White Paper

Managing Safety in Nitrogen Inerting Fire Sprinkler Systems

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Oxygen Corrosion in Fire Sprinkler Systems

The primary cause of corrosion in water based fire sprinkler systems is oxygen attack of the base metal of the pipe wall. While in the past Microbiologically Influenced Corrosion (MIC) has commonly been blamed as the root cause of corrosion related leaks in fire sprinkler systems, the vast amount of failed pipe analyses, water sample tests, and internal video scoping projects performed by Engineered Corrosion Solutions (ECS) all point to MIC as a secondary cause of internal corrosion. Oxygen attack of black steel and galvanized steel fire sprinkler piping is the primary cause of pin-hole leaks[1].

Oxygen enters a fire sprinkler system whenever fresh atmospheric air is introduced, which contains 21% oxygen. In the case of wet pipe fire sprinkler systems, this occurs whenever the system is drained. Water draining from the system creates a vacuum in the piping, which pulls fresh air in through the main drain of the system. For dry systems, oxygen is present in abundance and is frequently replenished every time the compressor operates to maintain system pressure.

From a chemistry and physics standpoint, the evidence is quite clear that every molecule of oxygen that is introduced to fire sprinkler piping will eventually react with pipe metal to create a pit in the pipe wall and produce metal oxide solids.

The use of nitrogen to displace the corrosive oxygen gas in fire sprinkler systems, both wet and dry, is becoming common practice. In the process nitrogen gas is used to displace oxygen before it can react and cause corrosion[2]. Nitrogen is an inert gas, non-reactive with the metals and all elastomeric materials commonly used in fire sprinkler systems. Chemical corrosion inhibitors almost always pose compatibility issues for fire sprinkler system components. The 2013 Edition of the NFPA 13 Installation Guide does not permit the use of chemical corrosion inhibitors or microbiocides that cannot demonstrate complete compatibility[3].

Nitrogen Inerting Fire Sprinkler Systems

The most effective method for removing oxygen from an enclosed space with nitrogen is using a “fill and purge” breathing process. This process consists of repeatedly filling and venting the closed vessel, in this case fire sprinkler system piping, with high purity nitrogen gas. Each high purity nitrogen fill step dilutes the gas mixture already present in the piping, lowering the resulting concentration of oxygen in the gas mixture. With repeated ‘fill and purge’ cycles, the oxygen concentration will eventually be reduced to extinction.

In the case of **Wet Pipe Nitrogen Inerting (WPNI)**, the inerting process is performed while the system piping is fully drained of water. The ‘fill and purge’ process is performed to bring the internal atmosphere of the entire piping network to greater than 98% nitrogen. When the system is finally filled with water, any trapped gas that remains in the system will be non-corrosive nitrogen gas. As part of the inerting process a system vent is installed on the far main for use during the purge cycles. It also works automatically at completion of the inerting process to remove any trapped compressible gas from the system piping that might adversely affect the hydraulic performance.

A similar process is used when **Dry Pipe Nitrogen Inerting (DPNI)**. A vent is installed on the system to act as a controlled leak. This vent allows the system to partially depressurize before the system is refilled with a high purity nitrogen gas. This 'fill and purge' breathing cycle is repeated until the gas concentration in the system reaches 98%+ nitrogen. Once the system has been inerted, the vent is closed and the nitrogen generator remains in place to accommodate system leaks and maintain system pressure with high purity nitrogen gas.

Sources of Nitrogen Gas and the Safety Issues

In the case of both WPNI and DPNI, a source of nitrogen gas is required to perform the fire sprinkler pipe inerting process. There are three primary sources of nitrogen gas. Each has its own associated safety risk:

1. Liquid Nitrogen Dewars
2. High Pressure Nitrogen Cylinders
3. Nitrogen Generators

The primary danger of using nitrogen gas, regardless of its source, is the inherent risk of asphyxiation, i.e. limiting the availability of oxygen for human respiration. By definition, high purity nitrogen gas contains little to no oxygen, the gas required to support human life. Not only does exposure to an oxygen deficient environment reduce the amount of oxygen inhaled with each breath, inhalation of high purity nitrogen can act to draw dissolved oxygen out of the blood stream, vary rapidly reducing the blood oxygen content to dangerous levels. The table below gives the health effects of reduced oxygen concentrations.

Table 1 - Oxygen Content Effects and Symptoms of acute exposure (at Atmospheric Pressure)[4]

Health Effects of Persons at Rest	Concentration %
Decreased ability to perform tasks. May impair coordination and may induce early symptoms in persons with head, lung, or circulatory problems.	15-19
Breathing increases, especially in exertion. Pulse up. Impaired coordination, perception, and judgment.	12-15
Breathing further increases in rate and depth, poor coordination and judgment, lips slightly blue.	10-12
Mental failure, fainting, unconsciousness, ashen face, blueness of lips, nausea (upset stomach), and vomiting.	8-10
8 minutes, may be fatal in 50 to 100% of cases; 6 minutes, may be fatal in 25 to 50% of cases; 4-5 minutes, recovery with treatment	6-8
Coma in 40 seconds, followed by convulsions, breathing failure, death.	4-6

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For the purposes of these discussions, any environment with an oxygen concentration below 19.5% is considered by OSHA to be an oxygen deficient atmosphere.

*<u>Liquid Nitrogen Dewars (High Risk – Should **NEVER** be Used for Nitrogen Inerting of Fire Sprinkler Piping)</u>*

The primary risk posed by liquid nitrogen is the extremely large quantity of nitrogen gas that can be delivered instantaneously if a breach in the containment vessel occurs. A single gallon of liquid nitrogen produces more than 93 cubic feet, or 695 gallons, of nitrogen gas at standard temperature and pressure. If a 60 gallon liquid nitrogen dewar were to fall over, leak or release its contents in any way, over 40,000 gallons of nitrogen gas will be immediately released into the atmosphere. In any confined space the asphyxiation risk would be extremely high. Even in an outdoor setting, this high concentration of nitrogen gas delivered instantaneously in the event of a rupture would create an asphyxiation risk in the area adjacent to the liquid nitrogen dewar.

In the example above, the 40,000 gallons of nitrogen gas can immediately reduce the oxygen concentration in a 250 square foot room with a 10 foot ceiling to less than 7% and can asphyxiate every person in the room.

Liquid nitrogen also poses another very significant hazard. The extremely low temperature of liquid nitrogen poses a risk to both the person handling it and any components of a fire sprinkler system that come in contact with the liquid nitrogen. If liquid nitrogen contacts the steel pipe of the fire sprinkler system, the extremely low temperature would cause the pipe to become brittle and risk damaging the system. Fracturing the frozen steel pipe is a very real risk.

<u>High Pressure Nitrogen Cylinders (Moderate Risk for Use in Nitrogen Inerting of Fire Sprinkler Piping)</u>

Nitrogen gas cylinders pose two safety risks. First, a high pressure cylinder contains a fairly large amount of compressed nitrogen gas. A typical Type A cylinder contains 250 standard cubic feet or 1870 gallons of nitrogen gas at standard temperature and pressure. If released instantaneously into the atmosphere of a room, this amount of nitrogen is enough to create an oxygen deficient atmosphere (<19.5% O2) in a 250 square foot room with a 10 foot ceiling. To deplete the oxygen level in a room this size to less than 7% as was achieved in the liquid nitrogen example, 20 nitrogen cylinders would be needed. So with the nitrogen cylinders the risk is reduced because of the smaller quantity of nitrogen gas that is available for each cylinder.

Nitrogen cylinders also pose a risk due to their high pressure. A typical cylinder, when full, has a pressure of approximately 2,700 psi. If a cylinder were to fall over and break the valve off of the top, not only would all of the gas escape inside of the room, but the rapid release of the pressurized gas would propel the heavy cylinder, potentially causing damage, injury, or death. A detached, broken valve would have an even higher velocity in the event of a rupture.

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Despite the risks associated with nitrogen cylinders, when the appropriate safety precautions are followed they can be safely used with WPNI and DPNI. Compressed gas cylinders have been used in the fire protection industry in the past and most fire sprinkler contractors are comfortable with managing the safety concerns posed by the cylinders. It is very important that the cylinders be properly restrained when used, and that they be kept in a well-ventilated area in case of leaks.

Nitrogen Generators (Lowest Risk for Use in Nitrogen Inerting Fire Sprinkler Piping)

The use of nitrogen generators, both for WPNI and DPNI, creates the least amount of nitrogen gas asphyxiation risk. The generators utilize a separation membrane in the production of nitrogen gas, which acts as a molecular sieve to separate the gases in the supply air being passed through it. Typical installations include an air compressor providing a clean, dry compressed air stream to the separation membrane. The separation membrane produces two exhaust streams of gas, one rich in nitrogen and a second that is rich in oxygen.

The membrane in the nitrogen generator allows nitrogen gas to pass through into the fire sprinkler system while waste gases, primarily oxygen and carbon dioxide, are vented to atmosphere from the nitrogen generator where they instantly mix into the ambient atmosphere. The primary benefit of this design is that nitrogen gas produced using a separation membrane is produced on demand as an "instant on" and "instant off" source of nitrogen gas. There is no need for a nitrogen gas storage vessel. Eliminating the nitrogen gas storage vessel in the riser room or other indoor room greatly reduces the risk of nitrogen gas asphyxiation.

Using a nitrogen generator is inherently safe because the two exhaust gas streams that are produced already exist within the ambient atmosphere from which they were derived. Both the WPNI and DPNI processes use such small volumes of nitrogen gas that they cannot create the type of an instantaneous discharge risk that is created by liquid nitrogen and nitrogen cylinders.

Table 2. Nitrogen Discharge Required to Result in Oxygen Deficiency (<19.5%) in 250 sq. ft. Room with 10 ft. ceilings

Nitrogen Discharge Source	Discharge Needed to Reach 19.5%
Liquid Nitrogen	2 gallons of Liquid Nitrogen
High Pressure Cylinder	1 Type A (250scf) High Pressure Cylinder
Nitrogen Generator	N/A*

*****A nitrogen generator running in a closed room does not result in an overall change in the composition of room's internal atmosphere. Nitrogen stream and oxygen waste stream remix resulting in no net change in the atmospheric composition.

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Conclusions

Regardless of the source of nitrogen gas used when nitrogen inerting a fire sprinkler system, it is critical that the person performing the inerting be aware of the inherent hazards posed by the use of an inert gas in an enclosed space. In the event of an accidental instantaneous release of a large quantity of nitrogen gas into an enclosed space the area should be evacuated immediately and properly ventilated prior to re-entry. As has been presented, the risks vary greatly for each of the specific nitrogen sources being used. Liquid nitrogen should never be used.

Nitrogen generators that employ membranes for separation of nitrogen gas from the compressed air feed are the safest nitrogen gas source for performing Wet Pipe Nitrogen Inerting (WPNI) and Dry Pipe Nitrogen Inerting (DPNI) for the following reasons:

- No possibility for the instantaneous release of a large quantity of nitrogen gas
- Low rates of nitrogen gas production per minute
- Instant on/instant off nitrogen gas production
- Instant mixing of the oxygen waste stream into the atmosphere
- No need for nitrogen gas storage vessel
- No high pressures associated with the nitrogen gas production

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References:

[1]**"MIC is NOT the Primary Cause of Corrosion in Fire Sprinkler Systems"** by Jeffrey T. Kochelek*, Sprinkler Age Magazine*, October 2009

[2]**"Using Nitrogen Gas to Remove Corrosive Gases from Fire Sprinkler Water"** by Jeffrey T. Kochelek, White Paper, March 2009

[3]2013 Edition of the NFPA 13 Standard for the Installation of Sprinkler Systems

[4]Compressed Gas Association Inc. (1992) *Oxygen-Deficient Atmospheres (less than 19.5%).* Safety Bulletin SB-2. Third Edition.

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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.

For complete information about the entire line of corrosion management products and services please visit the Engineered Corrosion Solutions website at www.ecscorrosion.com for a the complete list of downloads of White Papers, FAQs, installation schematics and product spec sheets or contact us (314) 432-1377 and one of our engineers will assist in personally answering any of your questions.

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