PART ONE OF TWO

Fire Sprinkler Systems

Corrosion Related Failures

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Corrosion mechanisms are the primary cause of many Fire Sprinkler System (FSS) failures. These manifest themselves as pinhole leaks in the sprinkler piping and blockage due to accumulation of corrosion product deposits in the pipe interior. When pinhole leaks occur in critical manufacturing areas they can cause water damage to highly sophisticated and expensive tools and downtime for repairs and restoration of conditions. With the presence of corrosion product deposits there is a real concern if the systems will operate as intended in case of an emergency. Quite often the corrosion problems are difficult to locate, identify and treat in a cost-effective manner. However, a condition assessment of the affected system by qualified corrosion engineers with a working knowledge of FSS, is a cost-effective methodology to determine the nature and extent of necessary rehabilitation options.

"A catastrophic failure may have occurred and it could be too late to salvage the system."

Introduction:

In the U.S. alone, monetary losses due to corrosion total three to four percent of the gross domestic product[1]. Corrosion costs the utility industry billions of dollars each year in forced outages, repairs and replacements. Investigations of catastrophic aircraft accidents have shown corrosion mechanisms as the primary cause of failure. Everyone is certainly familiar with rust on your childhood swing set or the experiment in school, monitoring a nail rust in a glass of water. As it turns out, some of these same corrosion mechanisms have been identified as the root cause of failures in many FSS.

Fire Sprinkler Systems are failing prematurely due to corrosion related mechanisms that ultimately result in pinhole leaks in the sprinkler piping. In addition, the efficiency and operability of these systems are adversely affected by accumulation of corrosion product deposits in the pipe interior thereby impacting the designed hydraulic coefficients (C-Factors/Hazen-Williams Coefficient). There are a growing number of cases describing pinhole leaks in mission critical areas causing monetary losses due to damage to sensitive equipment, inventory or work/production stoppage[2]. Also, more alarming are the cases describing sprinkler heads activating in response to heat from a fire but little or no water being released due to internal blockage in the sprinkler pipe by corrosion products[3].

The internal accumulation of corrosion products in a FSS is difficult to locate in a cost effective manner due to the following reasons:

Smaller diameter branch lines and limited access to the piping (i.e. interstitial plenum areas in clean rooms) make it difficult to inspect. Often a small isolated part of the FSS may be impacted by corrosion, which can be a challenge to locate.

Therefore, the problems usually do not become apparent until a pinhole leak develops or the system is activated and no water is discharged. At this point a catastrophic failure may have occurred and it could be too late to salvage the system. The NFPA 25 2002 Chapter 13 (Maintenance…) requires an obstruction investigation every five years. However, without experience and a good understanding of the corrosion mechanisms at work, it will be very difficult to locate and investigate the susceptible areas of the FSS.

Corrosion control programs in other industries (i.e. municipal water, industrial cooling water) have been successful in controlling the problems described above in mechanical piping systems with circulating water. However, in the case of wet FSS, the water is static which makes it much more difficult to control the corrosion mechanisms by means of chemical treatment. In dry systems, undrained, residual water may have long residence times. In addition, any type of chemical treatment brings with it some degree of environmental impact and liability that may arise from accidental discharge and human contact.

Fire Protection Systems have been around for many years so why are the problems appearing now? Following are a few possible answers:

Renovation — as facilities expand, FSS need to be reconfigured. With draining and recharging of systems, aerated water is repeatedly introduced resulting in abundant availability of oxygen for the corrosion reaction to occur.

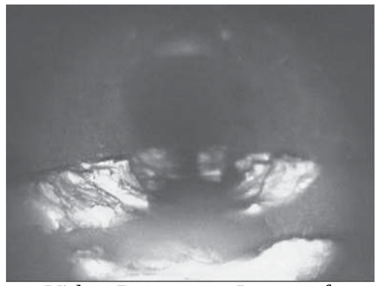
Pipe schedules — in recent years, lighter pipe schedules are being specified. If the conditions for corrosion exist, the pinhole leaks will certainly appear within a shorter period of time.

Maintenance and installation practices — when a wet system is being charged with water, the inspection port is not kept opened long enough to release as much of the air out of the system as possible. In many instances, the drain is not opened at all. (Veteran sprinkler fitters will attest to how sprinkler heads were not tightened on a new installation until water flowed from the opening thereby purging all trapped air from the system).

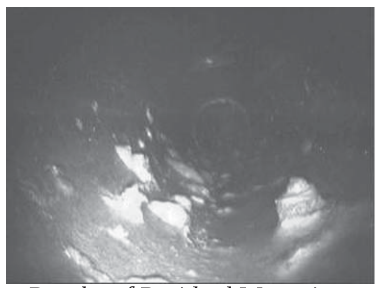
Disinfectant — the presence of corrosion products in the sprinkler pipe interior coupled with long residence times diminishes the available chlorine (typical disinfectant used in the water supply), which might otherwise limit biological fouling activities[4].

High Tech industry — as multi million dollar claims are investigated the awareness increases, along with media attention and liability/law suits.

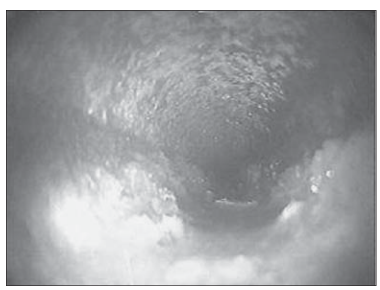
The fire protection industry is beginning to address corrosion issues. The National Fire Protection Association (NFPA) Research Foundation has initiated a project to research the extent and types of corrosion problems encountered in FSS. The American Fire Sprinkler Association (AFSA) and National Fire Sprinkler Association (NFSA) have conducted on-line seminars with corrosion experts and are actively participating in researching the issues. Society of Fire Protection Engineers (SFPE) has organized seminars and roundtable discussions with experts in the industry. The insurance companies are investing money into research and releasing information for their clients on how to prevent and remedy corrosion problems. Sprinkler pipe manufacturers are investing into research for the development of internal protective coatings.



Video-Borescope Image of a Dry, Galvanized System with Residual Water



Results of Residual Water in a Dry Sprinkler System



Tuberculation due to Residual Water in a Dry Sprinkler System

Corrosion Basics As they Relate to FSS

As all other corrosion reactions, corrosion of FSS piping is electrochemical in nature. Localized anodic and cathodic areas are dispersed over the exposed surface of the piping. The location of these may be related to local impurities and/or defects in the piping materials, the presence of an air/water interface, localized bacterial activity or may be entirely random.

In order for a corrosion reaction to initiate and progress, three requirements have to be met:

Unprotected Metal
Electrochemical Potential
Electrolyte (such as water)

If any one or more of these conditions do not exist, the corrosion reaction cannot take place. In FSS, water is the electrolyte and the availability of oxygen for the oxygen reduction reaction is required to maintain the oxidation of steel at the anode. Without the availability of oxygen, there is no electrochemical potential and no corrosion can take place.

When a wet FSS system is initially charged with fresh, oxygenated water, corrosion of the steel initiates, but the oxygen is quickly depleted and the corrosion reaction effectively stops. The product of this initial corrosion reaction is a characteristic layer of black iron oxide (magnetite) on the pipe ID surface. If the system is maintained in this condition, little or no further corrosion of the material occurs until the next time oxygen is introduced into the system. However, if the system is continuously drained and recharged with fresh oxygenated water, or if there is a substantial amount of air trapped in the system, corrosion continues to occur. This is especially true at the water/air interface in systems with trapped air.

Dry or pre-action systems are often found with residual water that remained trapped in the system due to inadequate sloping or inadequate provision for drainage after initial hydrotesting as required by NFPA 13. These systems are typically monitored with compressed air, thereby providing an unlimited supply of oxygen. Galvanized piping is frequently used for these systems. Initially, the zinc coating cathodically protects the underlying steel, but as the zinc is oxidized, localized penetration of the zinc coating takes place resulting in corrosion of the underlying steel. These areas of localized corrosion usually manifest itself at the six o'clock position and water/air interface in the form of reddish-brown nodules of iron oxide.

As the corrosion reaction progresses, the penetration rate of the localized pitting increases due to the occlusion resulting from the growing mound of corrosion products covering the pit. A reduction in the availability of oxygen in the bottom of the pit (referred to as differential aeration by corrosion engineers) results in changes in the local chemistry and pH, causing an increase in the rate of local oxidation of the steel leading to an "electrochemical drill" effect. If MIC (Microbiologically Influenced Corrosion) causing bacteria are present in significant quantities, this process can potentially be accelerated. The end result is the same for both wet systems with trapped air and dry systems with residual water — small pinhole leaks at these locations.

End of Part I. Part II, including references, will be in July. Or for the complete article you may contact the authors.

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