White Paper

Managing Fire Sprinkler System Risk in a Mission Critical Data Center Setting

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Important Questions to Ask

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Proper management in the mission critical data center space revolves around the incorporation and integration of systems and designs that optimize uptime. One of the primary elements of this approach is redundancy. One of the gauges of critical systems performance therefore is the degree to which back up accommodations are present in a system design to mitigate the risk of system failure and the associated potential downtime.

Yet, even with systems in place to manage downtime, the Uptime Institute identifies "human error" as the leading cause of data center downtime. In many industries, the appropriate response to human error risk is the development of detailed protocols, sometimes referred to as administrative controls, for mitigating errors in human judgment. The Uptime Institute's new Management & Operations (M&O) Stamp of Approval is designed to assess the risk and provide a protocol for improving performance and reducing risk.

There is however a commonly unidentified risk within the data center environment associated with fire sprinkler systems. This risk is one that few owners consider and even fewer properly understand. Most IT professionals who manage data centers are very uneasy at the thought of water filled pipes above their data halls. As such the "typical" fire sprinkler design employs double-interlock preaction systems which do not have pipes in the ceilings that are filled with water. In the double-interlock preaction design water fills the fire sprinkler piping only after the designated detection system(s) and a sprinkler activation (which is recognized by a quick pressure loss in the system). The system incorporates redundant detection in order to reduce the chances that a false alarm or the loss of supervisory gas pressure will fill the pipes with water and discharge water through any open sprinkler(s).

Despite the obvious advantages of these systems, they introduce another risk that is often overlooked, a high propensity for internal corrosion in the fire sprinkler piping. To address this risk of corrosion, most data center double-interlock preaction fire sprinkler systems also employ galvanized steel piping to provide an additional layer of protection to prevent corrosion related leaks. The industry started using galvanized steel piping several decades ago as a response to corrosion problems in black steel piping. The most common application for galvanized steel piping was generally for water filled domestic supply pipes that had regular water flow. Galvanization was shown to significantly delay the normal occurrence of corrosion in ordinary domestic piping. The use of galvanized steel piping was applied to preaction fire sprinkler system piping because it was known to be vulnerable to accelerated corrosion rates.

The use of galvanized piping drove up the cost of the systems but the investment was considered appropriate as the presence of corrosion in fire sprinkler piping could cause plugging at the sprinkler due to the creation of corrosion by-product and corrosion tuberculation in the piping. Galvanized piping was also recommended by insurance companies to insure optimal performance of the suppression systems. However, recent research[1] has suggested that galvanized steel piping may in fact be more vulnerable to corrosive degradation than was previously believed. Numerous recent case studies in the last four years have validated the suspicion as highlighted below:

> **Case No. 1:** Large co-location data center operator in the Eastern US spends in excess of $1MM replacing corroded galvanized steel piping over a "live" data center. The system was less than 10 years old and showed significant corrosion and through the wall failures throughout the piping network. The failed galvanized steel piping was replaced with galvanized steel piping.

> **Case No. 2:** Leak in 3" fire sprinkler main line above a data hall in the Midwestern US. Subsequent video inspection of the internal surfaces of the fire sprinkler piping revealed significant trapped water throughout the fire sprinkler system. Analysis of fire sprinkler pipe samples from the system indicates 60%+ pipe wall penetration in many locations.

> **Case No. 3:** Entire double-interlock preaction fire sprinkler system in the Southwestern US is replaced by general contractor in a new data center after less than five years of service due to corrosion related leaks. Galvanized steel piping had been used throughout the systems.

> **Case No. 4:** Leaks in fire sprinkler piping in a multi-story data center facility in the Midwestern US. An analysis of the failed galvanized steel piping revealed corrosive attack of the pipe seams under trapped water within the systems. This same type corrosion related failure of the galvanized pipe identified on several different floors of the facility.

In one last sample case study located in the Southeastern US a wet pipe fire sprinkler system in the office floor above a data hall failed and flowed for 20 minutes producing 6 inches of standing water. As the fire sprinkler water cascaded onto the data hall below, the data center was shut down. In this particular mission critical setting the resulting costs due to the shutdown were estimated at $100M. A gasket in a fire sprinkler main coupling failed after a repair for a corrosion related leak. So although the corrosion leak did not occur in the data hall piping, the line failure that occurred after the leak repair indirectly caused the shutdown.

Unfortunately, these case histories are only a small sampling of the many unexpected incidents I have been requested to investigate. More importantly, these incidents are from diverse geographical regions and data center types.

The record of these dire events reveals several significant facts regarding galvanized sprinkler system piping and the associated corrosion problem. It is evident that the problem:

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- is very widespread
- is not limited to a certain geographic region
- can occur very early in the life of the piping system
- is not necessarily limited to certain locations or joints in a system
- is not necessarily confined to where a pinhole occurs
- can be present in a very large portion of the system
- can have severe ramifications
- can be extremely expensive to remedy

These observations can hardly be considered to be overstatements for the cases speak for themselves. They reflect the sobering discoveries within these data centers and are provided simply to communicate the experience of various unrelated data centers across the industry. However, as a scientist reviewing these case history events, the data from the field is quite compelling regarding corrosion in fire sprinkler systems and the potential for the number and frequency of corrosion related failures to occur.

Contributing Factors

The problem with the fire sprinkler industry relative to mission critical data center installations is that there are currently no "standards" for fire sprinkler design and installation that take into effect the elevated risks associated with corrosion. In general, all businesses carry four different types of fire sprinkler system related risk:

- **Life safety risk** – will the fire sprinkler system provide the appropriate level of response to prevent injury or loss of life?
- **Catastrophic structure risk** – will the fire sprinkler system prevent loss of the structure?
- **Piping failure risk** – will the sprinkler piping fail and leak during a dormant period resulting in water damage to the structure and contents?
- **Business continuity risk** – will the failed (leaking) fire sprinkler system cause business interruption?

It would appear that all businesses bear some level of risk from each of these categories. However, data centers carry a very disproportionate risk in two key areas: ***Hardware risk*** and ***business continuity*** risk. Even a small leak in the fire sprinkler piping above a data hall can easily damage the water sensitive hardware stored and operating in the data hall. A leaking pipe could easily destroy a stack of servers resulting in a million dollar loss. But the million dollar hardware loss is dwarfed by the loss potential that resides in the business continuity risk. For example, shutting down a data center serving a financial institution that is active during the trading day on the stock exchanges could result in multiple millions of dollars in losses not to mention the liability risks associated with their client losses. In data center colocation installations the chain of liability risks associated with a leak failure could be myriad with many lawyers and many parties pointing fingers.

In the past, the data center industry has believed that they were managing risk by using dry pipe (preaction) fire sprinkler systems in place of the water filled wet pipe systems. Further there was a strong belief that the use of galvanized steel piping in data centers would mitigate the leak risk. All of the other risk management energy within data centers focused on HVAC cooling systems, electrical systems, air quality systems, back-up power systems and reserve fuel storage systems. It would be unfortunate if a catastrophic fire sprinkler system failure was the necessary impetus that generated the necessary focus on this potential problem.

The source of the risks that are created within fire sprinkler systems in the data center setting come from a variety of areas within the chain of involved parties. A ranking of the risk elements that contribute to corrosion risk is as follows:

1. Design Practices

For the most part fire sprinkler specifying engineers for the data center industry have chosen to use a design that on the surface appears to mitigate risk, i.e. the double-interlocked preaction fire sprinkler system using schedule 10 galvanized steel piping. First of all, the preaction system is a "dry pipe" system wherein the piping above the ceiling is not completely filled with water during the pre-response time interval. Second, the double interlocked design puts time into the fire sprinkler response equation because it requires more detection signals before the preaction water valve is opened. Unlike a simple differential pressure dry pipe valve which is mechanical, a preaction system requires an electrical signal to open the water valve. Third, the use of galvanized steel pipe ostensibly provides another margin of safety for protection against corrosion of black (mild) steel piping.

The National Fire Protection Association (NFPA) requires that all dry and preaction fire sprinkler systems be hydrostatically tested before they are commissioned for service. The result of this necessary exercise is that there are always small pools of trapped water in the fire sprinkler piping. It is virtually impossible to drain out all of the water after the test. Additional amounts of water are added to the piping during periodic system testing (also required by the NFPA). A third source adds moist air each time the pressure maintenance compressor clicks on to keep the piping pressurized. The moisture in the air eventually condenses to produce condensate water within the piping. Until the 2007 edition of the installation standard for fire sprinkler systems, NFPA 13 did not require preaction fire sprinkler systems be "pitched" to allow draining of trapped water from the piping. This means that most preaction systems installed before enforcement of the 2007 edition of NFPA 13 are not pitched and invariably contain significant amounts of trapped water.

Corrosion cannot occur without liquid water. In the case of preaction fire sprinkler pipes, all of the necessary elements are present: the steel piping, water and plenty of oxygen. Corrosion is inevitable in these systems and depending on the number of trapped pools of water, the amount of water and the amount of oxygen the corrosion rates can be quite high.

Evidence of trapped water in piping

One other ironic twist in the corrosion equation is that any pin holes that develop are always in intimate contact with the pool of water that formed them. Further, they are almost always located at the 6 o'clock position in the fire sprinkler piping. The net result is that the corrosion hole almost always delivers a significant quantity of water into the protected space when the leak finally breaks open. The pressurized air pushes rusty water through the pin hole as a fine mist propelled by the pressurized air in the system onto the electrical circuitry of the servers below.

2. Construction Materials

Anodic hot spot due to weld-o-let installation

Fire sprinkler systems in data centers use galvanized steel piping almost exclusively. In fact although the NFPA does not require galvanized steel piping in dry and preaction systems, insurance underwriters have recommended/required its use in most of their client data center installations for at least the past 15 years. The problem with galvanized steel piping is that the most recent findings from the field and the laboratory indicate that it is more susceptible to corrosion related leaks than black steel[2,3]. If schedule 10 piping is used, documented failures in fire sprinkler piping have occurred in as little as 12 months[4].

Our extensive case log of data center fire sprinkler piping failures proves conclusively that galvanized steel is more susceptible to corrosion related leaks than black steel. Further, in order to reduce the corrosion risk removing oxygen from the piping atmosphere appears to be the only remedy to the corrosion problem. Even if expensive dryers are employed to reduce the amount of water that is introduced by the pressure maintenance compressors, small amounts of trapped water are inevitable because of the commissioning and testing protocols for fire sprinkler systems.

Another factor contributing to corrosion related leaks is the lack of heat annealing of the weld seam on fire sprinkler piping. The current ASTM Standards for the fire sprinkler industry do not require that the weld seams be heat annealed, the result is that the piping is subject to "knife cut" corrosion wherein the weld metal and the heat affected zone adjacent to the weld corrode preferentially to the rest of the pipe. If the weld seam happens to end up installed under trapped water, failures in schedule 10 galvanized steel piping have occurred in as little as 12 months.

Knife cut corrosion on submerged weld seam (galvanized steel pipe)

3. Installation Practices

As with any trade in the construction industry the quality of the finished product varies with the quality of the installing contractor. Unfortunately, in the case of the fire sprinkler system the burden of risk that is attributable to a poor installation ultimately falls on the data center operator. The most common problems include:

- Fire sprinkler piping that is not pitched to drain effectively
- Water traps that are inadvertently created within the piping network
- Insufficient number of auxiliary drains within the systems to remove accumulations of trapped water
- Systems that leak air from the piping in much greater quantities than the code permits which result in more frequent addition of warm, moist oxygen from the pressure maintenance compressor

Recommendations

The greatest risk to data center uptime may be the risk that has not yet been sufficiently recognized or quantified. There is now a significant body of field and laboratory evidence that suggests that many data centers may start seeing increased leak frequency in the fire sprinkler systems that protect the data halls. As data centers age the likelihood of leaks related to corrosion grows. As more and more data centers are constructed to support the expanding need for IT services the contributing risk factors will need to be addressed to protect against downtime.

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For existing data centers

1. Employ a corrosion engineering firm that is well versed in the unique attributes of fire sprinkler system corrosion to evaluate the current failure risk and to design a comprehensive remediation and corrosion management strategy moving forward
2. Perform internal video assessments of the existing double-interlock preaction fire sprinkler systems to determine the current level of risk using an experienced fire sprinkler system corrosion engineering firm
3. Retrofit and remediate existing fire sprinkler systems to reduce the current level of risk
    a. Replace piping that has deteriorated beyond it usable life
    b. Install auxiliary drains as necessary to ensure adequate drainage of trapped water
4. Install an integrated **Dry Pipe Nitrogen Inerting (DPNI)** system to remove oxygen and prevent oxygen corrosion within the fire sprinkler system piping
5. Develop a set of standards for DPNI systems that address the unique needs and risks for fire sprinkler systems in the data center industry

For new data centers

1. Utilize a competent corrosion engineering firm that is knowledgeable in the unique attributes of fire sprinkler system corrosion to integrate a comprehensive corrosion control strategy into the fire sprinkler system design
2. Stop using galvanized steel piping in data center fire sprinkler systems
3. Create a more stringent installation standard – consider certifying or otherwise qualifying fire sprinkler contractors
4. Integrate **Dry Pipe Nitrogen Inerting (DPNI)** into the fire sprinkler system design to prevent oxygen corrosion and to reduce the leak risk in data center double-interlock preaction fire sprinkler systems
5. Develop a set of standards for DPNI systems that address the unique needs and risks for fire sprinkler systems in the data center industry

The bottom line is that data center professionals cannot afford to ignore the risks that corrosion in fire sprinkler piping creates within their data halls. Standards must be developed and adopted for the design, installation and maintenance of fire sprinkler systems in the mission critical setting. Management of the risks associated with these systems must become an integral part of the uptime management process.

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References

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[3] "Mission Critical Facilities – Is the Use of Galvanized Pipe an Effective Corrosion Control Strategy in Double Interlock Preaction Fire Protection Systems?" by Jeffrey Kochelek, **White Paper - Mission Critical Magazine**, Spring 2010.

[4] Failure analysis results from internal research work performed on dry pipe canopy system using schedule 10 galvanized steel piping.

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Engineered Corrosion Solutions, LLC is a corrosion management consulting firm that offers fire sprinkler system assessment and analysis coupled with design services and a full suite of corrosion management strategies that include equipment and integrated devices for controlling corrosion in water-based wet, dry, and preaction fire sprinkler systems. We understand the science of corrosion in fire sprinkler systems in a complete variety of different settings from parking structures to warehouses to clean rooms to data centers.

Engineered Corrosion Solutions, LLC offers proprietary dry pipe nitrogen inerting technology (DPNI) and wet pipe nitrogen inerting technology (WPNI), which includes the ECS Protector Nitrogen Generator, Pre-Engineered Skid Mounted Nitrogen Generator, Gas Analyzers, SMART Dry Vent, Two (2) Wet Pipe Nitrogen Inerting Vents and the industry's first real time in-situ corrosion monitoring device the ECS In-Line Corrosion Detector. Finally, we offer the first comprehensive remote corrosion monitoring system that provides live validation of the corrosion control strategy that is in place within your facility.

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