MANAGING SAFETY IN NITROGEN INERTING FIRE SPRINKLER SYSTEMS

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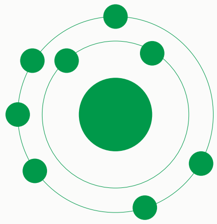
Introduction

As nitrogen inerting becomes a mainstream solution for managing oxygen corrosion in fire sprinkler systems, the development of best practices with respect to safe supplies of nitrogen gas are an important collective goal. This whitepaper reviews potential safety hazards related to various nitrogen supply mechanisms and proposes that nitrogen generators are the safest source of nitrogen for fire sprinkler system inerting. Nitrogen generators pose essentially no asphyxiation hazards and require no special handling whereas alternative compressed nitrogen and liquid nitrogen sources present greater hazards and should not be used.

Background on Oxygen Corrosion in Fire Sprinkler Systems

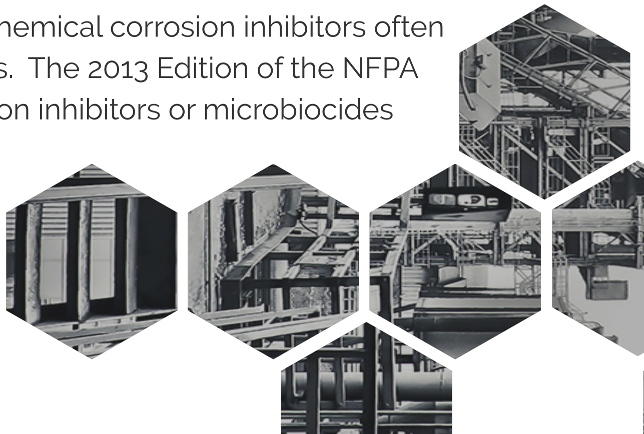


Oxygen gas is the primary cause of corrosion and pinhole leaks in **fire sprinkler systems**.

Oxygen attack of black steel and galvanized steel fire sprinkler piping is the primary cause of pinhole leaks in water based fire sprinkler systems.[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.

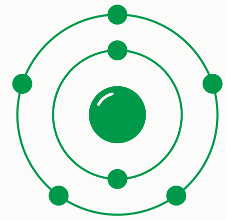
From a chemistry and physics standpoint, the evidence is quite clear that every molecule of oxygen that is introduced to fire sprinkler piping will eventually react with pipe metal to create a pit in the pipe wall and produce metal oxide solids.

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 displaces oxygen before it reacts to cause corrosion.[2] Nitrogen is an inert gas, nonreactive with the metals and all elastomeric materials commonly used in fire sprinkler systems. Alternative chemical corrosion inhibitors often present 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.



Nitrogen is used to remove enclosed **oxygen**

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 noncorrosive 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 the 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 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

In the case of both WPNI and DPNI, a source of nitrogen gas is required to perform the fire sprinkler pipe inerting process. Although ECS generally recommends the use of nitrogen generators, there are three primary sources of nitrogen gas that are generally available:

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

Accordingly, implementing WPNI and DPNI safely will require a choice from among these sources.

Potential Safety Hazards

High concentrations of **nitrogen** can pose an **asphyxiation risk**

Nitrogen makes up 78% of atmospheric air. It is not inherently hazardous. However, in high concentrations nitrogen gas can pose an asphyxiation risk by limiting the availability of oxygen for human respiration. By definition, high purity nitrogen gas contains little to no oxygen. 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 and vary rapidly reduce blood oxygen content to dangerous levels. Table 1 lists the health effects of reduced oxygen concentrations. Notably, OSHA considers any environment with an oxygen concentration below 19.5% to be an oxygendeficient atmosphere.[5]

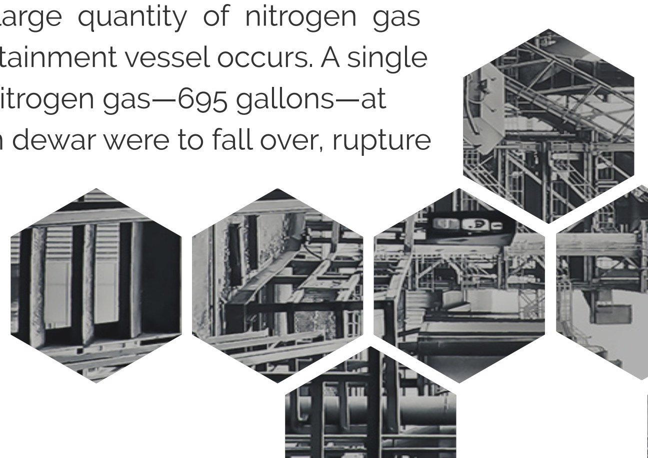
Because nitrogen is only hazardous at high concentrations, safe use of nitrogen requires management of situations that can deplete oxygen concentrations to unsafe levels. The types of situations that can create a hazard depend directly on the type of nitrogen source used as discussed below.

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; 45 minutes, recovery with treatment	6 - 8
Coma in 40 seconds, followed by convulsions, breathing failure, death.	4 - 6

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

Liquid Nitrogen Dewars — Very High Safety Risk

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 expands to more than 93 cubic feet of nitrogen gas—695 gallons—at standard temperature and pressure. If a 60 gallon liquid nitrogen dewar were to fall over, rupture or release its contents, over 5,500 cubic feet of nitrogen gas—40,000 gallons—would be released into the vicinity.



Confined to a space smaller than 70,000 cubic feet—7,000 square feet with 10foot ceilings—such a release would deplete the oxygen content below the 19.5% OSHA deficiency level. Confined to a 20'x10' room with 10foot ceilings, a release would cause a coma in under a minute. Even in an outdoor setting, a nitrogen release of this magnitude would create an asphyxiation risk in the area adjacent to the liquid nitrogen dewar. Thus, the asphyxiation risk presented by using liquid nitrogen as a source of gaseous nitrogen is very significant.

Liquid nitrogen poses many **safety risks**

Liquid nitrogen also poses a second significant hazard: its extremely low temperature. The 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.

Based on the asphyxiation risks presented over a large area and the risks posed by extremely low temperatures, liquid nitrogen generators would present an extreme safety risk when used for nitrogen inerting of a fire sprinkler system. Alternatives are typically more readily available and far safer. Liquid nitrogen should **NEVER** be used for inerting fire sprinkler systems.

High pressure nitrogen cylinders are safer than liquid nitrogen, but still pose **safety risks**

High Pressure Nitrogen Cylinders — Moderate Safety Risk

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, this amount of nitrogen would create an oxygen deficient atmosphere (<19.5% O2) in a 20'x10' square foot room with a 10 foot ceiling. Depleting the oxygen level in a room this size to a comainducing level would require 20 nitrogen cylinders. Relative to liquid nitrogen, nitrogen cylinders are lower risk because of the smaller volume 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. Despite the moderate safety risks associated with nitrogen cylinders, when the appropriate safety precautions are taken nitrogen cylinders can be safely used with WPNI and DPNI. It is very important that the cylinders be properly restrained when used, and that they be kept in a wellventilated area in case of leaks.

Nitrogen generators pose the lowest **safety risk**

Nitrogen Generators — Lowest Safety Risk

The use of nitrogen generators, both for WPNI and DPNI, poses the least asphyxiation risk associated with nitrogen gas sources. This level of safety is a direct result of the way nitrogen generators operate to produce nitrogen from air. At a high level, nitrogen generators operate to separate nitrogen from air, which is already 78% nitrogen. This separation produces two output gas streams, a nitrogenrich stream, and an exhaust stream composed of everything else in air. As a result, nitrogen generators can be reasonably called nitrogen separators because all they do is separate gases that are already present in the environment. Unlike liquid nitrogen dewars or high pressure nitrogen cylinders, nitrogen generators do not introduce any additional nitrogen into an environment.

Moreover, nitrogen generators do not require a nitrogen storage vessel. For example, many nitrogen generators use 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.

Without a storage vessel, 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. If a nitrogen generator were mistakenly left running in a confined space the air concentration would not change. The nitrogen and exhaustgas streams would continue to mix and the concentration in the room would stay the same. This operation could not produce an oxygen content below the OSHA deficiency level. Moreover, 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.

Thus, the way nitrogen generators work—by separating nitrogen from air and venting leftover gas as exhaust—ensures that nitrogen generators cannot pose an asphyxiation risk. Therefore, among the three common sources of nitrogen gas, nitrogen generators pose the lowest safety risk.
Table 2 below summarizes the volumes of accidental discharge that could create an unsafe environment.

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*

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

**A nitrogen generator running in a closed room does not result in a 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.*

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 reentry. As has been presented, the risks vary greatly for each of the specific nitrogen sources being used, but the raking of risks is clear. 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:

1. No possibility for instantaneous release of large volume of nitrogen gas
2. Low rates of nitrogen gas production per minute
3. Instant on/instant off nitrogen gas production
5. No need for nitrogen gas storage vessel
6. Instant mixing of the oxygen waste stream into the atmosphere
7. No high pressures associated with the nitrogen gas production

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) OxygenDeficient Atmospheres (less than 19.5%). Safety Bulletin SB2. Third Edition.

[5]Occupational Safety and Health Standards, 29 CFR § 1910.134(b).

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 waterbased 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, PreEngineered Skid Mounted Nitrogen Generator, Gas Analyzers, SMART Dry Vent, Two (2) Wet Pipe Nitrogen Inerting Vents and the industry's first real time insitu corrosion monitoring device the ECS InLine 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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