White Paper

12 Month Follow Up: Vapor Corrosion Inhibitors Maintain Stronger Corrosion Protection Than 98% Purity Nitrogen

December, 2024

Abstract

Dry and pre-action fire sprinkler systems face unique challenges from internal corrosion, which can compromise their performance and service life. While high-purity nitrogen has long been used to mitigate these effects, Vapor Corrosion Inhibitors (VCIs) are now being tested for application in fire protection systems. This study compares compressed air, 98% nitrogen, and VCIs over 12 months, demonstrating VCIs significantly reduce corrosion—up to 7x more effectively than nitrogen and 34x more than air—offering a proven, reliable solution for the Fire Sprinkler Industry.

GENERAL AIR PRODUCTS

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1. Introduction

Dry and pre-action fire sprinkler systems face unique challenges from internal corrosion, which can compromise their performance and service life. While high-purity nitrogen has long been used to mitigate these effects, Vapor Corrosion Inhibitors (VCIs) are now being tested for application in fire protection systems.

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2. Testing Overview

2.1 Objective

The primary objective of this five-year study is to evaluate the corrosion mitigation performance of VCIs against industry benchmarks: compressed air and 98% purity nitrogen. By analyzing corrosion rates and patterns, this study aims to demonstrate the superior efficacy of VCIs in protecting fire sprinkler systems.

2.2 Test Setup

The testing is being conducted in partnership with a third-party laboratory, Corrosion Testing Laboratories, Inc., under controlled conditions. The setup consists of three test stations representing the systems under evaluation:

- **Compressed Air:** Simulates untreated systems with atmospheric air.
- **98% Purity Nitrogen:** Reflects the current industry standard for corrosion mitigation.
- **Vapor Corrosion Inhibitor (VCI):** Uses vapor-phase corrosion inhibitors to form a protective molecular barrier.

Each test station contains 12 chambers partially filled with water to simulate real-world conditions where water accumulates in sprinkler piping. Coupons made from C1018 carbon steel are submerged and exposed to the vapor phase in each chamber. Corrosion is measured using mass loss, visual inspection, and electrical resistance (ER) probes at six-month intervals. The following information provides two sets of findings over the first year of testing.

12 chambers partially filled with water where coupons made from C1018 carbon steel are submerged.

3. Methodology

The study follows ASTM G1 standards for preparing, cleaning, and evaluating corrosion specimens. These specimens are evaluated by an Independent 3rd Party laboratory (Corrosion Laboratories, Inc. – MD, USA).

- **Coupons:** The test involves metal coupons in submerged (low) and vapor (high) positions.
- **ER Probes:** Collect data from vapor and liquid phases to correlate with mass loss observations.
- **Corrosion Rate Calculation:** Rates are calculated in mils per year (mpy) and adjusted based on surface area exposed to water.

4. Key Results

4.1 Six Months Findings

- VCIs demonstrated exceptional performance with minimal corrosion compared to nitrogen and air systems.
- Metal loss for VCIs was 1/3 of that observed in the nitrogen system and approximately 1/10 of the air system.

4.2 Twelve Months Findings

The data from the 12-month evaluation confirm the trend observed in the six-month results. Key observations include:

- **Compressed Air:** Exhibited the highest corrosion rates. Low-position coupons showed significant pitting with a corrosion rate of 5.53 mpy (adjusted).
- **98% Purity Nitrogen:** Reduced corrosion compared to air but still caused notable metal loss, with an adjusted rate of 1.1 mpy.
- **VCIs:** Outperformed both air and nitrogen systems, with an adjusted rate of just 0.16 mpy. Superficial corrosion was observed, with no significant pitting or localized attack.

4.3 Twelve Months Findings Data

Compressed Air	
Date of Test	Estimated Total Mills Lost
10/20/2023	0.24
11/20/2023	0.87
1/10/2024	2.3
2/23/2024	2.7
3/11/2024	2.85
4/22/2024	3.15
5/15/2024	3.33
6/20/2024	3.56
7/18/2024	3.99
8/22/2024	4.7
9/19/2024	5.14
10/9/2024	5.53

98% Purity Nitrogen	
Date of Test	Estimated Total Mills Lost
10/20/2023	0.01
11/20/2023	0.09
1/10/2024	0.18
2/23/2024	0.22
3/11/2024	0.26
4/22/2024	0.4
5/15/2024	0.49
6/20/2024	0.6
7/18/2024	0.74
8/22/2024	0.81
9/19/2024	0.96
10/9/2024	1.1

Vapor Corrosion Inhibitor	
Date of Test	Estimated Total Mills Lost
10/20/2023	0.05
11/20/2023	0.13
1/10/2024	0.09
2/23/2024	0.03
3/11/2024	0.08
4/22/2024	0.08
5/15/2024	0.14
6/20/2024	0.12
7/18/2024	0.13
8/22/2024	0.12
9/19/2024	0.14
10/9/2024	0.16

5. Visual and Analytical Insights

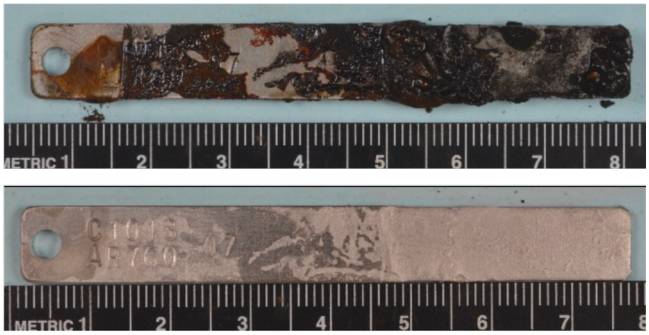
Photographic documentation reveals stark contrasts between the systems:

- » Compressed air coupons displayed extensive corrosion and material degradation, particularly in the liquid-vapor interface.
- » Nitrogen coupons showed some improvement but still exhibited localized corrosion.
- » VCI coupons maintained their integrity, with only superficial pitting observed in some cases.

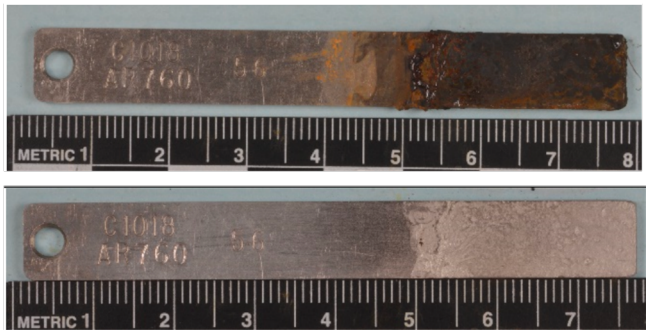
ER probe data corroborate these findings, showing the least material loss in VCI-treated chambers.

Depicted images were taken before and after cleansing.

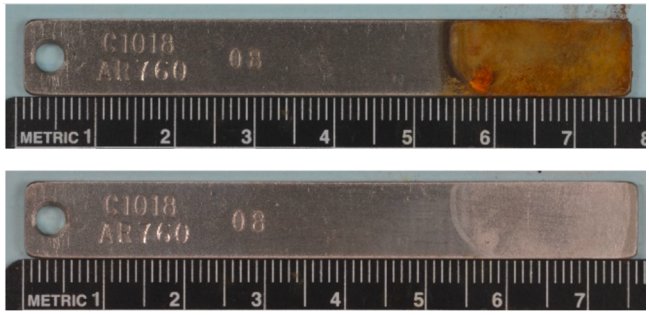
Compressed Air



98% Purity Nitrogen



Vapor Corrosion Inhibitor



6. Discussion

These findings underscore the transformative potential of VCI technology in mitigating corrosion. While nitrogen systems reduce oxygen levels, they cannot address other corrosive factors, such as microbial activity or deposit corrosion. VCIs form a molecular barrier, offering comprehensive protection that extends to hard-to-reach areas within the system.

The study also highlights the limitations of traditional methods. Despite the widespread adoption of nitrogen generators, the sevenfold higher corrosion rate compared to VCIs indicates that industry standards may need reevaluation.

This testing follows similar parameters to a those conducted when nitrogen was first introduced to the fire protection industry nearly two decades ago, comparing of 95% purity nitrogen to 98% purity. It was determined then that 95% purity was not sufficient in its corrosion mitigation effects, and 98% was deemed the only acceptable standard.

7. Conclusion and Future Implications

The 12-month results affirm VCI's position as a superior solution for corrosion mitigation in dry and pre-action fire sprinkler systems. As the study progresses, additional data will provide further insights, reinforcing the long-term benefits of vapor-phase corrosion inhibitors.

This research holds implications beyond fire safety, suggesting broader applications for VCIs in industries where corrosion control is critical. By demonstrating the limitations of current methods and the efficacy of innovative solutions, this study aims to drive change in industry practices, enhancing system longevity and reliability.

This study is slated to run for 5 consecutive years, and subsequent results will be published by General Air Products going forward.

8. About General Air Products

General Air Products is the trusted leader in fire protection air supply solutions. With over 80 years in the industry, we specialize in high-quality air compressors, dry air generators, nitrogen generators, and vapor corrosion inhibitor technologies designed to prevent corrosion and supervise dry and pre-action fire sprinkler systems.