Part Two of Two [For the complete article, contact the authors, or info@fpcmag.com.]

Fundamentals of
Microbiologically Influenced Corrosion (MIC)
In Water-Based Fire Protection Sprinkler Systems

By Daniel H. Pope, Ph.D., and John L. Lovell

Part One of this article is in the January edition and includes an abstract-outline, definitions, background, terminology, main sources of MIC, and Phase one and Phase two. This article picks up in Phase two.

Phase 2 (see *Figure 2*) involves growth of the MIC bacteria community and recruitment of additional types of MIC bacteria such as; anaerobes (ANA), which don't like oxygen, acid producing bacteria (APB), sulfate-reducing bacteria (SRB), which produce corrosive hydrogen sulfide, and iron-related bacteria (IRB), which deposit iron and manganese, thus increasing the size and hardness of what is now recognizable as a discrete deposit.

The discrete deposits form crevices on the metal where crevice corrosion occurs. Because aerobic bacteria consume oxygen in the deposit and the metal surfaces surrounding the discrete deposits are in contact with oxygen, differential oxygen cell corrosion can occur. The oxygen-free areas in discrete deposits allow acid producing bacteria (APB) to make acids, hydrogen, carbon dioxide (which in water forms carbonic acid), and sulfate-reducing bacteria (SRB) to make hydrogen sulfide, all of which are corrosive and concentrated in and under the discrete deposit. Areas under the discrete deposits become anodes (where the metal is dissolving to form metal ions and electrons), while the rest of the metal surface outside the discrete deposits serves as cathodes (where electrons react with acceptors such as oxygen and some forms of iron oxide). Electrons must be discharged to these acceptors for corrosion to continue under the discrete deposit.

The positively-charged metal ions produced by corrosion combine with other molecules to form more deposits. Also, iron and manganese ions react with negatively-charged chloride to form very corrosive metal chlorides.

Figure 2 – Mid-stage MIC, black pipe in wet FPS

Since the metabolic processes and corrosion are concentrated in and under the discrete deposits, corrosion begins to take the form of observable pitting with characteristics of MIC (e.g., pits within pits and pits limited to the special extent of the discrete deposits — see *Figure 3*.

In Phase 3 (see *Figure 4*), the under-deposit pitting contains positively charged hydrogen ions (protons) that attract chloride into the pits, forming hydrochloric acid, which is a STRONG acid. This further causes the pH in the pits to drop. Uhlig (see Reference 3) reported that at pH values below 4, the solubility of iron greatly increases and pitting corrosion rates can increase dramatically, often resulting in leaks (see *Figure 5*). Dr. Pope and others have observed corrosion rates of over 100 mils per year in some carbon steels.

In latter stages of Phase 3, conditions (i.e., acidity and lack of nutrients, including oxygen, in the bulk of the discrete deposit and pits) are not conducive to the growth, or even survival, of MIC bacteria. This is the reason for failure of some investigators to culture many live MIC bacteria in mature MIC deposits, as the viable microbes are concentrated on the *outer surface* of the deposits. At this point in the development of a "MIC site," MIC bacteria are relatively unimportant in controlling the rate of corrosion in the pit, therefore killing them does little to stop the pitting because conditions in the pit allow rapid pitting to occur, as long as oxygen and other electron acceptors are present.

Preventing and Treating MIC in FPS

Mechanical cleaning is functionally impossible or prohibitively expensive in most FPS. Film-forming corrosion inhibitors don't work well in non-recirculating systems such as FPS, as some parts of the film are lost over time and cannot reform as they do not receive additional corrosion inhibitors to repair the film. Many biocides and oxygen scavengers cannot be used in FPS due to toxicity or incompatibility with FPS materials.

Recently, several companies have promoted the use of dry nitrogen, alone, to prevent corrosion in FPS. According to documents from suppliers of nitrogen generators, such treatments may require that nitrogen be flowed through the FPS for up to three weeks or more. Also, flowing nitrogen must reach ALL portions of the FPS. In tree-type FPS, flow of nitrogen to a purge point will be inadequate through dead legs. In gridded systems, the nitrogen will follow the path of least resistance to the purge valve (as does water flow during inspector's tests) with much of the FPS seeing little nitrogen flow. It should be noted that even large nitrogen generators are

Figure 3 — Under-deposit pitting corrosion showing distinct pits within pits, characteristic of MIC.

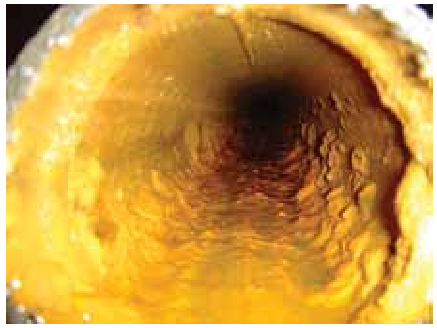

Figure 4 — Mature MIC, black pipe in wet FPS.

Figure 5 — Pinhole leak in dry galvanized FPS pipe. This pitting occurred under discrete deposits located where water puddles had been.

generally limited to treating five riser systems or less at a time.

What does prevent and treat MIC in FPS?

The authors' experience with hundreds of FPS has shown that automatically metering the proper amount of phosphonium, tetrakis(hydroxymethyl)-sulfate (THPS) to *all* water entering an FPS, kills MIC bacteria and eliminates oxygen and quickly stops corrosion and leaks. This also prevents reactivation of existing MIC sites during accidental trips, required water flow tests, and addition of waters to wet FPS during operation of jockey pumps. THPS treatment agent is safe for use by properly informed FPS personnel, is compatible with FPS components, and is rapidly degraded to a non-toxic form on discharge from the FPS. To our knowledge, THPS is still the only biocide/oxygen scavenger chemical registered by the Environmental Protection Agency (EPA) for use in FPS.

The authors have routinely recommended and written about the advantages of replacing air in dry and preaction FPS with dry nitrogen, in addition to treatment with THPS. Because THPS treatment agent provides longlasting protection against MIC in puddles in dry and preaction FPS and in areas adjacent to air pockets in wet FPS, nitrogen does not need to be flowed through the FPS for long periods of time.

In the interest of full disclosure, it should be noted that the author Dr. Daniel Pope holds the only patent for automatic treatment delivery systems for FPS systems.

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