HUGUENOT
LABORATORIES

XYZ Building

City, State

Fire Sprinkler System

Microbiological Influenced Corrosion

Metallurgical Reference Analysis

Requested By:
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ABC Industries
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RE: XYZ Building – 2.5" Inch Schedule Pipe Sch 10 Black Iron Pipe

Comments of Sample as Received:
We received a section of 2.5" inch fire sprinkler pipe which was removed from the fire sprinkler system at the XYZ Building. The visual inspection of the pipe showed it to be in poor condition with corrosion debris witnessed in the bottom and upper quadrant of the inside diameter of the pipe. Where there was evidence of stagnate water that created localized corrosion. Large areas of oxygen cell corrosion were witnessed throughout the entire pipe. The purpose of this examination was to determine the overall condition of the pipe samples as well as identify the remaining wall thickness of the received sample.

FIGURE 1: Pipe Sample as Received:

2.5 Inch Schedule 10 Black Iron Pipe

Pipe Size and Schedule Determination:
In order to determine the pipe size and schedule type, a digital micrometer caliper and an ultrasonic gauge measuring system was used to measure the outside diameter, inside diameter, and remaining wall thickness of the sample. The individual measurements and allowable tolerances are individually detailed below. All obtained measurements were then referenced to the ASTM A795 standard to determine the actual type and size of the sample. The sample was confirmed as 2.5-inch Schedule 10 black iron pipe. The physical condition

of the pipe sample of the 2.5 inch was not within FM standards for continued use. Wall thickness data is listed below which identifies the average (nominal) thickness of piping versus expected wall thickness of new pipe specifications.

MEASURED RESULTS versus EXPECTED RESULTS

Sample ID#1, 2.5 Inch Schedule 10 Black Iron Pipe.

Sample Size	Expected OD	Actual OD	Expected Wall Thickness	Actual Wall Thickness At Pinhole	FM Minimal Requirement	Nominal (Average) Thickness Upper Quadrant
2.5 Inch	2.875 Inch	2.895 Inch	0.120 Inch	0.000	0.090	0.086

FM Global Standards:

2.2.1.3 Where the extent of corrosion damage to remaining pipe needs to be determined, use the FM Global protocol for in-situ UT examination of piping given in section 3.3 below. Consider replacement of any section of pipe exhibiting pit sites with remaining wall thickness less than shown in Table 1.

Table 1. Guideline for Retaining Pipe Based on Extent of Corrosion Damage

Pipe Schedule	% Wall Remaining in Any Single Pit
Schedule 40	50 % Loss
Schedule 10	25 % Loss
Schedule 5	25 % Loss
Hybrid Schedule 7	25 % Loss

Note: The information in Table 1 provides a working guide for determining whether piping should be retained or replaced. It is based on engineering judgment and on several cases of corrosion examined by Factory Mutual Research. This guidance is intended to identify those sections of pipe which, because of the depth of the pit, a pinhole leak could develop in a relatively short period of time. However, it does not reflect the remaining useful life of a pipe.

General Observations:

The visual inspection of the sample revealed very small tubercles with areas of oxygen cell corrosion pits in the location of the lower quadrant of the pipe. Mild localized pitting was witnessed in this area. The pitting is typical of pipe that has been subject to environments where stagnate water remains in wet pipe fire sprinkler system. The sample was noted as received with mild evidence of MIC and mineral related corrosion.

FIGURE 2; 1 Pipe Sample Sectioned: 2.5" Black Iron Schedule 10 Pipe

PROCEDURE AND RESULTS:

The as-received appearance of the submitted sample is shown. The laboratory received the pipe with no orientation identified. The pipe was marked, anticipating the 180° mark to be the top of the pipe for discussion purposes. Similarly, the bottom of the pipe was marked as the 0° position which is the location of corroded area along the bottom half of the pipe.

The pipe was then longitudinally split to allow examination of the inside diameter surface. Visual examination of the inner pipe surface disclosed the presence of reddish-brown corrosion product along the inner surface of the pipe. It was noted that significantly less corrosion was visible along the top half of the pipe. The typical appearance of this condition is shown in the figure below where the sample was sectioned to reveal the interior condition of the pipe sample.

Further examination of the interior surfaces of the pipe revealed the presence of localized areas of dark, reddish corrosion along the bottom half of the pipe. This condition was suggestive of corrosion mounds present in this location during service. The typical appearance of this condition is shown these figures.
Specimens of the corrosion products from the inner surface of the pipe were removed and prepared for analysis. The analysis of the corrosion on the inner surface of the pipe disclosed the presence of primarily iron with lesser concentrations sulfate, chlorides and oxygen. The composition of the corrosion sample was consistent with iron oxide (rust).

A section of the inside diameter surface of the pipe was then cleaned to allow further examination. Visual examination of the cleaned surface of the pipe section disclosed the presence of broad pits in the locations corresponding to the areas of localized dark reddish corrosion. The typical appearance of this condition is shown these figures.

Internal Section of Pipe Clean

The pictures on the next page are a sectional view of sample after being cleaned it revealed isolated small areas of pooling and generalized pitting. Further microscopic analysis was completed and is further discussed in detail later in this report. Looking at the center of the photos you will notice the etching into the pipe surface. This is typical of piping which has been compromised by both Oxygen Cell and Microbiologically Induced Corrosion. The corrosion patterns are consistent with Iron Related and Slime Producing corrosion damage.

Sample 1 – 2.5 Inch Black Iron Schedule 10 Pipe Cleaned Sample Section

The surface cleaning process was completed, and the photographs revealed the samples have localized areas where pitting and wall thickness loss occurred due to processes associated with Oxygen Cell Corrosion and Acid Slime Bacteria contamination. An “Acid Slime Attack” will produce the pooling effect on the metal as seen in these samples. Acid Slime bacteria consume chlorides and sulfate minerals in the water and produce acid excretion in the process. An Iron Related Bacteria attack will produce an acidic condition that results in areas where pitting will occur, which accelerates the corrosion process from within an oxygen cell pit.

Conclusion:

This analysis indicates that the submitted pipe samples had experienced small pitting corrosion. Pitting is a form of generalized corrosive attack and microbiological influenced corrosion, which is associated with this breakdown. All samples received were in good condition, based on brand new pipe. The outside environment containing cold weather and snow caused this sample to begin corroding before these sample were placed in a fire sprinkler system.

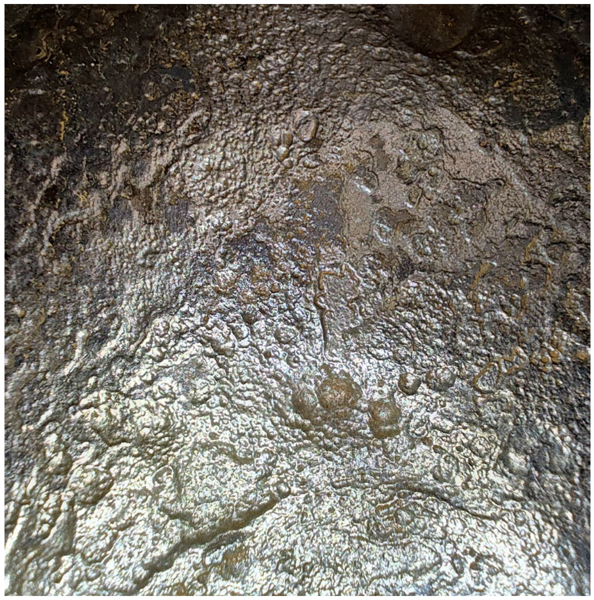
The primary mechanism of the pitting appeared to be under-deposit corrosion. Under-deposit corrosion is commonly associated with oxygen pitting (oxygen cell differential). Corrosion products are initially deposited on the metal surface. These corrosion products form mounds of deposits known as tubercles. The oxygen concentration becomes depleted under the tubercles with the oxygen concentration of the bulk water remaining higher; this along with an MIC bacteria present produces the pitting seen in these photos. Additionally, corrosive species such as chlorides and sulfur compounds can concentrate under these deposits, further accelerating the corrosion rate.

Sample 2 – 2.5 Inch Black Iron Pipe

SUMMARY OF FINDINGS: Oxygen Cell Corrosion

The type of corrosion which was observed is being caused by several factors. The three components of corrosion are Water, Oxygen, and Steel Pipe. The rusting process of an oxygen rich environment formed the initial corrosion cycle. The precipitation of deposits in the bottom area of the pipe occurred next. The deposit formation condition then resulted in the formation of Oxygen Cells which is the initial formation of a Tubercle.

Fire Sprinkler systems are especially vulnerable to experiencing this type of condition due to a stagnant water environment and the presence of trapped air typically found in these systems. Any daily temperature fluctuation on the system likely advanced the precipitation of the minerals in the water. Oils left in the piping systems from fabrication and manufacturing act as a nutrient for the bacteria to thrive. The minerals that dropped out of the solution in the form of deposits started the initial Under-Deposit Corrosion via "Differential Oxygen Cell" corrosion. Differential Oxygen Cell Corrosion followed by additional (MIC) corrosion process caused by the Acid Slime Producing bacteria which was documented.



The smaller generalized acid tubercles mentioned above were observed in the perimeter surrounding the majority of the corrosion attack area and are small Oxygen Cell pits. Acid Slime bacteria function initially by consuming dissolved oxygen that was present in the water. This is one of the initial reactions that occur with oxygen cell corrosion. Once the oxygen is consumed, the reaction caused by Acid Slime bacteria reverts to an electro-chemical reaction where the Acid Slime bacteria consume chlorides and sulfate minerals in the water and produce an acid excretion in the process. The generalized reddish-brown coating on all metals is Ferrous Hydroxide. This product is the beginning process of iron migration that turns to the deep red-brown color where more oxygen can come in contact with the steel surface producing Ferric Hydroxide. An "Acid Slime Attack" will produce a pooling effect on the metal as seen in this sample. Iron Related Bacteria will produce an Acidic condition that will accelerate the corrosion process from within an oxygen cell pit.

We thank you for the opportunity to be of service. If there are any questions regarding this report, please call us at 800-228-3793.

Respectfully Submitted,

Mike O'Leary

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Vice President

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