White Paper

Controlling Ice Plugs and Corrosion in Fire Sprinkler Systems Protecting Cold Storage (Freezer) Applications

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Automatic fire sprinkler systems that are used in cold storage freezer installations present unique problems that require special design considerations regarding corrosion and potential ice plug obstructions. Historically, fire sprinkler designs for freezers have involved the removal of water content from the pressure maintenance air to prevent ice plugs at the point of penetration of the dry pipe main into the freezer. The chemistry and physics of the corrosion reaction at freezing temperatures are very different from installations at room temperature and above.

Oxygen Corrosion at Freezing Temperatures

There are two (2) significant physical attributes that affect the oxygen corrosion reaction in freezing environments. First, for oxygen corrosion of steel piping to occur, liquid water must be present. Liquid water provides the medium by which oxygen can dissolve to react with the iron in the pipe. Under freezing conditions there is no liquid water present and as such the oxygen solubilization cannot occur. Second, all chemical reactions speed up at elevated temperatures. The rule of thumb in chemistry is that for every 18^{o}F (10^{o}C) increase in temperature, the rate of any chemical reaction doubles. The opposite is true for decreasing temperatures. This means that chemical reactions at 75^{o}F are two times faster than chemical reactions at 57^{o}F and four times faster than chemical reactions at 39^{o}F. The same is true for the oxygen corrosion reaction with iron or zinc for systems with galvanized steel pipe.

The lack of liquid water and temperatures below 32^{o}F would suggest that corrosion in dry and preaction fire sprinkler systems inside freezers is virtually impossible. The fact that most cold storage freezers are kept at temperatures approaching 0^{o}F further reduces the likelihood that corrosion will occur.

Removal of Relative Humidity to Prevent Ice Plugs

The removal of water from the compressed air stream used for pressure maintenance in dry and preaction fire sprinkler systems for freezer service has historically been accomplished by using a regenerative desiccant type air dryer in conjunction with the air compressor. Using this approach, the air entering the freezer would have a lower dew point than the temperature within the freezer which should prevent condensation and freezing of moisture in the pipeline. Ice plugs in the sprinkler mains have the potential to greatly restrict or completely restrict water flow into the freezer.

The FM Global Property Loss Prevention Data Sheet 8-29 entitled *Refrigerated Storage* suggests that the dew point target of the pressure maintenance air for the dry or preaction fire sprinkler system should be 20^{o}F (11.1^{o}C) below the temperature inside of the freezer that is being protected[1]. This reduced dew point would achieve a relative humidity of 30% for the air within the piping at temperature within the freezer. This "dried" air should not form ice plugs in the transition zone piping entering the freezer.

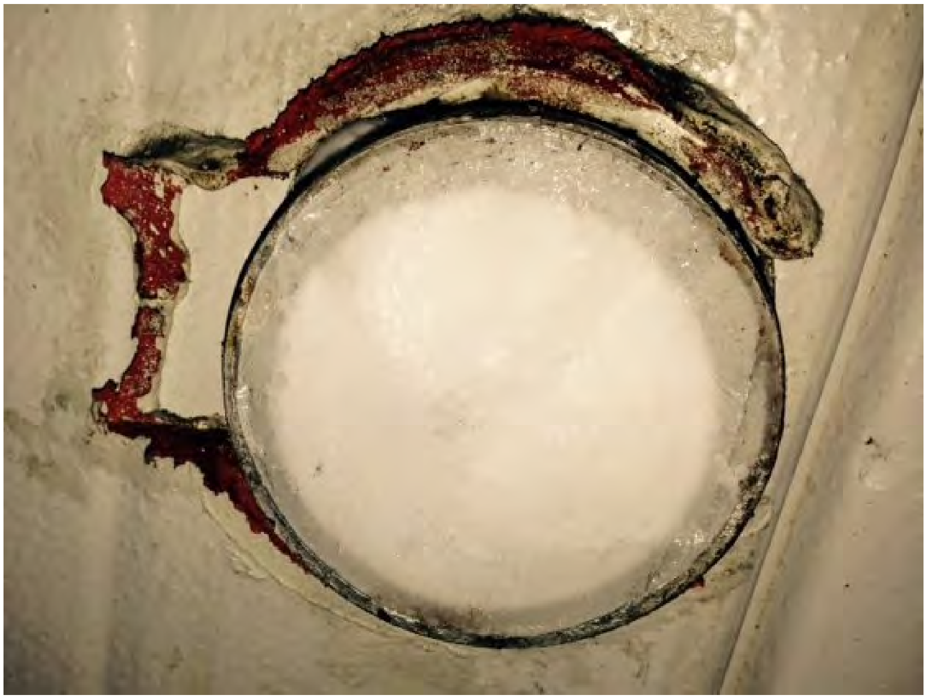

Figure 1: Ice Plug formed inside of Freezer System

Corrosion and Conventional Air Compressors

One area of fire sprinkler piping outside the freezer envelope is subject to oxygen corrosion because liquid water can be present. That portion of the fire sprinkler bulk feed piping from the riser to the freezer penetration is typically held at temperatures that are above freezing. When conventional air compressors are used to supply pressure maintenance air in dry and preaction fire sprinkler systems they support corrosion of the fire sprinkler piping in three (3) ways:

1. The compressed air contains 21% oxygen gas which causes oxygen corrosion wherever trapped water is present[2].
2. The compressed air that is delivered to the fire sprinkler system is saturated with water which condenses within the system piping to support the oxygen corrosion reaction wherever trapped pools of the condensate water are formed.
3. Condensate water is essentially "distilled water" which contains no mineral content and is not buffered against pH changes. Thus, when carbon dioxide gas in the pressure maintenance air dissolves into the distilled condensate water trapped in the piping, it forms carbonic acid which makes the water acidic and accelerates corrosion.

Liquid water is necessary for oxygen corrosion to occur and to the extent that the amount of water introduced to the piping can be reduced by using a regenerative desiccant dryer, it can help in controlling corrosion. However, oxygen is by far the greatest contributor to corrosion that occurs in fire sprinkler piping[2] and the regenerative desiccant dryer does nothing to reduce the amount of oxygen that is added to the fire sprinkler system.

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It should be noted that water is almost always introduced during the initial hydrostatic test of the sprinkler system and during periodic code mandated trip testing. Once water is introduced to the system piping it is all but impossible to remove all of it. A sheen of liquid water on the pipe surface is all that is necessary to support the oxygen corrosion reaction. Control of corrosion in dry and preaction fire sprinkler systems can only be accomplished by reducing or eliminating the introduction of oxygen gas.

An Alternative to the Regenerative Desiccant Dryer

An FM Approved membrane type nitrogen generator is a much better solution for controlling ice plugs than a regenerative desiccant dryer. The benefits of using an FM Approved membrane type nitrogen generator for pressure maintenance gas in a freezer installation include:

- The 98% nitrogen gas produced using a membrane type nitrogen generator has a **much lower dew point** of -70°F to -90°F than the dry air typically produced by a regenerative desiccant dryer at about -40°F. As such the membrane type nitrogen generator can easily meet the FM Global dew point requirement for freezer installations[1].
- Membrane type nitrogen generators also **prevent oxygen corrosion** by reducing the oxygen content in the pressure maintenance gas to less than 2%. Dry air from a regenerative desiccant dryer contains 21% oxygen which is the primary cause of corrosion in fire sprinkler systems.
- Nitrogen generators **cost less to operate** because they run less frequently than a comparably sized regenerative desiccant dryer which must constantly use dry air or heat to regenerate the desiccant bed.
- When maintained properly, membrane separators that are used in an FM Approved nitrogen generator **can last up to 20 years** according to the manufacturer[3], while the desiccant material must be replaced every year in a typical regenerative desiccant dryer[4].
- FM Approved membrane type nitrogen generators **cost approximately the same** as regenerative desiccant dryers for equivalent size dry and preaction system installations.

Other operating factors that make regenerative desiccant dryers more expensive to install, commission, operate and maintain compared to a membrane type nitrogen generator:

- Regenerative desiccant dryers require an **8-hour break-in**[4] to create enough dry air capacity for initial introduction to the freezer. This can represent a significant labor expense for the property owner while the contractor is present for this process. An FM Approved nitrogen generator **instantly produces** low dew point (-70°F) pressure maintenance nitrogen gas with no break-in period.

- During the initial commissioning with a regenerative desiccant dryer it is necessary to purge the moist air from the fire sprinkler system piping by manually opening a valve at the inspector's test for a 24-hour period. After 24 hours of purging moist air, the valve must be manually closed[4]. This again creates a labor expense for the property owner. An FM Approved membrane type nitrogen generator **automatically removes the moist air and oxygen** from the system piping as part of the normal operation using an integral venting device that is located on the system riser[5].
- As desiccant material breaks down in the desiccant towers they can produce **particulates that have the potential to clog** valves and fittings downstream of the dryer[4].
- Recommended annual maintenance of the regenerative desiccant dryer is complicated and time consuming. In addition to coalescing cartridge filter replacement the desiccant beds of the dryer must be removed and replaced. Once again, the 8-hour break-in must be performed before the dryer can be placed back in service. An FM Approved membrane type nitrogen generator requires simple annual replacement of the coalescing cartridge filters.

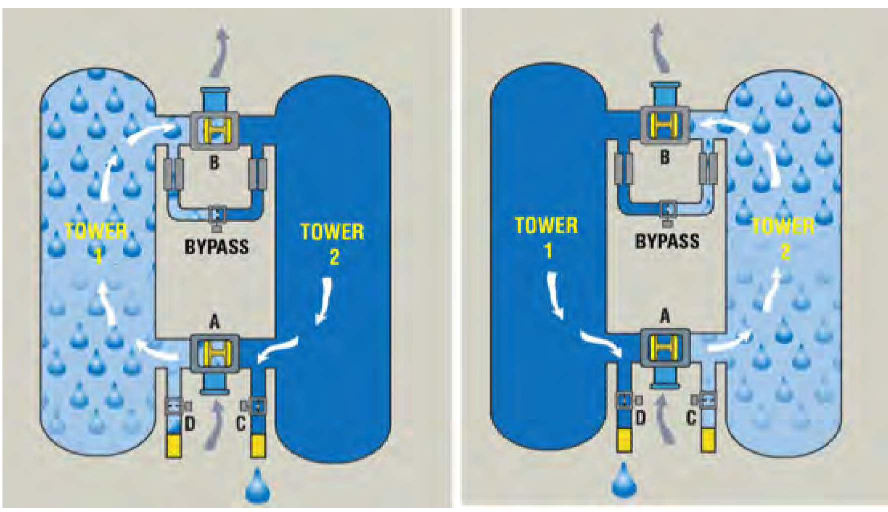

Figure 2: Operation of Heatless Dessicant Dryer

Field trials with FM Approved membrane type nitrogen generators in freezer installations have proven to be more effective in preventing ice plugs[6]. There are many potential operational pitfalls associated with a regenerative desiccant dryer that do not exist with an FM Approved membrane type nitrogen generator including:

- Failure to set up the cycle frequency on the desiccant towers properly to maintain low dew point dry air delivery.
- Failure to account for system pipe leakage can cause short cycling and lead to the delivery of high dew point air.
- Failure to perform 8-hour break-in during initial commissioning can deliver high dew point air.

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- Failure to perform the 24-hour purging of the system piping can lead to high dew point air within the system piping.
- Failure to change out degraded desiccant in a timely manner can result in the delivery of high dew point air.

Figure 3: Freezer System Piping Maintained by Nitrogen Gas

Given the complexities involved with operating and maintaining a regenerative desiccant dryer combined with the minimal corrosion protection provided at the transition zone sprinkler piping, the fire sprinkler industry should reconsider the widespread use of these systems. FM Approved membrane type nitrogen generators offer superior moisture removal of the pressure maintenance gas while also providing proven corrosion control for the sprinkler system piping.

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References

[1]FM Global Property Loss Prevention Data Sheet 8-29 ***Refrigerated Storage*** – May 2007.

[2]FM Global Research Technical Report ***Corrosion and Corrosion Mitigation in Fire Protection Systems*** – Paul Su and David Fuller July 2014.

[3]Air Products ***PRISM Membrane*** technical literature.

[4]General Air Products Dry Air Pac™ Installation, Operation and Maintenance Manual Models DAP500, DAP1000 and DAP2000.

[5]Engineered Corrosion Solutions, ECS Protector Nitrogen Generation System Owner's Manual – covered by US Patents 9,144,700; 9,186,533; 9,526,933; 9,610,466.

[6]Engineered Corrosion Solutions – field trials with large retail foods company freezer storage systems.

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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