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Effect of Atmospheric Corrosion Toward Corrosion under Insulation (CUI)- A Case Study

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Abstract: Corrosion under insulation (CUI) can be classified as major problem. It is typically difficult to identify as it lies hidden under insulation material. This study only focused on two environmental factors which were pH and surrounding temperature. Besides that, Scanning Electron Microscope (SEM) and Energy Dispersive X-ray (EDX) and X-ray Diffraction (XRD) were used to investigate the corrosion properties. The Linear Polarisation Test and Mass Loss Test were used to calculate the corrosion rate. So, it can be concluded that the higher the temperature the higher the corrosion rate, while for the pH, the higher the pH, the lower the corrosion rate.

Keywords: Corrosion Under Insulation (CUI), Surrounding Temperature, Ph

1. Introduction

Corrosion under Insulation is one the vital problems in petrochemical industry because the moisture will be easily penetrated through the insulation of a pipe. Corrosion under insulation (CUI) is a corrosion failure that happened and observed between the metal surface and the insulation on that surface as a result of water penetration. The sources of the moisture may come from rain water, leakage, deluge system water, wash water, or sweating from temperature cycling or low temperature operation.[1]

It is typically difficult to identify the Corrosion under insulation (CUI) as it lies hidden under insulation material. Different temperature can lead to a different result of CUI. It is depending on the type of material that been used as the insulator for pipe. The objective of this case study is to review and investigate the effect of surrounding temperature and pH on the pipe corrosion properties. Besides that, we also need this case study to review and investigate the relationship between the temperature and pH on the corrosion rate. Scanning Electron Microscope (SEM) and Energy Dispersive X-ray (EDX) results were used to investigate the corrosion properties.

2. Materials and Methods

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The flow chart generated will help to elaborate the procedures that were carried out throughout this research study. This flow charts shown in Figure 1 is important as it gives and overview of the methodology form start to end.

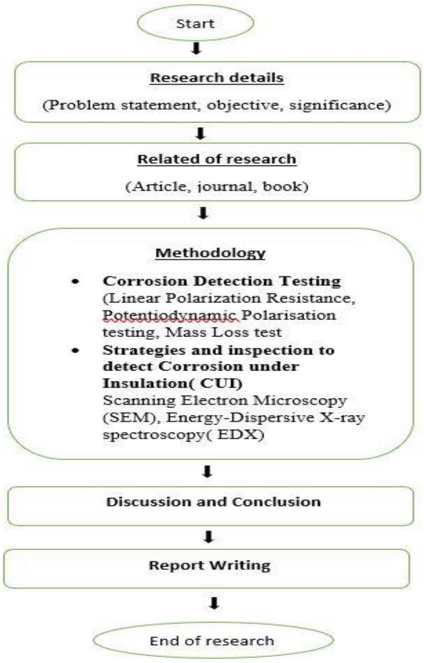

Figure 1: Research Flow Chart

The practice of evaluating and monitoring equipment components, structures, process units, and facilities for signs of corrosion is known as corrosion monitoring. Several parameters are used in this corrosion which was the surrounding temperature and pH value. There are 2 test which have been done by previous studies to identify the corrosion rate which was linear polarization test (LPR) and mass loss test.

The most frequently utilized corrosion monitoring using electronic equipment is based on the measurement of LPR. Besides that, a polarization resistance test was made for WE1 and WE2 where WE 1 is a working electrode which used a control and no coatings was applied and WE 2 is an electrode used with coating RG2400 using potentiostat. For three days, PR measurements were taken every 20 minutes. Because there was no electrolyte at 250 F during the wet/dry cycles, PR measurements were only taken during the wet cycle (150 F) [2].

Besides that, for the mass loss test the corrosion rate can be calculated by following the equation in ASTM Practice G3 The difference in initial pre-exposure mass (Mi) and the post-exposure (after cleaning) mass (Mf1) for the ring specimens have to be calculated to obtain mass loss corrosion rate using the following equation.

Corrosion Rate = (K × M) / (A × T × D) Eq.1

where:

K = constant (mpy: 3.45×106; mmpy:8.76×104),

M = mass loss (g) given by (Mi - Mf1),

A = exposed area in (cm^2),

T = time of exposure (h), and

D = density (g/cm^3)

Potention dynamic polarisation testing was also employed to explore CUI as a function of moisture pH. CUI as a function of moisture pH was also investigated using polarisation testing. Dry insulation was mixed with 50 percent reverse osmosis (RO) water, the pH of which was modified using sulphuric acid and sodium hydroxide to achieve various values (pH = 3, 5, 7, 9, 11, and 13). As a result, the MS specimens were subjected to wet insulation at various pH levels [3].

For the analysis of elemental peaks the complementary of SEM, Energy Dispersion for X-ray (EDX) analysis has been done. Inside the beam the electron beam is generated by the X-rays, this phenomenon occurs in EDX. Most of the X-ray carries the energy of element which is emitted by them, hence if we compute the X-ray energy, we can also know which elements are there in the sample. The X-ray diffraction (XRD) method was used to characterize the corrosion products produced on the specimens under wet insulation.

3. Results and Discussion

The past research [2] discussed that increase in temperature will reduce the corrosion rate due to the lack of a corrosive environment as water evaporates. However, as water evaporates, the concentration of corrosive species on the metal surface increases Furthermore, high temperatures reduces the service life of protective coatings and sealants. In an open system, the oxygen concentration in water decreases with increasing temperature, thus decreasing the corrosion rate. In contrast, the corrosion rate in a closed system increases with increasing temperature. The field measurements on CUI represents somewhat similar corrosion behaviour as in a closed system can be seen as in Figure 2.

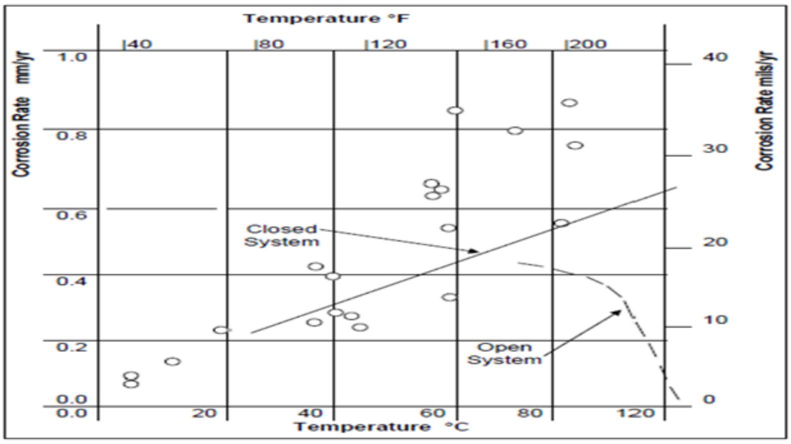

Figure 2: Comparison of Actual Plant CUI Corrosion Rates Measurements with Laboratory Corrosion Data Obtained in Open and Closed Systems[4][5]

Besides that, the corrosion rates calculated based on electrochemical polarization resistance data over the entire three day exposure period are graphically represented in Figure 3 for tests respectively. The efficiencies calculated for coating A applied to as machined ring specimens was 83 and 90 percent in isothermal (150 F) and wet/dry (150F/250F) tests, respectively. When coating A was applied to a pre-corroded specimen without any wicks, electrochemical measurements were unable to conduct due to the lack of a conductive medium [4].

Corrosion Rates from Electrochemical Data for CUI Tests

Environment: 100 ppm C1⁻ Initial pH adjusted to 6.0 (with H2-S04)

Test Number	Test Conditions	Steel Surface Conditions	Duration	Corrosion	% Efficiency
1	Isothermal (150°F)	as machined	74.0	10.5	
		w/ coating A	74.0	1.8	83
2	3 Wet/Dry Cycles (150°F/250°F)	as machined	72.0	10.0	
		w/ coating A	72.0	1.0	90
3	3 Wet/Dry Cycles (150°F/250°F)	pre-corroded †	70.5	14.0	
		w/ coating A	70.5	2.0	86

† Corrected for pre-exposure weight loss.

Figure 3: : Data on linear polarization resistance[4]

The mass loss corrosion rates obtained for the control (non-treated) specimen, ranged from 79 to 137 mph in the CUI cell design, these values were somewhat similar to those of actual plant data. The efficiencies calculated for coating A based on ML data were lower than those based on PR data in most cases. The efficiencies of the protection both ML and PR data are shown in Figure 4. The efficiencies calculated based on ML data for coating A was 65 percent, when tested on an as-machine specimen under isothermal conditions. During the wet/dry cycling tests, the coating A gave an efficiency of 79 percent when applied to an as machined specimen. The coating A applied to a pre-corroded ring and tested under wet/dry cycling conditions gave an of 70 percent [4].

Corrosion Rates from Weight Loss Data for CUI Test Environment: 100 ppm Cl^-; Initial pH adjusted to 6.0 (with H_2SO_4)

Test Number	Test Conditions	Steel Surface Conditions	Duration	Corrosion	% Efficiency
1	Isothermal (150°F)	as machined	74.0	79.0	
		w/ coating A	74.0	27.5	65
2	3 Wet/Dry Cycles (150°F/250°F)	as machined	72.0	137.0	
		w/ coating A	72.0	29.3	79
3	3 Wet/Dry Cycles (150°F/250°F)	pre-corroded †	142.5	77.2	
		w/ coating A	142.5	23.5	70

† Corrected for pre-exposure weight loss.

Figure 4: Corrosion rates from Mass Lost Data

For the observation on Scanning Electron Microscopy (SEM) Technique and X-ray diffraction analysis (XRD Based on Figure 5 the image of SEM can be clearly seen where at 80℃, it was a uniform corroded steel surface where there is no formation of $FeCO_3$ formation Besides that, at 120℃ and 150℃ we can observed that the surface morphology is almost similar result [6].

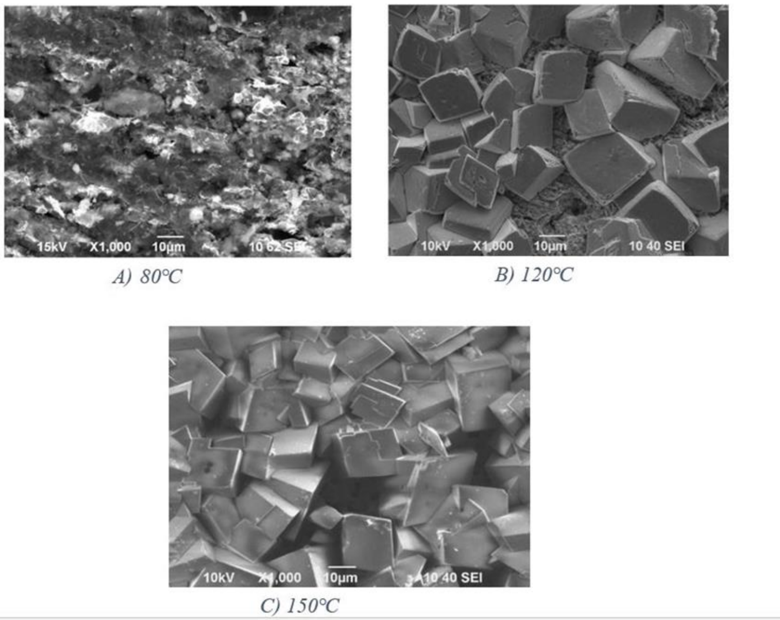

Figure 5: SEM images at (a)=80°C,(b)=120°C,(c)=150°C [6]

For the surface analysis, the steel surfaces 120, 150 and 200°C were analysed by XRD, as shown in Figure 6. The results show that FeCO3 was the main corrosion product at 120°C. A mixture of FeCO3 and Fe3O4 was found at 150°C and 200°C [6].

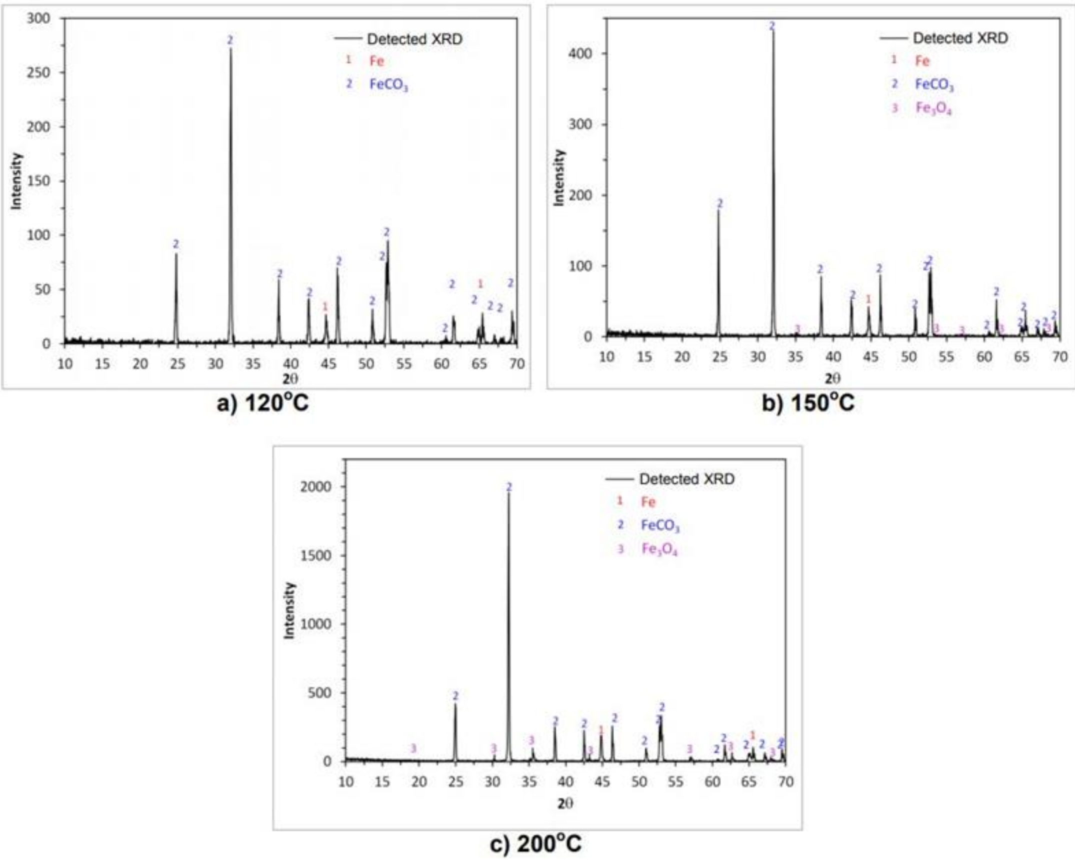

Figure 6: Image on XRD analysis [6]

Electrochemical polarisation testing on MS was carried out in moist insulation (50 vol.-%) with pH values from 1 to 13 Figure 7 [3]. In the acidic environment (pH 3–7), the measured corrosion current densities of mild steel were found to decrease with increasing pH values. On the contrary, the corrosion rates increased as solution pH increased in the alkaline environment (from pH 9 to pH 13). As expected, a passivation region was observed in the polarisation curve when solution pH equals to 13. The highest corrosion rate was observed at pH 3 and the lowest corrosion rate was noticed at pH 11, which could be attributed to the formation of passive lay [3].

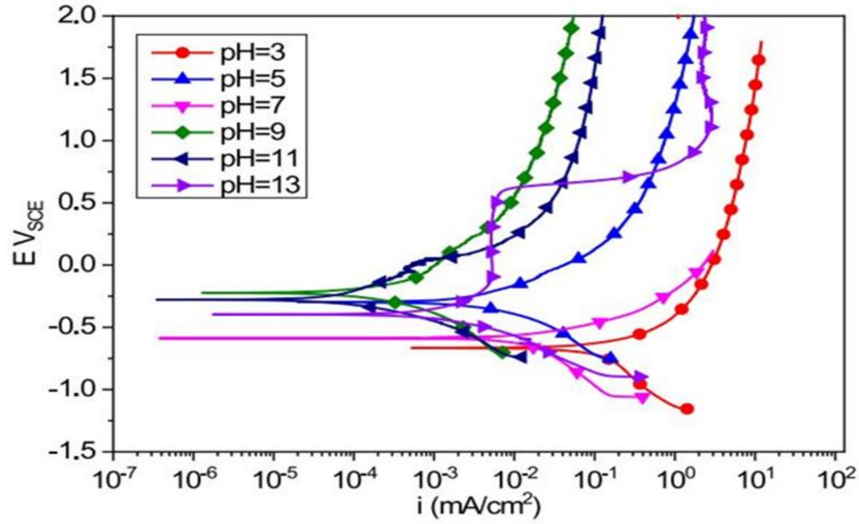

Figure 7: Potentiodynamic polarisation curves of the MS specimens immersed at different pH ranging from pH=3 to pH=13 [3]

4. Conclusion

In this study, the main objective is to analyse the effect of surrounding temperature and the pH on the corrosion rate. The corrosion rate for the varies surrounding was identified by using linear polarization test (LPR) and mass loss test. The corrosion rates calculated based on mass loss data were much higher than those obtained from polarisation resistance data. So, it can be concluded that the higher the temperature the higher the corrosion rate. Besides that, for the pH the corrosion rate which was calculated by potentiodynamic polarisation test, it can be concluded that the higher the pH, the lower the corrosion rate. The type of corrosion present in the surface was determined by the surface morphological techniques like SEM, EDX and XRD analysis.

Despite of what this study has achieved, there are some improvements needed in order to produce better outcomes such as firstly we need to conduct experiment using various type of temperature and pH . Although this study shows certain temperature such as 80, 120, 150°C and pH of 4 and 6. We should conduct experiment using various temperature and pH which makes the reading more accurate and precise. For future recommendation, different type of insulator should be used. The result of the experiment with different type of insulator can be compared in order to find the suitable type of insulator for any range of temperature

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References

[1] B. J. Fitzgerald and S. Winnik, "A corrosion under insulation prevention strategy for petrochemical industry piping," *Corros. Manag.*, no. 57, pp. 15–19, 2004.

[2] W. G. Ashbaugh, R. D. Kanev, N. Mcgowan, and B. Heimann, "Measurement of Corrosion Under Insulation," *97266 NACE Conf. Pap.*, 1997.

[3] Q. Cao, M. Esmaily, R. L. Liu, N. Birbilis, and S. Thomas, "Corrosion of mild steel under insulation–the effect of dissolved metal ions," *Corros. Eng. Sci. Technol.*, vol. 55, no. 4, pp. 322–330, 2020,

[4] D. Abayarathna, W. G. Ashbaugh, K. D. Kane, N. McGowan, and B. Heimann, "Measurement of corrosion under insulation and effectiveness of protective coatings," 1997.

[5] R. P. API, "571-Damage Mechanisms Affecting Fixed Equipment in the Refining Industry," *April 2011*, 2011.

[6] T. Tanupabrungsun, B. Brown, and S. Nesic, "Effect of pH on CO2 corrosion of mild steel at elevated temperatures," *NACE - Int. Corros. Conf. Ser.*, no. 2348, pp. 1–11, 2013