Detection, Treatment, and Prevention of Microbiologically Influenced Corrosion in Water-Based Fire Protection Systems

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Beginning in 1996, the National Fire Sprinkler Association (NFSA) began receiving inquiries regarding a previously unknown corrosion problem in the fire sprinkler industry. The problem was characterized by pinhole leaks in metallic piping systems, often after only a few years of service.

NFSA decided that an investigation was in order. A survey was conducted through NFSA's *Sprinkler TechNotes* publication requesting members to report their incidences regarding this corrosion problem. Approximately thirty responses were received. Twenty cases seemed to agree on the following characteristics: pinhole leaks with dark brown or rust colored slime on the interior of the piping. Some cases also included evidence of tubercles. As reported by the National Association of Corrosion Engineers (NACE) and other researchers, these characteristics were symptoms of Microbiologically Influenced Corrosion or MIC. Some researchers state that MIC comprises 10 to 30% of corrosion in all piping around the country.

This paper attempts to summarize what is known about MIC in the fire protection industry at the present time. It provides background on the corrosion process in general, specific information on microbiologically-influenced corrosion, and a review of detection, treatment and prevention methods.

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Introduction

MIC is a fairly rare but serious type of corrosion. Addressing it properly requires knowledge of the biological, chemical and metallurgical fields. Traditionally, corrosion dealt with metals and chemical reactions. However, MIC is a distinct type of corrosion in which microscopic organisms called *microbes* influence the corrosion process. These microscopic organisms are typically present as communities containing multiple types of bacteria and occasional fungi. Within the past few years, the sprinkler industry has began to recognize that these living organisms, along with tuberculation and corrosion, threaten not only carbon steel systems, but also copper tube and galvanized pipe systems. There has not been any reported MIC occurrence in nonmetallic pipe.

The problem can be re-occurring as well. In some cases documented to the NFSA, MIC created a pinhole leak only months after replacement of the infected pipe or tube.

Research of available literature indicates that other industries have admitted to having this type of corrosion for decades. When the oil and gas pipeline industry or the nuclear power plant industry run into corrosion problems, they generally pursue individual solutions through testing and research, since replacement of one run of pipe can run into the hundreds of thousands of dollars. Application of some of the methodologies developed by other industries may provide solutions for the fire sprinkler industry.

Basic Corrosion

Corrosion is an electro-chemical process in which at least one *oxidation* and *reduction* reaction takes place along with the flow of electrons through the metal. Oxidation is a reaction that involves removing an electron from an atom or ion and that occurs at a point called the *anode,* while reduction is a reaction that involves accepting an electron and that occurs at the *cathode*. Corrosion will only take place if oxidation, electron flow, and reduction take place. The rate at which corrosion takes place is determined by the slowest of these three parts of the corrosion process. This also implies that if one of these three processes is terminated then corrosion will cease. Figure 1 demonstrates this process in an extremely simplistic scenario. In reality, several assorted reactions can be occurring at the same time. The actual corrosion reactions in aerobic conditions take the following form:

$$\mathbf{Fe^0 \rightarrow Fe^{+2} + 2e^-} \text{ and } \mathbf{4e^- + O^2 + 2H_2O \rightarrow 4OH^-}$$

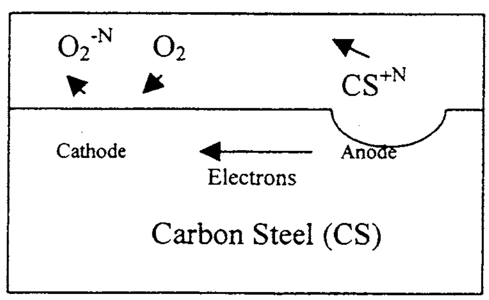


Figure 1

Carbon steel, the metal in this case, is being oxidized into its ionic state. This is called the oxidation reaction and occurs at the anode. The metal is losing an electron as demonstrated in the following reaction. $CS \rightarrow CS^{+N} + N^{e-}$. *(the* $^{+N}$ *denotes an extra N number of protons relative to electrons, meaning the element is in the ionic state.) The reduction reaction will take place with the oxygen* (O_2) *in neutral waters. By definition of the reduction reaction, the electrons are being absorbed by the oxygen at the cathode.* $O_2 + N^{e-} \rightarrow O_2^{-N}$.

Pitting Corrosion

In general, corrosion takes place in such a way that electrodes (the anode and cathode points) are constantly exchanging roles such that the result is uniform corrosion. But sometimes due to different behaviors in the metal, anodic behavior collects in one distinct area. The reasons for this "localized" corrosion is sometimes due to accumulation of corrosive deposits that make an ideal condition for anodic behavior that is not found in the other areas of the metal. Pitting corrosion is generally defined as corrosion in which the ratio of depth to width of corrosion are the same or greater.

Microbiologically Influenced Corrosion

Classification of the Types of MIC Organisms

Since carbon steel fire sprinkler systems contain untreated water in stagnant conditions for long periods of time with possible exposure to fresh aerated (containing air) water during maintenance or repair, MIC can occur through one or both of the following methods. *Note: The definitions given to these bacteria by the metallurgical industry are purely based on the function of the organism.*

1. The sprinkler system water de-oxygenates (oxygen is removed) over time due to a reaction of the oxygen and the pipe wall. This condition, along with proper nutrients, provides a perfect environment for anaerobic bacteria to grow (Kobrin). In these areas, nodules are typically smaller than nodules in aerated areas, and are usually gray to black. The following types of anaerobic bacteria can occur under this condition:

   Sulfate Reducing Bacteria (SRB) - SRB is one of the major types of anaerobic bacteria that are found in carbon steel sprinkler systems. SRB reduces sulfates to sulfides and can be known as Sulfide Producing Bacteria (SPB). Typically these sulfides when produced are represented in hydrogen sulfides (H_2S). Some SRB's also contain hydrogenase, which allows the SRB's to consume hydrogen. Some SRB's can also survive in an inactive state in aerated waters, including treated waters, until they find a location to breed.

   Acid Producing Bacteria (APB) - This type of anaerobic bacteria can be found in aerated or anaerobic microenvironments. One prime example is bacteria called Clostridium which will produce organic acids and stimulate SRB growth. This is a very important MIC microbe in carbon steel systems.

2. In systems or areas of systems in which flushing or draining and refilling of the system takes place, aerobic bacteria will thrive due to the combination of the proper microbes, nutrients, and fresh air. Depending on the amount of fresh water introduced, deaeration will eventually occur, thereby providing the ideal environment for anaerobic bacteria.

   A layer of aerobic bacteria can also create a prime location in the system for anaerobic bacteria to thrive, since little or no oxygen is available below such a layer. For this reason, flushing a sprinkler system without treatment may worsen the MIC condition. Flushing the system will create layers upon layers of aerobic and anaerobic bacteria as well as introduce new microbes, oxygen and nutrients to the system, allowing new MIC colonies to form.

   On the surface of each layer, a biofilm, composed of cells and polymeric substances (similar to the slime found on rocks in a stream or lake), begins to form, serving as a layer of protection (Figure 2). Unlike anaerobic nodules, these nodules are usually brown to a rusty color. The following is a brief description of some aerobic bacteria that can occur under these conditions:

Aerobic Slime Forming Bacteria (Aerobes) - Bacteria such as this can only be found in areas with substantial levels of air. Typically, areas that experience a cyclical flushing program are affected. These aerobes are known for consuming all sorts of nutrients and providing nutrients for anaerobic bacteria.

Iron Depositing Bacteria (IDB) – These bacteria are typically found on steel surfaces and are observed in tubercles over pitted areas. Gallionella and other IDB have been seen in numerous stainless steel cases and many carbon steel systems. This type of bacteria has been documented as another of the major contributors to MIC in carbon steel sprinkler systems.

Low Nutrient Bacteria - This form of bacteria is adapted to areas of low nutrients or attach other types of bacteria for their own purposes. It is an important contributor to the construction of biofilm and tubercles.

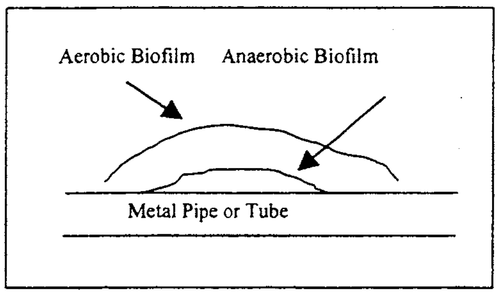


Figure 2

Conditions for MIC Growth and Survival

It is now time to discuss the environmental conditions that allow this bacteria to exist.

As displayed by the chart below (Jones), MIC can occur in almost all carbon steel sprinkler systems. Oxygen levels will support MIC growth from 0% to 100% saturation, and pH levels may range from 1 to 10, (extremely acidic to middle alkaline levels). Also, the temperature and salt levels can vary greatly. In short, most carbon steel systems contain the conditions needed for MIC to exist, regardless of geographic area.

Levels	*Oxygen*	*pH*	*Pressure*	*Salinity*	*Temperature*
Minimum	None	1	<1 Atm.	0 mg/l	0° F (-18°C)
Maximum	Saturated	10	>1000 Atm.	30,000 mg/l	220° F (104°C)

Detection

Detecting MIC is not as simple as one might assume. Often, systems are diagnosed with MIC just because a symptom like a pinhole leak may arise, but other types of chemical or physical damage can also produce a pinhole leak. If a pinhole leak exists along with other symptoms of MIC, then the system probably is infected with MIC.

The recommended method for detecting MIC is to consult with a biological and metallurgical laboratory. Some biological and metallurgical laboratories provide test kits for detection, and provide over-the-phone consultation. Some laboratories also allow contractors to bottle water from the infected environment and mail it for testing. These laboratories then notify the contractor with the test results regarding the type of MIC and how to treat it properly.

Most biological laboratories, will test for amount and type(s) of microbes present in a water source at a cost of approximately $100/hr. Test kits that allow the user to take samples and interpret the results within 24 hours cost approximately $50.00 to $80.00 per kit. Sources include:

BioIndustrial Technologies
Georgetown, Texas
(512) 869-0580

Thielsch Engineering
Cranston, Rhode Island
(401) 467-6454

Once the results have been obtained, treatment options can be explored.

Treatment

When the phrase "treatment of the system" is used in this discussion, it refers to any procedure or process which will play a part in the over all mitigation of MIC in a fire protection system. This includes the possibility of treating the water as it enters the system. The following guidelines are for information purposes only. The recommended treatment options are state-of-the-art at the time that this paper was published. Since relatively little is known about MIC in sprinkler systems, a blanket treatment procedure cannot be recommended at this time. The Association will continue researching all options with the goal of recommending prevention/treatment measures for all new systems.

Option 1: Replacement of Pipe

All sections of pipe with pinhole leaks should be considered unsalvageable and should be replaced. An interior inspection of the system for nodules and tubercles should then be conducted, starting at the area of the pinhole leak.

The inspection should include areas such as the riser, a few points in the crossmain(s) and a few branch lines. Since MIC can be very localized, a determination should be made whether the infected sections of pipe lack integrity and may fail a hydrostatic test. If the nodule and tubercle deposits are extremely severe and the pipe wall thickness has been reduced to less than half its original size, than replacement of the pipe is recommended.

If MIC has infected a small percentage (<5%) of the system with severe deposits and tubercles, then replacement of the affected sections is also recommended. This will probably be less expensive than the other options discussed later in this section.

Option 2: Flushing the System

In cases where MIC has not completely destroyed any section of pipe and the corrosion is relatively mild, flushing the system with biocide treated water may be all that is necessary. For example, if the deposits have not significantly broken the surface of the pipe and the nodules or tubercles are minimal and still soft, flushing the system with a biocide will be the best answer.

At this time, all that can be recommended is to consult a MIC specialist for the type and amount of biocide. Typically, the lab will need to know the conditions specified above about the water and components of the system before recommending an effective biocide.

Once this biocide is flushed for an extended period of time through the system, that same biocide must be used to treat the water that will be introduced to refill the system. The appendix lists typical biocides.

Option 3: Pipe Cleaning

Early in 1998, a technique was specifically developed for sprinkler systems with regards to MIC by HERC Products, Inc. in conjunction with the Grinnell Corporation. This is the only type of fire protection cleaning system that is patented at this time. The procedure involves circulating an acidic solution throughout the entire piping system to dissolve tubercles and nodules. Each sprinkler is removed and connected to hoses which connect to the main drain and to a special external pump. The solution is circulated from 24 to 48 hours throughout every line and sprinkler outlet to ensure that all corrosion deposits are dissolved. The cost of this treatment is expected to run from 25% to 50% of replacement of the entire piping system.

A cleaning service should be applied to systems in which the following conditions exist:

1. MIC is severe and widespread, covering large portions of the system. Replacement of the infected sections of pipe would involve more than 25% of the area.

2. The pipe is still salvageable. Nodule and tubercle deposits have hardened and are firmly attached to the pipe, but the integrity of the pipe is still preserved, and the probability of failing a hydrostatic test is minimal.

If both of these two sets of conditions are met, then this cleaning service may be worth investigating. HERC Products Inc. is located in Phoenix, Arizona and may be contacted at (602) 492-0336.

Misapplied Treatments

One treatment for MIC that is not recommended involves raising the level of pH in the system. Some sources state that raising the pH to 10.5, a level in which the microbes cannot grow, is a viable solution (Kobrin).

Even though this is true, this method of treatment is not recommended since it does not pose a solution for the removal of the existing debris. Remaining nodules and tubercles can affect the flow of water and thereby add to friction loss in sprinkler pipe and tube.

Physical treatments such as "pigging" are also not recommended. "Pigging" is a term applied to a type of physical treatment in which a cylindrical apparatus is fitted in specific pipe sizes. Pigging is extremely successful when used in seawater and oil pipeline systems. The apparatus is placed on one end of the system and large pressure is applied sending the apparatus down a run of pipe, scaling the walls and removing the MIC tubercles. The problem with this treatment is that it only works for one pipe size at a time. A 2-inch pig only works for 2-inch pipe sizes. Therefore, this treatment is expensive and tedious, especially since the path of travel for the pig must be isolated from cross-mains and branch lines to conserve pressure. It is only recommended in situations with long straight risers or mains with a single diameter size.

Recommended Prevention for New and Restored Systems

The number one measure that is repeatedly encouraged for the prevention of MIC is cleanliness of the interior of piping systems. The theory is simple: since the major problem is the micro-organisms, limiting or eliminating the nutrients available for microbial consumption is key. To the extent possible, dirt, excess cutting oils and standing water should be avoided or removed prior to installation.

New and newly restored systems should be considered alike with respect to preventing MIC. If untreated water (municipal water) is allowed back into a restored system, MIC can be re-established and the same set of conditions, including pinhole leaks, will develop in a short period of time. Many systems have experienced recurring pinhole leaks in the same section of pipe. Replacement of pipe does not change the environment in which MIC can thrive. This is why it is recommended that the water be treated as it enters the system.

The water entering a restored system should be treated with a biocide. Choosing the correct biocide and amount will depend on several factors. Chemical composition of the water is the leading factor, along with the material composition of the various elements of components in the fire protection system. Each biocide will react differently based on these factors, which include pH level, temperature, and levels of ammonia, chlorine, iron, manganese, and hardness of the water. Materials within the system such as rubber gaskets will dictate the choice of one biocide over another.

Appendix A references examples of various biocides and suggested concentrations. Recommendations for biocide selection should come from a biological consultant. As time goes on, one biocide may become the appropriate treatment additive for fire protection systems in a given area. Unfortunately, this will need to develop from experience. A consultant will typically want to test the water available at the entrance to a system and thereby prescribe the appropriate biocide. After the biocide has been added, it will typically dissipate in a period of a few hours to few days. Once this process is complete, the water in the system should be considered treated for MIC.

After the correct levels of the disinfectant are applied, an effort must be made to treat new water as it enters the system in the future. Therefore, an apparatus similar to a foam proportioner should be installed at the entrance of the system that can detect the addition of municipal water into the system and add the appropriate levels of the disinfectant. The cost of such a device is approximately $300-$500. If this step is not completed, MIC will not be present initially, but may appear in the future, depending on the activity of the sprinkler system.

Cautions:

1. Depending on the amount and type of biocide applicable to the situation, a backflow preventer (RPZ) may be required if not already present. Remember to contact the water authority for maximum concentrations and types of biocides permitted without a backflow preventer.

2. When providing inspection, testing, or maintenance on a system that involves dispensing of water with disinfectant additives, remember to dispose of the water properly. Open discharge of some treated waters may lead to heavy fines by environmental authorities.

Conclusion

Aside from the pinhole leaks that MIC creates, tubercles and nodules located on the interior of the pipe are a major concern, since the C-factor that is applied to sprinkler piping used to determine friction loss does not anticipate severe MIC. In some cases of MIC, the person(s) investigating have stated that the obstructions caused by tubercles were so great that there was almost no cross-sectional area of the opening in the pipe remaining.

In conclusion, MIC is a corrosion issue that the fire sprinkler industry cannot afford to ignore. MIC has the capability to significantly lower the reliability factor of sprinkler systems, and must be properly addressed to maintain the excellent performance record of automatic sprinkler systems.

Cited References

Jones, Douglas S., "Bacteria Fungi and Other Causes of MIC", Presented at the NACE MIC TechEdge Program, Houston, Texas, October 29-31, 1997.

Pope, Daniel H., "Final Report on the Investigation of a Fire Protection System for Evidence of Microbiologically Influenced Corrosion", BioIndustrial Technologies Inc., Georgetown, Texas, 1994.

Kobrin, Gregory, "A Practical Manual on Microbiologically Influenced Corrosion", NACE International, Houston, Texas, 1993.

Additional Reading

Licina, George, "Microbiologically Influenced Corrosion", Structural Integrity Associates, San Jose, California, 1997.

Little, Brenda J., "What MIC Is and Isn't", Presented at the NACE MIC TechEdge Program, Houston Texas, October 29-31, 1998.

Little, Brenda J., "Myths Related to Microbiologically Influenced Corrosion", Materials Performance, Houston, Texas, June 1997.

Thielsch, Helmut and Freeman, Susan., "Microbiological Corrosion in Municipal Water Treatment Plant Piping", WATER Engineering and Management, May 1997.

Appendix A – Examples of Biocides

Chlorine: A very effective biocide, chlorine has been proven to be an excellent MIC treatment agent. It is a relatively inexpensive and simple solution, active for periods of time from minutes to a few hours. Some of the technical data that is required before this biocide is added include the pH level, and temperature, along with the chlorine, ammonia, iron and manganese levels of the water supply. The only drawback is that after this biocide is applied, minor electrochemical corrosion can develop. The municipal water authority will probably allow the addition this biocide without the requirement for a reduced pressure zone backflow preventer. The amount that should be added should be a minimum of 10 ppm (Kobrin, Pope).

Iodine: A very effective biocide, iodine has been proven to be an excellent MIC treatment agent. It is a relatively inexpensive and simple solution, and remains active longer then chlorine. Some of the technical data that is required before this biocide is added include the pH level and temperature, along with the chlorine, ammonia, iron and manganese levels of the water supply. The municipal water authority will probably allow the addition of this biocide without the requirement for a reduced pressure zone backflow preventer. The amount of this biocide to be added should be in the area of 10 ppm (Pope).

Hydrogen Peroxide: A very good oxidizing biocide, hydrogen peroxide has been proven to be an excellent MIC treatment agent. This biocide has the capability not only to kill MIC cells but also to help loosen nodules and debris at the same time. It is a relatively inexpensive and simple solution, active for relatively long periods of time (24 hrs.). Some of the technical data that is required before this biocide is added include the pH level and temperature, along with the chlorine, ammonia, iron and manganese levels of the water supply. The drawback is that minor rust and gas may develop in the system after this biocide is applied. The municipal water authority will probably allow the addition of this biocide without the requirement for a reduced pressure zone backflow preventer. The amount that should be added should be a minimum of 50 ppm (Kobrin, Pope).

Ozone: Probably one of the most effective chemical methods of fighting MIC, ozone has also been proven to kill and loosen up MIC cells. Seasonal variations may limit the use of this biocide, as well as the pH level, water temperature, and ammonia, iron, and manganese levels. Other factors that will affect the use of this biocide are the amounts of organic materials and suspended solids, and the chlorine demands of the system.

Major drawbacks concerning the use of ozone as a biocide include its short half-life of 20 minutes and its damaging effect on rubber components such as gaskets. The amount that should be added should be a minimum of 2 ppm (Kobrin, Pope).

Appendix B - Definitions

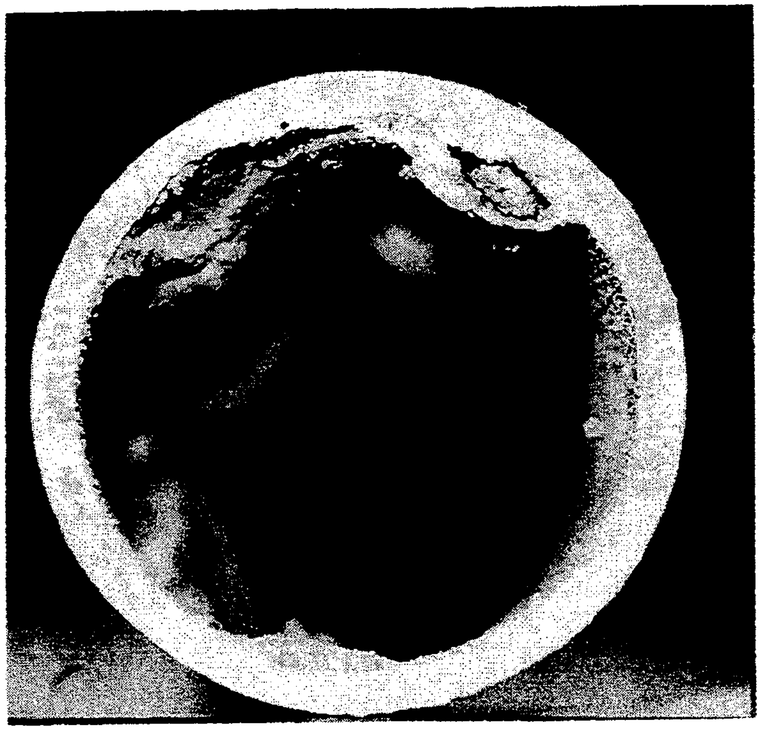
1. Aerobe: An organism requiring oxygen to survive.
2. Aerobic: In contact with oxygen.
3. Anaerobe: An organism that survives and grows without oxygen.
4. Anode: Location of oxidation reaction. Electrons will flow away from the anode in a circuit. Corrosion occurs here and metal ions are produced.
5. Bacteria: A single-celled microscopic organism. There are many thousand species of bacteria.
6. Biocide: A substance toxic to living organisms.
7. Cathode: Location of reduction reaction. Electrons will flow toward the cathode in the circuit. Oxygen as well as other elements can be reduced from a higher to lower valance state.
8. Corrosion: The dissolution of metals due to a reaction caused by the environment.
9. Deaereate: Remove air from.
10. Electrolyte: Substance or mixture that contains ions that move in an electric field.
11. Microbe: A microscopic organism.
12. Oxidation: Removal of electrons from an atom, ion or molecule.
13. Pitting: Localized corrosion that leads to deep cavities.
14. Reduction: Reaction in which the consumption of electrons occurs.
15. Tubercles: Mounds of localized corrosion/bacterial biomass and products.

Appendix C- Microbiologically Influenced Corrosion (MIC) Reports to NFSA

Year of Inst.	Year of Detect-ion	Time to Detection (yrs)	Type of Pipe	Tubercles Evident?	Slime Evident?	Color	Water Source	Tested/ Flushed Regular Schedule?	City/State	Multiple Systems Evident?	Other Helpful Information
1986	1996	10	Schedule 10 4" pipe	YES	YES	Orange	Well	YES	New Paris, IN	NO	N/A
1965	1995	30	Schedule 10 Steel	YES	N/A	Rusty Orange & Black	Well	YES	Union City, CA	YES, 3	Tested positive For Gallionella
N/A	1995	N/A	Steel	YES	YES	Orange & Brown	Public	YES	Union City, CA	N/A	Fire sprinkler, Dom. systems
1980	1995	15	6", 8" Thinwall	YES	YES	Orange & Black	Public	NO	Bellevue, WA	N/A	Both sides of fire pump
1988	1995	7	Steel 4" Thinwall	YES	NO	Orange & Black	Public	YES	Seattle, WA	YES, 2	Wet and dry systems
1987	1990	3	Copper	YES	NO	Bluish Green	Public	YES	Nova Scotia, Canada	N/A	Entire building
1990	1993	3	Galvanized 40 Thinwall	YES	NO	Bluish Bubbles	Public	NO	Piscataway, NJ	N/A	Pre-action system
1981	1991	10	Schedule 10 Steel	YES	YES	Tan to Black	Public	YES	Minneapolis, MN	N/A	Fire pump tested annually
1987	1995	8	Schedule 10 6"	YES	NO	Green & Yellow	Public	YES	Seattle, WA	N/A	N/A
N/A	N/A	.75	Schedule 5	YES	YES	Orange	Public	YES	CA	N/A	N/A
N/A	N/A	2	Steel	YES	YES	Orange	Well	YES	Madison, WI	N/A	@ Air/water interface
1978	1995	7	Schedule 40 6" Steel	YES	YES	Black & Orange	Public	YES	Union City, CA	N/A	N/A
1984	1996	12	Schedule 40 Steel	YES	NO	Orange	Public	NO	Fairfax, VA	YES, 9	N/A

Year of Inst.	Year of Detect-ion	Time to Detection (yrs)	Type of Pipe	Tubercles Evident?	Slime Evident?	Color	Water Source	Tested/ Flushed Regular Schedule?	City/State	Multiple Systems Evident?	Other Helpful Information
1980	N/A	15	Steel	YES	YES	Black & Orange	N/A	NO	Tempe, AZ	YES, 10	Wet pipe system
1984	1994	10	Schedule 40 Steel	YES	YES	Orange	Public	YES	Indianapolis, IN	N/A	N/A
1977	1982	5	M Copper	YES	NO	Green	Public	NO	Cleveland, OH	NO	N/A
1978	1994	16	Schedule 10 4" Steel	YES	YES	Orange & Green	Public	YES	Crawford, IN	N/A	Feed fain
N/A	N/A	N/A	Schedule 10	YES	YES	Orange	Public	N/A	Seritos, CA	N/A	@ b/o riser
N/A	N/A	1	Galvanized Lightwall	YES	YES	Orange	Public	N/A	Newark, NJ	N/A	N/A
1985	1995	10	Schedule 10,40	YES	YES	Orange	Public	N/A	NY and NJ	YES	N/A
N/A	N/A	.65	Schedule 7	YES	YES	Orange	Public	N/A	TX	N/A	Evident at air/water Interface
1981-1984	1988	4-7	M Copper	YES	YES	Grayish Green	Public	NO	Montreal, Canada	N/A	Since 1988, 1000 leaks
1988	1991-1992	3-4	Galvanized Schedule 10,40	YES	YES	White & Tan	Public	NO	Jacksonville, FL	YES, 15	All dry pipe systems
1987	1992	5	Steel	YES	NO	Orange	Public	YES	Mesa, AZ	N/A	N/A
1979	1996	17	Schedule 40 Steel	YES	NO	Orange	Public	YES	Indianapolis, IN	YES	N/A
1992	1996	4	Schedule 10 Steel	YES	NO	Dark Orange	Public	YES	Indianapolis, IN	NO	N/A
1991	1993	2	M Copper	YES	NO	Green	Public	YES	Auborun, CA	YES	N/A
1973	1996	23	Schedule 10	NO	NO	NO	Public	YES	Anderson, IN	NO	Pinhole @ air/water interface

Appendix D



View of a carbon steel pipe section covered with corrosion by-products and tubercles formed by aerobic bacteria. (Photo courtesy of BioIndustrial Technologies).

Appendix E – **Proposal for Appendix of NFPA 25** (accepted for 1998 edition)

Microbiologically Influenced Corrosion (MIC) has been observed in some areas, involving the creation of tubercle-covered or slime-covered pits on the interior pipe wall, in which certain types of bacteria are able to thrive. In steel pipe, the MIC is often evidenced as orange or black tubercles and/or black mud-like slime. In copper, the coloration can be blue or green. The most obvious indication of MIC is pinhole leaks occurring after only a few years of service.

Probable verification of the presence of MIC is obtained by doing a general check for bacterial evidence in the corrosion by-product. A simple chemical analysis may be performed by a metallurgical lab on the corrosion by-product from the inside of the pipe or tube. If this testing shows the amounts of carbon or sulfur to be over 3-5% range in that sludge, MIC of some type is likely.

Some things that will probably increase the occurrence of MIC are:

1. Draining a system and leaving it empty, although still wet, for periods of time.
2. Excessive flushing of systems.
3. Any other unnecessary introduction of oxygen or new water in the system.