FIRE PROTECTION LABS
DYNE™

2357 Ventura Drive, Suite 108
Woodbury, MN 55125
(651) 917-0644
(800) 632-2304 Toll Free
(651) 917-0646 Fax
dyne.lab@nfpaglobal.com

Corrosion & MIC Testing Explanation

Corrosion occurs in all fire protection sprinkler systems. Corrosion damage/products and mineral deposits can restrict water flow and impair mechanical operation, leaving facilities vulnerable. For these reasons, the 2025 edition of NFPA 13, *Standard for the Installation of Sprinkler Systems*, requires the following during system installation:

> **5.1.4.1** Water supplies and environmental conditions shall be evaluated for the existence of microbes and conditions that contribute to microbiologically influenced corrosion (MIC).
>
> **5.1.4.2** Water supplies and environmental conditions shall be evaluated for conditions that contribute to unusual corrosive properties.

The 2026 edition of NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* then requires an assessment of the internal condition of the piping at a minimum of every 5 years. As part of this assessment:

> **14.2.1.3** Tubercules or slime, if found, shall be tested for indications of microbiologically influenced corrosion (MIC).

No further guidance is given in regard to test methods or requirements in these NFPA standards. For that, we must look to other industry standards and white papers. Among them, FM Global's Research Technical Report from 2014, *Corrosion and Corrosion Mitigation in Fire Protection Systems*, is one of the most in depth and fairly recent. According to this report:

> The corrosivity of sprinkler water in [a fire protection system] is significantly influenced by water quality and chemistry parameters, such as concentration of dissolved gases (O_2, CO_2), dissolved anions (chloride, sulfate, etc.), pH, alkalinity (HCO_3^- and CO_3^{2-}), solids (hardness and deposits), and microorganisms.

Dissolved Gases

Dissolved oxygen (DO) concentration in sprinkler water is one of the biggest factors when determining corrosivity in sprinkler systems. Corrosion is fundamentally a chemical reaction, involving metal, water, and oxygen. The higher the concentration of dissolved oxygen in the water, the higher the corrosion rate

for steel sprinkler pipe. The relationship is fairly linear according to *Corrosion Inspection and Monitoring* by Pierre R. Roberge (2007).

Dissolved oxygen at our laboratory is measured via an optical sensor (luminescence quenching). At room temperature, fresh water can hold about 9 ppm of DO but this can vary depending on environmental conditions (temperature, salinity, altitude, etc.). As water temperature, salinity, or altitude increases, DO decreases.

Note: Dissolved carbon dioxide also reacts with water to form a weak acid (carbonic acid) that is mildly corrosive toward steel pipe. However, accurate (representative) measuring of dissolved carbon dioxide can be quite difficult. Challenges include high volatility, speciation, and sensitivity to temperature and pressure. For these reasons, dissolved carbon dioxide is not measured/reported at our laboratory.

Dissolved Anions

Chloride (Cl^-) and sulfate (SO_4^{2-}) are two particularly aggressive anions, increasing metal corrosion. They can adsorb onto the metal surface, interfere with passive film formations, and lower solution pH in pits/crevices/tubercules. These dissolved anions are measured via ion chromatography (conductivity) at our laboratory. The impact of these anions is evaluated via the Larson-Skold Index (LSI), developed to evaluate the corrosion of mild steel pipe transporting Great Lakes waters:

$$\text{Larson-Skold index} = (\text{epm } Cl^- + \text{epm } SO_4^{2-}) / (\text{epm } HCO_3^- + \text{epm } CO_3^{2-})$$

The Larson-Skold Index can be interpreted as follows:

- < 0.8: Chloride and sulfate will probably NOT interfere with natural film formation
- 0.8-1.2: Chloride and sulfate may interfere with natural film formation, resulting in higher corrosion rates.
- >1.2: Higher corrosion rates should be expected as the index increases

Note: Because the index was developed for Great Lakes water (bicarbonate rich), this index may not (beyond scope of original data) be applicable for water with very low or extreme alkalinity.

pH

pH is a measure of how acidic or basic (alkaline) a solution is. It is measured via a pH electrode (voltage potential). The pH of water in most sprinkler systems varies from a weak acid (pH 5-7) to a mild basic solution (pH 7-10) according to FM Global. According to *Corrosion Inspection and Monitoring* by Pierre R. Roberge (2007), the corrosivity of steel significantly increases at pHs below 5. Corrosivity of steel decreases above pH 10 given “the deposition of insoluble ferric hydroxide tends to stifle the corrosion attack”.

Alkalinity

Alkalinity, that is the measure of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}), can act as a buffer, resisting changes in pH and stable water chemistry. It can also help to form a protective film (scale), inhibiting corrosion. It is measured via an acid-base titration, where the reaction is monitored via an electrode (voltage potential). Its impact on corrosivity is evaluated via the Larson-Skold Index.

Hardness

Dissolved calcium and magnesium in sprinkler systems (if hard water is used) can react with bicarbonate to form a film (scale) of calcium carbonate or magnesium carbonate in neutral or alkaline environments. This scale forms a protective barrier between the metal piping and the dissolved oxygen. Typically, hardness is classified as follows:

- <60 ppm = Soft
- 61-120 ppm = Moderately Hard
- >120 = Hard

Indexes, such as the Langelier Saturation Index (also abbreviated LSI) and the Ryznar Stability Index, exist to evaluate the scaling tendency of water in piping systems. However, FM Global notes:

> There is no definitive correlation between these indexes and corrosion of steel in water, and they do not consider the effects of chloride and sulfate anions on steel pipe corrosion. Thus, these indexes are not used in water chemistry analysis of sprinkler water often containing these anions.

Microorganisms

Microbiologically influenced corrosion (MIC) is corrosion caused by the presence and activities of microorganisms and/or the products produced by them. According to FM Global, MIC is only responsible for 10-20% of the damage caused by corrosion. MIC can form tubercules (a mound) and deposits that can lead to the obstruction of water and/or blockage of valves and sprinklers. MIC can also lead to localized metal loss (or pitting) underneath these tubercules (anerobic environment) leading to leakage.

Our laboratory currently quantifies the following bacteria via qPCR (quantitative polymerase chain reaction), selected to represent dominant microbial mechanisms associated with MIC:

- Sulfate-reducing bacteria (SRB)
    - Anaerobic (do not need oxygen) bacteria that consume sulfate as part of their metabolism, producing hydrogen sulfide (H_2S). These bacteria are widely recognized as primary contributors to MIC, particularly through sulfide production, iron sulfide formation, and pitting corrosion mechanisms.
- Sulfur-oxidizing bacteria (SOB)
    - Aerobic (need oxygen) bacteria that consume sulfur compounds (e.g. the H_2S produced by SRB) as part of their metabolism, converting reduced sulfur compounds into sulfuric acid

(H_2SO_4). These organisms typically act as part of a two-stage corrosion mechanism, where SRB generate H_2S under anaerobic conditions and SOB subsequently oxidize these compounds under aerobic conditions, resulting in localized acidification and accelerated corrosion.

- Iron-reducing bacteria (IRB)
    - Anaerobic bacteria that consume iron as part of their metabolism, specifically converting protective (scale), insoluble ferric iron (Fe^{3+}) to a more soluble ferrous iron (Fe^{2+}). This process destabilizes protective oxide layers, increasing susceptibility to corrosion.
- Corrosive Methanogens (micH)
    - Most methanogens corrode indirectly by removing protective hydrogen layers, exposing iron to further oxidation. Some, those with the micH (hydrogenase) gene that our analysis looks for, can directly transfer electrons from iron, resulting in accelerated electrochemical corrosion and representing a high-confidence MIC mechanism.

This group of bacteria, and our evaluation of their risk, driven by LuminUltra's MIC panel system, is based on a mechanism-driven selection framework designed to capture dominant microbial pathways responsible for microbiologically influenced corrosion.

The following microbial groups are sometimes referenced in MIC discussions but are not explicitly included in the panel:

- Acid-producing bacteria (APB)
    - APB is a broad functional category rather than a specific taxonomic group. Acid production in MIC systems is primarily associated with sulfur-oxidizing bacteria and fermentative organisms. As such, acid-related corrosion risk is effectively captured through SOB activity and supporting system chemistry indicators.
- Slime-forming bacteria (SFB)
    - Slime-forming bacteria are fairly ubiquitous. Their impact is generally associated with biofilm formation and is indirectly captured through biomass indicators and system observations (e.g., visible fouling, as referenced in NFPA 25 practices).
- Iron-oxidizing bacteria (IOB)
    - These bacteria are opposite of IRB – they convert soluble ferrous iron (Fe^{2+}) back into insoluble ferric iron (Fe^{3+}) forming visually identifiable tubercles. While not currently included in the panel, their activity can often be inferred through iron cycling dynamics and may be incorporated in future panel expansions.
- Nitrate-reducing bacteria (NRB)
    - These bacteria consume nitrate in your water and convert it to nitrite, which reacts (oxidizes) with iron. NRB are typically system-dependent and often associated with nitrate treatment programs (common in oilfield applications as an SRB control). They commonly coexist with SRB and are considered secondary contributors depending on system chemistry.

DISCLAIMERS

Our evaluation is on a single water sample and does not represent the entire system. It should be considered preliminary. Further investigation (e.g. internal inspection) is required to fully evaluate overall system performance and identify any additional issues (e.g. excess scaling) or concerns that could be localized in specific areas of the system (e.g. pockets of trapped air in a wet system).

The selected biological panel is not intended to capture every organism/functional group identified in literature, but rather to represent dominant corrosion mechanisms. This approach provides actionable insight while maintaining operational practicality when interpreted alongside water chemistry parameters.