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MP MATERIALS PERFORMANCE CORROSION INNOVATION OF THE YEAR AWARDS - WINNER 2014 -

Nitrogen generator inhibits corrosion within fire protection systems

When dry and pre-action fire protection systems experience internal corrosion in their piping network, several problems can ensue for building owners and operators. The build-up of corrosion product deposits can reduce the efficiency of the sprinkler system and worse, water can leak from pinholes causing property damage. According to NACE International member Ockert J. Van Der Schijff, senior manager with engineering and scientific consulting firm Exponent, Inc. (Natick, Massachusetts), the cost to repair a single pinhole leak in sprinkler pipe is usually in excess of $1,200 per event. Even more alarming is that often times before the pinhole leak has occurred, tuberculation, scaling, and other corrosion products accumulate within the sprinkler piping. This could cause obstructions that will slow down the water flow in the event of a fire, or potentially plug a sprinkler head rendering that sprinkler head/s completely inoperable. Since only heads in the immediate vicinity of a fire will activate, the plugging of such components can create life-threatening conditions in the event of a fire.

Dry and pre-action sprinkler systems are not charged with water, but use a compressed supervisory gas instead, says Scott Bodemann, senior vice president of sales & marketing for South-Tek Systems, LLC (Wilmington, North Carolina). The pressure of the supervisory gas in dry systems balances a valve in the sprinkler system with water line pressure until a pressure drop occurs due to activation of a sprinkler head. Water is then introduced into the piping to suppress the fire. Pre-action systems essentially utilize the same principal, but require activation of an additional signal such as a temperature sensor or smoke alarm before the valve opens and water is introduced into the piping. Typically, dry and pre-action fire protection systems use compressed air as the supervisory gas to keep the piping system pressurized. However, compressed air from the atmosphere contains both moisture and oxygen, which can cause corrosion of the steel piping. A proven solution to mitigate corrosion in sprinkler systems is the use of compressed nitrogen instead of compressed air as the supervisory gas. The nitrogen displaces the oxygen from within the sprinkler piping, therefore effectively removing a key contributor to corrosion. To meet the need for this continuous supply of compressed nitrogen gas, South-Tek has developed a corrosion inhibiting nitrogen generation system, the N_2-Blast, which provides inert nitrogen specifically for fire protection systems.

Many new dry and pre-action fire protection system are constructed of hot-dip galvanized steel, although the use of black steel pipe is on the rise. In their paper that reports the preliminary findings of an exposure test experiment on piping materials currently used for dry and pre-action sprinkler installations,[1] Van Der Schijff and Bodemann comment that the use of galvanized steel is based on the principle of cathodic protection (CP) for corrosion protection—the zinc coating on the interior of the pipe will corrode sacrificially and protect the underlying steel. They add, however, that under certain conditions, galvanizing the interior surfaces of the pipes has been found to be ineffective for mitigating corrosion in sprinkler systems.

The low points in sprinkler piping are most often wet as a result of the accumulation of water and condensate. Due to the stagnant nature of sprinkler systems, corrosion products, which are deposited on the corroding metal, remain where they are formed. In galvanized pipe, the efficiency of the galvanic CP process decreases as the surface becomes covered with nonconductive zinc oxide. Eventually, the zinc coating is penetrated and the underlying steel experiences localized corrosion in the form of pits covered by a mound of oxide called a tubercle. Numerous owners have reported premature galvanized pipe failures in as little as three years after commissioning due to multiple pinhole leaks at locations where penetration of the zinc coating had occurred under tubercles.

Van Der Schijff and Bodemann report that subsequent investigations found common conditions in all instances of galvanized pipe failure, including the lack of an adequate method for completely draining the fire protection system after initial hydro testing and/or code required flow testing, multiple pockets of trapped water, localized tubercles with underlying pits that penetrated the steel at breaches in the zinc coating, and intact zinc coating that covered surfaces surrounding the localized tubercles. They also note that corrosion of black steel pipe without a protective interior coating initially results in even, uniform thinning of the steel pipe wall with a considerably slower rate of penetration. It is only later when significant amounts of corrosion product deposits have accumulated within the piping that the corrosion mechanism transitions into localized pitting, primarily driven by differential aeration. In general, once corrosion has initiated, the time-to-failure for black steel piping is longer than then of galvanized steel.

When compressed air is used as the supervisory gas for dry and pre-action fire sprinkler systems, oxygen (which makes up ~21% of the compressed air stream) is constantly introduced into the sprinkler system. The oxygen content, in combination with residual moisture in the air stream and/or residual water in the piping, creates optimum conditions for corrosion to initiate. Oxygen is the key driver of electrochemical corrosion in sprinkler piping, Bodemann explains, which produces detrimental results in both black steel pipe and galvanized pipe sprinkler systems. The nitrogen generator produces a continuous supply of supervisory gas that is comprised of >98% nitrogen, a percentage that has been shown to reduce the oxygen content within the sprinkler system to a concentration where the onset of corrosion is effectively inhibited.

In the long-term exposure test experiment, Schedule 10 black and galvanized steel sections were half filled with water and subjected to a supervisory gas comprised of either compressed air, 95% nitrogen, or 98% nitrogen. The pipe sections were pulled out of the test environments at roughly 1-year intervals. Recent results of samples pulled after 1,116 days of continuous exposure showed that when exposed to supervisory gas comprised of 98% nitrogen, the corrosion penetration rate in black steel pipe was 66% less than it was when exposed to compressed air. For galvanized pipe, the 98% nitrogen supervisory gas reduced the corrosion penetration rate by ~94% and prevented the formation of localized pits. Ongoing research, they say, continues to prove that 98% nitrogen supervision is a very effective means of addressing dry and pre-action sprinkler pipe corrosion.

In the past to inhibit corrosion, banks of high-pressure nitrogen gas cylinders were sometimes used as a source of supervisory nitrogen gas. However, cylinders contain a finite supply of nitrogen which is an issue in dry and pre-action applications. Due to the magnitude of fittings within a fire protection system, there will always be some degree of leaks, which is recognized within both NFPA 13 and 25 as the “acceptable leak rate.” This results in the continuous consumption of nitrogen within the cylinders and creates the risk of the gas supply being depleted, potentially leading to the sprinkler system being activated if the low pressure alarm is not acknowledged.

The nitrogen generator for fire protection systems was developed to provide a safe alternative to high-pressure nitrogen gas cylinders and provide an infinite supply of nitrogen, which eliminates the potential for a supervisory gas run-out. The nitrogen generator draws on decades-old gas molecule separation technology, and similar systems have been used in the power industry for a long time for inhibition of corrosion in laid-up or mothballed boiler tubes.

The N_2-Blast is engineered to supply >98% nitrogen supervisory gas to dry and pre-action systems by mechanically separating nitrogen from the compressed air feed. It runs on electricity and is comprised of an integral air compressor and air dryer to provide ultra clean, dry feed air to the mechanism that separates the nitrogen from the air. The nitrogen generator used either membrane or pressure swing adsorption (PSA) technology to mechanically separate the nitrogen from the air stream. Which technology is used in a given nitrogen generation system is primarily based on the total volume capacity of the sprinkler system to be protected.

The membrane technology utilizes a filtration process featuring thousands of polymer fibers, each with a diameter of approximately the size of a human hair. Clean, pure compressed air passes through the membrane, and nitrogen is separated out of the air stream as a result of partial pressure differences between the external and internal membrane surfaces. PSA employs a carbon molecular sieve (CMS) adsorbent to extract the oxygen from the feed air. The Oxygen diffuses into the pores of the CMS under pressure, while the nitrogen molecules pass through. Bodemann comments that the membrane technology has a service life of up to ~ 13 years, while the PSA technology can provide between 18 to 25 years of service life.

The nitrogen gas produced is stored at a low pressure (~80 psi [552 kPa]) in a receiver tank and enters the building's fire protection system through the sprinkler system's supervisory air maintenance device. One generator system is capable of providing supervisory nitrogen to dry and pre-action sprinkler systems in upwards of 20,000 gal (68,130 L) of total sprinkler capacity. Separate and downstream from the nitrogen generator itself, a patent-pending pneumatic automatic purge system is installed on the sprinkler piping to expel a low-volume amount of supervisory gas from each fire protection zone. This allows for the introduction of fresh nitrogen into the system, thereby displacing and/or diluting any residual oxygen. The nitrogen purity can also be monitored at the point in which the gas is purged from the device. In addition, each South-Tek nitrogen generator is provided with an integrated leak-detection system as a proactive means of notifying the facility manager of excessive leaks downstream. Should an excessive lead develop within the fire protection system, an alarm will sound so that the facility manager can respond and prevent the nitrogen generation system from operating excessively to maintain supervisory pressure and in doing so, this feature helps maximize the life the nitrogen generation system.

The nitrogen gas generating system for fire protection systems has been installed in hundreds of facilities ranging from parking structures to mission-critical facilities since 2005.

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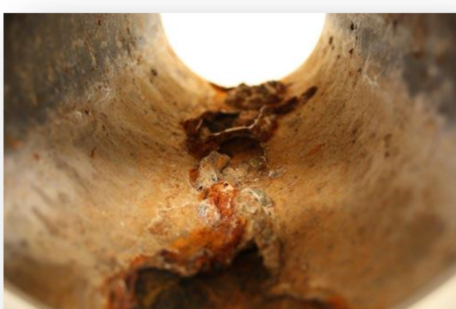
Reference

[1] O.J. Van Der Schijff and S.C Bodemann, "Corrosion of Piping in Dry and Preaction Fire Sprinkler Systems: Interim Results of Long Term Corrosion Testing under Compressed Air and Nitrogen Supervision," CORROSION 2013, paper no. 2846 (Houston, TX: NACE International, 2013).

Photos:



Examples of internal corrosion and corrosion products found in sprinkler pipes for dry and pre-action fire protection systems. Photos courtesy of South-Tek Systems.

This nitrogen generating system, which protects multiple fire protection systems in one building, consists of the nitrogen generator (left), the nitrogen gas receiver tank (center), and a control panel (right) that monitors the nitrogen purity concentration within the multiple pre-action systems. Photo courtesy of South-Tek Systems.