White Paper

External Atmospheric Corrosion of Malleable Iron and Cast Iron Fittings and Component Parts in Wet Pipe Fire Sprinkler Systems

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Wet pipe fire sprinkler systems are often installed in locations that involve exposure of the sprinkler piping to ambient unconditioned outside air. In areas of the country where there is no risk of freezing, wet pipe fire sprinkler systems can be installed outdoors. Exposure to ambient air may be constant as in the case with outside parking structures or intermittent as in the case with many warehouses where loading and unloading operations occur with open garage doors. Other examples where wet pipe fire sprinkler systems are exposed to ambient air include airports, garden centers and entry vestibules. In all of these examples, there can be times when warm, moist outside air flows across the fire sprinkler system piping.

This paper will explore ***external corrosion*** that occurs on the outside surfaces of wet pipe fire sprinkler piping from contact with ambient air. Three different installation settings will be addressed:

- Structures that are temperature controlled during winter months to prevent freezing but not temperature controlled during other times of the year, e.g. warehouses with open garage doors and vehicle repair facilities are good examples
- Structures that are temperature controlled year round that experience the intrusion of warm moist air at opened doors during the summer months, e.g. entry vestibules, parking garages under air conditioned buildings and retail store receiving docks
- Structures that house freezer/cooler installations and employ dry pendent sprinklers that protrude from the unconditioned air space above the freezer into the freezer itself

All of these fire sprinkler installation examples share several common items:

- There are times when the water filled **pipes are cooler** than the moist, ambient air that is surrounding them which will lead to condensation of water on the exterior surfaces
- These installations typically have **exposed pipe threads**
- These installations typically employ **malleable iron and cast iron fittings**

Condensation Corrosion on Fire Sprinkler Piping

The steel pipe and fittings that are used in fire sprinkler systems conduct temperature very efficiently. In the case of wet pipe fire sprinkler systems, as the temperature fluctuates in the air that surrounds the fire sprinkler piping the water temperature inside the pipe rises and falls as it equilibrates to a point near the temperature of the outside air. However, given the fact that the pipes

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are water filled and water has a higher heat capacity than air, there is **always a time lag** between a temperature change in the air and the resultant temperature change in the water. This means that at times there can be considerable temperature difference (ΔT^o) between the pipe surface and the air around it. This most often occurs during transitional seasons when cold nights accompany warm days.

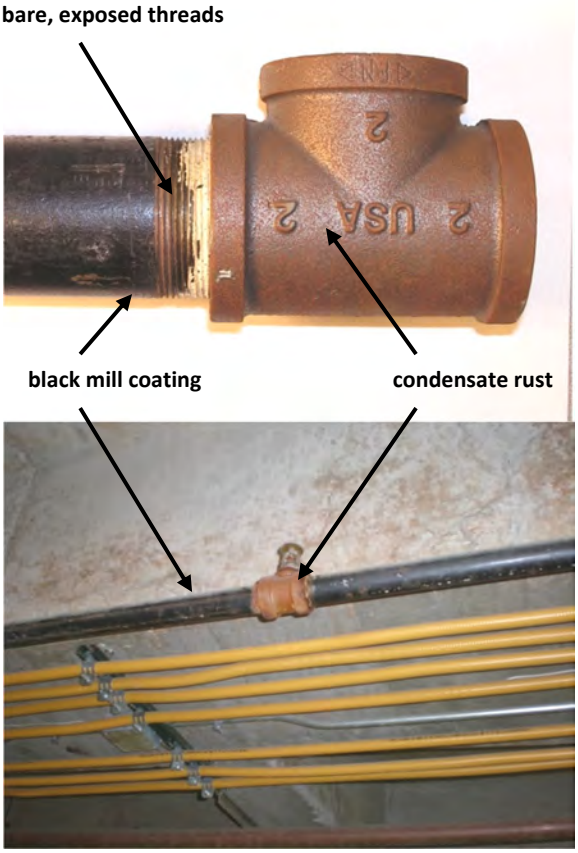
Whenever the temperature of the ambient air is warmer than the temperature of the fire sprinkler piping, there is a chance that water will condense on the outside surface of the pipe. This condition occurs whenever the temperature at the pipe surface is below the dew point for the air. The dew point is defined as the temperature at which the air becomes oversaturated with water and condensation takes place as water in the gas phase as vapor converts to liquid water condensate. The dew point coincides with a condition of 100% relative humidity. This phenomenon is commonly seen when a cold beverage container begins to sweat as water from the air condenses on the surface of the container.
The amount of condensation that is produced on a fire sprinkler pipe surface is dependent on four factors:

1. The **temperature difference** (ΔT^o) between the surface of the pipe and the dew point of the surrounding air; the larger the temperature difference (ΔT^o) below the dew point of the air the more moisture will condense on the pipe
2. The **amount of moisture** in the air; the more water that is held in the air as humidity the more moisture can condense on the pipe
3. The **volume of air** that is moving across the pipe surface; the higher the volume of air passing over the cooled pipe surface, the more moisture can condense
4. In marine environments, the presence of **air borne salt particles** can accelerate the rate of corrosion by increasing the salinity of the condensate

Black Steel Pipe Vs. Malleable Iron and Cast iron Fittings

Black steel fire sprinkler tubing typically comes from the manufacturer with a protective black “mill coating” on the outside of the piping that is designed to prevent flash oxidation (rust) of the external metal surface of the piping during storage and transport. Several of the tubing manufacturers make note of the “proprietary” nature of their protective coatings while others apply a light coating of black lacquer.

Unlike the fire sprinkler pipe, the couplings and fittings that are installed as components of the completed fire sprinkler systems **<u>are not</u>** coated to prevent flash rusting of the steel. As such, even short term exposure of the fittings to ambient air and moisture can result in the formation of a coating of iron oxide (rust) on the exposed surfaces.



In many installations, the installation routine involves painting the black steel piping and fittings after the fire sprinkler system installation is complete. In this manner, a uniform protective coating of paint is applied to all of the pipe and fittings to prevent external oxidation of the exposed black steel. The labor and material cost associated with painting the fire sprinkler system can be quite expensive. In many installations, it is common to leave the installed fire sprinkler system unpainted.

Corrosion of the External Pipe Surfaces

In order for corrosion to initiate on the external surfaces of a wet pipe fire sprinkler system, liquid water must be present. As water condenses on the cooled metal surfaces of the fire sprinkler piping, two different corrosion mechanisms can take place:

<u>Acid Condensate Corrosion</u> - Water that condenses from the air is essentially distilled water. This means that the water is chemically pure at the moment that condensation occurs and the water contains no dissolved ions. However, once the water droplet is formed, gases in the air begin to dissolve into the water. The dissolved gases immediately affect the chemistry and physical nature of the water. There are three acid gases in the air that can dissolve into the condensed water droplet:

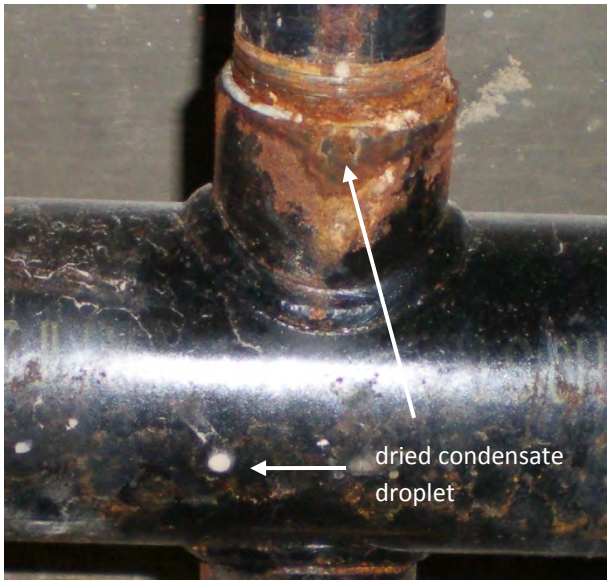
- Carbon dioxide – a natural component of the air
- Sulfur oxides – industrial pollutant primarily from power generation plants
- Nitrogen oxides – industrial pollutant primarily from vehicle exhaust

As the acid gases from the air dissolve in condensed water, they form aqueous acids. In the case of carbon dioxide, carbonic acid is formed:

CO_2 (gas) + H_2O (liquid) → H_2CO_3 (aqueous) carbonic acid

Sulfur oxides and nitrogen oxides in the air form sulfuric acid and nitric acid in the condensed water:

SO_x (gas) + H_2O (liquid) → H_2SO_4 (aqueous) sulfuric acid
NO_x (gas) + H_2O (liquid) → HNO_3 (aqueous) nitric acid



Buffering capacity is the resistance to changes in the pH of the water. Since the condensate water has no dissolved ions in it, it has no buffering capacity. As a result, the pH of condensate water drops very quickly. The degree of acid formation in the condensate will depend on the amount of the acid gases that are present in the localized atmosphere. In warehouse settings for example where propane powered forklifts are in constant use, the amount of pollutant gases in the air at the apex of the building can be considerable. Under some conditions, the localized pH of condensate can fall below 5.0. Condensate at a pH of 5.0 has 1,000 times as much acid in it as municipal drinking water which is typically around pH 8.0.

Acidic condensate water is **very corrosive** to mild steel and as such, it will immediately react with the iron in the steel to form hematite (rust). As temperatures stabilize, the condensed water on pipe surfaces will dry out. But each time the dew point is reached on the metal surface of the pipe, condensation will occur. With each cycle, more iron is liberated from the steel and a crust of iron oxide will form on the metal surface.

Oxygen Corrosion – Oxygen makes up 21% of the air volume. Oxygen from the air will dissolve in the condensed water on the pipe and immediately react with the iron to produce iron oxide as hematite Fe_2O_3. Every time water condenses on the pipe surface, oxygen corrosion will act to liberate iron from the surface of the pipe.

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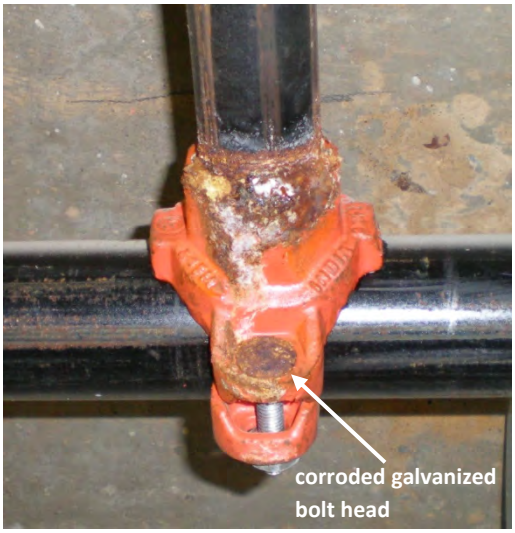
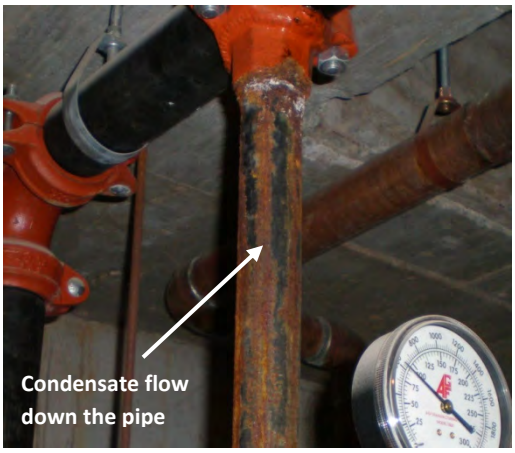
Two External Locations Vulnerable to Condensate Corrosion Attack (Acid and O_2)



Two external locations on the wet pipe fire sprinkler piping are most susceptible to condensate corrosion attack are the **exposed threads** at the ends of the pipe sections and the **malleable iron and cast iron fittings** themselves. The fact that these two components are always in close proximity can lead to significant deterioration of the fire sprinkler piping at a point where the metal is thinnest, i.e. the trough of the cut threads. This surface is particularly susceptible to corrosive attack because water sits in the threads and moves by capillary action into the seal between the threads and the fittings. Corrosion will occur at this surface each time the surface is wetted by condensate water and will continue for as long as the surface remains moist. Over time corrosion by-product (hematite) will build up at the point of corrosive attack to hold moisture on the pipe surface which acts to accelerate the rate of metal loss.



The vertical piping below joints with exposed threads can experience significant corrosion as the moisture acts to attack the metal surface as the water rolls down the pipe. Even the painted fittings can experience corrosion as the continuous attack at the interface between the exposed threads and the fittings are invaded. Once the corrosion begins to attack the edges of the fittings it gets beneath the paint and accelerates. The paint helps to retain the moisture as well. Under conditions where the exterior metal surfaces are moist for extended periods of time, even the galvanized bolts in the couplings can experience corrosion as the zinc layer is dissolved to expose the substrate black steel.

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Structures with Open Doors in Warm Months

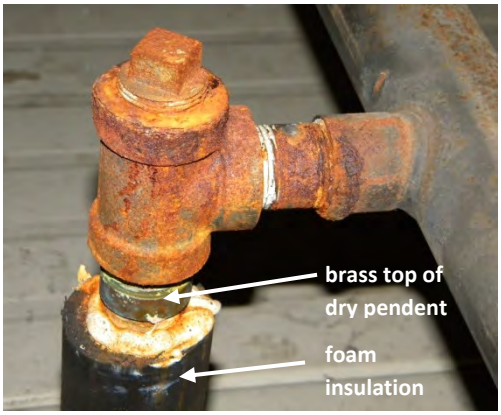
- Temperature controlled in winter to prevent freezing
- Ambient operating temperature during other seasons

These types of installations will be subject to moisture condensation during seasonal transitions especially during periods of cool/cold nights and warm days. During these time periods water will condense on the fire sprinkler system piping, as pipes cooled during the night cannot catch up with the warmed air that passes over them during the day.

In warehouse installations, acid gases from exhaust fumes can also collect in the roof areas. Since these tend to be non-public type installations, the wet pipe fire sprinkler systems are typically not painted during installation.

Structures with Conditioned Air Spaces Subject to Warm, Moist Air Intrusion

- Pipe cooled with air conditioning are subject to constant blasts of warm, moist outside air when doors are opened
- Warm, moist air rises to contact unpainted fire sprinkler piping



During the summer, fire sprinkler piping that is located in conditioned air spaces will maintain the cooler temperature that is created by the building air conditioning system. Whenever warm, humid air enters the building condensation can occur on the "cool" pipes. As warm moist air enters the building, convection will cause the air to rise and gather at the roof. If heat curtains are installed as part of the fire sprinkler design, the warm moist air can be concentrated at the location above the opened door that introduced the warm air. If enough humid air contacts the pipes they can "sweat" to the point where water drips from them.

Structures that House Freezer/Coolers

- Wet pipe fire sprinkler systems above the freezer/cooler with dry pendent drops through the ceiling of the freezer space
- Circulation and movement of warm moist air in the plenum space above the freezer/cool which contacts the cold fire sprinkler piping

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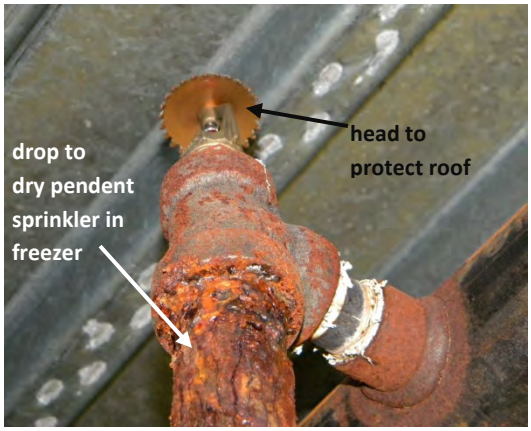
Constantly cold piping condenses large amounts of moisture especially in warm, humid climates. Depending on the volume of air movement through the plenum (attic) area above the freezer/cooler, the amount of condensate formation can be extreme because the piping remains so cold.



Insulation conducts the cold from the freezer/cooler to the point in the piping just above where the insulation stops. Condensation will occur on all of the "cooled" piping.

Options for Controlling Atmospheric Condensate Corrosion

- **Painting**

The first most logical option for controlling atmospheric condensate corrosion is to paint the entire exterior surface of the fire sprinkler system.

Advantages of Painting

- Complete coverage of all exposed metal surfaces including malleable iron and cast iron fittings and freshly cut exposed threads to prevent contact of the metal by the condensate
- Improves appearance of the fire sprinkler system
- If done during construction phase can be painted along with the ceiling

Disadvantages of Painting

- Material and labor costs can be very expensive
- Piping must be cleaned to ensure adhesion of the paint and uniform coverage of all of the piping

- **Corrosion Resistant Metallurgy**

The use of corrosion resistant piping materials like copper and stainless steel would be a very expensive option that would not be considered for most of these type installations, e.g. parking garages and warehouses. Using galvanized steel would be a good option for the exterior surfaces of the pipe, however, galvanized steel interior surfaces are completely inappropriate for use in wet pipe fire sprinkler systems because of the high levels of corrosion.

- **Spray Applied Atmospheric Corrosion Inhibitors**

Atmospheric corrosion inhibitors are probably the most cost effective approach to controlling atmospheric condensate corrosion. During installation of the fire

sprinkler piping all malleable iron and cast iron fittings and exposed fresh cut threads can be coated with the aerosol type inhibitor.

Advantages of Atmospheric Corrosion Inhibitors

- Inexpensive compared to other options – only applied to fittings and fresh exposed threads
- Easily penetrates fresh cut exposed threads and seams at the make-up
- Easy to apply during installation phase of fire sprinkler systems - aerosol can
- Inhibitors prevent contact of the metal by condensate water
- Inhibitors are persistent and long lasting

Disadvantages of Atmospheric Corrosion Inhibitors

- May need to reapply depending on environment
- Like any aerosol, must be handled with care (flammable)

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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