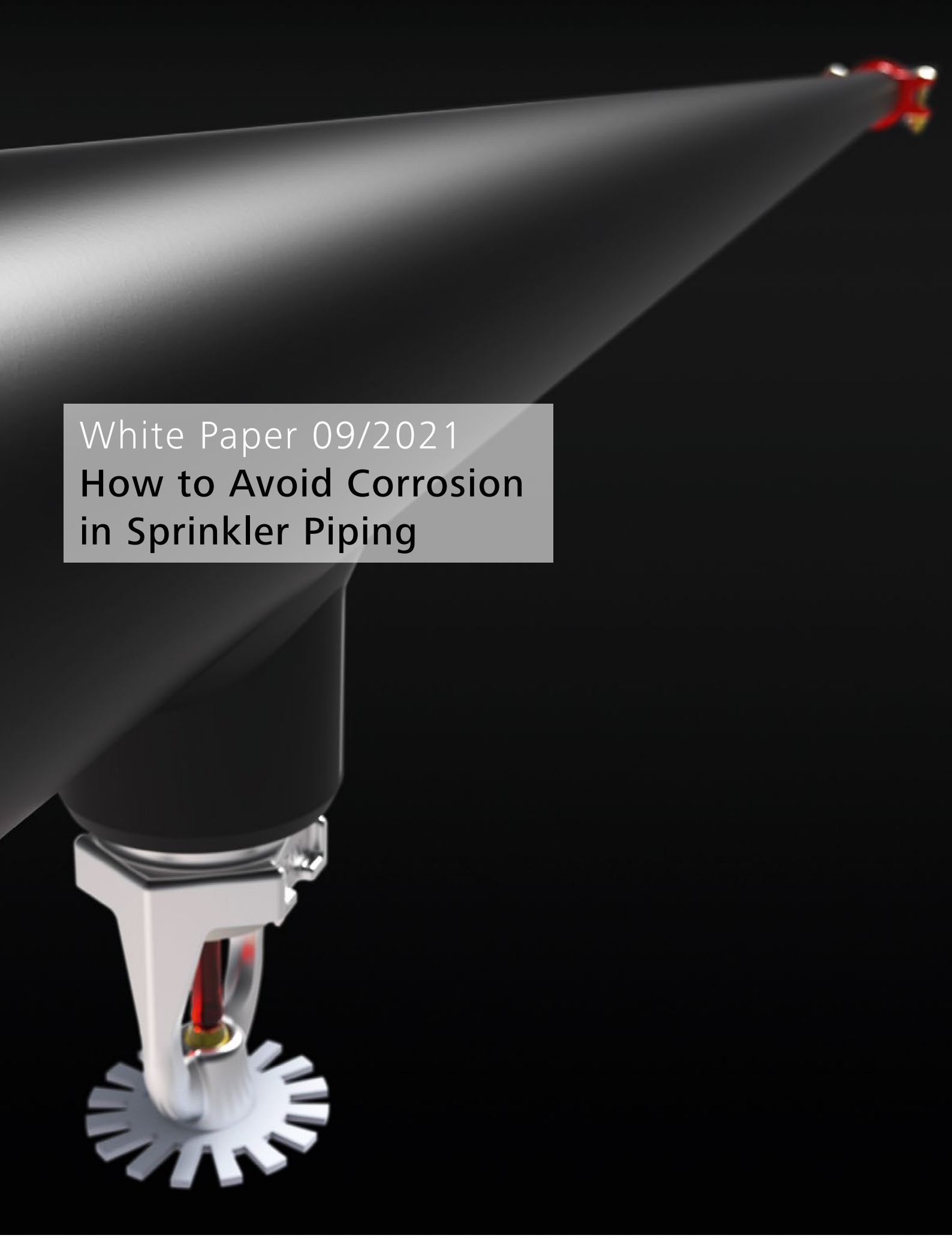


White Paper 09/2021

How to Avoid Corrosion in Sprinkler Piping

TECHNOLOGY

WATER-BASED EXTINGUISHING SYSTEMS

Fendium White Paper 09/2021

How to Avoid Corrosion in Sprinkler Piping

Fire suppression systems typically remain unused for many years, and fortunately, in most cases they are never needed. Nevertheless, they must be ready for operation at any time. Corrosive conditions are often present in the piping of water-based fire suppression systems, which may not only cause perforation of the pipes, but also produce deposits that can reduce the internal pipe diameter.

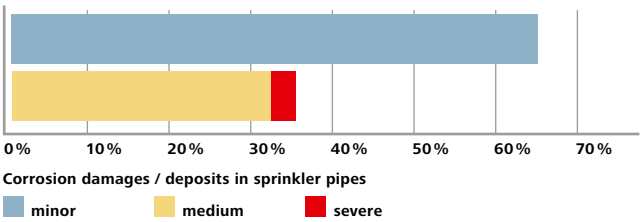
Corrosion causes many problems

Rough and constricted pipes, as well as pipe corrosion products, collecting upstream of sprinklers or nozzles and clogging them impair the system`s extinguishing effectiveness in the event of a fire, thus eventually putting people and assets at risk and jeopardizing the continued operation of the business. Even when the suppression system is in standby mode, corrosion may cause problems: Leakages may occur not only as a result of rust-through, but also due to the roughened surfaces under the gaskets of pipe couplings. Furthermore, it affects the hydraulics. The system is no longer able to provide the amount of water and/or the pressure for which the system was originally designed.

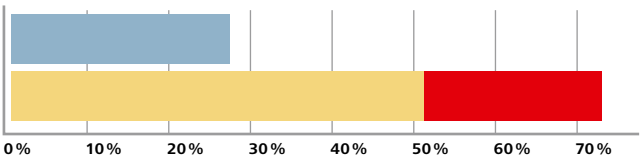
Corrosion may result in costly water damage, business interruptions and reduced system reliability. At the end of the day, corrosion has an impact on the overall safety of fire suppression systems.

The negative impact that corrosion has on sprinkler systems has also been investigated by VdS (VdS Schadenverhütung – an independent approval and inspection body for fire protection products and systems). One in three wet pipe systems shows medium to severe corrosion issues within 25 years, which often requires replacement of the affected pipes. In two out of three dry pipe systems, repair and/or replacement is required after only 12½ years. This means that corrosion impairs not only the functional safety of the fire suppression system, but also leads to substantial repair costs for system owners and operators in the long term.

Wet pipe systems after 25 years



Dry pipe systems after 12½ years



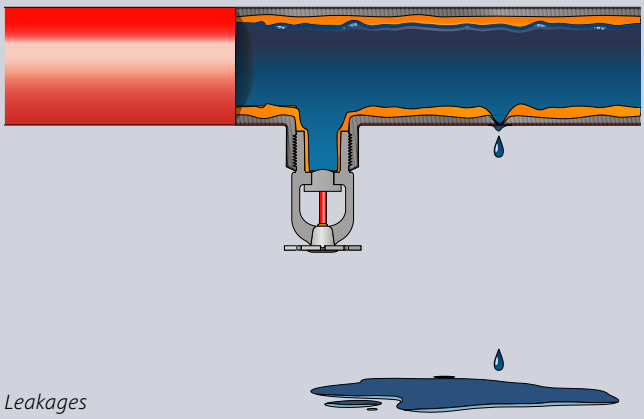
VdS statistics on inspections of old systems

Insurance companies are also aware of the problem with corrosion. FM Global has carried out thorough investigations in this area and has published a research paper (Paul Su et al. 2014) and a data sheet (FM Global 2018) on the subject. Their investigations show that corrosion "occurs in all sprinkler systems and is one of the major issues for maintenance and operation of Fire Protection Systems such as wet pipe, dry pipe, and preaction systems. Corrosion damage/products and mineral deposits can restrict water flow to sprinklers and impair mechanical operation of fire protection system equipment, leaving facilities vulnerable to uncontrolled fire loss". (Paul Su et al. 2014, p. i)

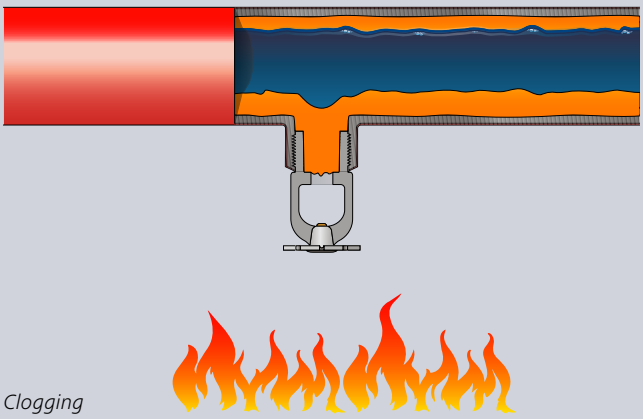
Corrosion has many faces

The FM report describes corrosion as a process that "involves the reaction between a metal or alloy and its environment. It is an irreversible interfacial process, which causes the gradual deterioration of metal surface by water (or moisture) and corrosive chemicals."
(Paul Su et al. 2014, p. 7)

Corrosion in the steel pipes used traditionally for water-based suppression systems comes in many forms: Pitting corrosion causes perforation and rust-through. Surface corrosion leads to rough surfaces, encrustations and deposits that increase pipe friction and reduce the clear cross-section of the pipes. Corrosion deposits may come loose and cause clogging.



Leakages



Clogging

The problem of corrosion occurs not only in wet pipe systems, which are permanently filled with water, but also in dry pipe and preaction systems, which are particularly at risk due to moist compressed air and water that collects in the low points of the piping. As the problems start on the inside of the pipes, they often remain undetected for long periods of time.

Many approaches have unsuccessfully tried to solve the problem

Traditionally, water-based suppression systems are installed using steel pipes with paint or powder coating on the outside. On the inside, however, these pipes are untreated and are, therefore, not protected against corrosion. For many years, galvanized pipes were considered as an alternative, especially for dry pipe systems. Indeed, even small quantities of water contained in dry pipe and preaction systems – in conjunction with salts, oxygen and carbon dioxide – can lead to a disintegration of the zinc coating.

Corrosion could largely be avoided by using stainless steel pipes in water-based fire suppression systems. Nevertheless, they are rarely used for this purpose due to cost reasons.

Galvanized pipes

Galvanized pipes are steel pipes that have a protective zinc coating on the outside and on the inside to prevent corrosion. For a long time, this was assumed to be the answer to corrosion. Today, it is known that exposure to water will cause galvanized pipes to corrode quickly in the environmental conditions often existing inside pressurized piping. The porous corrosion products of the zinc are an ideal ground for the growth of bacteria and local corrosion spots.

Furthermore, it is possible that hydrogen may accumulate due to corrosion in wet pipe systems. FM Global Data Sheet 2-1 recommends not to use galvanized pipes in wet systems. (FM Global 2018, p. 3)

Nitrogen fill

"Another corrosion mitigation approach is to fill the dry pipe or preaction systems with nitrogen gas from gas cylinders or an on-site nitrogen generating system." (Paul Su et al. 2014, p. 63)

FM Global Data Sheets 2-1 (FM Global 2018, p. 8) and 2-81 (FM Global 2020, p. 46) recommend the use of nitrogen gas as the supervisory gas where corrosion is a concern. Filling these systems with nitrogen gas can remove oxygen and decrease oxygen-related electrochemical reactions.

However, in order to have an effect, a very high nitrogen content of 98 % or more needs to be permanently provided in the pipework, which would mean costly devices. Such high nitrogen concentration, though, may result in health and safety issues when a high concentration of the gas is released into small rooms in the event of leakages or after a sprinkler activation.

Additives

The piping of fire suppression systems is sometimes treated with chemical agents in order to try to reduce chemically or microbiologically induced corrosion (MIC). Such treatment may have an effect if the origin of the corrosion is clearly known and the added chemical substances are exactly adapted to the environmental conditions in the piping, to the materials used and to the composition of the water. Due to the complexity of corrosion processes, this is rarely the case, especially when biological processes are involved.

Irrespective of this, adding chemical corrosion inhibitors needs costly technical devices and/or regular activities as well as regular measurement and refill. Consequently, FM Global does not recommend the use of pipe cleaning and water treatment chemicals for sprinkler systems. Indeed, they consider such agents as troublesome.

Fendium Polymer-Enhanced Steel Pipe is the answer to corrosion issues

Fendium pipe is steel pipe with a special polymer protecting it against corrosion on both the outside and the inside. In contrast to paint and powder coating, the polymer-protection is formed in a chemical process unifying polymer and steel.

The special Fendium polymer-protection is produced in several process steps. After thorough cleaning and pretreatment, the steel pipe to be enhanced is dipped in a tank filled with Fendium polymer emulsion. Iron fluorides contained in the emulsion are continuously supplied to the pipe and provide a release of iron ions on the surface of the steel pipe.

As soon as the positively charged iron ions collide with the polymer particles also contained in the emulsion, they adhere to them and partly neutralize their negative charge. The polymer particles are now able to combine with each other and are attracted to the positively polarized steel pipe surface.

In this way, the polymer-protection is created and the pipe's roughness is smoothed out. Once the desired level of polymer-protection is achieved, this process step is terminated by removing the pipe from the dip tank. To continue the process, gelling takes place in the pre-dryer. The pipe is warmed up, causing the polymer particles to run into each other and the pipe to be smoothened further. Finally, the polymer is baked and cured in a hot-air oven. The result of the polymer-enhancement is a gradual transition from the steel core to pure polymer.

Fendium pipe can be used for almost all types of water-based suppression systems. It is available with different levels of polymer-protection suited to the respective corrosive conditions. The Basic Series of Fendium pipe are intended exclusively for use in wet pipe sprinkler systems. The Plus Series provide even stronger polymer-protection and are therefore also well-suited for areas with greater risk of corrosion, including dry pipe and preaction sprinkler systems, deluge systems, low-pressure water mist systems, hydrant systems and dry risers.

The Fendium polymer-protection is not only able to be applied to straight pieces of pipe. On the contrary, in the MV Pipe Technologies GmbH plant in Wittenberge, Germany, the polymer-enhancement is produced directly after the mechanical prefabrication of a piece of pipe. This means that, first of all, a piece of pipe is cut to length, bores are cut into the pipe where outlets will be located, those outlets are welded onto the pipe and grooved ends are rolled onto the pipe. Afterwards, the polymer-protection is produced, covering and providing corrosion protection on all surfaces. The geometry of each piece of pipe is as ordered by the sprinkler system contractor.

The corrosion resistance has been extensively tested

In order to evaluate the corrosion resistance of materials over a shorter period, many industries have developed methods using a salt fog environment. Standards like EN 12259-1 (sprinklers) or EN ISO 7384 (corrosion tests in artificial atmospheres) use this.

In order to assess the corrosion resistance of Fendium pipes, FM carried out extensive investigations and developed a new test protocol representing the situation in real fire suppression systems. (Paul Su et al. 2019) Four materials were analyzed and compared in terms of their corrosion resistance: stainless steel, galvanized steel, carbon steel without inside protection and Fendium pipes. A standard salt fog cyclic corrosion test chamber was used to expose specimen to an aqueous suspended fog environment created by a 5.5 % Sodium Chloride (NaCl) solution.

Coupons and pipe sections were removed from the test chamber for corrosion evaluation and ranked after 0.5, 1, 3, and 6 months of exposure in terms of the extent of corrosion which had occurred (material degradation/loss).

The galvanized steel and carbon steel pipe sections exhibited severe corrosion after one month of testing. The reddish-brown corrosion products on the carbon steel pipe surface are so-called "rust" [i.e. hydrated iron (III) oxides $Fe_2O_3 \cdot nH_2O$ and iron (III) oxide-hydroxide (FeO(OH))]. For galvanized steel specimens, white corrosion products [e.g. zinc oxide (ZnO) and zinc hydroxide ($Zn(OH)_2$)] cover their surfaces, along with reddish-brown rust, indicating that the sacrificial zinc layer on the galvanized steel pipe surface was locally depleted, which led to the corrosion of the underlying bare steel. Conversely, only minimum corrosion was observed on the stainless steel and Fendium pipe sections.

Results after one month salt fog exposure

Stainless steel	Fendium	Galvanized steel	Carbon steel

In summary, based on the corrosion rate data of coupons for up to six months of testing, corrosion resistance of the four types of coupons can be qualitatively ranked as

1. stainless steel
2. Fendium
3. galvanized steel
4. carbon steel,

which is the same ranking result as for the pipe sections after exposure.

The corrosion rate of Fendium Polymer-Enhanced Pipe was shown to be only slightly worse than the stainless steel samples.

Galvanized steel pipe was shown to have a corrosion rate approximately six times the rate of Fendium pipe.

Carbon steel pipe had a corrosion rate of approximately 16 times the rate of Fendium pipe.

The hydraulic benefits of Fendium

As the interior surface of Fendium pipes over time is much smoother than standard carbon steel or even galvanized pipes, the friction losses are much lower. This results in Fendium pipes having a C-value (a factor used in the calculation of friction losses) closer to stainless steel and plastic pipes. This allows the system designer to use a different factor in their calculation and design which can result in smaller and lighter pipes.

Fendium also ensures better long-term hydraulic performance from the system. Otherwise, if corrosion occurs, it will lead to deposits, a reduction in internal pipe diameter and also increased roughness. This results in a reduction in hydraulic performance of the system as friction losses increase.

Compared to carbon steel and galvanized pipes, this reduction in hydraulic performance is significantly reduced with Fendium pipes, meaning the system will perform as intended for a longer period. In addition, based on the corrosion testing of coupons and pipe sections in this study, (Paul Su et al. 2019), the C-value of the Fendium piping can be qualitatively categorized as being higher than those of galvanized steel and carbon steel piping but less than that of the stainless steel piping. Based upon this work, FM supports the use of a C-value of 140 in the design of both wet and dry sprinkler systems using Fendium pipes.

Conclusion

Corrosion can have several detrimental effects on the performance of water-based fire protection systems. The products of the corrosion process can restrict or even completely block the flow of water through the system, rust-through can cause costly damage and business interruption, and the roughness can reduce the hydraulic performance of the system over time. Fendium pipes have been tested and certificated by VdS and FM who have recognized that Fendium provides better protection against corrosion and improves the system hydraulics when compared to traditional black steel or galvanized pipes.

References

FM Global, *Property Loss Prevention Data Sheets 2-1, Corrosion in automatic sprinkler systems,* 2018.

FM Global, *Property Loss Prevention Data Sheets 2-81, Fire protection system inspection, testing and maintenance,* 2020.

Paul Su and David B. Fuller, *Corrosion and Corrosion Mitigation in Fire Protection Systems,* 2014.

Paul Su, Rajni Madan and Fred W. Tatar, *Corrosion Evaluation of Coated Steel Sprinkler Pipe by Minimax Viking,* 2019

VdS

FM APPROVED