HUGUENOT LABORATORIES

Tech Center

Fire Sprinkler System

Microbiological Influenced Corrosion

3 Bottle Water Analysis

Requested By:
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August 25th, 2015

ABC Industries
Attn: Mr. John Doe,
15 Anywhere Drive
Newark, DE 19702

Re: Corporate Interiors, 3 Bottle Water Analyses

Dear Mr. David Majewski,

We received your documentation and the three bottle set of water samples that were taken from the Corporate Interiors building fire sprinkler system located at 123 Anywhere Drive, in New Castle, Delaware, 19720. The three samples as received were labeled as "City water", "Main drain", and "Inspector's test". Each of these samples was analyzed for 22 mineral contents, physical properties, and microbiological contamination.

The recommendations in this report are consistent with "Standard EPA Water Testing", "A.S.T.M. G-4-84 Corrosion Testing Standards" and "Standard methods for the Examination of Water and Wastewater" 20th edition for Microbiological evaluations.

General Observations and Overview:

The attached water analysis sheet has been color coded to assist with those items requiring your attention. Test items in **red** require action and are better described in the paragraphs below.

- The individual biological analysis tests confirm that the sample labeled as city water tested negative for bacterial contamination.

- The individual biological analysis tests confirm that the sample labeled as main drain water tested positive for Total Aerobic, Coliform, Iron Related, and Slime Producing bacterium contamination.

- The individual biological analysis tests confirm that the sample labeled as inspector's test tested positive for Iron Related, and Slime Producing bacterium contamination.

- **Recommendation**: Call Tim O'Leary at Huguenot Laboratories to explain further the analysis herein and its potential impact on this facility.

PHYSICAL TESTS:

- The physical tests from the sample labeled as city water showed no discoloration with a chlorine odor. The sample was free of deposit material.

- The physical tests from the sample labeled as main drain water showed an orange and brown tint discoloration with no odor. The sample had orange and brown deposit material that was non-magnetic in nature. The presence of non-magnetic deposit material in the system water sample is confirmation that corrosion is actively occurring in the tested system.

- The physical tests from the sample labeled as inspector's test water showed no discoloration or odor. The sample was free of deposit material.

CHEMICAL CONDITIONS – Background information:

We consider all the water samples as being typical in mineral content. That is the "Total Dissolved Solids" within the water samples would fall into an average range when compared to other city waters. When rainwater comes in contact with the ground and or surface it dissolves minerals that are in the rocks and soils. These minerals comprise the quality of the water and can affect all metals in a fire sprinkler system.

City waters are different throughout the country because of their mineral content. Water also contains various gases, some manmade, others natural from the atmosphere. Oxygen is one gas that must be monitored within fire sprinkler systems. Attached to this report is our laboratory report showing the types and amounts of key minerals that effect fire sprinkler systems. It is important to realize that all minerals entering a fire sprinkler system should exit that system. That is all minerals in the city water should appear in the Inspector's Test water. Any lost minerals will show up as deposits inside of the fire sprinkler piping system. Different type minerals affect fire sprinkler metallurgy differently, and for this reason we test all troubling minerals coming into and exiting a fire sprinkler system.

YOUR CHEMICAL CONDITIONS:

The "Langelier Index" is a chemical calculation that determines if water is corrosive or scaling in nature. This index if + (positive) indicates that the water is dropping minerals out of solution. If the index is – (negative) then it is absorbing minerals into the water.

- Your city water sample has a Langelier index of -1.3 which indicates that the fire sprinkler system feed water is corrosive in nature.

- Your main drain water sample has a Langelier index of -0.9 which indicates that the fire sprinkler system water is corrosive in nature.

- Your inspector's test water sample has a Langelier index of -0.6 which indicates that the fire sprinkler system water is corrosive in nature. The negative index value witnessed in all samples confirms that the water samples are corrosive in nature.

pH test:

The "pH" test is an electrical/chemical measurement that determines if water is acidic (attacking) or alkaline (caustic / depositing). The pH test has a range of 1.0 pH to 14.0 pH. The middle of the range is 7.0 pH and this is considered neutral that is neither acid nor alkaline. It is important to know that water in the pH acid range will attack almost all metals; therefore it is generally desirable to have a neutral pH. A high pH has two effects that are detrimental to a fire sprinkler system. High pH's cause most minerals to drop out of solution causing deposits. A very high pH attacks soft metals like brass and bronze. Galvanized metal (Zinc coated) is attacked at both ends of the pH range.

- The city water sample has a tested pH value of 6.7 which is considered slightly depressed. A depressed pH will cause elevated corrosion rates in fire sprinkler systems.

- The main drain water sample has a tested pH value of 7.1 which is considered neutral.

- The inspector's test water sample has a tested pH value of 7.5 which is considered neutral.

HARDNESS SALTS:

"Hardness salts" are minerals such as Calcium and Magnesium that buffer the water to keep the water balanced or neutral. These mineral salts are the primary minerals in all waters that will protect metal from an acid attack. These minerals are different from other water minerals because they are affected by temperature. A higher temperature causes them to drop out of solution and deposit on pipe surfaces. These deposits may cause a problem known as Under Deposit Corrosion. This corrosion will be discussed later.

- The city water sample has a Calcium value of 34 parts per million (ppm). The Magnesium test shows 48 ppm with a Total Hardness of 81.6 ppm.

- The main drain water sample had a Calcium value of 30 ppm. The Magnesium test was 31 ppm with a Total Hardness of 61.2 ppm.

- The inspector's test water sample had a Calcium value of 25 ppm. The Magnesium test was 16 ppm with a Total Hardness of 40.8 ppm. The reduction of soluble Total Hardness as the water runs through the system to the inspector's test sample location confirms hardness minerals are falling out of solution in the form of deposits.

DISSOLVED OXYGEN:

Water can absorb oxygen up to about 10 ppm. The actual amount is governed by temperature, pressure and dissolved solids. Air (Oxygen) gives good taste to water and reacts with some gases to purify water. Other gases also can be absorbed but normally affect each other.

- The water sample labeled city water had a dissolved oxygen level of 5.77 ppm.

- The water sample labeled main drain had a dissolved oxygen level of 4.98 ppm.

- The water sample labeled inspector's test had a dissolved oxygen level of 4.64 ppm. The reduction of dissolved oxygen confirms that oxygen is being consumed through the process of generalized corrosion and biological contamination.

IRON:

There are two types of iron that can be present in water, Magnetic iron or non-magnetic iron. Magnetic iron comes from processed metal i.e. Steel pipe. Non–magnetic iron comes from the ground and usually enters the ground water by bacterial activity.

Our "Iron" test is a chemical test that determines if iron has been dissolved into the water. An acid condition, or low pH, will dissolve iron from the pipes into the water. Iron can also enter the water by biological attack (MIC). Bacteria such as "Iron Related, Sulfate or Acid Slime" bacteria can cause an acid condition that attacks the metal pipes causing "Iron" to be dissolved into the water.

If non-magnetic iron enters in the city water, this Iron (ferrous hydroxide) can drop out of solution as Ferric Hydroxide, a red brown colored deposit after entering the fire sprinkler system. This Iron is non-magnetic and therefore is in a different state or level than the fire sprinkler iron pipe. This mineral can cause "Galvanic Corrosion" or "Differential Metal Corrosion".

- The sample labeled as city water had an iron content of 0.0 ppm.
- The sample labeled as main drain had an iron content of +5.0 ppm.
- The sample labeled as inspector's test had an iron content of 1.0 ppm. The increase in soluble iron confirms that corrosion is actively occurring in the tested fire sprinkler system.

TOTAL DISSOLVED SOLIDS:

The "Total Dissolved Solids" (TDS) test is an Electrical /Chemical Test and calculation that determine the solids that have been dissolved by the water as it moved through the ground. The higher the TDS number is, the greater the chance for scaling or deposits. If this TDS test changes between water samples it indicates that the water is dropping minerals out of solution and producing an unhealthy environment for sprinkler system metallurgy.

- The city water sample had a TDS of 127.4 ppm.
- The main drain water sample had a TDS of 121.9 ppm.
- The inspector's test water sample had a TDS of 116.3 ppm. The decrease in TDS as the water flows through the system to the inspector's test to the sample location is an indication that minerals are precipitating out of solution as deposits.

SILICA:

The “Silica” test is a good indicator of electro-chemical reactions. This test indicates that the water is reacting and producing deposit that builds tubercles and drop minerals out of solution. It is a key indicator, in conjunction with others that under deposit differential oxygen cell corrosion” is occurring.

- The water sample labeled as city water had a silica level of 16 ppm.
- The water sample labeled as main drain had a silica level of 10 ppm.
- The water sample labeled as inspector’s test had a silica level of 6 ppm. The reduction in silica when compared to the city water sample is an indication that oxygen cell corrosion is actively occurring in the fire sprinkler system.

AMMONIA AND CHLORIDE

Ammonia and Chloride can combine to form (**Ammonium Chloride**). This chemical compound forms a highly acidic water condition which can aggressively corrode the metallurgy of a fire sprinkler system. Ammonium Chloride Corrosion will normally occur as part of “Under Deposit Corrosion” in the fire sprinkler piping. Under Deposit Corrosion is the primary method of “Pit” development that causes “Pin Hole Leaks”. These are commonly seen as Tubercles on the inside of the pipe.

- The main drain and inspector’s test water sample had an ammonia level of 0.5 and 1.0 ppm and a chloride level of 32 and 36 ppm. The value witnessed is an indication that Ammonium Chloride is likely present as a component of Under Deposit Corrosion. This condition will cause elevated corrosion and pinhole leaks in fire sprinkler systems.

SULFATE, HYDROGEN SULFIDE

The “Sulfate” test is a very important test. It can tell the stability or activity of a water sample. Sulfate Reducing Bacteria utilize sulfates to survive. This bacterium is VERY DESTRUCTIVE and can eat through schedule 40 pipes in less than one year. This bacterium eats “Sulfate” and produces Sulfuric Acid. These bacteria require a very low to no dissolved oxygen level. This condition can occur under a deposit or crevice in a pipe. Threaded pipe joints and poor welds are good places to examine when looking for these bacteria. These bacteria also produce Hydrogen Sulfide Gas (sewer gas or smells like rotten eggs); Hydrogen Sulfide Gas is an explosive gas. This condition also produces Iron Sulfide (black water), which is often seen in the Inspector’s test sample.

- There were no reductions in “Sulfates” in the system samples and there was no Hydrogen Sulfide present. This confirms the absence of Sulfate Reducing Bacteria.

OXYGEN CELL CORROSION:

Oxygen cell corrosion is a problem in every fire sprinkler system that has deposits. This destructive force is the same one we see when we look at an iron post rusting outside. The only conditions needed for this form of corrosion are:

Air
Water
Iron

These conditions occur in all fire sprinkler systems. This condition is often called "generalized (rusting) oxygen cell corrosion". It occurs in all water systems. So why don't we see it (pinhole leaks) on all pipes? The reason is very simple. Other water systems do not run out of dissolved oxygen, which often occurs in fire sprinkler systems.

In the rusting process dissolved oxygen is consumed and the level of dissolved oxygen is reduced. If deposits are present then there can be two different levels of dissolved oxygen present on either side of the deposit. The level under the deposit continues to react with the iron. This electrochemical process consumes the hydrogen and oxygen, while converting the iron to "Ferrous Hydroxide". The oxygen level in the water above the deposit has a higher dissolved oxygen content then below the deposit. The difference in oxygen produces a greater electrical differential driving the reaction (attack) faster. As the dissolved oxygen level under the deposit approaches zero the reaction starts producing organic acids. If no dissolved oxygen is present, the remaining hydrogen will convert the chlorides and sulfates to produce hydrochloric and sulfuric acids compounds.

AGGRESSIVITY INDEX:

The aggressively index is a numeric index value that is used to quantify the level of bacteria discovered in a sample. This index is also used as a reference to determine the aggressive nature of the bacteria and its effect it can have in advancing the process of corrosion in a fire sprinkler system.

High Aggressivity = Aggressive damage to sprinkler piping is probable
Medium Aggressivity = Moderate damage to sprinkler piping is probable
Low Aggressivity = Low possibility that bacteria will cause sprinkler pipe damage

Aerobic	**(1 MM-1,000 =)**	**(999-100 =)**
Anaerobic	**(Positive Result =)**	**(Negative Result =)**
Coliform	**(Positive Result =)**	**(Negative Result =)**
Sulfate Reducing	**(6.8MM-1,200 CFU =)**	**(1,199-200 CFU =)**
Iron Related	**(540,000-500 CFU =)**	**(499-25 CFU =)**
Slime Producing	**(1.8MM-12,500 CFU =)**	**(12,499-500 CFU=)**

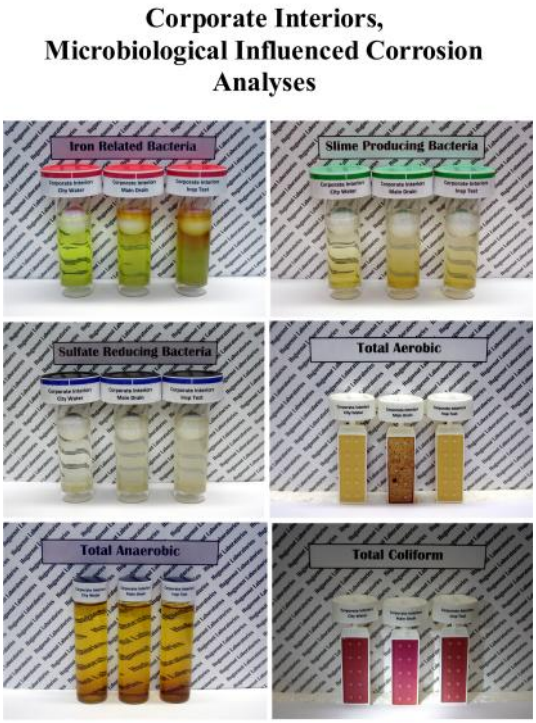
YOUR BIOLOGICAL CONDITIONS:

Bacteria thrive in fire sprinkler systems. The water is stagnant, normally contains oil (a food for most bacteria), and is normally at a perfect temperature for growth. The water is rarely dumped, and seldom disturbed.

There are two main bacteria groups: Aerobic and Anaerobic. The aerobic bacteria live in an oxygen environment, while the anaerobic live in no oxygen. Both conditions can occur in a fire sprinkler system at the same time. Dissolved Oxygen will be in the water and no Dissolved Oxygen will exist under a deposit. Bacteria culture tests studies were completed and the results are as follows:

	City water	Main drain	Inspector's test
Aerobic	Negative =	**10,000 CFU's** =	Negative =
Anaerobic	Negative =	Negative =	Negative =
Coliform	Negative =	**Positive** =	Negative =
Sulfate Reducing	Negative =	Negative =	Negative =
Iron Related	Negative =	**140,000 CFU's** =	**140,000 CFU's** =
Slime Producing	Negative =	**1.8MM CFU's** =	**1.8MM CFU's** =

The pictures below are of your microbiological analysis which is also attached to the end of this report:



The city water sample tested negative for bacterial contamination.

The main drain sample tested positive for Total Aerobic, Coliform, Iron Related, and Slime Producing bacterium contamination.

The inspector's test sample tested positive for Iron Related, and Slime Producing bacterium contamination.

CONCLUSION:

The negative "Langelier Index" value in all of the samples is an indication that the water is prone to elevated corrosion rates due to the negative index values. Total Hardness, TDS (Total Dissolved Solids), Silica, Conductivity and Dissolved Oxygen were reduced while the Soluble Iron increased when referenced to the city water sample. Ammonia was present which confirms the presence of bacterial contamination. Bacterium known to cause Microbiological Influenced Corrosion was also detected in excessive high levels. It is our opinion that you have the following problems:

- Unstable water causing elevated corrosion rates.
- Evidence of Oxygen Cell corrosion exists.
- Bacterium known to cause MIC (Microbiological Influenced Corrosion) is present.

MICROBIOLOGICAL ELIMINATION EFFECTIVNESS:

We completed a toxicity study to determine the best effective product and concentration to eliminate bacterial growth in your water system. The water was treated with four (4) known chemical products used today to treat bacterial contamination in fire sprinkler systems. The object was to determine the most cost effective product to obtain an effective bacterial kill rate.

Product	Concentration	Contact Time	Kill Rate
FFS Bio-Guard Plus (Bromochloro-dimethylhydantoin)	1 gal / 1000 gal	1 hr	85%
	1.5 gal/1000 gal	1 hr	92%
	2 gal / 1000 gal	1 hr	96%
FFS Bio-Guard B (Proprietary)	1.0 gal / 1000 gal	1 hr	82%
	1.5 gal / 1000 gal	1 hr	92%
	2.0 gal / 1000 gal	1 hr	99%
C-105 (Glutaraldehyde)	¼ gal / 1000 gal	1 hr	84%
	½ gal / 1000 gal	1 hr	88%
	¾ gal / 1000 gal	1 hr	92%
	1 gal / 1000 gal	1 hr	96%
C-110 (Isothiazolinones-and polyionene)	¼ gal / 1000 gal	1 hr	67%
	½ gal / 1000 gal	1 hr	85%
	¾ gal / 1000 gal	1 hr	91%
	1 gal / 1000 gal	1 hr	96%

Indicates Product of Choice

CORROSION ELIMINATION EFFECTIVENESS STUDY:

We completed a corrosion effectiveness study to determine the actual corrosion rate of the city water which is listed on the following page. A secondary study was completed to identify the most effective corrosion inhibitor product and feed rate to reduce or eliminate corrosion in your fire sprinkler system. The water was treated with five (5) known chemical products used today. The object of this study was to determine the most cost-effective product and feed rate to obtain a desirable result.

To obtain this data we needed to determine a base line corrosion rate for the sample water sent to us. Then we put known amounts of treatment into the water and ran a 7-day corrosion study. We then compared it to the base line result. This study is an indication of expected results and does not replace a 30-day in line corrosion test as outline in this report.

Product	Concentration	Contact Time	Corrosion Rate
City water	None	7 days	8.79 mpy
C-205	1 gal / 1500 gal	7 days	4.0 mpy
(Molybdate- Phosphonate)	2 gal / 1500 gal	7 days	3.0 mpy
FSS-ProGuard Green	1.0 gal / 1000 gal	7 days	3.8 mpy
(Green Chemistry)	4.0 gal / 1000 gal	7 days	0.21 mpy
C-DWA	¼ gal / 1000 gal	7 days	6.0 mpy
(Drinking Water Inhibitor)	½ gal / 1000 gal	7 days	5.0 mpy
C-FSP-VCI	30 gal / 1000 gal	7 days	1 mpy
(VaporPhase)	50 gal / 1000 gal	7 days	0.74 mpy
C-111 (THPS)	¼ gal / 1000 gal	7 days	16 mpy
(Phosphonium-	2 gal / 1000 gal	7 days	14 mpy
sulfates)	3.0 gal / 1000 gal	7 days	8 mpy

Indicates Product of Choice

CORROSION ANALYSIS RESULTS:

Number of years of life for various schedule of pipe

Water without and with Treatment	Mils Per Year	Days Tested	Sch 40 4 Inch	Sch 10 4 Inch	Sch 5 4 Inch
City water	8.79	7	26.9	13.6	9.4
ProGuard Green	0.21	7	1128.5	571.4	395.2

The corrosion effectiveness study was completed on the city water you supplied us. The results of this corrosion study determined that the city water had a tested corrosion rate of 8.79 MPY (Mils Per Year) with no treatment applied. A secondary test was then conducted with your city water where FFS ProGuard Green was added at a concentration of 400 parts of corrosion inhibitor product to 100,000 parts of water. This treatment concentration on a volume basis equals 4 gallons of treatment protection to 1000 gallons of system volume. The expected performance of this product normally controls corrosion at a rate of 2.0 mils per year. The actual measured corrosion protection results were a measured corrosion rate of only **0.21** mils per year. As you can see from the data above, treatment of this fire protection system will significantly increase the usable life of the system. The expected corrosion analysis results were used to determine the pipe schedule life expectancy. The actual tested results for corrosion protection were significantly improved over the expected results.

THE SOLUTION:

The answer to reducing or eliminating the expensive effects of the corrosion witnessed in this system requires a two-step treatment methodology. First drain the system and fill with an approved biocide and oil absorber such as FSS-ProClean B to penetrate the bio-slime mass. Allow the system to soak for 2 to 4 hours to kill all bacteria. Drain the system again to remove dirt and biological wastes then refill with our proven and approved FSS-ProGuard Copper environmentally friendly corrosion inhibitor and our FSS-BioGuard B bio-static environmentally friendly MIC controller specifically designed for fire sprinkler systems.

VERIFY EFFECTIVNESS:

One of the most proven methods of testing corrosion potential is with corrosion coupons. The American Society of Corrosion Engineers has developed test method ASTM-G4-84 specifically testing iron pipes in plants and building. This test reports the corrosion rates and types of corrosion. It is very cost effective and proves the effectiveness of treating. Huguenot Laboratories Inc. believes it is in the best interest of owners to test before and after treatment in order to appreciate the cost effectiveness of protecting their capital investment. This simple insertion probe is one of the many methods available which evaluate the potential of corrosion.

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,

Tim O'Leary- President
(800) 228-3793
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Location: Corporate Interiors

223 Lisa Drive
New Castle, DE 19720

Contractor: Bear Industries, Inc
15 Albe Drive
Newark, DE 19702
Attn: David Majewski

Color codes	Normal = No Action
Color codes	Trouble = Action req'd

Date: 8/17/2015

Analysis	Sample Points: City Water	Main Drain	Insp Test			Analysis	Sample Points: City Water	Main Drain	Insp Test		
Total Hardness as $CaCO_3$, ppm	81.6	61.2	40.8			**Total Diss. Solids** as, ppm	127.4	121.9	116.3		
Calcium as $CaCO_3$, ppm	34	30	25			**Sulfate** as SO_4, ppm	0	0	0		
Magnesium as $CaCO_3$, ppm	48	31	16			**Hydrogen Sulfide** as H_2S, ppm	0	0	0		
P-Alkalinity as $CaCO_3$, ppm	0	0	0			**Manganese** as, Mn ppm	0	0	0		
M-Alkalinity as $CaCO_3$, ppm	40	50	60			**Diss. Oxygen*** as, O_2 ppm	5.77	4.98	4.64		
Silica as SiO_2, ppm	16	10	6			**Total Iron** as Fe, ppm	0	<5	1		
Nitrite as NO_2, ppm	0	1	0.5			**Chloride** as Cl, ppm	37	32	36		
Ammonia as NH_3/NH_4, ppm	0	0.5	1			**Total Chlorine** as, ppm	<0.5	0	0		
Total Phosphate as PO_4, ppm						**Free Chlorine** as, ppm	<0.5	0	0		
Ortho Phosphate as PO_4, ppm	0.2	0	0								
pH	6.7	7.1	7.5								
Specific Cond. micromhos 25° C	267.2	255.9	244.6								
pHs	8.0	8.0	8.1								
Langlier Index	-1.3	-0.9	-0.6								
Ryznar Stability index @ 80° F	9.3	8.9	8.7								

* Residual Chlorine can create a positive DO interference

Initial Weight (g)	10.7625
Final Weight (g)	10.6889
Days Tested	7
Corrosion Rate (Mil/yr)	8.79

Years of life for various scheduled pipe sizes at corrosion rate above

Schedule 40	Schedule 10	Schedule 5
26.9	13.6	9.4

Special Biological Testing

cfu/mL

	NEG	POS	NEG		
Total Aerobic Bacteria		10000			
Total Coliform Bacteria	NEG	POS	NEG		
		10			
Total Anaerobic Bacteria	NEG	NEG	NEG		
Iron Related	NEG	POS	POS		
Sulfate Reducing	NEG	NEG	NEG		
SRB 14 day results	NEG	NEG	NEG		
Slime producing	NEG	POS	POS		

Physical Tests	City Water	Main Drain	Insp Test		
Color	clear	orange tint	clear		
Deposit	none	orange-brown	none		
Odor	chlorine	none	none		
Other		Non-Mag			

Comments: * Description not recorded

Corporate Interiors, Microbiological Influenced Corrosion Analyses