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CORROSION ISSUES IN FIRE SYSTEMS V2

Fire and Security Consulting Services (FSCS) is frequently consulted regarding the presence and effects of corrosion in fire protection systems pipework and equipment.

After 45 years in the industry and significant experience in marine and offshore projects, Rick is uniquely qualified to provide advice on this issue.

In general, the fire protection industry does not consider corrosion an issue. They are aware of environmentally induced corrosion affecting the exterior of the components. This has been remedied by galvanised and copper pipe and sprinklers with special coatings. They are also aware of oxidation which affects the entire surface. This typically affects the inner pipe wall and is generally not a problem except for dry pipe systems that are overly tested.

What is Corrosion

Corrosion, or more commonly termed *rusting*, occurs when metals are exposed to oxygen. The technical term is oxidisation which describes the electro-chemical elimination of the subject material, (usually a ferrous metal), when subject to an oxygen atmosphere, the atmosphere having a water or moisture content sufficient to promote the formation of oxides or “salts” of the subject metal. The evidence is the presence of these oxides either on the surface of or inside pipes and ferrous metal components.

Galvanic Corrosion

Galvanic corrosion occurs when the moist contact between two metals sets up an “electrochemical” cell where electricity flows between the two metals. This is also the principle behind a common battery.

The rate and appearance of oxidisation is dependant on the type of metal and different metals will corrode at different rater dependant on their position in the Galvanic Corrosion table shown in **Figure 1**.

This table lists some metals in order of their “nobleness” or propensity to oxidation. Whilst this is normally seen to be unique to the presence of different materials in contact, oxidation of metals does not necessarily require the presence of another metal in contact.

Figure 1 – Galvanic Table

A complete chart of the Galvanic Order and guidelines for treating differing metals in contact is provided on Page 4 of this paper.

Effects of Corrosion

Corrosion is responsible for the degradation of the mechanical properties of the subject material to an extent where the strength of the material no longer meets the design requirements.

Corrosion may be visually evident on the surfaces of the material but in the worst case scenarios, is usually evident and not seen inside tanks, pressure vessels and the like. Corrosion also can occur between riveted or welded metal plates. It is in these unseen locations that corrosion is most worrying. Tank and pressure vessel design criteria include for a "corrosion allowance" but still require controls on the type of contents and maintenance.

Typical examples of corrosion are shown below.

Figure 2 is the corrosion of a sprinkler head. This was caused by leakage of water from a pinhole in the soldered the joint between the copper pipe and pipe fitting. Note the presence of PTFE jointing tape on the screwed connection commonly used today. PTFE tape, poorly applied is also prone to leakage. In the past a jointing compound of hemp and soap proved to be very effective but is rarely used today.

Note that the detecting element (solder cup link) and the orifice seal are completely oxidized and in the event of fire, this sprinkler will, at best be delayed in operation and at worst will not operate.

Figure 2 – Corroded Sprinkler

Figure 3 is the corrosion of a decorative sprinkler escutcheon plate. The cause of this corrosion is either leakage of the connection above the ceiling panel or incorrect selection of material for the environment.

Whilst this surface corrosion does not necessarily impair system performance, it certainly demonstrates poor equipment selection and quality control by the contractor.

Figure 3 – Corroded Sprinkler Escutcheon Plate

Figure 4 is the corrosion of a galvanized (zinc) nut and bolt connecting a steel pipe flange to a gunmetal (bronze) valve. Note the effects of corrosion appearing through the paint.

This is a classic example of galvanic corrosion where zinc is in contact with bronze and steel in a coastal “moist” environment.

Whilst this surface corrosion does not necessarily impair system performance, it certainly demonstrates poor equipment selection and quality control by the contractor.

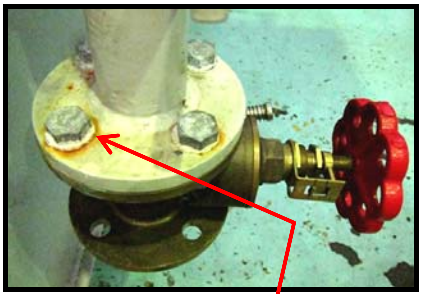

Figure 4 – Corroded Bolts

Figure 5 is a puzzling appearance of significant corrosion “salts” appearing at the brazed / soldered junction of a copper pipe and a brass fitting. Note that the valve body is also either brass or gunmetal.

In this case it was determined that the cause of the corrosion was contamination in the brazing / soldering process by either wire brushing the pipe with a steel brush which deposited iron *on and into* the copper or contaminated brazing / solder rods.

Whilst this surface corrosion does not necessarily impair system performance, in either case it demonstrates poor equipment selection and quality control by the contractor.

Figure 5 – Corroded Bracket Bolt

Figure 6 is the corrosion of stainless steel pipe fittings and a section of pipe. Despite all three pieces being stainless steel, this photograph demonstrates that <u>different grades</u> of stainless steel can still set up a galvanic cell.

In this case the elbow on the left and the piece of joining pipe are Grade 316L stainless steel whilst the elbow on the right and the piece of pipe are Grade 304 stainless steel.

Grade 304 stainless steel is usually only used for decorative items and should never be used where corrosion resistance of fire safety systems is important.

FSCS often specifies stainless steel for diesel fire pump exhaust pipes and mufflers. The effects of heat increase the propensity for corrosion and 316 grade should always be used in these circumstances.

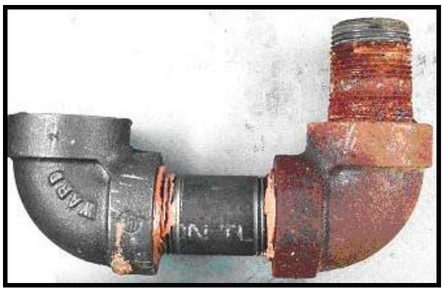

Figure 6– Stainless Steel Corrosion

Figure 7 below is a chart provided to me whilst in the UK as a contractor providing fire systems design and deliverables to major International oil companies (see my work history narrative at http://fscs-techtalk.com). All designers and contractors were required to address galvanic corrosion as part of their defects liability obligations. Equipment with observed corrosion was required to be rectified / replaced at no cost to the client!

	MAGNESIUM ALLOY	ALUMINIUM ALLOY	STAINLESS STEEL	GALVANISED IRON	ZINC BASE	MILD STEEL	CADMIUM PLATED STEEL	CHROME PLATED STEEL	BRASS	COPPER	GUNMETAL	PHOSPOR BRONZE	NICKEL	MONEL METAL	TIN	LEAD	TINMANS SOLDER A	ZINC CADMIUM SOLDER	ALUMINIUM BRONZE
MAGNESIUM ALLOY	0	→ 820	→ 1530	→ 520	→ 490	→ 880	→ 800	→ 1050	→ 1280	→ 1400	→ 1340	→ 1360	→ 1440	→ 1420	→ 1120	→ 1140	→ 1110	→ 540	→ 1350
ALUMINIUM ALLOY		0	→ 710	↑ 300	↑ 330	→ 60	↑ 20	→ 230	→ 460	→ 580	→ 520	→ 540	→ 620	→ 600	→ 300	→ 320	→ 290	↑ 280	→ 530
STAINLESS STEEL			0	↑ 1010	↑ 1040	↑ 650	↑ 730	↑ 480	↑ 250	↑ 130	↑ 190	↑ 170	↑ 90	↑ 110	↑ 410	↑ 390	↑ 420	↑ 990	↑ 180
GALVANISED IRON				0	↑ 30	→ 360	→ 280	→ 530	→ 760	→ 830	→ 820	→ 840	→ 920	→ 900	→ 600	→ 620	→ 590	→ 20	→ 830
ZINC BASE					0	→ 390	→ 310	→ 560	→ 790	→ 910	→ 850	→ 870	→ 950	→ 930	→ 630	→ 650	→ 620	→ 50	→ 860
MILD STEEL						0	↑ 80	→ 170	→ 400	→ 520	→ 460	→ 480	→ 560	→ 540	→ 240	→ 260	→ 230	↑ 340	→ 470
CADMIUM PLATED STEEL							0	→ 250	→ 480	→ 600	→ 540	→ 560	→ 640	→ 620	→ 320	→ 340	→ 310	↑ 260	→ 550
CHROME PLATED STEEL								0	→ 230	→ 350	→ 290	→ 310	→ 390	→ 370	→ 70	→ 90	→ 60	↑ 510	→ 300
BRASS									0	→ 120	→ 60	→ 80	→ 160	→ 140	↑ 160	↑ 140	↑ 170	↑ 740	→ 70
COPPER										0	→ 60	→ 40	→ 40	→ 20	↑ 280	↑ 260	↑ 290	↑ 860	→ 50
GUNMETAL											0	→ 20	→ 100	→ 80	↑ 220	↑ 200	↑ 230	↑ 800	↑ 10
PHOSPHOR BRONZE												0	→ 80	→ 60	↑ 240	↑ 220	↑ 250	↑ 820	↑ 10
NICKEL													0	↑ 20	↑ 320	↑ 300	↑ 330	↑ 900	↑ 90
MONEL METAL														0	↑ 300	↑ 280	↑ 310	↑ 880	↑ 70
TIN															0	↑ 20	↑ 10	↑ 580	→ 230
LEAD																0	↑ 30	↑ 600	→ 210
TINMANS SOLDER A																	0	↑ 570	→ 240
ZINC CADMIUM SOLDER																		0	→ 810
ALUMINIUM BRONZE																			0

This table shows the electrode potential difference between any two of 19 different metals and alloys.

The figures (which are in Millivolts) in each of the squares refer to the two metals in the associated co-ordinates.

For example, the electrode potential difference between mild steel in the right-hand column and copper in the top column is shown as 520 M/volts in the square associated with these two columns.

The arrow in the square points to which of the two metals will suffer corrosion as a result of this potential difference.

These figures should be taken as indicative of the tendency to, and not proportional to the rate of corrosion resulting from bi-metallic contact. They have been obtained from laboratory experiments under carefully controlled conditions. In actual usage many variables arise, most of them tending to slow down corrosion rate especially in the case of aluminium alloys.

As a guide it is suggested that:-

a) When the figure is less than 100 no special protective measures are needed.

b) Where the figure is between 100 and 500 no special protection is needed unless the junction between the two metals is normally moist.

c) Where the figure is over 500 protection is essential unless the junction is always dry.

Figure 7 – Galvanic Table

The circled number relates to the assembly in Figure 4 - ~820 to 850 mV requiring special protective measures!

Microbiological Corrosion MIC

The fire protection industry is generally not aware of Microbiological Corrosion (MIC) and even though it may be new to them, it is not new to other industries. Buildings and facilities with cooling towers have been dealing with MIC for awhile. As a result, a lot is known about it.

MIC is the term used for corrosion influenced by microbes in the water. The primary concern is that the influence of these microbes is often an extremely accelerated rate of corrosion. MIC is not caused by a single microbe, but is attributed to many different microbes. These are often categorised by common characteristics such as by-products (i.e., sludge producing) or compounds they effect (i.e. sulphur oxidising). In a general sense, they all fall into one of two groups based upon their oxygen requirements:-

1. Aerobic (requires oxygen) such as sulphur oxidising bacteria; and;
2. Anaerobic, (requires little or no oxygen), such as sulphate reducing bacteria.

Although there have been regions in Australia where MIC cases have been reported and documented, there is presently no indication that MIC is confined to any specific geographical area. One of the primary reasons for the commencement of MIC is the quality of water. In urban areas where the municipal water supply is generally chlorinated, MIC is unlikely to be an issue.

MIC almost always occurs concurrently with other corrosion mechanisms, and it is virtually impossible to separate them. This is in part due to the fact that microbes help create conditions under which other corrosion mechanisms can occur, such as crevice corrosion, pitting, and under-deposit corrosion.

Figure 8 below shows a pipe section with advanced MIC evidence.

Figure 8 - Advanced MIC evidence.

Additional Reading

1. The SFPE Journal of Fire Protection Engineering provides a comprehensive coverage of corrosion issues inside steel sprinkler piping. You need not be a member to access this or print this article. http://magazine.sfpe.org/sprinklers/corrosion-process-inside-steel-fire-sprinkler-piping
2. The NFPA has issued a media paper entitled "Corrosion in steel pipe – not one but many problems". In particular, stainless steel is addressed.

   http://www.nfpa.org/~/media/Files/proceedings/corrosioninsprinklersystemsbhjorth.pdf

Maintenance

A key solution in eliminating and subsequently the effects of corrosion is regular and effective maintenance.

Preventive maintenance refers to activities performed according to fixed schedules as described in AS1851 2005. When certain changes in system characteristics are noted, corrective maintenance is required. AS 1851 does not describe or specify corrective maintenance and for circumstances where corrosion issues are identified, it is often necessary to obtain specialist advice.

Periodically inspecting fire sprinkler systems for the presence of MIC or Corrosion allows the facility manager to accurately monitor the condition of the system, schedule localised replacement and significantly reduce the risk and costs associated with corrective maintenance.

Often, using non-invasive, ultrasonic inspection techniques, a cost-effective **predictive maintenance** programme can be implemented to detect the presence and the progression of corrosion or MIC inside the sprinkler piping. The density of inspection locations and the frequency of inspections should be chosen based on the risk associated with a leak or operational failure, history of the system, and condition of the sprinkler system water supply.

Risk Mitigation

The risk of MIC or Corrosion in fire sprinkler piping can be broken into two general categories:-

1. Loss of life or property damage caused by fire that spreads due to an operational failure; and
2. Significant property damage caused by a leak from corrosive pitting.

Almost any facility that is required to have a fire sprinkler system is subject to the first risk, but several types of facilities rely on the sprinkler system to extinguish or slow the spread of fire more so than other structures. These include military and commercial ships at sea, correctional facilities, petroleum refineries, chemical plants, power plants (oil, coal, and especially nuclear).

The potential of fire sprinkler leaks may not seem especially risky, but for facilities that house sensitive electronics and equipment such as clean rooms and computer data centres a single small leak can produce potentially catastrophic financial losses.

Return on Investment

Calculating the Return on Investment in a **predictive maintenance** programme for MIC and corrosion in the fire sprinkler piping requires assessing the risk of either type of system failure, estimating the potential cost of such a failure, estimating the cost of a corrective maintenance approach once a problem is discovered. Once these costs are estimated they need to be weighed against the cost of inspecting the system using a non-invasive, ultrasonic technique and monitoring the level of corrosion at suitable intervals for the associated level of risk.

I trust that this explains some of the corrosion issues.

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RPEQ Mechanical – 7753: Accredited by Board of Professional Engineers as a Fire Safety Engineer

Principal – Fire and Security Consulting Services

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