What’s Eating Your Pipes?
How Corrosion Can Cause Your Sprinkler System to Fail and How to Fight It

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Agenda

- Introduction
- Facts
- Types of corrosion
- Factors that accelerate corrosion
- NFPA – 25
- Sizing up the problem
- Mitigation
- Conclusion

A Story of a Nursing Home

- Nursing home facilities average 2,300 fires nationally per year.
- Centers for Medicare & Medicaid Services mandate.
A Story of a Nursing Home

- April 30, 1998 at the Lamoni Nursing Center.
- Fire in the north wing laundry room.
- Total failure of the sprinkler system.
- A single head should have controlled the fire.

Dry system had been installed in 1972.

- Sprinkler found plugged with hardened, rust-colored, granular material.
- Every head in the wing.
- Branch lines severely corroded and partially plugged.

A Story of Reaction

- In recent years a state agency had a fire which ended up killing some group home residents.
- The reaction – fix all sprinkler systems that might have problems.
- State identified 5 group homes.
A Story of Reaction

➢ Just one of the homes had a problem due to leaking. The other 4 were unknown but built at the same time.

➢ The reaction was rip out all the systems.

➢ The solution required education in corrosion.

➢ Ultrasonic testing was performed.

A Story of Reaction

➢ 4 out of the 5 group homes had a corrosion issue.

➢ One of the homes was close to near perfect condition.

➢ Replaced 4 systems, saved 1.

➢ Over a $150,000 savings for a small investment.

Case Example: Five High-Rise Buildings

Where to start?
**Case Example: High-Rises**

**Given:**
- 5 High-Rises.
- 44 stories and 22 stories.
- Fully occupied.
- Standpipe system only, no sprinkler system.

**Problems:**
- Waterflow switches not working.
- Investigation reveals slime in water when replacing switches.
- Plugged piping observed.
- Extent of problem not known.

**Options:**
- Destructive testing – one location – cost $18,000 + downtime
- Ultrasonic Testing – 250 locations – Cost $25,000 – No downtime, more locations.

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**Corrosion - Definition**

- Naturally destroys metal at a very slow rate
- Reactions between metal + water = rust
- Result - "pit" the inside pipe wall or deposit tubercles (corrosion byproducts) there
Losses Due To Corrosion

Corrosion can be Indicative of Other Problems
- Non-compliance with NFPA 13
- Improper installation including improper slope, trapped air, or inadequate drainage
- Improper operation or maintenance
- Possible MIC activity

Corrosion Can Cause Pinhole Leaks
- Disruptive to normal operations
- Potential damage to equipment and/or property
- Lead to loss of revenue due to shutdowns
- Cause the continuous introduction of oxygenated water due to repeated draining for repairs
- Lead to costly ongoing repairs
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Two Main Types of Corrosion

Interior
Exterior

Exterior Corrosion

- Corrosive atmosphere exists = corrosion-resistant sprinklers.
  - Stainless steel sprinklers
  - Sprinkler coatings

- Shop paint and manufacturer's coatings on the outside of the piping help some.

- Rust film (oxide layer) that is found on pipe and fitting exteriors actually serves as a corrosion inhibitor.
Types of Interior Corrosion

- Electrochemical Corrosion
- Under Deposit Corrosion
- Galvanic Corrosion
- Microbiologically Influenced Corrosion (MIC)
- Limescale Accumulation
- Hypochlorite Corrosion
- Dezincification
- Welding

Electrochemical Corrosion

**Oxygen Corrosion**

- Steel pipe is 98% iron.
- Oxygen dissolved in water react with the iron.
- Forms iron hydroxide (rust).
- Fresh water = restart of corrosion process.

Under Deposit Corrosion

- Very common
- Forms under sediment, deposits of debris or corrosion products
- As corrosion continues the pit will deepen
- A tubercle could form over the pit
Galvanic Corrosion

- Dissimilar metals in physical contact
- Requires the presence of water
- Black pipe connected to galvanized pipe – the zinc will dissolve

Microbiologically Influenced Corrosion (MIC)

- Corrosion caused by bacteria
- Two main classes of bacteria
  - Aerobic – needs oxygen
  - Anaerobic – doesn’t require oxygen
- 6 primary types

Mid-1980s.

- More prevalent in areas with warmer climates.
- Hard data confirming known causes of MIC in sprinkler systems is scarce.
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Lifespan

- Anticipated lifespan of a sprinkler system is 30-40 years.
- Lifespan of wet-pipe sprinkler systems exceed those of dry-pipe systems.
- Any testing over and above NFPA 25 or insurance carrier guidelines will cause added oxygen to rust system piping prematurely.

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The type of black steel (domestic or imported) used to make the pipe matters little.

- Using galvanized steel can help with a longer system life.
- It is mainly what goes into the pipe.
**Corrosion Rates**

- Schedule 40
  - Acceptable Rate < 0.5 MPY
  - Low Rate = 1 MPY
  - Aggressive Rate > 3.0 MPY

- Schedule 10
  - Aggressive Rate > 1.5 MPY

**4″ Pipe Wall Thickness Comparison**

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Thickness (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sch 80</td>
<td>0.317</td>
</tr>
<tr>
<td>Sch 40</td>
<td>0.237</td>
</tr>
<tr>
<td>Sch 10</td>
<td>0.120</td>
</tr>
<tr>
<td>Sch 5</td>
<td>0.083</td>
</tr>
</tbody>
</table>

**Corrosion Effect**

- Steel, when corroded back into iron oxide (rust), produces a greater volume of less dense material by a factor of approximately 20 times.

- A 4″ Schedule 40 pipe corroding at a rate of 5 MPY will lose about 20 lbs in 100 ft in 1 year.

- 2 years of corroding means 40 lbs of rust is in the 4 inch pipe.
Wet Pipe System Corrosion

- Oxygen is the rate limiting component.

\[ 4\text{Fe(s)} + 3\text{O}_2(g) \rightarrow 2\text{Fe}_2\text{O}_3(s) \]

Dry Pipe & Preaction System Corrosion

- Oxygen corrosion is more aggressive in dry and preaction systems.
- Oxygen corrosion is limited to areas of the pipe that are wet with liquid moisture.
- Oxygen for the corrosion reaction is in great excess and it will continue to react.

Dry Pipe & Preaction System Corrosion

- Temperature fluctuations cause the compressed air in the system piping to fall below the dew point, water condenses on the pipe walls as small droplets.
- Distilled water
- CO\textsubscript{2} dissolves in the distilled water and forms carbonic acid which reduces the pH to about 5.5
### Conditions and Results

<table>
<thead>
<tr>
<th>Condition for Corrosion</th>
<th>Type(s) of Deposits</th>
<th>Type(s) of Corrosion</th>
<th>Relative Rates of Corrosion</th>
<th>Relative Rates of Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron + Water + Oxygen</td>
<td>Generalized</td>
<td>Generalized</td>
<td>Slow</td>
<td>Slow</td>
</tr>
<tr>
<td>Iron + Water + Oxygen + Chloride</td>
<td>Generalized</td>
<td>Some pitting</td>
<td>Generalized faster</td>
<td>Penetration faster</td>
</tr>
<tr>
<td>Iron + Water + Oxygen + Microbes</td>
<td>Isolated Localized</td>
<td>Pitting</td>
<td>Much faster</td>
<td>Much faster</td>
</tr>
<tr>
<td>Iron + Water + Chloride (no oxygen)</td>
<td>None Localized</td>
<td>Under-deposit acid attack</td>
<td>Generalized slower</td>
<td>Very slow</td>
</tr>
<tr>
<td>Iron + Water + Microbes (no oxygen)</td>
<td>Localized Localized</td>
<td>Pitting</td>
<td>Very fast</td>
<td>Very fast</td>
</tr>
<tr>
<td>Iron + Oxygen + Microbes + Chloride (no water)</td>
<td>None None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

### Accelerate the Rate of Corrosion

1. More oxygen becomes available.
2. Solids (e.g., iron oxides, particulate matter, etc.).
3. Microbial contamination.
5. Draining and refilling the system.
6. The low pH of condensate (dry and preaction systems).

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Corrosion – NFPA 25

1.2 Purpose.
The purpose of this document is to provide requirements that ensure a reasonable degree of protection for life and property from fire through minimum inspection, testing, and maintenance methods for water-based fire protection systems. In those cases where it is determined that an existing situation involves a distinct hazard to life or property, the authority having jurisdiction shall be permitted to require inspection, testing, and maintenance methods in excess of those required by the standard.

NFPA 25 Requirement

13.2.1 An investigation of piping and branch line conditions shall be conducted every 5 years by opening a flushing connection at the end of one main and by removing a sprinkler toward the end of one branch line for the purpose of investigating for the presence of foreign organic and inorganic material.

13.2.1.1 Alternative nondestructive examination methods shall be permitted.

NFPA 25 Requirements and Options

Two levels of inspection:
1. Assessment of internal condition – every 5 years. Does not require taking the piping apart.
2. Obstruction investigation – triggered by certain events.
Obstruction Investigations:
When to Conduct per NFPA 25

- The discharge of obstructive material during routine water tests
- Foreign materials in fire pumps, in dry pipe valves, or in check valves
- Foreign material in water during drain tests or plugging of inspector’s test connection(s)
- Plugged sprinklers
- Plugged piping in sprinkler systems dismantled during building alterations

Obstruction Investigations:
When to Conduct cont...

- Abnormally frequent false tripping of a dry pipe valve(s)
- A system that is returned to service after an extended shutdown (greater than 1 year)
- A system has been supplied with raw water via the fire department connection
- Pinhole leaks
- A 50-percent increase in the time it takes water to travel to the inspector’s test connection from the time the valve trips during a full flow trip test of a dry pipe sprinkler system when compared to the original system acceptance test

Justification for Maintenance

- The NFPA ranks improper maintenance as the second most common reason for sprinkler system failure.
- National Fire Sprinkler Association lists corrosion as a major cause behind sprinkler system failure.
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Steps to Assess Corrosion Damage

- There are five critical steps to addressing the damaging effects of corrosion, and the factors include:
  1. Understanding the effects of the destructive process.
  2. Properly assessing corrosion damage.
  3. Correcting system deficiencies.
  4. Implementing a cleaning program.
  5. Corrosion mitigation plan and ongoing monitoring.

Step 1: Effects

Effect of the destructive process ➔

ATTACKS WEAKEST LINK
Locations of the Weakest Link

- The thinnest pipe wall is often the first to go (Sch 5 & Sch 10)
- Piping near the higher elevations of a wet-pipe system
- Closest to the water source is also at high risk

Locations of the Weakest Link

- On a dry-pipe system, piping near the low areas where water accumulates is at a higher corrosive risk
- At the threaded ends of the piping (adjacent to fittings), where the pipe wall is the thinnest.

Step 2: Assessing Corrosion Damage

- Some of the options to assess the corrosion damage are:
  1. Corrosion Coupons
  2. Visual Observation (Section Removal)
  3. Borescope (Video)
  4. Water Testing
  5. Ultrasonic Testing
Comparison: Assessment Alternatives

<table>
<thead>
<tr>
<th>Analysis Technique</th>
<th>Corrosion Coupons</th>
<th>Cross Section Removal</th>
<th>Video Inspection</th>
<th>Water Testing</th>
<th>Ultrasonic Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain System</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>Change in System Conditions</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
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<tr>
<td>Holistic Analysis</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Determine Remaining Service Life</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Cost/Sample</td>
<td>LOW</td>
<td>HIGH</td>
<td>MODERATE</td>
<td>MODERATE</td>
<td>MODERATE</td>
</tr>
<tr>
<td>Cost/Sq. Ft.</td>
<td>MODERATE</td>
<td>HIGH</td>
<td>HIGH</td>
<td>LOW</td>
<td>LOW</td>
</tr>
</tbody>
</table>

Holistic Analysis NO NO NO NO
Determine Remaining Service Life NO NO NO NO
Cost/Sample LOW HIGH MODERATE MODERATE
Cost/Sq. Ft. MODERATE HIGH HIGH LOW

Analysis Example: Parking Garage

- +200K Sq. Ft., Multiple Levels
- Constructed ~2002
- Unclear Service History
- Extent of Corrosion is Unknown

**CHALLENGE:** HOW TO COST EFFECTIVELY ASSESS WHICH AREAS NEED REPLACEMENT?

Application: Using Video Inspection

- Video Inspection requires access to the system
- Cannot determine the amount of corrosion
**Application: Using Ultrasonic Testing**

- Ultrasonic Inspection does not require access
- Determines the precise amount of corrosion

**Application: Data Analysis**

- Thickness data by itself is meaningless
- Requires a contextual assessment
- Raw data needs analysis
- Classifies each test location
- Allows the creation of an "actionable plan"

**Step 3: Correcting system deficiencies**

Corrosion is divided into 3 categories:

- **Little Damage**: flushing
- **Medium Damage**: some replacement & flushing
- **Heavy Damage**: complete pipe array or parts replaced
**Step 4: Corrosion Cleaning**

- Flushing
- Hydraulic method
- Hydropneumatic method

Once a system is properly cleaned, a secondary corrosion inhibitor can be injected if applicable.

- Solution
- Powder

**Step 5: Corrosion Control Measures**

- When designing provide corrosion allowance to extend the life of the piping.

- Inspect piping for wall thinning or build-up of corrosion.
  - Using non-destructive technique of ultrasound
  - An internal inspection using video boroscope

**Corrosion Control Measures**

- Flush the piping system with a solution to remove insoluble material and biofilms

- Remove all filings from cutting, threading, & drilling

- Keep pH below 9.0
Corrosion Control Measures

- Treat water to minimize chloride & sulphate concentrations and reduce acid corrosion.
- Limit organic matter and lubricants.
- Internal coating of the pipe to block electrochemical reactions.

Corrosion Control Measures

- Uncontaminated water source.
- Reduce the frequency of filling a piping system.
- Vent trapped air to minimize oxygen in the system.
- Institute a monitoring program.

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Myth - Reality

Myth:
Microbiologically-influenced corrosion (MIC) is the major corrosion problem in fire protection systems.

Reality:
In a study of 155 cases of failed sprinkler components collected between 1994 and 2000, the FM Global metallurgical laboratory found evidence of MIC in about 40% of the cases.

Myth - Reality

Myth:
Galvanized piping solves all corrosion problems.

Reality:
Galvanized piping allows zinc to corrode first. Lack of zinc in an area becomes the point where corrosion is extremely aggressive to the steel.

Galvanized piping MIGHT be PART of a solution.

Myth - Reality

Myth:
Roll grooved piping will decrease corrosion because material is not removed from the pipe.

Reality:
Roll groove piping creates a dam effect inside the piping, allowing water to be trapped in dry pipe systems.
**Myth - Reality**

**Myth:**
Water treating dry and preaction systems will stop corrosion.

**Reality:**
This is an oxymoron type of approach. No water is supposed to be in these systems. Therefore, treating a system without water does not address the basis of the corrosion problem.

**Specific Building Situations**

**Problem 1:**
What are the options for meeting NFPA 25 obstruction investigation requirements?

**Solution 1:**
Annual inspections including:
1. external visual,
2. internal by borescope,
3. water analysis chemical & microbiological,
4. solids and tubercles (if found in flow test)
5. ultrasonic pipe wall thickness evaluation.

Cost: Varies
Effectiveness: Varies depending on method.

**Problem 2:**
What is an option of localized corrosion monitoring?

**Solution 2:**
Corrosion monitoring and evaluation of coupons and/or report by corrosion monitoring probe.

Cost: Low
Effectiveness: Very limited to localized area.
**Specific Building Situations**

**Problem 3:** Are there coatings available for treating corrosion?

**Solution 3:** It is evolving, corrosion mitigation by treating the internal system is typically done before corrosion occurs.

Cost: Moderate.
Effectiveness: Very limited in most cases.

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**Specific Building Situations**

**Problem 4:** What is one option for reducing corrosion in dry systems?

**Solution 4:** Convert to Nitrogen.

Cost: Low
Effectiveness: Could be effective for general corrosion.

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**Specific Building Situations**

**Problem 5:** What is the worse case solution for corrosion in a system?

**Solution 5:** Remediation may require the replacement of piping where integrity, flow restrictions and heavy tuberculation are present.

Cost: High
Effectiveness: Limited if underlying reason for corrosion is not addressed.
Conclusions

➢ We only scratched the surface of corrosion in fire protection piping.

➢ Corrosion is a very real threat to the functionality of fire protection systems.

➢ Properly address corrosion has to be done on a case by case basis.

A Word of Caution

➢ Need to use all appropriate evaluation options.

➢ There isn't an all encompassing single type of mitigation technique.

➢ Ignoring a problem will not make it go away.